DECONSTRUCTION AND MATERIALS REUSE - AN INTERNATIONAL OVERVIEW

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TG39
Deconstruction

Deconstruction and Materials Reuse – an International Overview

CIB Publication 300

Final Report of Task Group 39 on Deconstruction

Edited by

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TG 39

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PREFACE

Task Group 39 of International Council for Research and Innovation in Building Construction (**CIB**) was formed on 5 May 1999 in Gainesville, Florida (University of Florida) to produce a comprehensive analysis of, and a report on, worldwide building deconstruction and materials reuse programs that address the key technical, economic, and policy issues needed to make deconstruction and reuse of building materials a viable option to demolition and landfilling. The first meeting of TG 39 was on 19 May 2000 in Watford, England (BRE), which resulted in the group's first publication (CIB Publication 252), "Overview of Deconstruction in Selected Countries." This publication addresses the subject of deconstruction in eight countries: Australia, Germany, Israel, Japan, the Netherlands, Norway, the United Kingdom, and the United States.

The second publication of TG 39 is the CIB Publication 266, "Deconstruction and Materials Reuse: Technology, Economic, and Policy." This electronic Proceeding includes ten fully reviewed papers presented at the second annual meeting of TG 39 that took place in conjunction with the CIB World Building Congress in Wellington, New Zealand on 6 April 2001. The papers address the technical, economic, and policy issues related to deconstruction and materials reuse in eight countries: Australia, Germany, Japan, the Netherlands, South Africa, Sweden, the United Kingdom, and the United States.

The third product of the group is the Proceedings of the third annual meeting of TG 39 that took place in Karlsruhe, Germany (DFIU - University of Karlsruhe) on 9 April 2002. This Proceeding (CIB Publication 272) includes eighteen fully reviewed papers discussing design for deconstruction and other collateral issues such as recycling potential and materials reuse in eleven countries: Australia, Germany, Italy, Japan, the Netherlands, New Zealand, South Africa, Turkey, the United Kingdom, the United States, and Venezuela.

The final meeting of TG 39 took place in Gainesville, Florida on 8 May 2003 in conjunction with the 11th Rinker International Conference on Deconstruction and Materials Reuse. The CIB Publication 287 is the electronic Proceedings of this conference and includes 36 fully reviewed papers discussing different issues of deconstruction and materials reuse in twelve countries: Germany, Italy, Japan, the Netherlands, New Zealand, Poland, Spain, Sweden, Turkey, the United Kingdom, the United States, and Venezuela.

All four publications can be downloaded at the Center for Construction and Environment website at the University of Florida (www.cce.ufl.edu/affiliations/cib).

This document is the final report of TG 39. It is a state-of-the-art report on deconstruction and materials reuse in ten countries: Australia, Germany, Israel, Japan, the Netherlands, New Zealand, Norway, Turkey, the United Kingdom, and the United States. In addition to the authors of these reports, several members of TG 39 had major impacts in completion of this report and their contributions are acknowledged. Helen Bowes, Bryn Golton, Bradley Guy, Dennis Macozoma, Anette Muller, Axel Seemann, Carlos

Suarez, Catarina Thormark, and David Wyatt. Special thanks to Charles Kibert and Clodagh Mc Grath who served as co-coordinators of TG 39 in 1999 and 2000.

Abdol Chini and Gilli Hobbs,
TG 39 Co-Coordinators

INTRODUCTION: DECONSTRUCTION AND MATERIALS REUSE, AN INTERNATIONAL OVERVIEW

Abdol Chini, University of Florida, USA

The demolition of buildings produces enormous amounts of debris that in most countries results in a significant portion of the total municipal waste stream. Deconstruction is emerging as an alternative to demolition around the world. Deconstruction is the systematic disassembly of buildings in order to maximize recovered materials reuse and recycling. While the process of demolition often leads to the mixing of various materials and contamination of non-hazardous components, deconstruction is actually the source separation of materials.

Deconstruction of buildings has several advantages over conventional demolition and is also faced with several challenges. The advantages are an increased diversion rate of demolition debris from landfills; "sustainable" economic development through reuse and recycling; potential reuse of building components; increased ease of materials recycling; and enhanced environmental protection, both locally and globally. Deconstruction preserves the invested embodied energy of materials, thus substituting recovered existing materials for the input of embodied energy in the harvesting and manufacturing of new materials.

The challenges faced by deconstruction are significant but readily overcome if changes in design and policy occur. These challenges include: existing buildings have not been designed for dismantling; building components have not been designed for disassembly; tools for deconstructing existing buildings often do not exist; disposal costs for demolition waste are frequently low; dismantling of buildings requires additional time; building codes and materials standards often do not address the reuse of building components; unknown cost factors in the deconstruction process; lack of a broad industry identity with commensurate standardized practices; buildings built before the mid-1970's with lead-based paint and asbestos containing materials; and the economic and environmental benefits that are not well-established.

Generally the main problem facing deconstruction today is the fact that architects and builders of the past visualized their creations as being permanent and did not make provisions for their future disassembly. Consequently, techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at institutions around the world, and government policy is beginning to address the advantages of deconstruction by increasing disposal costs or in some cases, forbidding the disposal of otherwise useful materials. Designing buildings to build for ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings.

The main objective of this report is to provide information about worldwide building deconstruction and materials reuse programs that address the key technical, economic, environmental, and policy issues needed to make deconstruction and reuse of building materials a viable option to demolition and landfilling.

This chapter provides a brief summary of the country reports from Australia, Germany, Israel, Japan, the Netherlands, New Zealand, Norway, Turkey, the United Kingdom, and the United States to represent the differences and commonalities in these countries.

SUMMARY OF REPORT FROM AUSTRALIA

Author: Philip Crowther , Queensland University of Technology, Brisbane, Australia

Australia, as an industrialized nation, not only consumes a large amount of materials and energy but also has one of the highest rates of solid-waste disposal in the world. The solid waste generated annually represents about one ton per person, of which 16 percent to 40 percent is generated by construction and demolition. Timber, concrete, and masonry are among the major contributors.

Though there is no Australia-wide data available, local research shows that the recycling rate of residential building materials is higher than that of commercial and industrial buildings. An added advantage of most residential salvage is that the materials and components can be reused in their existing state, whereas commercial salvage is primarily recycled or reprocessed. Deconstruction of 70- to 100-year-old timber houses in Australia is a common practice, with about 80 percent of the recovered materials being reused in renovation of existing homes or in new-home construction. Additionally, the relocation of houses is common. In the Melbourne area, 1,000 homes are moved each year of a total housing stock of 800,000. For residential structures overall, an estimated 50 percent to 80 percent of materials are recovered in the demolition process.

In Australia there is a growing awareness about reducing the consumption of embodied energy by reusing and recycling building materials after deconstruction. Retaining the frame and slabs of a multistory office building, for example, could conserve up to 60 percent of the building's total embodied energy.

Dividing this house in two facilitated its relocation. (By Jeremy Salmon/Architect).

Australians have lived in temporary structures and reused building materials for 40,000 years. Even in the last 200 years of European settlement there has been considerable activity in the area of reuse. In particular, initiatives have been taken to incorporate deconstruction into design. Since each building is unique, a strategy is being formulated to evaluate and improve a building's life cycle and environmental performance on a case-by-case basis.

SUMMARY OF REPORT FROM GERMANY

Author: Frank Schultmann, Chair of Construction Management and Economics, University of Siegen, Germany

Although recycling construction materials has long been a tradition in Germany, the use of recycled materials remains limited to primarily low-grade applications due to heterogeneity of the composition and contamination of construction and demolition waste. Efforts have been made to develop more effective methods of deconstruction, such as selective dismantling of buildings, manual sorting, and the use of automated separation devices. It is estimated that about 45 million tons of C&D waste are generated in Germany, where more than 1,600 C&D landfills exist. Meanwhile, about 650 companies work in the field of construction material recycling.

In Germany the recycling costs near demolition costs. Therefore it can be financially advantageous to reuse as many building elements as possible. A methodology for deconstruction and recycling management has been developed at the French-German Institute for Environmental Research. According to the Institute's advanced computer modeling system, cost savings up to 50 percent can be achieved by employing optimized dismantling schedules. In some cases, usage of partly automated devices can reduce deconstruction time by a factor of 2, and a recycling rate of more than 97 percent can be accomplished.

Dismantling of the Hotel Post in Dobel

Analysis of German deconstruction projects shows that deconstruction can be an economical alternative. Determining factors include the building type, the recycling options available, and the disposal costs or reuse options for mixed and sorted demolition materials.

SUMMARY OF REPORT FROM ISRAEL

Author: Amnon Katz, National Building Research Institute, Department of Civil & Environmental Engineering, Technion- Israel Institute of Technology, Haifa, Israel

Israel is a relatively young country. As a result, just five to 10 buildings are demolished a year in Israel's larger cities. Most of these structures were built in the 1940s and '50s, a period marked by financial depression, with relatively low-grade materials. Some valuable materials can be obtained upon demolition, such as aluminum, copper, and steel, and melted for reuse, but remaining materials are landfilled. The amount of annual construction waste in Israel is estimated to be 350,000 to 700,000 tons; this represents approximately 60 percent of the country's solid waste. Major motivation to explore recycling and reuse options stems from the fact that certified landfill locations are becoming scarce in Israel.

Typical structures in Israel have concrete frames and block partition walls. Dismantling of such building elements is almost impossible, unless the building is designed for deconstruction. However, the National Building Research Institute has conducted several studies on the secondary use of construction materials, such as using industrial byproducts for the production of Controlled Low Strength Materials and coal fly ash to partially replace Portland cement or natural sand in concrete. Unfortunately, building elements are sometimes not reused because they are viewed as unsuitable for new construction of high-value structures. Only structures and elements that can withstand the changes that occur (in strength, durability, social and aesthetic standards) in the time between the first erection and the second use may be suitable for the implementation of deconstruction.

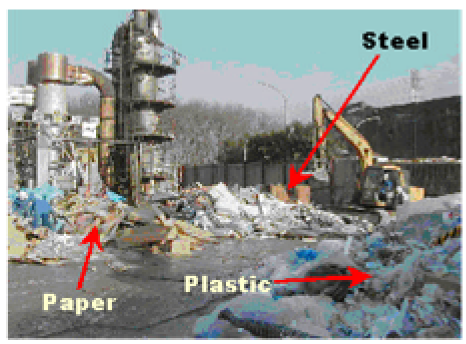
This parking structure being erected is designed for deconstruction (Design: Villa Nir. Structure: Moshe Peer. Construction: Solel Boneh).

Deconstruction activity is relatively low in Israel due to the dominance of concrete construction, a low rate of demolition, and a poor image of products made from used elements. Two niches, however, have been defined: parking garages and military structures. Designing for deconstruction led to the development of a four-story parking garage that can be dismantled and relocated according to market demands. The need to transfer army camps has initiated careful planning for deconstruction of existing structures in order to maximize reuse of the building elements.

SUMMARY OF REPORT FROM JAPAN

Author: Shiro Nakajima, Building Research Institute, Ibaraki, Japan

Japan's landfills are no match for its waste production. Construction waste has become a serious social problem in Japan. The total amount of waste generated by Japan's construction industry in 2001 was approximately 85 million tons. Construction waste represents 20 percent of Japan's industrial waste, and uses about 40 percent of its landfill volume. Construction waste accounts for 90 percent of illegal dumping as well. In May 2000, the former Ministry of Construction (now the Ministry of Land, Infrastructure and Transport) announced a law that stipulates the deconstruction process and promotes recycling of construction and demolition waste. The law became effective in May 2002.



Construction and demolition waste arrives at the recycling center, left; materials are separated into appropriate areas.

The deconstruction and demolition technique used in Japan depends upon the structure to be demolished. Timber houses, the most common type of home in Japan, contain 22 percent natural Japanese forest timber or 48 percent artificially produced wood. Selective dismantling of wooden houses in Japan is done by hand, machine, or combination (usually by hand because of costs). Concrete buildings are dismantled with different types of static or dynamic energy, such as blowing power, oil pressure, water pressure, electricity, or heat. Though spread footings often are demolished because new buildings on-site render them unnecessary or insufficient, existing piles can often be reused. Finally, in order to dismantle a steel structure, interior decorations are removed before the steel elements are cropped out. The steel is then crushed into pieces by hydraulic compressive smash machines.

Japan’s frequent use of recycled concrete (in place of crushed stone and sand) is a prime example of its recycling progress. Steel scraps from demolition total 27 million tons and new construction sites produce 8 million tons. Japan produces 90 to 100 million tons of steel overall; scrap that is recycled for raw material comprises a 30 percent share of the market. Wood scraps generated due to construction activity can be broadly divided into factory off-cuts and waste timber (from construction and demolition job sites). Off-cuts are generally used as boiler fuel, whereas waste timber is burnt or disposed because processing and sorting costs render recycling economically unfeasible.

SUMMARY OF REPORT FROM THE NETHERLANDS

Authors: Bart J.H. te Dorsthorst, Delft university of technology, Delft, The Netherlands; Ton Kowalczyk, TNO, Delft, The Netherlands

The Netherlands has achieved much success in its deconstruction efforts. In 1990, the Dutch government proclaimed that 90 percent of construction and demolition waste (CDW) should be reused by the year 2000. As of 2003, 95 percent of CDW in the Netherlands is reused, mainly as road base material. Across the European Union, recycling rates vary from 5 percent (Greece, Ireland, Portugal, and Spain) to more than 80 percent (the Netherlands, Belgium, and Denmark). The efficiency of recovery and reuse of CDW varies among EU nations based on factors such as natural resources, transport distances, economics, technology, and population densities. The production of CDW in the Netherlands is about 21 million tons a year and is increasing at an annual rate of 2 million tons.

Demolishing buildings with a heavy steel ball is no longer in practice in the Netherlands because of the noise and vibration impacts. Demolition often is done by blasting, and sites are screened to prevent flying debris from affecting surroundings areas. Dismantling building elements for reuse is gaining in popularity (as is designing structures for reuse). After demolition materials are processed (separated, crushed, sieved), they are used as raw material for road building and concrete production. Because worker safety and training are heavily emphasized in the Netherlands, courses educate workers as to the proper procedures for demolition and deconstruction.

Before and after: An artist’s rendering, right, of a building being retrofitted for reuse as family dwellings.

SUMMARY OF REPORT FROM NEW ZEALAND

Authors: John B Storey, Morten Gjerde, Andrew Charleson, Maibritt Pedersen: Centre of Building Performance Research, Victoria University, Wellington, New Zealand

The New Zealand government, in its policy document *The New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002,* calls for a 50 percent reduction in construction and demolition waste disposed at landfills by 2008. The C&D waste comprises 17 percent of total landfill waste in New Zealand. The construction industry in New Zealand is currently not sustainable, leading to evident problems such as resource depletion and pollution. Deconstruction can be crucial in terms of creating a loop in resource use and consumption and energy expenditure. Deconstruction has the potential to shift the C&D industry to a more sustainable level in New Zealand. For example, ddeconstruction can help facilitate recycling and prevent contaminants from entering the waste stream. Deconstruction can also provide jobs and low-cost building materials; it is estimated that 18 percent of New Zealanders live in poverty or at low-income levels.

It is common in New Zealand to reuse whole buildings—moving existing buildings to new sites for reuse. This is not driven by environmental concerns but rather by building economics; it is often financially advantageous to reuse rather than demolish and build anew. Generally, the country's demolition companies concentrate on select salvage items, including small amounts of high value and easy-to-extract materials such as native timbers, antique items, aluminium and high-value metals, and bricks. This process is referred to in New Zealand as 'cherry picking.' According to one demolition contractor, older houses have recovery rates up to 100 percent and can be worth NZ$4,000 to $20,000 when deconstructed. The demolition industry in New Zealand is currently unregulated; anyone with a project can call himself a demolition contractor. This has resulted in a number of undesirable practices, such as inappropriate cost cutting.

The recycling industry in New Zealand is relatively large, with export earnings comparable to the country's wine and organic produce industries. New Zealand's recycling industry exports more than $100 million of recycling-related commodities annually.

Deconstruction is very much in its infancy in New Zealand. Education and research is needed to raise its profile as a viable option that can make a significant contribution to achieving the government's resource recovery targets. A small but growing number of New Zealand architects, consultants, and engineers are designing for disassembly and designing with reused materials. This is reflective of changing attitudes and a growing awareness of the construction and demolition waste problem in New Zealand.

SUMMARY OF REPORT FROM NORWAY

Author: Lars Myhre, Norwegian Building Research Institute

Though at present Norway trails European countries regarding reuse and recycling of building waste, efforts are being made to bridge that gap. Deconstruction continues to attract attention and support from the industry and its authorities. Reuse of buildings and materials is not a foreign concept in Norway. The log houses historically commonplace in Norway were often expanded, transported, or deconstructed for further use—and this practice continues. But today the total quantity of construction waste reused or recycled is rather low. In the Oslo region, an estimated 25 to 50 percent of waste is reused or recycled; yet in the remainder of the country this share is nearly zero. In contrast, in Denmark as much as 90 percent of construction waste is recycled or reused. The total amount of construction and demolition waste generated in Norway is about 1.5 million tons. Seventy percent of the waste is concrete and brick; 14 percent is wood.

Dismantling a log home, left, and assembling a similar structure. (Photos by K.I. Edvardsen)

Several groups and their efforts illustrate the current wave of change in Norway. NORSAS, a national center for waste management and recycling, promotes waste reduction, increased recycling, and safe handling and appropriate final treatment of waste. EcoBuild (Økobygg) is an initiative of the building and property trades that advocates national environmental goals. Two trade organizations, BNL and TELFO, are creating a national action plan for construction waste. The Gaia architects have developed the ADISA principles to design a building system adapted for future replacement, reuse, and recycling of materials and components. Some of the ideas behind ADISA are being applied in the design of an ecovillage outside Kristiansand.

SUMMARY OF REPORT FROM TURKEY

Author: Soofia Tahira Elias-Ozkan, Middle East Technical University, Ankara, Turkey

The type of construction practiced in Turkey limits the scope of deconstruction. Conventional buildings are constructed with reinforced concrete; the masonry walls are then plastered and painted. Doors are wooden; terrazzo and ceramic tile are used for flooring. Typically, building services such as electrical wiring and plumbing are embedded in the walls. Despite these factors, local tradition of reuse has been instrumental in the establishment of a thriving market for used building materials. Large cities in Turkey, including Ankara, Izmir, and Istanbul, have used building material outlets, normally owned by demolition contractors. A detailed survey of the current state of deconstruction in Turkey, based on information from demolition contractors and

Turkish legislation, has revealed that the opportunities for deconstruction outweigh the barriers.

Recovery of materials in Turkey's concrete structures is completed by manually dismantling and removing the building elements prior to demolition. Sledgehammers and pickaxes are the usual tools of demolition; pneumatic drills and excavating machines are sometimes used as well. The used building materials are bought primarily by squatters who cannot afford professional design services; homeowners/builders who employ architects usually want to use new materials only. For this reason, reuse of building components is not popular within the construction industry.

Although Turkey is a developing country, its industrial waste is similar to that encountered in the world's developed countries, according to Turkey's "National Report on Sustainable Development 2002." About 13 million tons of industrial waste are generated annually in Turkey, of which about 57 percent is disposed. Of that disposed waste, 70 percent goes to municipal dump yards and 30 percent is disposed of in an unregulated manner. Construction and demolition waste is not calculated in these industrial waste statistics. The need for recycling C&D waste and the impact of this waste on the environment has not been realized yet in Turkey. Recycling of building materials is a new concept. It is only after the devastating earthquake of 1999 in the Marmara region that some attention was paid to the vast amount of building debris that resulted from damaged and collapsed buildings.

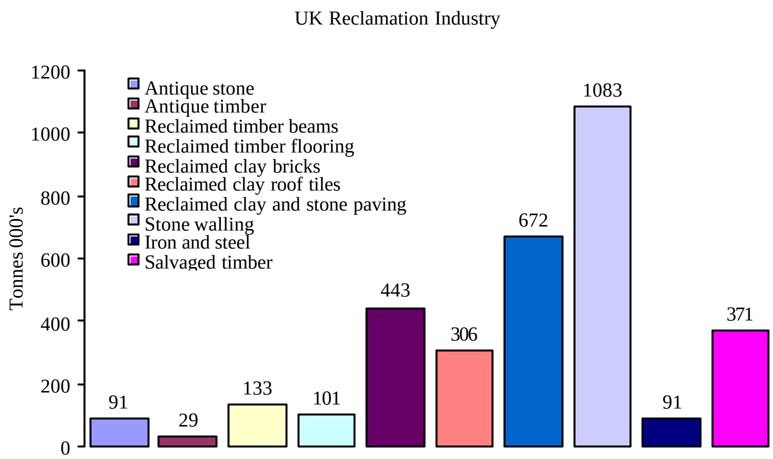
Windows on display in a used building materials outlet in Istanbul, left; lavatories, terrazzo, and roofing tiles for sale in a demolition contractor's yard in Izmir.

SUMMARY OF REPORT FROM UNITED KINGDOM

Authors: James Hurley & Gilli Hobbs, Building research Establishment (BRE), UK

The core construction and demolition waste generated in the United Kingdom is estimated to be about 94 million tons per year; this excludes another 40 million tons of mixed waste that includes inert fines, timber, metals, plastics, and packaging. Recent estimates suggest that only 934,000 tons of waste is being recycled in the UK. Encouragingly, though, about 33 million tons of architectural and ornamental components are salvaged annually for reuse. The demolition industry in the UK has undergone major changes in the past 20 years. It is no longer a poorly regulated, labor-intensive industry—machines and technology have replaced low-skilled laborers. A Work Group on Sustainable Construction was established in the UK in 1999 as one of the

14 priority actions for improving competitiveness in construction. This work group included a CDW task group who focused on how to improve C&D waste management through planning, reduction, and reclamation. One of the task group's main findings was that "optimal separation of CDW must take place to maximize recovery of material for reuse and recycling."



UK Reclamation in 1998

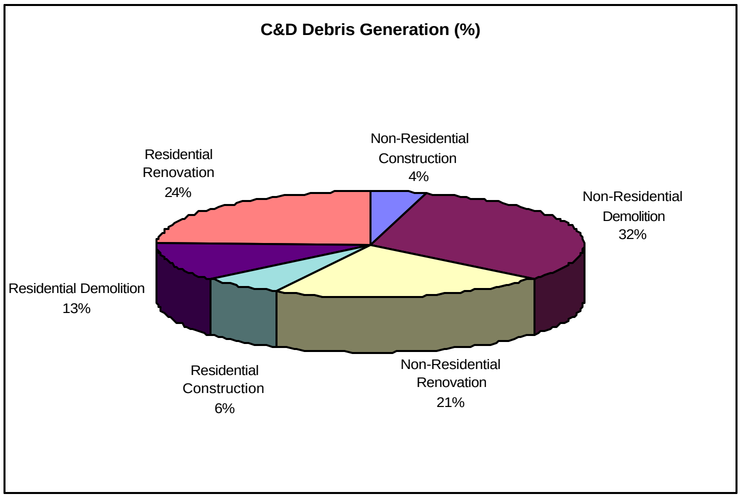
Concrete is a major contributor to CDW, and very little of it is reused or reclaimed. Most commercial concrete buildings have a reinforced concrete shell that must be demolished. But some concrete elements, such as precast beams and masonry blocks, can be easily dismantled and reused. Steel can fortunately be completely recycled at the end of a particular product's life. In the UK, steel structures equate to 50 percent of the multistory buildings. The UK's demolition codes for timber structures call for deliberate collapse demolition methodology or deconstruction. Issues faced with deconstruction include complex designs, lack of foresight, the bonding of dissimilar materials, and the contamination of waste streams.

SUMMARY OF REPORT FROM UNITED STATES OF AMERICA

Authors: Abdol Chini and Stuart Bruening, University of Florida, USA

In the United States the construction industry contributes largely to the municipal solid waste stream. The demolition industry, encompassing demolition and renovation projects, produced more than 140 million tons of waste in 2000. This equated to 90 percent of the C&D waste generated. The Environmental Protection Agency estimates that 35 to 45 percent of this debris is sent to municipal landfills or nonpermitted landfills, and 20 to 30 percent is reused or recycled.

Each year in the United States more than 42 billion board feet of lumber is dumped into landfills. It is estimated that for every 2,000 square feet of wood floor recovered, one acre of woodland is spared. Meanwhile, with an overall recycling rate of nearly 68 percent, the steel industry of North America is one of the most efficient industries. Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States for one year, and every ton of steel recycled saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone.



U.S. Construction and Demolition Waste Generation in 2000

Deconstruction has several advantages over conventional demolition, including the facilitation of building material recycling and reuse. But deconstruction has its challenges. Most existing buildings have not been designed for dismantling, and the majority of building components have not been designed for disassembly. Tools for deconstructing existing buildings often do not exist. Disposal costs for demolition waste are frequently low. Dismantling of buildings requires additional time. Building codes and materials standards often do not address the reuse of building components. Unknown cost factors arise in the deconstruction process. Buildings constructed before the mid-1970s often contain lead-based paint and asbestos materials. Though these barriers often can be overcome by design and policy modifications, the economic and environmental benefits of deconstruction are not yet well established in the United States.

Adaptive reuse is another way to reduce C&D waste; deconstruction should be considered only if a building is not fit for adaptive reuse. Renovating a structure for reuse is always environmentally preferable to demolition. But designers and architects of the next generation of buildings are rightfully beginning to consider deconstruction of structures at the end of their useful lives. Tools have been developed to facilitate the speed of deconstruction and improve worker safety during the process. Forty-four states and the District of Columbia have set solid waste diversion and/or recycling goals. Several states are beginning to insist on environmental preservation. A number of associations have formed to promote networking and information exchange, lobby for government support, and improve the efficiency of the construction industry.

CONCLUSIONS

Deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the materials. Deconstruction is emerging as an alternative to demolition around the world. Techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at several institutions, and some government agencies are realizing the advantages of deconstruction over demolition by funding research in area of deconstruction and materials reuse. Designing buildings to be built in ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. The first international conference on deconstruction and materials reuse was organized by the Powell Center for Construction and Environment at the University of Florida on May 7-10, 2003 in Gainesville, Florida. This conference was an excellent forum for exchange of information among research organizations, practitioners, manufacturers, and used building materials businesses around the world.

REPORT 1
THE STATE OF BUILDING DECONSTRUCTION IN AUSTRALIA

Philip Crowther (Queensland University of Technology, Brisbane, Australia)

ABSTRACT

This report presents information on current issues regarding the state of deconstruction in Australia. These issues include; quantities of waste and recycling, embodied energy, policy and legislation, design practice, demolition, initiatives in recycling, initiatives in deconstruction, and current research in design for deconstruction. The report concludes with recommendations for future research and for changes in design practice and government policy.

Like other industrialised nations, Australia has high levels of material consumption and correspondingly high levels of waste disposal. The construction industry is a major contributor to these levels of waste creation and consequently a major potential market for reused and recycled materials. Recent government policies have attempted to address aspects of these issues but as yet they are neither wide reaching enough nor coordinated enough to have any real effect.

The recycling of small scale residential building materials is well established and high rates or reuse are achieved, but this is not the case for commercial and industrial buildings where the only major recycling to occur is the crushing of concrete for aggregate.

There is some research in Australia into recycling technologies, issues of embodied energy, and design for deconstruction. This research is not however well integrated with the construction industry in general. Deconstruction, like other environmentally sustainable issues, is at present an interesting concept that fails to achieve wide spread understanding or implementation.

KEYWORDS: Australia; Disassembly; History; Policy; Recycling; Technology.

ACKNOWLEDGEMENTS

The assistance of the Queensland University of Technology, Professor Gordon Holden, and Professor Bill Lim, in the production of this report is greatly appreciated.

1.0 INTRODUCTION

Australians have one of the highest standards of living in the world. Unfortunately part of the price that is paid for this standard is major environmental degradation. Current industrialised practice in Australia, as in many parts of the world, results in the production of large amounts of waste. A major part of this waste is the result of building demolition. This problem has only recently received attention. Government policy, building practice, and design education are now starting to address the issues of waste associated with the built environment and in particular demolition.

Deconstruction, the systematic taking apart of a building for the purpose of materials reuse as opposed to destructive demolition, is not a new concept, but it has not previously been the topic of research in Australia. This report presents the current state of building deconstruction in Australia. It is a compilation of information from many sources and relies heavily on related research.

Information Sources
The information presented in this report has been sourced through contact with: government departments - including Environmental Protection Agencies in each state; universities and academics - including all universities with architecture schools; government and private research organisations; and a literature review of the field.

1.1 Quantities Of Waste And Recycling

Australia, as an industrialised nation, consumes large amounts of materials and energy and produces large amounts of waste and pollution per capita. The creation and maintenance of the built environment is responsible for a major part of this consumption and production.

The role that demolition plays in this waste production scheme is unclear, as is the role of recycling and reuse. It can be seen below, that there is no comprehensive understanding of the quantities and types of demolition waste and recycling, but rather a scattering of research studies in small scale.

Quantities of Waste
Australia has one of the highest rates of solid waste disposal in the world. Nearly one tonne of solid waste is sent to landfill per person each year, approximately 14 million tonnes [i]. Of this the amount, construction and demolition waste has been measured and estimated at from 16% to 40% [ii] [iii].

Type and Sources of Waste
There is no Australia wide research into the types and sources of construction or demolition waste. There are however some recent isolated local studies. Research has been conducted in Melbourne to investigate the sources of demolition waste and the quantities of waste that are recycled [iv], see Table 1.

Table 1 Amount of demolition waste in Melbourne 1993 by building type, in tonnes per m^2 of floor area.

BUILDING TYPE	MEAN WASTE t/m^2	MAXIMUM WASTE t/m^2
Residential detached	0.5	2.3
Residential other	1.2	6.3
Residential total	0.7	6.3
Non residential total	0.6	2.0

In another study, published in 1998, EcoRecycle Victoria conducted a series of surveys at landfill sites to identify quantities and type of solid waste in the Melbourne metropolitan area [[v]]. Construction and Demolition waste was estimated at 40% of the volume of total landfill waste. The sources of construction and demolition waste are presented in Table 2, and the type of materials presented in Table 3.

Table 2 Percentage of construction and demolition waste in Victoria by building type.

BUILDING TYPE	PERCENTAGE OF TOTAL C&D WASTE
Residential demolition	39.3
Commercial demolition	33.3
Residential construction	10.5
Commercial construction	4.9
Civil construction	4.0
Road and landscape construction	1.7
Road and landscape demolition	1.2
Civil demolition	0.8
Other	4.3

Table 3 Percentage of total solid waste in Victoria by material type (building materials only).

MATERIAL TYPE	PERCENTAGE OF TOTAL SOLID WASTE STREAM
Timber and wood	26
Concrete	14
Brick	6

While this research shows timber as a major contributor to the solid waste stream, many other research projects suggest that concrete and masonry represent the major portion of construction and demolition waste, at least 75% [[vi]]. With no Australia-wide data, comprehensive figures of overall demolition waste quantities and types can only be estimated from the data of local studies.

Quantities of Recycling
Australia wide figures for the recycling and reuse of construction and demolition material are similarly not available, but some local research has been conducted. Generally, reuse and recycling of residential building materials is much higher than for commercial and industrial buildings, with most states having well established markets for second-hand residential components and materials [vii].

For example, in Brisbane, the traditional detached timber house has achieved high levels of popularity in inner city suburbs. As such there is a well-developed market for reused doors, windows, floorboards, wall lining boards, framing, and the like, to be used in residential restoration, renovation and in new replica character housing. These activities extend to whole house relocation, (discussed later). This trend in reused materials is however generally limited to niche markets.

It should be noted that the construction technology used in these houses (typically from 70 to 100 years old) is very conducive to their deconstruction. These buildings are primarily made from standard dimensional lumber, nailed in place, with a very limited amount of 'wet' trade work (such as plastering, concreting, tiling). The technology used in contemporary houses by comparison may be considerably less conducive, particularly with modern glues and sealants, and increased reliance on 'wet' trades.

Figure 1 Typical timber house built in 1920's, now derelict and awaiting relocation or deconstruction for materials recycling.

Research in Melbourne has shown quite high rates of material reuse and recycling of residential building materials [viii]. This survey, though of a relatively small sample, shows percentages of building components and materials that were recovered for reuse by residential demolition companies, Table 4.

Table 4 Percentages of materials by weight recovered from residential building demolition in Melbourne, and the type of recovery (as the number of traders out of the total surveyed).

TYPE OF MATERIAL	**TOTAL PERCENTAGE RECOVERED**	**REUSED OR RENOVATED**	**RECYCLED**
Brick	77	10/10	-
Timber	79	10/10	-
Structural steel	78	3/5	2/5
Doors	71	11/11	-
Windows	73	12/12	-
Iron roofing	88	7/7	-
Flooring	78	2/2	-
Roof tiles	50	1/1	-
Plumbing	73	6/6	-

As well as the recycling and reuse of demolition materials there is a large market for relocating whole houses. Timber houses are regularly cut into large sections to be transported to new sites for reassembly and reuse. Research has suggested that as many as 1000 houses a year are relocated in the Melbourne district alone, which has a total housing stock of 800,000 detached houses [[ix]]. This practice is certainly not limited to Melbourne, and similar rates of relocation could be expected in other areas.

The same research shows that while rates of recovery in residential building demolition are quite high, commercial office building demolition results in much lower rates of recovery [[x]]. The study also shows that while the majority of materials and components from residential salvage are reused in their existing state, the majority of materials from commercial salvage are recycled or reprocessed, Table 5.

Table 5 Percentages of materials by weight recovered from CBD office building demolition in Melbourne, and the type of recovery.

TYPE OF MATERIAL	**TOTAL PERCENTAGE RECOVERED**	**REUSED**	**RECYCLED**
Concrete	70	-	70
Brick and tiles	75	60	15
Structural steel	95	15	80
Steel reinforcing	50	-	50
Timber & timber products	50	50	-
Cast iron pipe	80	40	40

Concrete block	25	25	-
Copper	90	-	90
Aluminium	90	-	90
Screenings	80	20	60
Other	5	1	4
TOTAL	**69**	**11**	**58**

Also in Victoria, EcoRecycle Victoria provides some information on quantities and types of materials that were recycled in 1996, including construction and demolition waste, see Table 6 [xi].

Table 6 Quantities of building materials recycled in Victoria in 1996.

TYPE OF MATERIAL	QUANTITY RECYCLED in tonnes
Concrete	748,000
Steel	630,000
Brick and brick rubble	102,000
Timber	12,000
Plaster	10,000

In Sydney, where demolition waste represents approximately 43% of the total solid waste stream, 40% of that demolition waste is recycled, the majority of this being crushed concrete, see Table 7 [xii].

Table 7 Quantities of building material recycled in Sydney.

TYPE OF MATERIAL	QUANTITY in tonnes
Concrete	510,000
Other	90,000

Approximately 350,000 tonnes of demolition waste was recycled in South Australia in 1998 [xiii] and solid waste disposal in landfill has been reduced by 27% in the past eight years. This is partly due to a dramatic increase in demolition material recycling in the state.

Quantities of Waste and Recycling Summary
Australia wide there are quite good rates of reuse and recycling for demolished residential building materials. From 50% to 80% of materials are salvaged, and the majority of this is reused without any form of reprocessing. The rates of recovery for commercial buildings is much lower, in some places up to 69% of demolished materials, but the majority of this is reprocessed or recycled to make new materials and components. The majority of this recycled material is crushed concrete. Approximately 70-80% of demolished concrete is recovered for crushing and reuse as aggregate.

Figure 2 Concrete recycling plant, Brisbane.

EMBODIED ENERGY

One of the more significant issues related to reusing materials, is that of embodied energy. Embodied energy is the energy required to produce or manufacture a product. This includes all or the direct energy used in the manufacturing process, and all of the indirect energy required to obtain the raw materials, transport them, and to produce the machines and infrastructure used in these production activities.

Reusing materials can greatly reduce, or avoid, the energy required for the production of new materials to replace those already in service. Reduction in energy requirements from reusing materials produces a corresponding reduction in environmental damage, particularly greenhouse gas production. Several researchers have pointed out the energy benefits of reusing materials, and the benefits of a design for disassembly or design for deconstruction strategy that would make it easier to recover materials for reuse [xiv] [xv].

Data Quality

Embodied energy analysis in Australia is not well developed, primarily due to the lack of reliable process analysis data for building materials and components, and the lack of consensus in the mater of measurement systems [xvi]. While there are recent databases for embodied energy values, the validity of those values has been questioned by several researchers [xvii] [xviii] [xix].

Significance

Despite these concerns there has been valuable research into the significance of embodied energy within the life cycle energy of the built environment. This research highlights the potential energy savings that could be made through the reuse of materials and components. Different researchers show that embodied energy can be from 30% to 50% of total life cycle energy [xx] [xxi] [xxii] [xxiii]. One of the reasons for these high percentages of embodied energy, is the low level of operational energy in Australia compared with other developed countries. This is due to the relatively mild Australian climate that results in buildings that need much less artificial heating or cooling than those in more severe climates.

These studies show that while research into reducing operational energy is still important, more research on reducing embodied energy is needed. Deconstruction for reuse and recycling is emerging as one strategy that has the potential to significantly reduce the overall embodied energy consumed by buildings.

The embodied energy significance of different parts of the building has also been investigated [xxiv]. A study of the refurbishment of a multi story office building, has shown that the retained structural frame and floor slabs represented approximately 60% of the total embodied energy, while the removed cladding, internal walls, services, and fit-out represented approximately 40%. The potential energy saving in reusing removed items is very high. In the case study building, the removed items were replaced with new materials and components whose embodied energy represented more than half as much again as those removed.

One Australian study of embodied energy significance, using international data, has also considered the energy of refurbishment within the whole life cycle energy consumption scenario. This study highlights further the significance of energy savings to be made through reuse of materials and components by showing the comparatively large portion of total energy use that is embodied in the building fabric, see Figure 3 [xxv].

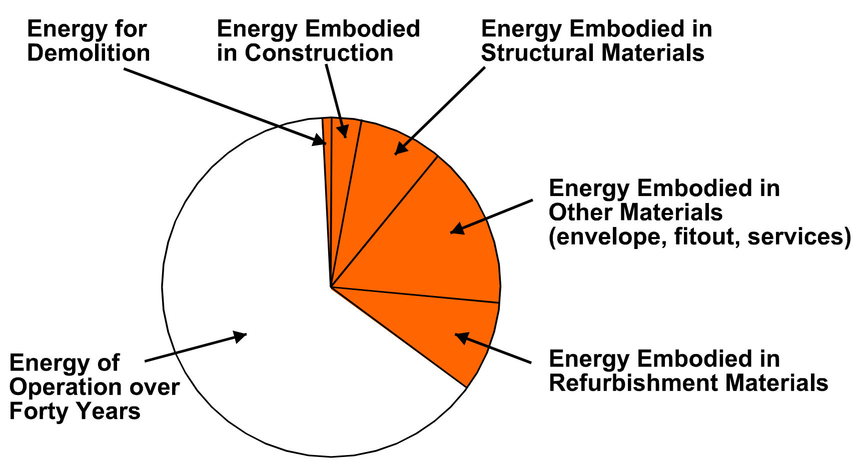


Figure 3 Total life cycle energy use over the typical forty year life of an office building, showing embodied energy to be 30% of total energy use.

Recycling Energy
There are several Australian research projects that have investigated the energy savings to be made through reuse and recycling of demolished or deconstructed building materials.

Research at Deakin University has investigated the embodied energy values of timber wall studs, steel studs, and recycled steel stud [xxvi]. The study shows that 'recycled steel' studs require approximately half the embodied energy of 'average steel' studs, but the study also points out that the methods of assessment are not consistent enough to draw any meaningful conclusions.

Research has been conducted by the government research organisation CSIRO into the energy expenditure of recycling demolished concrete [xxvii], which as mentioned previously has high recovery rates of up to 80% in Australia. Surprisingly this case study showed that using recycled crushed concrete as aggregate used 37% more energy than using new quarried aggregate. The greater energy requirement is primarily caused by increased transportation requirements. In the case study the concrete rubble was transported further to the crushing plant than if it had been transported to a landfill site. The study points out that;

"with all other factors remaining unchanged the recycling option becomes favourable (break-even) when the (demolished) concrete rubble has to be transported to a (landfill) tip more than 13km from the demolition site".

This study is obviously limited to energy consumption issues and does not take into account other environmental burdens associated with the disposal of demolished concrete. Despite this, this study does show that it is not always reasonable to assume that recycling is the most environmentally beneficial option, and that a holistic life cycle assessment needs to be made.

Embodied Energy Summary
Embodied energy, and other life cycle assessment knowledge, is not well developed in Australia, but there is a growing awareness of the significance of the energy of consumption and the part that materials reuse can play in reducing energy consumption. In Australia, with its mild climate where the majority of the population lives, the issues of embodied energy are highly significant in comparison with operational energy issues. As yet though, operational energy research is far ahead of that for embodied energy.

POLICY AND LEGISLATION

Australia has three hierarchical levels of government: the Commonwealth Government which represents the whole country, the State and Territory Governments, and the local Governments and Councils. All three levels of government have various responsibilities in the areas of environment, waste minimisation, recycling, and construction and demolition.

Table 8 Australian waste management and recycling legislation and policy [xxviii].

STATE/TERRITORY	LEGISLATION	POLICY
Commonwealth	Natural Heritage Trust of Australia Act 1997 National Environment Protection Measures (Implementation) Act 1998 Environmental Protection and Biodiversity Conservation Act 1999	Waste Management Awareness Program Natural heritage Trust – Waste Wise Construction Program Building Code of Australia
Australian Capital Territory	Environmental Protection Act 1997	No Waste by 2010 strategy Development Control Code for Best Practice Waste Management in the ACT 1999
New South Wales	Waste Minimisation and Management Act 1995 Protection of the Environment Operations Act 1997	Construction and Demolition Waste Action Plan 1998 Waste Planning and Management Fund Waste Reduction and Purchasing Policy – A Guide for Agencies 1997 Waste Education Strategic Directions Statement 2000-2002
Northern Territory	Waste Management and Pollution Control Act 1999 Environmental Assessment Act 1994	Waste Management and Pollution Control Strategy 1995
Queensland	Environmental Protection Act 1994	Waste Management Strategy for Queensland 1996
South Australia	Environment Protection Act 1993	Environment Protection (Waste Management) Policy 1994 (Draft) Environmental Protection (Waste Reduction, Recycling and Disposal) Policy 1999
Tasmania	Environmental Management and Pollution Control Act 1994 Land Use Planning and	

	Approvals Act 1993 Environmental Protection (Waste Disposal) Regulation 1974	
Victoria	Environment Protection Act 1970 Environment Protection (Amendment) Act 1996	Becoming Waste Wise Education Program EcoRecycle Victoria
Western Australia	Environmental Protection Amendment Act 1998 Environmental Protection (Landfill) Levy Act 1998	WA Waste Reduction and Recycling Policy Waste Management and Recycling Fund

Commonwealth Government
Australia is a signatory to the United Nations *Agenda 21*, and since 1992 has been committed to the *National Strategy for Ecologically Sustainable Development*.

Australia, as a member of the *Australian and New Zealand Environment Conservation Council* (ANZACC), is committed to achieving a target of a 50% reduction in waste going into landfill by the year 2000, based on 1990 levels. The Commonwealth Government's primary initiative to help achieve this goal has been the *Waste Management Awareness Program*, which among its funding initiatives supports the *WasteWise Construction Program*. The construction and demolition industry has been specifically targeted for waste reduction because up to 40% of landfill waste is generated by the building industry [xxix].

The *WasteWise Construction Program* was initiated in 1995 as an agreement between five major construction companies and the Commonwealth Government, with an aim to develop best practice in waste minimisation during construction and demolition. The program achieved greatly improved rates of recycling and reuse though most attention was centred on construction rather than demolition. The first stage of the program has resulted in the publication of a guide*, WasteWise Construction Program Handbook: Techniques for reducing Construction Waste*, but as the title suggests this publication does not cover demolition material recycling or reuse [xxx].

Other Commonwealth Government initiatives include the Housing Industry Association's *Partnership Advancing The Housing Environment* (PATHE) program which was launched in 1999 and which will deliver projects that aim to reduce waste, encourage recycling and enhance the housing industry's overall environment management practices.

The Commonwealth Government will also shortly commence the program *Lifecycle Assessment In Building And Construction*, which will seek to promote life cycle considerations in the construction and demolition industry to improve understanding of material and building impacts and opportunities for reuse and recycling of building materials and components.

The *Commonwealth Environment Protection Agency* is responsible for many issues regarding waste management and pollution but does not directly address issues of demolition waste. It does however identify common barriers to greater waste minimisation in general, and these barriers are true for demolition waste in particular [[xxxi]];

- Absence to uniform national approach to waste minimisation.
- Lack of information on the extent, types and source of waste.
- Waste management charges that are; too low to be an incentive to avoid waste, unable to provide funding for the environmental cost of waste disposal, and poorly structured.
- Insufficient private sector interest for investment in waste management technologies.

The Commonwealth Government is also responsible for the *Building Code of Australia*. This code is not in itself legislation, but is called up by individual state legislation. The code is one of the primary sources of building regulations that affect the design of buildings. The code however has no reference, recommendations or restrictions on the use of reused, recycled or second-hand materials, nor does it address the issues of deconstruction.

While Australia seeks to improve its rates of recycling and reuse, particularly in the construction and demolition industry, Commonwealth Government policies have been quite broad and unspecific with no particular guidance, initiatives, or legislation on the topic of building deconstruction and material reuse. In general, most controls over construction and demolition issues rest with the state, territory and local governments.

Australian Capital Territory Government

In 1996 the Australian Capital Territory (ACT) Government launched the *No Waste By 2010 Waste Management Strategy*. This strategy aims at elimination of all waste going to landfill by the year 2010. In the last five years significant gains in resource recovery have been made, particularly with demolition waste which now represents 50% of total waste being recycled or reused. The new *Development Control Code for Best Practice Waste Management in the ACT*, which at present relates only to the demolition sector, is expected to guide the way to total landfill elimination, though it is too early to judge results [[xxxii]].

Legislation

Unlike other State governments, who rely on environmental legislation to achieve waste management policy, the ACT Government relies upon building and development legislation. Amendments to the Building Act 1998 require a waste management plan be incorporated into the approval process for demolition of any building. Any application for building demolition must be accompanied by a waste management plan, which must outline the proposed reuse, recycling or disposal of materials and components.

Market development
The ACT Government has established the *Canberra (ACT) Resource Exchange Network*, an Internet exchange base for reusable materials and items. The ACT Government is also the administrator of the *Australian Reusable Resource Network*, an Australia wide Internet exchange service where individuals and companies can list items for exchange, or requests for items they seek. Both of these networks include building materials and components. In April 2003, they could be found at:

http://www.act.gov.au/nowaste/

http://www.arrnetwork.com.au/workplace/sb_sab.main

New South Wales State Government
The New South Wales (NSW) Government introduced the *Waste Minimisation and Management Act* in 1995, and the *Protection of the Environment Operations Act* in 1997. Under these acts the government established eight regional Waste Planning and Management Boards and initiated a number of waste management programs targeted at the construction and demolition industry. These initiatives include the development of a waste exchange directory for construction and demolition materials. This directory lists businesses that transport, recycle and reuse construction and demolition materials and building components [[xxxiii]].

Building approval
Under the *Local Government (Approvals) Regulation NSW 1993*, all applications for permission to build in New South Wales must identify the reuse of second-hand materials [[xxxiv]].

"The specification of the building is … to state whether the materials will be new or second-hand and give particulars of any second-hand materials to be used."

This requires the person preparing the application, usually the architect, to identify all reused and recycled materials at the time of seeking council approval. Since approval is usually sought as soon as possible, before all construction details are resolved, this requirement means that architects must attempt to predict the use of reused materials. Any changes to the reused materials specified during the project must be later processed through council as an amendment to the application. Such bureaucratic requirements are unlikely to encourage creative thinking about specifying reused materials and components.

All applications for construction and demolition work to be undertaken in NSW must also now be accompanied by a waste management plan that outlines the quantities and types of waste that will be generated and the intended means of treatment. This is the first step in legislation that will eventually set compliance levels in an effort to increase the rates of reuse of demolition materials.

L*andfill levy*
The NSW Government, like many other states, has introduced a waste levy on materials going to landfill with a view to encouraging recycling and reuse as alternatives, this levy is currently set at $17.00 per tonne.

Grants
The NSW Government has also provided grants to private industry, each up to $50,000 for the development of recycling and reuse technologies and practice. Projects funded to date under this scheme include [[xxxv]]:

- development of new methods of blending recycled brick to meet existing engineering specifications as new construction products.

- development of an air classification process to extract lightweight contaminants such as wood, paper and plastic from residual hard waste collected at demolition sites.

- support of the onSITE Internet site for construction and demolition waste minimisation, developed by the Centre for Design at RMIT, this Internet site includes a database of contacts for used building materials exchange. In April 2003 this site was at:

  http://onsite.rmit.edu.au

Northern Territory Government
Although the Northern Territory Government recently implemented the *Waste Management and Pollution Control Act 1999*, no particular actions or strategies were identified for the construction and demolition industry. There are policies on waste minimisation, but no reference to construction or demolition waste.

Queensland State Government
In 1996 the Queensland State Government introduced the *Waste Management Strategy for Queensland*. This strategy identified a number of objectives with direct relevance to the construction and demolition industry, two of which address the reuse of demolished building materials:

- Objective 7.1 states that *'where any government building is being demolished or any site redeveloped by a government agency, a waste recovery program for all useable materials will be introduced where practicable'*.

- Objective 5.9 the Queensland Government is to develop material specification guidelines for the recycling of secondary aggregates.

These initiatives have not yet produced any measurable results or case studies that have been researched.

Building Approvals
The *Queensland Standard Building Law 1991*, like that of New South Wales, requires the use of any reused or recycled materials to be specified at the time of application [xxxvi].

"lodge specifications … stating whether the materials will be new or second-hand and, if second-hand materials are to be used, giving particulars as required by the appropriate building officer; …"

Landfill Levy
There is currently no landfill levy in Queensland.

Grants
In 1993-94 the Queensland Government initiated the *Recycling Industry Incentive Scheme* with an aim of increasing the demand and supply of recycled materials. This scheme provides grants for establishing or developing industry that utilises recycled and reused materials or produces equipment for new recycling processes [xxxvii].

South Australian State Government
The primary piece of waste management legislation in South Australia is *the Environment protection Act 1993* which operates in conjunction with the *Environment Protection (Waste Management) Policy 1994*. The legislation does not however have any particular references to construction and demolition waste, nor the recycling of it.

Landfill Levy
The South Australian landfill levy is $4.00 per tonne.

Tasmanian State Government
The *Environmental Management and Pollution Control Act 1994* is the primary piece of legislation dealing with waste management and recycling in Tasmania. The act sets out many objectives for waste reduction and improved recycling but has no specific requirements for the construction and demolition industry.

The Tasmanian Government has established a target of 50% solid waste reduction by the year 2005 compared with 1990 levels. To this end the government is producing a *Waste Recovery and Recycling Directory* that will list organisations involved in the reuse and recycling of materials including construction and demolition waste.

Landfill Levy
There is currently no landfill waste levy in Tasmania

Victorian State Government
The government body, EcoRecycle Victoria, is the agency responsible for waste minimisation and recycling in Victoria. EcoRecycle Victoria is not a legislative body but attempts to achieve its goals through co-operation with local government and private industry. EcoRecycle Victoria is funding a number of activities with construction and demolition industry relevance [xxxviii]:

- a market development program for recycled and reused materials including an Internet site with recycling guidelines and information on material availability in the form of an exchange database.
  http://www.ecorecycle.vic.gov.au/

- best practice education and promotion through conferences and exhibitions such as *The Business of Recycling* (June 1999).

- government purchasing procedures including tender guidelines that address issues of, waste management, material recycling, design for disassembly, and standardisation, (discussed in section on 'Design Practice' in more detail).

Landfill levy

EcoRecycle Victoria is primarily funded by the landfill levy, which is currently set at the comparatively low rate of $3.00 per tonne.

Western Australian State Government

The Western Australian Government's *Waste Reduction and Recycling Policy* of 1997 is an attempt at addressing the rates of waste disposal in that state. The policy does not however specifically address the issues of construction and demolition waste. Despite this the government has initiated a number of demolition waste reduction and recycling projects.

Grants

The Western Australian Government established a landfill levy in 1998, the funds from which have been used in the form of grants to fund a variety of industrial waste minimisation and recycling projects including [[xxxix]]:

- develop guidelines to recycle concrete and masonry aggregate for use in new concrete construction.

- develop certified road base to Main Roads specifications from recycled demolition waste.

Policy and Legislation Summary

In general, Australian legislation and policy is silent on the issues of demolition and deconstruction, and demolition material recycling and reuse. There are some government programs in place that encourage or promote building material recycling and reuse but these are fairly limited:

- Commonwealth commitment to a 50% reduction in solid waste creation, with the construction and demolition industry targeted as a major contributor.

- Landfill levies in most states used to discourage waste disposal, but fees are generally set too low to encourage wide scope recycling.

- Grants for the development of new recycling and reuse technologies including construction and demolition waste, primarily concerned with recycled concrete and aggregate.

- The promotion and development of markets for reused building materials, particularly through Internet exchange databases.

DESIGN PRACTICE

The use of reused and recycled materials in new construction is often controlled by a variety of documents that are used both before and during the construction process. These include contracts, specifications, tender applications, building codes, and building approval applications. These various design process documents can have a major bearing on the decision to reuse or recycle materials. In Australia there are so called 'standard' forms of many of these documents that may be used and adapted for individual projects. Unfortunately the standard forms of some of these documents, in their current draft, actually work to discourage the creative deconstruction of buildings and the reuse of second-hand materials.

Contracts

Australia has a number of widely used standard forms of building contract. These contracts are written and recommended by organisations such as the Australian Standards Association, the Royal Australian Institute of Architects, the Master Builders Association, and the Commonwealth Government. While none of the commonly used standard contracts specifically cover deconstruction or the use of reused materials, many of them do prohibit the use of reused materials through a default clause that states that materials should be new unless otherwise specified [[xl]]. Typical examples include:

- AS 4000 clause 29.1 *"Unless otherwise provided the Contractor shall use suitable new materials.."*

- JCC clause 6.08.02 *"Any material not otherwise specified shall be new."*

- EJCDC clause 6.5 *"All materials and equipment shall be of good quality and new, except as otherwise provided in the Contract Documents."*

- AIA A201 clause 3.5.1 *"The Contractor warrants ... that materials and equipment furnished under the Contract will be of good quality and new unless otherwise required or permitted by the Contract Documents, ..."*

- C21 clause 53.2 *"Where the nature of materials is not specified in the Contract, new materials are to be used unless the Principal agrees in writing to the use of recycled materials of equivalent standard."*

- PC-1 clause 9.1 *"The Contractor must in carrying out the Contractor's Activities … use materials which … if not fully described in the Contract, are new … and of merchantable quality …"*

The effect of these default clauses is to require the person preparing the contract documents, usually the architect, to specifically state which items are to be of reused or recycled materials. In large projects this task is quite onerous, and any changes to the specifying of reused materials during the project will require the issue of notifications to the contractor and the processing of paperwork. This all has the risk of encouraging the architect to simply leave the matter alone and let the default clause take effect.

Although these contracts represent a large portion of the standard contracts used in Australia, there are some standard contracts that do not default to the use of new materials. These include SBW-2, UAV, JCT-80, and ICE.

Specifications

There are several forms of standard specification used in Australia, the most widely used is perhaps *Natspec*. This family of standard specifications does make reference to demolition, and provides for a 'salvaged items disposal schedule' and a 're-used items schedule' that can be used to list any demolished items or materials that are to be reincorporated into the works.

In new construction work, Natspec does not make any default requirements for the use of 'new' materials, but also offers no guidance for the specifying of reused or recycled materials.

Tender Guidelines

EcoRecycle Victoria provides guidance for waste minimisation in construction and demolition including *Tender Guidelines for Construction and Demolition Projects*. These guidelines are intended for inclusion in general tender guidelines for construction and demolition projects. They require tender applicants to submit information on a variety of topics, generally in the form of proposals for how the tenderer will deal with certain issues, including [[xli]]:

- Integrated waste minimisation
- Waste avoidance
- Building for disassembly
- Use of recycled and recyclable materials
- Deconstruction

These tender guidelines are intended to allow clients and architects to select a contractor who will be in sympathy with client aims regarding waste reduction and recycling.

Building Code

The *Building Code of Australia* is one of the main legislative instruments covering the design and construction of buildings. It consists of recommendations and minimum standards for a variety of structural, and health and safety issues. It makes no requirements or restrictions on deconstruction, nor the use of reused or recycled materials or components (see also 'Policy and Legislation').

Building Approvals
Some state government building regulations require that an application for building approval includes a specification of the building design that states whether any reused or recycled materials are to be used (see also individual state sections in 'Policy and Legislation').

Design Practice Summary
Many of the standard documents and mechanisms of design control and realisation work to encourage the use of new materials rather than reused materials. Most specifications, contracts, and materials standards are based on the use of new materials with the idea that new is better. Some are silent on the issue, but none, other than the EcoRecycle Victoria tender guidelines, actively promote the use of reused materials over new.

DEMOLITION METHODS

The most common method of demolition, particularly of commercial and industrial buildings, is a stage by stage removal of the building's fittings and fixtures, then the demolition of the building proper using large plant such as bulldozers, cranes, and excavators [[xlii]]. There is only limited explosive demolition conducted. As discussed elsewhere in this report the demolition of residential buildings is often conducted by manual labour to more successfully recover large amounts of materials.

The Australian Standard for demolition is *AS 2601-1991 The Demolition of Structures*. This standard allows for both destructive demolition, and deconstruction for the recovery of reusable materials and components. The standard requires the preparation of a demolition work plan for approval by the local government authority, which is to include description of the handling and disposal methods to be employed [[xliii]].

INITIATIVES IN RECYCLED MATERIALS

As discussed, high levels of residential material recycling occur in Australia. Up to 80% of all residential deconstructed materials and components can, and are, reused or recycled.

In Australia up to 70-80% of demolished concrete is crushed for reuse as aggregate. The majority of this is used for new road base aggregate. Recent increases in the rates of concrete crushing have altered the economic patterns of waste disposal. A few years ago concrete recyclers charged to remove demolished concrete, now competition is such that they remove it for free.

Demolished concrete is broken up using mechanical machinery and the reinforcing steel is removed for recycling. The concrete is then further crushed and the remaining steel is electro-magnetically removed before any other contaminants are removed by hand. In the mid 1990's crushed concrete sold as aggregate for up to $15 per tonne [[xliv]].

The Commonwealth Government research organisation, CSIRO, and Alex Fraser Recyclers Pty Ltd are currently conducting research into the use of crushed concrete as an aggregate for use in new concrete. This research includes trials of premix concrete made with 100% recycled concrete aggregate. Trials are currently for use in non-structural applications such as paths and driveways [[xlv]]. While there are definite environmental and economic benefits from recycling concrete in this way, the energy requirements of such a process have come under scrutiny as discussed elsewhere in “Embodied Energy”.

INITIATIVES IN DECONSTRUCTION

For forty thousand years Australians have lived with temporary structures that have reused materials in primitive dwellings. Even in the last two hundred years of European settlement there has been considerable activity in the are of reuse, and in particular, design for disassembly.

Portable Cottages

In 1788 when the first European settlers arrived in Sydney Cove in Australia, Governor Phillip brought with him from England a prefabricated portable house with a structural frame of timber and a roof and walls of painted cloth [[xlvi]]. This house was designed to be deconstructed for relocation. In the following decades many similar designs for portable cottages were seen in Australia. The success of this technology was in part due to the shortage of suitable material for building and the shortage of skilled labour.

Among the most successful manufacturers of these cottages was John Manning of London. Manning’s cottages, which came in standard designs of from one to four rooms, were constructed of a bolted timber frame and interchangeable timber panels [[xlvii]]. A newspaper advertisement of 1837 described the Manning portable cottage as being;

‘manufactured on the most simple and approved principles . . . complete for habitation in a few hours of landing. They may be taken to pieces and removed as often as the convenience of the settler may require’ [[xlviii]].

Timber was a popular choice for construction, but it was not the only material used in these prefabricated buildings. With the development of corrugated sheet iron in the early 1820’s and the patenting of hot-dip galvanising in 1837, portable iron cottages became a common way of dealing with the building shortage in Australia. The sheet metal’s light weight made it ideal for transport and for re-use, and it was soon used, and re-used, for everything from cottages to churches and from warehouses to hotels [[xlix]].

Timber Cottages

The development in the later part of the Nineteenth Century of modern timber framing techniques saw the proliferation of standard timber sizes for structural members and for wall and floor linings. Such developments eventually led to the kit house, a more permanent version of the portable cottage. The standardisation of materials and components allowed the houses to be easily adapted, extended or relocated.

Contemporary Houses
The continuing high rates of material and component re-use in the residential sector (as discussed earlier in 'Quantities of Waste and recycling') are perhaps best illustrated through two recent developments in residential construction. These are the use of relocated houses and parts of houses in projects by architects, and the emergence of new systems of prefabricated buildings that have the added advantage of being deconstructable for reuse or recycling.

Relocation
The relocation of timber houses has traditionally been the realm of speculative builders developing subdivided suburban blocks. Architects who have explored the greater possibilities from this activity are now adopting this common practice. In these projects, the halves or sections of relocated houses are re-joined in a new geometry that makes better use of environmental aspects such as solar access, cross ventilation, and general aspect [1]. In this way whole sections of houses are reused in a relatively intact form, Figures 4 and 5.

In these examples the nature of the material (timber), the joining techniques, and the standardisation of members, has allowed for large-scale reuse of building elements in a creative manner. This relocation of timber houses continues a strong history of building alteration and refurbishment for re-use.

Figure 4 House during relocation – house has been relocated in two halves that are set apart to create new relationship (by Jeremy Salmon Architect).

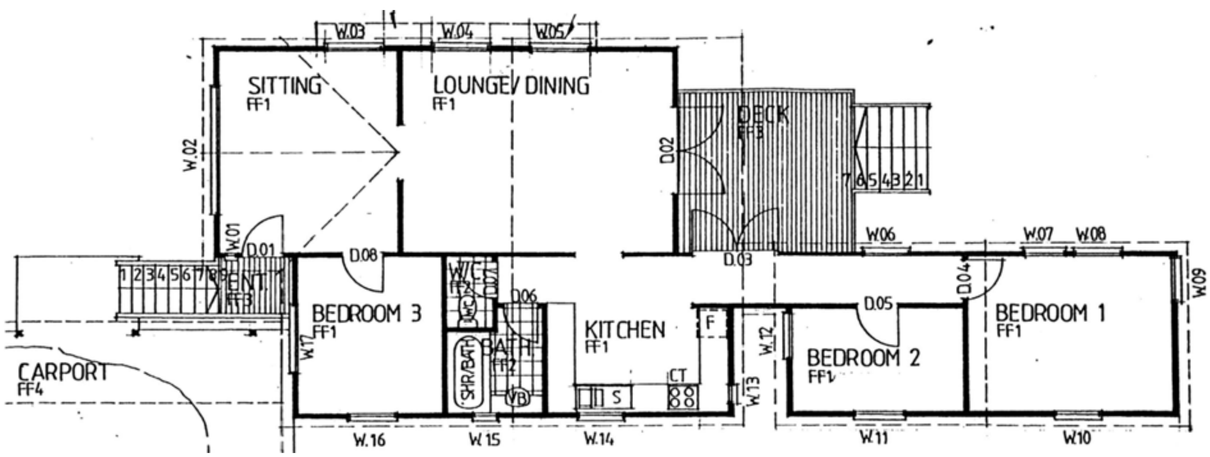


Figure 5 Floor plan of house relocated in two halves set apart (by Jeremy Salmon Architect).

Prefabrication

Prefabricated housing has not reached high levels in Australia where most new housing is in the form of detached houses built on site by major 'project' building companies. Some companies are however attempting to break into the 'project home' dominated market with prefabricated low-cost building systems. These companies are using various technologies, sometimes patented, to develop modular systems that allow not only assembly, but also future disassembly. Such disassembly is presented as an advantage for future adaptability of the house should the family structure alter. While the re-use of elements is limited to the same building or other buildings utilising the system, the environmental and waste management benefits of this practice have been identified [li] [lii].

Non-residential Examples

Although housing is the major area of deconstruction activity there are some other interesting examples and initiatives. The much-publicised 'Green' Olympics of Sydney 2000 have sadly failed to deliver much environmental sustainability. Deconstruction and reuse has been limited to the reuse of crushed concrete from demolished buildings on the site and relocation of rock and soil from excavations. The principle stadium for the games is believed to be the first major Australian building to have undergone a full life cycle assessment [liii]. The building does not however utilise recycled or reused materials though 76% of the structure is capable of being recycled in the future.

The Olympic Games site has also provided the opportunity for a relocatable viewing platform. A $200m^2$ platform was designed to allow for relocation to different parts of the site to best allow viewing of the various construction projects. Features of the structure that allow disassembly include; steel and timber construction as best to reduce size and load, paired structural members that support edges of roofs during disassembly, and stainless steel dowel connections [liv].

The World Exposition of 1988 in Brisbane saw the construction of numerous temporary buildings that were designed to be dismantled after the event and relocated for reuse. The prefabricated panel system and bolted external structural frame have allowed the buildings to be easily disassembled, relocated, and converted for use as commercial and industrial buildings.

There are other deconstruction projects, though most, such as remote research stations and the relocatable viewing platform in the Royal Botanical Gardens in Tasmania [lv], are isolated projects that are not accompanied by any research or greater intent other than fulfilling their own brief.

Initiatives in Deconstruction Summary
While these non-residential examples do illustrate the potential of deconstruction as a strategy for both economic and environmental benefit, they are isolated incidents. The vast majority of deconstruction activity in Australia is in the residential sector. Australia has a strong history of building material reuse that is in part due to;

- the construction technology and materials of older detached houses
- the history of the pattern of European settlement
- the current popularity of 'historic character' houses

RESEARCH IN DESIGN FOR DECONSTRUCTION

Design for deconstruction has a notable history in Australia, but an understanding of this as a strategy for environmental benefit is only just developing. A few authors and researchers have highlighted the environmental benefits of such a strategy and conducted some research into this area.

Research
In research led by an Australian academic, a survey of worldwide designers and construction professionals was used to develop a number of guidelines for designing for building systems replacement [lvi]. The resultant guidelines provide design assistance for designing for future disassembly of building services components. Though the research provided a large number of guidelines, many of them are very specific to certain building systems and services and have no apparent general relevance to disassembly issues.

Other authors have discussed deconstruction issues in a more general way and presented broad guidelines and policies for designing for deconstruction [lvii] [lviii]. These studies point out the environmental benefits of deconstruction in a generic sense.

Guidelines
A more comprehensive study of design for disassembly guidelines is currently being conducted at Queensland University of Technology [lix]. This study has analysed disassembly guidelines from industrial design practice, and guidelines from architectural technology, to develop a list of architectural guidelines to assist designers in creating a building that is easier to deconstruct. The guidelines can be used to assess the extent to which a building, or building design, can be deconstructed for material recovery. The guidelines will eventually be used in an assessment matrix to identify opportunities for

the redesign of the building to achieve improved rates of material and component reuse. The environmental benefits of such a strategy have also been investigated in a life cycle scenario [lx]. The guidelines being developed will be related to four possible scenarios of recovery (see Figure 6) which are presented as a hierarchy where reuse is preferred to reprocessing or recycling.

Strategies for Material Recycling

- Use recycled materials – increased use of recycled materials will encourage industry and governments to investigate new technologies for recycling, and to create a larger support network for future recycling and reuse
- Minimise the number of different types of materials – this will simplify the process of sorting materials on site and reduce transport to separate reprocessing plants
- Avoid hazardous or toxic materials – this will reduce the potential of contaminating materials that are being sorted for recycling and will also reduce the potential for human health risks during disassembly that may make recycling a less attractive option
- Make inseparable sub assemblies from the same material – this means that larger amounts of one material will not be contaminated by small amounts of a foreign material that can not be separated
- Avoid secondary finishes and coatings where possible – such coating may contaminate the base material and make recycling less practical, where possible use materials that provide their own suitable surface finish or use separate mechanically connected finishes (some protective coatings such as galvanizing will still be desirable in some situations for other reasons)
- Provide permanent identification of material types – many materials such as plastics are not easily identified and should have some form of non removable and non contaminating identification mark to allow future sorting of materials

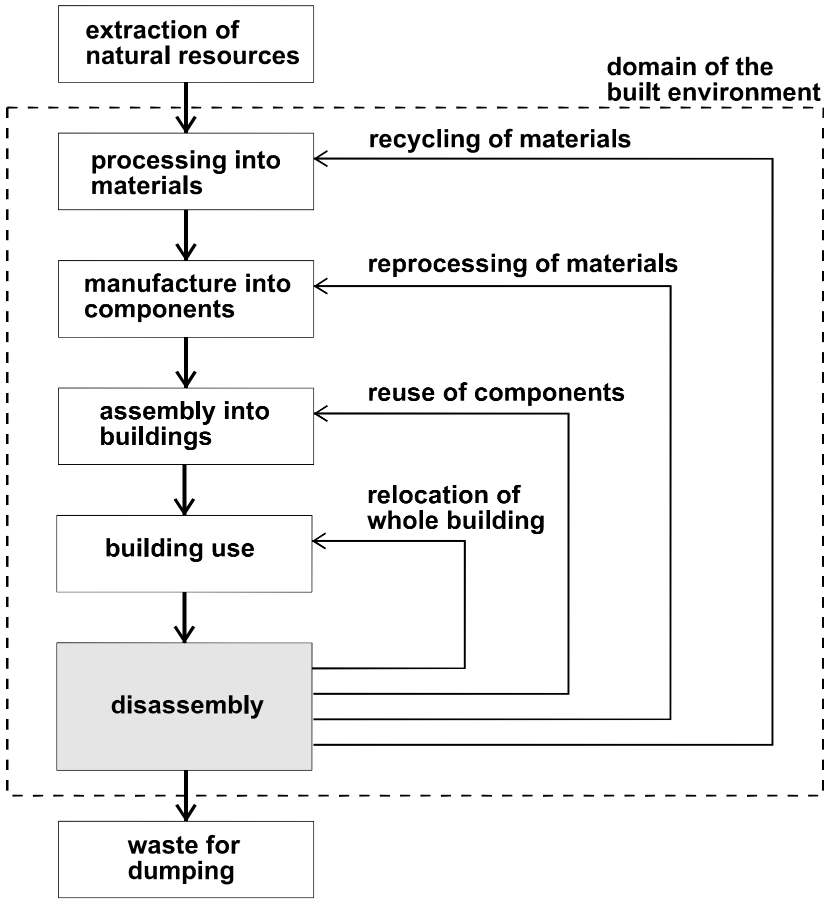


Figure 6 The four scenarios for materials reuse in the built environment.

Strategies for Component Reprocessing

- Minimize the number of different types of components – this will simplify the process of sorting on site and make the potential for reprocess more attractive due to the larger quantities of same or similar items
- Use a minimum number of wearing parts – this will reduce the number of parts that need to be removed in the remanufacturing process and thereby make reprocessing more efficient
- Use mechanical connections rather than chemical ones – this will allow the easy separation of components and materials without force, and reduce contamination to materials and damage to components
- Make chemical bonds weaker than the parts being connected – if chemical bonds are used they should be weaker than the components so that the bonds will break during disassembly rather than the components, for example mortar should be significantly weaker than the bricks

Strategies for Component Reuse

- Use an open building system – this will allow alterations in the building layout through the relocation of components without significant construction work
- Use assembly technologies that are compatible with standard building practice – specialist technologies will make disassembly difficult to perform and may require specialist labour and equipment that makes the option of reuse less attractive
- Separate the structure from the cladding, the internal walls, and the services – to allow parallel disassembly where some parts of the building may be removed without affecting other parts
- Provide access to all parts of the building and all components – ease of access will allow ease of disassembly, if possible allow for components to be recovered from within the building without the use of specialist plant equipment
- Use components that are sized to suit the intended means of handling – allow for various possible handling options at all stages of disassembly, transport, reprocessing, and reassembly
- Provide a means of handling components during disassembly – handling during disassembly may require points of connection for lifting equipment or temporary supporting devices
- Provide realistic tolerances to allow for movement during disassembly – the disassembly process may require greater tolerances than the manufacture process or the initial assembly process
- Use a minimum number of different types of connectors – standardisation of connectors will make disassembly quicker and require fewer types of tools, even if this result in the over sizing of some connections, it will save on assembly and disassembly time
- Use a hierarchy of disassembly related to expected life span of the components – make components with a short life expectancy readily accessible and easy to disassemble, components with longer life expectancy may be less accessible or less easy to disassemble
- Provide permanent identification of component type – similar to material identification, may use electronically readable information such as barcodes to international standards

Strategies for Building Relocation

- Standardise the parts while allowing for an infinite variety of the whole – this will allow minor alterations to the building without major building works
- Use a standard structural grid – grid sizes should be related to the materials used such that structural spans are designed to make most efficient use of material type
- Use a minimum number of different types of components – fewer types of component means fewer different disassembly operations that need to be known, learned or remembered – it also means more standardisation in the reassembly process which will make the option of relocation more attractive
- Use lightweight materials and components – this will make handling easier, quicker, and less costly, thereby making reuse a more attractive option
- Permanently identify point of disassembly – points of disassembly should be clearly identifiable and not be confused with other design features

- Sustain all information on the building manufacture and assembly process – measures should be taken to ensure the preservation of information such as 'as built drawing', information about disassembly process, material and component life expectancy, and maintenance requirements

Research in Design for Deconstruction Summary
The first research steps in understanding how to achieve better building deconstruction through design are being taken. Several researchers have presented strategies for designing for better deconstruction. These strategies or guidelines are presented as a starting point in thinking about design for deconstruction. As each building project is unique there can be no universal strategies that will always apply, and some of these strategies may be in direct conflict with other environmentally sustainable strategies. Like all attempts at improving our environmental performance, design for disassembly must be considered in a holistic way along with all of the environmental life cycle factors that may affect a project.

RECOMMENDATIONS

There are many issues regarding deconstruction in Australia that need to be reformed. The high rate of material and component reuse in the residential building sector offers a good example, but performance in the commercial and industrial building sector is poor. In general government policy is neither helpful nor encouraging, and it is still too easy to simply throw used materials and components away.

Waste and Recycling
As is evident in this report, there is no comprehensive understanding of current rates of building material waste or recycling and reuse. Better information on the rate of waste disposal is needed to highlight the extent of the problem and the need for more action. Similarly, more comprehensive information on the rates of recycling and reuse is required, and could be used to set benchmarks for compliance. It is not yet known if the Commonwealth Government will reach the target of a 50% reduction in waste going into landfill by the year 2000.

Policy
There are no effective Australia wide policies on building material and component reuse. Individual state legislation is patchy and in general does not address demolition waste directly. Since demolition waste is such a major part of the waste stream, specific policy and legislation on these matters are required, covering issues such as;

- Waste reduction
- Second-hand materials usage
- Levies and fees for waste disposal that work to encourage reuse and recycling
- Grants for research and development of reuse and recycling technologies
- Market development for reused materials and components

Design Practice
Many of the documents associated with building design, and building procurement, (specifications, contracts, applications) work directly against the encouragement of using reused materials and components. Existing documents need to be redrafted to make specification of second-hand materials easier, and to make the salvage of materials during demolition or deconstruction a more attractive option for the contractor, the client, and the designer.

Initiatives in Deconstruction
There are high rates of deconstruction and material reuse in the residential sector. The demolition of commercial buildings however does not result in such high rates of reuse. One of the possible problems is the development of suitable stable markets for these much higher quantities of materials. Some recent attempts at establishing Internet materials exchange networks have been attempted but are as yet not well supported at a commercial scale.

Other problems include the perceived economic costs associated with the time required to deconstruct rather than demolish. Experience in residential deconstruction, and research in other countries, suggests that the income from material salvage can outweigh the time costs. Research is needed to illustrate these benefits in case study building deconstruction projects in Australia.

In general, while deconstruction is practiced widely in the detached residential building sector, there is not a good understanding of it economically, or environmentally. It is also strongly reliant on the construction technology employed in those buildings. Therefore this level of reuse may not be sustainable in the decades to come when 'modern' buildings utilising 'modern' construction techniques are to be demolished or deconstructed.

Regardless, current residential practice should be used as an example to the greater construction industry of how improved levels of reuse can be achieved.

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REPORT 2
DECONSTRUCTION IN GERMANY

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ABSTRACT

This report deals with the state of the art of deconstruction in Germany. It comprises the general framework for deconstruction in Germany as well as sophisticated tools for deconstruction planning and optimization. Case studies carried out in Germany and France show the technical feasibility of deconstruction work as well as considerable potentials for preserving and reusing material.

KEYWORDS: Deconstruction; Dismantling and Recycling Planning; Building Audit; Case Studies; Optimization

1.0 INTRODUCTION

Although recycling of construction materials has a long tradition in Germany the use of recycled materials is still mainly focused on low-grade applications. One of the main obstacles to the use of recycled construction materials in high-grade applications is the heterogeneity of the composition and the contamination of construction and demolition waste (C&D waste) resulting from demolition of buildings. As an improvement in the quality of recycled materials in processing is technically limited, efforts have been made to improve the quality of the waste arising on demolition sites. While demolition often leads to mixing of various materials and contamination of non-hazardous components, deconstruction or selective dismantling of buildings instead of demolition help to preserve and reuse material. The latest developments in the German law on waste management encourage the efforts of deconstruction.

In recent years several projects have been conducted to analyse the technical and economical feasibility of various deconstruction strategies. Even though, in most cases the information published on these projects is not very detailed and the results of most of the projects conducted by private companies have not even been published, some projects are well documented and allow deriving valuable information for future activities.

In the following, the state of the art in deconstruction in Germany is shown and some case studies in Germany and France are presented. Moreover, a sophisticated planning approach and a computer tool for decision support and optimisation of deconstruction work will be introduced.

1.2 Classification and Composition of Demolition Waste

In general, figures about the amount and composition of demolition waste are found together with construction waste. The term construction and demolition waste covers a wide range of materials, for instance [18]:

- Waste arising from the total or partial demolition of buildings and/or civil infrastructure;
- Waste arising from the construction of buildings and/or civil infrastructure;
- Soil, rocks and vegetation arising from land levelling, civil works and/or general foundations;
- Road planning and associated materials arising from road maintenance activities.

One characteristic of construction and demolition waste arising from demolition (and construction) is the heterogeneity of its composition depending on the different construction types, as well as the multitude of materials, elements and aids, used in the construction area. Cross-contamination and general mixing of materials have to be avoided according to the regulations mentioned above. Nevertheless, demolition still often results in a mixture of materials.

In Germany, construction and demolition waste was classified according to a waste catalogue issued by the Länder Working Group Waste (LAGA Katalog) which distinguishes between the main groups shown in Table 1.

Table 1 Construction and demolition waste according to LAGA-classification

Waste Code	Description
31409	demolition debris
31410	road construction debris
31411	excavation debris
31441	contaminated demolition waste and excavation debris
91206	waste from construction sites
31407	ceramic and stone wastes
31408	glass waste
31423; 31424	contaminated soil
31436	asbestos waste
31438	gypsum waste
54912	bitumen, asphalt waste
55508	painting materials
57	various plastic and rubber waste
58	textile waste

The former LAGA catalogue was not compatible with the European Waste Catalogue (EWC) due to the different approaches adapted to the structuring. Since 1 January 1999 EWC came into force in Germany enforced by the corresponding national ordinance (Verordnung zur Einführung des Europäischen Abfallkataloges (EAKV)) [79]. For an intermediate period a combined catalogue [34] gives references as far as possible in order to facilitate the introduction of the EWC. According to the EWC, construction and demolition waste is grouped in Section 17 00 00 comprising the materials listed in Table 2.

Table 2 Construction and demolition waste in the European Waste Catalogue

Waste Code	Description
17	**Construction and Demolition Waste**
17 01	concrete, bricks, tiles, ceramics and gypsum based materials
17 01 01	concrete
17 01 02	bricks
17 01 03	tiles and ceramics
17 01 04	gypsum based construction materials
17 01 05	asbestos based construction materials
17 02	**wood, glass and plastic**
17 02 01	wood
17 02 02	glass
17 02 03	plastic
17 03	**asphalt, tar and tarred products**
17 03 01	asphalt (containing tar)
17 03 02	asphalt (not containing tar)
17 03 03	tar and tar products
17 04	**metals (including their alloys)**
17 04 01	copper, bronze, brass
17 04 02	aluminium
17 04 03	lead
17 04 04	zinc
17 04 05	iron and steel
17 04 06	tin
17 04 07	mixed metals
17 04 08	cables
17 05	**soil and dredging spoil**
17 05 01	soil and stones
17 05 02	dredging spoil
17 06	**insulation materials**
17 06 01	insulation materials containing asbestos
17 06 02	other insulation materials
17 07	**mixed construction and demolition waste**
17 07 01	mixed construction and demolition waste

Up to now, no official statistics are available about the arising and composition of waste resulting from the demolition or deconstruction of buildings. Some hints about the composition and amount of demolition waste are given in [80,54]. Recent figures can also be found in [18]. It can be assumed that demolition waste arising from the demolition of buildings in Germany sums up to 45 Mio. tonnes per year [33].

In order to obtain reliable data about the amount and composition of demolition waste resulting (only) from the demolition or deconstruction of buildings, the French-German Institute for Environmental Research has carried out studies to determine these composition using a model where existing buildings were first classified by the criterion size, age and building type [70]. Based on detailed bill of materials for the predominant buildings the average composition of demolition waste from buildings can be determined. A validation of this model for the Upper-Rhine Region (Baden (D) - Alsace (F)) shows that the major shares of the components are minerals (cf. Figure 1).

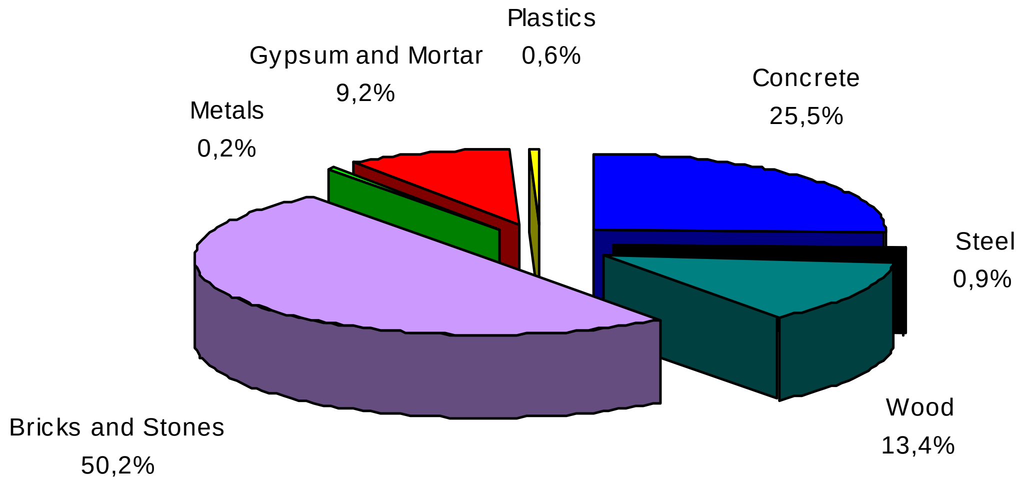


Figure 1 Composition of demolition waste from residential buildings

2.0 DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY, AND TOOLS

Separation of building waste

The separation of building materials can be achieved by different techniques. The most efficient among them is the selective dismantling of buildings. Due to the fact, that every single building element can be separated from the others, the achievable separation of the building materials is extremely high. But on the other hand an extensive dismantling leads to high personnel costs. Depending on the prices for disposal and recycling in the region the building is situated in these personnel costs can be higher than the savings caused by less expansive disposal.

More frequently than by selective dismantling, different building materials are separated by manual sorting after a demolition. The material separation achieved by manual sorting is not as exact as if the building were dismantled. In many cases sorting takes less time, which makes it cheaper, compared to dismantling. That means, that if the requirements regarding the purity of the recycling material are not very strict, sorting is probably preferred. Some building elements such as water pipes and cables, located under the plaster or iron radiators can even be better sorted afterwards rather than being dismantled, at least from an economic point of view.

A further possibility to separate the foreign matter from the mineral building waste is the use of separating devices in recycling plants. The main principles and techniques of separation devices will be explained more closely in the following (cf. [67]).

Most stationary recycling plants in Germany possess either an air flow based or a water based separation device, whereby the majority of German recycling plants use air flow based separation devices, although the water based technique provides the better quality [29], [6]. Wet separation techniques use water to separate lighter and heavier materials. In some cases other substances are added to the water to increase the specific weight of the water and to change the point light materials flow up. Some water based separating devices use supplementary water jets or air to support the separation by density differences. Figure 2 gives a general overview of the different kinds of water based separating techniques, which can be differentiated by the four categories: thin film separation, jig separation, up current separation, float and sink separation. Within these four categories several different devices are available based on the same technique which each vary in detail.

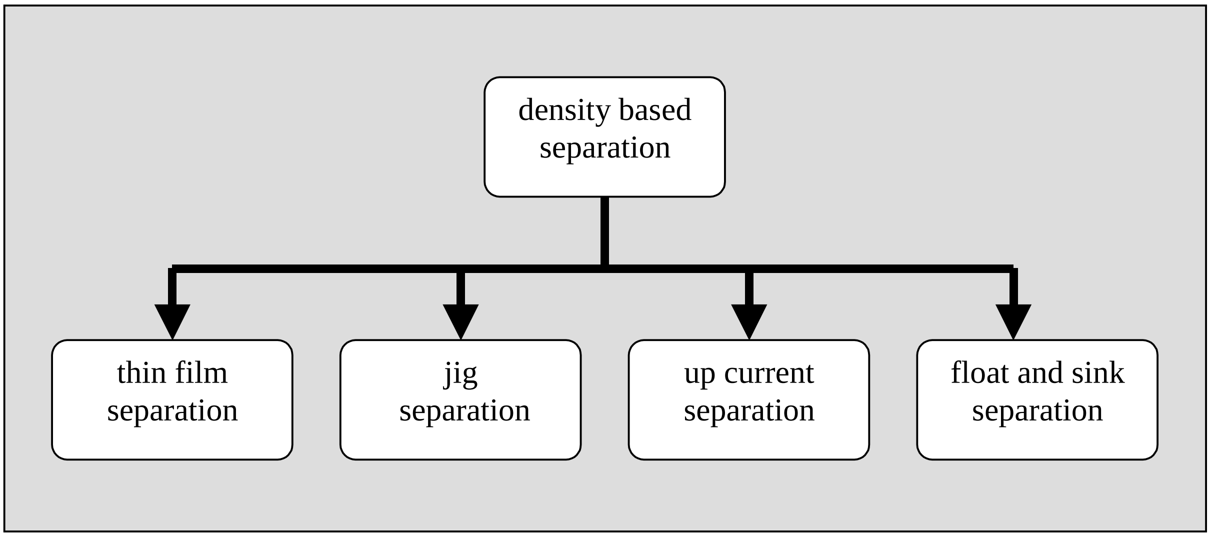


Figure 2 Overview of water based separating techniques

Air flow based separating devices use the air flow to "blow away" light materials and to isolate the lighter non mineral materials from the heavier material materials. In general the airflow-based techniques are characterised by lower operationg costs. But, on the other hand, the resulting material separation is not as exact as with the wet techniques. Figure 3 shows the functionality of frequently applied airflow based separating devices. The "reverse air flow sorting technique" and the "cross air flow sorting technique" are the fundamental systems in the field of airflow based separating devices. Cross airflow sorting has the advantage that the materials remain in the device for a much shorter time, which increases performance. In addition the geometric form of materials to be separated is much more important than with reverse airflow sorting. As a consequence, modern cross air flow sorting devices use the correlation of geometric form and the quality of material separation to achieve a better sorting [10]. The "exhaust of foreign matter" is a modification of the cross airflow sorting technique. Instead of using a free fall system, the materials to be sorted lie on a vibrating conveyor belt that preseparates the light materials from the mineral fraction. Zig-zag separation devices use the reverse air flow sorting technique, which is modified by the zig-zag form of the mechanism. Thus the effectiveness of sorting can be increased, because the zig-zag form has the same effect as a succession of several single cross air flow sorting devices [71].

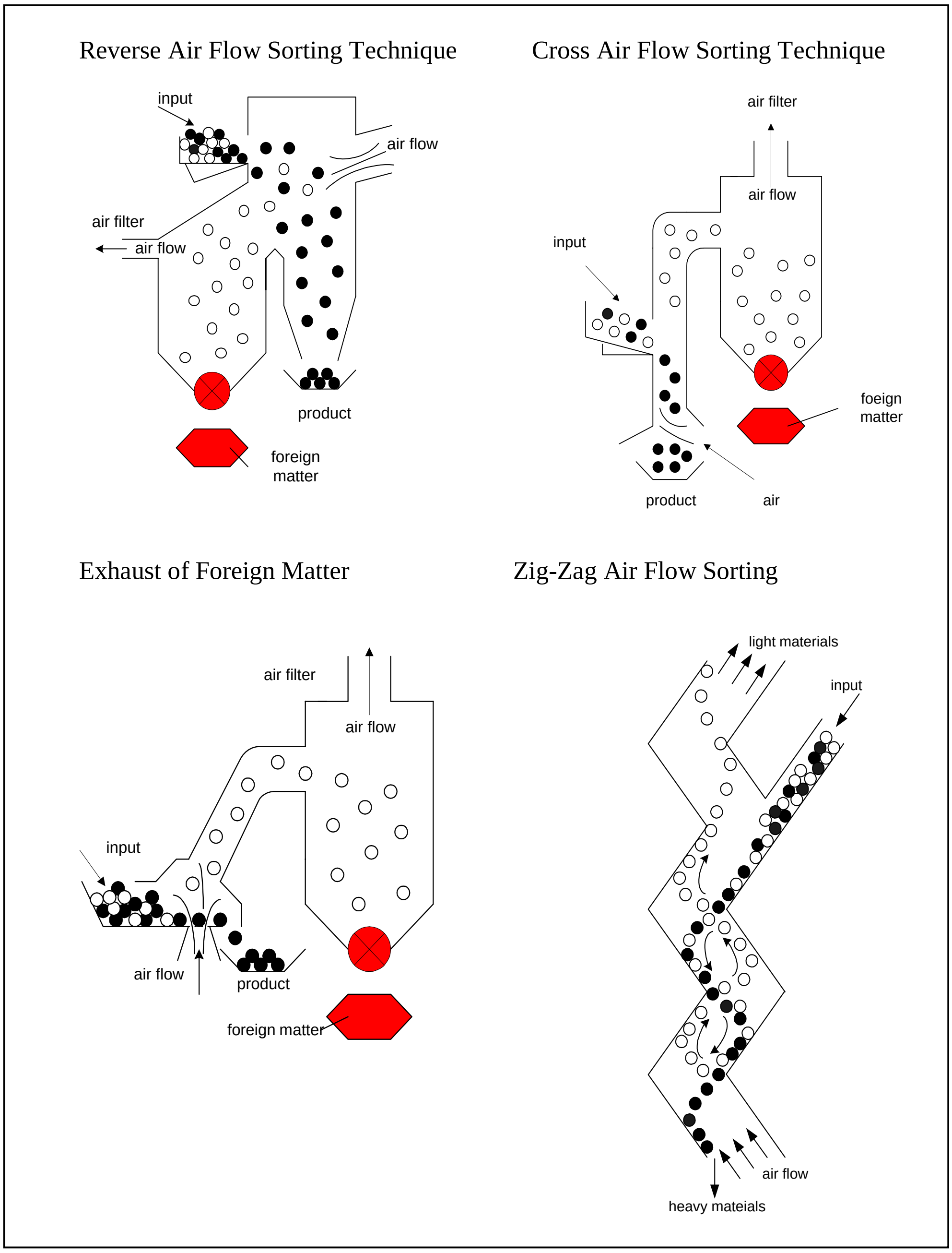


Figure 3 Main principles of flow based separating techniques [2], [30]

4.0 ENHANCING MATERIALS RECYCLABILITY

Pollutant Sources in Buildings

Recycled construction materials from deconstructed buildings should be available in such quality, that they meet the required profile for natural construction materials. It should also be observed that both plain and mixed grades of building waste could contain pollutants, which could damage the environment during storage or re-use. These pollutants are contained in construction materials due to their natural material composition, or were artificially added during manufacture, for example in the form of additives. Nevertheless very few materials in demolition waste are invariably hazardous (as defined in European Council Directive 91/689/EEC). The major pollutant sources in buildings were identified mainly through studies in building examination laboratories and are to be seen in Table 3 [57,48]. A great share of pollutants is caused by surface area treatment such as paint. They are added partly for improvement and partly to protect the construction materials.

Table 3 Potential Pollutant Sources in Buildings

Origin	Relevant Pollutants
Natural stone	Heavy metals
Gypsum	Sulphate, heavy metals
Asbestos	Asbestos
Treated wood	Heavy metals, lime, phenol, PCP
Plastics	Phenol, CH_x, organic components
Sealant	PCB
Roofing felt	CH_x, PAH, phenol
Tech. installation	PCB, Hg, Cd
Soot	Heavy metals, PAH
Dust	Heavy metals
Fire	PAH, PCDD/PCDF
Accidents (use)	Includes oil, alkalis, acid

In order to classify pollutants according to their damaging properties, a modelling approach has been developed (cf. [58]). This methodology helps to set up a detailed deconstruction planning with the aim of minimal pollutant remaining in materials arising after deconstruction (cf. below).

Recycling and reuse of construction materials

In Germany, about 1600 landfills for construction and demolition waste exist. In general however, according to the requirements set up in the TA Siedlungsabfall (see above), mineral and unsorted construction and demolition waste may not be disposed to landfill. Disposal of other construction and demolition waste is strongly affected by the Recycling and Waste Management Act and by the corresponding ordinances (see above).

Additionally, there is a considerable capacity for the treatment of demolition waste. There are about 650 companies operating around 1000 crushers (mobile, semi-mobile and stationary/fixed facilities). Nevertheless the availability of processing facilities highly depends on the regions. Figure 4 demonstrates as an example the location of recycling facilities for demolition waste in the region of the upper Rhine Valley, covering an area of 16450 km² (Baden (D), Regierungsbezirk Freiburg/Karlsruhe and Alsace (F), Département Du Bas-Rhin/Haut-Rhin) [70,62].

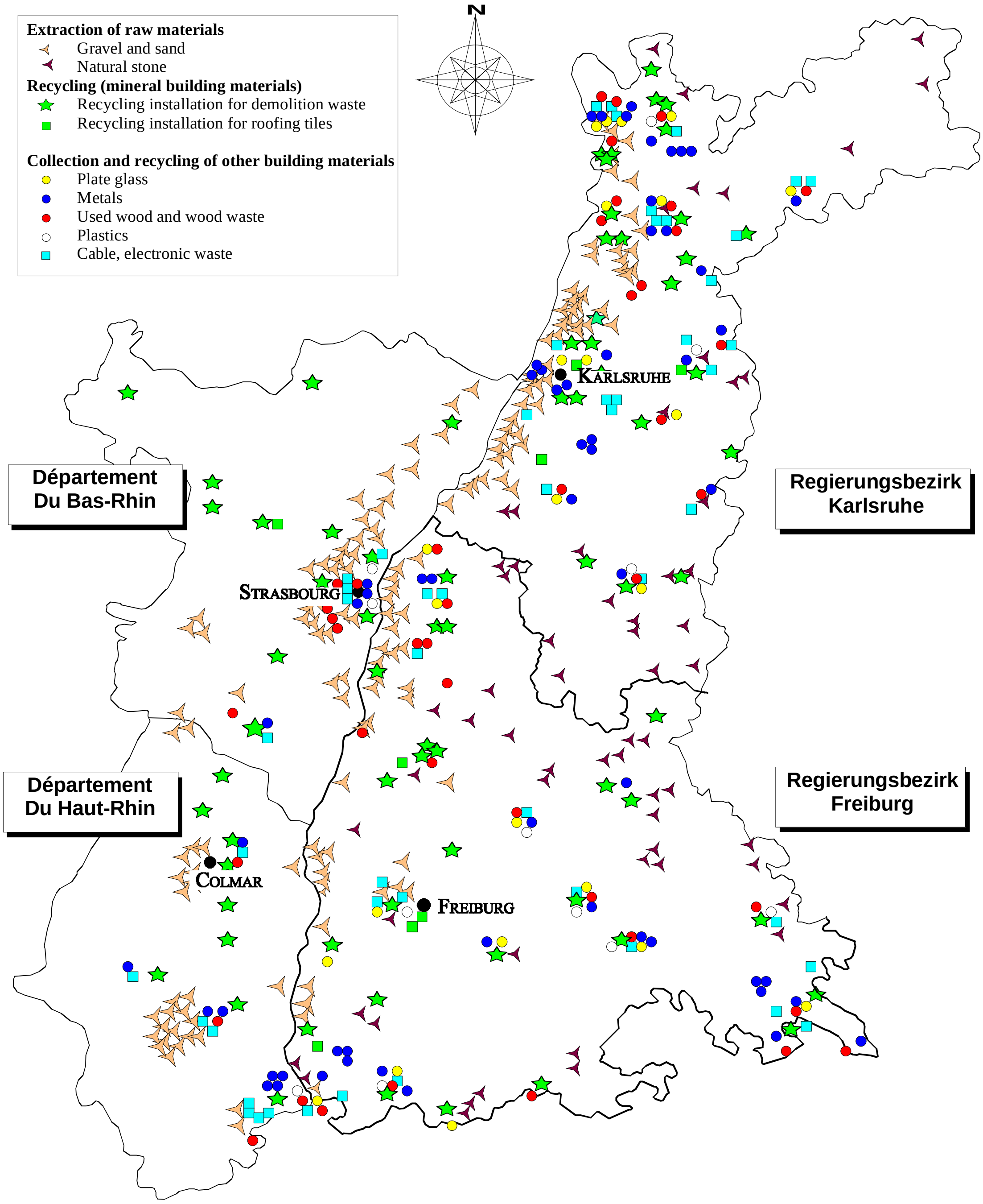


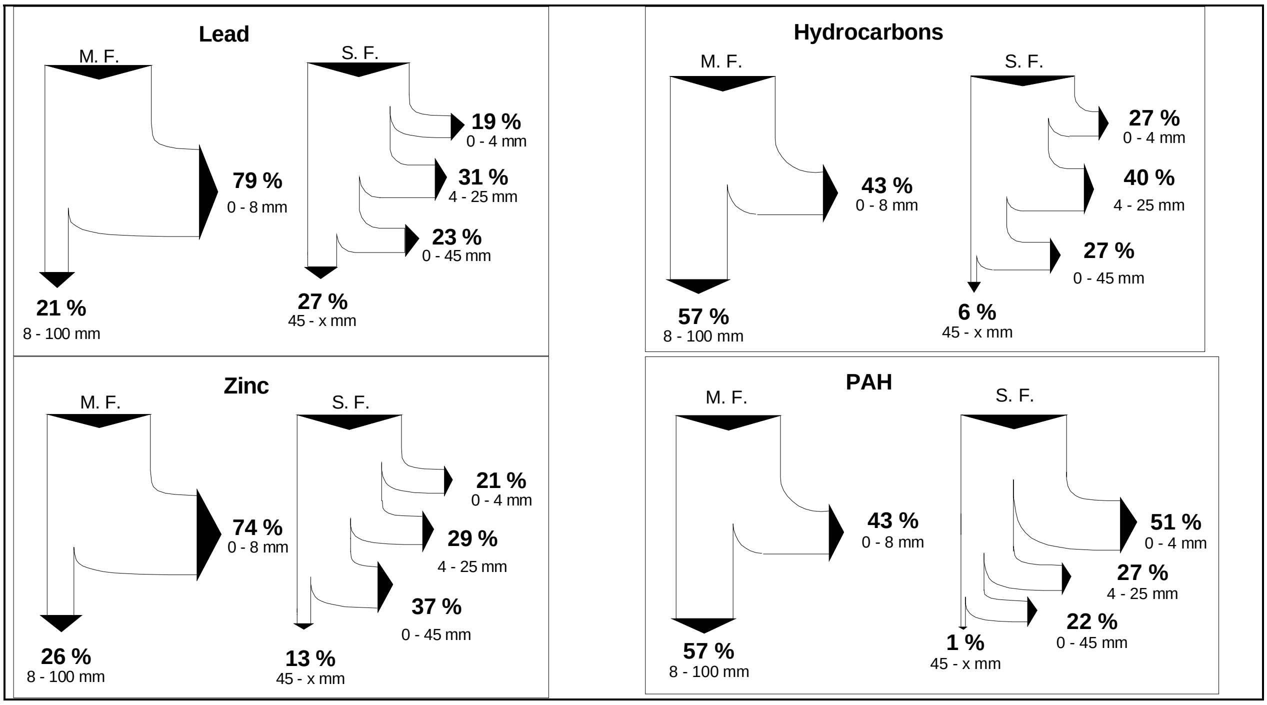
Figure 4 Extraction of raw materials and recycling in the Upper Rhine Valley [62]

Recycling and direct re-use can be supported by waste exchanges that have been established both, on national and regional levels. Furthermore, specialised operators dealing with used construction materials have established several outlets in Germany.

4.3 Deconstruction as a method for increasing materials recyclability

Although, in Germany sophisticated recycling facilities for demolition waste are already available since several years, recycling becomes problematic when mixed materials or materials containing pollutants are introduced in recycling facilities.

In order to examine the influence of the processing techniques on the environmental compatibility on the components of the recycling material, unsorted material from the demolition of similar buildings was processed and characterised (for details see [57,48,69,41]). This was carried out in two recycling plants of different configuration, one mobile and one stationary facility. Mobile facilities are set-up on larger demolition sites, so that the demolition waste can be processed on site. The advantage of processing building waste in a stationary facility is that this process type, due to its' complex configuration, makes it possible to produce high quality recycling material.
Pollutant balances show that the coarse fraction have a low pollutant content (see Figure 5). Most of the pollutants were to be found in the finer fractions, so that through the removal of these fractions the total pollutant content can be significantly reduced (e. g. up to 51% of polycyclic aromatic hydrocarbons (PAH) and 79% of the lead content.



M.F. = Mobile Facility   S.F. = Stationary Facility

Figure 5 Distribution of Pollutants in Processing Facilities

The examinations demonstrated in the previous show the borders of the pollutant removal through the existing process technical operations. Therefore in this section it should be shown, which influences the composition of the demolition waste has on the quality of recycled components, with regard to environmental compatibility.

Different compositions can be reached through division of the material before processing, for instance through a pre-sorting in a sorter facility, or even through separation of the demolition waste on-site by application of adequate deconstruction methods. By the use of appropriate deconstruction techniques construction elements containing pollutants can be dismantled and the quality of the remaining materials can be improved. Figure 6 illustrates the influence of the deconstruction, respectively the demolition method on the environmental compatibility of processed recycling materials.

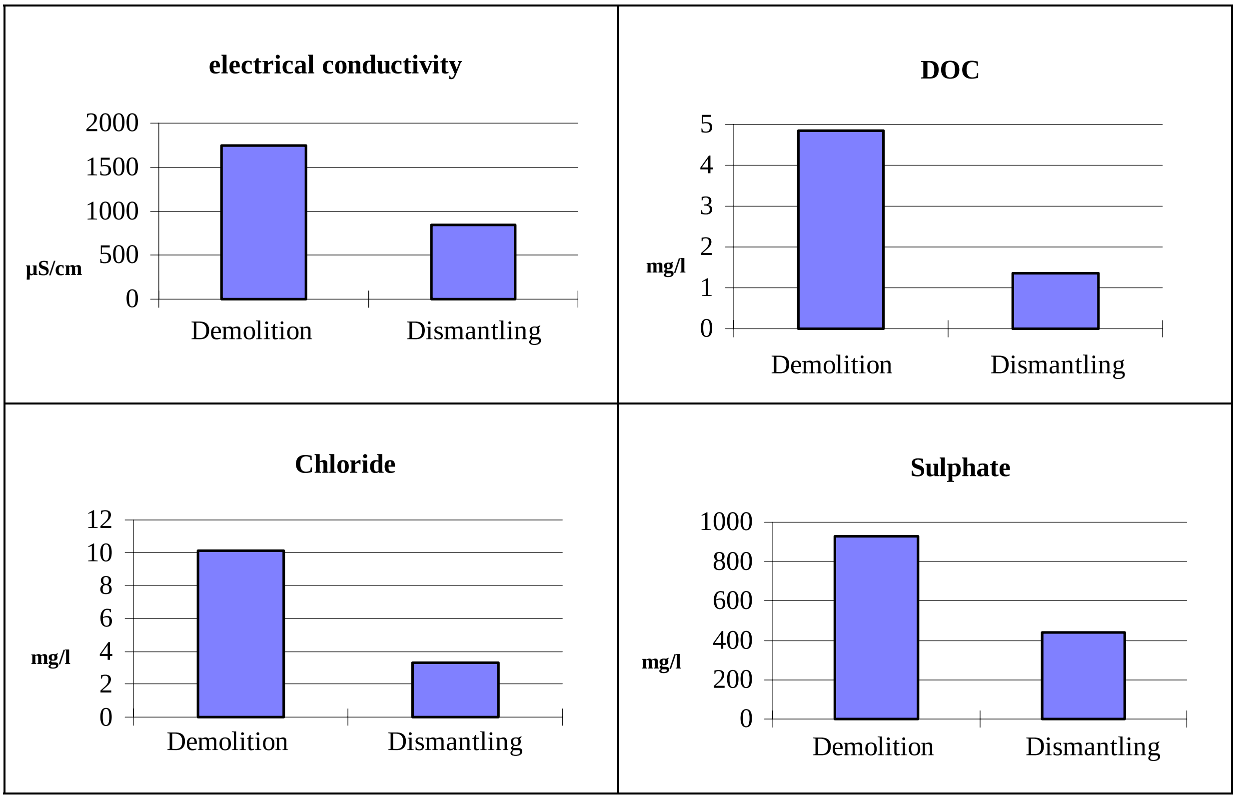


Figure 6 Eluate analysis of demolition waste (Fraction 0 - 8 mm) resulting from demolition and dismantling

It could be shown for instance that only by the separation of chimneys, or more specifically their inner walls from the rest of the demolition waste the pollutant content could be significantly reduced. Dismantling or separation techniques for the removal of chimneys must be found so that the occurring masses of the deposited chimneys are not excessive. Options here include the use of a milling cutter or sandblaster, to wash the chimney or the surface construction of the inner walls of the chimney.

6.0 ECONOMICS OF DECONSTRUCTION AND MARKETING OF USED BUILDING MATERIALS

Taxes for Construction and Demolition Waste

In Germany, no federal taxes or levies are charged to the disposal of construction and demolition waste. Apart from the obligation of recovery imposed by the Recycling and Waste Management Act, an incentive to separate and sort construction and demolition waste is given to landfill tariffs. These tariffs show considerable differences depending on the composition of the waste and the region where the landfill is located. For example, in 1996 the tariffs for mixed construction and demolition waste, not considered as being hazardous, ranged between 50 and 100 EUR/tonne [18,25].

No official statistics are available concerning the tariffs for recoverable construction materials charged by the operators of processing facilities. These tariffs vary wildly depending mainly on the market conditions and the region. Table 4 gives a survey of the prices based on a market study of 195 recycling facilities operating in the South West of Germany [62].

Table 4 Prices for demolition waste

Materials		Average price charged (∅) [DM/tonne] Variation (Δ) [DM/tonne]				
Demolition Waste (minerals)		Quality 1	Quality 2	Quality 3		1)
	∅	16,5	50,1	66,7		
	Δ	5,8 - 30	19,5 - 150	25 - 160		
Roofing Tiles	Δ	-20 - 18				
Used Wood		untreated	treated			
	∅	151	217			
	Δ	70 - 262	155 - 360			
Metals		Scarp Iron	Copper	Brass	Zinc	
	Δ	0 - 80	-2600 - 1500	-1700 - 400	-450 - 200	
Cable, Electronic Waste	Δ	400 - 850				
Plate Glass		Plate Glass		Windows incl frame		
	Δ	-55 - 110	90 - 320	275 - 320		
Plastics	Δ	350 - 600				

[1] Quality 1: Demolition waste without fine fraction or mixed materials
Quality 2: Demolition waste with low content of mixed materials (<30%)
Quality 3: Demolition waste with high content of mixed materials (>30%)

In Germany the costs for recycling and disposal of demolition waste range in the same category as the costs for demolition. So it can be advantageous to dismantle as many building elements as possible if this leads to a decreasing of the recycling and disposal costs. Table 5 shows the average costs for the recycling and disposal of various kinds of demolition waste.

Table 5 Average deposit fees and recycling costs for various types of materials in Germany [66].

Category of Materials	Deposit Fees [EUR]	Recycling Costs [EUR]
Mineral materials		
Concrete Scrap	-	7 to 10 EUR/t
Bricks	-	7 to 10 EUR/t
Mixed mineral Materials	80 to 200 EUR/t	9 to 13 EUR/t
Metals		
Iron	-	-40 to 0 EUR/t
Aluminium	-	-250 to -100 EUR/t
Copper	-	-1000 to -250 EUR/t
Wood		
Untreated Wood	-	35 to 65 EUR/t
Lightly treated Wood	-	50 to 100 EUR/t
Treated Wood (pressure impregnation)		50 to 250 EUR/t
Other Building Materials		
Glass	-	30 to 65 EUR/t
Plastics	-	50 to 200 EUR/t
Mixed Building Materials *		
Mixed Materials (only recycling)		125 to 200 EUR/t
Mixed Materials (recycling and disposal)	125 to 300 EUR/t	
Mixed Materials (only disposal)	125 to 300 EUR/t	

* Mixed Material have to be sorted according to their material composition

6.3 Deconstruction assessment tools

The aim of efficient deconstruction is to reduce the whole duration for dismantling on the site, to lower the costs, to improve the working conditions and to assure the required quality of the materials. In order to optimise deconstruction, a methodology for the deconstruction and recycling management for buildings has been developed at the French-German Institute for Environmental Research, which is explained in the following. In order to facilitate the task described, a sophisticated computer aided dismantling and recycling planning system is used [60,61,62]. The methodology for optimization is based on resource-constrained project scheduling, described in detail in [62, 63,64]. The structure of this system is illustrated in Figure 7.

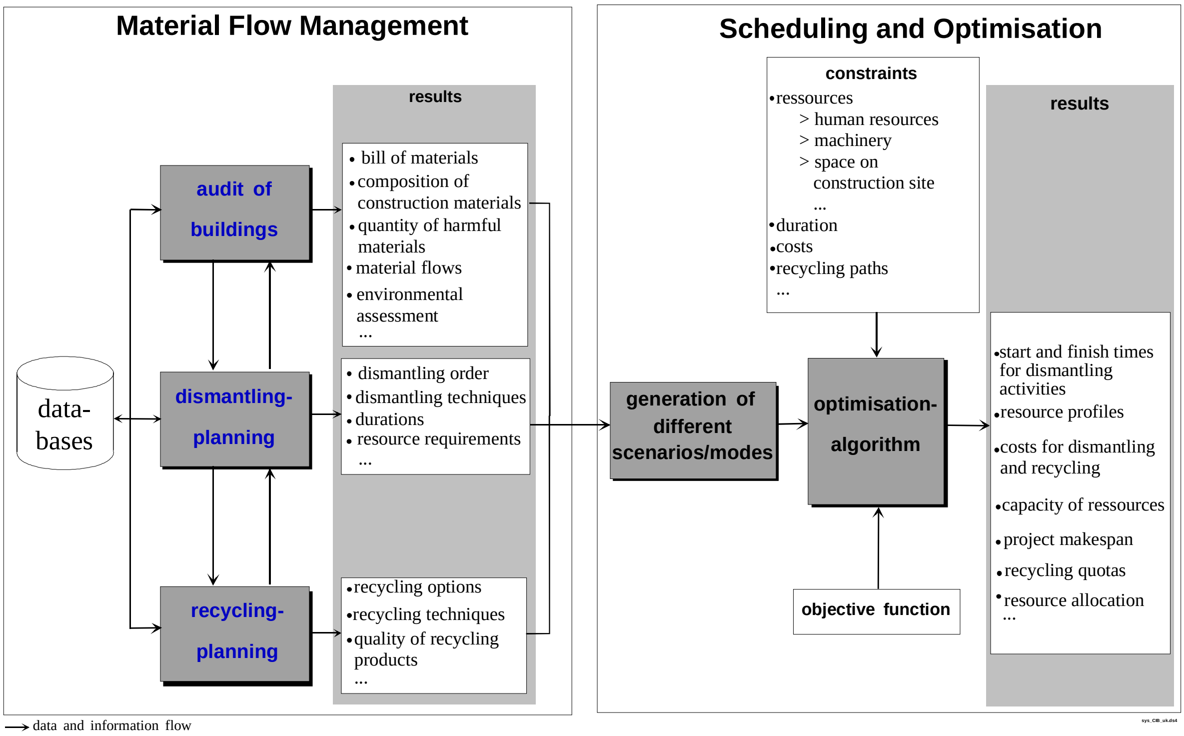


Figure 7 Structure of the deconstruction planning system

Audit of Buildings

An essential step both for deconstruction planning and for the quality assurance of materials that are encountered as a result of demolition is a proper pre-deconstruction survey, also called building audit [65]. Although it is not absolutely certain what will be found when structures are broken open during dismantling of demolition, carrying out such a building audit can reduce much uncertainty. The building audit mainly consists of making a detailed description of the building and identifying materials. Based on the documents of the building (construction plans, descriptions, history) detailed data on the composition of the building has to be collected and analysed. Due to the fact that deconstruction normally affects older buildings, reliable information documenting the current state is rarely available. During this audit indications of substances contained in the building, which may influence the quality of the materials must be collected and analysed. The audit also gives precise information for further investigation on possible pollutant sources and contamination of the building.

The planning system supports the audit by the preparation of bills of materials, which contain details of the materials and the locations of building elements and pollutant sources (cf. Table 6). The content of pollutants can be addressed by a methodology using so-called pollutant vectors for materials and surfaces [58].

Table 6 Bill of materials for a residential building (excerpt)

item no.	construction	room	connected	length	width	area	height	volume	volume	quantity	no.	building	density	portion	coating
	element	no.	room									material			
				[m]	[m]	[m²]	[m]	[m³]	[kg]				[kg/m³]	[%]	
33120	masonry	01010	01001	4,67	2,95	10,58	0,5	5,29	12375	1	1140	sandstone	2500	80	
	(exterior)										2110	lime mortar	1700	20	
33410	door	00070	00001	0,85	2,10	1,79	0,03	0,04	36	1	5100	cast iron	7800	8	
	(exterior)										6300	spruce	600	92	paint
33411	door-frame	00070	00001	6,00	0,35	2,1	0,02	0,04	20	1	5100	cast iron	7800	2	
											6300	spruce	600	98	paint
33430	window	01090	01002	0,60	1,22	0,73	0,05	0,04	83	2	4100	sheet glas	2500	80	
											5100	cast iron	7800	2	
											6300	spruce	600	18	paint
33440	window-ledge	01080	01002	2,20	0,20	0,44	0,15	0,07	165	1	1140	sandstone	2500	100	
33450	window-frame	01090	01002	3,60	0,20	0,72	0,2	0,14	360	1	1140	sandstone	2500	100	paint
33510	plaster (exterior)	02080	02002	2,89	3,20	5,45	0,02	0,11	185	1	2110	lime mortar	1700	100	paint
34120	masonry	02020	02090	4,90	3,20	15,68	0,08	1,18	1682	0,5	3300	solid brick	1400	90	
	(interior)										2110	lime mortar	1700	10	
		02090	02020	4,90	3,20	15,68	0,08	1,18	1682	0,5	3300	solid brick	1400	90	
											2110	lime mortar	1700	10	
		total:					0,15	2,36	3364	1					
34410	door	00140	00150	0,86	1,98	1,70	0,01	0,017	16	0,5	5100	cast iron	7800	5	
	(interior)										6300	spruce	600	95	paint
		00150	00140	0,86	1,98	1,70	0,01	0,017	16	0,5	5100	cast iron	7800	5	
											6300	spruce	600	95	paint
		total:					0,02	0,034	33	1					
34510	plaster (interior)	01010	01020	3,60	2,65	7,86	0,02	0,16	189	1	2210	gypsum mortar	1200	100	adhesive
35110	ceiling	00010		11,14	2,86	31,86	0,15	4,78	6834	1	2110	lime mortar	1700	10	
											3300	solid brick	1400	90	
35112	ceiling filling	02050		4,97	3,71	18,44	0,22	4,06	1988	1	1530	expanded clay	600	35	
	material										1610	slag	700	30	paint
											6830	thatch	200	35	
35210	floor covering	03100		3,60	1,20	4,32	0	0,02	26	1	7100	plastic	1500	100	adhesive
36300	roof covering	03010		0,40	0,25	0,1	0,02	0,0015	3	280	3600	roofing tile	1700	100	
36370	downspout			9,00	0,20	1,8	0,01	0,01	15	2	5600	zinc	7200	100	
41242	W.C.	01060							21	1	3900	porcelain	1100	100	

Dismantling Planning

With the available information about the composition of the building combined with the information about the regional framework for waste management, the planning of the dismantling work can be carried out.

On the basis of the bill of materials, appropriate dismantling techniques are selected and aggregated to dismantling activities. Information about dismantling techniques and corresponding costs can be found in [62,19]. The configuration of the dismantling activities comprises the determination of the corresponding construction elements (found in the bill of materials) and the selection of the resources necessary. Since the aim of the dismantling planning can be dismantling with minimal costs, dismantling with the aim of preserving building elements intact for later re-use, or dismantling due to technical restrictions etc., the determination of dismantling activities may vary considerably. The computer-supported configuration of a dismantling activity is illustrated in Figure 8 [56]. For the temporal planning of the dismantling work reference numbers, stored in a database, can be chosen for each construction element depending on the dismantling techniques available (cf. Figure 9).

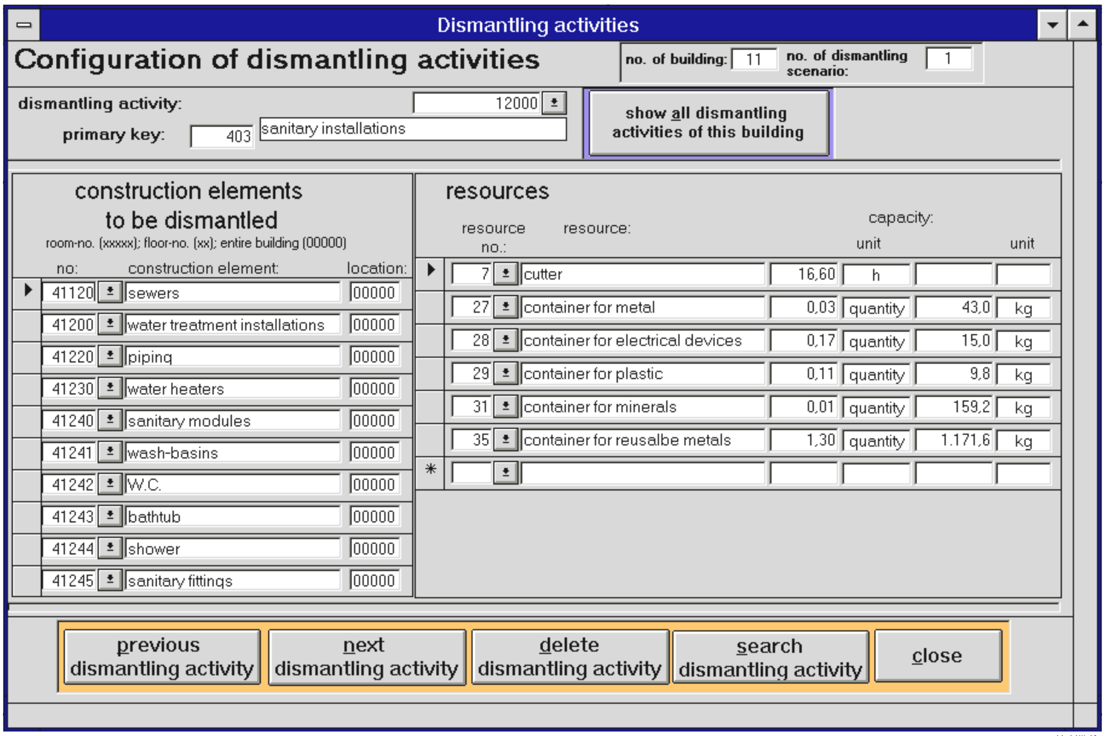


Figure 8 Configuration of dismantling activities [62]

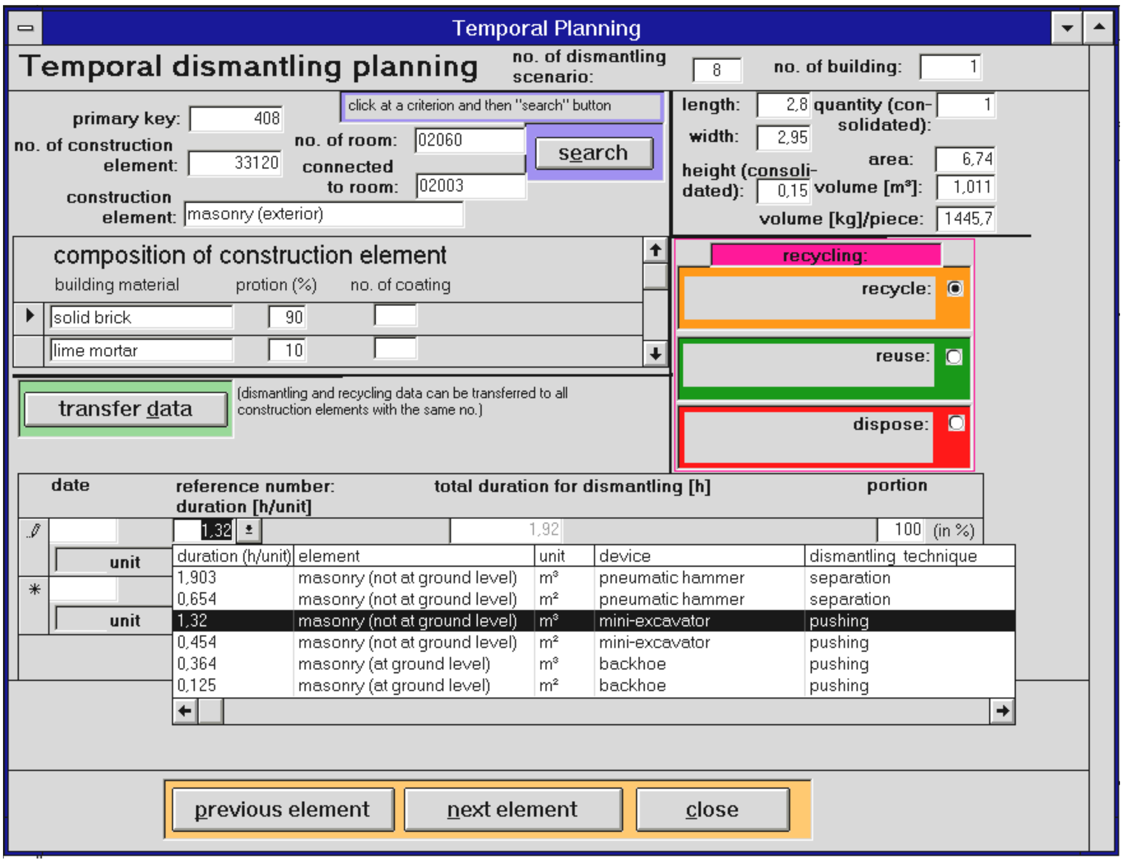


Figure 9 Computer aided dismantling planning [62]

The dismantling order respecting technological relations as well as security aspects and environmental requirements (like the decontamination of buildings) can be illustrated in so called dismantling networks. Figure 10 gives an example of a dismantling network for a residential building [58].

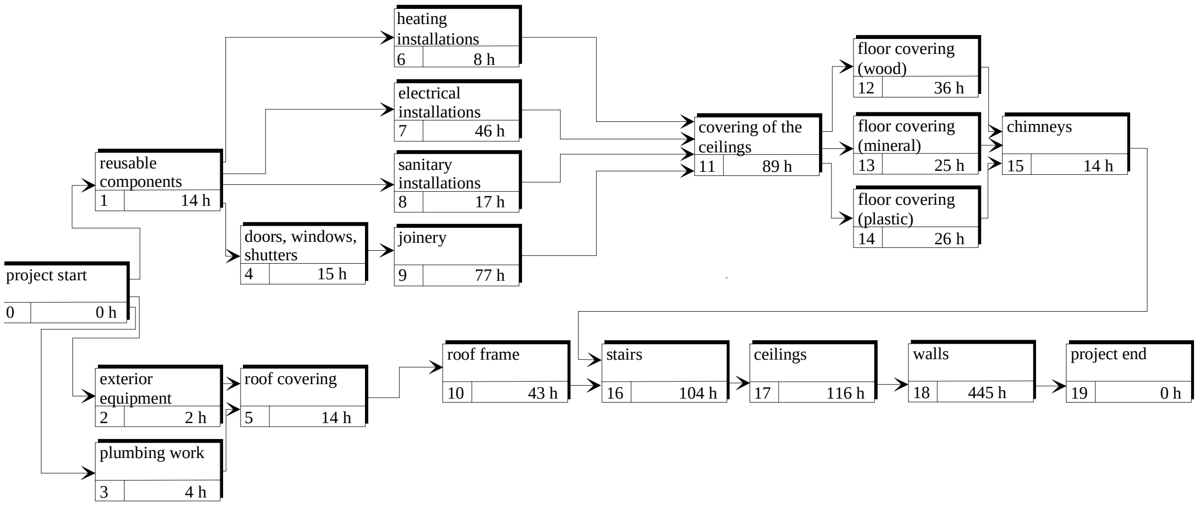


Figure 10 Dismantling-network for a residential building

After determining the dismantling activities and precedence relations the target of dismantling planning is to find feasible or “optimal“ working schedules. If resources (machines, workers, space on the construction site, budget) are limited this problem becomes extremely complex.

Recycling and Reuse Planning

The objective of recycling planning is the design of optimal recycling techniques for processing dismantled materials and building components into reusable materials. Depending on the stage of dismantling, the feed can be either a single material or a mix of all building materials. For certain individual materials such as metals, glass and minerals or plastics, recycling techniques already exist. In this case recycling planning is a simple co-ordination. Recycling is difficult, when materials are mixed, when composite materials occur or when pollutants like hydrocarbons or asbestos are present. In order to obtain materials in an optimal composition for recycling facilities, the available recycling techniques as well as the location of processing facilities (see above) have to be considered during dismantling planning. Case studies have shown, that direct re-use of elements can be a promising alternative if dismantling is planned well (cf. [59,50,40,38]).

Optimization of deconstruction works

The projects carried out in practice and analysed so far have shown a potential for further improvements concerning cost reduction as well as environmental benefits. Based on these results, computer simulation helps to reveal improvement potentials for deconstruction. In order to show some possible improvements, various simulations and optimisations using the planning tool described above were carried out. Due to this high complexity of the dismantling and recycling planning a sophisticated mathematical optimisation model is used as decision support. The model takes into account the interrelations between material flow management (concerning dismantling and recycling) and project management. The consideration of both, material as well as monetary flows during the various planning stages enables the elaboration of time and cost efficient as well as environmental friendly deconstruction strategies.

In order to evaluate optimal schedules for dismantling different scenarios might be applied, for instance:

- Dismantling of buildings using of the possibilities of parallel work as much as possible,
- dismantling using mainly manual techniques,
- dismantling using partly automated devices and a
- dismantling strategy strictly focused on “optimal” recycling possibilities according to the material flow analysis.

Computational results for different deconstruction strategies for a building show considerable economic improvement compared with a deconstruction project in practice. As illustrated in Figure 11 construction site management can be drastically improved. Optimised dismantling schedules, based on the same framework as in practice, show cost savings up to 50 %. In some cases the dismantling time can be reduced by a factor 2 applying partly automated devices. Furthermore, a recycling rate of more than 97 % can be realised [58,62].

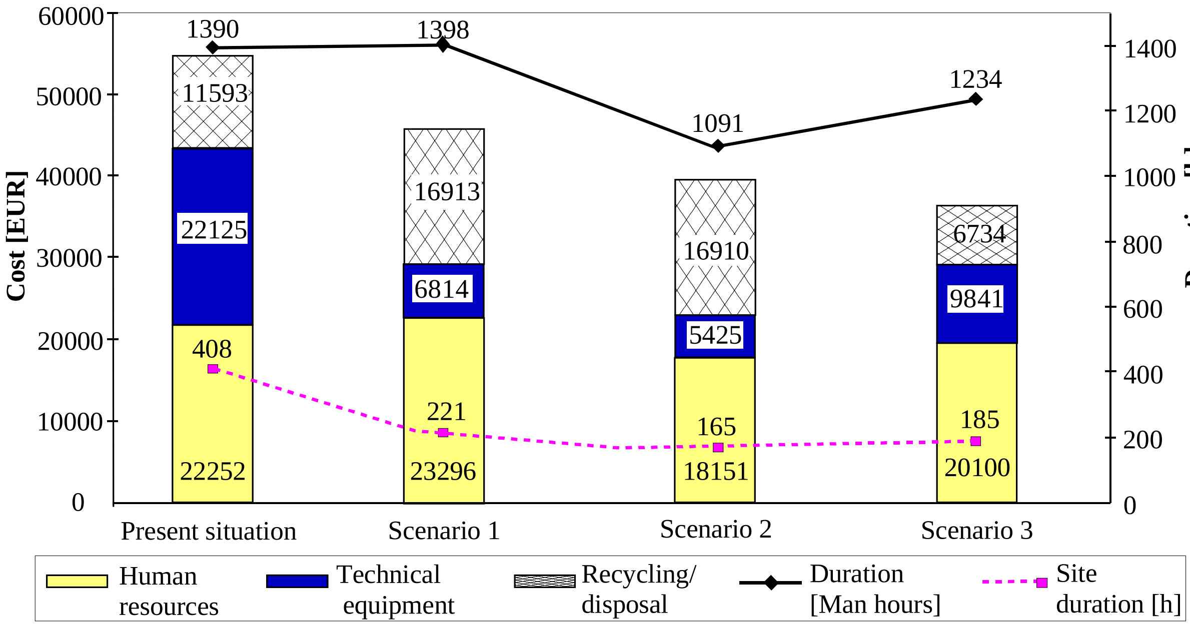


Figure 11 Cost and duration of different dismantling strategies for a residential building

Based on selected deconstruction strategies the detailed planning and optimisation of deconstruction work can be done. Figure 12 shows the results of minimising the duration of deconstruction. The complete schedules for two different dismantling scenarios (*partly automated* and *material oriented*) and the corresponding project costs show that an environmental oriented dismantling strategy imposes a higher effort to the dismantling work. That is, more jobs have to be carried out in order to avoid a mix of hazardous and non-hazardous materials. Nevertheless, environmental oriented dismantling strategies are not necessarily disadvantageous from an economic point of view, if disposal fees are graded according to the degree of mixed materials.

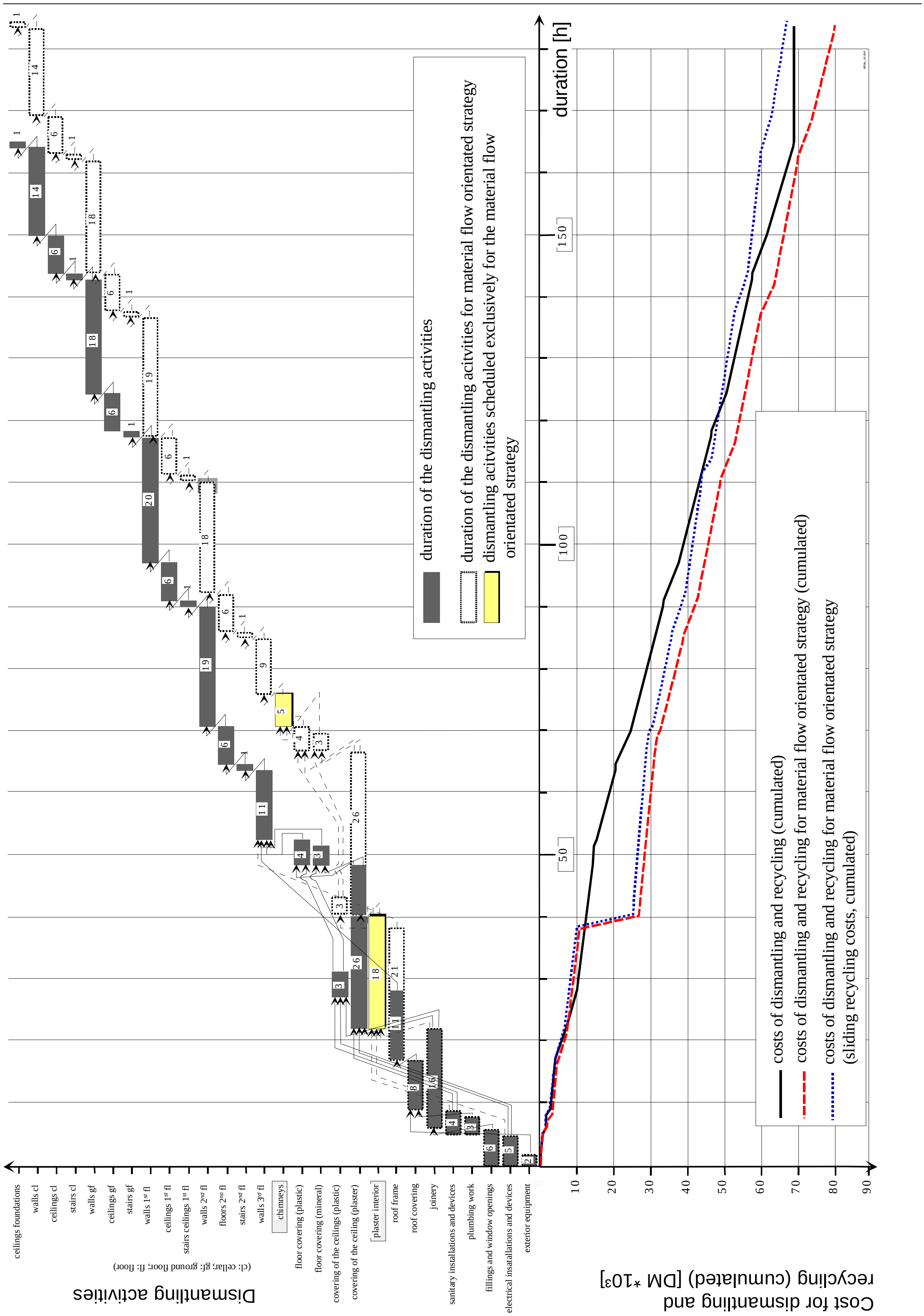


Figure 12 Schedule and project costs for the dismantling of a domestic building

8.0 POLICY, REGULATIONS, STANDARDS, LIABILITY

The process of deconstruction is not well suited to regulation by conventional German legislation. In the following, the main fields of national regulation with respect to deconstruction are shortly surveyed.

Waste mangement

Legislation in the field of deconstruction is mainly focused on construction and demolition waste management, which has already quite a long history in Germany. The first federal law dealing with waste was enacted in 1972; it was the law for the prevention and disposal of waste of 27th August 1986, which outlined for the first time the principles for the transition from disposal to waste management. Accordingly, the first goal must be the prevention of waste and if prevention is not possible, the composition of waste must be improved in order to permit reuse or recycling. In July 1994, the Recycling and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz - KrW-/AbfG) was passed by parliament. This law, which was enacted in October 1996, set new principles for the development of waste management towards a closed loop economy. It contains the basic principles of German waste management and closed-loop recycling strategies [28] and introduced several principles for waste management. For instance a new hierarchy for waste treatment where the avoidance of waste is better than the recycling of waste, but recycling is more preferable to the disposal of waste. The disposal of waste is only allowed when recycling is much more expensive or impossible and the waste is unavoidable. Another important innovation of the new Recycling and Waste Management Act is the responsibility of the producers for the waste arising from their products.

The Recycling and Waste Management Act implements the European Council Directive 91/156/EEC (revised Framework Directive on Waste, amending Council Directive 75/442 EEC) and Council Directive 91/689 EEC on Hazardous Waste, into national legislation[1]. The Recycling and Waste Management Act came into force two years after promulgation, on October 7th, 1996. The hierarchy of the Act assigns priority on waste prevention. Waste that cannot be prevented should be recovered. When neither prevention nor recovery is feasible or economically reasonable waste has to be disposed. In order to comply with the principle objectives, waste designed for recovery is to be kept separate and treated separate. Recovery of waste has priority to disposal to the extent that recovery is technically possible and economically reasonable (Art. 5 Krw-/AbfG). Art. 7, 23 and 24 KrW-/AbfG authorises the federal government to enact administrative orders and statutory ordinances with the aim of enforcing prevention, recovery and to reduce contamination on wastes. The supplementary subsidiary regulations of the Recycling and Waste Management Act consist of various ordinances. These can be classified as follows:

- Ordinances that restructure supervision under waste management law and align it with EU law:

1) The Ordinance on the Classification of Waste Requiring Special Supervision (Verordnung zur Bestimmung von besonders überwachungsbedürftigen Abfällen - BestbüAbfV) [73];
2) the Ordinance on the Classification of Waste for Recovery that Requires

[1] An overview about European legislation can be found in [0].

Supervision
(Verordnung zur Bestimmung von überwachungsbedürftigen Abfällen zur Verwertung - BestüVAbfV) [74];

3) the Ordinance on the Furnishing or Proof
(Verordnung über Verwertungs- und Beseitigungsnachweise - NachwV) [75] and

4) the Ordinance on Licensing of Transport
(Verordnung zur Transportgenehmigung - TgV) [76].

- Ordinances that create a basis for further deregulation of supervision:

5) The Ordinance on Waste Management Concepts and Waste Life Cycle Analysis
(Verordnung über Abfallwirtschaftskonzepte und Abfallbilanzen - AbfKoBiV) [77];

6) the Ordinance on Specialised Waste Management Companies
(Verordnung über Entsorgungsfachbetriebe - EfbV)) [78] and

7) the Directive on the Activities and Approval of Waste Management Partnerships.

One of the major general administrative orders concerning construction and demolition waste is the Technical Instruction for Municipal Waste (TA Siedlungsabfall) [18] that is originally based on Art. 14 of the former Law on Prevention and Disposal of Waste (Abfallgesetz of 27th August 1986). The German Technical Instruction for Municipal Waste specifies the treatment and disposal of waste and deals with waste streams of great importance such as domestic waste and building and demolition waste. The goals of this administrative order are to recycle unavoidable waste, to reduce the toxicity of waste and to ensure that an environment friendly treatment or disposal of waste is maintained. It describes that construction and demolition waste should be collected and prepared for recovery separately at the place of arising. The responsible municipalities should encourage the utilisation of mobile or semi-mobile recovery installations. It also contains requirements concerning the disposal of waste. Fractions which do not meet the requirements set out in the TA Siedlungsabfall will not be allowed to be landfilled and will have to be treated further.

The federal states (German Bundesländer) count on their own and more specific laws and regulations on waste (e.g. [27]). Some states have already introduced topics for demolition requiring organised dismantling and separation of waste on-site or at specialised treatment facilities. The municipalities or local authorities have further regulations like demolition permits or dismantling ordinances. In some cities it is already compulsory to add a deconstruction plan presenting the phases of preparation, the method of deconstruction or demolition and detailed information on the recycling of the various materials when demolition permits are required.

The German government has drafted a statutory ordinance of their objectives in the context of construction and demolition waste [82] already in 1992, which contains the requirements of waste prevention, recovery and disposal without affecting the quality of the environment. The draft also contains targets for waste management. For demolition waste ("Bauschutt") a recycling rate of 60% should be accomplished by 1995. In 1993 a draft of an ordinance of construction and demolition waste was formulated and in 1996 a new draft of the objectives of the federal government was launched which contains certain requirements for the demolition or deconstruction, respectively [83]. For the first time the draft requests, among other things, a deconstruction planning that enables a separation of recyclable materials. The recycling rates of the former draft were modified in a way that the disposal of recyclable construction and demolition waste should be reduced by 50% based on 1995 levels by 2005.

The mentioned drafts have not come into force yet but instead a Voluntary Agreement has been signed (see below).

Requirements for the environmental compatibility of recycling material

In order to utilise processed construction and demolition waste it has to compete with new materials. In Germany several instructions and regulations determining quality standards for recycling materials have been elaborated. Most of them are for the use in road construction (e.g. regulations by the research institute for road and traffic systems [22,21] or RAL quality labels (RAL 501-1: Recycling-Baustoffe für den Strassenbau) [42]. (cf .Table 7). Especially in the field of mineral waste arising from the demolition of buildings, new ways have been developed such as the use of recycled aggregates for the production of concrete. The use of recycled building materials in such highly sophisticated recycling options requires defined information about material characteristics of the recycling materials as well as strict standards for the composition and production of the recycling materials [67].

Table 7 Selection of guidelines for the use of recycled mineral materials in Germany

Area of Application	Regulation	Application
General use of mineral recycling materials	• Technische Regeln der LAGA [35]	⇒ Requirements for the recycling of mineral wastes
Road construction with recycling materials	• RAL-RG 501/1 [42]	⇒ Quality assessment for recycled materials in road construction
	• TL Min-StB 2000 [23]	⇒ Technical delivery conditions for mineral materials in road construction
	• TL RC ToB-StB 1995 [21]	⇒ Supplementary technical delivery conditions for recycled mineral materials in road construction
Concrete with recycled aggregates	• Richtlinie des Deutschen Ausschusses für Stahlbeton "Beton mit rezykliertem Zuschlag" [11]	⇒ Guideline for concrete with recycled aggregates 1998 (revised edition will be published in spring 2002)
	• DIN 4226-100 [15]	⇒ Recycled aggregates for concrete and mortar
	• DIN 4226 [16]	⇒ Aggregates for concrete
	• DIN 1045 [17]	⇒ Concrete and reinforced concrete: dimensioning

The Länder Working Group Waste (Länderarbeitsgruppe Abfall – LAGA) elaborated technical rules for the valuation of mineral residue and waste, especially building waste [35]. In these, the parameters to be examined, as well as standardised examination methods were lad down. Installation classes containing reference values for the examination of building waste were set up as in accordance with Figure 13. Decisive in the lay down of these reference values is, by rule, the protected groundwater. In addition to this, effects on the natural ground function by the inserted recycling materials should be minimised. This is why values for both eluate and solid materials were supplied.

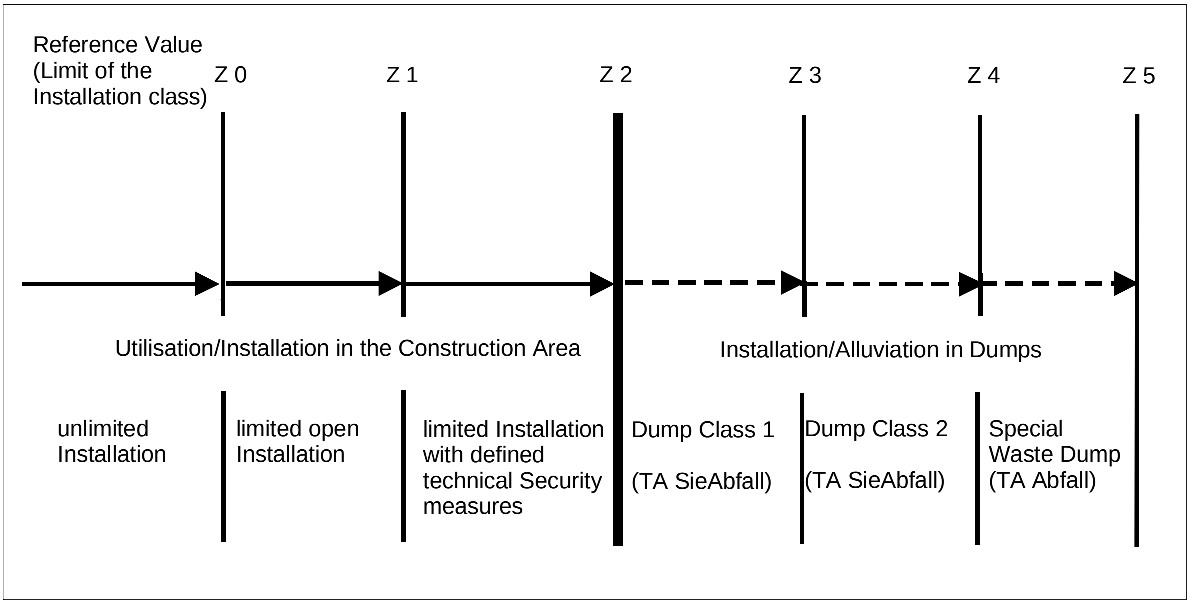


Figure 13 Installation Class with the relevant Reference Values

An unlimited installation (complying with reference value Z 0) is permitted if the recycling material shows similar pollutant content to the regionally occurring ground/rocks. If Z 1 is not exceeded, a limited open insertion under agreed user limits is allowed. Depending on the hydro-geological requirements of the area Z 1 is divided into Z 1.1 and Z 1.2. By exceeding these values Z 2 becomes effective. This gives the limit for the insertion of recycled building materials with defined technical safety measures, so that the transfer of substances into the subsurface and the groundwater is prevented. If Z 2 is exceeded, then the reference criterion for the disposal of waste in accordance with the TA Siedlungsabfall (see above) becomes effective. By exceeding Z 4 the rules for special waste deposit, laid down in the Technical Instruction for Waste (TA Abfall) [26] take effect.

For the general use of mineral recycling materials the Technische Regeln der LAGA (technical guidelines of LAGA) must be applied. The guidelines contain values limiting the content of different chemical substances either in the material or in the eluate and apply to all applications except for the use as aggregates in concrete. In the field of road construction different regulations exist, where the application area ranges from the characterisation of the materials to chemical, load capacity and frost resistant aspects.

Table 8 Composition of categories for recycled aggregates in concrete and mortar [15]

PROPERTIES		Composition [Mass %]			
		Type 1	Type 2	Type 3	Type 4
Concrete, aggregate according to DIN 4226-1		≥ 90	≥ 70	≤ 20	
Clinker, non aerated bricks		≤ 10	≤ 30	≥ 80	≥ 80
Sand lime block				≤ 5	
Other mineral properties are		≤ 2	≤ 3	≤ 5	
Foreign matter	asphalt	≤ 1	≤ 1	≤ 1	≤ 20
	mineral	≤ 2	≤ 2	≤ 2	
	Non mineral	≤ 0,5	≤ 0,5	≤ 0,5	≤ 1
Other mineral properties are e.g.:					
Aerated bricks, light concrete, aerated concrete, plaster, mortar Aerated slag, pumice					
Mineral foreign matters are e.g.:					
Glass, ceramics, non iron metal slag, plaster of Paris					
Non mineral foreign matters are e.g.:					
Rubber, plastics, metal, wood, organics, other materials					

8.3 Guidelines and regulations for demolition and deconstruction

Up to now, no general regulations concerning demolition works are available in Germany. According to the Recycling and Waste Management Act, federal authorities and many other public agencies under federal supervision are obliged to contribute to the attainment of the aims of the Act.

In the field of demolition and deconstruction of buildings several guidelines were published during recent years by public authorities. The aim of these guidelines is to inform how demolition and deconstruction work can be performed in an economical way without neglecting ecological issues. This was necessary because on the one hand significant improvements in the quality of waste arising can be achieved by the application of selective dismantling techniques. On the other hand the dismantling of buildings requires more manpower and technical equipment than traditional demolition, which leads to increasing costs. These higher costs can be compensated in some cases by lower costs for the reuse, recycling or disposal of the materials, if dismantling and recycling are planned well. These guidelines were published in order to facilitate the planning of the renovation or dismantling of a building. The following table gives an impression of some of the existing guidelines for the deconstruction of buildings in Germany. As mentioned above, some states (Bundesländer) have already introduced requirements for demolition. The municipalities or local authorities have further regulations like demolition permits or dismantling ordinances.

Table 9 Guidelines for the deconstruction of buildings in Germany [66]

Title	Content	Date
Demolition of residential and administrative buildings -guideline **(Abbruch von Wohn- und Verwaltungsgebäuden-Handlungsanleitung)** Landesanstalt für Umweltschutz Baden-Württemberg (LfU) [36]	• See text below	2001
Guideline for sustainable construction of public buildings **(Leitfaden nachhaltiges Bauen bei Bundesbauten)** Bundesministerium für Raumordnung und Städtebau [4]	• Guideline only for public buildings • Ecological assessment of construction, use and deconstruction of a building • Basic demands on planning of sustainable construction • Proposal for a building certificate	2000
Development of methodologies for the assessment of contamination of building materials before deconstruction **(Entwicklung von Verfahren zur Beurteilung der Kontaminierung der Baustoffe vor dem Abbruch)** Deutscher Ausschuss für Stahlbeton [12]	• General view of analysis methodologies for building materials • Instructions for testing	2000
Guideline for the determination of masses and recycling planning of buildings to be demolished **(Leitfaden für die Erfassung und Verwertung der Materialien eines Abbruchobjektes)** Deutscher Ausschuss für Stahlbeton [13]	• Check list for: - Inspection of the building - investigation of building elements - investigation of the foundation of the building - analysis of harmful substances - information about buildings in the neighbourhood • detailed example	1999
Deconstruction and demolition of buildings **(Rückbau und Abbruch baulicher Anlagen)** Umweltamt Düsseldorf [72]	• Basic facts of laws in the field of waste • Procedure of deconstruction planning (inspection, bill of quantities, recycling planning) • Flowchart of deconstruction • Demands on recycling concepts	1997
Recycling guideline **(Arbeitshilfen Recycling)** Bundesministerium für Raumordnung und Städtebau [5]	• Guideline only for public buildings • Basic facts of laws in the field of waste • Waste management for the construction of public buildings • Deconstruction of public buildings - instructions for inspection of the building in tecninal and historical respect - investigation of harmful substances • - Instructions about deconstruction planning, calling for tenders and contract letting-	1997
Environmentally advantageous and low cost treatment of demolition waste **(Umweltgerechter und kostensparender Umgang mit Bauabfällen)** Zentralverband des Deutschen Baugewerbes [81]	• Basic facts of laws in the field of waste • Explanation of recycling options • Instructions for a recycling strategy (deals also with construction)	1997

The guideline "Demolition of residential and administrative buildings" [36] gives a short general view of current terms in the field of deconstruction of buildings as well as a summary of laws concerning demolition. The guideline explains the three principal procedures for the demolition of buildings: conventional demolition, partly selective dismantling and selective dismantling. In the chapter on legislation in the field of waste, the most important laws and administrative orders are summarised. To permit a quick understanding of the legislative situation, the guideline has a table containing the main laws and administrative orders arranged under "Demolition", "Recycling" and "Harmful Materials".

Due to the fact, that buildings and building elements can contain many different harmful substances, the guideline informs about building elements, which could contain such substances. Furthermore advice is given on which procedure has to be carried out before the demolition of buildings containing the mentioned building elements.

The guideline aims mainly to provide a decision support for the choice of the adequate demolition techniques. Therefore advantages and disadvantages of the different demolition techniques will be analysed according to economic, environmental and other aspects. The guideline lists different tools for disposal to support this decision: a flowchart showing the procedure of planning, permission and contract letting of the deconstruction of a building (compare Figure 14), a calculation sheet for the determination of costs for demolition and recycling/disposal and a computer tool.

The computer tool permits a quick survey of the material composition of the building as well as the costs for demolition and recycling/disposal of the demolition waste arising. The program contains a database, which supports the data input supplying information concerning the costs of dismantling and recycling. The calculation can be performed using two different calculation methods.

1. A rough estimation of costs and material composition of the building on the basis of the type and the volume of the building.
2. A detailed determination of the building masses including mineral building structure as well as the internal finish. For each building element, data concerning dismantling and recycling can be determined by the user or can be found in the database.

Both calculation methods permit the calculation of three deconstruction scenarios: conventional demolition, partly selective dismantling and selective dismantling

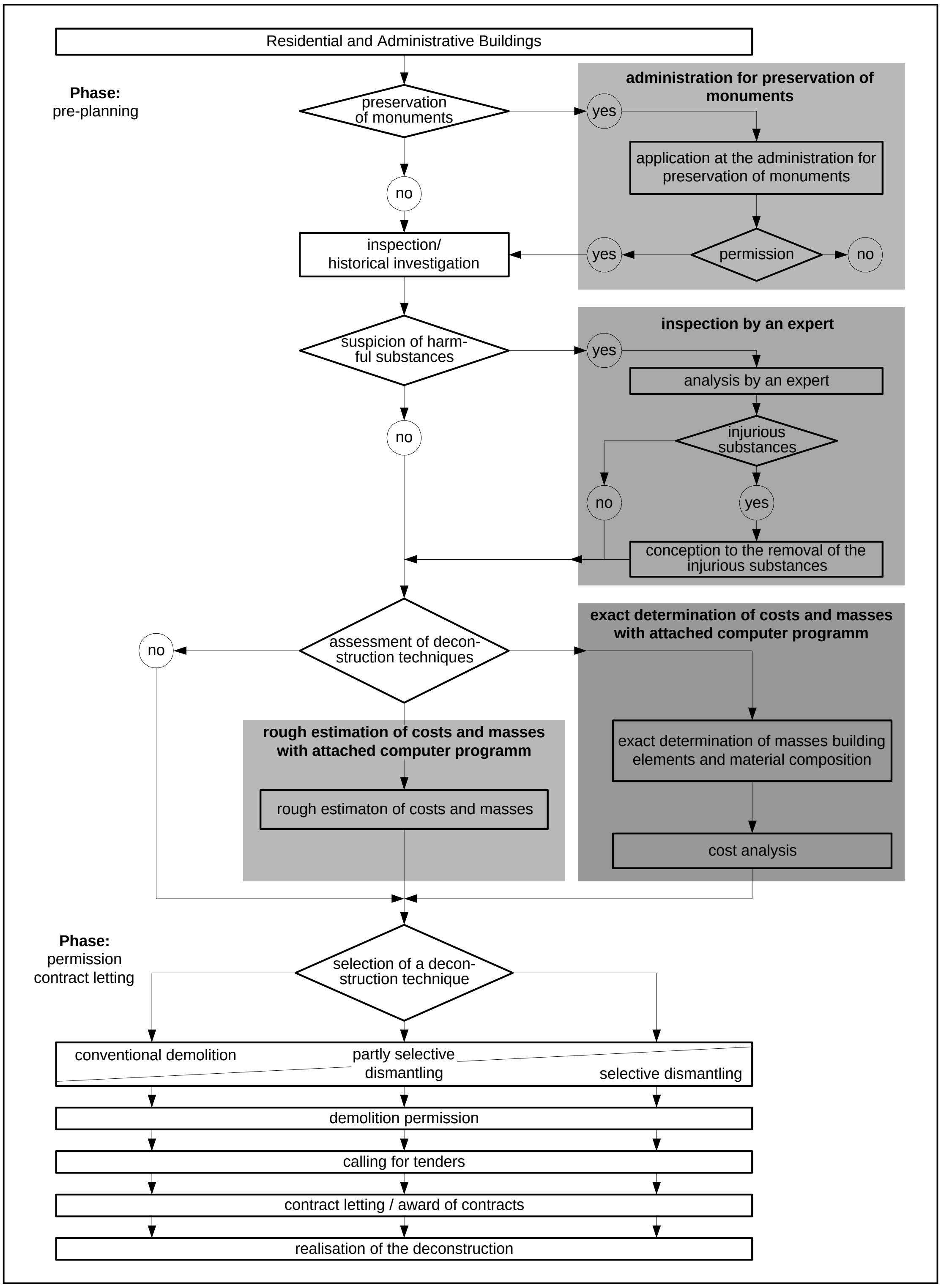


Figure 14 Flowchart of planning, permission and contract letting of the deconstruction of a building [36], [66]

A Voluntary Agreement, signed 1996 by several industrial organisations, is mainly focused on construction and demolition waste management ensuring that the objectives of the federal government concerning the targets for waste management are met. It contains the following measures [24,18]:

- Information and advisory services to be made available to construction and demolition companies;
- R&D about avoidance of construction and demolition waste, separation and sorting of wastes and recovery measures, quality assurance for recycled materials and promotion of applications for recycled materials.

The industrial organisations that signed the agreement will set up an advisory committee or board responsible for monitoring progress and for reporting annually to the Ministry of Environment. These reports should also contain information about the development of dismantling techniques.

A new standard for demolition (DIN 18007) [14] has been published. The objective of this standard is to specify definitions for demolition and to describe different demolition activities.

CASE STUDIES OF THE DECONSTRUCTION OF BUILDINGS IN GERMANY AND FRANCE

In recent years, several case studies about deconstruction have been carried out in Germany and France (cf. [59, 50, 40, 38, 49, 51, 44, 45, 46, 47, 48, 44, 8, 39, 3, 1, 31, 20, 37, 55, 54]). Nevertheless, only few studies are well documented. An overview about different deconstruction studies can be found in [62,52]. A comparison between these studies is impeded not only because of the heterogeneity of the documentation, but also the scope of the projects and the different conditions. In fact, the same aspects in the studies are not addressed in the same way (e.g. costs, recycling rates etc.). As a consequence, results have to be compared with great care. Bearing in mind these obstacles, Table 10 shows a coarse comparison between some of the case studies indicated above.

Table 10 Comparison between different case studies [62]

Project	Location, Year	Type of building	Construction	Volume	Dismantling Time, Project duration [weeks]	Costs	Recycling rate
1	**D, 1991**	Foundry	Masonry	263000 m^3	n.a.	11,8 EUR / m^3	94 %
2	**D, 1993**	Brewery	Concrete and Masonry	210000 m^3	n.a.	n.a.	> 96 %
3	**D, 1994**	Residential Building	Timber Frame	4950 m^3	6	13,5 EUR / m^3	94 %
4	**D, 1993**	Industrial	Concrete	58000 m^3	11	27,1 EUR / m^3	74 %
5	**D, 1993**	Residential	Concrete	684 m^3	n.a.	n.a.	> 90 %
6	**D, 1994**	Industrial Building	Masonry	183100 m^3	13	n.a.	n.a.
7	**F, 1995**	Residential Building	Masonry	4200 m^3	11	13,3 EUR / m^3	95 %
8	**D, 1995**	Industrial Building	Masonry, Steelframe	22086 m^3	6	9,7 EUR / m^3	98,5 %
9	**D, 1995**	Office Building	Masonry	11000 m^3	n.a.	n.a.	n.a.
10	**D, 1996**	Industrial Building	Masonry	n.a.	22	n.a.	97 - 98 %
11	**F, 1997**	Industrial Building	Masonry	13250 m^3	4	1,5 EUR / m^3	98%
12	**D, 1998**	School Building	Masonry	50000 m^3	18	15,1 EUR / m^3	98%

n.a.: no inform. available D: Germany; F: France

Case studies using the same approach concerning cost allocation, recycling rates etc. could be compared quite well.

For the evaluation of different dismantling techniques and the determination of the resulting dismantling times and costs, the French-German Institute for Environmental Research launched several projects in Germany and France. During the first project in Germany that was well documented [49,51], a timber framed building located in the black forest was completely dismantled and more than 94 % of all the materials could be recycled (cf. Figure 15).

Figure 15 Dismantling of the Hotel Post in Dobel [49]

In order to compare deconstruction with demolition, the deconstruction carried out in practice has been analysed and compared with the alternative of demolition. While in this project, demolition was calculated using simulation with the computer tool described above, another project was especially focused on the comparison between deconstruction and dismantling in reality [50,44,53]. The buildings located in Mulhouse (F) were divided into two parts, of which one was demolished (using a backhoe) and the other was dismantled (cf. Figure 16 and 17). The location of the building near to the Swiss and German border also allowed the analysis of the possibilities of recycling of materials on an international level.

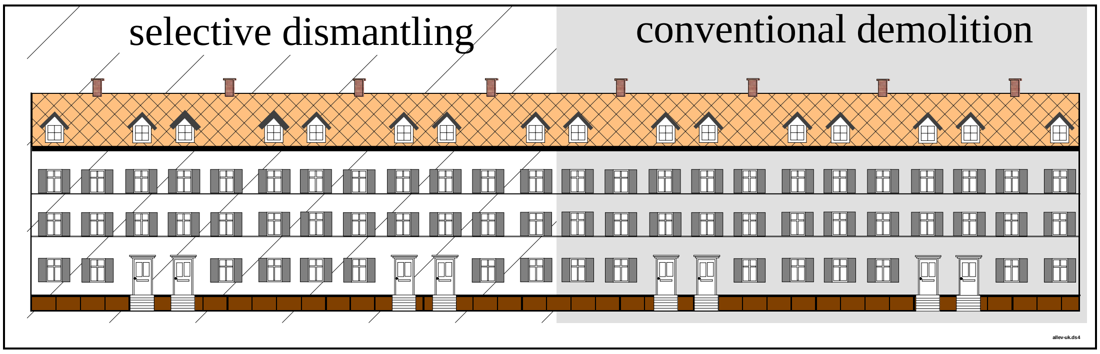


Figure 16 Dismantled and demolished buildings in Mulhouse

Figure 17 Dismantling in Mulhouse

During these projects detailed data on the composition of the dismantled buildings, the duration of the dismantling and demolition activities, the associated dismantling costs and on the recycling options were collected and analysed. Results show that dismantling can already be an economical solution, depending on the type of the building, the recycling options available and the prices charged for mixed and sorted demolition materials. As Figure 18 shows, the costs for deconstruction were in some cases lower than those of demolition (data based on [62,44,46,47]). Due to different types of buildings, different disposal fees and different transportation distances, costs for dismantling and recycling show tremendous variations.

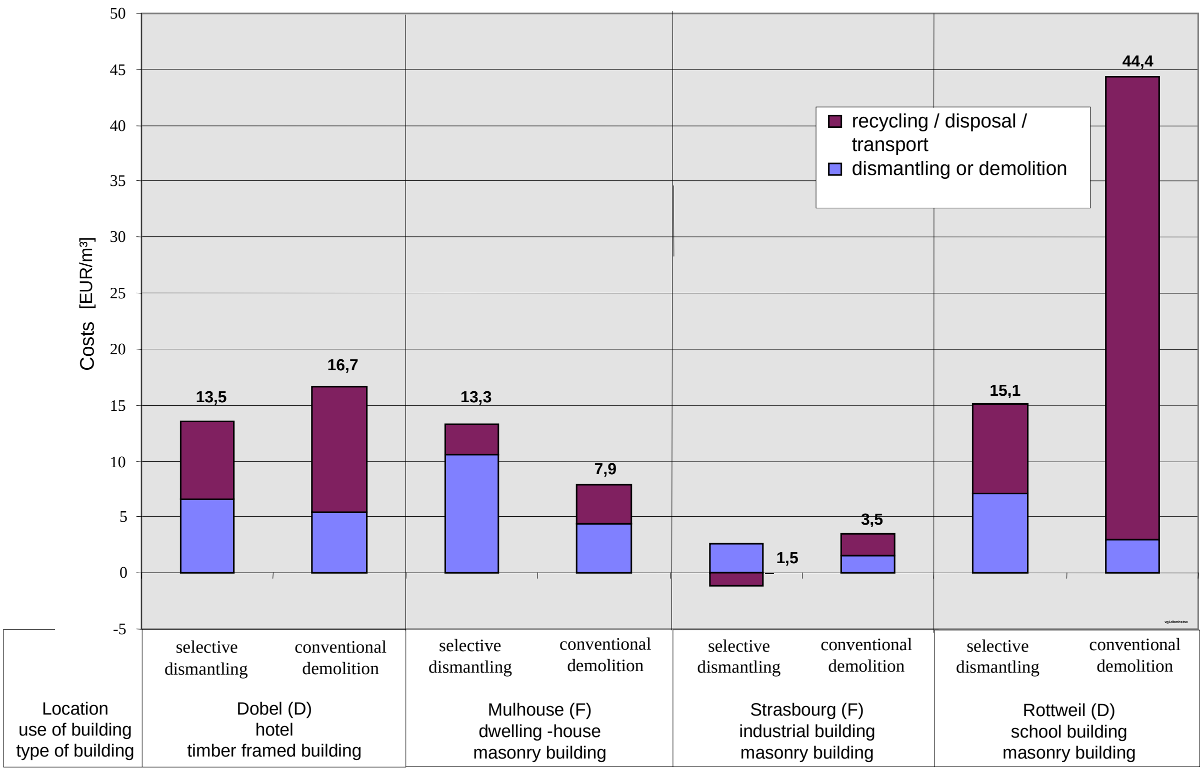


Figure 18 Comparison of selective dismantling and demolition

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REPORT 3
THE STATE OF DECONSTRUCTION IN ISRAEL

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1.0 INTRODUCTION

1.2 Waste statistics; percentages of C&D waste reused, recycled, or landfilled

General Overview

As a relatively new country with a large growing rate, the amount of construction removal is relatively limited. The number of buildings that are to be destroyed is estimated by 5-10/year in the large cities. This amount is relatively too little to be considered as effective enough for finding a special solution for recycling or re-use of the building elements. In addition, most of these structures were erected during the 40' and 50' that were years of depression and were made from low-grade materials. Therefore, in most of the cases only basic materials are removed from the structure (like valuable aluminum, copper or steel that are molten for the production of raw materials) and the rest of the structure is demolished and landfilled in certified locations.
The amount of construction waste was estimated as 350,000-700,000 ton/year, which is approximately 60% of the solid waste in Israel (not including household waste). Most of the waste comes from the erection of new structures.

Regulations regarding construction waste forbid landfilling of the waste unless dumped in certified locations. Certified locations become rare and only few of them are now available in certain local municipalities. This process takes place gradually, leading to shortage with landfilling sites, increased landfilling fees and increased transportation distance and cost. This process increases the motivation for recycling and reclaiming of materials and elements from old structures.

2.0 DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY, AND TOOLS

Structure type in Israel: the common structure in Israel is made of reinforced concrete frame with partition walls made of concrete blocks. The walls are then covered with cementitious plaster. Utilities lines of water, electricity, communication etc are placed trough the walls before plastering. Floors are mostly covered with tiles (ceramics, terrazzo etc)

When considering recycling of these materials, deconstruction or design for deconstruction the structure habits need to be considered. Careful dismantling of building elements as those noted above is almost impossible, unless special considerations are taken during the erection of the building. Structures made of precast concrete elements might be suitable for deconstruction, under two restrictions: 1. Connection of the element is done in dry methods. 2. The amount of internal finishes (plastering, floor tiling etc) is reduced to a minimum.

Adding on top of it the low image of using used elements in new structures, it appears that only limited types of structures might be considered for deconstruction: industrial structures including parking lots, and military structures. Examples to these two are listed below.

3.0 REUSE OF BUILDINGS AND COMPONENTS

3.1 In situ building reuse

3.2 Moving buildings to new sites for reuse

Examples for deconstruction

Military structures: Most of the military structures comply with the terms defined earlier for easing deconstruction. It should be noted that full size structures of the permanent army camps are discussed and not the small temporary structures that are designed for dismantling. A good example of this type of a process of deconstruction took place during the evacuation of the Sinai Peninsula after the peace agreement between Israel and Egypt in 1979. Following the agreement, all army camps had to be removed. Many structures (mostly steel structure) were dismantled and most of their elements were used in new locations for the erection of similar structures. The process was done in a methodological manner as follows:

1. Preliminary survey to define the structures for removal and relocation.
2. Preparation of a detailed program for deconstruction, including a detailed list of items that can be used again (down to details of small items like doors lock, door/window hinges etc).
3. Deconstruction
4. Transportation
5. Reconstruction using new elements where needed
6. Control

Figures 4 and 5 present an example for this activity done for one type of structure (architectural design office of Amos Livnat, Nurit Shapira- architect in charge for the project). Figure 4 presents an example of a look at the west facade and Figure 5 is the plan for this wing. All the elements of the existing building were marked and numbered, including structure elements, wall cladding, windows frames, doors, etc. All the elements that could be retrieved from the building were listed and an attempt was done to find a suitable use to them in the new building. Later, a new list that included all unusable elements was prepared in order to use these elements in other buildings.

4.0 ENHANCING MATERIALS RECYCLABILITY

4.1 General issues of materials recycling (upcycling, downcycling)
4.2 Recycling issues for specific materials (concrete, metals, plastics, glass, etc.)

Research on secondary use of materials

Several studies on the secondary use of materials in the construction industry have been done at the National Building Research Institute (NBRI) and they will be described briefly in the followings:

1. Re-use of construction waste. This is an ongoing study that began a couple of years ago. The purpose of the study is to test solutions for the re-use of construction waste in Israel. The study is carried out in three phases. The first phase is conducting a survey on the type and quantities of construction waste, the second phase is identifying proper solutions to the different wastes that will be identified in the first phase, and the last phase is testing the proposed solutions in terms of quality, properties and sustainability.

2. Using industrial by-products for the production of Controlled Low Strength Materials (CLSM). Large part of the industrial by-products are not suitable for the construction industry because of it fineness. CLSM, however, needs to be of low strength. Therefore low-grade materials that can not be used for the production of high strength concrete can be used for CLSM. Good results were obtained for various types of industrial by-products that are made of dust collected from different industries.

3. Using coal fly ash as partial replacement of Portland cement or natural sand. The utilization of coal fly ash as partial replacement of cement is a well known worldwide and a wide study on this topic was done in the past decade at the NBRI. Lately, the sources of natural sand became short in Israel and a partial replacement of the sand by fly ash was considered. The quantity of the fly ash in the concrete became much larger than before (similar to the one of the cement) and its effect on the properties of the fresh and hardened concrete in our region are considered in this study.

7.0 DESIGN OF BUILDING AND COMPONENTS FOR DECONSTRUCTION

7.1 Design techniques for allowing component extraction by disassembly
7.2 Design of components for disassembly

Examples for deconstruction

<u>Design for deconstruction of a parking lot (Figure 1):</u> A commercial company in Israel (design: Villa Nir,: structure: Moshe Peer, construction: Solel Boneh) has design lately a

parking lot with a total area ranging from a few hundreds to several thousands square meters, allowing parking space for hundreds of cars (see Appendix A for more details). The structure was designed for dismantling and transference after a relatively short using time of 5-10 years. On the one hand, this period of time is too short for using normal grade building materials and elements that usually have life expectancy of 50-70 years. On the other hand, this period of time is long enough to prevent the use of low-grade materials and elements that commonly used in temporary structures. The solution to the conflict is to design a full size structure that is made from high grade materials and can be dismantled at the end of using time and transferred, with some modifications, to a new location.

This solution is suitable for empty spaces in urban areas where the destination of the land has not been determined yet, or for parking lot near commercial centers that are built in several stages. This type of structure can provide with a good solution until a final destination for the land will be determined.

9.0 BARRIERS AND OPPORTUNITIES FOR DECONSTRUCTION

Examples for deconstruction

An example of unsuccessful trial for deconstruction is taken also from the period of time of the evacuation of the Sinai Peninsula in 1981. Some of the civil structures were dismantle and moved away from the area in order to use the elements again. The structures were made of precast concrete and were used for residential housing. After the elements were carefully disassembled they were moved to a special area where they were kept for further use in the future. Unfortunately it appeared later that these elements can not be used again from the reasoned previously discussed: the low image of using used elements for the construction of high value structure (high value is also from the emotional view of the potential owner). In addition, the architectural style became old during the time that passed between the erection and disassembling, in a way that prevented motivation for re-using these elements.

This last case strengthen the hypothesis that not all the structures can be considered for deconstruction and re-use. Only structures and elements that can withstand the changes that occur in the period of time between the first erection and the second use (durability, strength, standards, social and fashion) might be suitable for the implementation of the deconstruction concept.

9.1 Consumer tastes

9.2 Lack of design for deconstruction strategies

Summary

The activity on deconstruction is currently relatively low in Israel due to the habits of construction (various types of concrete), relatively small number of structures for destruction and a poor image of a product that is made from used elements.

Two niches, however, were defined: parking lots and military structures. Design for deconstruction initiated the development of a 4-story parking lot that can be dismantled and relocated according to market demands. The need to transfer army camps initiated careful plan for deconstruction of existing structure, in order to maximize second use the building elements.

APPENDIX A

The design of the parking lot is based on a three dimensional concrete element seen in Figure 2. The basic elements are connected by hollow prestressed slabs of different lengths allowing the erection of a structure of various sizes as seen for example in Figure 3. A 4-story structure is design to withstand a mild earthquake without additional supports. Additional stability is gained through external prestressing that is accessible for dismantling at any time when deconstruction is needed.

Figure 1: Computerized image of a full size parking structure designed for deconstruction (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

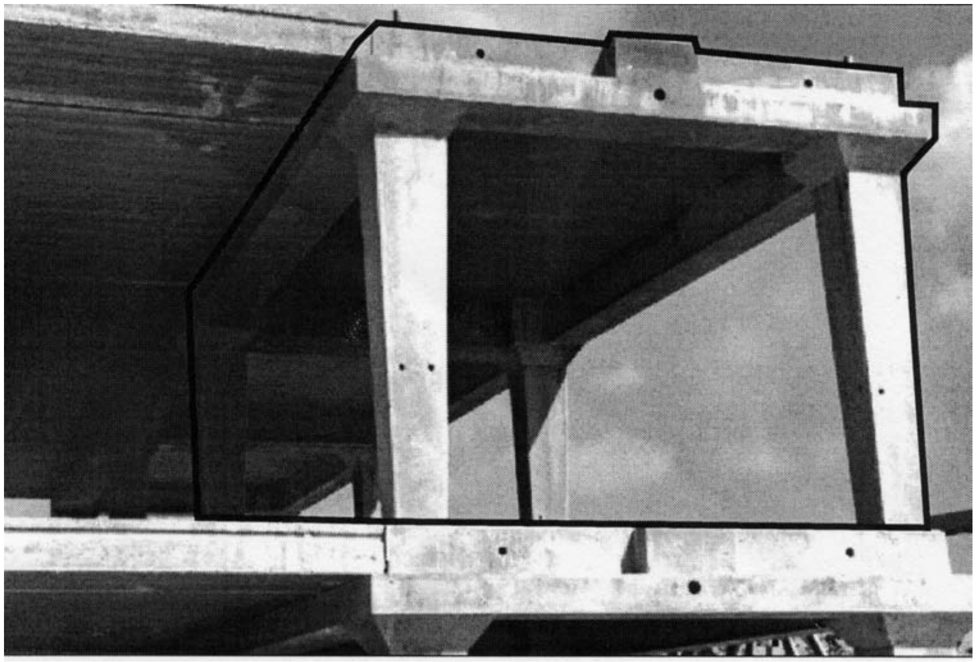

Figure 2: Basic 3-D element of the parking lot structure (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

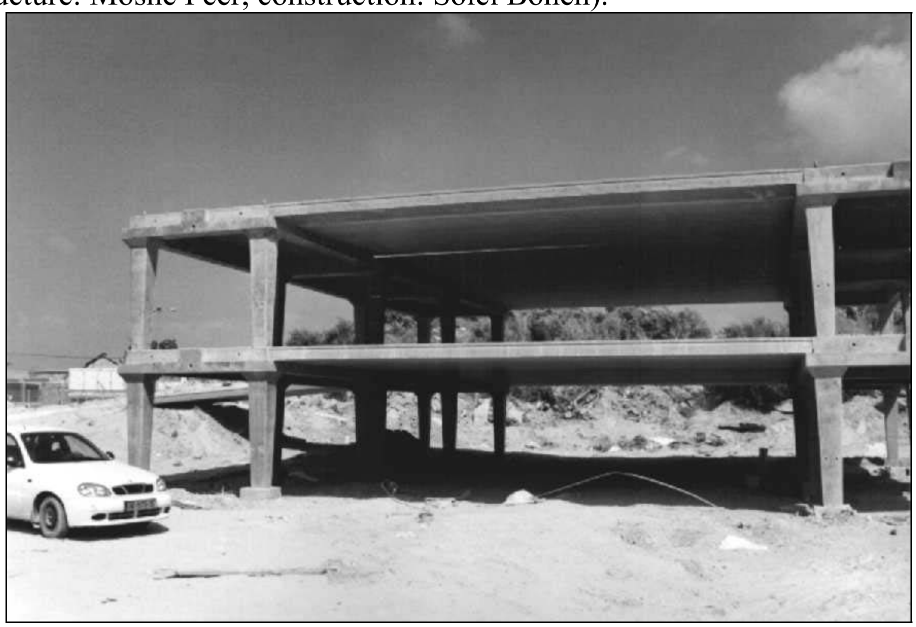

Figure 3: A full size structure of a parking lot at erection (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

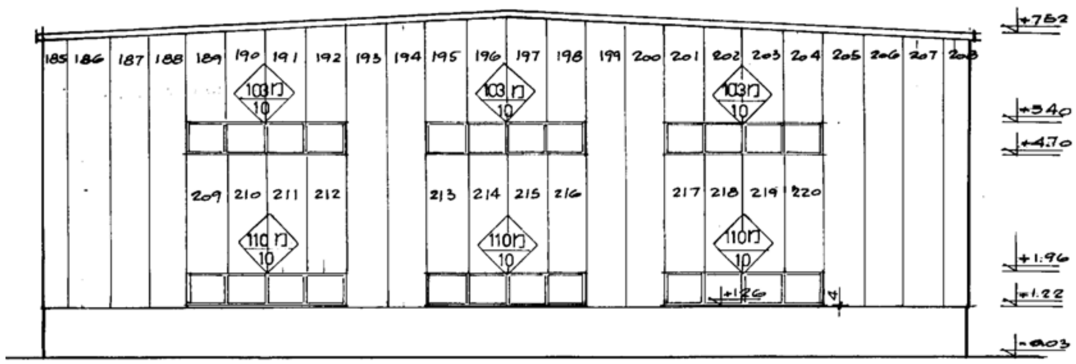

Figure 4: Plan for deconstruction of the west facade, windows frames and wall cladding are numbered (architectural design office of Amos Livnat, Nurit Shapira-architect in charge for the project).

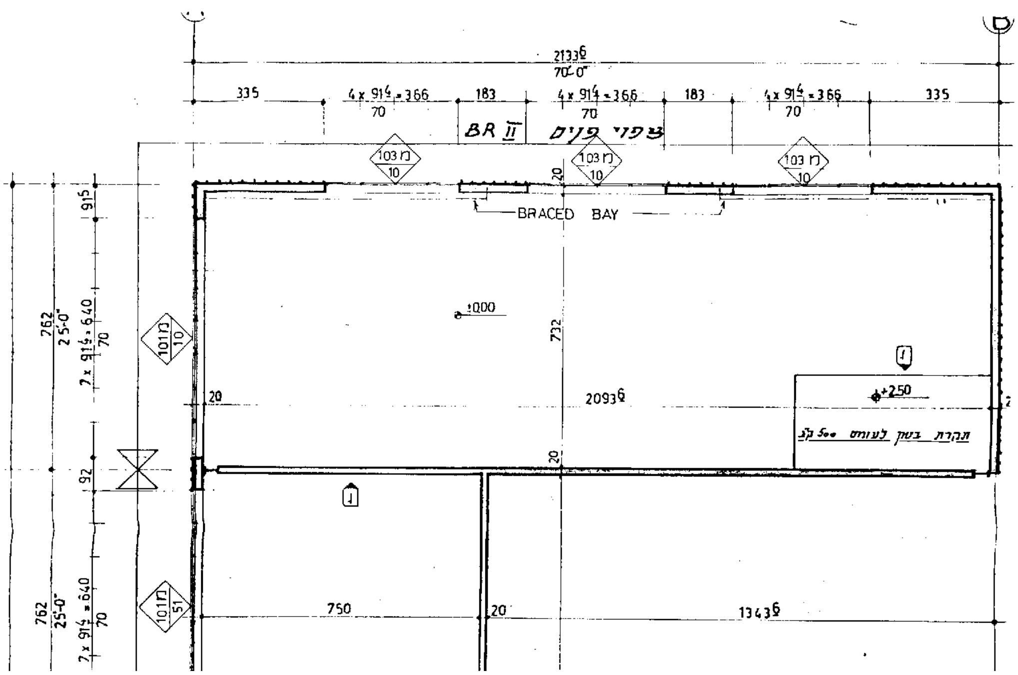

Figure 5: Floor plan of the west wing in the building designated for deconstruction (architectural design office of Amos Livnat, Nurit Shapira-architect in charge for the project).

REPORT 4
THE STATE OF DECONSTRUCTION IN JAPAN

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ABSTRACT

This report deals with the state of demolition in Japan. Demolition includes the dismantling, recycling, reuse and re-construction of buildings. In addition to addressing demolition, this report discusses Japanese law and regulations, the process of deconstruction and demolition for four types of structures (reinforced concrete structure, steel structure, wooden houses, and building foundations). Four issues are addressed for each type of structure: methods; designing in consideration of deconstruction; recycling and reuse; and research. Japan has begun enforcing new laws addressing demolition effective 2000.

KEYWORDS: Law, waste material, recycle, reuse, demolition

2. DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY AND TOOLS IN JAPAN

OUTLINE OF THE DECONSTRUCTION AND DEMOLITION TECHNIQUES

Reinforced concrete structures

Demolition Practices

Demolition works of general reinforced concrete building in the city are proceeded under many limitations such as regulation of the noise, vibration, mine dust, work time or work time period. The method to dismantle building is different by kinds of energy, such as the blowing power, oil pressure, water pressure, electricity or heat, and by the form of dynamic or static method to dismantle. In addition, it will be affected by kinds of the dismantling locations such as walls, floors, pillars, beams or foundations, and by the way in carrying out dismantled waste or the shape of it. Until around 30 years before, steel ball method or giant breaker method has been used for demolition works in Japan. But many problems such as vibration or the noise are closed-up. Therefore, new dismantling methods in place of these methods have been investigated. Arranging them by a form of dismantling method, it is classified as followings.

<u>Compressive smash method</u>

A concrete member is inserted in a small frame to be compressed and bent. Next, it is smashed by using a hydraulic jack through the compressive smash mechanism. The compressive smash frame is equipped with a large-scale boom and can cut the reinforcement. This machine is the most widely used tool for demolition these days, because it can be used for demolition of pillar, beam, wall or floor slab. Its capacity to smash is approximately four or five tons/h.

<u>Wire-sewing method</u>

This is a method in which a wire with diamond beads coils a concrete member, and cuts it off by spinning in high speed. This system has the ability to cut 0.4-0.6tons/h of reinforced concrete members. It is suitable for narrow, dangerous places or in the water.

Cutter method
Special diamond blade is equipped with the machine being able to drive and press, by which a building would be cut off and be dismantled. This is low pollution, and it is possible to work systematically with high safety

Abrasive water jet method
The mixture with ultra high pressure liquid and abrasive fluid is jetted from a nozzle of 3-5mm in diameter, by which reinforcement and concrete is cut off simultaneously with around 50 cm in depth by cutting and with ability of 1.2 m2/h approximately. Water supply of around 50 l/min, is necessary in cutting, but with the countermeasures to high noises during operation.

Static dismantling method with crusher material
In case of crusher to foundations concrete, usual crusher has small opening width of blade. Under the hydraulic breaker, static crusher material is effective for decreasing strong vibration and high noises. The static crusher materials are installed into holes, which generate expanding pressure toward outside in halls, resulting of many cracks in concrete 12 to 24 hours later.

The current situation of recycling and reuse
At present, concrete pieces are almost recycled in place of crushed stones and sands being used for reclaimed ground or roadbed. The type of concrete dismantled wastes varies with the demolition method. In particular, larger ones have less adhesive and mixtures of small ones in products at the case of reproductive concrete aggregate. On the contrary, smaller ones would contain much soils and impurities, and hence, the most suitable demolition method must be applied, taking into account of secondary product, waste disposal or transportation construction with enough. Regarding to usage in reproduction aggregate of concrete, it has noted to be available for no reinforced concrete in the common specification applying to public building constructions (1997). Japan architecture society has introduced examples for building foundations, the underground beams in temporary works, precast concrete piles in the publication of “Manual of demolition works in reinforced concrete building (temporary)” But it is very difficult to realize the recycle as artificial aggregates because of the mixture with finishing or lath materials, which should be collected selectively. We have to investigate about the following issues in future:(1) certificate of quality for recycled aggregate, (2) production technology for recycle aggregate, (3) establishment of supply system for recycled concrete aggregate, and (4) durability of recycled concrete aggregate.

The current research and development in demolition of reinforced concrete buildings
There are few on-going research projects for demolition and recycling of reinforced concrete buildings at present in Japan:

1) The development of easy demolition and reproduction in design and materials
2) Development of new systems with prefabricated structures and proper units considering demolition and recycle
3) Development of high performance machines for demolition works with remote control and automated dismantling
4) Development of small size machines suited for partial collections with low powder scattering, low vibration, and low noise
5) The development of effective usage of refuses (concrete pieces, surplus soil) in construction site

Steel buildings

The current situation of demolition method

First of all, all interior decoration materials are removed from the structure in the dismantling of steel building. These interior decoration materials are taken out to intermediate disposal factory and would be disposed. For steel building, fireproof coating is disposed in site with only the structure removed interior decoration materials. When asbestos is used as fireproof coating materials, the dismantling work is done while monitoring the asbestos density in air with keeping good conditions in circumferences as same as rock wool. After steel frame members are cropped out, the structures are dismantled by using hydraulic compressive smash machine used by the demolition subcontractor. Then elements, such as the slab, which is mixed with deck plate (iron and floor slab), are crushed into pieces by compressive smash, and reinforcement of floor slabs are also selected to some extent, resulting that collecting dealer brings them to intermediate dealer. As the dismantling cost is contracted by a unit price of square mete, the selectiveness is realized decently in the site. Collected wastes in intermediate disposal factory are recycled or turn to final disposal site in part. By management list (manifest) system, In demolition works for steel structure, illegal dumping is rare, because of direct money delivery and receipt between prime contractor company and each disposal supplier (the dismantling, collection and transportation, intermediate disposal, the final disposal). As for iron material, it is recycled in the electric furnace as scrap. As general consideration, scrap includes own scrap and the city scrap. The city scrap includes one from the factory and waste scrap. Scraps derived from cars, ships and buildings, are classified in waste scrap. As for waste scrap, press (empty cans), shirring (cutting by guillotine for the materials with long length like pipes), shredder (non-ferrous metals is contained), gas cutting, are adopted according to the process. In particular, wastes through shredder are selected by using dust separation device, collection dust device, magnetic device, and non-ferrous metals sorting device. Scraps are generally classified in quality by grade.

The current situation of recycling and reuse

In recent years, production of steel is between 90 to 100 millions tons in Japan. Revolving furnace, in which all scraps are recycled as raw materials completely, has a 30%share of the market. Most converters produce pig iron of blast furnace. According to the statistics, scraps are around 10%. A mount of demand for scraps of iron is around 45 million tons. Scraps, which are called waste taken out by demolition, are around 27 million tons and 8 million tones are from construction sites. It is uncertain how much steel becomes waste in the actually existing dismantling buildings. As mentioned above, steel materials are recycled by scraps to a great content, but reuse of it, however, seems not to be done at all. The wastes are also taken out of steel buildings, resulting that these would be recycled to roadbed etc. or transported in final disposal site through the intermediate dealers.

The current research and development in demolition of steel buildings

Design for dismantling or deconstruction has not yet been considered for steel structures. Development regarding life cycle resources (LCR), life cycle cost (LCC), and life cycle energy (LCE) seems to be proceeded by general contractors. The noise during demolition is such a major concern that a new machinery and technique for low vibration and noise are under development. It would be a right direction of selective demolition as possible from a point of view to decrease steel wastes. There, however, seems to be no idea to recycle with the same form as being used in present buildings.

Timber and wooden houses

The state of demolition method

There are three methods for selectively dismantling wooden houses in Japan: by hand, by machine and by composite way with machine and hand. Demolition methods are affected by building structure, scale, years, and other conditions of neighbor environment, road condition, budget and term of works, but cost cannot be ignored. It generally seems suitable to dismantle by hand. It, however, is difficult to select which method is better, because of the Indispensable transportation to recycle facilities after the selection of waste. The outlines of three kinds of methods are as followings, Selective dismantling by hand this is traditionally used to be in Japan. Most demolition are carried out selectively by hand in the case that a suitable machine can not be used for the reason of road condition, lot condition, neighbor environment, hope of the owner, or house of reconstruction. Selective dismantling by machine is available to use when suitable machine can work without the restriction of road condition, lots condition, and neighbor environment etc. It is very familiar in Japan with the high working efficiency, selecting a small machine for the reason of higher noise by bigger machine in general. By the difficulty in selection, waste should be selected in unit as much as possible before the working by machine. The mince dismantling is the indiscriminate (mince) dismantling method from a roof at a stretch by machine. It was used most in the case of such mince demolition for wooden buildings. It is almost impossible to select wastes and recycle them, resulting that it has given mixed wastes and remarkable bad influence to environment. The selective dismantling by hand and machine together makes use of good points in hand dismantling and in machine, resulting that it is possible to collect wastes in unit selectively by hand and to improve recycling rate as much as possible. Table.1 shows the example of the rates of recycling and the cost to dispose by three methods.

Table 1 The rate of recycling and cost

	Method 1	Method 2		Method 3	
Kinds	No mixed	mix- > sele	mix->disp	mix-> sele	mix->disp
Rate of recycle	75%	74%	73%	50%	0%
Ratio of cost	1.05	1.00	1.13	1.06	1.54

Deconstruction of building foundation and excavated soils

The state of demolition method

Foundations are generally demolished and not dismantled because new buildings cannot use existing foundations. In general, spread footings can not be reused because of the difference in plans or different bearing capacities. Foundations are dismantled and recycled as aggregates the same as superstructures. As for pile foundations, existing piles can be used even if the plans are different. If the bearing capacity is not satisfied, additional piles would be constructed. In few cases some piles should be removed from site because of change in floor plan and elevation. It is difficult to dismantle and remove piles from deep ground

The state of recycle and reuse

The situation for reuse and recycling of foundation materials is similar to reinforced concrete structures. As for soils from construction site, details are noted in the guideline related to ‘The law concerning waste disposal and public cleanliness”(mentioned above). The amount of soil excavated from public works was about 450 million tons in 1995 and only around 30% was reused. Soils from construction site are classified in construction soil and mud (or sludge). Mud is also classified as construction mud, dredged soil and others. Only construction mud is regulated as industrial wastes.

The state of research activities
There have been a lot of investigations about construction wastes related to foundations. Construction mud is industrial waste and is taken a lot of sites and this has been studied quite extensively.

METHODS OF DEMOLISHING WOODEN BUILDINGS AND DEFINITIONS OF TERMS [1] [2]

Manual demolition

A manual method refers to a method in which simple hand tools such as wrecking bars are used for demolishing. It is systematically carried out by skilled workers specializing in the work. All of the wood structural segments are demolished by this method.
Characteristics:
(1) Allows easy reuse and recycling of demolished wood.
(2) Minimizes the impact of vibration and noise on the community.
(3) Allows easy source-segregation of waste.
(4) Suitable for work in congested or small areas.

Mechanical segregated demolition

A mechanical segregated demolition refers to a method using a crawler-mounted excavator (hydraulic backhoe) to which a head for demolition is attached. Demolition is carried out using this machine after removing tatami mats, doors, roof tile, etc. The waste is segregated into wood, other combustibles, noncombustibles, etc., during demolition. Most demolition of present-day wooden buildings is carried out by this method.

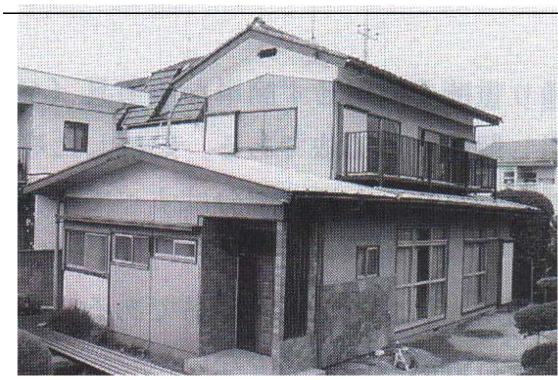
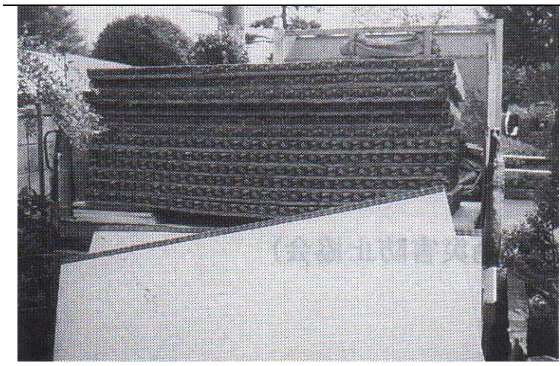
Mechanical demolition combined with manual demolition

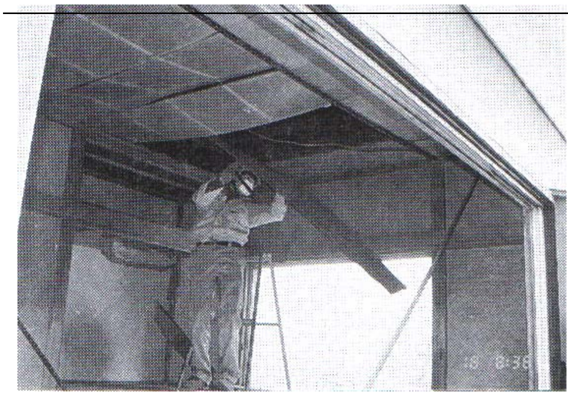
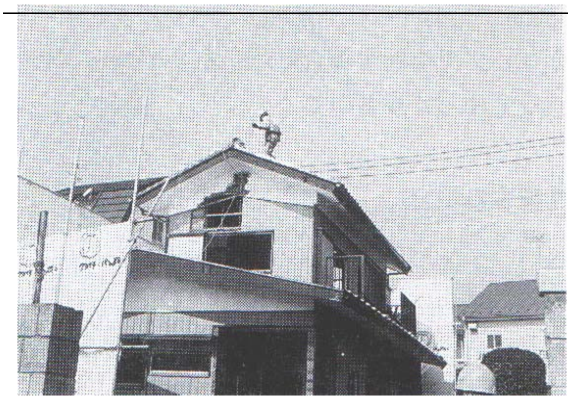
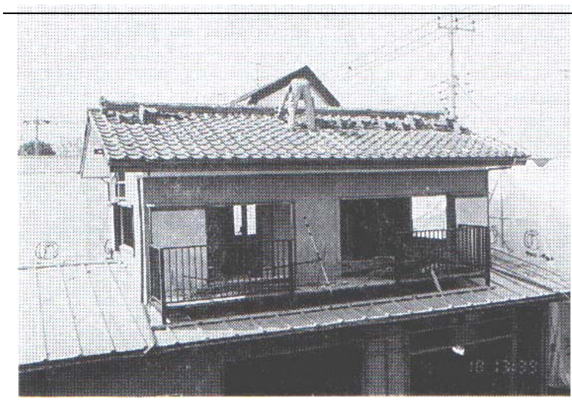
Where direct mechanical demolition is impossible due to site conditions, manual demolition is partially applied beforehand to prepare for mechanical demolition. This is followed by source-segregated mechanical demolition.

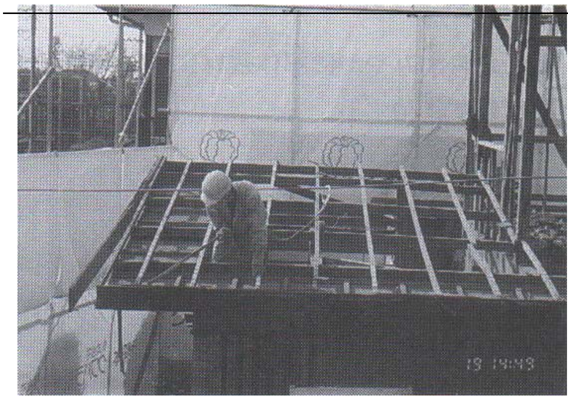
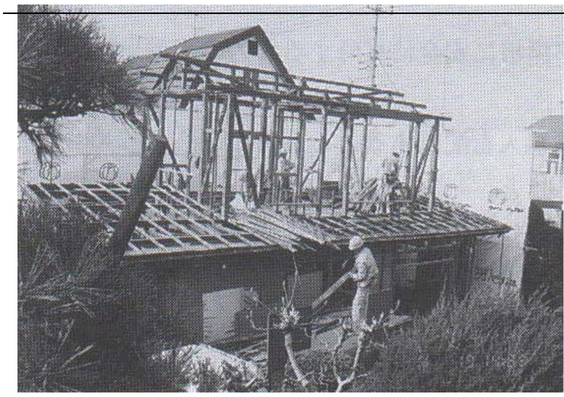
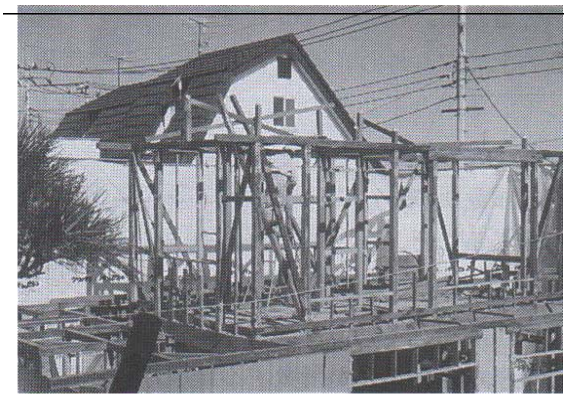
Unsegregated demolition

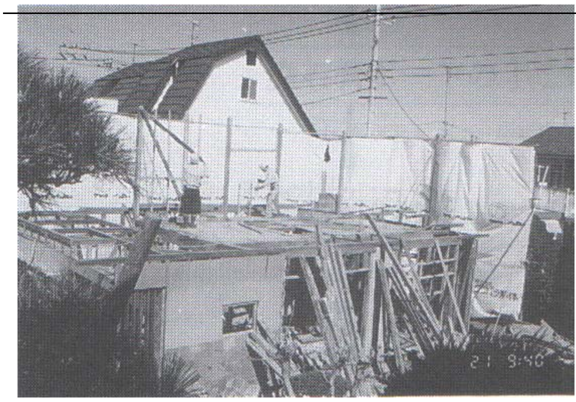
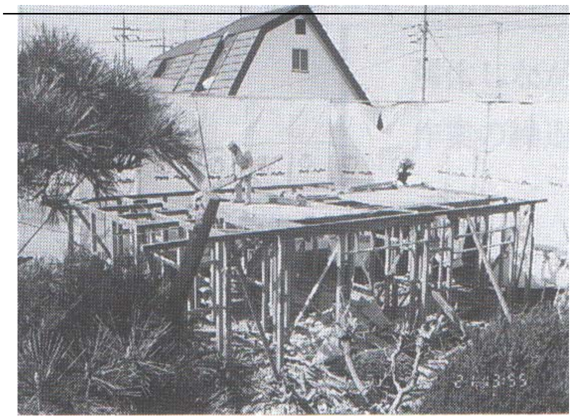
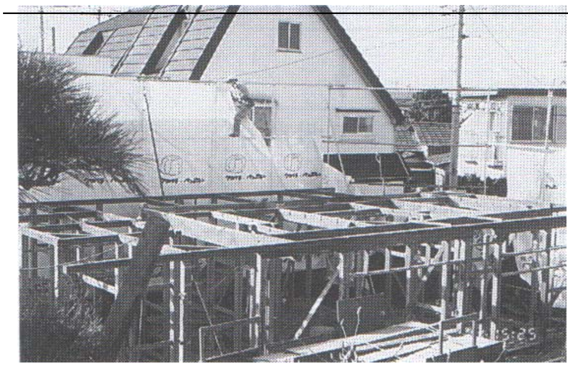
This is a method in which all parts of the building are mechanically demolished together without segregation. This method prevents recycling of waste materials, being prone to cause field burning and inappropriate disposal.

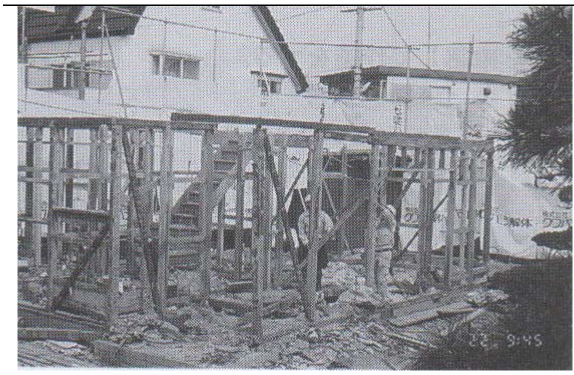
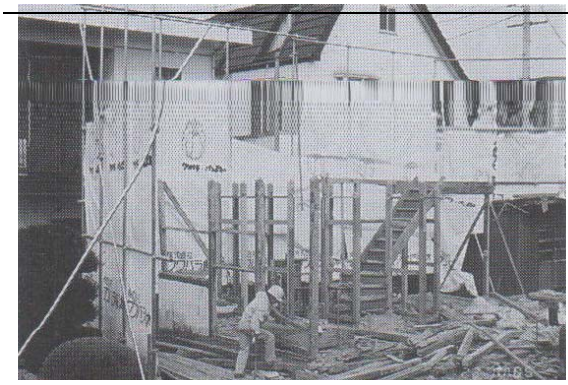
Guideline for manual demolition of wooden buildings

	Safety guidelines for demolition
	**A view of a two-story wooden building to be demolished** - Use materials with no defects for scaffolding. - Use suitable tools and devices. - Provide fences or ropes to keep general people out of the area for the erection or disassembly of scaffolding and post “no entry” signs. - Provide protective sheeting and wire net, preferably in two layers, and fix their edges firmly. However, remove the protective sheeting in a strong wind to prevent collapse.
	**Place temporary enclosure** When placing temporary enclosure, its height should be suitable for the situation and rigid enough to prevent collapse in a strong wind. **Erect scaffolding** - When erecting or disassembling scaffolding, select a person who directly supervises the work and have the person supervise the work. When the height of the scaffolding exceeds 5 m, select a “work manager for scaffolding erection and disassembly.” - The work manager should brief the conditions of the work place and procedure to the workers using drawings, giving proper instructions regarding the temporary storage and handling of materials and how to use personal protective equipment. He should also check the clothing of the workers as well as the manner of wearing protective helmets and safety belts and promptly correct when they are inappropriate.
	**Check “OY” gypsum boards** Remove gypsum board and check if it is “OY.” Take pictures of the gypsum board. - Remove waste gypsum board. - Wear a dust respirator while working. - Try to keep the gypsum board in large pieces to prevent them from powdering.
	**Remove tatami mats, doors, and windows** **Load them onto the truck** **Dismantle glazed doors and windows** Exercise care to avoid glass dislocation when carrying glazed doors and windows. Do not drop tatami mats from a high level such as the second floor. When removing tatami mats, try to walk on tatami mats to stay out of floor boards, as the floor boards may be rotten or dislocated off the joists. When walking on the floor boards is inevitable, exercise care not to step through the boards or fall down.

	Safety guidelines for demolition
	**Remove joinery and interior materials** **Remove ceiling** - When removing ceiling boards, provide an adequate work platform. Also, check if any object is left behind the ceiling.
	**Remove joinery in the 1st and 2nd floors** Promptly collect dismantled joinery on a truck.
	**Make arrangement for roof tile removal** **Prepare main rope** - Provide equipment for safe lifting and lowering of workers to and from the roof. - Place a watchman on the ground. Ensure that signs are confirmed beforehand. - Tie the main rope to the ridge beam and use safety belts.
	**String lifelines from the main rope and pile 4 to 5 roof tile in a determined work area.** When dismantling and conveying roof tile on the roof, try to walk on the roof tile to avoid stepping on roof boards or rafters, as they may be rotten. - Rope off the point on the ground where roof tile is thrown down. - Do not drop roof tile directly from a height of more than 3m but use a lift or auxiliary equipment. - Spray sufficient water on dusting points, e.g., where roof tile are dropped.

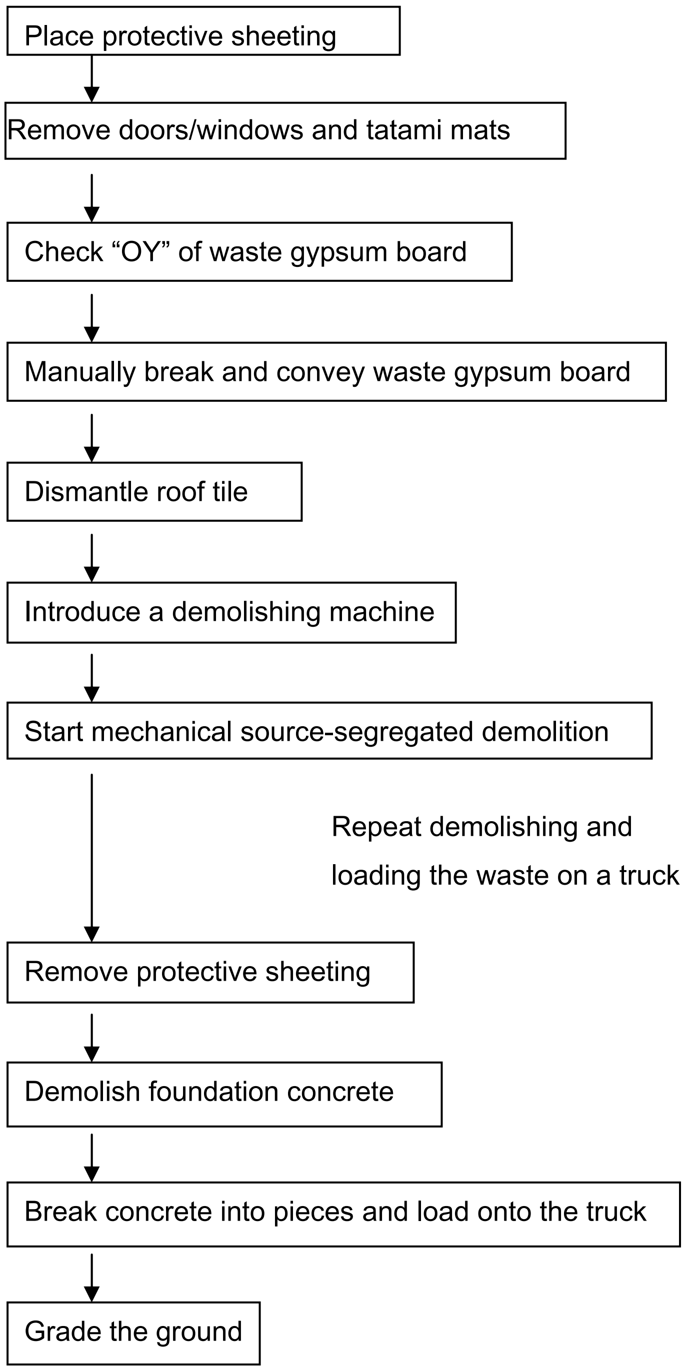
	Safety guidelines for demolition
	**Remove sheathing and rafters** - When dismantling rafters, ridge beams, purlins, and struts, tie the main rope to a beam or other member and use safety belts.
	- When dismantling exterior wall materials at high positions, prepare an adequate work platform. - Rope off the area outside the exterior wall materials to be removed, as the materials can scatter or collapse outward.
	**Dismantle roof trusses on the second floor** When throwing down the beams and columns with ropes from both sides, pull them slowly while balancing the forces on both ropes. When two people work together, ensure that signs are confirmed.
	**Dismantle roof trusses**

	Safety guidelines for demolition
	**Dismantle second floor framing** Work while watching steps. Exercise care not to step through the floor boards.
	**Dismantle the second floor**
	**Dismantle the floor of the second floor**
	**Remove the upper protective sheeting**

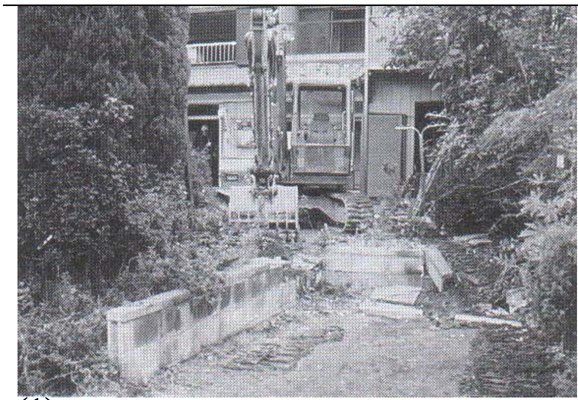
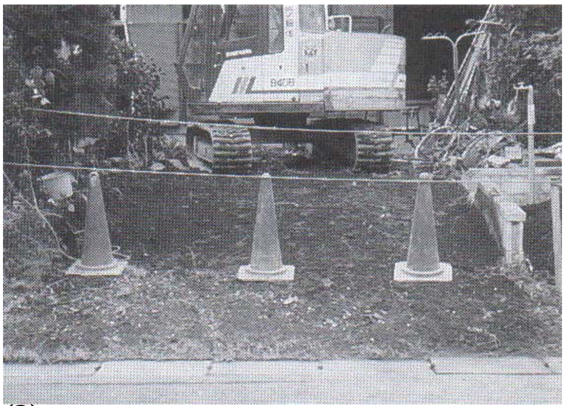
	Safety guidelines for demolition
	**Place new bracing to reinforce the framing before demolition**
	**Dismantle the framing progressively from outside**
	**The end of demolition of wooden building**

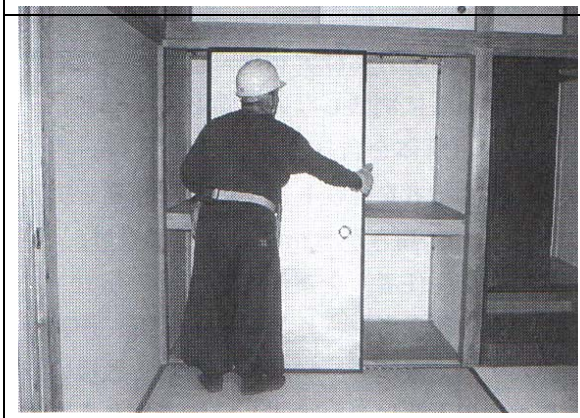
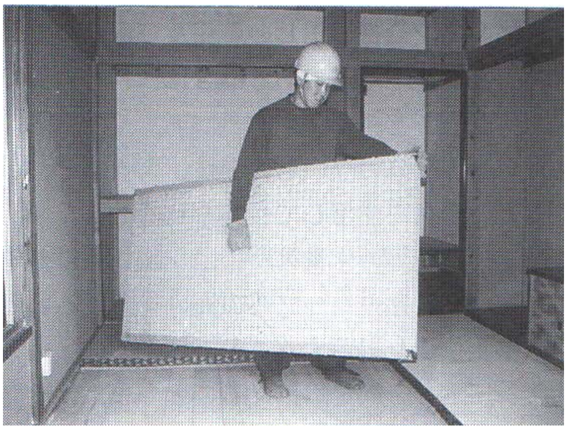
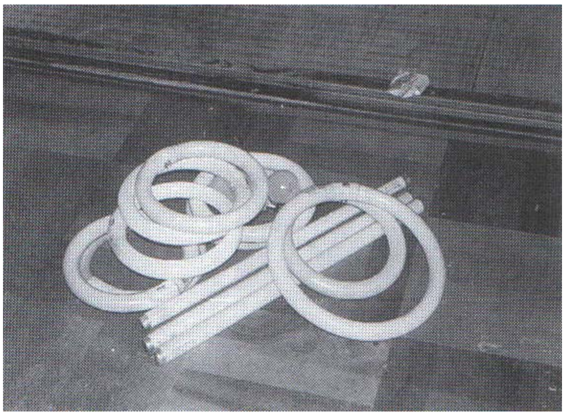
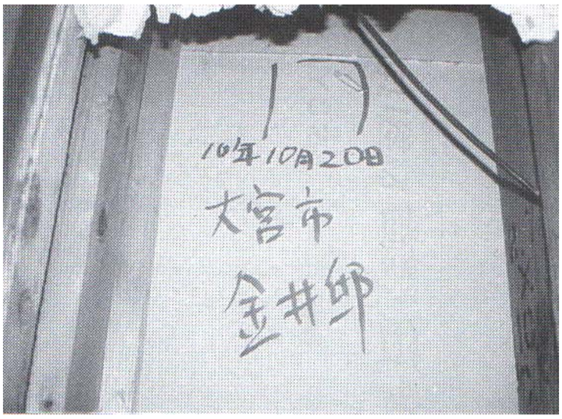
Mechanical source segregated demolition

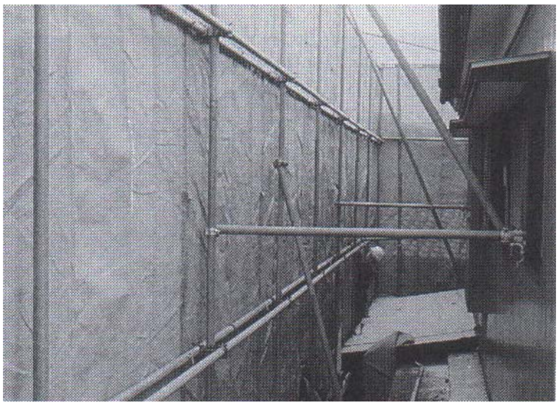
As waste gypsum board was designated as a controlled disposal item as of June 17, 2000, with a 1-year notice, the demolition procedure is changed as follows:



Note: In the following source-segregated demolition, gypsum board is not removed.

	Technical safety guidelines
 (1)	**Remove obstacles** Remove trees, gates, fences, and other obstacles to secure the spaces for operating a backhoe, collecting demolished materials, and loading onto vehicles. Securing accessibility and turning radius of a backhoe, as well as a space for loading demolished materials is a key to the selection of mechanical source-segregated demolition. (1) Secure an access road for a backhoe.
 (2)	(2) Remove masonry units and level the access road.
 (3)	(3) Lay steel plates to secure the access road.

	Technical safety guidelines
	**Remove doors, windows, and tatami mats** a. Exercise care when dismantling and conveying glazed doors and windows, as glass may be dislocated. b. Do not drop doors and windows from a high level, such as the second floor.
	a. Do not drop tatami mats from a high level, such as the second floor. b. When removing tatami mats, try to walk on tatami mats to stay away from the floor boards, as they can be rotten or dislocated off the joists. When walking on the floor boards is inevitable, exercise care not to step through them or fall down.
	Remove fluorescent tubes
	Check waste gypsum board Check if the gypsum board is “OY” and take pictures. The disposal method for controlled items and OY boards after June 17, 2000 is specified separately.



Technical safety guidelines

Erect scaffolding
Place temporary enclosure

a. When placing temporary enclosure, it should be of a height suitable for the situation and rigid enough to prevent collapse in a strong wind.

b. When erecting or disassembling scaffolding, select a person who directly supervises the work and have the person supervise the work. When the height of the scaffolding exceeds 5 m, select a “work manager for scaffolding erection and disassembly.”

c. The work manager should brief the conditions of the work place and procedure to the workers using drawings, giving proper instructions regarding the temporary storage and handling of materials and how to use personal protective equipment.
He should also check the clothing of the workers as well as the manner they wear protective helmets and safety belts and correct on the spot when they are inappropriate.

d. Use materials with no defect for scaffolding.

e. Use suitable tools and devices.

f. Provide fences or ropes to keep general people out of the area of erection or disassembly of scaffolding and post “no entry” signs.

g. Provide protective sheeting and wire net, preferably in two layers, and fix their edges firmly.
However, remove the protective sheeting in a strong wind to prevent collapse.

Technical safety guidelines

Remove roof tile

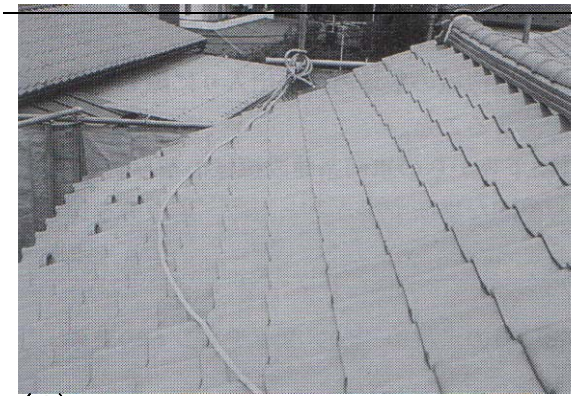
a. Provide equipment for safe lifting and lowering of workers to and from the roof.

b. Place a watchman on the ground. Ensure that signs are confirmed beforehand.

c. Tie the main rope to the ridge beam and use safety belts.

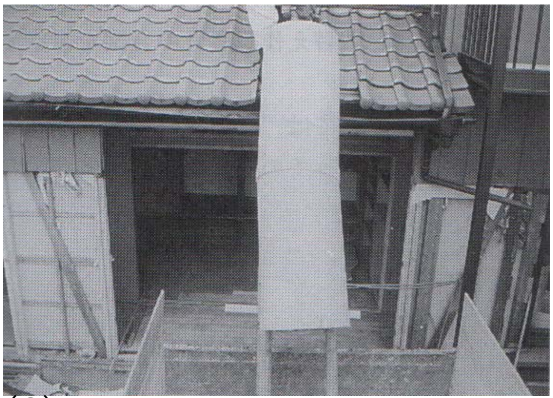
d. When dismantling and conveying tile on the roof, try to walk on the roof tile to keep away from the roof boards or rafters, as they can be rotten.

e. Rope off the point on the ground where roof tile is dropped.



(1)

(1) Tie the main rope.



(2)

(2) When dropping roof tile from a height exceeding 3m, use auxiliary equipment.

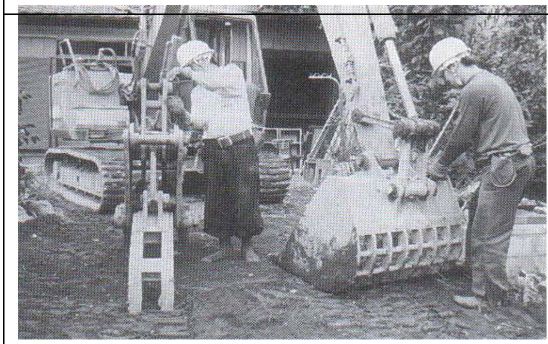
(3)

(3) Tie the lifeline, send roof tile from hand to hand, and let them slide down to a dump truck through a chute.

(4)

(4) A truck load of roof tile.
Exercise care not to overload the truck.

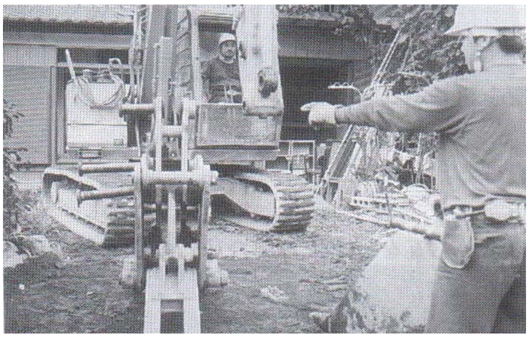
Technical safety guidelines



Bring in a backhoe

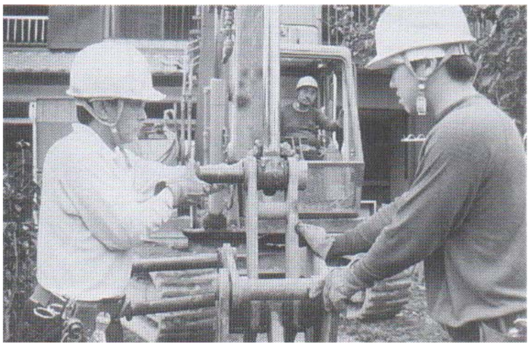
a. When a backhoe moves into or out of the site, place personnel to guide it.

b. Loading and unloading of a backhoe to and from a truck should be carried out on a flat and robust ground while appropriately using gangboards.



Check the backhoe
Change the head

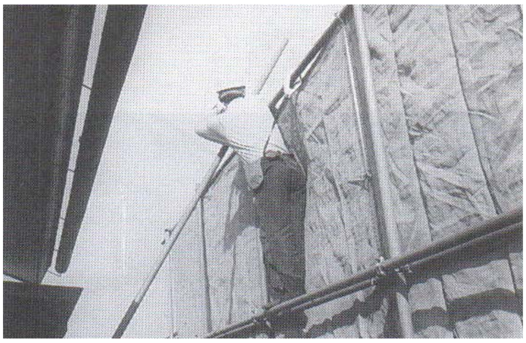
a. Changing the head of the backhoe should be carried out on a flat ground. Make sure that signs are confirmed between the operator and the workers changing the head.



b. Inspect the brake and clutch functions of the backhoe prior to the start of work everyday.

Remove the temporary enclosure and struts for scaffolding

When removing the temporary enclosure and struts for scaffolding from the building, make the scaffolding completely independent of the building by staying it beforehand with, e.g., trees. Also, confirm the independence of the scaffolding from the building.



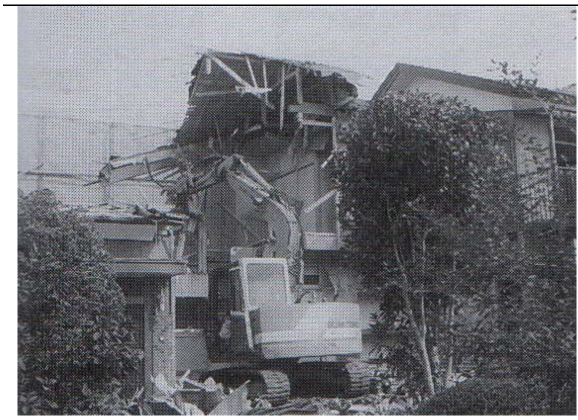
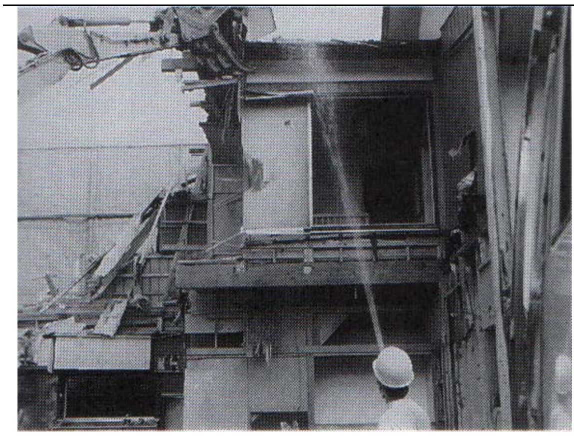
In the case of a two-storied building, replace the temporary enclosure and struts for scaffolding.

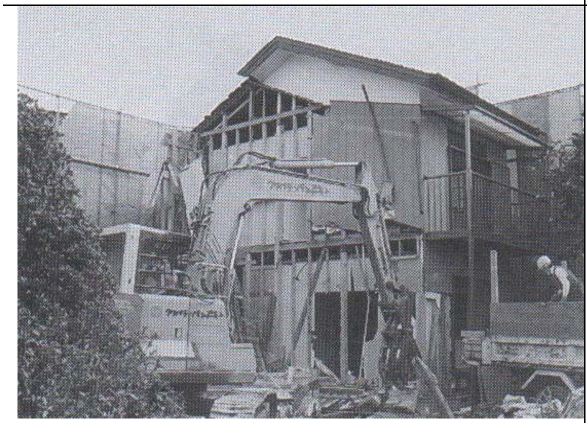
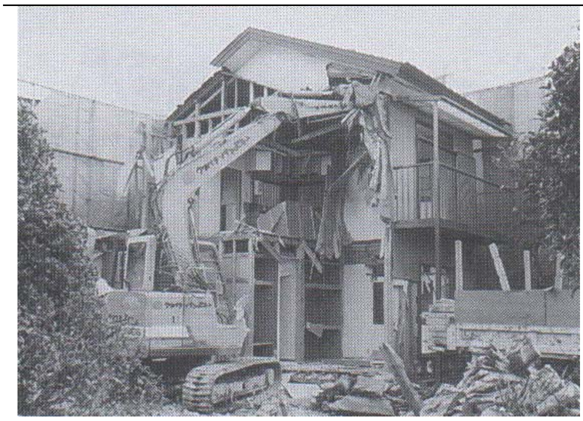
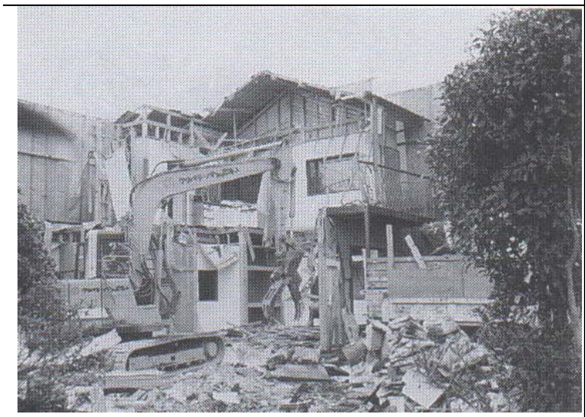
(1) The worker removes clamps wearing a lifeline.

(2) The workers remove the round pipes to lower the scaffolding level while strutting the scaffolding to make it independent of the building.

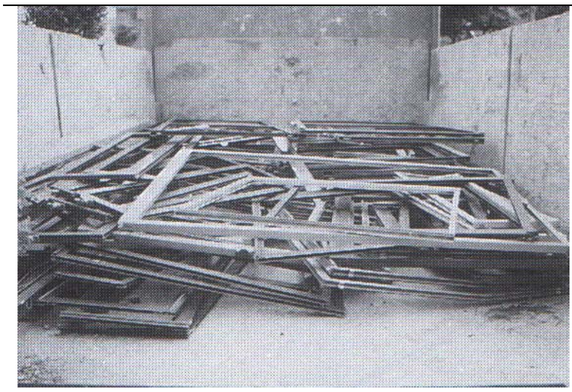
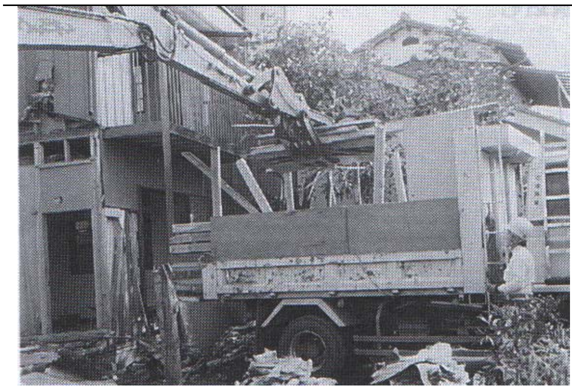
	Technical safety guidelines
	A view of the two-story wooden building.
	A view of the building to be demolished.
	After removing tatami mats, doors, windows, and roof tile, start mechanical demolition.
	Start from the ground floor.

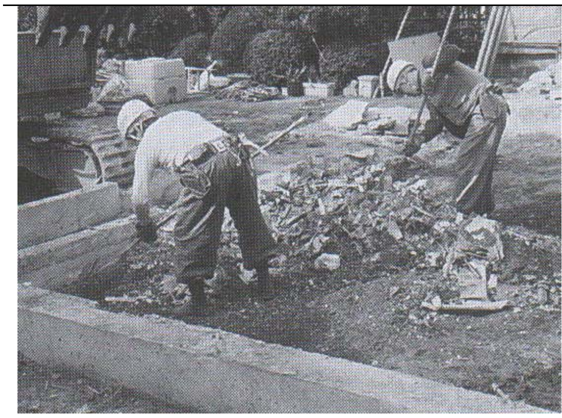
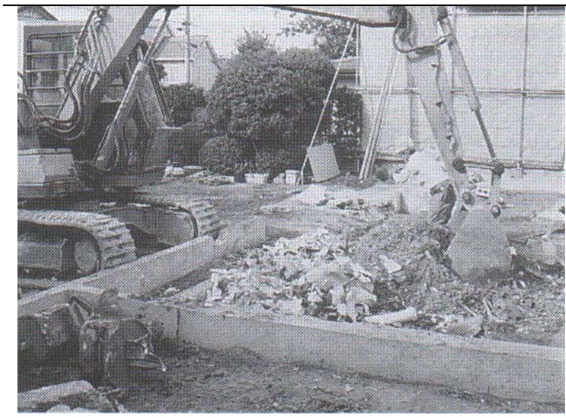
	Technical safety guidelines
	Dismantle the joinery on the first and second floors.
	Demolish the roof of the second floor. While demolishing, load the demolished wood onto a dump truck.
	Grab the roof and demolish progressively.
	

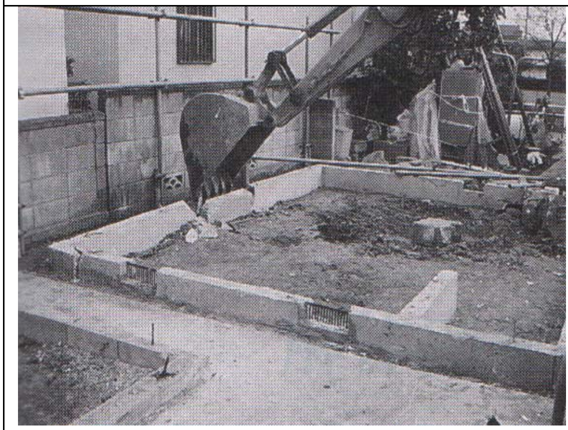
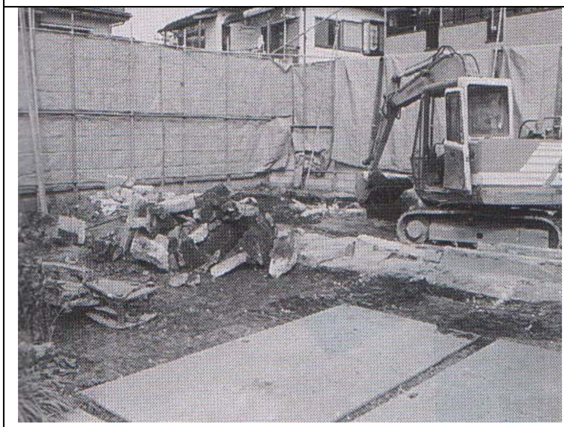
	Technical safety guidelines
	Demolish the roof on the second floor.
	Demolish the roof span by span.
	Spray sufficient water on dusting parts as required.
	When loading demolished members, exercise care not to overload the truck.

	Technical safety guidelines
	After demolishing the two-story building on the near side, start demolishing the two-story wooden building on the far side.
	Demolish joinery on the first floor, second floor, and roof span by span. Segregate wood, metal, insulation, etc., while demolishing.
	Demolish the roof span by span.
	The end of demolition of wooden segments.

Segregation processes

	Technical safety guidelines
	When bolts are present in wood, remove them manually.
	Collect sashes.
	After finishing segregated mechanical demolition of each span, load demolished wood onto a dump truck.
	After finishing segregated mechanical demolition of each span, insulation, etc., should be collected mechanically by the backhoe or manually by workers.

	Technical safety guidelines
	After demolishing wooden segments, demolish the foundation concrete.
	Mixed waste present around the foundations should be collected beforehand by workers.
	Load the mixed waste collected in the foundation concrete with the backhoe.
	Demolish the foundations. When piping not recognized during the preliminary survey is found, stop the work promptly and check/treat the piping. Rope off the radius of operation of the backhoe or place personnel for guiding the traffic while making sure to confirm signs between the operator and the personnel.

	Technical safety guidelines
	Demolish the foundation concrete.
	Demolish and collect foundation concrete.
	Load the foundation concrete broken into pieces onto a dump truck.
	The end of grading.

DEMOLITION TECHNOLOGY FOR STEEL-FRAMED BUILDINGS: THE MOVE HAT METHOD FOR DEMOLISHING HIGH-RISE BUILDINGS [3]

Introduction

By the method normally adopted for demolishing a high-rise building, large demolishing machines placed on the top floor crush concrete and cut reinforcement and structural steel, thereby breaking the building body into fine pieces. In this case, the demolishing machines are moved down progressively to the floor under demolition while concrete and steel lumps are simultaneously dropped to lower floors. Substantial time and labor have conventionally been consumed for placing heavy-duty supports to carry the weights of the machines and demolished concrete/steel, as well as for source-segregating and withdrawing the mixed waste materials. Protective scaffolding with sound insulation panels has been provided around the building for safety of workers and environment protection, which has had to be much more robust than for a medium- or low-rise building. Also, the erection and disassembly of such scaffolding have involved high-elevation work, which are prone to labor accidents, such as falling and injury by falling objects.

With the aim of improving such a hazardous work environment and addressing the problem of construction waste, Nishimatsu Construction developed a method of demolishing high-rise buildings referred to as the Move Hat method, which is characterized by the use of an elevating protective frame (the move hat). This paper reports on the outline of this method, which has already been applied to actual demolition sites.

Outline of demolition site

The building to which the Move Hat demolition method was applied is a high-rise building built in 1973 having 19 stories above ground, 2 stories underground, and 2-storied penthouse with a floor area of the standard floor of 1,318 m^2. It is located in a corner near the metropolitan expressway in Roppongi, Tokyo. The superstructure is of steel structure (columns and beams), with the floors made of lightweight concrete placed on the floor decks. Precast concrete curtainwall panels with cast-in tiles (see Photo 1) are used for the external walls.

Photo 1 Bird's eye view of the building and surrounding area

Characteristics of MOVE HTA method

This method was developed with the characteristics given below to improve safety and ease of demolition of high-rise buildings and promote environmental protection.

(1) Protective scaffolding and soundproof panels are provided only for the part being demolished. The adoption of a hoisted protective frame eliminated the hazardous work for installing and dismantling protective scaffolding and sound-insulation panels, which is

essential for conventional methods, while preventing accidents involving third parties.

(2) Small and lightweight demolishing machines and equipment are adopted. Demolition is carried out primarily by cutting and dismantling of members, thereby reducing the exhaust gas emission and vibration when compared with the case of using large and heavy-duty demolishing machines.

(3) The structural body is cut and removed out of place in blocks of members and hung down to the ground. Streamlined and efficient source-segregated demolition is achieved by carrying out in principle the so-called “member demolition method.”

(4) The dismantled blocks are separated and crushed on the ground. This enables safer and more efficient disposal, while facilitating separation of concrete from metals, thereby increasing the recycling ratio.

Outline of the demolition method

General plan
The demolition work was planned as follows: Dismantle the interior materials and utilities and dispose of the fireproof covering to expose the structural body. Assemble the Move Hat, a structural steel frame, on the ground on supports for ground assembly. Hoist the Move Hat to the top floor. Carry out supplementary work including roofing. Complete the demolition work of the top floor and lower the Move Hat to the next floor. Repeat this step from the 19thfloor to the 5th floor, which are the standard floors, as this method is applied only to these floors due to the ground level difference of 10 m. The penthouse and the 4th and lower floors were to be demolished by a conventional method (see Figure. 1).

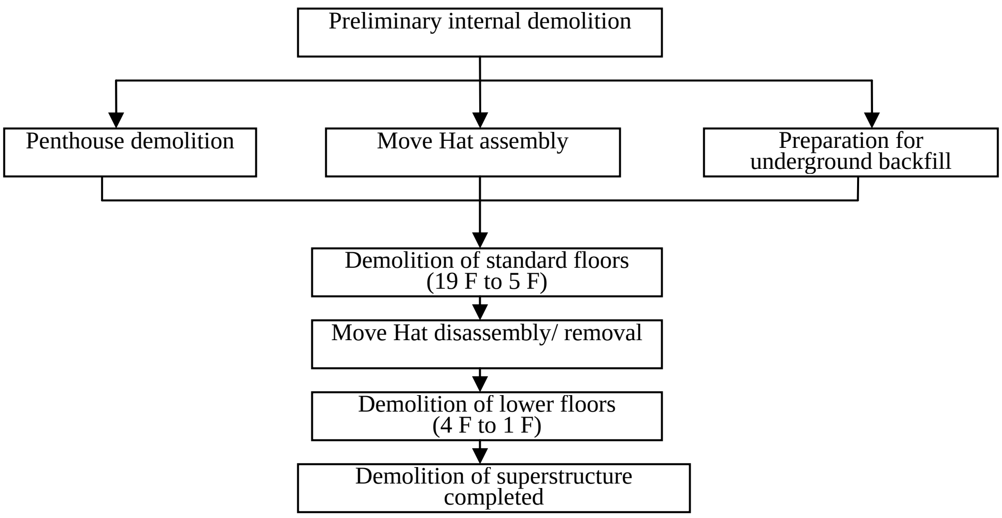


Figure 2　Flow of demolition work

Demolition procedure
First, the slab was cut into blocks and removed. The internal beams were then cut, and finally the columns were cut. The same procedure was applied to the peripheral parts after dismantling the curtainwalls. Sash windows in the curtainwalls were removed beforehand using trolley motor chain blocks provided in the Move Hat (hereafter referred to as curtainwall telphers) (see Figure. 3).

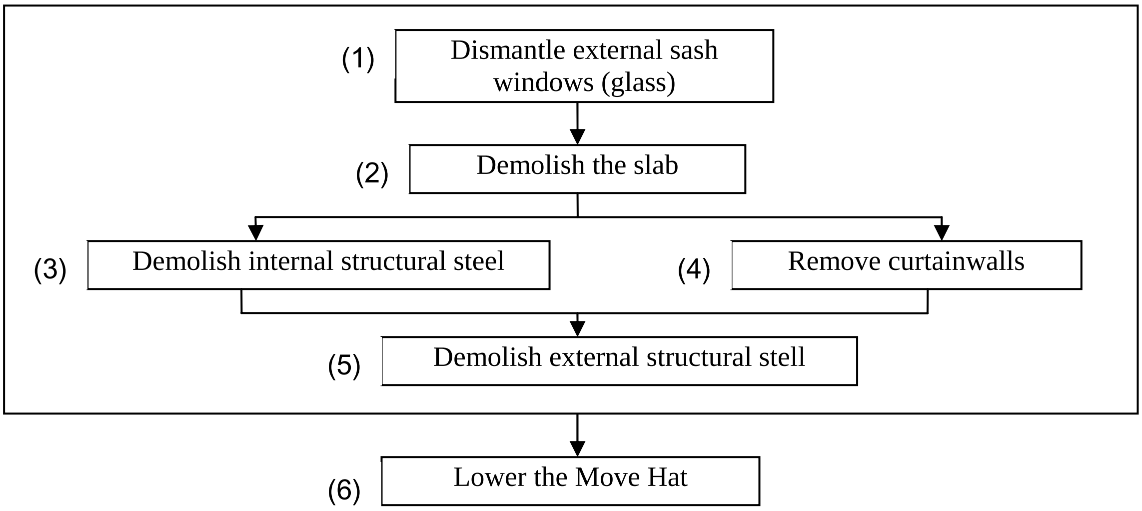


Figure 3　Demolition procedure of structural body

Method of demolishing structural body

Small-size cutters, cranes, and conveyers were used for demolition of the structural body. The cut pieces were lowered to the ground through the two steel-covered external shafts for unloading located outside the east and west sides of the building and two openings in the floor slab. Curtainwall telphers for 2.8 t were run along the inner side of the Move Hat to be used for dismantling and conveying curtainwalls.

Road cutters were used for cutting slabs 180 to 200 mm in thickness while arranging forklifts under the slab for receiving and conveying cut pieces. The size of the cut slab was 3.3 m by 1.5 m in consideration of the weight and handling.

Gas cutting was applied to structural steel beams and columns. Beams were cut by workers on mobile work platforms while the beams were suspended by a 2.9-t mini crane. The upper slab concrete at the cut position was chipped off beforehand. Columns were cut at a level of 1 m from the floor so that handrails and main ropes can be attached according to the progress of slab cutting (opening protection). Peripheral columns were cut while preventing outward falling with lever blocks (see Figure 4 and 5).

Curtainwall panels were dismantled one by one by cutting the setting fasteners while each panel (3.5 by 3.25 by 0.18 m) was suspended by a curtainwall telpher. Those on the east and west sides of the building were horizontally moved to the external shafts and lowered to the ground. Those on the north and south sides were moved inward and lowered to the ground through floor slab openings (see Figure 4 and 5).

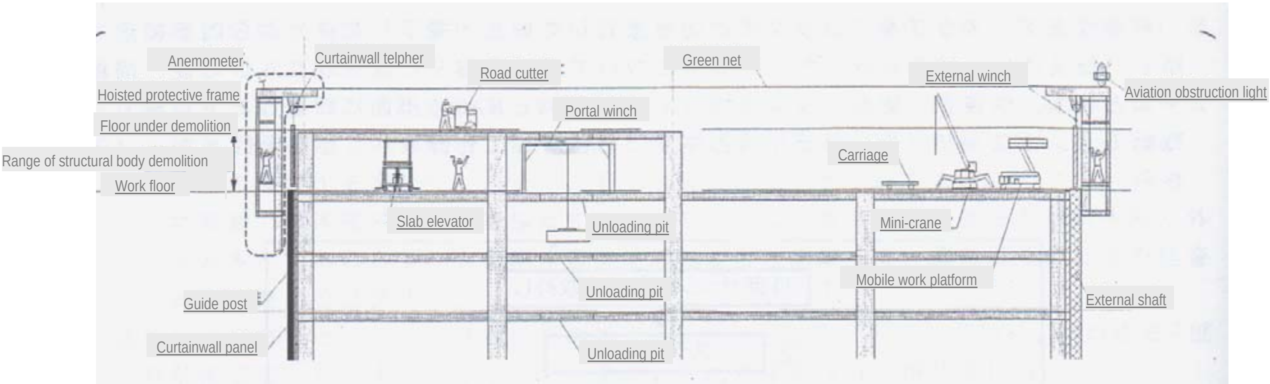


Figure 4 Demolition method (vertical cross-section)

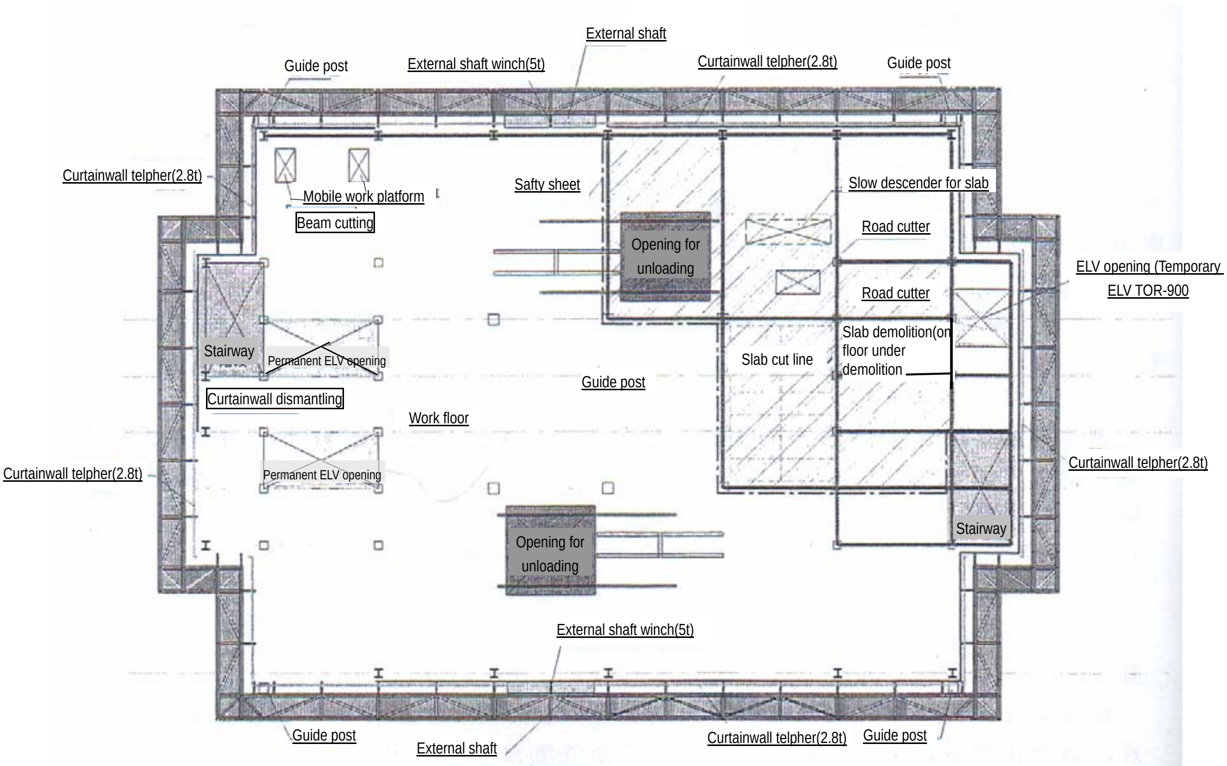


Figure 5 Demoliton method(plan)

Outline of hoisting system

The Move Hat was suspended against the sheaves on the tops of four guide posts placed on the four corners of the building by the wires of winches set on the ground via load cells.

The weight of the Move Hat eventually turned out to be approximately 180 t with all the equipment attached, including the roof and motor chain blocks, after being elevated to the top floor. A four-wheel sheave unit was therefore provided at each of the tops of the guide posts and the suspension points of the frame.

The guide posts consisted of units with a height of one story (3.52 m), which were connected using the motor chain blocks placed above the guide post tops in line with the rise of the Move Hat. The posts were then bolted to stays welded to structural steel columns of the building. Bracket-shaped stoppers were fixed to the sides of the guide posts to serve as supports for the Move Hat during elevation or demolition.

During lowering of the Move Hat, the guide post units were removed piece by piece by a similar procedure (see Figure. 5 and 6 and Photo 2).

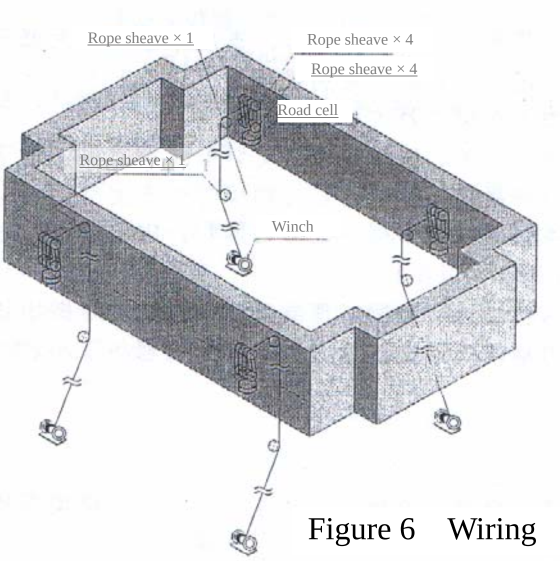


Figure 6 Wiring

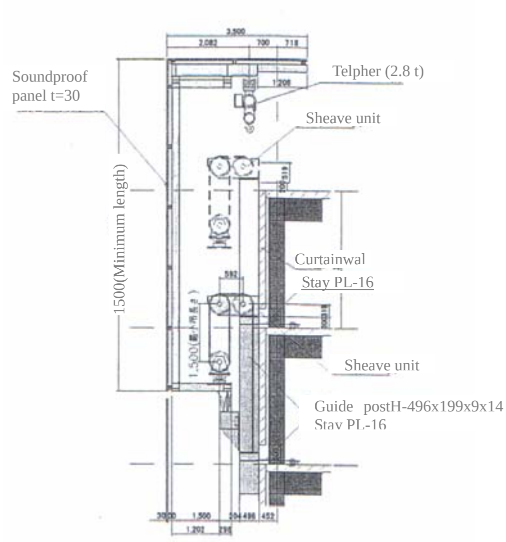


Figure 7 Hoisting system

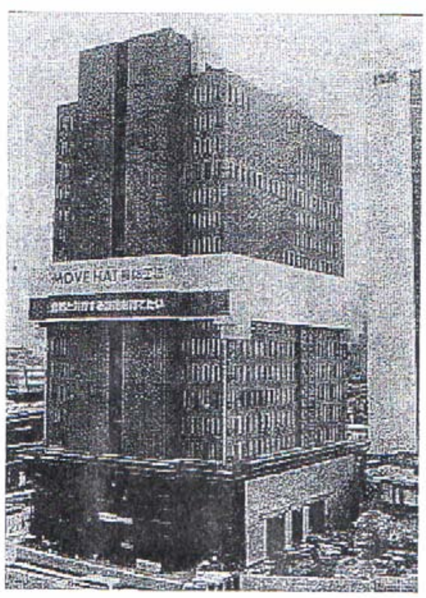


Photo 2 Rising Move Hat

Results of demolition

Partly because this building was the first application of the new system, it took one month excepting the summer vacation to raise the Move Hat. The delay is attributed to the adjustment of equipment and unexpected work. For the stories demolished using the Move Hat (19^{th} to 5^{th} floors), the work was carried out day and night for 16 hours a day in two shifts. Though it took five days to finish a floor in the beginning, the time was shortened to 2 days toward the end, owing to the shortened lifting time necessary for low floors and improvement by experience.

Waste disposal

In this method, curtainwall panels were dismantled as such, whereas most of the structural body was cut into blocks, lowered to the ground, and then subjected to crushing and source segregation. This improved work safety and efficiency.

The scope of the present demolition was limited to the superstructure. Since the work for the substructure was included in the subsequent construction of the new building, all of the waste concrete was finely crushed and backfilled in the substructure, so as to be utilized as a strengthening material for the ground floor slab, which would serve as the working floor for subsequent construction.

Metal wastes were classified by type and shape and sent out for assignment to services specializing in disposal of each material. Scrapped steel was classified by type and treated for reuse in future construction.

Afterword

Demolition generates a large amount of construction waste. In view of the social consciousness of environmental protection in recent years, it has become increasingly important to consider the method of demolition from the aspect of not only safety and efficiency but also environmental protection.

The present method is considered to be an effective method of demolishing high-rise buildings also from the aspects of the effective use of construction waste and recycling.

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4.0 ENSURING MATERIALS RECYCLABILITY

INTRODUCTION

Today, demand for reduction in the generation of waste, as well as its recycling is increasing more and more, due to the scarcity of residual areas as sites for waste disposal, and intensifying activities towards the establishment of a recycling society. Above all, construction waste accounted for 19% of approx. 400 million tons of industrial waste (1999 survey by the Ministry of the Environment), of which 15% was sent for final waste disposal [1]. Under such circumstances, effective measures for the reduction of waste generation are now hoped for.

With respect to construction waste, recycling is being promoted following the Construction Materials Recycling Act which took full effect in May 2002. Specific construction materials such as waste concrete, wood and asphalt-concrete, were designated by this law to be recycled or reduced, and recycling measures have already been implemented for a significant volume of these materials [1]. However, in terms of materials other than these, no measures have yet been established. Although such non-specified materials, e.g. mixed construction waste account for only 8% of the entire construction waste, its final disposal amounts to as much as 5.4 million tons [1], and measures for its reduction are a pressing need. Among these non-specified materials, there are some including unused wood resulting from the building of new houses, which are recovered for recycling by the manufacturers of building materials. On the other hand, there are few cases in which such systems have been established regarding old used materials resulting from the demolition of buildings, except in the case of valuable resources like aluminum sashes.

Various recycling methods exist, including those which produce secondary materials from waste, and thermal recycling which recovers heat by burning. This research focused on the example in which non-specified wood waste resulting from the building of new houses or demolition of buildings is recovered and recycled as a secondary material of a similar kind. As this type of recycling is implemented on an integrated basis by the party which manufactures the original products, and recovers and recycles them within their own industry, the manufacturer enjoys the advantage of easy management concerning product quality and information. Such a system has been implemented for the recovery and recycling of domestic electrical appliances such as TVs and refrigerators, following the Specific Household Appliance Recycling Act enforced in 2001. Under this system, the manufacturer of the product is responsible for its collection and recycling, and it is anticipated that consideration concerning recycling will be encouraged during the initial manufacturing stage.

CONSTRUCTION WASTE RECYCLING AT AN INTERMEDIATE TREATMENT OLANT

Backgrounds

Construction waste accounts for a large percentage of the total industrial waste, while the final disposal areas are becoming filled up (the Ministry of Environment predicting that Japan's landfills will be full by August 2002 according to its statement dated June 22, 2001), demanding immediate measures. Possible approaches to waste reduction include extending the service lives of structures, improving the material efficiency at the time of construction, and recycling of waste. This paper focuses on waste recycling and explores the prospects and problems of construction waste recycling while introducing the examples of recycling at an intermediate treatment plant.

Examples of recycling treatment

In December 2000, the authors visited Tokorozawa Intermediate Treatment Plant of Ohzora Recycling Center, an affiliate of Ohzora Group, located in Tokorozawa, Saitama Pref. to see the plant's treatment processes achieving one of the highest recycling ratios in the industry. The group has made a variety of attempts toward a recycling-oriented society. Ohzora Recycling Center processes construction waste and sends out to other plants or treatment plants for a next stage as recycled materials. Sixty to seventy percent of the accepted waste materials are those from new construction sites, and the rest are those generated by demolition. Figure 1 shows the flow from acceptance to shipment. The flow is explained in the following sections.

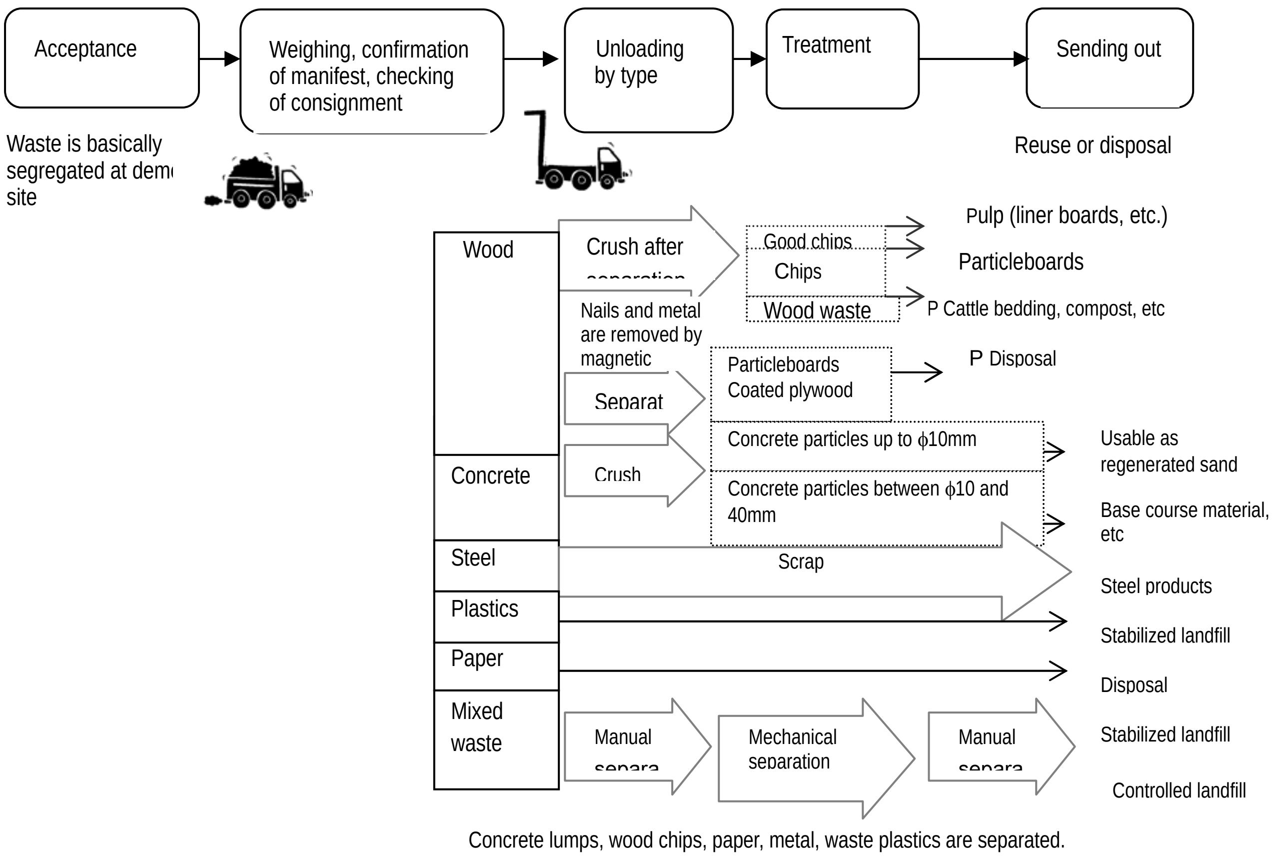

Figure 1 Treatment processes in intermediate treatment plant

Acceptance

The plant asks in principle that the waste be source-segregated at the point of discharge.

Photo 1 Waste acceptance and weighing

Segregated waste at the point of acceptance significantly improves the efficiency of subsequent processes, contributing to the improvement of the recycling ratio. The plant weights the load (Photo 1), confirm the manifest, and check the load at the point of acceptance to carry out strict control of the accepted waste. Also, waste is accepted through a single entrance to prevent unauthorized entering.

From treatment to shipping

Accepted waste is unloaded at different points by type. The stockyard is filled with piles of waste (Photos 2 and 4). Each type of waste is then subjected to treatment for each type.

Wood waste

Waste beams and columns are crushed into chips for regenerated pulp (Photo 3). Other wood waste is crushed into chips for particle boards. Though chips are shipped as valuables, the price is nearly offset by the transportation fee, and the demand for recycled chips is low, due to the small price difference from virgin chips. Recycled chips are therefore weak in the recycled materials market. Fine wood particles resulting from chip production can be used for cattle bedding and compost, but are oversupplied. Coated plywood waste is currently disposed of due to difficulty in recycling. (Photo 2)

Photo 2 Wood waste

Photo 3 Chipped waste

Concrete waste

Concrete waste is crushed after removing reinforcement. Grains with a diameter of up to 10 mm can be reused as recycled sand, for which applications are being explored. Grains with a diameter between 10 and 40 mm are reused for road subbase courses. (Photo 4)

Photo 4　Concrete waste

Steel

Steel is scrapped and used for recycled steel products

Plastics waste

Relatively large lumps are diced into cubes and transported by train, while those that cannot be crushed together are transported by truck to stabilized landfills.

Paper waste

Corrugated boards used as containers are sent in as waste. These can be recycled if segregated, but are currently sent to other facilities for disposal due to the high processing cost

Mixed waste

Though mixed waste is not currently recycled, it is segregated for appropriate disposal. In regard to waste to be sent to disposal sites, strict quality control is carried out by separate treatment, as stabilized and controlled disposal sites accept different waste contents. The process begins with spreading the waste on a work field and pick large steel and wood waste manually (Photo 5). The rest is then put on an operation line, on which the waste is subjected to sieve separation, separation of metal by a magnetic separator (Photo 6), and manual separation (Photo 7).

Photo 5　Segregation of mixed waste

Photo 6　Metal removal by magnetic separator

At the end of the line after separation (Photo 8), the organic material content is reduced to a level acceptable at stabilized landfills.

Photo 7 Manual segregation of mixed waste

Photo 8 Exit of mixed waste treatment line

For a higher recycling ratio

Setting aside various problems related to recycling, proper segregation and development of the demand for recycled materials are considered to be the first steps for increasing the recycling ratio.

Segregation of mixed waste is the hardest and most time-consuming work at Ohzora Recycling Center as well as other facilities. Though source-segregation at demolition sites may be difficult, requiring, e.g., stockyards for various materials, it is desirable that the waste be segregated before being brought to intermediate treatment facilities. Even if mixed demolition is inevitable, at least demolition with consideration to the work at intermediate treatment facilities would mitigate the current difficulty at such facilities. For instance, crushing into small pieces should be avoided, because larger pieces of waste are easier to pick up during the separation work and easier to find their uses.

While waste recycling is pursued, the demand for recycled materials remains low. The improvement in the recycling ratio is hindered by the small number of users of recycled materials, as well as their limited merits and low prices. The recycling center endeavors to promote demand for recycled materials, including developing new demand, but this is an issue that should be addressed not only by such facilities but also by various sectors concerned.

Afterward

The treatment processes at an intermediate treatment plant was introduced, and the points to improve the recycling ratio were considered. The plant introduced in this paper may not be regarded as a representative plant, as few plants achieve such a high recycling ratio. However, it was selected as an example from which the problems related to recycling can be properly extracted.

A number of other problems related to intermediate treatment plants remain unsolved, including the relationship with the recently enforced environment-related laws, depletion of disposal sites, and consideration to the environment. These should be addressed by the society as a whole.

Needless to say, it is necessary not only to recycle but also to extend the service life of structures, improve the methods of design and planning, address the problems from various aspects, and to adequately treat generated waste, in order to reduce waste.

RECYCLE AND REUSE OF BUILDING MATERIALS

Concrete

Outline

At present, concrete pieces are almost recycled in place of crushed stones and sands being used for reclaimed ground or roadbed. The type of concrete dismantled wastes varies with the demolition method. In particular, larger ones have less adhesive and mixtures of small ones in products at the case of reproductive concrete aggregate. On the contrary, smaller ones would contain much soils and impurities, and hence, the most suitable demolition method must be applied, taking into account of secondary product, waste disposal or transportation construction with enough. Regarding to usage in reproduction aggregate of concrete, it has noted to be available for no reinforced concrete in the common specification applying to public building constructions (1997). Japan architecture society has introduced examples for building foundations, the underground beams in temporary works, precast concrete piles in the publication of "Manual of demolition works in reinforced concrete building (temporary)" But it is very difficult to realize the recycle as artificial aggregates because of the mixture with finishing or lath materials, which should be collected selectively. We have to investigate about the following issues in future:(1) certificate of quality for recycled aggregate, (2) production technology for recycle aggregate, (3) establishment of supply system for recycled concrete aggregate, and (4) durability of recycled concrete aggregate.

The current research and development in demolition of reinforced concrete buildings

There are few on-going research projects for demolition and recycling of reinforced concrete buildings at present in Japan:

1) The development of easy demolition and reproduction in design and materials
2) Development of new systems with prefabricated structures and proper units considering demolition and recycle
3) Development of high performance machines for demolition works with remote control and automated dismantling
4) Development of small size machines suited for partial collections with low powder scattering, low vibration, and low noise
5) The development of effective usage of refuses (concrete pieces, surplus soil) in construction site

Steel

Outline

In recent years, the amount of the steel production in Japan ranges from 90 to 100 millions tons. Revolving furnace, in which all scraps are recycled as raw materials completely, has a 30%share of the market. Most converters produce pig iron of blast furnace. According to the statistics, scraps are around 10%. A mount of demand for scraps of iron is around 45 million tons. Scraps, which are called waste taken out by demolition, are around 27 million tons and 8 million tones are from construction sites. It is uncertain how much steel becomes waste in the actually existing dismantling buildings. As mentioned above, steel materials are recycled by scraps to a great content, but reuse of it, however, seems not to be done at all. The wastes are also taken out of steel buildings, resulting that these would be recycled to roadbed etc. or transported in final disposal site through the intermediate dealers.

The current research and development in demolition of steel buildings
Design for dismantling or deconstruction has not yet been considered for steel structures. Development regarding life cycle resources (LCR), life cycle cost (LCC), and life cycle energy (LCE) seems to be proceeded by general contractors. The noise during demolition is such a major concern that a new machinery and technique for low vibration and noise are under development. It would be a right direction of selective demolition as possible from a point of view to decrease steel wastes. There, however, seems to be no idea to recycle with the same form as being used in present buildings.

Wood

Outline
Use of timber resources is often touted as a root cause of environmental destruction because of the effect on tree and forest ecosystems. At the same time, however, timber and wood products represent the only basic construction material that can be reproduced repeatedly using natural energy. Timber and wood products in fact consume far less fossil fuel resources in manufacturing and recycling than other construction materials, and hence generate much lower levels of carbon dioxide emissions. Furthermore, the plantation trees from which we make timber and wood products absorb carbon dioxide from the atmosphere. And finally, carbon-the main constituent element of plants-is fixed by the action of the sun and remains within the tree after harvesting, eventually finding its way into urban areas in the from of timber and wood products.

The average Japanese timber house contains 76kg/m^2 of carbon, calculated on the basis of the quantity of wood used in construction. This figure is roughly equal to the amount of carbon generated in the manufacture of all the materials required in a timber house. Taken in isolation, then, the timber materials account for just 6% of the total carbon generated, thus providing some 16 times more carbon than they generate.

Timber houses-the most common type of house in Japan-contain the equivalent of 22% of natural Japanese forests or 48% of artificially produced forests. Timber and wood resources therefore represent an effective and very substantial stockpile of carbon.

Reforestation and ongoing management of plantations continues the cycle of carbon dioxide absorption and carbon fixing through new trees. Thus, if the volume of carbon generated from harvest thorough to ultimate incineration or natural decay is less than the volume produced via natural growth, then the net amount of carbon generated by this sub-system actually falls. In order to maintain carbon-fixing levels in housing construction, we need to work towards long-term usage of resources through strategies such as:

1) Reusing off-cuts produced during the manufacture of timber and wood products
2) Improving the durability of timber used in structural members (such as beams and posts) and non-structural members
3) Recycling wood scraps generated during the construction and subsequent dismantling processes

Recycling of timber and wood materials at present
Wood scraps can be broadly divided into off-cuts (from the factory) and waste timber (from on-site construction and dismantling). While off-cuts are generally used as boiler fuel or to make other wood products, waste timber from construction and dismantling is usually burnt in the open or disposed of as rubbish, since sorting and processing costs effectively render recycling economically unfeasible. In any case, most waste timber transported to intermediate processing yards is turned into wood chips for boiler fuel, which instantly releases the stored carbon into the atmosphere.

Timber resources are utilized in stages, beginning with finished timber and pre-cut sections, and moving through laminated lumber, particle and fiberboard to woodchips. While technology for recycling wood scrapes from construction and dismantling exists to some extent, the general lack of progress in this area can be attributed mainly to social and economic factors and poor environmental awareness. Recycling of timber materials, like any other natural resource, presents a number of problems, but these are not insurmountable. With the right strategies, we can help to increase the rate of carbon fixing on the ground and help to reduce global warming. Timber resources are the keys to solving many environmental problems.

The current research and development in demolition of reinforced wood buildings
In Japan, projects concerning research and development on design and construction works of wooden house considering recycling after the dismantling have already begun. Easy dismantling for wooden structures will be developed between2000 and 2002 at Building Research Institute, Ministry of Construction. The Ministry of Construction had developed technical information on waste reduction and recycling of construction waste (secondary products) twice previously:

1) Technical development to use wastes in construction (1981-1985:called “the waste project”)
2) Technical development of waste reduction and recycling technology of secondary products (1990-1994:called “ the secondary products project”)

<u>Technical development for use of waste in construction</u>
Finding possibility to use construction waste in site, various technical developments have been carried out concerning usage to the ground, reclaimed ground, roadbed, pavement, civil structure, and buildings. As for using in buildings, amount of waste of each type of buildings has been estimated and various technical results have been proposed to recycle such materials as waste of timber scrap, concrete, decoration finishing materials in concrete, scrap wood, bed materials etc. On recycling of timber scrap, the following have been developed:
1) Comparison of possibility to use waste between hand demolition and machine
2) Comparison of quality of new wood and waste wood
3) Usage as laminated lumbers, core tips of panel, wooden brick, particleboard
4) Reuse in new construction as structural members (column, beam)

A model houses has been constructed in the site of BRI Technical Development of Waste Reduction and recycling Technology of Secondary Products. This has been investigated regarding the law concerning the promotion of recycled material. A new concept, Secondary Products in Construction (not wastes), has been introduced.

<u>A study to reduce waste from wood house construction</u>
Three technologies are necessary to reduce waste from construction of a wooden house. First,

the technology to build wooden houses to last long, which results in restrained wastes. Second is, a technical issue in designing a new house using salvaged timber or wood. Third, using recycled wastes from wooden houses in new construction or remodeling.

The development to construct long life house

B.R.I started this project from 1998 (for 3 years). The aim of this project is to propose a social system able to realize long life houses by developing new technologies such as increasing good stocks of houses resulting less waste.

Housing construction method to restraint waste (2000-2002)

Building has a long life in comparison to electric appliances. As the effect of long life measures would not be seen for a short time, it is difficult to decide how to take care of this matter. It, however, is necessary to develop new construction methods considering easy reuse of existing house elements. To achieve this aim, the effects to restraint waste in future are considered at the stage of planning and designing for new houses.

The usage of dismantled wastes as resources

Various ideas have been proposed to reuse timber and wooden products. Reuse as resources is away to get effective result for a short time. But, we should note that reuse of some materials is difficult at the end of their life such as boards with adhesive. The similar researches have started in several institutes or universities. Other researchers have introduced a new concept, LCW (life cycle waste) and are considering new materials, construction methods, evaluation method of emission etc. to recycle and reuse.

Foundation and excavated soils

Outline

The situation for reuse and recycling of foundation materials is similar to reinforced concrete structures. As for soils from construction site, details are noted in the guideline related to ‘The law concerning waste disposal and public cleanliness”(mentioned above). The amount of soil excavated from public works was about 450 million tons in 1995 and only around 30% was reused. Soils from construction site are classified in construction soil and mud (or sludge). Mud is also classified as construction mud, dredged soil and others. Only construction mud is regulated as industrial wastes.

The state of research activities

There have been a lot of investigations about construction wastes related to foundations. Construction mud is industrial waste and is taken a lot of sites and this has been studied quite extensively.

Gypsum board

Gypsum board is widely used as a wall and ceiling material with approx. 4.5 million tons being manufactured in 2001, showing a rapid increase in its manufactured volume during the past 20 to 30 years. As it is projected that the generation of its waste will increase in the near future, it is an important task to provide appropriate measures regarding it’s recycling. To this end, efforts have been initiated by gypsum board manufacturers as follows.

Gypsum board waste resulting from the construction of new buildings above a certain size, is often separated and recovered, but that from smaller scale constructions such as private houses, is often disposed of as mixed construction waste at industrial waste dumps.

The gypsum board manufacturer’s organization carries out the recovery of discarded gypsum

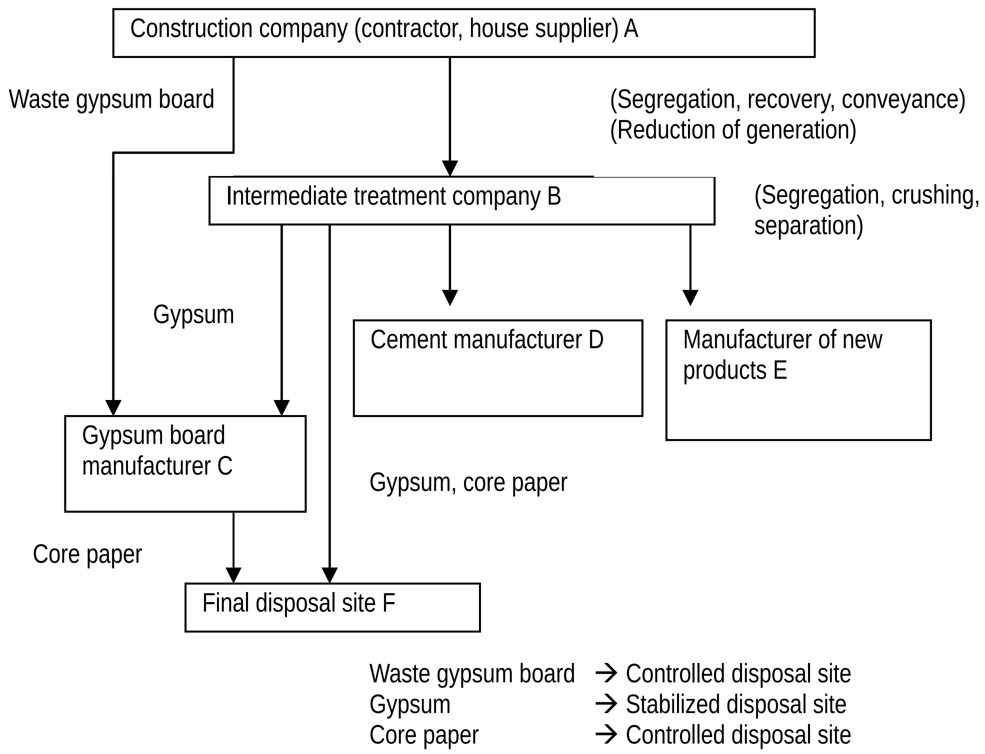

Figure 2 Recovery and disposal flow of waste gypsum board from new construction. [2]

board at construction sites and recycles it as raw material on a contracted basis between individual companies, following the Law for the Promotion of Utilization of Recycled Resources, with its 24 plants being designated as users of recycled resources under the “wide-area recycling and reusing designation program”. The processing fee required for recycling is in principle borne by the party which generates the waste.

Waste gypsum board resulting from the construction of new buildings is estimated as approx. 360,000 tons nationwide (2001), of which 50% is currently recovered. Further reduction in its generation and a larger recovery rate is hoped for.

The recovery and disposal flow of waste gypsum board from new construction is figure 2.

On the other hand, regarding waste gypsum board resulting from the demolition of both large buildings and houses, there remain many unsolved problems regarding its recovery and recycling from the technical and economical viewpoint.

Although at present the receiving and recycling of such waste gypsum board is carried out on a trial basis only, due to the fact that it is not yet isolated from other waste materials and the quality stability of its recycled materials is not yet assured, technical verification and establishment of a receiving system for its recycling are now under study.

Polyvinyl chloride pipes/fittings

Polyvinyl chloride (PVC) pipes and fittings are widely used for piping systems of buildings with approx. 500,000 tons of them being currently produced annually. As these materials can be recycled with stains and some deterioration, the recovery and recycling of both used and unused items began in 1998. Presently, they are received at 53 facilities in Japan, and for example, 17,000 tons out of the 35,500 tons of used PVC pipes and fittings generated during 2003 were recycled.

PVC pipes and fittings are purchased at the receiving facilities as resources, following a process of removing foreign matter and stains in accordance with the stipulated acceptance criteria. These resources are then transported to recycling plants where they are first crushed and reproduced as recycled pipes.

In 2003, PVC pipes and fittings with foreign matter and stains became acceptable at reception facilities. This is now being implemented throughout Japan in anticipation of further promoting the recycling of these materials.

Glass wool

Glass wool is used extensively as a building insulation material, with approx. 200,000 tons being currently produced annually. This is recycled as material for glass fiber, by melting it to produce cullet. Glass wool manufacturers have begun the recycling of materials limited to those resulting from the construction of new buildings, such as unused odd waste materials, by being designated as industrial waste disposers under the “wide-area recycling and reusing designation program”.

On the other hand, regarding glass wool waste resulting from the demolition of buildings and houses, no receiving systems have yet been established. It has been confirmed that glass wool recovered from such demolition sites is recyclable even with the presence of dust and mold, as long as other foreign matter such as nails and film are removed. However, their recovery and recycling have not yet been implemented due to economic reasons.

SUMMARY

Examples of construction materials, the waste of which is already being recovered and recycled under the established recycling system in Japan, have been introduced. Among waste materials generated from the construction of new buildings, similar measures have been gradually introduced to those not mentioned here.

Concerning waste generated from the demolition of buildings, the recycling of which is hardly carried out except for metallic materials, this is largely due to the fact that thorough implementation of source-segregated recovery is necessary in order to apply the recycling technology developed to date. It is therefore difficult under the present situation to implement it due to economic considerations, and further concrete studies are required. For the future promotion of recycling, focus should be placed not only on technical tasks, but also on the establishment of recovery channels and development of demand for recycled materials.

ACKNOWLEDGMENTS

The authors express their gratitude to President Saburo Watanabe and the staff of Tokorozawa Intermediate Treatment Plant, Ohzora Recycling Center for their kind attendance in their busy schedule when we visited the plant.

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7.0 DESIGN OF BUILDINGS AND COMPONENTS FOR DECONSTRUCTION

INTRODUCTION

The total weight of the waste generated from the construction industries in 2001 was approximately 85 million tons in Japan and three fifth of the waste was generated from the civil engineering activities and the two fifth of the waste was generated from the building activities [1][2].

Illegal or improper disposal of waste is a social problem in Japan that should be immediately solved. The Ministry of Environment reported in 2001 [2] that 433 thousand tons of waste was improperly disposed of in 2000. The amount of the illegally disposed construction waste was 303 thousand tons and it was more than 70% of total amount of the illegally disposed waste. When we look at the type of the illegally disposed waste 25% is concrete, 25% is wood and 20% is other construction waste. Wood waste generated in the process of constructing and dismantling wooden houses is largely the cause of this situation.

On the other hand it is estimated that the landfill sites have their capacities to accept waste no longer than 0.8 years in the Tokyo area and 3.3 years in the whole country.

As the waste coming out from the construction industry is getting a serious social problem in Japan several organizations and groups have started new projects to reduce the production of waste and also to promote the reuse and recycle of construction and demolition waste. And in May 2000 the former Ministry of Construction (current Ministry of Land, Infrastructure and Transport) announced officially a new law that stipulates the deconstruction process and promotes the recycling of construction and demolition waste. The whole part of the law was fully effective in May 2002.

The Building Research Institute and the National Institute for Land and Infrastructure Management started a joint national R&D projects to develop technologies to reduce waste and to promote reuse and recycle of building materials and components in 2000. The final target of this R&D projects is to reduce the amount of the waste and also to promote the recycle and reuse of construction and demolition waste in the whole life cycle of timber buildings [4][5][6][7].

ANALYSIS OF THE CURRENT 2BY4 CONSTRUCTION SYSTEM

Detail study of dismantle and deconstruction

To analyze the whole deconstruction process of the 2by4 wooden houses the deconstruction process of a single detached 2by4 wooden house was investigated. The house was built in 1980 and has been used for 20 years. The total floor area of the house was approximately 150m^2 and it took 9 days to deconstruct the whole house including the foundation.

The processes of deconstruction are as follows:
(1) Remove the window glass by hand.
(2) Remove the joiners by hand.
(3) Remove the wallpaper and gypsum board by hand.
(4) Remove the roofing materials by hand.
(5) Remove the insulation materials by hand.

(6) Remove the steel materials by hand.
(7) Dismantle the structure by machine.
(8) Dismantle the foundation by machine.

Gypsum boards were removed by hand using the traditional deconstruction tools as shown in photo 1. Almost one-fourth the total deconstruction time was spent in the process of removing the gypsum boards. The wooden frame of the house was dismantled by the aid of the dismantling machine as shown in photo 2. And it took 4 days to dismantle the wooden frame. Most of the dismantle works were consumed in the hand selection process. Lumbers, boards and other materials were separated on site according to its type as shown in photo 3.

Alternative design for wooden buildings should be propose to improve the deconstruction process and reduce the time consumed in the process of hand separation and also increase the recycle potential of the materials collected from the deconstructed houses.

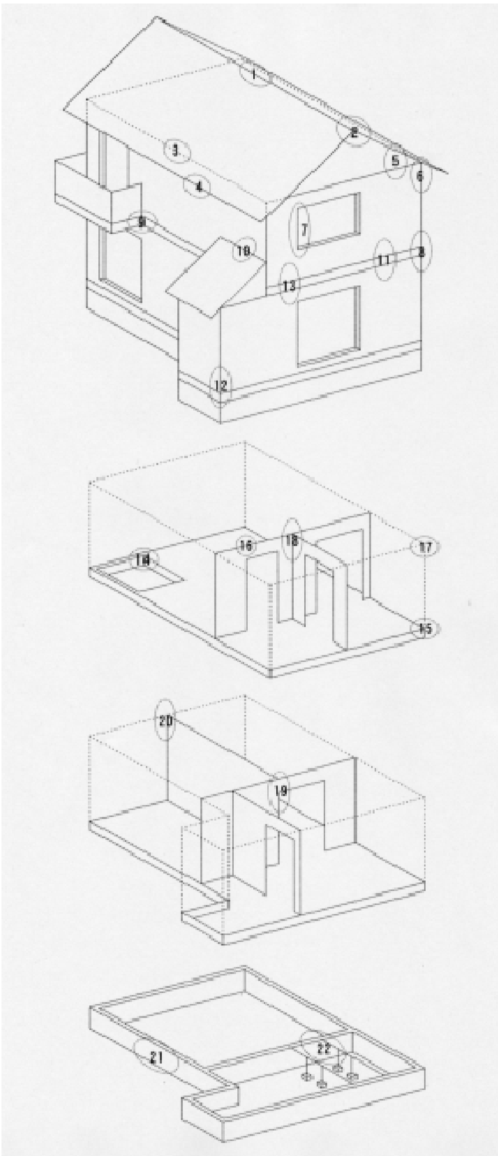

Photo 1 Gypsum boards remove by hand.

Photo 2 Wood frames demolished by machine.


Photo 3 Selection process on site.

Analysis of the current design of the 2 by 4 construction system

To propose new designing ideas to make 2by4 houses remountable the current designing methods were analyzed. All types of joints used in the 2by4 construction system were listed up. Figure 1 shows locations and types of the joints listed up. Approximately 70 joints were listed up and the barriers for deconstruction and selection caused by the currently used joints were analyzed to discuss the alternative design. The result of the analysis was summarized in a summary sheet for each joint respectively. Figure 2 shows the summary sheet for the roof framing. As the roof framings are deconstructed at high locations connectors should be designed so that the time consuming and dangerous works can be avoided. And the connecters should also be designed so that the lumbers would not be damaged in the process of removing the connectors.



(1) Ridge board - Rafter
Roof sheathing -after - Ridge board
Truss - Blocking
Roof sheathing - Truss
(2) Ridge beam - Rafter
Gable frame: Ridge beam - Rafter
Hip frame: Ridge beam - Rafter
(3) Rafter - Top plate
Rafter - metal connector - External wall
Truss - Top plate
Truss - Metal connector - External wall
Truss - Blocking
(4) Eave, Overhang: Rafter
Eave, Overhang: Rafter - Sheathing
(5) End wall - Top plate
(6) End wall sheathing - External wall sheathing
(7) Lintel - Inner stud
Lintel - Sheathing
(8) Wall - Floor - Wall
Wall - Floor - Wall (Sheathing)
(9) Overhang Balcony: Floor joist - Header
(10) Rafter – External wall
Rafter – External wall (Sheathing)
(11) 2nd floor bottom plate – Floor – 1st floor: top plate
2nd floor: bottom plate – Floor – 1st floor: top plate (Sheathing)
(12) 1st floor: external walls – Floor
External wall – Sill- Header/Trimmer joist
External wall – Sill- Header/Trimmer joist (sheathing)
(13) 2nd floor: wall – 1st floor: wall above the opening
(14) Floor opening: Joist
Floor opening: Joist (Sheathing)
(15) Corner: Joist – Sheathing
(16) 2nd floor: Load bearing wall – Ceiling joist
2nd floor: Load bearing wall – Ceiling joist (Insulation)
2nd floor: Load bearing wall – Ceiling joist (Gypsum board)
(17) Corner: Load bearing wall - Load bearing wall
(18) Internal wall: Load bearing wall - Load bearing wall
(19) Internal opening: Lintel
(20) External wall – Partition wall – Insulation
External wall – Partition wall – Insulation (Gypsum board)
(21) Foundation – Sill
(22) Sill – 1st floor beam – Post
(23) Sill – 1st floor beam – Post (Insulation)

Figure 1 Location and types of joints used in the 2by4 construction system.

Summary sheet of the analysis (Roof structure)

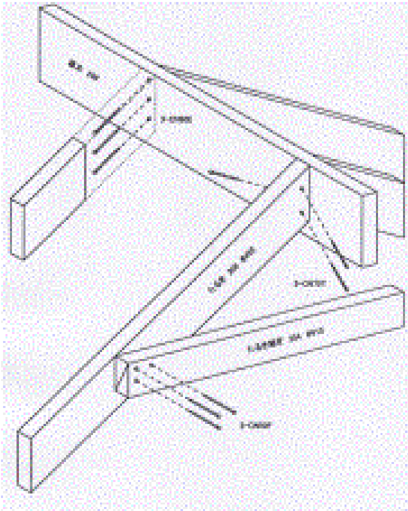
<table>
<tr><td>【Construction Method】</td><td colspan="3">2 by 4 Construction System</td></tr>
<tr><td>【Component】</td><td>Rafter /Ridge board</td><td>【Joint】</td><td>Rafter – Ridge board</td></tr>
<tr><td colspan="2" rowspan="2">【Figure】
</td><td colspan="2">【Design】
Rafters are connected to the ridge beam by nail (CN75 or CN90) .</td></tr>
<tr><td colspan="2">【Problem for recycling】
・ Roof structure is deconstructed in the following order.
1) Girder
2) Rafter
3) Roof joist
・ Roof structure becomes unstable when deconstruction proceeds.
・ Difficult to pull out nails in a high place.
・ The members composing the attic have the possibility to be damaged in the process of deconstruction.</td></tr>
<tr><td colspan="4">【Measurement】
・ Review the joints that connect the members that compose the roof structure and propose connecting methods that can be easily removed in high places. For example use dual head nails or wood screws for the connecting device.
・ Use jointing methods that can minimize the damage of the members in</td></tr>
<tr><td colspan="4">【Other issues】
・ The shear strength and deformation of the dual head nailed joints or the wood screwed joints should be clarified and meet the requirement of the building regulations..</td></tr>
</table>

Figure 2 Example of the summary sheets.

The summary sheets were prepared for the roofs, walls, floors, floor openings, balconies and foundations. Some of the barriers of the current design and construction methods that make the deconstruction process complicated and time consuming are listed in table 1. And the necessary measurements are also listed in the same table.

Table 1 Barriers of the current design and construction methods against deconstruction and reuse

Barriers	Requirements
It is time and labor consuming to pull out all the nails to remove the roof sheathings of the roofs.	Easy to remove connecters should be developed.
Staples cannot be removed from the roof sheathing. But most of the roofing felts are connected to the roof sheathing by staples.	Alternative connecting methods should be developed.
As the deconstruction works are done at high places it is time and labor consuming to deconstruct the roof frames.	Connectors that can be easily removed at high places should be developed.
It is time and labor consuming to take apart lumbers laminated by nails such as lintel and double studs at openings.	Alternative connecting methods should be developed.
It is time and labor consuming to pull out all the nails to remove the sheathing materials of the external walls.	Connectors that can be easily removed should be developed.
Gypsum boards break into small pieces during deconstruction. It is time and labor consuming to collect every piece of the removed gypsum boards.	Connectors that can be easily removed without breaking gypsum boards into small pieces should be developed.
It is time and labor consuming to remove hard wood floorings. And adhesive cannot be removed from the floor sheathings.	Hard wood flooring that can be installed without nailing and gluing should be developed.
Staples and adhesives cannot be removed from the floor sheathings if these connecting materials are used to install the padding.	Alternative installing methods for the carpets should be developed.
Staples cannot be removed from the studs if the insulation materials are connected to the studs by staples.	Alternative installing methods for the insulation materials should be developed.
The viscose tape to watertight the aluminum sash cannot be removed from the sash.	Measurements to remove the viscose tape from the aluminum sash should be developed.

CASE STUDY

Building design for reuse and recycle

The designing philosophy and construction methods for buildings should be reviewed to reduce the waste from the building activities. As buildings were designed and built to satisfy the requirement of the customers their performance such as structural performance, durability or indoor air quality was only taken into account. The performance of the buildings after their service life was seldom discussed in the process of building design. Recently as the effective utilization of natural resources and the reduction of waste is the key issues in Japan and probably in many countries buildings should be designed considering every aspect through their lifecycle. So the possibility of recycle and reuse of the building itself should also be taken into account in the process of initial design.

Taking into account of the results of the analysis some new ideas for design were proposed by the member of the research group composed by BRI members, university staffs, homebuilders and designers.　Some examples of the ideas are as follows:

(1) Use double head nails to connect metal connectors, studs and boards.
(2) Use wood screws to connect boards.
(3) Standardize the joints.
(4) Standardize the module of the members.
(5) Use easy to remove installing methods for finishing materials.

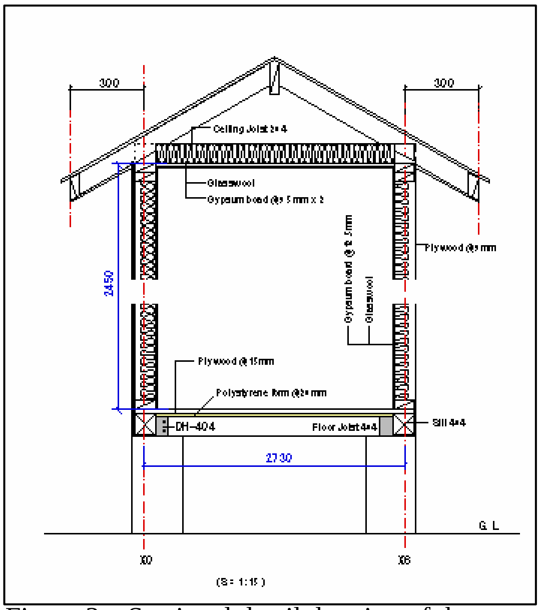


Figure 3　Sectional detail drawing of the test house “Improved”.

Photo 4 The test houses. Left “Improved” and right “Benchmark”.

Outline of the case study

To verify the effect of the proposed ideas a construction and deconstruction test was conducted.　Two test houses, “Benchmark” and “Improved”, were constructed by the 2by4 construction system.　The test house “Benchmark” was constructed by the design and construction methods commonly used to construct the 2by4 houses in Japan.　And the test house “Improved” was constructed by the design and construction methods proposed to improve the process of deconstruction and increase the potential of reuse and recycle.

The whole process of the construction and deconstruction was recorded by the video cameras and every deconstruction process was precisely analyzed to prepare data that can tell what process of deconstruction consumed time and labor and how it can be improved by using alternative designs and construction methods.

Construction

The approximate size and shape of the test houses are shown in figure 3 and photo 4. Some of the design and construction methods applied to the test house “Improve” are as follows:

(1) Use wood screws to connect roofing tiles and tile batten. See photo 5 and 6.
(2) Connect roof felt without using staples. See photo 5.
(3) Use dual head nails or wood screws to connect the lumbers and metal fasteners. See photo 7 and 8.
(4) Use dual head nails or wood screws to connect the sheathings.
(5) Use mortal based sheathing materials to finish the external walls. See photo 9.
(6) Use metal connectors to install the gypsum boards to the ceilings. See photo 11.
(7) Mask the heads of the wood screws by tapes. The heads of the wood screws can be easily found by pealing the tapes.
(8) Use easy to remove wallpapers.
(9) Install and fix insulation without stapling. See photo 11.
(10) Use 404 and 2-204 for the corner framing instead of using 3-204.
(11) Install non-skid rubber under the padding instead of stapling or gluing the padding to the floor sheathings. See photo 9.
(12) Use hard wood floorings with specially shaped T&G so that the floorings can be fixed without nailing and gluing.
(13) Use 404 and thick plywood for the framings of the first floor. See photo 10.

Photo 5 Roof tiles and roof felts.

Photo 6 Dual head nails.

Photo 7 Joints of the framing members of the roof.

Deconstruction

The outline of the deconstruction works is summarized in table 2. It took almost 2days to deconstruct the “Benchmark” test house and another 2 days to deconstruct the “Improved” test house. Most of the deconstruction time was consumed in the process of removing the gypsum boards, removing the roof and wall sheathing and deconstructing the framings. It took almost 3 hours to remove the gypsum boards from the “Benchmark” test house and 3 hours to deconstruct the wall framings and 2 hours to deconstruct the roof framings.


Photo 8 Joist hanger. Dual head nails are used to connect the joist hanger.


Photo 9 Mortal based sheathing (right) and non-skid rubber (left).


Photo 10 404 joist and thick plywood floor sheathing.


Photo 11 Ceiling gypsum boards hanged by metal connectors. Insulation fixed without using staples.

To decrease the total deconstruction time we have to decrease the necessary deconstruction works consumed in the process of removing gypsum boars and deconstructing the framings of the walls and roof. And we also have to propose alternative design that can reduce the deconstruction works. When we look at the removing process of the gypsum boards the boards installed around the openings were most difficult to remove. The fastening methods of the gypsum boards should be carefully designed particularly around the openings and the corners.

Results

The deconstruction time and deconstruction process were analyzed and the proposed alternative design methods were discussed for their usefulness. The time consumed in each deconstruction work and the quality of the building materials corrected from the deconstructed test houses were measured and investigated. And we also asked the workers for their comments. All the comments were recorded as technical information to improve the proposed alternative design methods.

Table 2　Outline of the deconstruction works.

Day	Deconstruction Time		Deconstruction works
1st day	Deconstruction of the test house “Benchmark”		
	09:18-09:28	0hr., 10min.	**Remove the carpet**
	09:23-09:23	0hr., 10min.	Remove the wallpaper
	09:38-11:58 13:22-14:56	3hr., 54min.	Remove the gypsum boards (wall)
	14:29-14:56	0hr., 27min.	Remove the gypsum boards (ceiling)
	15:27-15:52	0hr., 25min.	Remove the Japanese type roofing tiles
	15:53-16:24	0hr., 31min.	Remove the slate roofing tiles
2nd day	09:08-09:13	0hr., 5min.	Remove the tile battens
	09:13-09:21	0hr., 8min.	Remove the roofing felt
	09:21-11:16	1hr., 55min.	Deconstruct the roof framing and sheathings
	11:16-12:00 13:08-15:00 15:42-16:02	2hr., 56min.	Deconstruct the wall framing
	16:02-16:33	0hr., 45min.	Deconstruct the floor framing
3rd day	09:07-09:21		
	Deconstruction of the test house “Improved”		
	13:23-13:25	0hr., 2min.	Remove the carpet
	13:25-13:33	0hr., 8min.	Remove the wallpaper
	13:33-15:00 15:43-16:30	2hr., 14min.	Remove the gypsum boards (wall)
4th day	09:07-09:27	0hr., 20min	Remove the gypsum boards (ceiling)
	09:35-10:32	0hr., 57min.	Remove the roofing tiles and tile battens
	11:01-11:04	0hr., 3min.	Remove the roofing felt

Photo 12　Hard wood floorings removed.　Right: “Improved”. Flooring can be easily removed without damaging the floor sheathings and floorings.

Photo 13　Wallpaper removed. Left: vinyl type wallpaper. Right: cloth type wallpaper. Cloth type wallpaper can be easily removed compared with vinyl type wallpaper.

Some of the improvements achieved by the alternative design methods are as follows:

(1) Hard wood floorings with specially shaped T&G were easily removed. As this type of hard wood floorings do not have to be nailed or glued to the floor sheathings wood pieces and adhesive do not remain on the floor sheathings. See photo 12.

(2) Wallpapers made of cloth were easy to remove. On the other hand wallpapers made of vinyl took time to remove. See photo 13.

(3) Roofing tiles connected to the roof sheathings by wood screws were easily removed without damaging the tiles. See photo 14.

(4) The thick floor sheathings were easily removed when the sheathings were connected to the floor joists by wood screws. As no adhesive was used to fix the floor sheathings to the joists it was also easy to remove the sheathings without damaging the floor joists and the floor sheathings. See photo 15.

Photo 14 Roofing tiles removed. Right: "Improved". Roofing tiles connected by wood screws can be easily removed without damaging the roof tiles.

Photo 15 Floor sheathing removed. Right: "Improved". Floor sheathings can be easily removed when they are not glued to the floor joists and connected by wood screw.

The improved test house generated less damaged deconstructed materials compared to those generated from the benchmark test house. This was common to almost all deconstructed material except the mortal. The gypsum board generated from the benchmark test house and the improved test house are shown in photo 16. For example the damage of the gypsum board generated from the improved test house was less than that of the gypsum board generated from the benchmark test house. The test results indicate that the quality of the deconstructed materials can be improved by designing the house easy to deconstruct.

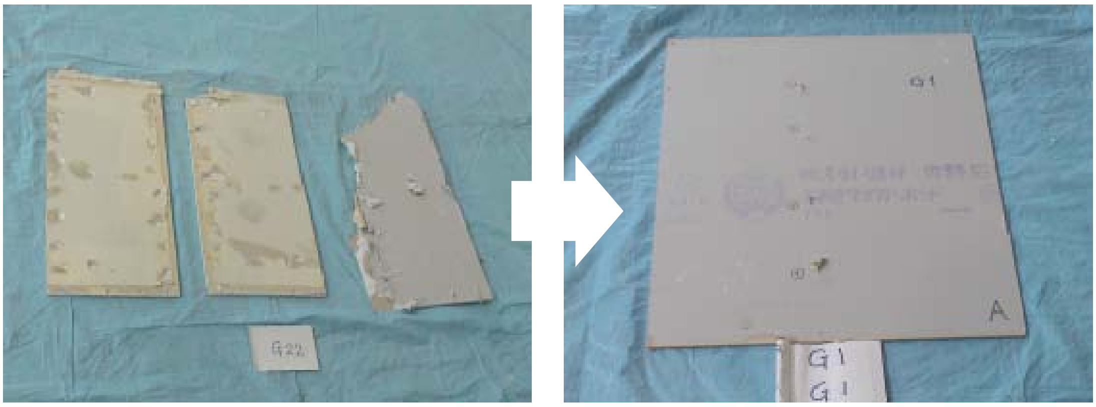


Photo 16　Damage of the gypsum board. Right: “Improved”.
The gypsum board generated from the improved test house is less damaged than that of the gypsum board generated from the benchmark test house.

DESIGN MANUAL

Table of contents

Based on the alternative design ideas and the test results the design and construction manual for the remountable and recyclable wooden buildings was drafted.　The table of contents of the manual is shown in figure 4.

Chapter 1; Introduction
Chapter 2; Materials and components to be used
Chapter 3; Designing methods
- 3.1; How to design foundation
- 3.2; How to design members
- 3.3; How to design Joints
- 3.4; How to design structural components
- 3.5; How to design non-structural components

Chapter 4; Construction methods
Chapter 5; Evaluation of the recycle and reuse potential
Appendix; Case study

Figure 4　The draft table of contents of the design manual.

Design methods

One page of chapter 3 of the drafted manual is introduced in figure 5.　Figure 5 shows some hints that help to design floorings easy to remove and recycle.

Designing and construction methods for floorings

- Hard wood floorings with specially shaped T&G can be easily removed. As this type of hard wood floorings do not have to be nailed or glued to the floor sheathings wood pieces and adhesive do not remain on the floor sheathings.
- Hard wood floorings with specially shaped T&G can be reused and the floor sheathings can be recycled.

Deconstruction time	↓ Reduced	Reuse	↑ Flooring can be reused
Amount of waste	↓ Reduced	Recycle	↑ Floor sheathing can be recycled as wood chips.
Easiness of construction	↑ Easy to construct than the currently used floorings.		
Usability	→Some limitation for use. See the note.		

<Problem and Solution>
The floorings commonly used for the finishing materials for wooden houses are installed as shown in figure 1. To prevent the squeezing of the floor floorings are nailed and glued to the floor sheathings. Floorings nailed and glued to the floor sheathings cannot be completely removed and the back surface of the floorings and adhesive remain on the floor sheathing. Floorings can be reused if they can be removed in good quality. And floor sheathings can be material recycled if they can be removed in good quality.

<Installation>
Hard wood floorings with specially shaped T&G can be easily installed. The process of installation is like making a puzzle and no nailing and no gluing is required. To finish the surface of the floor flat soft plastic sheets should be installed between the floorings and the floor sheathings. The soft plastic sheets should not be glued or stapled to the floor sheathing.

<Deconstruction and Reuse/Recycle>
Hard wood floorings with specially shaped T&G can be easily removed. As this type of hard wood floorings do not have to be nailed or glued to the floor sheathings wood pieces and adhesive do not remain on the floor sheathings. Hard wood floorings with specially shaped T&G can be reused and the floor sheathings can be recycled.

<Note>
As hard wood floorings with specially shaped T&G are not nailed or glued to the floor sheathing the floorings may pop up in humid climate. For the same reason the floor may squeeze. If squeezing is not preferable we had better not choose this type of hard wood floorings.

Figure 1. Installation of the flooring (Current design) – Floorings are nailed and glued to the floor sheathing.

Figure 2. Removal of the flooring (Current design) – Floorings are removed by using deconstruction tools. Wood pieces and adhesive remains on the floor sheathings.

Figure 5 An example of the contents of chapter 3 (Designing methods).

CONCLUSION

Alternative design methods for remountable wooden houses were discussed in the project. To propose new designing ideas for remountable wooden houses the current design was analyzed. Applying the alternative design for remountable wooden houses two types of 2by4 test houses were constructed and deconstructed as a case study.

The proposed designing methods will be put to practical use in the near future. The Japan 2by4 Home Builder's Association is going to use these technologies in their demonstrative houses and they will also put these technologies into practical use within a few years. At this time the design manual will help the designers and the homebuilders to design and construct their houses easy to deconstruct and recyclable.

We still have many things to solve before putting these technologies into practice. For example structural performance of the alternative fasteners should be examined and the durability of the newly used materials should be evaluated.

The challenge to construct recyclable 2by4 houses has just started. In the future building will become remountable like other industrial products such as automobile and home electronics.

ACKNOWLEDGEMENTS

The research was carried out in corroboration with the Japan 2by4 Home Builder's Association. The author gratefully acknowledges help given by Mr. A. Seino of the Japan 2by4 Home Builder's Association and Mr. K. Hatori of the Mitsui Home Co., Ltd. And the author gratefully acknowledges help given by Mr. K. Kuwabara, Mr. T. Kuwabara and Mr. M. Takatsuka of the Kuwabara-Pumpkin Co., Ltd.

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8.0 POLICY, REGULATION, STANDARDS, LIABILITY

OUTLINE OF LAWS AND REGULATIONS RELATED TO WASTE DISPOSAL AND RECYCLING IN JAPAN

Waste disposal and recycling system in Japan are based on “The law concerning waste disposal and public cleanliness”which was passed by the Diet in 1970.In the past, reducing and recycling domestic waste was strongly addressed. This attitude toward waste reduction and recycling was extended to industrial waste and public sanitation administration in the 1960s. Starting in 1988 substantially stronger waste reduction and recycling laws were introduced and additional laws were passed in the time frame 1991 to 2000.The major law addressing recycling was passed in 1991 and new government policies based on this law were enacted. The following is a list of major legislation addressing the reduction and recycling of waste in Japan:

1) The law concerning waste disposal and public cleanliness (1970:Ministry of Health and Welfare)
2) The law concerning the promotion of recycled material use (1993:Mnistry of Health and Welfare)
3) Recycle law of packaging materials and containers (1995:Ministry of Health and Welfare)
4) Recycle law of electric equipment for home use (1996 and 1999)
5) The law concerning the promotion of the recycle for the food resources (2000:Ministry of Agriculture Forestry and Fisheries)
6) Recycle law concerning materials of construction works (2000:Mnistry of Construction)

The purpose of these laws is to decrease domestic and industrial waste through voluntary actions by the various parties involved in waste generation. A new law, the Green Law, is also being considered to focus on appropriate behavior that would result in a significant reduction in waste quantities.

Waste disposal and public cleanliness law (1970)
The following is brief history of this law.

Filth cleaning law (in 1900)
This law was converted into the law for cleaning (in 1954). It was established to force towns and villages to appropriately dispose of human excrement and domestic waste.

The law concerning waste disposal and public cleanliness (1970)
Industrial pollution became a big social problem, and industrial waste was taken in the regulation in addition to domestic wastes.

The revised law concerning waste disposal and public cleanliness (1976)
When industrial waste with significant chromium content became a social problem, the regulations for industrial waste were strengthened, including the regulations concerning the final disposal site.

The revised law concerning waste disposal and public cleanliness (1991)
Reducing waste and recycling were being demanded by society as well as measures to control industrial waste. Because of the demands of the public, waste reduction and reuse were specified by this law. This was a major attempt to strengthen waste reduction regulations,

especially in the industrial arena.

The revised law concerning waste disposal and public cleanliness (1997)
The following points were strengthened in the revised law.

1. Establishment of the authorization system for the recycling
2. More demands to decrease waste

The laws concerning the promotion of recycled materials use (1995)
This is a new law to promote the use of recyclable resources. Several industries are prime candidates for this type of law because the resources they use are readily recycled. These industries are the paper manufacturing industry, the glass manufacturing industry, and construction. The law first defines products that are easy to recycle. These are cars, air-conditioners, televisions, refrigerators and others. It then indicates the materials that must be collected after use, such as alkali dry cells, aluminum and steel cans (secondary specified products). Specified by-products, such as blast furnace slag, coal ash, soil, concrete, asphalt, timber and wooden product, are specified as recyclable materials to promote recycling.

The law for recycling packaging materials and containers (1995)
The law obliges the recycling of containers such as bottles and packaging materials such as paper packaging. Both the consumer and manufacture are required to participate in recycling to decrease waste. The manufactures are required to recycle the containers and packaging materials while consumers are required to cooperate in selective collections. Another organization, which mediates between manufacturer and consumer and which promotes the commercialization of recycled materials is a characteristic of this law.

Recycle law of household electric appliances (1996 and 1999)
This is a special law concerning the recycling of home electrical appliances such as televisions, refrigerators, washing machines, etc. The manufacturer retains the responsibility for collecting and recycling these appliances at the end of their useful lives.

The law concerning the promotion of the recycling of waste food (2000)
To decrease food waste, this law required a reduction in food wastage and recycling of the waste that does occur into materials such as feed or manure.

Basic law concerning the promotion of forming circulated society (2000)
This law, also called the "organic law," integrates the recycling law with the law concerning waste disposal and cleanliness. The law promotes the minimization of consumption, perhaps the major step toward a healthier environment. This law also promotes renewable energy systems such as sun and wind energy, and aims to achieve good economic development. The priority of this law is waste reduction and it also protects the citizens from the impacts of illegal dumping. The development of recycling as a "social system" and the need for this approach is also addressed in this law.

The law concerning the promotion of supplying ecological goods procurement (2000)
This is the so-called the "green" procurement law. Taking the leadership, the government offices try to buy ecological goods and aim to expand the market of these goods by helping lower the cost. Government agencies are required to create a plan for the procurement of goods and participate in the education of the public about environmentally preferable goods, many of which carry the Japanese Eco-Mark ecolabel.

Law concerning the recycling of construction/demolition materials (2000)
Construction waste consists of 20% of Japan's industrial waste, and uses about 40% of disposal volume in landfills. Construction waste comprises 90% of illegal dumping, and hence promotion of recycling of construction waste is an important problem. Recycling of construction waste lags far behind the recycling of waste in other sectors. Consequently it is especially important that reuse and recycling of construction and demolition waste be addressed in an urgent manner.

Requirements for selective dismantling and recycling
For buildings beyond a certain minimum size, selective dismantling to recover specific materials such as concrete, asphalt, and timber and wood is required. Thus recovery and recycling of certain materials is required and it is expected that these requirements will expand and increase in the future (Figure 1).

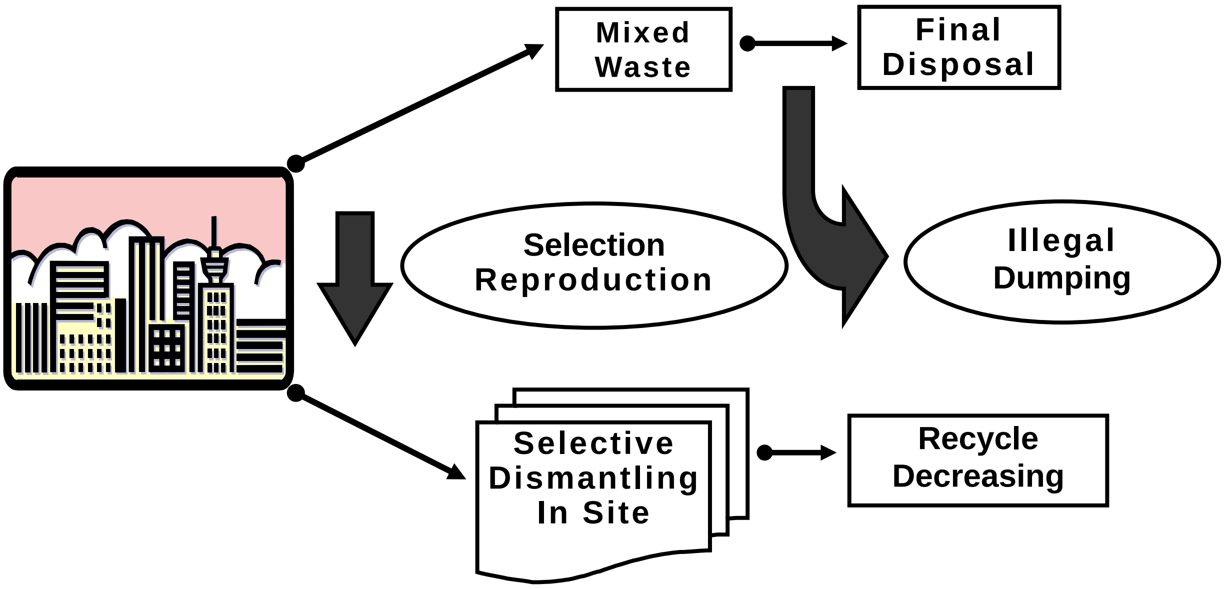

Figure 1 Selective dismantling.

Actions to promote recycling and demolition
The owner of a building scheduled for removal is required to report the removal prior to demolition and the results of dismantling and recycling of materials at the end of the process. (Figure 2).

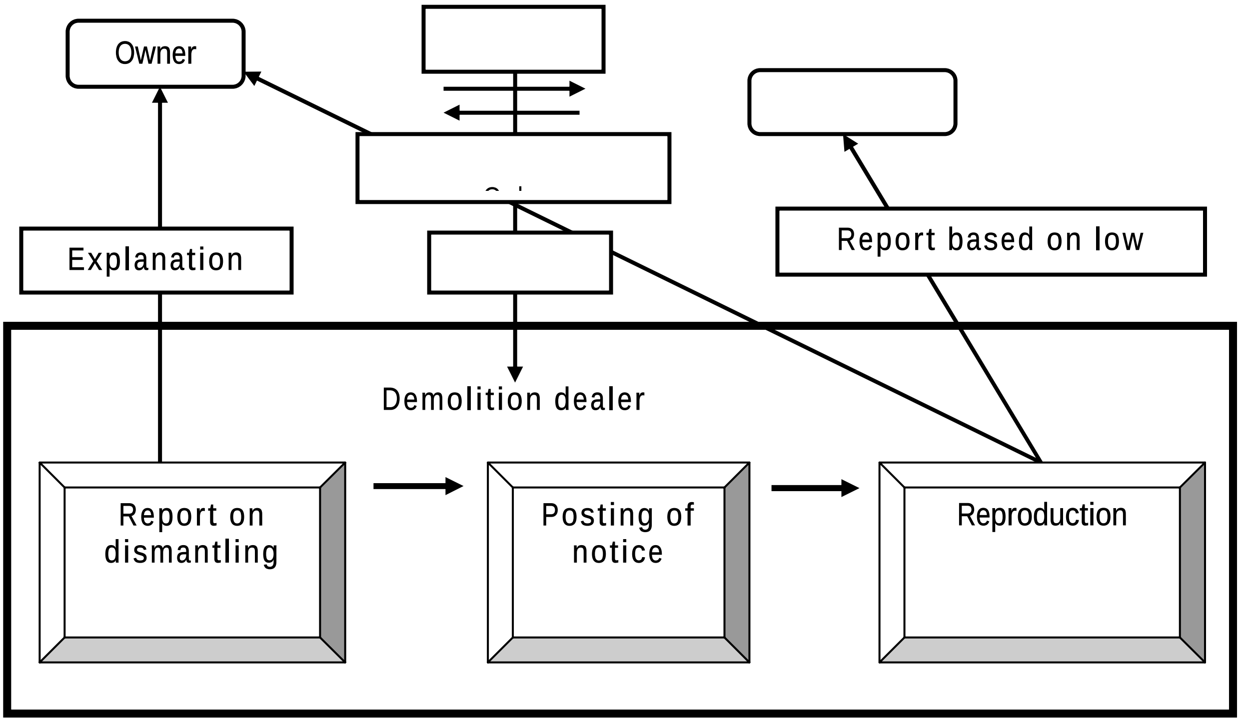

Figure 2 The action to achieve recycling.

Adjust the contract between the owner and the dealer
The subcontractor undertaking deconstruction must provide a plan for selective dismantling to the owner. The method of selective dismantling and the expense must be specified for the demolition work.

The establishment of registration system to demolition dealer
The subcontractor undertaking demolition needs to be registered with the municipality and local district. The demolition subcontractor must engage an engineer who manages the various technologies for demolition. Because the budget for demolition is typically small, it is not necessary to get the permission of local government. Thus it is easy for an unqualified and unlicensed contractor to provide demolition services. This is one of reasons why illegal dumping of waste occurs as well as indiscriminate dismantling (called mince dismantling) of structures (Figure 3).

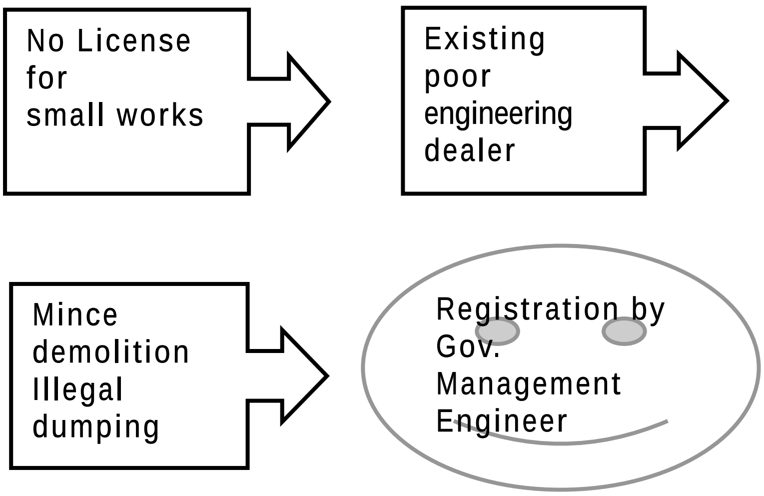

Figure 3 Registration of demolition dealer.

The setting of objectives concerning recycle
As the basic policy, the recycling and the reuse of construction materials are promoted by creating an action plan. Getting the cooperation of the owner is very helpful in recycling and reuse.

CURRENT SITUATION OF C&D WASTE IN JAPAN

The Japanese Government reports every 5 years the status of waste generated from the building construction activities [1][2].

The total weight of the waste generated from the construction industries in 1996 was approximately 99 million tons and three fifth of the waste was from the civil engineering activities and the two fifth of the waste was from the building activities. And as to the waste from the building activities two fifth of the waste was construction waste and three fifth of the waste was demolition waste. The amount of the waste has been reduced for approximately 10% and the total weight of the waste generated in 2001 was around 85 million tons. As to the waste from the building activities 40% of the waste was the construction waste and 60% of the waste was the demolition waste in 2001 (See Figure4).

Figure5 shows the amount of waste landfill and recycled in the construction industries in 1996 and 2001. The amount of landfill waste decreased significantly in these 5 years and the amount of waste that has been recycled increased in these 5 years.

Table1 shows the type, amount and recycle ratio of the waste discharged by the construction industries in 1991, 1996 and 2001. The main C&D waste was concrete aggregate, mixed waste and wooden waste. The recycle ratio has been improved for these five years but we still have to make efforts to increase the recycle ratio of some types of construction waste. For example the mixed waste and the wooden waste show lower recycle ratio than the concrete aggregates. The recycle ratio of the wooden waste was 38% in 2001 and this was 2 point less than the recycle ratio in 1996. And the recycle ratio of the mixed waste was still less than 10%.

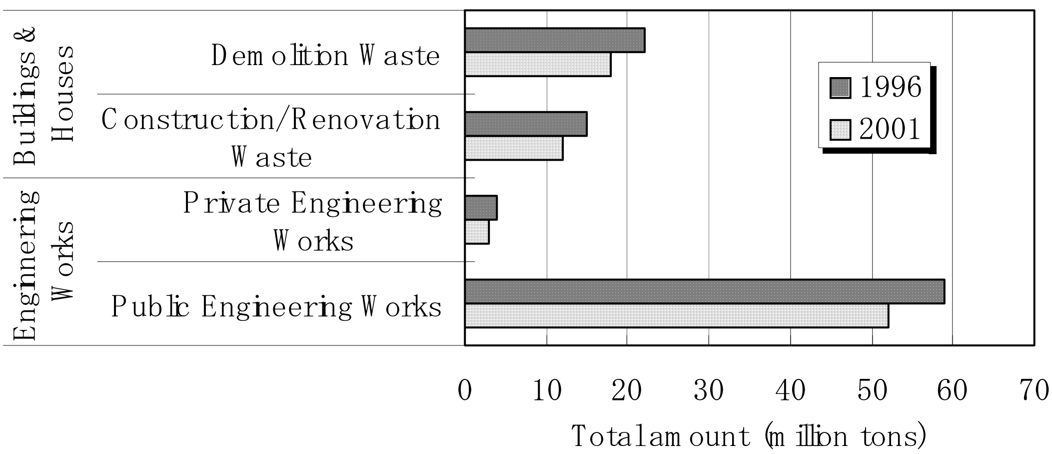

Figure 4 Waste generated from the construction industry in Japan – in the year 1996 and 2001.

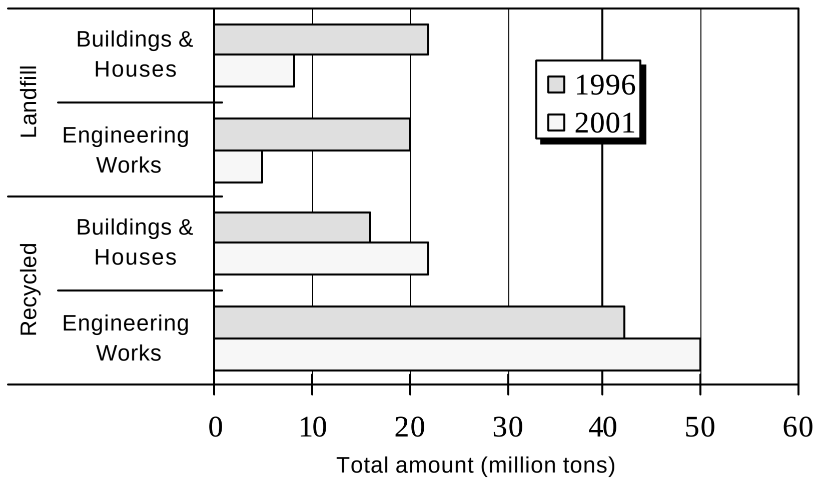

Figure 5 Amount of the waste landfilled and recycled.
Note: Recycle includes reduction by the methods of burning.

The government announced that the targeted recycle portion of the wooden waste in the year 2010 as 95%. In the sense that thermal recovery or simple burning will reduce the amount of landfill waste, thermal recovery or reduction by burning are categorized as recycle. The total amount of the wooden waste that went to thermal recovery, simple burning and material recycle was 83% of the whole wooden waste discharged from construction activities in Japan. Recycle ratio 83% seems to be close to the targeted recycle ratio for the year 2010. But as the actual recycle ratio of the wooden waste is 40%, new technologies and policies are still required to improve this situation.

Type of waste	1991		1996		2001	
	Weight (million tons)	Recycle ratio (%)	Weight (million tons)	Recycle ratio (%)	Weight (million tons)	Recycle ratio (%)
Construction waste	-	42	99	57	85	81
Asphalt	-	50	36	81	30	98
Concrete	-	48	36	65	35	96
Mixed	-	31	10	6	5	7
Wood	-	56	6	40	5	38
Soil and rock	-	21	10	6	8	30

Table 1 Type, amount and recycle ratio of the waste.

Illegal or improper disposal of waste is a social problem in Japan that should be immediately solved. Table 2 shows the types and amount of the improperly disposed waste reported by the Ministry of Environment in 2001[3]. 433,292.5tons of waste was improperly disposed of in 2000. The amount of the illegally disposed construction waste was 303,997.8tons and it was more than 70% of total amount of the illegally disposed waste. When we look at the type of the illegally disposed waste 25% is concrete, 25% is wood and 20% is other construction waste. Wood waste generated in the process of constructing and dismantling wooden houses is largely the cause of this situation.

Type of waste	Weight (tons)	Ratio (%)
Concrete	107,729.6	25%
Wood	108,233.3	25%
Other construction waste	88,034.9	20%
Plastics	76,961.4	18%
Steel	7,925.6	2%
Ash	9,458.9	2%
Mud waste	13,932.0	3%
Glass/Ceramic	2,582.8	1%
Organic waste	2,050.5	1%
Other	16,383.6	4%
Total	433,292.5	100%

Table 2 Type and weight of the improperly disposed waste.

Their issue is the capacity of the landfill sites. It is estimated that the landfill sites have their capacities to accept waste no longer than 0.8 years in the Tokyo area and 3.3 years in the whole country.

ASSEMLE PROCESS IN THE RECYCLE CENTER [4]

Construction and demolition waste is carried into the recycle centers and sorted again to minimize the amount of waste that should be controlled when they are taken into the land fill facilities (see photo1). Various types of waste are separated: steel waste, paper waste, plastic waste, wooden waste, concrete aggregates and mixed waste (see photo2). The wastes roughly assorted on the construction sites are almost separated when they come into the recycle center.

Photo 1 C&D waste carried into the recycle center.

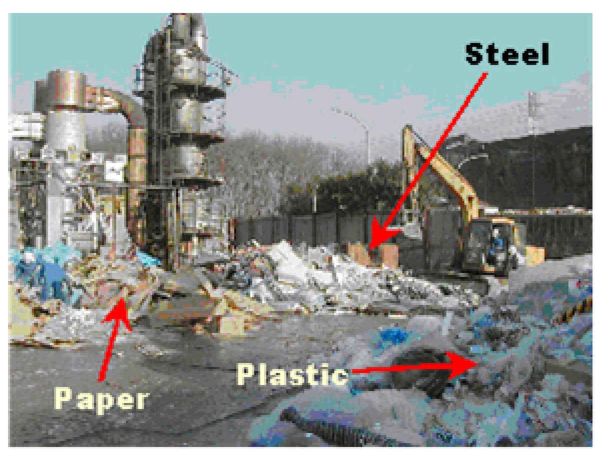

Photo 2 C&D waste.

Wooden waste

Photo 3 shows the wooden waste assembled in the recycle center.　Most of this waste is produced in the process of constructing or dismantling wooden houses.　Wood chips are produced from good quality wooden waste such as large size lumbers (see photo4).　But as the virgin chip is cheaper than the recycled one, some of the particleboard producing companies and the pulp and paper producing companies are still using the virgin chip for their products.

Photo 3　Wood waste.

Photo 4　Wood chips.

Plastic waste

Photo 5 shows the plastic waste assembled in the recycle center.　Plastic waste goes to the landfill site.　Plastic waste shown in photo5 travels to the landfill site located 1000km away from the recycle center.

Photo 5　Plastic waste.

Photo 6　Paper waste.

Paper waste

Photo 6 shows the paper waste assembled in the recycle center.　Paper materials are selected from the paper waste and non-paper materials are taken away by hand.

Steel waste
Photo 7 shows the steel waste assembled in the recycle center. Steel is the one of the materials that is well-recycled in Japan. Steel materials are collect by a magnetic device and separated from the non-steel waste.

Concrete waste.
Photo 8 shows the concrete waste assembled in the recycle center. Concrete wastes are also well-recycled in Japan and most of them are used as road construction materials.

Photo 7 Steel waste.

Photo 8 Concrete waste.

Mixed waste
Photo 9 shows the waste that was not sorted on the construction site. The mixed waste is separated into wooden waste, steel waste, plastic waste, etc. to maximize the recycle ratio and to minimize the amount of landfill waste. The sorting process will start from separating the waste roughly to several types. The waste are spread on the ground of the recycle center and four or five workers pick up big size steel, wood, plastic, concrete and others, and put them into the rooms that are prepared for each type of waste (see photo10). And the small size waste goes to a line separation process. And here again 10 or 11 workers separate the waste into several types (see photo11).

Photo 9 Mixed waste.

Photo10 Rough separation process of the mixed waste.

Photo11 Line separation process of the mixed waste.

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REPORT 5

STATE OF DECONSTRUCTION IN THE NETHERLANDS

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1.0 INTRODUCTION

1.1 Construction and demolition waste in the Netherlands

The production of construction and demolition waste (CDW) in the Netherlands is about 21 million ton a year. This amount is rising every year with about 2 million ton. In 1990 the Dutch government claimed that 90% of the total amount of CDW should be reused by the year 2000. Nowadays almost all of the CDW in the Netherlands is reused (95%). Almost all of the material is reused as a road base material. This is reuse at the material level.

1.2 CDW in the EU

The total production of CDW in the European Union (EU) is about 450 million tonnes. If one excludes earth and excavated road materials the amount of 'core' CDW is estimated to be roughly 180 million tonnes per year; 480 kg per person each year. There is no need to say that this is an enormous amount of material. Recycling rates vary from lower than 5% until 95% in the different Member States. The question is how to improve these recycling, both quantitative as qualitative.

In most countries of the EU the problem of the CDW occurs at the time a construction has to be demolished. By changing this system into integral chain management, both quantitative as qualitative recycling can be improved. Three different ways of re-using can be recognised; re-using the construction, the elements and recycling the material. Furthermore the materials can be recycled, downcycled and upcycled.

Member State	Core CDW Million tonnes	Re-use or recycle Percentage
Germany	59	17
UK	30	45
France	24	50
Italy	20	9
Spain	13	<5
The Netherlands	11	90
Belgium	7	87
Austria	5	41
Portugal	3	<5
Denmark	3	81
Greece	2	<5

Sweden	2	21
Finland	1	45
Ireland	1	<5
Luxembourg	0	
EU 15	180	28

Table 1. Re-use in the EU

CDW constitutes a highly significant proportion of all wastes. This waste also has a very high recovery potential. However only a small proportion of these waste streams is actually recovered in the EU as a whole. There is a big difference in recycling of CDW in the different countries of the EU. The main aspects regarding these differences are natural resources, transport distances, economic and technologic situation and the population density.

Recycling percentages vary from less than 5% (Greece, Ireland, Portugal and Spain) to more than 80% (Belgium, Denmark and the Netherlands). About 50 million tonnes of the 'core' CDW are being re-used or recycled. The rest, 130 million tonnes are incinerated or dumped on landfills. The total amount of core CDW and the recycling per Member State are reflected in table 1 [1].

2.0 DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY AND TOOLS

2.1 Planning issues for demolition and deconstruction

Architects and structural engineers are taught a great deal about how to build buildings, but little if anything about what happens to buildings during their life and at the end of it. In the Netherlands about 90% of DCW are currently being reused. Is the term 'wastes' appropriate, or should we refer to 'secondary raw materials'? If a building is to be demolished then the demolition process should aim for the reuse, at the highest possible level, of the materials released by the demolition activities. A demolition plan is essential when a building is demolished. Although developing such a plan costs time and money but it will reduce the costs of landfill.

CONTRACT AMOUNT = COST OF DEMOLITION + LANDFILL COSTS - REVENUES

The 'cost of demolition' includes all costs of equipment, labour, overheads, profit margin, etc. If the revenues (from the sale of materials) are high then a demolition contractor might even pay to get the work, but this would be an exception. Demolition contractors include the following factors in their assessments: location, type of building, construction method, materials used and the presence of any hazardous substances. These factors determine how the building will be demolished.

Demolition process

Firstly, it is investigated if the material contains any hazardous substances such as asbestos. If there are any such materials then a specialist contractor is engaged to remove them. Asbestos stripping in particular requires extensive safety measures. After completion of this investigation an architectural reclamation (salvage) company checks the building for any components which can be reused as they are. These include leaded glass, marble fireplaces, precious woods such as walnut and oak, central heating boilers, water heaters and radiators. Demolition contractors prefer it if these components are removed first, as this saves them work and their sales provide revenues.

Demolition contractors divide buildings into the following types:

- Buildings constructed of brickwork with wooden floors, wooden roof structures, flat roofs with bitumen roofing or roof tiles.
- Buildings with concrete skeleton frames, which may also include pre-stressed concrete elements.
- Buildings with steel frames.

Generally, all three building types are treated as follows:
First, the buildings are stripped of unusual or reusable components such as leaded glass, traditional sanitary ware, etc. Next, floor coverings and ceilings (plaster) are removed. Burnable and non-burnable materials are separated. Glass is removed from the window frames. Building services installations and plant are removed. Metals are removed. Piping is generally removed before the real demolition work starts. Roof tiles are removed. Roofing is removed and landfilled. The roofing ravel is contaminated with PAH (polycyclic aromatic hydrocarbons) and should be treated as chemical waste. The gravel can be washed and reused. The question arises if gravel could be reused on roofs without washing as this simply moves the chemical contamination rather than eliminating it.
Stripping a building produces a number of waste streams and a range of different materials. These are transported to a sorting plant where they are separated in burnable and nonburnable materials. The burnable fraction is incinerated in a waste incineration plant and the nonburnable fraction is landfilled.

Buildings constructed of brickwork with wooden floors, wooden roof structures, flat roofs with bitumen or roof tiles
Demolition: When only the brickwork and floors are left the building is taken down floor by floor. Joists (beams) and wooden floors are removed from the building using a crane and equaliser beam. The nails in joists and planks are removed by punching. The punching unit pushes the wood around the nail down and then extracts the nail by its head. There is currently a good market for second-hand wood. It is often used for floors and has the advantage that it is fully seasoned - it will not shrink. Wood which cannot be reused as planks or beams is transported to Germany for the production of chipboard.

Brickwork is cut into sections and taken to a crusher plant. Occasionally, the client intends to build a new building using the bricks from the old building. However, the mortar used after the Second World War is so strong that the bricks will break before the mortar does. In that case, the bricks are carefully removed one by one. This is mostly relevant in renovation projects when dealing with unusual and rare types of brick.

Buildings with concrete skeleton frames, which may also include pre-stressed concrete elements

Demolition: The roof, which is generally covered with bituminous material, is removed first. The gravel is removed from the roof The wooden roof structure is removed with a crane and equaliser beam. The wood is sold on the second hand market or to the chipboard industry The concrete structure is cut up using breaker shears and taken to a crusher. In the past, the rubble was reduced in size on site and the iron was removed from it. However, current crusher plants can handle large sections (2 m x 2 m) and it is more economical for demolition contractors not to break up larger sections. If the rubble fits in to a truck then the crusher can handle it. Hence, the maximum dimensions are what fits into a truck.

Pre-stressed concrete structures pose special problems. Often, nobody knows that there are pre-stressed elements. If it is suspected that a structure may be pre-stressed then a section is cut away to investigate this. If it is indeed found to be pre-stressed then the terminations are first cut away at the ends of the structure, which will often lead to its collapse. Structures with unexpected pre-stressed sections can be dangerous, because the structure may suddenly give way and the concrete may fly around.

Buildings with steel frames
If the beams can be reused then the structure is disassembled. Otherwise, the steel structure is cut up and sent to a steelworks. Occasionally, structures such as steel bridges are sold as a whole and shipped overseas.

Further demolition activities for all three types of buildings:
The foundations (masonry or concrete) are broken up, like the rest of the building, and removed by diggers or they are pulled out of the ground. If the foundations include a deep basement then it may be necessary to create an excavation in which the work is carried out. Groundwater lowering will then be necessary to work in the dry Clearly, this will be very expensive. It is difficult to remove wooden piles and piles formed in situ as they tend to break.. However, they can be broken up at some depth below the surface. In contrast, precast concrete piles can be successfully removed through simultaneous vibration and pulling.

Trends and developments:
If a building contains both brickwork and concrete then these materials are normally not separated. However, crushed concrete secondary aggregate is stronger than crushed masonry secondary aggregate and is therefore easier to sell. As a result, the crushing companies are left with the crushed masonry aggregate. Hence, they want to mix it with the crushed concrete aggregate to produce mixed crushed secondary aggregate. This material is mostly sold to the road construction industry. The demand for the brickwork fraction is expected to increase as a number of major road construction and water engineering projects are being planned.

The operators of fixed crushing plants, members of the BRBS, want to avoid competition from mobile crusher plants and demolition contractors selling crushed rubble directly to the road construction industry. Their plant and associated provisions for safe and efficient operation, such as impermeable floors, required substantial investments and enables them to deliver materials of consistent quality. According to the BRBS, demolition contractors and mobile crusher plants cannot provide this constant quality. Another argument they use is that fixed crusher plants have to meet a range of environmental standards relating, to noise and dust emissions, etc. which mobile crusher plants cannot meet.

Selective demolition is actually nothing new in this industry. It was only in the period from 1970 to 1985 that demolition was not done selectively At that time the capacity of the machines had developed so much that it was possible to demolish buildings quickly and it was assumed that our resources were inexhaustible.

Thanks to the landfill ban on CDW, materials will be selected at almost all demolition sites. It's much cheaper to sell (for some materials with a negative price) the selected materials, than the unselected materials. Therefore the planning of the demolition or deconstruction is very complicate. At site there must be place for different containers for the different waste fractions.

2.2 Demolition Techniques, methods and machinery

Balling, knocking down a building with a heavy steel ball, is no longer widely used. It has a major impact on the surrounding area through noise and vibration. The most difficult aspect of balling is aiming the ball accurately. A limited jib movement develops the large pendulum movement of the ball and this takes a great deal of experience.

Demolition by blasting is only used in the Netherlands when a building has to be brought down very quickly, for example if it is close to a major road and there is not enough space to screen the demolition site. Generally, buildings will only be demolished by blasting if the local authority or the client requires this. Removing the rubble takes a great deal of work.

As the economic life of buildings is getting shorter and shorter it is expected that there will be more demolition activities. Another development is that buildings are stripped, but not demolished in their entirety. In itself stripping is not a new development as all buildings are stripped before demolition. When a building is stripped and the structure should therefore remain intact, smaller builders' plant is used, which can move inside the buildings. These smaller diggers and cranes are more compact which allows them to work on intermediate floors and they are light enough to be supported by normal floors.

Demolition contractors can choose from a range of methods to demolish buildings and civil engineering structures. These range from manual demolition to the use of explosives, each with their own applications. A number of common techniques are described in chapter 4 of the State of the Art, Deconstruction in the Netherlands [2].

After a construction is demolished, the materials must be crushed and separated in order to create useful secondary material. Therefore there are several crushing plants in the Netherlands. At a crushing plant the material will be sieved, in order to get rid of the sieve-sands. After this first sieving the materials are fed into a pre-crusher to create smaller particles so that the largest parts will not damage the main crusher. Between the first and the second crusher, the materials are de-ironed by a magnetic separator and screened; the largest parts are fed back into the pre-crusher, the rest is fed into the second crusher. Other materials, like glass, plastic, wood etc are removed by washing, air separation or manual separation. At the end, the material is sieved in order to create the right fractions for the road building and concrete industry. A number of common techniques are described in chapter 5 of the State of the Art, Deconstruction in the Netherlands [2].

2.3 Deconstruction techniques, methods and tools

In the Netherlands there are no special techniques for deconstruction of the mainly concrete and masonry buildings. The techniques used are the same as the can be used for demolition. Precast concrete element buildings are the most easy to deconstruct. In that case the deconstruction is almost the same as reverse building.

2.4 Worker training and safety

Worker training and safety is a big issue. There are special courses for the training of the workers on the demolition/deconstruction site. An organisation called VOS (training for demolition) has different specialised courses at different levels. Demolition workers on site should have at least followed one of these courses.

3.0 DESIGN FOR REUSE

3.1 In situ building reuse

Case study; Maassluis [3]

In Maassluis, in the Netherlands, there is currently a re-use project ongoing. It is a project where six apartment buildings of four floors high will be re-used. Two apartment buildings have been renovated and a fifth floor has been added (fig 1). Of three apartment buildings, the two top floors have been removed and the remaining part of the building will be redesigned to become single-family dwellings (fig 2&3). The sixth apartment building has been demolished, only the foundation will be re-used for single-family dwellings.

Fig 1: The old and renovated apartment building

Fig 2: The remaining construction and the artist impression of the single-family dwellings

The dismantling of the three apartment buildings has just been finished and the experience will result in new solutions to the encountered problems, which then can be applied to future projects. One of the first and most important problems encountered is that the apartment building is not quite built as it was designed. During the building the contractor changed the details without giving any notice of it.

Fig 3: Artist Impression of single family dwellings

During the dismantling we came across the different details, which made it more difficult to dismantle without damaging the construction. Firstly, when the project was just in the initiative-stage, the idea was to dismantle the third and fourth floor. These elements would be used to build single-family dwellings just across the street. It was very complex to dismantle and to build synchronically with the same elements. And in this stage it wasn't clear whether the elements were reusable, so the second thought was to dismantle the two upper floors and store them on a nearby location to catalogue and test them. Realisation of this idea was not possible, two things went wrong during the process. Firstly there wasn't enough time and knowledge available and secondly the government wasn't intending to subsidise the project so all the risk was for the housing association and the contractor.

Fig 4: The newly settlement of the construction after sawing the wall in two sections. The right section will be removed.

Fig5: After removing the floor it is clearly to see that the wall is not standing 90°. This will be fixed during construction

The used building method is named after the factory where it was made: "Elementum". It is a precast building system where the connections between the floors and walls should have been filled up with a mixture of sand-cement, but during the construction a much stronger mixture was used. When a floor was removed with more force then initially thought the whole construction moved a bit and it stood out of plumb (fig 4&5). To prevent collapsing more safety supports had to be added.

Because this project is still going on and only the first stage (the dismantling) is completed. At a very slow rate the financial data is brought together. And at this moment of writing the second stage has just been started, so the financial data of building is not yet available. I hope that this data will be available to me at the start of

the conference. But one of the difficulties of getting these data is that the data is very sensitive in perspective of competitive position of the building company.
This project is the first in its kind in the Netherlands and so it is a learning project. About 2 million of these apartments have been built during the period 1946-1980, and nowadays a lot of these apartments cannot meet the standards of today. Because the housing association, the principal in this project, owns 2.500 of these same type apartments in the same condition as this project, it can be expected that more of these projects will follow in the future.

3.2 Moving builings to new sites for reuse

Case study; Middelburg [3]
In Middelburg one of the first projects with reuse of elements has been realised. The apartment building, 11 floors high, was built in 1971 and the dismantling started in 1986 when the building just was over 15 years old (figure 6). The reason for this was that the apartment building was having different kinds of social problems e.g. pollution, vandalism, drugs, alcohol and prostitution. Therefore the living conditions were not attractive at all and every year one third of the people moved, and the occupancy varied from 19 % to 32%. In 1981 the Housing association Middelburg (WVM) realised that the building was unlettable. One year later the idea was brought up to dismantle the apartment building and reuse the secondary elements. A study was carried out to prove the feasibility of the plan. After a few years of planning, designing and calculating, the dismantling of the first of three apartment buildings was started. The plan was to dismantle the top seven floors, renovate the remaining four floors and reuse the elements to build two apartment buildings of three and four floors high (figure 7).

Fig 6: The apartment building

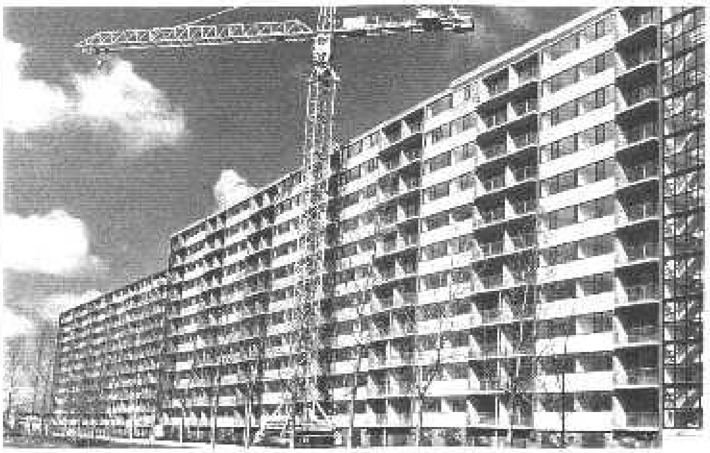
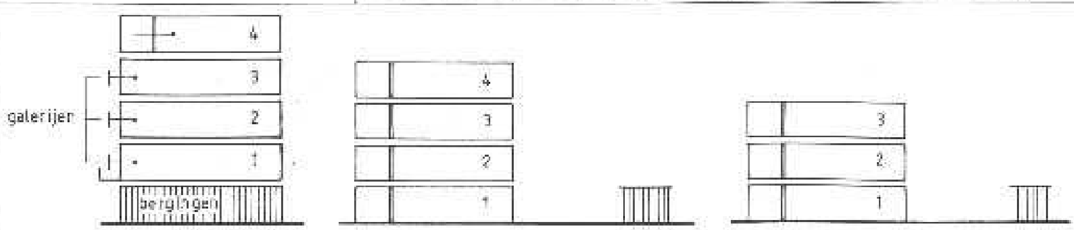


Fig 7: The plan: dismantling of the top seven floors and rebuilding new apartment buildings of four and three floors.



The dismantling was technically possible because the apartment building was built with the Delta BMB system. The name BMB refers to the mounting method

Simplified Brick Construction. The connections between the concrete components are established by means of dry-mounting, such as steel-strips or bolted connections. Grouted connections are avoided as much as possible, but still are applied for connections between floor components to achieve diaphragm-action of the floor surface.

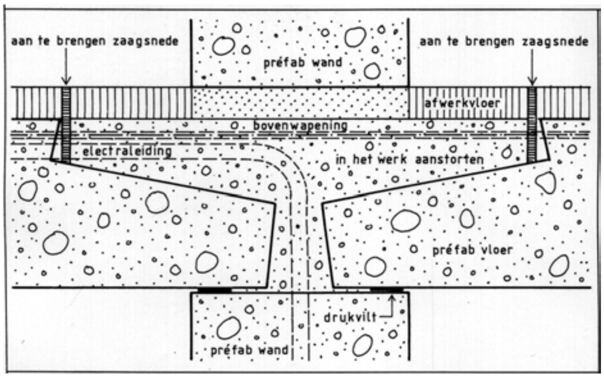


Fig 8: Detail of the connection between the walls and floor and where to place the two saw-cuts

The fact that the concrete structure of this building was constructed mainly with dry-mounting methods had contributed to the decision of dismantling. The walls were lifted so the grouted connections applied at floor-floor connections could easily be detached after 2 saw-cuts had been made with a sawing machine especially developed for this project (figure 8). After this a pneumatic hammer could easily break the grout and the prefabricated floor components were disconnected from their support by special hydraulic jackscrew.

Logistics

Directly after the dismantling, several activities were carried out to prepare the components for reuse. Each component was provided with a brand and codes to facilitate the reuse. Subsequently repair work was carried out, and then the components were transported to the storage. To maximize the impact and efficiency of the reuse, the new building site was used as storage site at the same time. When all the seven floors had been dismantled and transported to this storage site, the construction of the new buildings could start (figure 9).

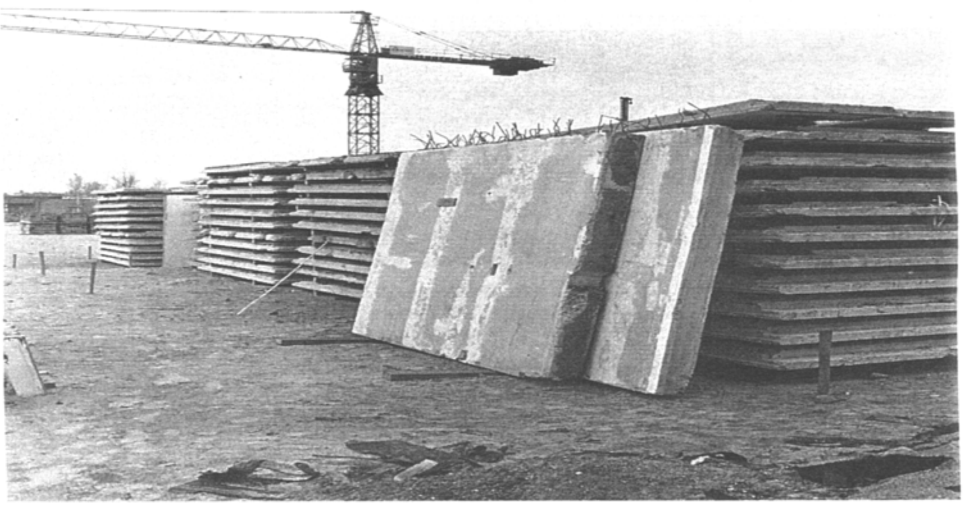


Fig 9: the storage site of the dismantled elements.

The Results

Did the dismantling of the apartment building into three smaller apartment buildings meet the original goals? The neighbourhood is now a safer place to be and for all three apartments buildings there is a waiting list. But was this a result of the dismantling the building or because the people who caused these social problems were housed in other neighbourhoods? The answer is the second option.
After the whole operation was completed, there was clarity in the financial situation [4]:

The total building costs	12.200.000,-	
Dismantling costs	1.495.278,-	-/-
Net building costs	10.704.722,-	
The supposed costs of a newly build building	9.021.092,-	-/-
The costs of the reuse	1.683.630,-	

The reuse of the elements made the building 1.683.630/9.021.092 = 18.7 % more expensive in comparison with a new building. But this figure should be higher because when the comparison is made with a new building then the old building will be demolished instead of dismantled. And the costs of demolition are less then the dismantling costs.

4.0 ENHANCING MATERIALS RECYCLABILITY

WASTE MANAGEMENT

The methods used to manage the CDW differ from one Member State to another. Although some countries introduced a system for managing this waste, based on the waste hierarchy, the waste managed by most of the Member States is quite simply; disposal to landfill. The large number of potential sources (demolition sites) and the fact that CDW is generally inert means that it is difficult to control and creates a high risk of illegal landfilling. These illegal landfills are widespread in some Member States.
Despite the recycling potential, about 75% of the ‘core’ CDW are being landfilled nowadays, only 25% are re-used.
In some Member States dangerous wastes, like asbestos and heavy metals, are not always separated from the rest of the CDW. Although their quantity is relatively small, their appearance can contaminate a significant part of the recycled materials or can contaminate landfills.
The composition of CDW differs per Member State. This composition is affected by numerous factors, including the raw materials used, architectural techniques, local construction and demolition practices. The main wastes present in the CDW are soil, ballast, concrete, asphalt, bricks, tiles, plaster, masonry, wood, metals, paper and plastics.
The rules and regulations governing this waste stream in the Member States also reveal the diversity of approaches to its management. The regulations are rarely binding in most Member States. Very few countries have specific management legislation. However those, which have introduced measures to improve its management (like Denmark and the Netherlands), have achieved high levels of recycling. Some examples of these measures:

The Netherlands have drawn up a national "Building site waste" plan for the period 1990-2000 comprising measures aimed at banning the landfilling of recoverable waste. Nowadays about 95% of the CDW is recovered and re-used. Since this year it is forbidden to dump reusable CDW on a landfill in the Netherlands.
In Denmark, municipalities are responsible for the collection of the CDW. More than half of them (especially the major cities) has introduced specific regulations on sorting of that waste in order to re-use the material again.
In Germany, a voluntary agreement was concluded in 1996 between the Federal Ministry of the Environment and the federation to which most construction and demolition undertakers belong. The aim is to reduce the volume of disposed CDW to landfills by 50% between 1995 and 2005.
The southern European countries (Greece, Italy, Portugal and Spain) recycle very little of their CDW. The market for recycled materials is not highly developed in those countries. Their natural resources are of sufficient quality and quantity to meet the demand for building materials at a moderate cost.
So the current management of the CDW can be described as waste management. The problem occurs at the end of the life cycle, as soon as a construction has to be demolished (figure 10).

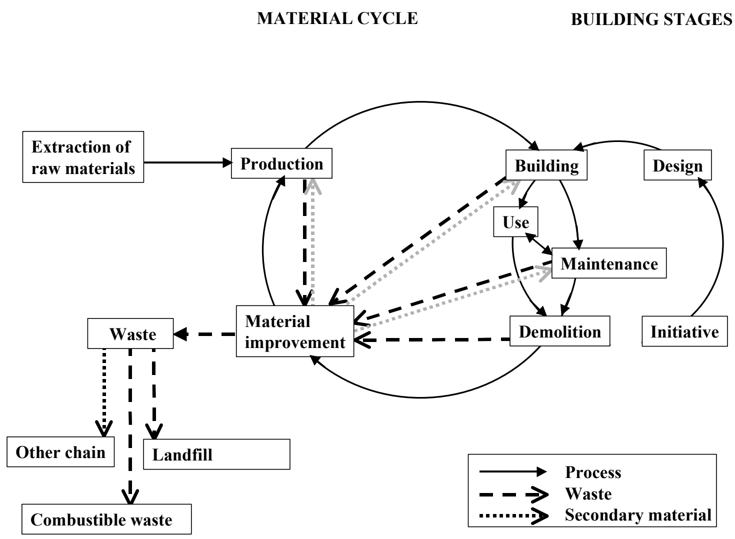


Figure 10 Waste management

Waste management hierarchy
In its Community Strategy for Waste Management [5], the commission describes the hierarchy in waste management. That is a three step hierarchy with prevention of waste as first priority, followed by the recovery of waste and the disposal of waste is the last option.
In some Member State this hierarchy has more steps. The Dutch government introduced a seven step hierarchy, called the Ladder of Lansink (table 3).

1	Prevention
2	Element reuse
3	Material reuse
4	Useful application
5	Incineration with energy recovery
6	Incineration
7	Landfil

table 3 Ladder of Lansink [6]

A disadvantage of such order is that it is a fixed top-down approach. The first option is always better than the second and so on. Nowadays there are more sophisticated models that calculate the best results on economic and ecological level. So this fixed order should become flexible. The Delft Ladder is a new, flexible model. It has more options, because more waste treatment options have been developed. The order can change thanks to the results of calculation methods like Life Cycle Analysis (LCA),

Prevention
Construction reuse
Element reuse
Material reuse
Useful application
Immobilisation with useful application
Immobilisation
Incineration with energy recovery
Incineration
Landfill

table 4 Delft Ladder

Integral chain management
With integral chain management the recycling industry can be changed. A definition of integral chain management runs as follows [7]: the maintenance of products and processes in such a way that all materials in a chain can perform their function as long as possible. So the degradation of materials must be kept at the lowest possible level. Translating this definition for the building and constructing industry, it means that all actors, at all building stages (initiative, design, building, use, maintenance and demolition) must do all they possibly can to improve the use of constructions, construction elements or materials after the demolition-stage [8]. Major issues concerning integral chain management are:

- The level of re-use (construction, construction elements or material level)
- The way of re-use (recycling, downcycling or upcycling)
- The building stages

Level of re-use
There are three different groups of re-use levels. The first group is prevention of waste, both quantitative and qualitative prevention (construction re-use, element re-use). The second group is re-use in a useful application (material re-use) and the third is the definite removement from the building and constructing industry.

Way of re-use
There is a difference in the re-use of CDW. This waste can be recycled, downcycled or upcycled [9]. When the material is used for the same function again, it is called recycling (steel scrap used for the production of steel). When the material is used for another function it is called down-cycling (mixed granulates used as a road base material) and when the recycled material is used for a better function than the original material it is called upcycling (fly ash used in cement or concrete).

Building stages
Re-use at the highest level is only possible if every actor in the building cycle is aware of the fact that the used materials are to be re-used after demolition. So at every

building stage, from the initiative, design, building, use, maintenance to the demolition stage, measures must be taken to improve re-use at the highest possible level. In the following diagram the building stages are coupled with the material cycle (figure 11). The right part of the diagram shows the building cycle, the left side the material cycle. All actions in the right cycle have their effects on the closure of the left cycle. So maximal efforts are needed in the building cycle to close the material cycle. A problem is the lifetime of buildings. Normally these constructions exist for about 20-250 years. So the use and maintenance stage are the longest in time. The most important decisions, about reusing materials, however can be taken in the first stages (initiative, design and building stage). So to reach an optimal re-use of the construction, construction element, or materials, there are a few important preconditions:
Design for recycling (DFR). Materials, which are difficult to recycle, should not be used at all, or it must be (technically) easy to separate them, before or after, demolition
Design for disassembly (DFD). To re-use building elements, a construction should be designed to disassemble these elements at the demolition stage. This DFD also makes constructions more adaptable.
Assembling and dismantling techniques. To use building elements a second time they must be dismantled carefully in order to prevent being damaged as much as possible.

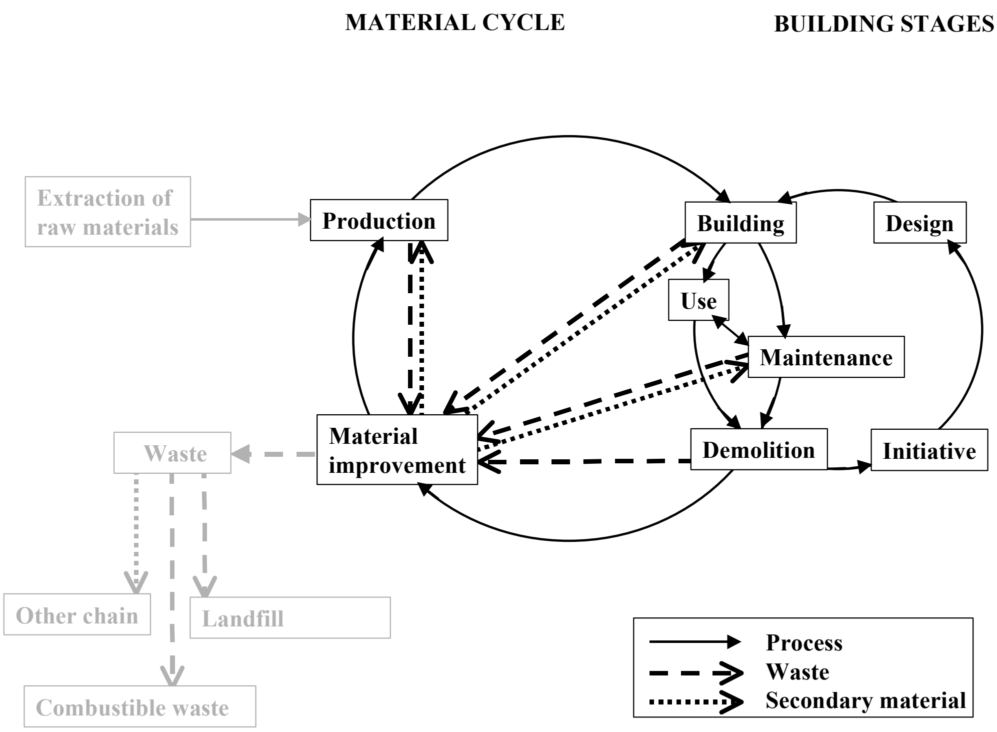


Figure 11 Integral chain management

Advantages of integral chain management

- Integral chain management helps with the following items:
- Less waste is produced because most of the waste will be used again after a construction is demolished;
- By closing the material cycle, the need for raw materials will be reduced, due to secondary materials;

- And so, by using more secondary material, save on the use of space for landfills.

The effects of integral chain management on the environment are both positive and negative. Producing a qualitatively good secondary material out of construction and demolition waste needs energy, transportation and causes emissions. On the other hand, due to the production of fewer raw materials, there are savings in energy, transportation and emissions. These environmental advantages and disadvantages of integral chain management can and must be calculated with life cycle assessment methods, according to ISO 14000. Tools as SimaPro, Greencalc and EcoQuantum are specially developed for these calculations.

5.0 ENVIRONMENT, HEALTH AND SAFETY

5.2 Asbestos

An investigation of asbestos must be done before the deconstruction of demolition of any building. If any asbestos is found, it will be marked. Afterwards it must be removed separately under special circumstances. A tent must be placed around the asbestos-containing object. Inside this tens there must be an under pressure at all times during the deconstruction, so no asbestos fibres can escape. The deconstruction workers should wear special suits.

The asbestos containing material must be placed in special containers. These containers will be sealed off twice. These containers will be stored (or dumped) on special landfills. The costs for landfilling this material is very high.

In Pernis (near Rotterdam) a special plant has been built for the separation of asbestos from pipes. In this plant there is a continuously under-pressure (during operation). The asbestos containing material will b separated from the steel pipes so the pipes can be reused again.

7.0 DESIGN OF BUILDINGS AND COMPONENTS FOR DECONSTRUCTION

Design for adaptability

Design for adaptability is useful for constructions with a long (expected) lifetime. Especially when the use of the building changes or is expected to change before the lifetime of the building [10]

An example for a building that has been designed for adaptability is a combined school and apartment building in Schijndel, The Netherlands (figure 12-17). This building is located in a new neighbourhood were the expectation is that a lot of children will go to primary school in the next decade. The school is located on the ground floor. This school also has classes at the first floor, but these classrooms could be adapted to apartments when the total amount of children was falling. At the upper (second) floor the apartments were located. Originally these apartments were for rent and, when necessary, they should be adapted into classrooms. This has never happened because no property developer dare to built it this way. Now these apartments were sold to private owners. Ironically emergency accommodation must be built within five years after completing this construction [11].

Figure 12 Front view

Figure 13 Rear view

Figure 14 Course

Figure 15 Inner course

FIGURE 16 APARTMENT

FIGURE 17 CLASSROOM

Design for Deconstruction

This design method opts for reusing hole elements after deconstruction. So when the building is constructed for the first lifecycle one should know how to deconstruct and how to rebuild. So constructing and deconstructing details are very important. Furthermore sizes, like length and height, must be standardised. Only then secondary elements can be re-used again. In the Netherlands a special program, IFD-building (industrial flexible and demountable building) was launched to reach more deconstructable buildings or building methods.

Design for deconstruction is useful when the expected lifetime of the building elements is longer than the expected lifetime of the whole building.

An example of a building that was built for deconstruction is a building in Vleuten, the Netherlands (figure 18-20). In that area a lot of houses were built and those had to be sold in a period of about 10 years. So in this building an info-centre was located for the plans of the new residential area. At the time, all these houses were built, this info-centre will be deconstruct.

FIGURE 18 VLEUTEN

FIGURE 19 VLEUTEN

Figure 20 MX-5 System

This building is built with the MX-5-method, a building method with concrete walls, columns and floors. These elements are bolted together and thus they are demountable.

The concept of Demountable Building was first introduced in the Netherlands by professor H.W. Reinhardt during his inaugural speech at the Technical University of Delft on May 19th, 1976. Focusing on the multi-purpose character of modern buildings, he recommended the application of demountable connection within precast concrete systems. A variety of steel connections such as bolts and screws form the basic of the structural joints in the demountable system. The conventional poured connections were no longer the only option to achieve stability, unity and rigidity within precast structure. Dry assembling methods using steel connection devices are gaining territory in an increasing degree.

Later on, a special committee D7 (a division of CUR-VB) was founded in order to explore the possibilities for research and development of Demountable Building for concrete structures in the Netherlands. This committee executed many laboratory experiments regarding the innovation and safety aspects of demountable connections in precast concrete. On May 1985 an international symposium on this topic was held in Rotterdam, featuring worldwide challenge and research topics on demountable building.

Despite of two decades of research on this topic, the demountable building systems have less than 1% market share in the current building industry in the Netherlands. The barriers to introduce Demountable Building as a form of reuse has failed to reduce the waste production within the building industry in the Netherlands, which has meanwhile reached the annual amount of 15 million tons.

The Dutch authority took responsibility to promote further development of demountable building and stimulated new interest from the environmental point of view. Governmental contribution were given to projects which applied flexible and demountable assembling methods on precast concrete structure instead of conventional poured connections. The authority took action by means of new policy and regulation concerning flexibility and demountability of buildings, which also involve increasing the cost for waste disposal and waste treatment.

The Government Buildings Agency, a division of Ministry of Housing, spatial Planning and Environment, performed research in analysing the existing demountable building-systems in the Netherlands. This assignment resulted in classification and comparison study of five major precast concrete systems, published in final report "Demontabele bouwsystemen in beton" (Demountable buildingsystems in concrete) on July 1996. Those five demountable systems are described in the State of the Art report on deconstruction in the Netherlands (Dorsthorst e.a., 2000).

8.0 POLICY, REGULATIONS AND LIABILITY

8.1 Government policy supporting deconstruction

The policy of the Dutch government is to reduce the total amount of CDW. Therefore there is a landfill ban for reusable and burnable CDW. SO the government supports the reuse of old building parts and/ or elements. In one of their own buildings, the ministry of VROM (housing and the environment) they tried to use as much reused and reusable materials as they could.

Furthermore at more local level, the communities support special projects like the reuse of old apartment buildings in Maassluis, or the reuse of the apartment building in Middelburg.

8.2 Building codes
The Dutch building codes allow all materials that have been certified to be used in the building industry. With old reused materials these certification is a problem. Are these materials as good (or better) as the new ones.
Another problem is that the codes have been renewed last year. One of the major problems is the change in floor heights. Therefore almost all of the used columns and walls are to small for reuse.

8.3 Creating standards for deconstruction and material reuse.
Standards for demolition (and deconstruction) are being prepared. They are not yet available.

Standards for reuse materials in concrete are common now in the Netherlands. An example of these standards is the replacement of 20% of natural gravel by an secondary aggregate in concrete. This replacement can be done without any other calculation. Some communities demand for the use of such concrete.

9.0 BARRIERS

One of the major barriers for deconstruction and object reuse is the money. The demand for secondary materials from the road constructing industry is that high, that it needs almost all of the available CDW. There is no need now to (financial) to investigate and to support case studies and research.

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REPORT 6
THE STATE OF DECONSTRUCTION IN NEW ZEALAND

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ABSTRACT:
This paper discusses the state of deconstruction in New Zealand. It outlines specific circumstances in New Zealand which affect deconstruction and materials reuse. The paper details techniques, strategies and examples of deconstruction in New Zealand, and provides an overview of legislation, guidelines, governmental bodies and industry organisations that are associated with construction and demolition as well as waste minimisation in New Zealand.

The key document relating to the potential for wide spread implementation of deconstruction and other materials reuse strategies in New Zealand is the recently published a strategy document '*The New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002*[1], which sets the nation a target of reducing construction and demolition waste going to landfills by 50% of the 2005 figure by 2008. Half of the Territorial Authorities in New Zealand have set themselves the even more ambitious target of zero waste by 2015.

KEYWORDS: Deconstruction; New Zealand; Demolition; Recycling; Design; Waste minimisation.

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CHAPTER 1: INTRODUCTION

Overview

New Zealand (NZ) is a country of 4 million people, living in an area of 268,021 square kilometres[2]. It consists of two main islands, is 1600 kilometres (1000miles) in length and is located some 2100 kilometres (1300 miles) east of Australia.

Auckland is the only conurbation of more than one million people, although there are two other conurbations with populations of more than 350,000 and a further four with populations in excess of 100,000 people[3]. These centres are distributed along the entire length of New Zealand, although three-quarters of the population live on the slightly smaller north island.

Figure 1 Main Population Centres in New Zealand

Population is dispersed and travel distances can be quite large. Demographic and therefore also economic conditions supporting the construction and demolition industry and the reused building materials market, create very different conditions related to aspects of deconstruction in Auckland compared to the rest of the country.

Away from the generally quite small central business districts (CBDs), urban settlement is dispersed and consists mainly of one or two storey light timber frame construction. Construction within CBDs employs the full range of building materials and construction systems utilised internationally.

The indigenous people of New Zealand / Aotearoa are the Māori[4] (Tangata Whenua). The Treaty of Waitangi / Te Tiriti o Waitangi[5] was signed in 1840 and is an agreement between most Maori Chiefs and the Crown (Monarchy of the United Kingdom)[6]. The agreements and articles in this document are what central and local government policy as a matter of honour is obliged to adhere to.[7]

Of direct relevance to this report is Article 2 of the Treaty where Taonga (treasures – including biodiversity, native ecosystems, mahinga kai (food gathering areas), waterways, language, culture etc) are guaranteed to Maori.

Better waste minimisation schemes, of which deconstruction could be a major component, are therefore part of Pākehā[8] honorable kawanatanga (governorship) in NZ. Current waste disposal methods in NZ are damaging Taonga directly and indirectly in that more new resources are being extracted from the environment with all of the associated problems.

The NZ government, in their newly released policy document *The New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002*[9], requires a 50% reduction by weight in construction and demolition waste going to landfills by 2008, however further action by the Ministry for the Environment on C&D waste minimisation remains speculative.

Over half of the Territorial Authorities (TAs) in New Zealand have in fact gone a step beyond the government policy document and declared that they will aim to have zero waste by 2015. This is an encouraging sign for the future of resource use and waste minimisation in NZ and the Zero Waste goal continues to receive the encouragement of Central Government.

1.1 Waste Impact of the Construction Industry in NZ

Although the often quoted figure for construction and demolition waste in New Zealand is 17%[10] of total landfilled waste, (10% of residential landfilled waste and 22% of industrial landfilled waste), these figures does not include C&D waste taken to privately owned 'cleanfill' dumps or illegal dumping of C&D waste.

There are no national records or statistics on operating cleanfills in NZ, but it is recognised that cleanfills receive most of the waste from the C&D industry[11]. For example, in Auckland approximately the same amount of demolition and excavation materials go to cleanfill as total amounts of materials that go to landfill.[12] The 17% figure also does not include figures from all Territorial Authorities.

Dumping charges vary widely from region to region, with some being free for hardfill and in other situations over $NZ 100 per load. One of the clearest examples of variation in tipping rates is in charges for polystyrene tipping. In Wellington commercial fees for tipping of polystyrene are $62.50 per tonne, while in Onehanga in Auckland the rate is $1000 per tonne[13]. Often cleanfill dump rates are very much cheaper than municipal landfill rates[14]. Therefore, although there are currently no accurate figures for C&D waste, it is considered to be substantially higher than the 17% of total waste figure.

Currently the government's main motivation for reducing C&D waste is to reduce pressure on landfills. The concept that we can reduce waste generation and resource depletion, and maximise the utilisation of our existing material investments, is touched on in the NZ Waste Strategy[15], but does not seem to be a large part of government thinking at this point in time. Nevertheless it obviously makes good sense to do this from a national perspective, both economically and environmentally. So the signs are positive with regard to waste minimisation in New Zealand but the linkages to deconstruction and the opportunities for resource conservation through material and component recovery, which are implicit in deconstruction strategies, do not seem to have yet been widely recognised.

1.2 Waste Statistics in NZ

It is recognised that there is a lack of coordination in waste minimisation in NZ[16] and that there is limited information on the size and nature of the waste stream.[17] Information available generally relates to the amount of waste disposed of rather than that generated. A 'Solid Waste Analysis Protocol' exists but is used inconsistently.[18] This has recently been reviewed and republished (2002).

National waste statistics that do exist (1997 Figure 2) are broken down into a combination of materials (plastics, paper, metal, glass) and sources (C&D) as well as environmental or health impact (potentially hazardous) (see Figure 2).

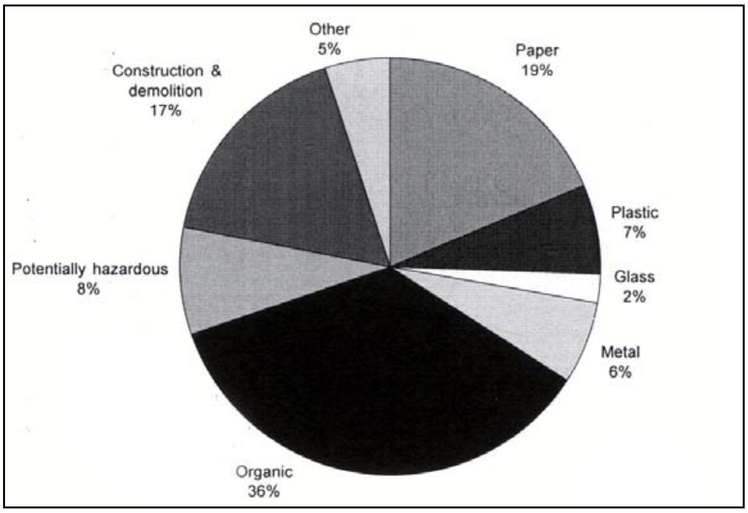

Figure 2 Composition of total landfilled waste in New Zealand in 1995[19]

It is unclear when looking at the categories whether any C&D material counted is paper, plastic, glass or metal or if all of these materials are counted in their own sections. According to the Solid Waste Analysis Protocol,[20] the construction and demolition category only includes wood, wood fibre, rubble, cleanfill and 'other construction and demolition' wastes. C&D wastes are also included in the plastics, metals, glass and 'other' categories. This problem in definition of waste categories, particularly with C&D waste had been addressed and according to the latest Solid Waste Analysis Protocol of 2003[21], all waste is now to be categorised according to material rather than source or potential environmental impact.

Statistics on amounts of resources that are reused and recycled are also lacking on a national scale. The only national data of the production, consumption and collection of recyclables[22] available comes from the Packaging Industry Advisory Council (PIAC) in 1994. Approximately 33% of recyclables consumed in NZ in 1994 were collected for recycling[23]. It is unclear what percentage of these is attributable to the C&D industry. Other Specific materials industry associations such as Plastics New Zealand may have data on their particular materials also. Wellington City statistics from 1996 suggest that 8% of recyclables are diverted from landfill[24]. Again it is unclear whether this is attributable to the C&D industry.

There are no national statistics on amounts of materials that are reused in or from the C&D industry. Preliminary Studies into the export earning potential of the recycling industry have been compiled.[25]

Reasons for Deconstruction with Respect to Sustainability

The concept of sustainability is based on an understanding of the natural ordering and continued success of natural ecosystems[26]. It is about understanding the cyclic nature of both growth and decomposition and re-growth, and energy in its immediate and embodied forms.

Currently, production processes in NZ, as a ‘developed’ nation[27] are generally of a linear nature. Sustainability seeks to make the process cyclic, which considers ‘waste’ as the primary input for another process, thus linking resources into an infinite cycle.

The role that deconstruction has in the construction and demolition (C&D) process, is crucial in terms of creating a loop in resource use and consumption and energy expenditure. Deconstruction has the potential to shift the C&D industry to a more sustainable level in NZ.

The construction and demolition industry in its current form in NZ is not sustainable and problems are becoming evident with scarcity of some resources and pollution in general. The main issues relating particularly to concrete and timber construction are outlined in Chapter Four.

Although NZ is still a sparsely populated country relative to other developed nations[28], it is becoming difficult in some areas to find land for new landfills[29] that are acceptable to the public, are economic, or environmentally adequate. Increased deconstruction in NZ may divert some ‘waste’ from landfill in NZ.

The Waste Management Hierarchy

The Ministry for the Environment (MfE) generally uses and recognises the ‘5rs’: Reduce, reuse, recycling, recovery and residual management as a useful waste management guideline. Recovery in this context generally refers to the incineration of material to ‘recover’ energy. Residual management refers to landfilling. This hierarchy is used as a tool to analyse current practices in a sustainability framework and guide policy to be more sustainability focused.

Current thinking is questioning the focus of waste management, and resource allocation in dealing with waste. This seems to be at odds with the adopted waste management hierarchy and still seems to be very much focused on recovery and residual waste management in NZ rather then on reduce, reuse and recycle as waste minimisation strategies.

NZ Specific Benefits of Deconstruction

Social / Cultural

Deconstruction could provide low cost materials to low income communities in NZ. It is estimated that about 18.5% of people live in low income or poverty situations in NZ.[30]

The NZ unemployment rate is officially at 4.9% for December 2002[31], and the ‘jobless’ rate is at approximately 8.3%[32]. Construction was recorded as having a rise in employment in the year 2002[33]. Deconstruction provides training for the construction industry as a byproduct of the already economical practice of deconstruction. Deconstruction may create jobs in NZ and have spin off into the associated recovered materials industry. It is estimated that there are 20% more jobs in the recycling industry than in landfilling in NZ.[34]

Specific cultural values and concepts of Māori (tangata whenua), who are the indigenous people of New Zealand, relate to preservation and rejuvenation of the natural environment through waste minimisation and resource conservation, to which deconstruction is inherently linked.

> *'Waste weakens our connection to the environment. If we think of the environment as a dumping ground, it is harder to value its other qualities. For some, this directly affects cultural and spiritual values and our role as kaitiaki[35], or stewards, of natural resources.'[36]*

Maori have been the drivers behind many environmental initiatives in NZ and have in some cases extensive knowledge of customary practice and specific geographic environments.[37]

Waste Minimisation Case Studies in NZ

Waste minimisation case studies in the construction industry have been carried out by Sinclair Knight Merz for Target Zero and the Christchurch City Council[38]. Case studies have also been carried out by REBRI in the construction and demolition industries [39].

REBRI Case Studies

The REBRI case studies are divided into domestic and commercial studies in the areas of construction or demolition. They took place from 1995 to 1997 and were mostly in the Auckland region.

The construction case studies indicate that careful sorting of waste, education of subcontractors, appropriate storage, material recycling and reuse and design modification are successful waste minimisation strategies that can be employed in both the commercial and domestic sectors to reduce waste. For example in the construction of the Lower Hutt Te Puni St Warehouse in 1997 by Jarrah Construction, tilt up slabs were prefabricated off-site and were designed to require minimum fixings and detailing, the site was kept clean and organised, the subcontractors collected and were responsible for most of their own waste and timber was carefully sorted and de-nailed for reuse on the next site, which resulted in less waste going to landfill.

Both on-site and off-site waste separation occurred. In the earlier case studies, waste separation was on-site using a series of labeled skips to make sorting easier. The more recent studies used the services of a specialist waste management contractor who picked up the combined waste from construction sites and then separated the waste in a warehouse designed for this purpose[40]. It was concluded from the studies that on-site sorting was possible and that subcontractors could do this with simple training.

Reasons for incorporating waste minimisation strategies in the case studies were noted as: cost savings, reduction of environmental impact, worker health and safety and community benefits. Case study summaries show that significant savings both financially and in terms of resource use were made.

The commercial demolition case study gives a summary of the 1996 demolition of the Blows building in Auckland by Ward Demolition. The type of project was listed as 'careful demolition of a building to salvage as much material as possible' and the reason for the project was cited as 'cost savings and reduced environmental impact'. It was noted that waste minimisation depends largely on the time available for demolition and the value of the materials in the building that is being demolished. In this case study, the building consisted of high value materials such as kauri (native timber) flooring and beams, iron roofing and bricks. There was a six week time frame to complete the demolition in. At the conclusion of the project 95% of the building had been salvaged and NZ$153 000 had been saved on demolition costs. The extra labour costs incurred were covered by reduced dumping fees and money earned from on-sold materials.

Christchurch City Council Case Studies

The Christchurch City Council case studies were conducted in 2000 and 2001 and involved two prominent construction companies in Christchurch. The aims of the study were to provide training for site foremen in waste minimisation techniques, to implement waste minimisation practices on construction sites, to obtain data on the C&D waste stream and to confirm the benefits of waste minimisation.

Workshops were held with the construction companies, and waste audits were done weekly to measure the waste volumes and types in each of the construction sites. The main waste minimisation initiative was to set up separate bins for the sorting of wastes on-site, to ensure easier reuse or recycling of materials. Financial savings through waste minimisation ranged from $NZ 385 to $NZ 1615.

The case study report concluded that the success of waste minimisation relies on an organised foreman as well as external support for company management or external consultants. Results obtained showed that 20% to 40% of materials were separated from the general waste stream through on-site sorting and that at least 50% of construction waste could be diverted from landfill using the existing facilities in the Christchurch region.[41]

CHAPTER 2:
DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY AND TOOLS

Introduction

There is an enormous range of approaches to demolition in New Zealand. Some of the larger firms are actively increasing recovery rates and have resource recovery initiatives in place,[42] because of increased profitability in this sector of the industry. Only two companies are known to refer to their work as deconstruction. Both of these companies are Auckland based. One of these is currently pondering a name change to Nikau Deconstruction Engineers. The other, Ward Demolition, has an arm of the company called Ward Resource Recovery. Ward sent a delegation to the American National Association of Demolition Contractors annual conference to bring back 'best practice' techniques and to learn from overseas experience. Both of these companies operate at a fairly sophisticated level on large urban buildings, but they are currently the exception rather than the rule, although some other contractors in the Auckland region are following their lead. Another company, Cedar New Zealand Ltd. has developed quite sophisticated techniques for optimising the recovery rates for native timbers.

Other demolition companies, particularly those outside the Auckland Region salvage selected and usually small amounts of high value, easy to extract materials such as native timbers, antique items, aluminium and high value metals, and bricks when demolishing large urban buildings, in a process which is normally referred to in New Zealand as 'cherry-picking'.

Most of the widespread deconstruction that does occur is the recovery of native timber, and timber door and window components from old domestic dwellings (Figure 3). In old, unaltered timber domestic buildings close to 100% recovery rates have been achieved. According to one demolition contractor older houses can be worth anywhere between NZ$4000 and 20,000 when deconstructed[43]. Sanitaryware, plumbing items and kitchen cupboards and worktops are being recovered from much newer homes, where kitchens and bathrooms have undergone 'fashion upgrading'. With the widespread use of less durable materials in new houses, many demolition contractors see a reduction rather than an increase in opportunities to recover materials in the future.

Figure 3 Jarrah flooring recovered for reuse from St Joseph's Church in Wellington

2.1 Planning Issues for Demolition and Deconstruction

In NZ a building consent from the local territorial authority is required for demolition. The building consent application must include a demolition plan and method statement. Waste plans are not compulsory but guides to preparing these plans are available from Resource Efficiency in Building Related Industries (REBRI)[44], a NZ joint initiative of the Auckland Regional Council (ARC) and the Building Research Association of New Zealand (BRANZ). In all cases hazardous materials have to be identified and a plan devised for their extraction and disposal as part of the building consent process.

Increased planning at all stages of the process is needed for deconstruction to ensure accurate pre-deconstruction evaluation (including structural analysis), correct dismantling sequencing and maximum recovery of components or materials. Deconstruction involves more people, more time and more dealings with other business, such as accessing markets, on-selling to salvage goods dealers or direct selling to customers from site. Management skills are therefore crucial to successful deconstruction. Many demolition contractors do not consider that the increased time and effort involved results in sufficiently increased profits.

Inappropriate or non-existent planning of deconstruction work sequence is often a source of contamination of elements and precludes reuse. Even when deconstruction or element recovery is intended and planned for, lack of incentive and poor motivation of operatives combined with poor knowledge of deconstruction techniques often undermines the process and results in lower than expected recovery rates.[45]

Most demolition projects can be regarded as hybrids offering opportunities for resource recovery and the need for some measure of landfilling / disposal. The fundamental planning or management skill required in this context, is to set the balance between these two strategies in order to maximise the financial return. Environmental considerations seldom if ever enter this equation unless required under the contract. Even then, pecuniary factors tend to triumph over environmental factors. That is unless the contractor and client are in absolute accord over the overarching importance of resource recovery and the contract is written in such away that the contractor does not suffer financial loss due to any extra care taken to maximise recovery.

Table 1 Planning Issues for Demolition and Deconstruction

	Planning Issues for Demolition and Deconstruction	
	Demolition	**Deconstruction**
Site	Storage for recycled materials	Increased storage needed
	Access (nuisance / safety / machinery)	Possible increases in noise and dust over longer periods can irritate neighbours
	Proximity of site to building recycling centres	Travel distances affect economic viability of deconstruction.
Time	Duration of work	Longer for deconstruction
	Programming constraints in developer driven projects	Unless legislation requires deconstruction of previous buildings deconstruction is unlikely.
Money	Specialist skills	Careful disassembly of building generally requires higher skill levels than demolition
	Specialist equipment	Less heavy equipment may be required but some specialised tools may be needed.
Environment	Waste disposal	Reduced environmental impact of resource recovery and waste diversion over waste disposal.
	Life-cycle impact	Reuse of materials through deconstruction means life-cycle of components is extended.
	On-site sorting	Increased deconstruction and material recovery means increased sorting. Sorting most economically achieved on-site
	Sequencing of operation	Important to ensure maximum resource recovery
Information	Availability of accurate drawings	Accurate information vital to maximise resource recovery and ensure operative safety. May require additional survey work
	Hazardous substances	Increased manual nature of deconstruction means that accurate identification and planning for hazardous substances is even more important.
	Heritage status	Deconstruction may be only acceptable way of dealing with heritage buildings. e.g. by relocation
	Identification of materials	Identification of materials means recycling opportunities can be clearly identified.

Marketing	Identification of market opportunities for reusable goods.	Only an issue with deconstruction
	Transport	Material types and transport distances to markets influence viability of deconstruction in many cases
Construction	Structural Evaluation	Earthquake design often requires monolithic structures which are more difficult to deconstruct
	Construction method used	In-situ and chemical bonding methods are difficult to deconstruct
	Age of building	Older buildings often contain more desirable and durable materials and are easier to deconstruct.
	Separated building layers	Separated building layers make deconstruction and in-life modification much easier
Legal issues	Building consent is required for demolition in NZ including a demolition plan and a method statement	Building consent would also be required for deconstruction but methodology is likely to be more complex.
Safety and general precautions	Public safety (high traffic / falling debris / noise / earthquake)	Due to increased duration, exposure to these hazards is prolonged with deconstruction
	Worker safety	More operatives and more hands-on work can result in increased hazard to operatives. Training and careful planning are required to mitigate hazard.
	Habitat and environmental impact	Regarded as less of an issue with deconstruction
	Safe removal and handling of hazardous substances.	Equally important
Management	Complexity	Planning and management of the project is much more complex and generally requires exercise of higher management skill levels over longer periods of time

2.2 Demolition Techniques, Methods and Machinery

Anecdotal evidence suggests that demolition is becoming much more complex in New Zealand, with new techniques and machinery being employed and higher standards strived for[46]. NZ is in a high seismic zone which means extra precautions are necessary in the demolition of buildings to mitigate earthquake collapse risks, as detailed in clause 5.2 of the NZ Approved Code of Practice for Demolition.

This code[47] outlines some of the common demolition methods in NZ and the safety protocols surrounding these. These may be summarised as follows:

Demolition by Hand
May be used in conjunction with cranes and sheer legs to hold or lower beams during cutting. Chutes lift shafts or cranes and skips are usually used to get debris to ground level. Care is to be taken not to let debris build up on floors or against walls. It is considered that this method is slow.

Ball
Converted drag lines are considered to be the best machines for this work in NZ. Cranes with hydraulic rams are not to be used as they have proved to be unsafe in practice.

Pusher Arm
Hydraulically operated excavators and loaders continue to be fitted with specialised attachments for demolition work. Examples are excavator buckets, boom mounted hydraulic percussion breakers and pusher arms. It is considered that theses machines have an advantage in that they are mobile, have high output, can work on vertical faces. They do however require flat ground and can only work within certain ranges. The pusher arm method is suggested for sites that are not confined and for masonry infill buildings.

Deliberate Collapse
Engineering expertise is required to remove correct structural members. It is considered that this method is best used on bridges and for buildings on isolated sites.

Wire Rope Pulling
Another form of deliberate collapse, cables and wires are fixed to key structural members and pulled down by tractors or winches. This method is suggested for detached buildings on non-confined sites. It is suitable for timber framed housing, bridges, chimneys, masts and spires.

Explosion or Implosion
Expert direction is required for this method of demolition. This is not suitable for timber framed or brick structures, which account for most NZ domestic buildings. There are OSH guidelines related to the use of explosives. The main way explosives are used in NZ for demolition is to cut or disintegrate key structural elements by loading drilled holes with explosives or alternatively fixing plastic explosive charges to these structural elements.

Grapples and Shears
Power shears are used to cut through metal (steel reinforcing in beams) and concrete. This is used where there may be risk of fire or when a more accurate cutting torch cannot be used or is not needed. Grapples generally handle waste material by moving it to safe areas on the site and loading it onto transport vehicles.

Other Methods:
Other methods used in NZ are thermic lances, drilling and sawing and bursting. NZ OSH guidelines make reference to British Standard Codes for guidelines on these

techniques[48]. Standard demolition machinery such as front end loaders, backhoes, excavators, bulldozers and trucks are used extensively in NZ.

Ward Demolition along with Nikau Demolition account for about 50% of the demolition being undertaken in the Auckland Region[49]. They are the largest and arguably the best organised and most technically advanced of the demolition companies operating in New Zealand.

Ward have made a major investment in concrete crushing equipment (Figure 4) and crush and sell-on upwards of 4000 cubic metres of concrete aggregate per month. This goes largely to small contractors for use as hardfill and sub-bases on footpaths and driveways. On large demolition jobs they give their clients the option of bringing their crusher to the site and removing the steel off-site and leaving the crushing concrete on site for use as hardfill. Facade systems are disassembled and the materials recycled. The market for window glass is very variable. Much window glass is crushed and becomes aggregate. A controlled percentage of glass is allowed in recycled concrete aggregate for certain purposes. Ward say[50] that they experience no particular difficulties in crushing up pre-stressed concrete elements.

Figure 4 Impact Concrete Crusher from Ward Resource Recovery Ltd[51]

On large demolition jobs the interior has to be stripped out by hand so that when the concrete structure is demolished there is no contamination. It makes sense therefore that during this manual process resource recovery is maximised, both in terms of quantity and quality. While this process is more time consuming than straight demolition, it is economically advantageous, and is becoming ever more so as landfill charges continue to increase and local councils close down cleanfill sites. Outside the Auckland Region the availability of cleanfill sites and lower landfill charges currently make the deconstruction option less financially attractive. However it would be true to say that the trend is towards increased resource recovery, only that the timescale is different in different parts of the country.

Most old domestic buildings in the Auckland region are now deconstructed. Roof iron, steel, floor joists, windows and doors, weatherboards, flooring timber, good quality fittings and fixtures, carpet and easy-to-strip-out wall timbers and foundations are all salvaged. Most of the timber is native hardwood and is sold at premium prices. Pine timber, which is now extensively used in buildings in New Zealand, is not salvaged unless it is easy to strip-out and even then the economics are marginal. Walls with plasterboard finish are not generally regarded as economic to strip unless they are made from good quality native hardwood framing. It generally takes about 3 to 4 days to entirely deconstruct these buildings. This is about double the time it takes to demolish the same building, but the economic equation now favours deconstruction. While most techniques involve reverse construction sequencing, Ward conventionally pull timber raised floors off their piled foundations whole, turn them over and knock off the floor joists. This has proved to be a quick and economical method of flooring timber recovery and results in minimal damage to the timber.

Recovery rates can be as high as 95% on some old houses. Newer houses, sometimes only 15-20 years old, are now being demolished to make way for more intensive development. These newer buildings are more difficult to take apart because of the widespread use of building adhesives, nail-plate connections and nail-guns. Many of the materials used are of inferior quality and currently have no market. Fixtures and fittings, concrete foundations and slabs and some joinery items are salvaged but little timber unless it is easy to strip out. Plasterboard has some market as a soil conditioner but is otherwise not recycled.

Domestic deconstruction is mainly carried out by hand. A few specialist tools have been developed by individual demolition contractors in response to a need to carry out certain processes more effectively. These are not sold onto the open market and are often made up in the contractor's workshops. Ward Demolition has developed a number of tools of this nature. They have also developed a number of specialised attachments for mechanised equipment. One such tool is a steel reinforcement cutter to fit onto the end of an excavator. This tool has met with considerable export success, particularly in the United States[52].

Demolition is an intensely competitive field in New Zealand and it has become clear that the above methods of deconstruction maximise profitability. In order to remain competitive other demolition contractors in Auckland Region are now following Ward and Nikau down the deconstruction path.

Most of the smallest demolition companies focus on the deconstruction of timber buildings, which account for 95% of the nation's building stock. Most of these companies also have selling yards for a wide range of recycled domestic materials and products. Some of these companies also specialise in the supply of a particular range of products, such as brassware or native timber on a regional or even a national basis.

Cedar Demolition is a medium size demolition company which seeks to deconstruct wherever possible and demonstrates considerable ingenuity in maximising returns. They were commissioned to carry out resource recovery by the main building contractor on the Wrightsons Woolshed Buildings in Napier. Over a period of nine and a half months they removed two acres of native hardwood flooring. They also removed most of the roof timbers. In all they recovered some 760 cubic metres of irreplaceable high quality rimu, matai and oregon timber[53].

In order to minimise damage to the tongue and groove flooring Cedar developed a special hydraulic rig which gently lifted the flooring away from the floor joists. With the roof beams, a scissor lift on tracks was employed to access the roof beams, which were unbolted and lowered to the floor rather than being dropped, which is the normal method. This resulted in much higher levels of good quality timber recovery than is normally the case with roof timber.

On the same contract, Cedar recovered about 200 hundred tonnes of Georgian wired glass but the main contractor did not find a buyer and it was eventually crushed and landfilled. Large amounts of roof iron were also recovered but were left uncovered and water was allowed to enter between the sheets and rapid deterioration occurred. This roof sheeting was eventually sold as steel scrap instead of roofing at a considerable financial loss to the main contractor[54].

A similar lack of understanding of how to make the most of resource recovery opportunities occurred on the Old Napier Hospital demolition contract. In this instance Cedar had agreed to recover all of the 1000 plus solid core rimu faced interior doors. However the main contractor did not organise Cedar to remove the doors before removing the roof. As a result, rainwater caused de-lamination of all but 90 of the interior doors, the rest had to be landfilled[55]. Such horror stories concerning the wastage of resource recovery opportunities, to the financial and environmental detriment of all parties involved, abound and re-emphasise the need for education of operatives in deconstruction ideas, practices and opportunities and the financial benefits that can accrue.

2.4 Worker Training and Safety

The demolition industry in New Zealand is currently unregulated. Anyone can call themselves a demolition contractor and undertake demolition work of any scale. This situation applies to the whole of the building industry and has resulted in serious downskilling of personnel and a number of undesirable practices, centred on inappropriate cost cutting, becoming established in the industry. The government is currently contemplating re-regulation of the building industry but whether they will apply the same regulatory mode in the demolition sector is uncertain. The NZ Demolition Contractors Association (NZDCA) is currently working on measures to professionalise the demolition industry[56] which seems entirely meritorious, by developing New Zealand Qualifications Authority (NZQA)[57] recognised qualifications for demolition contractors. However the NZDCA is seen by many demolition contractors around the country as a North Island, even an Auckland organisation rather than one that can speak for the industry as a whole. In the interim skill levels within the demolition industry vary drastically.

The NZDCA states that demolition has become much more technical over the years especially when dealing with historic places and with newly established operational requirements and that a general lack of skill base in the demolition industry means optimal recovery of potentially valuable materials is not occurring which in turn means that less money and less profit is made by the contractors.[58]

The Building Act of 1991 (as detailed in Chapter 8) has specific sections that relate to worker training and safety. Of particular relevance are details of necessary controls related to building activities and use of buildings and procedures designed to safeguard people from injury, illness or loss of amenity in the use of any building. Clause NZBC B1.3.5 states that demolition of buildings shall be carried out in a way that prevents premature collapse.

The building consent process for demolition requires provision for protection of the public including dust suppression, disposal of waste, disconnection from amenities, mitigation of noise and protective fencing, as well as a demolition plan and method statement.

The Building Code of NZ which is the First Schedule to the Building Regulations 1992, requires that construction and demolition work is undertaken in such a way as to avoid: objects falling onto people or property; hazards arising from the site affecting people on and off site; and unauthorised entry of children onto the site.

Occupational Safety and Health inspectors have the authority to issue notices to stop work if hazards are identified. Territorial Authorities are also able to impose conditions in the control of hazards.

Employers have the most duties according to the Health and Safety in Employment (HSE) Act[59] to ensure health and safety of employees. They are to: Provide and maintain a safe working environment and facilities for the safety and health of employees at work; ensure machinery and equipment is safe for employees; ensure that working arrangements are not hazardous to employees; and provide procedures to deal with emergencies. The HSE Act also requires a register of work-related accidents and serious harm to be kept by the employer.

Occupational Health and Safety (OSH) has released guidelines and publications relating to worker safety in the demolition and construction industries in compliance with the HSE Act 1992. There are no deconstruction specific codes or guidelines.

'The Approved Code of Practice for Demolition'[60] of 1994 was produced with the intention that *'safe practices recommended will be a useful aid to those involved in demolition, to avoid the potential hazards associated with the work'*[61]. It outlines regulations, duties and responsibilities of workers and employers, safe use of specific equipment and methods, accident and injury procedures, pre demolition checks, house removal, and cleanup of contaminated sites.

Clause 1.2.7 – Training of Employees states *'Employers must ensure employees are either sufficiently experienced to do their work or are supervised by an experienced person. In addition, employees must be adequately trained in the safe use of equipment in the place of work, including protective clothing and equipment.'*[62] Employers are also expected to involve employees in development of health and safety procedures as detailed in clause 1.2.6.

'Guidelines for the Provision of Facilities and General Safety in the Construction Industry'[63] published by OSH in 1995 lays out relevant safety and health information for the construction industry, of which demolition is considered a part in NZ. It covers amenities, work at height, electrical work, hazardous chemicals and materials, machinery, special situations and public and general safety, and details which activities must be notified and procedures that must be followed.

'Health and Safety Guidelines on the Cleanup of Contaminated Sites'[64] is another OSH publication relevant to deconstruction activities. Published in 1994, it details procedures for hazards, planning and organisation, site assessment, monitoring, training and supervision, personal protection and site control.

Additional OSH publications of significance are Approved Code of Practice for the Safe Erection and use of Scaffolding[65] and Approved Code of Practice for Cranes[66].

Issues and regulations detailing specific hazardous materials handling is detailed in chapter 5.

CHAPTER 3:
WHOLE BUILDING AND COMPONENT REUSE

Introduction

Whole building reuse and moving existing buildings to new sites for reuse are common practices in New Zealand. Moving, in most cases is not driven by environmental concerns but rather by building economics. It is often economically advantageous to reuse rather than demolish and build anew.

Component reuse is common in New Zealand in the domestic extension and refurbishment areas, but is less common in new domestic buildings and the whole of the non-domestic market.

3.1 Adaptive Reuse of Buildings

In situ reuse is the most efficient form of reuse and recycling. For a given project, physical resources, energy, pollution and greenfield land use are minimised.

Over the last few years two of New Zealand's largest cities, Auckland and Wellington have experienced an upsurge of adaptive building reuse, particularly within their central business districts (CBDs). The most common example of reuse is where commercial office buildings are converted to apartments. Developers are responding to a strong demand for inner-city accommodation. Worsening traffic congestion and a shortage of student accommodation are the main drivers for change in Auckland, while in Wellington changing household composition patterns, a desire to live in the inner city, an excess of office space and unacceptable floor to floor space standards in new office buildings are common reasons behind this type of development activity.

While commercial building to apartment reuse is common, other examples of adaptive building reuse include warehouses to restaurants, retail to educational, and industrial to retail. In fact, it would probably be possible to find an example of any type of reuse however much unexpected and unforeseen by the original designer. In general though there is little adaptive reuse of domestic dwellings. In a few cases houses have been converted to medical centres, offices or other uses, but town planning constraints and a lack of other pressures have seen adaptive building reuse largely confined to inner city areas.

Buildings will be demolished rather than reused if they are in a very poor condition or built using low value materials such as polystyrene of fiberboard. According to a leading demolition contractor modern 'polystyrene and wheat-bix' houses may not last 30 years and are often only suitable for demolition. Some modern rotting houses have been demolished after only 3 years.[67]

3.2 Moving Buildings to a New Site for Reuse

Domestic dwellings are much more likely to be moved to a new site than commercial buildings. Approximately 3,000 buildings, mostly houses, are relocated each year in NZ[68]. The typical New Zealand house with its light timber frame, timber weatherboard cladding, raised timber floor sitting on piles and corrugated steel roof is well suited for removal. Houses are often moved in New Zealand because it is more economical to buy the house where it is and move it than to build new. An example of this is the proposed plan to move heritage listed houses and buildings out of the way of a proposed inner city bypass in Wellington. With houses ranging in weight from 20 to 30 tonnes house removals are an every day occurrence (Fig.5).

Figure 5 House leaving site on the back of a truck[69]

Figure 6 Larger houses that have been moved a distance of several hundred metres[70]

Houses or building for transporting to a new site can be purchased privately or from a house moving company, who store buildings in yards for inspection and purchase. The regulations governing moving buildings changed in July of 2002 and are described in the *Land Transport Rule: Vehicle Dimensions and Mass 2002*[71]. There are now four levels of size dimensions, dependant on how much road space a building will take up. Each tier has more stringent requirements associated with it such as using escorts, flags, lights etc. (Fig.7). The safety requirements are also extended accordingly[72]. These rules are outlined in the Land Transport Safety Authority's, Fact Sheet 53*, Over Dimension Vehicles and Loads,* available on the website: http://www.ltsa.govt.nz/factsheets/53.html.

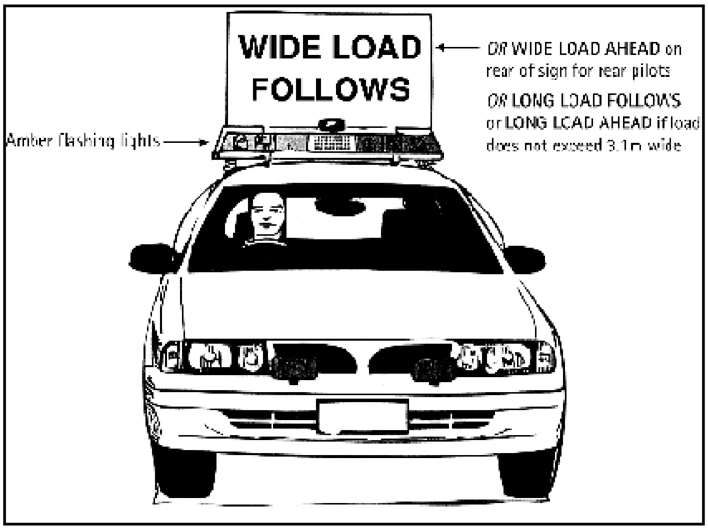

Figure 7 Example of an escort vehicle[73]

Council requirements for the legal removal, moving and re-siting of a building vary throughout New Zealand. Typically councils require a floor plan, site plans of the new site, pile plans and plumbing and drainage details.[74] A demolition consent is required if a building is to be removed from a site other than a sale yard. Relocation and building consents will also be required. Treatment of the original site for remediation or re-vegetation and permission of neighbours may be a required part of the relocation process.

Prices and time periods required for consents vary across the country, and people moving buildings between two districts will have to deal with both councils concerned. The council will inspect the house and property and usually set a bond based on the amount of work needed to make the house look 'tidy'. Upon completion of the house to council standards, the bond is refunded.[75]

While Doevandans[76] suggests that building character, construction quality issues and lower building costs are the main reasons people purchase houses to move, site redevelopment is often the catalyst for house removal. This is an example of the often differing motivations between buyers and sellers of buildings for removal. As a consequence of both urban and suburban densification, single houses are removed or even relocated on the same site to accommodate more intensive site development.

Although possibly not as efficient in terms of recycling as reusing buildings in-situ, moving buildings for reuse minimises the construction demolition usually associated with redevelopment. Foundations, services, steps, paths and masonry or concrete chimneys require demolition, and replacement at the new site, but otherwise the whole building can be uplifted from its foundations and moved. The transportation energy expended should be taken into account in assessing the net environmental benefit of this method of building reuse.

Building removal for reuse is not entirely confined to houses. NZ has an established practice of using relocatable prefabricated classrooms in schools. Classrooms are easily moved between schools and other institutions to match demand. A recent example of this is the relocation of five prefabricated classrooms from South

Auckland schools, to form a new and adaptable learning complex in the Mangere Refugee Resettlement Centre in Auckland.

Other larger light-weight structures have also been moved and reused successfully. A most notable building move, and one that attracted enormous public attention was the 1993 moving of a reinforced concrete hotel in Wellington.

In order to avoid demolition for the new Museum of New Zealand a five storey, 3,500 tonne hotel was separated from its foundations, transferred onto a 'railway carriage' and moved 120 metres across a busy urban street to a new site (Fig. 8). Prior to beginning the move the contractor undertook some stabilization of the soil over which the museum was to travel and laid a network of railway tracks. Hydraulic jacks attached to movable reaction points provided the necessary push. The move took only two days and the building reached its destination in perfect condition, allowing the hotel to reopen only five months after the project started[77].

Figure 8 Reinforced concrete hotel being moved on its railway carriage

The modern trend is for houses to be built on a concrete slab, which makes it very difficult to move them. To shift a house on a concrete slab the interior linings have to be removed to give access to the bottom plates. The bottom plates are usually bolted into the concrete using making it very difficult to remove without damaging the plates. A complete sub-frame and suitable bracing may be required to shift a house built on a concrete slab[78]

While it is relatively common for buildings to be moved in New Zealand it is less common for them to be designed to be moved. Recently a commuter airline terminal was constructed at Christchurch International Airport with a view to it being relocated in the future[79].

The Origin Pacific Airlines terminal completed in 2003 was designed by Holmes Consulting Group to be unbolted from the concrete pads it rests on and moved by truck to a new location when the existing domestic terminal at the airport is to be extended and refurbished. The steel frame structure was detailed with only minor additional structure to facilitate this planned move (see Figures 17 and 18). Longitudinal stiffeners have been included at roof and floor level and the timber framed floor is integral with the structure. It is conceivable that the building can be relocated in less than a day although it will no doubt take longer to reconnect services in the new location.

Figure 9 Origin Pacific Terminal exterior detail of base

Figure 10 Interior of Origin Pacific Terminal

Issues of Component Reuse: Overview

There is a great deal of alteration work carried out in New Zealand both by professional builders and by homeowners. Many New Zealanders engage in building or renovating domestic scale buildings. Such projects have fostered the development of a healthy recycling industry for domestic scale building components across the country. The recycling of components for larger buildings has tended to be more variable in nature, being more sensitive to economic cycles, stylistic barriers and regulatory barriers.

3.3 Benefits of Component Reuse

Materials that are no longer available as new materials are incorporated into new or refurbished buildings. This is particularly true of recovered native hardwood components, either in their original form such as flooring or remade into furniture and fittings.

The majority of component reuse in the New Zealand context is of timber based components and plumbing fittings at the residential scale. According to one Wellington building product recycler, the attraction of these components is the chance to match the period of the house and the uniqueness of the timber[80]. Many also recognise in these pre-loved items a quality of craft and durability which is very difficult to equal in new items.

Territorial Authorities in the Auckland[81] and Canterbury[82] regions are encouraging reuse of building components, particularly through specifications for their own projects. They have recognised the potential to reduce landfill requirements with this and other recycling strategies.

3.4 Damage During Extraction

Although older houses have a potentially higher recovery rate due to the quality of the components and the absence of 'permanent' fixing methods, one demolition contractor revealed that large elements are not always able to be extracted complete, or in a size that is desirable, as previous building processes have relied heavily on site assembly without a view to eventual disassembly[83]. While this has the feature of reducing transport costs and offering more flexibility to the eventual user of the component, in reality the component is more prone to damage and to pieces being lost. It also has the effect of increasing the cost of deconstruction.

It is also useful to consider damage prior to extraction. This can have consequential effects on the salvage and reuse of those components. As background, New Zealand has an environment that is harsh toward building materials[84]. The country enjoys very clear skies owing to strong and consistent winds that remove pollution. Through this clean atmosphere the ultraviolet light is strong and can cause early aging of building materials. UV is particularly damaging to paint and other protective coatings and to organic materials and compounds, particularly those which contain volatiles. Coupled with the often rapid changes in temperature and moisture that can occur, and the persistent wind in many areas, exterior components are prone to early deterioration. This combination of factors can affect the condition of exterior components from buildings. Domestic scale buildings are often not well maintained in New Zealand[85]. This too can lead to damage of components prior to or during extraction. It may be that the effects are not fully apparent until the component is reused elsewhere.

3.5 Component Recertification Requirements

The New Zealand building industry operates under a performance based building regulatory system which is both a blessing and a curse for the reuse of building components. The opportunity to reuse components exists within in the regulatory regime, however determining the capability of a recycled component to meet the objectives set out in the code is difficult.

Two main durability requirements set out in the New Zealand Building Code can affect the potential to reuse components. All elements that can be accessed for maintenance without affecting the structure of a building must have a minimum life expectancy of 15 years, although it is generally acknowledged that owners and the industry as a whole expect that they will last longer than this. Structural elements, that is every part of the building that is necessary to allow it to remain intact, or those elements that are not accessible for replacement, must meet a minimum life expectancy of 50 years.

A Territorial Authority can require components offered for reuse to be certified by a recognised expert in the field as being able to satisfy mandatory durability criteria. Generally this is only required when the building inspectors are not able to be convinced by visual inspection that the element is sound. In many cases the Territorial Authority (TA) is able to use a fair degree of discretion. In some cases a Territorial Authority may require the designers to certify the reused item if no other method of certification is available. This is particularly the case when dealing with the reuse of structural members. It is not likely that the TAs will require destructive testing to be carried out, but they will require and rely on the expert advice of others[86].

Changing and evolving codes and standards can affect the reuse of components. Several categories of components are affected by this in New Zealand. Glazed components must meet the current safety requirements and there appears to be no room for relaxation of these standards. One materials merchant was told by inspectors from the Commerce Commission to dump a load of glass doors that were found to have uncertified glazing[87].

It does not appear that it is necessary for components to comply with changed regulations in areas other than 'falling' under the broad heading of safety related issues. For example, reused windows, provided they meet safety standards of the day would not currently be required to meet any new thermal performance criteria.

The question of liability in the current New Zealand context is one that causes most professionals to take a cautious approach. and affects the extent to which components are recovered for reuse.

The reuse of building components in New Zealand appears to have a good foundation, with a stable base in the domestic scale of building. Reuse of components in commercial buildings is more variable in locations around the country. The reuse of components is affected by the buoyancy of the economy and the level of building activity. Nonetheless, the potential for greater reuse of components exists within the building industry.

Component Reuse in NZ, Case Studies:

There are a small but growing number of architects in New Zealand who deliberately incorporate ideas of reuse into their designs such as Melling Morse Architects, Symbiosis Architects and Matthew ter Borg Architect.

Alan Morse, of Melling Morse Architects designed the St John's Presbyterian Church Hall in Wellington in 1983. The clients required a new building which preserved the character of the old. The strategy therefore, was to stockpile the components of varying age and quality from the old building and by repairing, rearranging or discarding, create a new building from these components.[88]

The original timber hall, along with the existing timber gothic church was built in the late 19th century by Thomas Turnbull. Alan Morse was commissioned in 1981 after estimates for the construction of a conventional new hall and demolition of the old proved to be beyond the church's budget. An estimate suggested that by reusing facade sections, gabled fronts, porches, windows, wooden linings and flooring and roof timbers as verticals for new portal frames, a recycled hall could be constructed for less than a quarter of the cost of a new hall.[89]

Deconstruction began in April 1982. The upper floor was deconstructed first with its facades separated into panels centered around the gothic windows or the gabled ends. Panels, roof trusses, wall and ceiling linings, internal partitions, doors and windows were all carefully numbered and stored according to a code related to the new construction.

The resulting building was successful in retaining the proportions of the old hall and creating a strong sense of place while providing a cost effective, resource and waste efficient solution (Figure 9).[90]

Figure 11 Reconstructed St John's Hall, Wellington[91]

Symbiosis Architects was commissioned in 1998 to carry out a major renovation and upgrade of a 1950s house in Wellington. The existing house was built with high quality, durable materials but was poorly planned, crudely built and did not fit the client's existing or planned future lifestyle.[92] The major imperatives of the renovation were to incorporate deconstruction and waste minimisation strategies where possible.

As many of the existing building components were reused in the renovation as possible. All of the existing windows and exterior doors were reused except one of each. All interior doors were reused except for three, which had boring insect damage. It was noted that the reuse of windows and exterior door components resulted in financial savings, as well as considerable resource savings (Figures 10 and 11).

Figure 12 Lambie House, reused windows

Figure 13 Lambie House, reused door

The existing roof was altered and retained, existing native timber flooring was retained and existing fittings and fixtures were reused where possible. The original intention was to reuse as many of the cedar weatherboards as possible that had to make way for the extension, however a recovery rate of just 40% was achieved.[93] This was assumed to be due to insufficient care or skill exercised by the builder in the deconstruction process, and served to illustrate the need for clear understanding of intentions and expectations and suitable training for deconstruction.

The project was a successful example of resource conservation and waste mimimisation with only minimal amounts of materials going to landfill.[94]

Matthew ter Borg, an Architect based in the Wellington region is involved in the deconstruction and reconfiguration of a pre 1960s home in Rotorua which is being moved to make way for a highway realignment (2003).

The home was purchased in the 1960s and was restored, renovated and added to in the following decades predominantly using reused materials either from the original home or local buildings which were being demolished. Out-buildings were similarly constructed from recycled materials.[95]

The Territorial Authority (TA) would not permit the lifting of the building for removal and this, combined with different requirements for a building on the new site lead to the decision to deconstruct the home and all out-buildings and reconfigure as many of the salvaged components as possible into a new house, reminiscent in form to the existing house. Additional materials including timber flooring and ceramic tiles for the new construction have been sourced from a government building demolition project in the local area.[96]

The proposal is to reuse windows, kitchen joinery, bathroom and laundry fittings, fire place and surround, interior doors and ceiling linings. Where new windows are to be used, window frames are to be made from recycled timbers.

The clients are to demolish the building themselves to assure maximum materials salvage. The architect says of the project ‘what will be intriguing to see is if the same unpretentious cottage character and cosy interior feeling will be recreated.[97]

CHAPTER 4: ENHANCING MATERIALS RECYCLABILITY:

4.1 General Issues of Materials Recycling in NZ

The recycling industry in NZ is relatively large, being comparable in export earnings to the wine industry and the organic produce industry.[98] Zero Waste NZ has identified in a preliminary scoping study of the NZ recycling industry[99], that NZ exports over $100 million[100] of recycling related commodities ($70 million), products ($7 million), technologies ($6 million) and consultancy ($3 million) per annum. They believe this is set to rise.[101]

The recycling industry in NZ is recognised as complex and variable and has little practical support from central government. It is characterised by medium to small businesses and individuals. The industry income is made from a variety of services, products and activities dealing with commodities (such as metal and glass etc), products made from recycled materials (such as building materials utilising recycled plastic), technology (machinery such as mobile concrete crushers) and expertise (waste minimisation / recycling consulting). Exact numbers and sizes of businesses are not available.

General recycling issues such as contamination of materials to be processed, high volume low value materials, economic viability and value and resource depleting down-cycling all apply to NZ.

A specific and important recycling issue in NZ is the long distances that materials for recycling have to travel in some cases. These transportation costs can affect economic viability. Most major recycling processors are in the Auckland region of the North Island. This has implications for the economic viability of recycling for regions further away or on different islands. The net environmental benefit may be negative in instances where heavy weight materials such as concrete for example have to be transported even relatively short distances for recycling.

Export prices provide benchmarks for collected materials. Due to the negative economic implications of internal transport costs between islands, many South Island materials collected for recycling end up being exported. Landfill charges which do not reflect the true cost of dumping, combined with low cleanfill charges in some areas, also undermine the viability of the recycling industry in NZ.[102]

Due to the low population of New Zealand and the current economic barriers discussed in chapter nine, not all materials which could be recycled in NZ are actually recycled. This is due to low actual economic returns or because in many cases, machinery or processing systems have not been purchased or developed for NZ conditions, and building styles. There are some notable exceptions to this however, such as machinery developed by Ward Demolition Contractors in Auckland which is used locally and is also sold overseas[103].

4.2 Recycling Issues for Specific Materials

Concrete:

Concrete is crushed in some areas of NZ for reuse as hardfill. This practice is well established, even prevalent in the Auckland region and is being adopted or investigated in many other urban centres.[104] Enquiry and research into the use of recycled concrete aggregate, for use as roading sub base is ongoing and is particularly relevant in the Auckland region where a major roading development is shortly to commence. In the Auckland region in particular, it is becoming more economical to use recycled aggregate in concrete elements such as paths and driveways and in smaller developments. This is attributable to increasing costs of virgin aggregate when purchased in small quantities, due to greater transport distances from quarries that are further away from Auckland city that was previously the case. It has become more economical in some parts of Auckland were quarries may have been, to use this land for subdivisions or other developments[105]. Water table quality preservation and landscape conservation of Auckland's multiple volcanic cones have also been cited as reasons for the decline in quarrying within the city limits.

There is currently no known research into using crushed concrete as aggregate for building structures being carried out in New Zealand. In part, this is due to the stringent earthquake code requirements for concrete strength but also due to the generally plentiful supply of virgin crushed stone aggregate in most areas of the country. The Aggregate and Quarry Association of NZ (AQA) as well as the NZ Mixed Concrete Association (RMCA) advocate and encourage environmental initiatives and concrete recycling. It has been suggested however that there is some resistance to using recycled materials from engineers in the field[106] and cement manufacturers.

The AQA notes that there is an increasing trend towards on-site recycling of demolition materials for use as backfill or base course due to the increasing availability of mobile concrete crushing machines.[107]

Moves to specify the use of recycled aggregate in NZ have been relatively slow despite comprehensive studies and testing undertaken by the Building Research Association of NZ (BRANZ) and some councils endorsing its use in footpaths and edging[108]. According to Ward Resource Recovery 'the introduction of quality controls ensures that recycled aggregates will give a comparable performance at the same or less cost of virgin materials.'[109] A BRANZ report also states that its research '…shows that recycled aggregate concrete is able to be produced in New Zealand, and that it is technically feasible'[110].

Some demolition concrete waste is being crushed back into an alternative high grade aggregate and base course for roading following the issue of Transit New Zealand (the crown entity managing the national roading system in NZ) guidelines.[111] Transit NZ has recently sent out a benchmarking survey on recycling to their staff. The aim was to get an idea of what recycling is done on New Zealand state highway and to be able to show trends in the use of recycled materials in the future. Results are being compiled at present (2003). It is perceived that 'these results will certainly contribute to incorporation of more recycled aggregate in roading, as will other transit initiatives, such as Transit's waste minimisation policy (currently under development) that will include a focus on recycling, and substitution of locally available and alternative materials'.[112]

Aside from universal concrete recycling issues, unique NZ conditions mean that regional contexts have an important impact on the economic and environmental viability of concrete recycling. Transport costs, landfill disposal charges, regional waste policy and availability of virgin aggregates all vary from region to region in NZ. Supplies of good quality virgin aggregates now have to be quarried from more distant quarries in the Auckland region than was previously the case[113].

Contaminants are an additional recycling issue. AQA notes on the regulation and specification of recycled concrete state that contamination with other materials such as asbestos will render entire batches of recycled concrete unusable[114]. Similarly acceptance percentages of organic material and other contaminates are detailed in these notes. Efficient sorting of piles of concrete is therefore essential. Recycling Operators of New Zealand (RONZ) has developed a series of signs to aid in sorting, one of which is concrete. Only reinforced concrete is crushed. Concrete masonry and blockwork is not crushed and recycled.

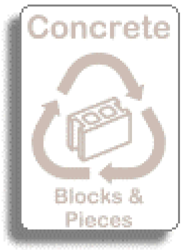

Figure 14 Concrete recycling sign developed by RONZ

Brick:

Until recently brick has not been in common use in New Zealand, apart from its use in chimney stacks, and in some more geologically stable areas such as the Waikato. This is due to its inability to withstand earthquake shocks. Currently it is used almost entirely as an external veneer attached to earthquake resistant structures. Brickwork in early structures used lime-based mortars, making recovery comparatively easy. Recycled bricks from such sources are sought after, mainly for use in landscaping. Because of their rarity, recovered bricks are able to command a price premium and cost approximately the same as new bricks.

Virtually all brick work built today in New Zealand uses cement based mortar, which is stronger than the bricks it connects. This causes fracture of the bricks during attempted separation of bricks from their mortar, rendering the bricks useless. Therefore supplies of recycled bricks are set to decline. There is no known research being conducted in New Zealand on flexible, lime-based mortar which would be able to resist earthquake shocks and facilitate brick reuse. Cement mortared brickwork is most likely to be recycled as hardfill.

Timber:

Issues that effect timber recycling and reuse in NZ generally relate to contamination, care in demolition, market demand, economic viability and chemical treatments. There are no known figures for the volume of construction timber recycled in NZ. It is expected however that reused timber must comply with all the standards and regulations relevant to the use of timber.[115]

Until the 1960s most timber used in New Zealand buildings was the heartwood of native hardwoods. This timber is very durable and even after being incorporated in a building for a century or more it is still suitable for recycling and in this reused state is likely to outlast currently plantation grown softwoods. Boring insects can attack such timbers but severe attack is generally restricted to small amounts of sapwood which was inadvertently retained with the heartwood. Generally such attacks are obvious and this timber is not reused.

From the 1960s onwards as native timber became depleted, imported tropical hardwoods and imported softwoods were utilised until plantation grown Radiata Pine and Douglas Fir came onto the market. The most common plantation grown wood used for framing, Radiata Pine, needs to be treated with chemical preservatives to be durable when exposed to exterior conditions. It is not always obvious which Radiata Pine has been treated and which has not. Precautionary principles apply and it should be regarded as a hazardous material and dealt with accordingly.

PCPs were used initially and currently copper chrome arsenate treatment is common even today. This does not seem to play a large part in inhibiting reuse and recycling. The primary reason which restricts the reuse of softwood timbers, including Radiata Pine is that despite a cost differential in the material, recycled timber is generally regarded by builders as being more difficult to use than new timber. Therefore in overall terms there is no economic benefit to them.

In New Zealand in April 2002, any form of logging in publicly owned native forests was banned. Some of the rarer species of trees had been protected before this date. Small quantities of native timbers are still logged from private forests or are recovered for use from swaps and river beds. These supplies do not however meet demand. Based on anecdotal evidence from various materials salvagers from around the country, this has led to greater demand for recycled native timbers, desirable for their appearance and durability characteristics. The salvage of native timbers is a very economic enterprise in NZ. There are a number of NZ salvage businesses that re-machine timber to add value, consistency and quality in resale[116].

Recovered native hardwood is sometimes used for large trusses or beams, but is more commonly used as flooring, furniture and other high-grade timber products[117]. While some of these products are made in New Zealand, a considerable proportion is exported for these purposes. In discussions between Forest Research[118] and other international deconstruction researchers[119], it appears that NZ may be one of the few countries that reuse building timbers for high-grade furniture[120]. High price premiums are obtained for recycled native timber used for new timber products.

Low cost imported furniture is a major barrier to recycling domestic native timbers, despite the ban on native logging which increased demand for native timber. With increased demand came an increased price for timber to produce furniture, forcing many rimu furniture manufacturers into modifying and staining virgin radiata for furniture manufacture, to maintain supply to their target markets.[121]

A lack of a grading system and therefore of clear liability in the specification of reused timber in structural applications is one reason why little reuse of softwood and native timber which is suitable for structural use occurs in NZ. This may mean that structurally sound salvaged timber is down-cycled into low value products such as wood chips etc unnecessarily. Generally, non-native timber is not reused. Much of this non-native timber is chemically treated which also limits its recycling or even energy recovery potential. The available amount of waste sawdust, off-cuts and composite materials made from treated timber, exceeds demand by re-users or recyclers in NZ, however demand for bark, chips and shavings, generally from untreated wood may outstrip supply[122]. Often the problem is that it is not economic to transport 'waste' materials to where they could be used in NZ.

In a recent Forest Research study report[123] all NZ demolition contractors contacted reported that radiata pine framing could not be economically recycled. If radiata pine was reused, it was often only as concrete formwork boxing. The reasons given were the low cost of virgin radiata pine and also because of the problems associated with removing nails.[124] The same study report revealed that although there are commercial 'guns' available for driving out old nails in recycled timber, they appear to not be in favour with NZ contractors.

Lead based paint[125] and other coatings applied to timber, generally do not prevent reuse as whole components in NZ. There are no regulations preventing the reuse of a lead painted component although there are strict guidelines concerning their stripping and disposal as detailed in chapter 5. Paint from old timber elements is often removed by 'dip-stripping'. This is an easy process for the removal of lead and oil paint, but is less effective in the removal of water based acrylics. The stripping process darkens the timber, which can be restored using oxalic acid.[126] Once spent the chemicals go to a hazardous waste treatment facility, where the chemicals are 'de-watered', resulting in water and chemical sludge. The water is treated and goes into the sewage system. The chemical sludge contained the lead is neutralised (by the addition of more chemicals), and bound with other substances such as lime and sawdust to make it solid. After analysis to check that the resulting material complies with Ministry for the Environment landfill acceptance criteria, it goes to landfill.[127] Another method used in NZ is to coat the lead paint with a caustic paste and wrap the element in a protective coating. After approximately three days the wrapping is removed and the paint comes off with the paste.

Currently in NZ weathertightness is a major issue in the building industry. Prevalent modern construction practices in NZ, with certain methods of building and related selection of materials may render timber from these buildings un-reusable or un-recyclable due to rot and mould. Appropriate use and storage of wood or timber elements is crucial to its potential reuse and is a NZ specific issue.

Substantial quantities of chipboard and fibreboard products are manufactured using waste products in New Zealand. However these wastes are generally sourced from pre-consumer timber manufacturing wastes rather than from post-consumer sources such as construction and demolition wastes. Unless such industries can access clean, untreated and uncontaminated timber wastes this situation seems unlikely to change. The reutilisation of 'urban wood' from old buildings for particleboard and MDF is also affected by the fact that there are plentiful virgin plantation timbers in New Zealand.[128]

Use of adhesives/glues as well as screws/nails is a common practice for fixing flooring. These glues are typically thermoplastic that have a high level of rigidity in the conditions found in most residential and commercial buildings. Separation of such bonded materials is a difficult and destructive process. Use reversible fixings in the fastening of floors, walls, ceilings and roofs would facilitate easier renovation or deconstruction[129].

Plastics:

Plastics New Zealand Incorporated is the national industry group for plastics manufacturers, raw material suppliers and recyclers in New Zealand. They contend that there are specific circumstances that set the plastics industry in NZ apart from plastics industries in other countries. No polymer resins are manufactured in NZ. They are all imported, making the plastics industry in NZ solely a processing industry.[130] About 21% of plastics processed in NZ are for construction purposes[131], however recycling of construction plastics is very limited in NZ[132]. There is little plastic product manufacturing in NZ from recycled plastics, but some does exist in the construction materials sector, such as one company that uses flexible PVC from cables to make floor matting.[133]

Plastics are used in NZ construction for short term purposes, such as packaging of materials and components; for medium term uses such as bathroom and kitchen fittings, flooring and guttering; and for long term uses such as electric cabling, plumbing, and cladding. The diversity of types of plastics used in construction, results in both a wide variety of barriers and opportunities for recycling and reuse.

Plastics NZ advocates increased recycling of plastics in the following ways: advanced design to facilitate recycling, material identification to aid sorting and collecting, stimulation of new markets to ensure an end-use for recyclate and the investment in new technologies to support material recycling and new techniques.[134]

Particular issues for plastics recycling in NZ can be divided into economic, behavioural and technical issues. NZ's small population and geographic isolation may have significant effects on plastics recycling in NZ.

Transport costs were identified as the largest cost in recycling plastic.[135] This is due to NZ's geography and demography. Most plastics recycling facilities are in the north or central area of the north island. Recycling of some plastic types does not occur at all in New Zealand. The main plastics export markets for NZ are in Asia.[136]

Market demand for recycled plastics is small in NZ due to the relatively small population. Quantities in terms of exports, may at times be too small to be economically viable when international market demand, raw material costs and shipping fees are considered[137].

A key issue in plastics recycling is the removal of contaminates which leads to increased costs in collection and sorting. This has direct implications in terms of C&D plastic recycling potential.

Another issue is the lack of labeling and therefore ability to identify plastics for appropriate recycling. Plastics used in construction are generally not labeled in NZ although Plastics NZ has a resin identification code. They advocate the use of ISO abbreviations or relevant product standards as identification codes for the construction industry.[138]

The economic viability of plastics recycling is largely determined by market demand. It has been suggested that inconsistent feedback and communication within the industry may have implications in terms of effective and efficient development of design for recycling or disassembly in new products to facilitate waste minimisation.[139] Plastics NZ, as part of their sustainability initiative is planning a workshop for September 2003 to provide an opportunity to form better linkages between manufacturers, consumers and recyclers. It is expected that the construction industry will take part in this[140].

Further technical and infrastructural capacity would need to be developed by NZ plastics recyclers to reuse the types and grades of plastics used in construction and end uses for recovered construction plastics need to be investigated.[141]

Because of the small quantities of plastics available for recycling in NZ, some technological innovations which are applicable to larger overseas markets are not an option presently in NZ. Plastics NZ states: ‘While the relatively small volumes of recyclable material available in this country may make such developments too expensive to establish here, the local industry continues to monitor, investigate and commit resources to seek a technology, or technologies, that would be applicable to the New Zealand situation.’[142]

Glass:

Approximately 4000 tonnes of bottle glass is recycled in New Zealand each month[143]. Window glass, the most common construction glass, is in general not recycled in NZ due to complex coatings, mixes and diverse chemical additives, and economic viability issues, although some is crushed and used as aggregate. There is one Auckland based company[144] that recycles sheet glass into sand blasting media and into fibre glass insulation for domestic use and for high temperature industrial applications. They recycle approximately 300 tonnes of sheet glass per month. Glass is collected free of charge around the Auckland region from various demolition activities, framers and manufacturers to prevent this material going to landfill. The Managing Director of the company estimates that there is 50% more glass available for this kind of recycling in the Auckland region alone, however local market demand is not there for the resulting products. Export of materials to satisfy markets beyond the relatively small NZ market has been considered but limited market potential and other economic factors are regarded as barriers. The current situation seems unlikely to change unless incentives are put in place to encourage the reuse of this material. It was considered that a directive from local councils to minimise dumping of sheet glass would be needed to increase the economic viability of sheet glass recycling in NZ in higher quantities.[145]

RONZ has developed a series of window glass signs to aid in sorting at the construction or demolition stages (Figure 13).

Figure 15 Glass recycling sign developed by RONZ

Plasterboard:

There is currently no plasterboard recycling occurring in NZ. The sole manufacturer of plasterboard in NZ, Winstone Wallboards has carried out research into the potential of recycling plasterboard. Recent research suggests that sorted construction plasterboard waste could be economically recycled in Auckland, based on logistical considerations and the amounts of waste available in the region.[146] The technology that would enable Winstone Wallboards to recycle pre and post consumer plasterboard waste does exist currently and the employment of such a system is estimated to have a payback of only three years.[147] It is unclear why recycling of plasterboard is not undertaken in NZ. Contamination in recovered plaster board, presumably from demolition sources, or imported plasterboards with different chemical compositions, as well as difficulty in sorting of different plasterboard types may be an issue according to anecdotal evidence. It is however not only technically but economically feasible to recycle offcuts from construction activities in NZ.[148]

In the late 1990s there was a patented product put forward for appraisal called the DozLock Clip. It was estimated to reduce the number of plasterboard sheets needed for construction by up to 10%. The clip allowed offcuts to be used by clipping together offcuts between studs. This would have translated to less virgin resource use and less plasterboard waste going to landfill. This product however was not supported by Winstone Wallboards, perhaps due to potential lost sales revenue, and was not successful.[149]

Plasterboard is defined by the Ministry for the Environment's 'A Guide to the Management of Cleanfills'[150] as 'conditionally acceptable'. This means that it is generally not allowed in cleanfills due to leachate and off gassing characteristics while decomposing. It is not defined as hazardous waste however and is permitted in municipal landfills. More stringent regulation of which materials are permitted to go to cleanfills and more realistic costing of landfilling, may see increased pressure on the manufacturer to accept the return of this waste in pre and post consumer form, or to investigate other recycling strategies.

Metals:

Metal recycling is well established in NZ with highest recycling rates and export earnings of any other recycled material[151]. It is estimated by a leading metal exporter based in NZ that about three-quarters of metals salvaged are recycled within NZ[152], and that the rest is exported. Approximately 60% of all metal recycled within NZ is ferrous, and of the approximate 150,000 tonnes of metal that is recycled annually, approximately 13% is from C&D activities.[153]

Some quantity of most types of metals are recycled within New Zealand. However, due to economic factors and limited local market demand, the majority of some types of metals are exported to other markets, either as scrap or in a partially recycled form[154]. An example of this is stainless steel which is collected, partly processed in New Zealand and then exported for melting down. Some metal recycling companies will provide free bins for collection of sorted or unsorted scrap metals to building sites depending on what quantity and type of scrap metal is expected to be recovered.[155]

The Scrap Metal Recycling Association of New Zealand is the national scrap metal recycling industry association. Members range from individual scrap collectors through to large processors and end-users of scrap metal. The majority of members deal primarily or exclusively in metals.

Two NZ specific conditions that distort the metal recycling market in NZ are a scarcity of scrap zinc[156] and the large amount of aluminium available in NZ. High prices are paid for scrap zinc while low prices are paid for aluminium. This situation is made worse in the case of aluminium due to the extensive use of alloys in the construction industry, which are more difficult to recycle. Some window manufacturers now use 100% pure aluminium to facilitate future recycling and use this fact as part of their marketing of their products.
Some metals are reused before they are recycled in NZ. Some high value construction components such as steel 'I' beams are also salvaged for reuse rather than recycling.[157] Deconstruction means steel components in particular can be more easily reused because damage (bending, warping etc) may be avoided during the more careful disassembly process.

4.3 Deconstruction as a Method for Increasing Materials Recyclability

Deconstruction rather than demolition, allows more careful sorting of materials at the site. This means that materials are more easily recycled because the intensive sorting process is minimised and some contaminants are prevented from entering the sorted waste stream. Interest in site sorting on construction sites is increasing in NZ according to industry opinion,[158] and is evidenced by various case studies and projects that have been completed or are currently in the development stages. Examples of these are the case studies carried out by Sinclair Knight Merz for Target Zero and the Christchurch City Council[159] and the REBRI case studies in Auckland[160] which are summarised in Chapter One.

As in many parts of the world, NZ recyclers recognise the economic benefits of separation at source. Often it is the factor which makes the difference between economic recycling of the product at all. There is some evidence that separation at source is being taken seriously on some building sites[161] as markets for some wastes expand and landfill charges continue to rise. A number of cleanfill operators now find it profitable to empty out skips into a yard area and pick over them to recover building materials rather then simply unloading them directly into a cleanfill, which is generally a euphemism for a hole in the ground.

Deconstruction's wider implications of closing life-cycle loops particularly in terms of resource use are becoming apparent in some sectors of NZ production, particularly in the industrial design field. Fisher and Paykel, NZ's only appliance manufacturer, has for example a reverse logistics system in place and the disassembly line is making profit in its own right. Second hand appliances are collected throughout the North Island of NZ. Dismantlers provide feedback to designers to enable future ease of disassembly. While there are no known counterparts in the construction and demolition industry, some of the principles and strategies used in the industrial sector may be able to be transferred to construction and demolition initiatives.

Deconstruction enables greater recycling and reuse because large sections or components are less likely to be damaged or broken up into pieces, which means they may be more easily reused. Details and examples of such reuse are detailed in the *Component Reuse in NZ, Case Studies* section in Chapter 3.

Similarly careful deconstruction processes must be in conjunction with careful storage. If things aren't left out to be weathered and get dirty, they can be reused more easily. An example of deliberate and careful storage of materials and components is the St John's Hall project in Wellington by Melling Morse Architects as detailed in Chapter 3.

CHAPTER 5:
ENVIRONMENT HEALTH AND SAFTEY

5.1 Structural Evaluation, Work at Height, Job Hazard Analysis and Other Safety Issues

Information about worker training and safety, and planning issues are outlined in Chapter Two. Occupational Health and Safety (OSH) documents and approved codes of practice have been developed to specifically address structural evaluation, fall protection, hazardous substances identification and handling and other safety issues. All work where employees are exposed to the risk of falling more than five meters must be notified to OSH at least 24 hours before the work commences. Of major significance are the Approved Code of Practice of Demolition, 1994[162], and other supporting guidelines such as Approved Code of Practice for the Safe Erection and use of Scaffolding[163] and Approved Code of Practice for Cranes[164].

Hazardous Materials

There is NZ specific legislation in place to deal with the handling and disposal of hazardous waste. The Ministry for the Environment (MfE) is responsible for the development of policy controlling the disposal of hazardous substances[165] and local government is responsible for the practicalities of waste management. The MfE monitors their management of waste and landfills. There is a general duty under the Resource Management Act (RMA) that every person must avoid, remedy or mitigate any adverse effect of their activities on the environment. This applies to the disposal of hazardous waste.

The Hazardous Waste Management Programme of the MfE was established in 1997 to improve the management of hazardous waste in NZ.

The Ministry for the Environment states:

> *'A policy framework for the management of hazardous waste is being developed. It will incorporate a mix of mechanisms for managing hazardous waste, from education and guidelines to regulation, as required. A key component of the hazardous waste management programme is a national definition of hazardous waste… The purpose of the definition is to provide consistency in defining hazardous waste for the purposes of resource consents, waste management planning, and other aspects of hazardous waste management. The current definition is in draft stage and will be finalised following consultation.'*[166]

The Environmental Risk Management Authority known as 'ERMA' (established under the Hazardous Substances and New Organisms Act - HSNO) is only responsible for the regulation and approval of new hazardous substances rather than for hazardous waste. However a hazardous substance is defined by ERMA as:

> *'Any substance that may be: Explosive, flammable, able to oxidise, corrosive, toxic or eco-toxic'.*[167]

Occupational Health and Safety (OSH) as part of the Department of Labour, has various regulations and approved codes of practices in place to deal with safety and health while removing and handling hazardous materials. It is expected that all codes of practice will be reviewed in the near future to come in line with the new Health and Safety in Employment Act of 2002.[168]

Approximately 282 000 tonnes of hazardous waste are landfilled in New Zealand each year and 70 000 tonnes are accepted at treatment facilities, although this figure from the Ministry for the Environment is based on data from different sources that define hazardous waste differently[169]. There are no known statistics on what proportion of this is attributable to C&D related materials.

The main hazardous materials dealt with by the demolition or renovation industry in NZ are: asbestos, lead based paint, PCPs and treated timber, and increasingly toxic molds[170] and fungi which develop in buildings which have weathertightness problems. MfE has produced a document called ‘Landfill Acceptance Criteria for Wastes with Hazardous Properties – Issues and Options’.[171] This can be used as a guideline for landfill operators and councils. There are trained and qualified asbestos, lead paint, PCP and other hazardous materials removal specialists in NZ. Some of these are incorporated into larger demolition firms and others work independently.

During the deconstruction process it is particularly important to have up-to-date and accurate information so that hazardous materials are not accidentally uncovered. Hazard identification and disposal pre-planning are important parts of the pre-deconstruction process

Contamination can lead to other materials being rendered unsuitable for reuse or recycling. (For example: if asbestos contaminates concrete rubble at all, rubble will not be accepted for use as recycled aggregate in NZ.)

OSH has prepared guidelines related to various hazardous materials and the safe management of their removal and disposal. Guidelines are different for different materials. Most have been prepared as part of the Health and Safety in Employment Act[172]. These are as follows:

- Guidelines for the Management and Removal of Asbestos[173]
- Asbestos Exposure and Disease Notes for Medical Practitioners[174]
- Guidelines for the Medical Surveillance of Lead Workers[175]
- Lead-based Paint - Repainting[176]
- Guidelines for the Management of Lead-Based Paints[177]
- Approved Code of Practice for the Safe Use of Timber Preservatives and Antisapstain Chemicals[178]
- Working with Timber Treatment Chemicals[179]
- Approved Code of Practice for the Management of Substances Hazardous to Health (MOSHH) in the Place of Work[180]
- An Introduction to the Guidelines for Workplace Health Surveillance Management of Substances Hazardous to Health (MOSHH)[181]
- Workplace Exposure Standards Effective From 2002[182]
- Health and Safety Guidelines on the Cleanup of Contaminated Sites[183]

The OSH document: ‘*The Approved Code of Practice for Demolition*’[184] of 1994, states that the main hazards to health during demolition work are: asbestos dust, lead poisoning, toxic fumes from gas cutting of galvanised steel, toxic substances present on site, synthetic mineral fibres, polychlorinated biphenyls (PCBs), and silica dust.

Table 2 Mitigation of health and safety issues when dealing with hazardous materials according to OSH

Mitigation of health and safety issues when dealing with hazardous materials in NZ according to OSH:
Identifying the hazard
Accessing the hazard
Managing the hazard - which may include:
Ensuring appropriately trained people doing the work.
Removing, isolating or minimising the hazard according to OSH, Ministry of Health and MfE regulations, guidelines and best practice
Notifying OSH of hazard in some cases
Contain and transporting the hazard according to OSH, Ministry of Health and MfE regulations, guidelines and best practice
Keeping hazardous materials separate from other materials.
Disposing in an appropriate manner
Banning the reuse of materials containing hazardous materials
Checking to ensure method of management is effective

The Public Health Association of New Zealand (PHA) is a voluntary association, which also provides some information and advice about hazardous materials and substances. The PHA NZ was at first affiliated with PHA Australia, and then formed its own organisation in 1989 so it could focus more fully on New Zealand issues. PHA NZ is a member of the World Federation of Public Health Associations.[185]

5.2 Asbestos

From the 1960s to the 1980s asbestos was used in New Zealand in the construction industry. In 1984 it was acknowledged as hazardous to human health and was banned. The most common building materials containing asbestos in New Zealand are cement cladding products, textured ceiling coatings, thermal insulation, fire protective coatings and vinyl flooring.[186]

Work concerned with the removal of asbestos is regulated under the Health and Safety in Employment (Asbestos) Regulations 1998[187]. Minor amendments were made to these regulations in 2002.

OSH document 'Guidelines for the Management and Removal of Asbestos'[188] outlines mandatory requirements and guidelines for the safe removal and disposal of asbestos products. OSH has also produced a number of other documents and guidelines relating to the removal of asbestos products.

Before 1998, it was mandatory to notify OSH of all asbestos work, defined as 'restricted work'. After a change in legislation in 1998[189], which changed the definition of 'restricted work', it was made non-mandatory to notify the removal of matrix (that is non-friable) asbestos products. Non-friable products are ones which do not easy crumble such as flooring tiles.

Asbestos removal companies and specialists that deal with friable asbestos removal must have a Certificate of Competence for restricted work issued by OSH. They are required to be recertified every four years. The definition of 'restricted work' covers different situations where asbestos is present. There are defined Workplace Exposure Standards related to asbestos that must be adhered to. Where restricted work is to take place, an employer is required to notify OSH and give reasonable notice of the activity. An explanation of methodology, equipment used and precautions taken is to be included with notification. Exact planning and programme requirements are detailed in the 'Guidelines for the Management and Removal of Asbestos' document.

All workers who remove asbestos are required to be trained to work with asbestos and be aware of the reasons why asbestos is a hazardous material. People are trained on-the-job and can work towards a 'certificate of competence for restricted work' from OSH, which allows them to remove friable asbestos without direct supervision from another holder of the certificate (such as their employer).

Property owners (with the exception of home owners) and employers are expected to identify asbestos hazards and take steps to mitigate any health or safety problems through risk evaluation, recording and communication of information, labeling of asbestos on plans and hazard control through the adoption of an asbestos management programme. Workers are required to wear and use appropriate safety equipment. Regulations for the laundering of such clothing or equipment are also strictly regulated.

Where possible, it is required that any asbestos removal in a demolition project happens before any other demolition work begins. Details of decontamination procedures are again outlined in the guidelines.

Various techniques are outlined in the guidelines to minimise dust escaping from asbestos products and mitigate hazards. These include spraying on of water or total saturation of certain products. Dry removal is considered to be the least desirable method for removal. It is required in some situations to monitor asbestos levels in the air. Visual inspection by an independent person or agent is required before reoccupation and is the responsibility of the owner.

All asbestos material to be disposed of must be contained in two layers of sealed plastic bags and labeled. This must be buried under a metre of earth[190] in a managed landfill. Any vehicles transporting asbestos must also be labeled. Reuse and resale of products containing asbestos is not allowed under these guidelines.

5.3 Lead Based Paint

The use of lead based paints was common in NZ until the 1980s[191].
Under the Health and Safety in Employment Act, employers are required to 'take all practical steps' to ensure that employees are kept safe from hazards. Lead is considered to be a 'significant hazard'. The OSH document 'Guidelines for the Management of Lead Based Paint'[192], is not legally enforceable but it is considered that 'all practical steps' includes following these guidelines.

With regards to deconstruction, OSH considers that workers in the demolition, deconstruction and salvage scrap metals industries are at risk of exposure to lead. Monitoring of employees *'working in a process where they may experience a blood lead level in excess of 1,5 ųmol/litre of whole blood are to be under surveillance until it can be demonstrated that excessive exposure in unlikely to occur'*[193], under sections 36 and 37 of the Health and Safety in Employment Act, a blood lead result of over 2.6 ųmol/litre whole blood must be reported to OSH.

'Lead Based Paint - Repainting'[194] is a pamphlet put out by OSH, and the Public Health Commission. The Steps for mitigating exposure to lead based paint are as follows: Wet sanding is the preferred method; debris, residue, dust to be wiped removed or vacuumed with a commercial vacuum cleaner in all cases; abrasive blasting is not recommended; tungsten tipped scrappers are recommended for use; toxic dust respirators are to be worn; hair is to be covered; hands / face / clothing are to be washed; no smoking is permitted during removal of paint. Over-coating is permitted but is not considered to be a permanent solution. Extra precautions are to be taken around children and pregnant women.

Recommended disposal of lead paint residue is to wrap it up securely in a plastic bag or plastic sheeting, with tape or some other secure fastening and take it to landfill. For larger quantities disposal at a controlled landfill is recommended. Burning is not recommended, but is not prohibited.

There are no regulations in place preventing the resale or reuse of components that have lead paint finishes in NZ. Retail building recyclers may often wash and clean new items for resale, but may not strip them or be aware of what paint has been used.

Others

Toxic Fumes and Substances:

The gas cutting of galvanised steel, lead pipes or elements in the presences of degreasers can release a number of toxic fumes such as ozone, phosgene, cadmium, fluorides, carbon monoxide etc. Workers in close confines must use a fume extractor or be supplied with life lines and air supplied respirators[195]. Toxic substances that may be present on-site from previous industrial processes require specialist identification and advice in how to deal with them[196]. OSH and the Ministry of Health (MOH) have released a series of guidelines[197] under the Heath Act 1956 and The Health and Safety in Employment Act (amended 2002), which includes disposal methods for some hazardous chemicals in the workplace.

Synthetic Mineral Fibres:

OSH produced a document called 'Health and Safety Guidelines for the Selection and Handling of Synthetic Mineral Fibres' in 1994[198]. This outlines OSH's concerned with synthetic mineral fibres and how to deal with them in the NZ context.

Polychlorinated biphenyls(PCB's)

PCBs are a group of over 200 chemicals with a variety of names. They were never manufactured in NZ but were imported. They were banned as an import in 1986 and banned from storage and use in 1994/5 due to their high dioxin content. PCBs were

commonly used in transformers and capacitors and in ballasts in fluorescent lighting fixtures in NZ but are being phased out.[199]
Disposal of PCBs or PCB containing equipment must be in accordance with Toxic Substances Regulations 1983. The Ministry of Health's publication '*Safe Management of PCBs'* [200]reprinted in 1993 outlines NZ standards in the handling and disposal of PCBs. PCB waste is generally shipped to France for disposal from New Zealand.

Treated timber and Pentachlorophenol(PCP)

Most Ministry of Health (MOH) and OSH publications relating to treated timber, such as *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* of 1997,[201] *Approved Code of Practice for the Safe Use of Timber Preservatives and Antisapstain Chemicals* of 1994[202] and *Working with Timber Treatment Chemicals* of 1994,[203] apply to the safe handling and disposal of the treatment chemicals rather than to treated timber itself. These publications are non-enforceable but MfE and the MOH recommended that guidelines be followed.[204]

The MfE considers that it is more appropriate to destroy PCP and high dioxin waste than to landfill it. Alternative options are discussed in the MfE report *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* of 1997.[205] Waste containing less than 10 ųg/kg[206] of dioxins may however be disposed of at a class 1, 2 or 3 landfill[207]. It is acknowledged in the report that acceptance criteria in the guidelines are based on protection of human health and that there is very little data available for ecological risk assessment in NZ. Treated timber from construction offcuts or demolition activities usually goes to landfill in NZ and is not currently recognised as a hazardous substance.

Dust:

During demolition / deconstruction, considerable quantities of dust is released. The only known guidelines relating to dust are in OSH's Approved Code of Practice for Demolition' 1994. This states that 'Dust can be dangerous to vehicular traffic and a nuisance and health hazard to the general public. Watering down of debris including loaded vehicles, chutes, floors, stairs and other places, must therefore be carried out regularly.' [208] In relation to silica dust the same code of practice states: 'When the demolition work creates silica dust, proper precautions must be taken.' No precautions for workers exposed to dust are discussed although dust is recognised as a health hazard for demolition workers in several other countries.

Toxic Moulds and biological hazards:

Many New Zealand buildings have moulds which only become obvious during demolition / deconstruction. Spores from such moulds are considered to be allergenic triggers, however there are currently no detailed guidelines concerning safety of operatives or outlining disposal methods for general moulds

Recent developments in NZ with weathertightness problems in new buildings have bought the issue of toxic moulds to the attention of the public and industry. Stachybotris is one form of the moulds that is considered hazardous to human health. The Ministry of Health (MOH), The Building Research Association of NZ (BRANZ) and OSH have released information bulletins, but in-depth research and formulated guidelines to deal with biological hazards of this nature do not currently exist in NZ. The MOH and BRANZ recommend cleaning away mould as it appears with a commercial mould remover.[209] Legislation on methods of removal and disposal of stachyboitris and the licensing of operatives is currently in preparation.

CFCs / HCFCs:

CFCs were not manufactured in NZ. Use in aerosols was banned in the late 80s. In the early 1990s CFCs were still used in foams and in refrigeration/air-conditioning. MfE states: *'we believe that 10-20,000 tonnes of CFCs may remain in industrial refrigeration systems, air conditioning plant, car air conditioning systems and old domestic refrigerators.'*[210] The Ozone Layer Protection Act of 1996[211] prohibits the importation or manufacture of CFCs in NZ, and prohibits the release of ozone depleting gases during installation or dismantling of equipment. Recovery and reuse of CFCs is however permitted in NZ. CFCs to be destroyed are sent to Australia.[212] Imports of HCFCs are to be phased out by 2015.

CHAPTER 6:
ECONOMICS OF DECONSTRUCTION AND MARKETING OF USED MATERIALS

6.1 Assessing the Economics of Deconstruction

The economic framework within which architecture, construction and deconstruction currently operates in developer driven projects and speculative housing in the commercial sector, is one that is based largely on first-cost considerations and increasing time pressures. Buildings are expected to be designed, built and demolished as quickly as possible to maximise profit. Central government is changing its thinking towards life-cycle costing but legislation to support this stance is still under development.

Building Salvaged Materials Markets

One of the key economic factors affecting deconstruction is the economic sustainability or profitability of associated salvaged building materials markets.

There are different market sectors in building salvage in NZ. Domestic, one off, antique or high value items; larger volume materials; complete building systems from the commercial sector; and specialist equipment and machinery. Industry opinion suggests that domestic, high value items have a higher individual payback but that the turnover and volume of commercial or lower value products is larger and generates more profit.

It should also be noted that markets are affected by the variability of NZ local market conditions. The Auckland region, where approximately a third of New Zealanders live, is of a sufficient size to support a self-supporting functioning salvage market. In other regional centres there is sufficient development activity and waste management issues to support some salvage markets, but there are a number of significant barriers to a fully self-supporting regime. In rural or small town New Zealand some salvage markets exist but only in a limited form. Therefore any comments on markets must be viewed in this context of regional variation.

The market for reused building materials and components is undermined to some extent by imported raw or new materials which have been subsidised in different ways before arriving in NZ. This factor is dealt with in detail in Chapter 9.

Waste Management Framework

Local authorities rather than central government are in control and responsible for waste management in NZ. This has a number of economic implications for deconstruction. Different councils have different levies, incentives and charges related to resource use and waste minimisation. While some may see this as an appropriate and direct response to devolved democracy, the actual effect is to create market uncertainty, even market chaos, as the ‘rules’ change constantly in response to fluctuating political agendas.

Waste management is the responsibility of local territorial authorities but increasingly it is an industry with large private sector involvement[213]. This takes the form of contractors providing services funded by local councils on a contestable basis[214]. Cleanfills, where most construction and demolition waste is currently disposed of in

NZ, are often privately owned and have less management standards imposed on them than municipally owned and run mixed waste landfills.[215] Some control is exercised however as they have to comply with permits issued under the Resource Management Act. Permit conditions vary however between councils and compliance verification is also very variable. In Auckland numbers of cleanfills with in the urban area are deliberately being reduced by a policy of non-renewal of licenses by Territorial Authorities[216].

Landfills dominate the waste disposal industry in NZ. In a report prepared for the Ministry for the Environment's Sustainable Management Fund, it was noted that the widespread involvement of local councils in landfills and the indirect price subsidy of these may in fact be distorting the market to a point where alternative options for waste disposal (such as deconstruction) are often not financially viable.[217]

The Landfill Full Cost Accounting Guide[218], published by the Ministry for the Environment in 1996 set out to address the improper setting of tipping rates, which directly affects the economics of deconstruction. It is however not used consistently by local councils and some economists question its accuracy.[219] Privately owned cleanfills often set their fees below those of municipal landfills. This is reasonable at one level as they do not have to cater for hazardous materials or for other troublesome mixed wastes. These low charges however make it even more difficult to establish economically viable recycling markets. Indeed cleanfill operators have a financial incentive to encourage disposal rather than recycling. It would take government intervention preferably centrally, to change this situation.

The Recycling Industry

The recycling industry in New Zealand is complex due to the wide range of materials collected and is seen to be difficult to define industry players and quantify amounts of materials collected, processed and exported[220]. Unassisted strong markets already exist in scrap metals and native timber. Strong markets also exist to a lesser extent in paper and building materials reuse or recycling in the North Island. Most materials reprocessors are in the Auckland region, in the North Island. Transport costs are seen to be a barrier to increased C&D (and general) recycling due to New Zealand's low density population and the high volume-low value nature of many of the materials generated. Considerable quantities of recovered materials are sold overseas, especially those generated in the South Island,[221] where in some cases it is more economic to export to other markets than to the North Island for processing.

Wider Context

Internationally New Zealand has a 'clean and green' image. Government is well aware of the importance of this perception and its value in terms of tourist and agricultural sectors[222]. Therefore it would be in the national economic interest to put in place effective waste reduction methods which might not only have inherent long term economic benefits for the country but at the same time bolster the country's 'clean green image'

Table 3 Economic factors in the deconstruction process in NZ

Economic factors in the deconstruction process in NZ:	
Positive	*Negative*
Money can be recovered from the sale of used materials and components.	Deconstruction takes longer (sorting etc). This has financial implications for developers who borrow large amounts of money and want to minimise interest charges.
Machinery is less cost intensive than in demolition due to increased used of manual techniques.	More storage is needed (for recovered resources), i.e. additional cost.
Landfill / cleanfill tipping costs avoided.	Increased transport costs may apply
Reduced primary resource use and waste can improve profit margins.	Reduced markets for NZ produced goods
Export opportunities exist for recycled materials in NZ	Low level of financial recovery from exporting items. Better to recycle and reuse within the country.
Increased employment opportunities for skilled and semi-skilled workers.	

6.2 Assessment Models / 6.3 Deconstruction Assessment Tools

Many financial modeling tools for use in deconstruction planning that have been developed in other countries. These, however do not appear to be in use in New Zealand.

The nearest such tool in use in New Zealand is a series of tips and key steps[223] to follow in the design, construction and demolition processes to improve resource efficiency. This information is produced by REBRI, (Resource Efficiency in Building and Related Industries). REBRI is a joint initiative by Auckland Regional Council and BRANZ (Building Research Association of NZ).

6.4 Life-cycle Costing of Deconstruction

It is considered at present that there is only a minimal level of use of formal life-cycle analysis tools in New Zealand but that it is increasing, primarily due to the development of the New Zealand Waste Strategy, New Zealand's recent ratification[224] of the Kyoto Protocol,[225] and recent government moves to place increasing stress on life-cycle performance in building regulations. The following is a summary of the known life-cycle assessment tools or research being carried out in New Zealand.

WISARD:

WISARD NZ (Waste Integrated Systems Assessment of Recovery and Disposal) is a software tool that has been developed and adapted to NZ conditions by PricewaterhouseCoopers and URS from the UK / European model which is a product of the Ecoliban Group. This was developed through funding from the Ministry for the Environment's Sustainable Management Fund.226

WISARD is a life-cycle assessment (LCA) tool used to assess waste composition, collection, transportation, recovery and disposal options. It offers impact assessments in a variety of categories such as energy use, global warming, acidification of air, ozone depletion, eutrophication and resource use. It was designed to aid territorial authorities in the development of council policy on waste management. The tool focuses primarily on household waste but can used to undertake environmental and economic analysis.

URS New Zealand, (a private services company comprising of engineers, planners, environmental scientists and project managers) states that there are only however ten license holders of WISARD in NZ. Southland Regional Council is a user of the WISARD tool and has used it to make predictions about environmental benefits of changing waste disposal methods over a ten year period[227].

BRANZ:

The Building Research Association of New Zealand (BRANZ) has undertaken LCA research primarily in the areas of concrete products, structural steel, fibre based composite boards, extruded aluminium and construction timber. Environmental impact analysis studies on the majority of building materials will be carried out over the next two years.[228] Economic LCA research has been carried out on common wall and roof claddings and supporting substructures. It is intended that this information will be used to allow designers, specifiers and the public to make more informed purchasing decisions.[229]

Forest Research Institute (FRI) :

Forest research is a New Zealand based service provider of research to the national and international forestry industry. They have undertaken LCA based research in a number of areas particularly in comparing bio-energy systems and wood products.[230] Other research areas such as biodiversity, dioxins and natural ecosystem impact are to be included in future LCA databases for wood products[231].

NZIA Life Cycle Impact Charts

The New Zealand Institute of Architects published a series of 20 charts and a user's guide called 'Life Cycle Environmental Impact Charts' researched and prepared by John Storey and Leanne Horrill and published by NZIA in 1997 (Figure 14). The intention of the documents is to provide easily accessible comparative information on the life-cycle environmental impacts of most of the common building materials used in New Zealand.

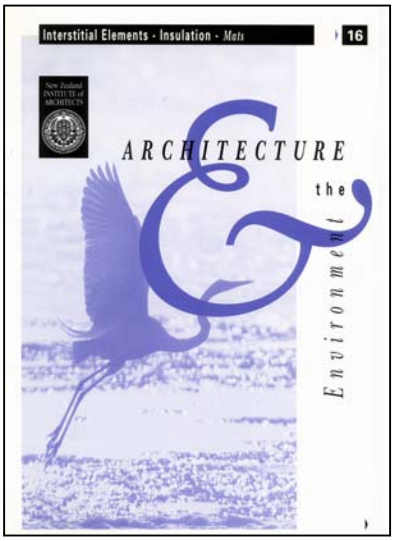

Figure 16 NZIA Life Cycle Impact Chart

Each chart is devoted to a particular building element (such as roof and wall cladding, finish, floor coverings etc) and goes through the impacts associated with each material commonly used in that section in the following life stages of a product: product composition and sustainability, materials acquisition, manufacturing, construction, operation (durability and maintenance), health in use, demolition and disposal, and general information including embodied energy. The charts identify the current condition and not what strategies and actions are necessary to improve the situation.

6.5 Materials Reuse Businesses, The Role of Demolition Contractors

The role of demolition contractors in NZ, in regards to deconstruction, varies with their specific circumstances such as their physical location in the country and the scale of the local economy and market conditions, as detailed in previous chapters. It is clear however, that demolition contractors have a crucial role to play in the adoption of deconstruction methods in NZ. Certain barriers that demolition contractors face in NZ are detailed in Chapter 9.

There is no information on how many demolition businesses actively promote or carry out deconstruction or partial deconstruction in NZ. The practice of selective salvage is common place however, and there are reports of increased salvage in many parts of the country. Rates of up to 95% salvage have been reported[232].

Some of the larger demolition contractors in Auckland in particular have already, without prompting or subsidy from central or local government, begun to incorporate environmental policies within their own companies. In many cases an increase in salvage and recycling of materials has been attributed, according to industry opinion, to the increased economic viability of such strategies.[233] Nikau Contractors, a demolition firm in Auckland, which is one of the two biggest demolition contractors in the country, is considering a name change to Nikau Deconstruction Engineers to position themselves for their perceived future role[234] and may be indicative of the changing attitudes, expertise and recognition of future roles by leaders in the field of demolition in some parts of NZ.

The NZDCA considers that demolition is becoming more complex that it has been in the past[235]. New machinery is being invested in by some companies, such as Nikau Contractors, who have recently invested in a concrete crusher, to cope with changing industry expectations. This is discussed further in Chapter 2.

Demolition contractors are bound in some respects by legislation (safety and health in employment for example), time pressure imposed by developers, and economic factors. It is for example still easier, cheaper and less time consuming to cleanfill waste rather than to recycle or reuse materials in many cases.

Some demolition contractors have noted an increase in on-site waste separation.[236] REBRI have developed case studies in this area (see Chapter One) and RONZ (Recycling Organisations of NZ), an organisation that represents recycling service providers, operators and educators in the recovered materials and recycling industry, has worked on developing signage to aid in the separation of waste at site. Some waste management companies (such as Mastagard in the South Island, and Waste Management NZ) provide multiple signed bins on demolition sites for easy separation of materials for recycling.

Some demolition contractors advertise that they recycle and have environmental policies, which may suggest that they perceive this as a marketing advantage. A few are actively recycling concrete for crushed aggregate such as Ward Resource Recovery in Auckland and Southern Demolition in the South Island. Re-machining of salvaged timber for on-selling is also carried out by some companies such as Nikau Contractors Ltd in Auckland.

Industry opinion generally reports that the industry is non-cohesive and highly competitive with individual companies tending to become isolated. It is unclear then if demolition contractors want to or are able to inform clients of end of building life-cycle choices such as demolition or deconstruction, and the environmental as well as economic implications of this. The amount of communication between demolition contractors and waste or resource use minimisation groups is also limited and appears to be undertaken by individuals within specific companies rather than as an industry initiative.

It is unclear whether demolition contractors are aware of, or assume part of the environmental responsibility for the large amount of demolition waste in the waste stream, or what affects various environmental or health legislation has on the industry in terms of moving towards deconstruction.

Building Recycling Outlets

There is a large overlap in New Zealand between demolition contractors and those that sell salvaged building components or materials. Some building recyclers are also demolition contractors such as Nikau Contractors in Auckland and Southern Demolition in Christchurch. Some demolition companies also sub-contract out salvage work where it is undesirable for them to undertake it themselves.[237]

Building recycling outlets where the public, commercial contractors, architects and designers can buy materials for reuse are common in NZ and are spread throughout the country. Generally they are advertised through a number of mediums, such as street signage, word of mouth and phone listings. Collective advertising of building recyclers appears on the yellow pages website and books and on two websites.

'The NZ Trades directory - Demolition Contractors Directory'
http://www.nztrades.com/demolitions/
A site listing contractors that work in the demolition and recycling sectors of New Zealand, including buyers and sellers of demolition material, house movers, salvage companies, asbestos removers, companies who carry out strip-outs of buildings, and suppliers of various metals and renovation materials.

'NZ Builders.com'
http://nzbuilders.co.nz/building_recyclers.htm.
A site detailing domestic and commercial demolition contractors and other construction related industries by location.

There is also a website devoted to advertising recycled components in New Zealand called New Zealand Demolition Materials www.demolition.co.nz. A number of building recycling companies contribute to it. This website seems to be well known amongst demolition and building recycling outlets but it is thought to cater to a fairly small antique or specialty items market niche.[238] Nevertheless its existence suggests however that some collective market development is already in progress.

New Zealand's demographic condition of a small dispersed population has a direct impact on the economic viability of building recycling outlets. This is discussed more thoroughly in Chapter 6 and Chapter 9.

RONZ have produced the NZ Recycling Directory in an effort to make it easier to identify organisations and individuals involved in the recycling industry in New Zealand.[239]

Many of the larger centres such as Auckland, Wellington and Christchurch have council funded or supported databases, publications or websites that make an effort to link waste stream materials with people who want such materials. 'Construction and Demolition Materials' are often sections in these databases published as websites or hard copy publications. While not an actual building recycling outlet they serve a similar function in that waste is diverted from landfill through on-selling or giving away of materials.

An example of this is the RENEW (Resource Exchange Network for Eliminating Waste) Resource Exchange developed by the Auckland Regional Council.

> *'RENEW… is a region-wide information exchange designed to help … business find markets for … industrial by-product, surplus materials and waste. Through RENEW, waste generators can be matched with waste users and re-users.'*[240]

Similarly the Wellington region has web based 'Enviromart[241]'.

> *'Enviromart is a service that assists Wellington organisations to find markets for unwanted materials that have traditionally gone to landfill or into the sewerage system. It is based on the waste minimisation principle of choosing to reuse resources rather than disposing of them'*[242]

The building recyclers' network may have similar communication issues to the demolition industry. It is has been suggested for instance, that there is little communication between architects and designers, construction contractors, demolition contractors and building recyclers.

There seems to be no collective voice from building recyclers advocating new standards and grading systems for recycled components or the resolution of liability and safety issues in the specification of recycled materials, as a way to increase market stability and profitability.

NZ Industry Associations and Non-Governmental Agencies Related to Deconstruction

Architecture / Construction / Building:

New Zealand Institute of Architects
http://www.nzia.co.nz/environment/index.htm
The NZIA is the professional body representing approximately 85% of registered architects in NZ[243]. The NZIA has a proposed environmental policy (2000) with one of its principles relating to minimising consumption of finite resources. The NZIA is also a signatory to an international agreement on sustainability with principles in line with deconstruction and design for deconstruction. Deconstruction and increased sustainability in the architecture industry is however not currently actively advocated by the NZIA.

BRANZ (The Building Research Association of New Zealand Incorporated)
http://www.branz.org.nz
BRANZ is the primary building research group in NZ. BRANZ is involved in various research projects that relate to deconstruction indirectly, such as the Urban Sustainability project and the Environmental Burdens from Buildings project under the Better Built Environments Programme. BRANZ also participates in the REBRI programme.

REBRI (Resource Efficiency in the Building and Related industries Programme)
http://www.rebri.org.nz
REBRI is a programme coordinated by BRANZ and the Auckland Regional Council. They help to put waste management plans together for business etc. Member companies commit to reducing resource use and environmental impact.

Habitat for Humanity NZ
http://www.habitatnz.co.nz/index.shtml
Habitat for Humanity is a non-profit charitable organisation dedicated to building better communities. They have a social justice focus, and work on a no profit, no interest basis, using donations of cash and materials and volunteer labour, to built housing for low income people. International Habitat for Humanity groups has worked with deconstruction, but so far Habitat for Humanity in NZ have not ventured into this field.

NZ Building Trades Union
http://www.nzbtu.org.nz/
The NZBTU negotiate wages, social policy and health and safety conditions for construction workers. They also advocate increased opportunities for training, although they do not appear to have made the link with deconstruction as strategy for increased labour and training opportunities.

ESR – Engineers for Social Responsibility
http://www.esr.org.nz
ESR is an independent group of engineers who consider that being knowledgeable in the field of technology means that they also have a special obligation to the public at large. They believe that *'in these days of greater accountability, the professional can no longer hide behind a mask of "professionalism"... An engineer has a duty not only to the client, but also to society and to the environment'*. ESR has links to international groups such as: Architects and Engineers for Social Responsibility, American Engineers for Social Responsibility and International Network of Engineers and Scientists for Global Responsibility, ESR has branches in Auckland, Wellington and Christchurch. They do not appear to have made the link with deconstruction's inherent social benefits.

Demolition:

NZ Demolition Contractors Association
NZDCA is representative of member contractors, particularly in the North Island of NZ. Primarily they are involved in the creation of a NZQA recognised qualification framework for the demolition industry, the redefining or establishment of a code or ethics, participation in defining of safety codes and looking at deconstruction and sustainability issues in the demolition industry. Contact is through Nikau Contractors.

New Zealand Demolition Materials
www.demolition.co.nz
See above.

Nikau Contractors Ltd
http://www.yellowpages.co.nz/for/nikaucontractors/dp15960.html
Nikau is a major NZ demolition company based in Auckland, which conventionally deconstruct buildings. They are the contact point for the NZ Demolition Contractors Association.

The Ward Group - Ward Demolition and Ward Resource Recovery
http://www.ward-demolition.co.nz
The Ward group, based in Auckland has a strong commitment to recycling and the re-use of recovered materials. The Ward Group established Ward Resource Recovery three years ago to utilise an increasing amount of recovered resources, such as concrete demolition materials which are crushed to make an alternative high grade aggregate. Ward Demolition also conventionally deconstruct buildings.

Recycling:

RONZ (Recycling Organisation of NZ)
http://www.ronz.org.nz/
Established in 1992, RONZ is a non-profit organisation that represents recycling service providers, operators and educators in the recovered materials and recycling industry. Identifying organisations and individuals involved in the recycling industry in New Zealand is now easier following the launch of the 2001/2002 New Zealand Recycling Directory. RONZ focuses on raising the profile of recycling in New Zealand through various initiatives, involving central government, local authorities and industry. They are the creator of NZ recycling symbols. They are involved with current and planned C&D waste minimisation projects.

Recovered Material Foundation (Christchurch City Council)
http://www.ccc.govt.nz/AnnualPlan/2003/Draft/Recovered_Materials_Foundation.pdf
'The RMF provides reuse and recycling development programmes on behalf of the Waste Management unit of the Christchurch City Council. It also has a focus on local employment and development through the creation of new recycling enterprises in Christchurch.' RMF also provide some waste minimisation funding in some cases, which could be relevant to deconstruction.

Scrap Metal Recycling Association of NZ
http://www.yellowpages.co.nz/for/nzscrapmetal/dp56425.html
They have lists of all metal scrap recyclers in NZ.

The Plastics Environmental & Advisory Council (PEAC)
http://www.plastics.org.nz/environment/index.htm
The environmental arm of Plastics New Zealand, PEAC is based at the national office of the Plastics New Zealand and offers advice and consultation in a number of areas. The construction industry is one of their service groups.

Waste Management / Minimisation:

WasteMINZ (Waste Management Institute of New Zealand)
http://www.wasteminz.org.nz/
The Waste Management Institute of New Zealand (WasteMINZ) is a non-profit organisation that was formed in 1989 to promote sustainable waste management practices. Their stated primary function is 'to provide a forum for presentation and dissemination of information and to act as a facilitator for the waste management industry in New Zealand'.

WasteMINZ hosts an annual conference, conducts regular workshops and seminars, and publishes a newsletter '. Their Life After Waste Project and publication is in direct response to the New Zealand Waste Strategy.

Zero Waste Trust NZ
http://www.zerowaste.co.nz/
Zero Waste Trust NZ focuses on there main areas: Advocacy and policy development, networking and technology transfer and funding. The Zero Waste Network is an affiliation of Councils, Community Groups, Consultants, Businesses, Academic Institutions, Recyclers and Individuals, all linked by a desire to create a sustainable New Zealand through the adoption of the Zero Waste goal. The website has links to all of the relevant NZ players in waste minimisation. Main sponsors of Zero Waste Trust NZ are the Tindall Foundation, The Sustainable Management Fund and The Community Employment Group.

Target Zero
http://www.ccc.govt.nz/TargetZero/
Target Zero is a Christchurch City Council resource efficiency/waste minimisation initiative working with Christchurch businesses to save money and reduce environmental impacts. They have been involved with construction and waste minimisation pilot studies.[244]

Business / Funding:

Sustainable Management Fund
www.smf.govt.nz
The SMF is part of the Ministry for the Environment. They fund projects which will have a nationwide benefit. SMF has in the past funded C&D waste minimisation projects.

Victoria University
http://www.arch.vuw.ac.nz/
Victoria University is currently funding two pieces of deconstruction research. The national representative on the CIB Task Group 39 on Deconstruction is a senior lecturer (John Storey) from the School of Architecture. This research is focused on the current state of deconstruction in NZ. The other piece of research is into future directions and strategies to develop deconstruction initiatives in NZ.

Land Care Research - Triple Bottom Line Advisory Service
http://www.landcareresearch.co.nz/research/sustain_business/triplebottomline/index.asp
'The Triple Bottom Line (TBL) concept widens the scope of traditional management and reporting to include the social, environmental, and economic performance of an organisation. Landcare Research offers advice in the development of a TBL approach to management and reporting'.

New Zealand Business Council for Sustainable Development
http://www.nzbcsd.org.nz
A list of businesses, companies, resources, projects etc appears on their website.
They aim to work for 'change toward sustainable development, and to promote eco-efficiency, innovation and responsible entrepreneurship'.

Business Care
http://www.nscc.govt.nz/Waste_Minimisation/rrbcbody.htm
'We actively promote cleaner production and waste reduction in business and will support North Shore City businesses to initiate systems to achieve this goal.'

Envirofunz
www.envirofunz.org.nz
Envirofunz is an online data base of environmental funding opportunity and providers in NZ.

NZ Recovered Materials Trust (RMET)
www.nzbcsd.org.nz/story.asp?StoryID=95
recycloans@pl.net
RMET is a charitable trust that provides funding through the RecycLoans Fund to support businesses that reduce waste to landfill.

The Green Heart Award
http://www.environment.org.nz
The Christchurch Environment Centre's Green Heart Award is open to wholesalers, retailers and the manufacturing sector as well as to service industries to reward an environmentally friendly philosophy that is daily put into practice.

Other agencies or groups that provide waste minimisation or C&D funding
The Ministry of Research, Science and Technology as related to the Science, and Innovation Policy of 2002,
The Energy Efficiency and Conservation Authority (EECA),
Zerowaste NZ
WasteMINZ
Various Territorial Authorities

CHAPTER 7:
DESIGN OF BUILDINGS AND COMPONENTS FOR DECONSTRUCTION

Introduction

Very few architects, designers or engineers in New Zealand consider design for deconstruction or disassembly in their designs unless there is a specific requirement to do so. When there are specific requirements for deconstruction defined in the brief the reason is generally economic rather than environmental. Such requirements might exist when temporary structures are erected or when change can be predetermined. In most cases however deconstruction is not considered at all and even when it is considered design for deconstruction is unlikely to receive approval if it were to add to the initial cost. In some cases techniques used to facilitate buildability serendipitously allow for future deconstruction but these are very much in the minority.

Information received from demolition contractors suggests that newer buildings are in fact more difficult to deconstruct than older buildings, due to the extensive use of multiple nailed joints, widespread use of glues, hidden fixings and composite construction. Economic recovery of useful components in these circumstances is often very difficult.

Many buildings of all scales in New Zealand are made using a high percentage of prefabricated components. Such construction would automatically seem to lend itself to reverse construction. However this does not seem to be the case. Some insitu work is conventionally carried out on-site in most buildings and this is often enough to make deconstruction of many building elements very difficult.

The salvage and reuse of structural elements is often not possible to any great extent due to the common methods of tying structural components together to assist in withstanding earthquake forces. To withstand powerful and cyclical movements of earthquake shaking, the structural strategy is often to create stiff walls or to use rigid column to beam joints. With precast concrete structures for example the normal way of construction is precast floor beams and precast beams and columns. The floors units are however leveled and connected to each other and the primary structure using insitu concrete. Joints in the main structure are also made using insitu concrete. The result is an essentially monolithic structure which is impossible to disassemble.

Although there are no known examples of any structural steel buildings specifically designed for deconstruction in New Zealand, some recent developments driven by the need to improve construction efficiencies will assist in component reuse. For example, whereas rigid steel joints in frame structures are traditionally reliant upon welding, some recent buildings, particularly low-use and long-span industrial structures have bolted connections between columns and beams. Many cross-braced steel frames also utilise bolted connections that are inherently deconstructable.

There is certainly scope for increasing structural component reuse from seismic resistant steel structures without compromising seismic performance standards. Provided that bolted connections do not become ‘weak links’ that prevent earthquake energy being absorbed by primary steel components, such an approach is quite acceptable. Unfortunately, steel beams supporting metal tray deck formwork and concrete topping are more difficult to deconstruct. Due to the pressure to reduce structural depth, steel beams are often monolithically joined to the concrete topping by steel studs that are welded along the beam top flanges. However an alternative bolted shear connection system could be developed to greatly facilitate deconstruction.

Most timber buildings in New Zealand, including domestic dwellings, rely on wall linings to resist wind and earthquake lateral loads. Nailed or screwed fastenings connect gypsum board wall linings, or in some cases, plywood bracing sheets to timber wall components. Component reuse will be increased only when methods of connection are re-engineered. To some extent the construction industry will need to move away from a heavy dependency on nail-guns, and return to more traditional reversible fixing methods, such as bolting. Recent methods of forming rigid joints between glue-laminated timber members by epoxied threaded steel rods will also need to be discontinued, although these almost indestructible joints can always be cut out to allow the rest of the timber to be reused.

New Zealand has a well developed timber industry. Traditional methods of construction do not easily facilitate deconstruction of timber structures. The methods are based on the successive layering of materials to achieve a stable structure. Current attitudes toward building generally in New Zealand do not make any special provision for the deconstruction of such buildings. It is generally accepted that demolition and deconstruction take place piece by piece, with as doors and windows generally being the largest recovered components.

Current masonry construction methods are not sympathetic to deconstruction. In particular it is difficult to envisage reinforced concrete masonry (RCM) being suitable for deconstruction. Due to the need for RCM walls to withstand in-plane and out-of-plane seismic loads, walls are reinforced by regularly spaced horizontal and vertical steel bars. There may however be potential for walls to be constructed from masonry panels that are post-tensioned to foundations by reversible, bolting systems. Polystyrene formwork blocks are a common method of construction for masonry walls in small buildings. Currently there are no markets for crushed masonry in New Zealand.

Similar comments apply to un-reinforced masonry construction. Again due to its significant seismicity, New Zealand requires all unreinforced masonry to be strongly tied back to supporting structure (usually timber stud walls). While the masonry-to-wall metal ties can be removed reasonably easily the use of cement mortar precludes masonry reuse currently. Cement mortar is stronger than clay bricks and the bricks from walls constructed with cement mortar cannot be recovered for reuse. The use of weaker mortars that can achieve both satisfactory seismic performance and deconstruction requires investigation.

There are more opportunities for deconstruction with non-structural units particularly if standard of the shelf components are used and compatible modular design strategies adopted. Both notions are uncommon in New Zealand and in fact fashionable design strategies lean more to achieving uniqueness and individuality than uniformity.

Anzac Avenue Car Park

There are however a few projects which demonstrate that by adapting the common methods of construction it is possible that a high proportion of the structural components of the building can be deconstructed.

The Anzac Avenue Car parking Building was developed in Auckland in 1990 following a period of economic uncertainty. The owners of the site required a new building which would provide an income until economic conditions were right to carry out their long term development aims, yet would not compromise their a long term plans . A reinforced concrete car parking building was therefore designed that was capable of being disassembled and re-erected on a different site at a future date.

Good quality precast concrete structural units are widely used and readily available in New Zealand. The challenge is to minimise or eliminate the use of cast-in-situ concrete to join the pre-cast concrete elements of a building. In this case lateral bracing of the structure is provided by four 'L' shaped cast-in-situ concrete shear walls at the outside corners of the plan (see Figure 15). The design strategy of resisting the lateral loads at these corners allowed the structural frame to take the gravity loading only, and as a consequence allow beam to column joints to be pin jointed.

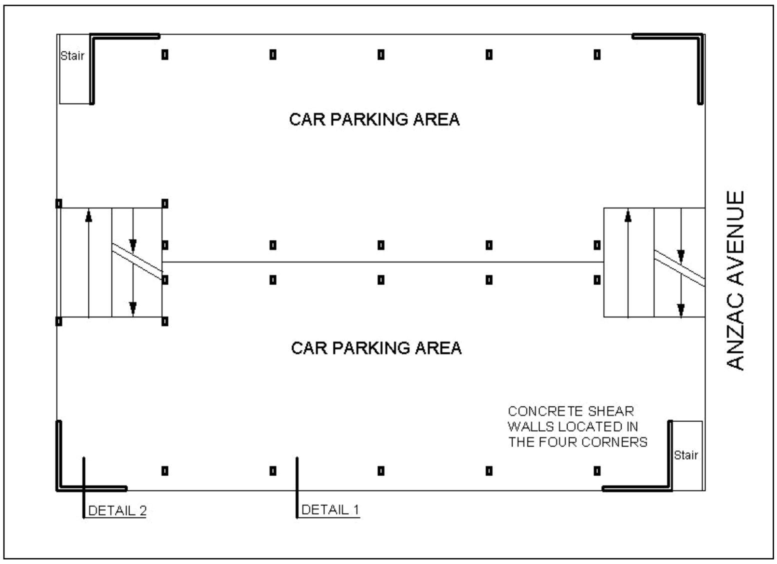

Figure 17 Anzac Avenue Car Park

The three main pre-cast concrete elements in the structure are pre-cast concrete flooring units, the pre-cast concrete columns cast to their full height of four floors with corbels to support the beams. The pinned beam to column joints were made by welded, freely accessible connections, able to be cut at the time of disassembly. With each floor designed as a seismic diaphragm a sturdy connection was required between pre-cast flooring units. This was achieved by joining the flanges of adjoining double-tees using bolts in preformed pockets cast in the flange, freely accessible for disassembly (see Figure 16)

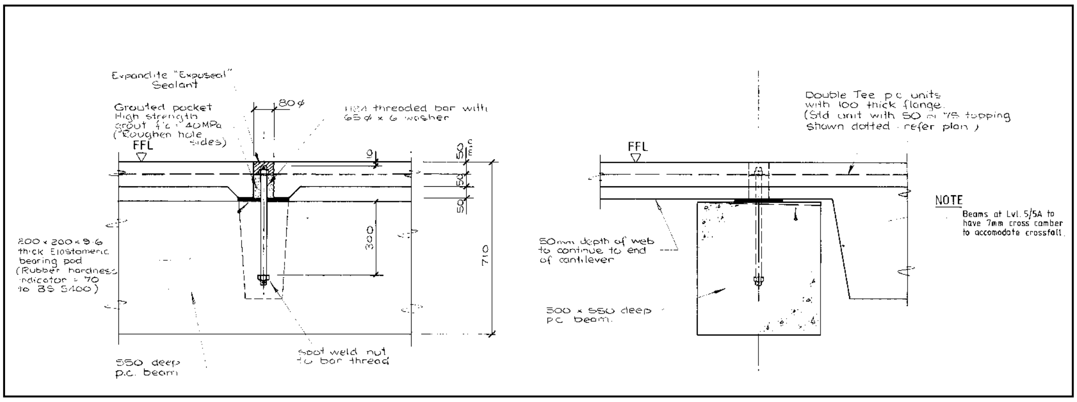

Figure 18 Anzac Avenue Car Park Construction Detail

The flooring and mechanical connections between units provide the structural capacity that is necessary for a floor, however without a topping, the concrete floor is not perfectly level or true. The connection between each floor unit and supporting beams was made by threaded rods, easily removable at a later date. The vertical stepping between flooring units is not enough to be of concern for foot or vehicle traffic in a car park but would not be suitable for most other building types, where would be necessary to employ a raised floor or a form of mechanically fixed modular leveling overlay to achieve a level floor while still allowing for disassembly.

The project demonstrates that it is feasible to design for deconstruction in a seismic zone without significant increase in cost;[245] however the strategy has not been widely adopted in New Zealand for this building type or indeed any others.

While much of this building can be deconstructed, the cast-in-situ shear walls will require demolition. If an alternative structural system, such as a steel eccentrically braced frame had been used, it could have been bolted to both the foundations and to the superstructure, increasing the extent of structural reuse.

Dickson Lonergan Limited
Dickson Lonergan Limited is an architectural practice operating on the North Island of New Zealand. They recognise the environmental and long term economic benefit to the community and their clients of designing for deconstruction into their buildings. They have now sought to allow for later disassembly in three projects carried out by the practice. The New Plymouth Girls High Millennium Block was designed, and in part constructed, with later disassembly in mind. The economic `realities' of matching budget to ambition saw the strategy employed only where it did not add cost.  The need to build a large building very quickly in a small `hole' in a very busy part of a busy school dictated that. Prefabrication was a necessity and this aided the architects to achieve some of their aims in regard to disassembly.

The Clifford Gate House was designed as a home for a temporary farm manager. The house was going to add no value to the farm property so it was suggested to the client they protect the value of their investment by making the building relocatable for later use as a bach. The building was designed closely with a structural engineer in a modular fashion. We were fortunate in that the house was built under a negotiated tender with an enthusiastic contractor who contributed to the process willingly and possibly at a cost to himself. The contractor demonstrated that it was most economical to line the building with plasterboard in the typical manner and accept the damage and repair than to form purpose made joints in the linings to allow for deconstruction. The primary structure and floors are all jointed at the module points for separations. The modules were sized to be transported on a truck thus minimising Transit NZ highway charges. The front deck is removable also using bolted connections.

In the case of extensions to a school in Wellington design for disassembly was presented as a key strategy in a collection of ESD strategies. The project is run by a project manager, which in New Zealand often means a financial manager whose primary skill is to minimise first cost rather than to ensure quality. In this case the PM is openly scornful of all the ESD strategies that the architects proposed. As a result the strategies have all been deleted, save for a solitary sun screen and higher than code insulation. The PM argues that extra expense now is not justified for something that may not be beneficial for many years to come, if at all; that the design will result in increased maintenance, and that the design will be more complex than necessary and be different to other parts of the school. The architects do not feel that they have been given the opportunity to argue their case to the client and feel very frustrated about the whole affair.

7.2 Design of Components / Buildings for Disassembly

Several other recent building projects in New Zealand have allowed for disassembly in their construction although this has not been a conscious choice in every case. These examples serve to highlight the opportunity for employing deconstruction techniques in buildings that are targeted for change or have come to the end of their economic life.

A project that was specifically designed for partial deconstruction to facilitate a planned expansion is the Antarctic Visitors' Centre in Christchurch (Figure 19). Since the project budget would not for the Visitor's Centre to proceed at the time of the second stage development without compromising other aspects of the design, it was decided to facilitate the later addition of the 'Snow & Ice Experience by planning and detailing for deconstruction. The idea was to make use of modular pre-cast concrete panels as the exterior structure and cladding. The design allowed the panels, approximately 8 metres tall, to be unbolted from the foundations, the roof framing and from each other and to be relocated and serve as structure for the extended building.

The expansion was undertaken in 1995 and completed successfully. The owner was able to engage the same contractor. This contractor had access to the original formwork which was used to cast the new makeup concrete panels required.

Figure 19 Antarctic Visitors Centre Christchurch

7.3 Parallels in Other Industries

Extended Producer Responsibility is just beginning to emerge as an issue in waste reduction. The notion appears in the Waste Management Strategy document but no known research is being carried out in New Zealand on this concept and how it might be applied to building Construction.

CHAPTER 8:
POLICY, REGULATIONS, STANDARDS, LIABILITY

8.1 Government Policy Supporting Deconstruction

There are a number of acts and policies which implicitly support the principles of deconstruction in NZ legislation, without their authors necessarily being specifically aware of deconstruction practices and principles. Only the NZ Waste Strategy actually mentions it explicitly however[246]. At present NZ does not have comprehensive legislation relating to waste minimisation[247]. A number of different acts are relied on as the framework for waste management. The most important document in terms of deconstruction in NZ is the NZ Waste Strategy.

In general, NZ environmental policy related to encouraging deconstruction is based on voluntary initiatives by industry and waste management policies rather that on waste minimisation. The Resource Management Act is a particular example of legislation which focuses on management of waste without considering the minimisation of waste.[248]

The implementation of waste minimisation policies is the responsibility of local government in New Zealand rather than the direct responsibility of Central Government. This is enforced through the local Government Amendment Act Number 4 of 1996, and the Health Act of 1956.

There are three types of councils in NZ. There are 12 Regional Councils (their responsibilities are the rivers, air, coast and soil etc), 70 City and District Councils (who deal with all of the aspects of maintenance of human settlements) and 4 Unitary Councils (who do the jobs of both regional and city/district councils). These bodies are sometimes referred to as Territorial Authorities (TAs).

Over half of the City and District Councils in New Zealand have in fact gone a step beyond the Central Government waste policy document[249] and declared that they will aim to have zero waste by 2015. Zero Waste Trust New Zealand is an advocacy, networking and funding support group that supports TAs, community groups and businesses in achieving the Zero Waste goal[250]. This is an encouraging sign for the future and the Zero Waste goal continues to receive the encouragement of Central Government.

Roles in waste minimisation in NZ, particularly in the C&D area, are currently unclear due to uncoordinated and sometimes confusing information, data and legislation. Key governmental strategies and policies relevant to deconstruction such as waste minimisation, resource conservation and socially beneficial initiatives are listed in the following table.

Table 4 NZ National Policy Related to Deconstruction

NZ National Policy Related to Deconstruction:	
Health Act	1956
Environment Act	1986
Building Act	1991
Resource Management Act	1991
Local Government Amendment Act Number 4	1996
Energy Efficiency and Conservation Act	2000
National Energy Efficiency and Conservation Strategy	2001
New Zealand Waste Strategy	2002

Central Government also has some obligations relating to waste minimisation and resource conservation under international treaties such as the Basel Convention, SPREP (The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region) and the Kyoto Protocol.

Table 5 International Agreements NZ is a Party to Related to Deconstruction

International Agreements NZ is a party to Related to Deconstruction:	
SPREP	1986 (NZ 1990)
Basel Convention	1989 (NZ 1994)
Kyoto Protocol	1998 (NZ 2002)

There follows an outline of each relevant pieces of legislation in chronological order.

Health Act 1956:
Administered by the Ministry of Health, this act requires all territorial authorities to provide sanitary works systems including the provision for the collection and disposal of waste, and the 'control of offensive trades'. Refuse collection comes within this definition.

Although the act requires councils to be responsible for waste collection, they do not have to be the service operators and are permitted to contract services out to private operators.

Resource Management Act (RMA) 1991:
The Resource Management Act covers planning and resource management. It is NZ's most comprehensive environmental legislation at present. The principle objective of the RMA is to provide for the sustainable management of NZ's natural resources. The RMA is however focused more on waste management than on waste minimisation.

There is provision for national policy statements and national environmental standards under the RMA to act as binding directives for the councils from central government. However none have been prepared to date (2003).

Under the RMA Councils are required to prepare 'regional plans' in relation to environmental management in their areas. The plans provide guidance to people and businesses concerning resource use.

Some activities, including demolition, deconstruction, relocation and building activities require a resource consent if they do not comply with the planning rules of the territorial authorities district plan. A summary of the anticipated environmental effects of the activity must be supplied upon application. Resource consents are awarded by the local authority.

Some councils are investigating the possible requirement of waste management and minimisation plans in resource consent applications for building and demolition related activities.

Some resource consent applications are publicly notified and any member of the public or organisations can make a submission opposing or supporting the application.

The RMA sets out and enforces liability for environmental degradation through instant infringement notices (on-the-spot fines), abatement notices (where activities are required to cease), excessive noise directions and enforcement orders issued by the Environment Court.

The RMA covers areas specific to deconstruction such as noise levels in demolition activities, heritage orders, subdivisions and reclamations of land, waste and hazardous substances.

The Building Act 1991:
The Building Act governs all building related activity in NZ and is administered through mandatory building regulations applying to the construction, alteration, demolition and maintenance of new and existing buildings. Government building work has to comply within the Act. The Building Act's stated intentions are to safeguard health and safety and use energy efficiently.

The Local Government Amendment Act 1996:
The local Government Act was brought in initially in 1974 and has had a series of amendments made to it since then. In 1996 the '5Rs'[251] waste management hierarchy was bought into force and local authorities were required to prepare waste management plans. There was no date for completion of these waste plans or any guidelines as to the kinds of waste they should cover, however most councils completed these plans by the end of 2002[252].

Energy Efficiency and Conservation Act 2000 and The National Energy Efficiency and Conservation Strategy 2001:
These deal mostly with energy efficiency rather than resource conservation or waste minimisation. When ones takes into account the embodied energy recovered with the salvage and reuse of building components however, deconstruction could be regarded as an important aspect of energy efficiency.

Much like the NZ Waste Strategy, the National Energy Efficiency Strategy is a set of targets and goals rather than a legally enforced statute. The strategy has been developed within the context of sustainability[253] and it is stated in the preface that strong links exist in its goals with those set out in the NZ Waste Strategy.

There is an established Buildings and Appliance programme in the strategy. It states that Buildings and Appliances used in them account for 22 per cent of consumer energy in NZ.[254]

The objectives of the Buildings and Appliance Programme if made legally enforceable in the future, will have a direct impact on possible future deconstruction activity in NZ. Relevant objectives are as follows:

> *'Progressively upgrade energy performance across all sectors of the existing building stock with the following 15 year targets:*
> *All pre 1977 houses to be retrofitted with a suite of cost effective energy efficiency measures.'*[255]

One of the strategic approach targets (number 51) states:

> *'Improving the design process especially for new commercial buildings is a priority. It is frequently disjointed and does not produce optimal energy, environmental design, cost and quality performance… A suite of measures is proposed to improve the effectiveness of the design process.'*[256]

Design for disassembly would obviously support both this target and the targets set in the NZ Waste Strategy.

The New Zealand Waste Strategy- Towards Zero Waste and a Sustainable New Zealand 2002:
This strategy is not legally enforceable currently, but is actually a waste minimisation proposal by the Ministry for the Environment which sets targets for Territorial Authorities to accept and follow if they choose to. Targets for waste minimisation across all waste areas are set up to 2020.

Central to the New Zealand Waste Strategy is that its focus is on waste minimisation rather than waste management as previous legislation has been such as the RMA.

The Strategy's C&D waste minimisation target requires a 50% reduction by weight in construction and demolition waste going to landfills by 2008, however it offers no construction and demolition (C&D) waste specific strategies for accomplishing this objective. The Ministry for the Environment who prepared and promulgated the document states:

> *'The strategy acknowledges the limits of the information on which the targets are based. It indicates that the targets should be considered as "goal statements rather than mandatory requirements". The targets are to be reviewed by December 2003. In the meantime councils are encouraged to set their own targets in line with those in the strategy. This request recognises that it may be impractical for local targets to be the exact equivalent of the provisional national targets.'*[257]

The Ministry for the Environment is currently setting priorities for national targets for waste to be considered for incorporation into legislation. The Strategy is due to be reviewed in December 2003.

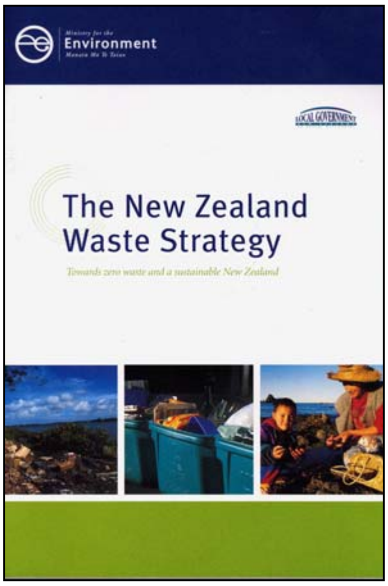

Figure 20 The New Zealand Waste Strategy

The Strategy identifies the role of central government in increased waste minimisation and states three priorities:
1. Waste Minimisation
2. Hazardous Waste
3. Waste Disposal[258].

These are centered on three goals:
1. Society: Lower costs and risks to society from waste
2. Environment: Reduce environmental damage from generation and disposal of waste
3. Economy: Increase economic benefit by using material resources more efficiently[259].

These goals are organised through six core principles[260]:
1. Global citizenship
   'Our responsibility to protect the environment extends beyond New Zealand's borders.'
2. Kaitiakitanga / stewardship
   'All members of society are responsible for looking after the environment, and for the impact of products and wastes they make, use and discard.'
3. Extended Producer Responsibility
   Producers have a degree of responsibility for their products throughout the product's life-cycle, from production through to final disposal'.
4. Full-cost Pricing
   The environmental effects of production, distribution, consumption and disposal of goods and services should be consistently costed, and charged as close as possible to the point they occur
5. Life-cycle Principle
   Products and substances should be designed, produced and managed so all environmental effects are accounted for and minimised during generation, use, recovery and disposal.
6. Precautionary principle
   Where there is a treat of serious or irreversible damage, lack of full scientific certainty should not be a reason for postponing cost-effective measures to prevent environmental degradation or potential adverse health effects[261]

International Agreements

SPREP - The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region 1986:
This was ratified by NZ in 1990. The South Pacific Regional Environment Programme, also known as SPREP, was formally established under a different agreement, called the Agreement Establishing the South Pacific Regional

Environment Programme, 1993, which was ratified by New Zealand on 16 December 1993.

This is an agreement covering primarily the protection of the coastal and marine environments of the South Pacific. Its relevance to deconstruction is again in its regulations for materials transported by sea through the region and appropriate waste management strategies for the region. The Ministry for the Environment states in relation to SPREP:

> *'Parties accept more specific obligations to control pollution from discrete sources, or to cooperate in specific aspects of environmental management.'*[262]

Basel Convention on the control of transboundary movements of hazardous wastes and their disposal 1989:
This was ratified by NZ in 1994. While not directly relevant to local deconstruction activity one of the waste management problems in NZ is the lack of clearly defined lists of hazardous materials and substances. This is currently being addressed by The Ministry for the Environment. A National Definition of Hazardous Waste is being developed. The Ministry for the Environment States:

> *'The purpose of the Definition is to provide consistency in defining hazardous waste for the purposes of resource consents, waste management planning, and other aspects of hazardous waste management. The current definition is in draft stage and will be finalised following consultation.*[263] *'*

If the reuse and recycling of materials under increased deconstruction is to occur with possible increased export of components,[264] internationally recognised conventions and standards of hazardous waste / materials definitions will become more important.

Kyoto Protocol 1998:
This was ratified by NZ in 2002. Central government is committed to its obligations under the Kyoto Protocol to cut back greenhouse gases in the period 2008 to 2012 to 1990 levels.

The building and demolition industries contribute to global warming and climate change through unsustainable resource and energy use and possible contribute to greenhouse gases through decomposition of some C&D waste in landfills and cleanfills in NZ. Deconstruction therefore is a tool NZ can employ in the future to mitigate effects from this industry and meet obligations under the Kyoto protocol.

Government Agencies

Table 6 NZ Governmental Agencies Related to Deconstruction

NZ Governmental Agencies Related to Deconstruction
Ministry for the Environment
Department of Conservation
Parliamentary Commissioner for the Environment
Department of Health
Department of Internal Affairs
Ministry of Housing
Department of Labour

There follows a brief outline of each agency's relevance to deconstruction.

Ministry for the Environment Manātu Mō Te Taiao (MfE)
The MfE was established under the Environment Act in 1986. The Ministry advises the government on environmental issues and assists and oversees councils in the meeting their obligations under the RMA.

The recent publishing of the *NZ Waste Strategy – Towards Zero Waste and a Sustainable New Zealand* signals the Ministry's commitment to resource conservation and waste minimisation. Deconstruction is however not a commonly recognised or promoted method of addressing the problems NZ is facing in the area of C&D waste.

Several C&D waste minimisation projects are funded through the Sustainable Management Fund which is provided by the MfE. The Ministry is also a supporter of Zero Waste Trust NZ

The MfE has published a series of national waste management guidelines as part of the Landfill Management Programme and Hazardous Waste Management Programme. The following are the most relevant in terms of directly or indirectly affecting deconstruction in NZ:

The Solid Waste Analysis Protocol (SWAP) 2003[265]
This Protocol was reviewed and republished from the 1992 Waste analysis Protocol. It provides non-mandatory guidelines on the collection of statistical information of data about landfills and waste (including construction and demolition waste) for local councils.

The Landfill Full Cost Accounting Guide for New Zealand 2002[266]
This guide, originally published in 1992, was reviewed and republished in 2002 from the 1992 version. It is aimed at local authorities, waste managers and commercial landfill operators to assist them to understand and implement a consistent Full Cost Accounting (FCA) approach to landfills (including landfill planning, development, operation, closure and aftercare), which more accurately takes account of environmental considerations in the management of landfills.

Use of the landfill full cost pricing model was *'intended to make the methods of funding for landfill projects more obvious, more uniform and more consistent than is currently the case. The model can be used in conjunction with other tools (like the Life-cycle Analysis computer tool - Wisard) to determine life-cycle product or waste disposal costs.'*[267]

The Guide to Managing Cleanfills 2002[268]
This guide provides national direction on definitions of cleanfill, acceptable materials for cleanfill and design, siting and operation considerations.

Landfill Waste Acceptance Criteria for Waste with Hazardous Properties: Issues and Options 2001[269]

This deals with the disposal of hazardous materials (including hazardous C&D waste) to landfill.

Landfill Guidelines 1992[270]*:*
These set up a framework for the development, use and management of landfills based on environmental and health requirements. It is for the use of planners, designers and operators

There are also guides dealing with acceptance criteria for hazardous wastes at landfills[271], and health and environmental guidelines for treated timber chemicals[272].

Parliamentary Commissioner for the Environment:
The Parliamentary Commissioner for the Environment's role is to investigate emerging environmental issues. The Commissioner is able to make recommendations to the appropriate agency on improvements or necessary changes to behaviour or policy.

Ministry of Economic Development Manatū Ōhanga:
Building Industry NZ (BIA)
http://www.bia.co.nz
Established in 1992, the BIA manages the building control system as set out by the Building Act 1991, and the NZ Building Code. The BIA advises the Minister of Economic Development on matters relating to building control and provides building control information and advice to the building industry and public. It is funded by a levy on building consents as part of the Building Act 1991 and the Building Regulations of 1992. Deconstruction and sustainability issues are not within the current mandate of the BIA.

Ministry of Housing Te Whare Āhuru:
Housing NZ Corporation (HNZC).
http://www.hnzc.co.nz
This is the national housing authority which is charged with the provision of affordable housing to low income families. They have design guides on their website and have made a commitment to renovating and reusing 'state' houses to better suit the cultural needs of Maori and Pacific Islanders. HNZC has a sustainability policy in their architecture guide. Part of this policy requires that 'materials should be recycled wherever possible' during disposal[273].

Department of Labour Te Tari Mahi:
Occupational Safety and Health Service of New Zealand (OSH):
http://www.osh.dol.govt.nz/
OSH deals with worker safety and health issues. They have guidelines on safe demolition and construction practices and safe removal of hazardous building materials such as asbestos (refer to Chapter 5).

Non Governmental Agencies

Much of the waste minimisation and resource conservation activity which is directly related to deconstruction in NZ is carried out by or supported by non-governmental agencies. The most prominent ones are discussed in this section. Other agencies which do not engage in these issues but are directly involved are also discussed.

Table 7 NZ Non-Governmental Agencies Related to Deconstruction

NZ Non-Governmental Agencies Related to Deconstruction
New Zealand Institute of Architects
Building Research Institute of New Zealand
Resource Efficiency in the Building and Related Industries Programme
Recycling Organisation of NZ
Waste Management Institute of New Zealand
Zero Waste NZ

A detailed outline of each agency or group's relevance to deconstruction is in Chapter 6 in the *NZ Industry Organisations and Non-Governmental Organisations* Section

8.2 Building Codes

NZ has a performance based building code rather than a prescriptive one. This theoretically allows the use of any material and system of construction if performance criteria are met. The use of reused and recycled components and new methods of building (i.e. for deconstruction) are therefore in theory allowed in NZ.

The New Zealand Building Code's performance durability requirements (B2.3 of the first schedule)[274] affect the viability of deconstruction. Structural components, including floors and walls which provide structural stability must last for a minimum of 50 years. Services which are difficult to access and hidden fixings must also last for a minimum of 50 years. The building envelope, supporting structures, and other difficult to replace elements must last 15 years. Linings, renewable protective coatings and other readily accessible building elements must last for 5 years.

Because there is no clear system for recertification of reused materials, it can be difficult to prove the projected durability of used materials particularly for structural uses, and to therefore obtain building consents based on the reuse or pre-used building components or materials.

8.4 Legal Issues

Legal issues arise with regard to deconstruction in NZ because all building activity including demolition / deconstruction is required to comply with the Building Code, the Resource Management Act and Occupational Safety and Health guidelines.

Liability of building certifiers, graders of recycled materials and designers of new deconstruction systems is a legal issue which currently is not addressed in NZ.

NZ has its own imposed waste minimisation targets (national and local) and is party to international agreements as well. If strategies such as the NZ Waste Strategy do become legally binding through formal enactment into national legislation, there will be a legal obligation for NZ to find ways to reduce the amount of waste going to landfill from construction and demolition. Deconstruction could be a major beneficiary, as currently approximately 1/3 of the waste stream is construction and demolition waste.

CHAPTER 9:
BARRIERS TO DECONSTRUCTION

Introduction

In addition to the general lack of awareness of the overall benefits of deconstruction there are significant barriers to the widespread adoption of deconstruction strategies in New Zealand, although none are insurmountable given the current governmental and local authority interest and support for waste minimisation in general.

Possible ways to overcome these barriers is beyond the scope of this report but research into this area has begun in NZ[275].

Table 8 Barriers to Deconstruction in NZ

Barriers to Deconstruction in NZ
Perception and Education
Designer/public/builder attitude: 'new is better'.
Lack of resources for education on deconstruction.
Lack of research into deconstruction.
Lack of information and tools to implement deconstruction.
Design for Deconstruction
Design for deconstruction in new buildings is not considered important.
Existing buildings are not designed to be deconstructed.
Lack of education about design for deconstruction.
Lack of understanding and use of LCA tools or concepts.
Lack of NZ specific case studies or examples.
Market Development
NZ's small, dispersed population and geographic isolation inhibits market growth.
The high cost of transport and storage of recycled components and materials.
Uses for some salvaged materials are undeveloped.
Guaranteed quality/quantities of reused materials are difficult.
Economics
Low cost of some new raw materials.
The tightening up of Health and Safety legislation.
Low tipping rates (including cleanfill).
Deconstruction needs a more skilled workforce than demolition.
The benefits of deconstruction are long term and collective but a first cost focus is dominant.
Market pressures - the current climate of 'as fast as possible'.
C + D Industry:
Unregulated industry.
Lack of communication and networking in the C&D industry and with waste minimisation organisations. There is no formal umbrella group to distribute information.
Demolition is generally a low profit margin industry.
Benefits of deconstruction over demolition are not understood.
Liability
Current standard specifications imply new materials should be used.
The lack of a grading system for reused components.
Liability in certification or advocation of reused components or materials not clear.

Legislation
C&D waste minimisation is not a priority for some local councils / central government.
Confusion as to what Government legislation is, relating to environmental responsibility.
Inconsistent units of measurement in local waste data, very limited national data.
Waste management is a local council responsibility, with no mandatory regulation.
Adherence to the targets and goals in the NZ Waste Strategy is voluntary only.
Technical Issues
Lack of documentation.
Some new materials are subsidised, creating unfair competition with reused materials.
Increased use of non-reversible technology, systems, construction, chemical bonds and plastic sealants etc.
NZ is in a high seismic activity region which makes design for disassembly more difficult.
New construction systems make recovery more difficult and less financially rewarding.

Perception and Education

Deconstruction is very much in its infancy in New Zealand and education and research is needed to raise its profile, to provide usable information and actively promote deconstruction as a worthwhile and viable option to make a real and significant contribution to achieving the government's resource recovery targets.

There appears to be some resistance amongst the general public, designers and amongst many builders to the use of pre-used materials. This is a worldwide problem and is of course not a single problem but a series of interlinked issues. The collective effect is to inhibit the use of pre-used materials and components and make their use the exception rather than the rule, at least in new buildings.

With the public there seem to be two contradictory influences at work. The notion that pre-used materials are inferior and that wear makes items undesirable and unfashionable seems pervasive and is perhaps the inevitable result of years of advertising which has consistently lauded the new, fashionable and unblemished. The common use of the term 'second-hand' in relation to pre-used materials is in itself quite pejorative.

This is counteracted to a certain extent in New Zealand by the perception that many new building materials are not as durable as older materials. This is particularly true when comparisons are being made with items such as first growth native hardwood which is extremely durable, and plantation grown timber. There seems to be little resistance to the use of pre-used items in alterations to existing buildings where there is a need to match what is already there. However the market for pre-used items in new buildings remains small. This may however be more a result of what owners think of as being appropriate in an aesthetic design sense rather than a resistance to the reuse of materials.

Amongst designers the imperatives appear to be somewhat different. Certainly designers are very fashion conscious and may well be resistant to the employment of obviously pre-used materials and components visible in the finished work, unless they, as designers, are making a deliberate design statement. A growing number of designers are in fact using pre-used materials in this way as detailed in Chapter 3.

One of the strategies of the 'information and communication measures and actions' contained in the *NZ Waste Strategy*, is to *"develop and implement programmes for public information and education"*[276]. It is perceived that there is a lack of resources to effectively deal with waste and waste minimisation education. Environmental education that does occur is usually localised, although there are some notable exceptions such as the 'Enviroschools Programme'.[277]

Design for Deconstruction

Several demolition contractors contacted have stated that if buildings and internal components were easier to disassemble, there would be greater materials salvage and possible reuse[278]. There is a perceived lack of New Zealand specific information and case study examples concerned with implementing deconstruction.

This call for increased design for disassembly is an issue that designers, and tertiary engineering, architecture and design teaching establishments do not appear to be aware of, although some effort is being made in this direction at Victoria University of Wellington's School of Architecture and Auckland University's School of Engineering. Currently there is no in-depth teaching of these issues in tertiary institutions or within continuing professional development (CPD) environments.

Although some life-cycle analysis (LCA) tools exist in NZ, LCA is not commonly considered in design or evaluation of costings. Little research is currently being carried out concerning suitable designs and construction practices regarding life-cycle considerations or deconstruction. It is probably true to say that the design professions and most tertiary educators in New Zealand remain largely ignorant of life-cycle resource conservation and deconstruction and demonstrate little inclination to take these issues onboard. Life-cycle costing of deconstruction is dealt with in-depth in Chapter 6.

Market Development for Resource Recovery

There are two distinct market sectors related to resource recovery in NZ, each with their own characteristics and issues as discussed in Chapter 6. Markets for low volume, high value, rare, unique or antique architectural components appear to be well established or developing, and are largely self supporting economically. Some other recovered materials are high volume, low value, such as concrete. The market for such materials in New Zealand is currently restricted.

Similarly there are really two demographic conditions which directly relate to market development. Markets are bourgeoning in the Auckland region but elsewhere in geographically isolated areas or those with low or dispersed populations it is more difficult for the salvaged goods market to grow. This is due to the scale of the local economy and the inherent physical and economic feasibility of finding local markets or transporting heavy and bulky items to larger centres.[279] Growth in these areas may require subsidies which would have the effect of distorting the market and would be unlikely to find favour in NZ's current political climate.

For builders, issues such as the extra time and effort it takes to access and prepare pre-used materials in sufficient quantity, sizes and quality are important to note. It is obviously far easier and more convenient for them to ring up a single builder's merchant, than to access materials from a whole series of smaller outlets. The answer might be for builders' merchants to stock pre-used materials and components but this is unlikely to happen in the foreseeable future as the two main chains of builder's merchants in New Zealand are owned by large, diversified companies who produce or import many new building materials and so have a vested interest in selling new product, preferably their own.

One of the problems identified by some of the councils, particularly those involved with the Zero Waste[280] goal is that the collection, sorting and treatment of waste is less of an issue than finding uses for the collected waste.[281] If new and diverse, localised uses for waste C&D material can be identified and developed, this may help to solve the problem of how to deal with waste in smaller communities. Achieving secure and economically viable volumes of waste/recycled materials remains one of the most intransigent problems in rural areas.

Economic Factors

In the last few years there has been a perceived increased interest in resource recovery within the demolition industry as discussed in detail in Chapter 6. The primary driver for this observable increase has been economic rather than environmental[282]. The main barrier to further development in this area is also economic. There is considerable variation from region to region concerning the economics of resource recovery.[283]

The existing demolition market is highly competitive and tenders are sometimes offered at a price lower than the cost of demolition with profit coming from the salvage sold.[284] In centres such as Wellington, the lower cost of raw materials means a less stable and profitable salvage market. This, combined with the increased health, safety and operational requirements and low landfill charges makes comprehensive resource recovery less viable in most commercial situations. Salvage in these circumstances is mostly restricted to 'cherry picking' as discussed in Chapter 2.[285]

A major problem in the commercial sector in NZ may be the unwillingness of developers to allow sufficient time for deconstruction to occur. In many cases developers are working with borrowed money, at high interest rates and endeavour by every method possible, to shorten their loan period and so reduce their costs.

The Construction and Demolition Industry

There is a perceived general lack of networking within the industry which may be a result of the contractors operating in a very competitive market, the localised nature of most demolition contracting organisations and great disparities in the skill levels across the industry, caused by the unregulated nature of the industry.[286] Survival is the prime motivator for most demolition contractors and issues such as waste minimisation and environmental responsibility are generally not seen as a priority.[287]

The building industry as a whole is very fragmented and hierarchical,[288] with little meaningful dialogue on broader environmental issues between architects, designers, builders and demolition contractors. Unless economic benefits can be clearly identified and information on how such benefits relate to the various parties is disseminated, voluntary action may only involve a small minority of the industry organisations. There may be a need for all the involved parties to get together and start to listen to and understand each other's points of view, issues and problems.

Liability
Liability connected with the reuse of materials is also an issue. Most specifications while not specifying 'new' materials do call up the notion of them being 'the best of their kind and in compliance with the performance and durability requirements of the New Zealand Building Code'. If new materials are used and have been assessed as being code compliant and they fail, designers and structural engineers generally feel confident that they will not be held liable. However with reused materials the situation is not so straightforward. Many designers feel that they are taking an increased personal risk and few may be willing to do this in the absence of any pre-used materials testing or certification schemes in New Zealand. Clients too may feel the need for the reassurance that certification brings to the employment of pre-used materials.

The lack of performance specifications and testing regimes for reused components is linked to current difficulties in acquiring council approval for building consents and this situation is cited by some demolition contractors as a barrier to the incorporation of pre-used materials and components into new development[289]. Some local councils may not easily approve[290] the use of recycled components especially in relation to structural and energy conservation use, because of the lack of certainty in the performance of such items. Building inspectors may be rather dubious about the employment of 'second-hand' materials and components, especially when used in structural or drainage/plumbing situations.

There is an almost complete lack of research into ways to achieve New Zealand Building Code compliance, while using reused materials and components. The development of nationally accepted standard specifications and certification for reused components and materials which may serve to save time and confusion during the approval process has not yet begun in NZ.

Legislation and Regulations
Although it is encouraging that the current government seems to be taking resource use reduction more seriously than previous governments, little action is occurring at present and C&D waste minimisation has been given a low priority for action and presumably, funding.

Existing legislation related to construction and demolition waste minimisation is spread throughout a number of acts, policies and targets in NZ. There is no Waste Minimisation Act or anything similar and 'waste' is dealt with by different health, safety, and environmental legislation as detailed in Chapter 8 of this report. The New Zealand Waste Strategy is a document which sets out general government thinking on, and targets for, waste minimisation, but its status, or implications for people are generally unclear, which remains a barrier to it being an effective driver of change.

It is difficult to find or use comprehensive statistical data related to waste in NZ. The actual amount of C&D waste is currently unclear and there is an urgent need to establish an accurate database. The target date for completion of this phase of the work is 2005 as detailed in the New Zealand Waste Strategy[291] but there is as yet no legislation to back up this request. Central government is encouraging this through voluntary adoption of strategies and targets in the NZ Waste Strategy and the recent review and re-publication of the Solid Waste Analysis Protocol.[292]

Local authorities currently devise their own measurement criteria with or without the help of the Solid Waste Analysis Protocol and this will undoubtedly lead to a considerable number of compatibility of data problems in the future and a waste of resources and time their eventual integration into the necessary national database.

Lack of mandatory requirements, and transitional support and funding from Central Government, is seen by some as inhibiting nationwide adoption of the NZ Waste Strategy. In the absence of common national guidelines, technical backup and a legislative base from which to operate, each local authority establishes and implements waste minimisation and management strategies within its own local area. These schemes vary widely in terms of their effectiveness, and can and are changed at the political whim of both elected officers and non-elected officials.

Technical Issues

Lack of detailed information on the actual materials and construction systems employed in a building may add to uncertainty in deconstruction in NZ. This may affect both its technical and economic feasibility. While the original contract drawings are usually available through council archives and will give much valuable information, substitution of materials noted in the specification is common, as are unrecorded changes which occur during the life of the building.

Quite a number of new materials coming into New Zealand from overseas are given subsidies in their country of origin and this makes it difficult for recovered materials and products to compete. This is particularly difficult for a country like New Zealand to deal with, as New Zealand trade policy does not favour the application of subsidies and tariffs.

The use of composite materials, chemical bonding and other non-reversible building techniques continues to expand in NZ as it does elsewhere. All such methodologies make deconstruction of buildings more difficult.

NZ is in a high seismic zone. This means that some deconstruction systems or methods are not easily applicable to the NZ condition.

New construction methods such as gang nailing and the use of low quality materials such as particle board, makes resource recovery more difficult and less financially rewarding and reduces the economic feasibility of full resource recovery from such buildings in the immediate future.

CONCLUSION:

In conclusion, deconstruction is not in widespread use in New Zealand as a waste minimisation strategy, although there are some notable exceptions which are detailed in various case studies[293]. Where deconstruction does occur it is greatly influenced by demographic and economic factors. This is demonstrated by the higher salvage rates achieved and increased materials reuse initiatives in the larger city of Auckland than in some of the less densely populated regions of the country.

A small but growing number of architects, consultants and engineers are designing for disassembly and designing with reused materials in New Zealand. This is reflective of changing attitudes and a growing awareness of the construction and demolition waste problem in New Zealand.

Central government has begun to address this problem with the recent publication of '*The New Zealand Waste Strategy – Towards Zero Waste and a Sustainable New Zealand 2002*[294], which sets the nation a target of reducing construction and demolition waste going to landfills by 50% of the 2005 figure by 2008. While this is not yet a legally enforceable target and is a target that remains a secondary priority according to the government, it nevertheless signals that central government is taking as active interest in waste reduction.

Half of the Territorial Authorities in New Zealand have set themselves the ambitious target of zero waste by 2015. It is many of these and other local councils, along with waste minimisation groups such as Zero Waste NZ, REBRI, RONZ and the Waste Management Institute of NZ as well as academic institutions such as Victoria University of Wellington, that are driving current and proposed waste minimisation and materials reuse initiatives and research in the construction and demolition area.

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[5] There are two different versions of the Treaty, one in English and one in Māori. This report will refer to the Māori version.
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[7] At present the Treaty of Waitangi is not adhered to by the government in NZ. The treaty is not recognised in the NZ court system but is recognised increasingly by the general public and government.
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[27] NZers generally have a lifestyle and ecological footprint comparable to those in Australia or America.

[28] The land mass of the three main NZ islands is slightly larger than the UK, however there are only 3.8 million people in NZ compared to 59 million in the UK.
[29] The closing of landfills or the foreseeable end of life of landfills or high transport costs to truck waste to larger landfills were sited as reasons for territorial authorities adopting Zero Waste goals during interviews in Opotiki, Tauranga, Hastings, Masterton – Carterton, Waimate, Christchurch.
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REPORT 7
THE STATE OF DECONSTRUCTION IN NORWAY

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SUMMARY

This paper presents the status in Norway on deconstruction related issues. The share of the building and construction waste that is being reused or recycled is currently rather low, and Norway is far from a forerunner with regard to deconstruction related issues. The annual production of waste related to building and construction works has been estimated to be about 1.5 million tons of building waste from the construction, renovation and dismantling of buildings, and about 22 million tons from the construction of bridges, ports, roads, railroads, airports etc.

Important laws and regulations concerning waste handling are referred to, and waste charges and taxes are commented. Several initiatives taken by the trade and the authorities to promote reuse and recycling of building materials are presented, and three examples of deconstruction projects in Norway are shown. These three are the ADISA principles developed by the GAIA architects, the RESIBA project which aim is to make recycled aggregate a competitive product, and Pilestredet Park which is a project on the conversion of an old hospital in Oslo centre into a small town with nearly 1,000 apartments, a college and many offices and shops.

Currently, Norway lies behind many other European countries with regard to reuse and recycling of building and construction materials. Many promising deconstruction initiatives however indicate that the general awareness about deconstruction related issues is increasing, and that more reuse and recycling will take place in the future.

KEY WORDS: Deconstruction, Reuse, Recycling, Buildings

1.0 INTRODUCTION

There is a growing interest for deconstructed related issues in Norway. Waste handling is attracting increasing attention, and several initiatives are taken by trade and the authorities to encourage recycling of building and construction waste. Several pilot projects on reuse and recycling are also being undertaken.

Reuse of buildings and building materials was common in former days in Norway. Log houses are very well suited for deconstruction and transport, and in Norway as well as in other countries with tradition for log houses, removing of houses was rather widespread. The logs in many of the old log houses in Norway show marks from having been removed once or several times. It was common practice several places in Norway to expand houses by adding a new unit. Houses were often given as wedding presents, or removed in connection with inheritance or sale of property. Some rural districts in Norway even made business on fabricating log houses and storing them in order to wait for the demand for temporary houses that would rise when a town or city in the vicinity was struck by fire.

Figure 1 Removing of a log house. Dismantling (left) and assembling (right). Photos: K.I. Edvardsen.

A growing interest for protecting the cultural heritage arose in the early 19th Century. Many buildings were removed to save them when other forms of protection did not succeed. A stave church in an inland valley in Norway (Valdres) was the first building to be saved this way. This specific church was actually removed to Schlesien, Preussen (now Poland) where it was assembled in 1844 [1]. From the turn of the century, several outdoor museums in Norway started collecting old houses to save them and exhibiting them to make them available for visitors.

1.1 Waste Impact of the construction industry

Deconstruction status in Norway
The share of the building and construction waste that is being recycled or reused in Norway is currently rather low. Little has been done up to now to reduce the amount of building and construction waste when designing and constructing buildings. For the Oslo region, it has been estimated that between 25 and 50 % of the waste are recycled or reused, while the corresponding share is estimated to be close to zero for the rest of the country [2]. In Denmark, in contrast, as much as 90 % of the building and construction waste is being recycled or reused, and only 10 % disposed of. It thus seems to be a long way to go before Norway can be said to be a forerunner with regard to waste handling and reuse and recycling.

1.2 Waste statistics; percentages of C&D waste reused, recycled, or landfilled

Building and construction waste
The statistical information about the Norwegian building and construction related waste is rather weak, and large uncertainties are involved in the estimation of the annual waste volumes being generated in the building sector.

Statistics Norway and Green Warriors of Norway has analysed the average waste volumes being generated during building works as seen from Table 1. The figures vary significantly within each type of waste. The amount of wood being generated during renovation works, as an example, is estimated to range from 2.3 kg per square metre to 42.6 kg per square metre. The large variations may be explained by different types of constructions used in the case buildings in the surveys, as well as different routines and practise on the building site with regard to minimising the waste volumes.

Table 1 Building related waste. Waste volumes (kg per square metre) being generated per square metre floor space during construction, renovation and demolition of buildings [3].

	Construction	Renovation	Demotion
Concrete and brick	6.5 - 15.7	18.8 – 40.4	387 – 1164
Wood	2.8 - 1.1	2.3 – 42.6	23.6 - 98.5
Paper/plastic	0.3 - 2.6	0.1 - 1	0.3 - 6.5
Metals	0.2 - 1.2	0.2 - 4	3.3 – 29
Plaster boards	0.8 - 3.5	2.3 – 5.9	0 - 4.1
Mineral wool	0.1 - 1.2	0.1 – 0.6	0.1 - 2.2
Asbestos	0	0.5	1
Special waste	0.017	0.05	0.57
Glass	0 - 0.3	0.4	0.3 - 3.3
Polluted waste	0	0	9.9
Unsorted waste	8.8 - 9.6	2.2 – 10.8	22.8 - 35.3
Asphalt	0.7	0	1
Soil, rock etc.	2	2	2

Based on information about the total floor space of new buildings in Norway in 1998 and the space of buildings being renovated or demolished, the total amount of building waste has been estimated to be about 1.5 million tons as shown in Table 2., whereof about 70 % concrete and brick tiles and 14 % wood.

Statistics Norway does not provide a similar statistics on waste from construction works (waste generated during the construction of bridges, ports, roads, railroads, airports etc.). Instead, in Table 2 the amount of such waste has been estimated by using Finnish data, correcting to Norwegian conditions by adjusting for different population sizes. This way, the total amount of construction waste (predominantly soil and rock) has been estimated to be 22 million tons. Even though the waste generated during construction works is about eight times the waste from building works, the construction related waste is not considered as a big environmental problem. Construction waste predominantly consists of non-polluted soil and rock and is more considered as a space problem than a pollution problem by the authorities. The waste is often used for road fillings and in foundations.

Table 2 Building and construction waste in Norway in 1998 by type of waste (1,000 tons). Building waste includes waste from the construction of new buildings, and renovation and demolition of existing buildings. Construction waste includes waste from works related to bridges, ports, telecommunication, roads, railroads, airports, sewage systems, hydro power plants etc. [3].

Type of waste	Building waste					Construction waste	Total waste
	Const-ruction	Reno-vation	Demo-lition	Total			
Concrete and brick	77	155	799	1,031	69%	0	1,031
Wood	41	96	76	213	14%	36	249
Paper/plastic	8	2	6	16	1%	0	16
Electric cables	0	0	0	0	0%	10	10
Metals	3	8	31	42	3%	1	43
Plaster boards	14	18	2	34	2%	0	34
Mineral wool	4	2	1	6	0%	0	6
Asbestos	0	2	4	6	0%	0	6
Special waste	0	0	1	1	0%	1	2
Glass	1	2	2	4	0%	0	4
Asphalt	5	0	2	6	0%	226	232
Polluted waste	0	0	15	15	1%	0	15
Unsorted waste	61	26	40	127	8%	14	141
Total	213	311	978	1,502	100%	287	1,790
Soil, rock etc.	13	0	3	16		22,090	22,106

The Norwegian building waste of 1.5 million tons per year correspond to about 340 kg per capita which is lower than in most other European countries. The average waste volume per capita in 1996 in the member countries of the European Union has been estimated to range from 140 kg per capita in Sweden, to as much as 6,750 kg per capita in Luxembourg as seen from Table 3. Different types of constructions and consequently different composition of the waste may be one reason for the variations in the table. Lightweight, wooden constructions are for instance very common in Norway. This contributes to a lower density of the building and construction waste in Norway than in other European countries where brick and concrete constructions are more common. A survey conducted by Statistics Norway, for example, shows that more than 90 % of all one-family and divided small houses in Norway had wood as main construction material.

Table 3 Building and construction waste in Norway and the member states of the European Community [4].

Country	Million tons	kg/capita/year
Norway	1.5	340
EU-countries		
Belgium	7.5-8.0	700-800
Denmark	2.3-5.0	460-1000
Finland	1.6	320
France	20-25	340-450
Greece	?	-
The Netherlands	13-14	870-930
Ireland	2.5	710
Italy	35-40	600-930
Luxembourg	2.7	6750
Portugal	?	-
Spain	11-22	280-560
Great Britain	50-70	880-1220
Sweden	1.2	140
Austria	52-120	840-1900
Germany	22	2860
EU, total	221-334	607-918

In addition to the effect of different constructions types used in the countries, the large variations in Table 3 are probably also caused by different definitions on what is considered as building and construction waste, and different routines concerning registration of the waste.

3.0 REUSE OF BUILDINGS AND COMPONENTS
3.1 In situ building reuse

EXAMPLES OF DECONSTRUCTION RELATED PROJECTS IN NORWAY

There is a number of deconstruction related projects ongoing in Norway. In the following, three interesting examples are shown. The first one is a large renovation project in Oslo city where reuse and recycling of materials, components and buildings are emphasised. The second is a large project on the use of recycled aggregate in the building and construction industry. The third is a system for reusing building components developed by the GAIA architects.

Pilestredet Park
A new State Hospital will open just outside Oslo in July 2000. The old State Hospital is located in the centre of Oslo. A project called Pilestredet Park has been established to convert the old hospital area into a small town with about 900 apartments, the Oslo University College and it's 3,000 students, and a number of offices and shops.

It is a goal that Pilestredet Park shall be a leading example on sustainable urban development. An urban ecology program has been established, providing requirements and recommendations for different environmental issues. Pilestredet Park is expected to be completed in year 2004 or 2005.

Today, the hospital buildings comprise approximately 110,000 square metres above ground, whereof about 50,000 square metres will be demolished. When completed, Pilestredet Park will include 63,000 square metres of renovated buildings, and 72,000 square metres new buildings [10]. One important reason for demolishing such a large share of the existing buildings, and not to renovate them, is the need for private car parking. The new buildings will be constructed with parking in the basement.

The old hospital was owned by the state, but most of the site has now been sold to private developers. The contracts include strict requirements with regard to reuse and recycling of the demolition materials. It is a general goal to recycle at least 90 % of the waste materials generated during the building and construction works, and maximum 10 % of the total demolition waste is allowed to be deposited. It has been estimated that the development of the Pilestredet Park projects will generate about 85,000 tons of building and construction waste, not included soil and rock from the digging works. The waste from digging works is estimated to be between 300,000 and 400,000 tons. Since Pilestredet Park is located in the centre of Oslo, it will be aimed at reducing the transport of waste as much as possible. Most of the waste will therefore be seeked reused or recycled on the site. A large share of the concrete and brick waste, for instance, will be used as aggregate in new concrete.

The state has kept some part of the site for public buildings. One of the existing buildings (The Pathology Building) will be converted into the head office of the National Insurance Administration with 560 employees, another will be the new National Medical-Historical Museum. A pilot project has also been started called “The Reused House”, where the goal is to construct a house on the Pilestredet Park area using recycled and reused materials and components. The house will contain apartments for members of the Norwegian Parliament (Storting), and it will hopefully contribute to increase the members’ awareness about deconstruction related issues and the need for increased reuse and recycling.

4.0 ENHANCING MATERIALS RECYCLABILITY

Deconstruction initiatives

The general environmental awareness in the building and construction trade is increasing, and several initiatives have been taken by the trade and by the authorities to reduce the waste volumes and increase the recycling rate.

NORSAS is a national competence centre for waste and recycling. NORSAS shall promote waste reductions, increased recycling and safe handling and final treatment of waste. Furthermore, the centre shall support local councils, the industry and the authorities in the work for reduced waste volumes and increased recycling rates. NORSAS shall collect, treat and disseminate information and knowledge about waste handling. One important task for NORSAS is to operate a national register on waste handling, where all enterprises involved in waste handling are registered. The enterprises are instructed to report annually the volume, type, origin, transport and handling of waste. This information will contribute to increase the knowledge about the waste streams in Norwegian.

EcoBuild (Økobygg) is an initiative from the building and real property trade to contribute to environmental improvements and the achievement of national, environmental goals. The programme, which runs over five years (1998 - 2002), shall engage the whole trade in a co-ordinated and comprehensive effort on environmental improvements. The total budget is around 50 million NOK per year (close to 7 million USD) The financing comes from both governmental and private funds. Four ministries are involved; Ministry of Local Government and Regional Affairs, Ministry of the Environment, Ministry of Trade and Industry, and Ministry of Petroleum and Energy. A board of representatives from the building and real property trade directs the programme. Eight main areas of work are defined for EcoBuild. One of these is building and construction waste. The goal is to reduce the building and construction waste by more than 70 % by establishing a commercial market system for recycling of waste. Improved waste handling in the industry and improved practise on waste minimisation, sorting of waste and controlled handling of toxic waste in connection with building projects will be important factors to reach the waste reduction goal.

Two trade organisations, BNL and TELFO, are developing a national action plan for building and construction waste. Phase I of this work, a state of the art report on building and construction waste, was completed in December 1999 [3]. In Phase 2, specific goals for waste reductions and recycling will be established together with measures to reach these goals. The work is partly financed by EcoBuild.

4.2 Recycling issues for specific materials (concrete, metals, plastics, glass, etc.)

Norsk betongforening (The Norwegian Concrete Association) has developed national guidelines for classification of the use of recycled aggregate in the production of new concrete. Depending on the classification of the aggregate and the quality of the concrete, up to 30 weight-% of recycled aggregate is allowed.

RESIBA

RESIBA (Recycled Aggregate in Building and Construction) is a three-year research project carried out by a number of manufacturers, enterprises and organisations in the Norwegian building and construction trade. The project is financed by the involved industrial partners and the EcoBuild programme. The aim of RESIBA is to make recycled aggregate to a competitive product, and to bring Norway up to the same level as rest of Europe with regard to the use of recycle based building materials [9].

The background for RESIBA is the fact that concrete, brick and rock represent the dominating part of the total waste produced by the building and construction industry. The benefits of recycling heavy building and construction waste should be large. Crushed concrete, brick and rocks can be recycled in unbound form (as filling material in foundations etc.) as well as in bound form (as aggregate in concrete).

RESIBA consists of three sub-projects. The first sub-project is titled “Declaration and quality control”. The aim of this project is to provide basis information about the most important technical properties of recycled products, and to estimate possible environmental burdens. The development of routines for quality control of recycled product is also an important. The project is linked to the European research programme “Use of Recycled Aggregate in the Construction Industry”.

The aim of the second sub-project, “Demonstration projects”, is to evaluate the use of recycled aggregate in full-scale constructions and initiate pilot projects. The use of recycled aggregate in roads, ditches and different types of concrete shall be investigated through these pilot projects. One interesting pilot project that already has been carried is the use of recycled aggregate in sprayed concrete. The sprayed concrete was used to cover EPS insulation used in the foundation of a tramcar line in Oslo. The project is claimed to be the first in the world where recycled aggregate has been used in sprayed concrete. Totally 720 square metres of EPS were covered with four different types of sprayed concrete: without recycled aggregate, and with 7 %, 14 % and 20 % recycled aggregate. The project showed promising results with regard to mixing, spraying and mechanical properties of the concrete.

The aim of the third sub-programme, “Information dissemination”, is to spread knowledge and results from the project to the building and construction trade, as well as to the politicians and the authorities.

7.0 DESIGN OF BUILDING AND COMPONENTS FOR DECONSTRUCTION

7.2 Design of components for disassembly

GAIA architects
The GAIA group is a small group of idealists promoting ecological construction in Norway. Professional architects sharing an interest in ecological issues in house building and area planning established the group in 1983. The members of the GAIA group promote the use of traditional, locally produced building materials and well-known and simple technology. Many of their constructions are also rather labour intensive, which make the GAIA solutions rather controversial, and often difficult to implement in modern, industrialised building production.

The GAIA architects early saw the need for developing building systems that were adapted for future replacement, reuse and recycling of materials and components. But, they did not succeed in obtaining the required financing to do this until the mid 1990s when the project “Building System for Reuse” was carried out [6]. In this project, a building system called BfO was tested out. The system was based on three main principles:

- separation of the different layers of the building (with reference to Brand’s principle of “Shearing layers of change” [7])
- easily dismantling and replacement of components within each layer (extensive use of screws, weak mortar in brick works, and avoidance of glue),
- the use of mono-materials (no composites).

The BfO system included 88 specially designed wood and concrete components that could be assembled with standard components into a large number of different constructions. The specially designed components were meant to be locally produced. It was aimed at utilising wood from small-sized timber. It was further a goal to use mono-materials that could easily be dismantled for replacement or reuse in another building. A main idea behind the BfO system was that easily dismantling would make it easy to change the size and the shape of the building according to the occupant’s needs.

In the project, the BfO system and the reusability of the BfO components were tested out by first erecting a pavilion using such components. Thereafter, the pavilion was dismantled, and the components used in the construction of a prototype BfO house with gross floor space of 130 square metres. In the project, the dismantling and reuse of the BfO components were successful. It was however also learned that the number of special components should be reduced to simplify the system, as well as it was a need for more standardised wood components, even though this would mean larger pieces of wood and not the same potential for utilising small-sized timber.

Based on the idea of the BfO system, and the experience from the BfO pilot project, the ADISA principle was developed. ADISA (Assemble for DIS-Assembly) consists of 45 standardised components (as compared to 88 for BfO) [8]. Space plans are flexible within a module of 600 mm. This ADISA principle has not been fully tested in a pilot project yet. But, some of the ideas and principles are currently used in the design of Prestheia eco-village outside Kristiansand. At Prestheia, several row houses consisting of totally 19 dwellings will be constructed during 2000 and 2001. In the design of the houses, it is aimed at using dismantleable solutions, and to obtain flexible space plans.

The original intention behind the ADISA principles was to establish a market based system where the used components could be returned to the local manufacturer for quality control, and thereafter used in a new building project within the region. But, in practise, it has been difficult to establish a market based system based on the ADISA principles.

8.0 POLICY, REGULATIONS, STANDARDS, LIABILITY

The authorities involvement in deconstruction

The involvement of the authorities is important for what is happening in the building and construction industry with regard to deconstruction related activities. The main strategy of the authorities within the field of waste handling is:

- first of all to prevent waste from being produced and to reduce the amount of harmful substances,
- secondly to promote reuse, recycling and energy utilisation of the waste,
- and finally to ensure an environmental sound treatment of the remaining waste being disposed of.

8.1 Government policy supporting deconstruction

Laws and regulations

The Pollution Law from 1981 is one important law regulating the handling of building waste. This law is based on two principles; the first principle is that waste should be handled in a way that minimise damage and inconvenience, and recycled where this is environmentally beneficial, resource efficient and economic acceptable. The second principle is that the polluters should pay the full costs of the environmental damage they are causing (Polluter Pays Principle).

According to the law, building and construction waste is defined as production waste, and the same requirements therefore apply as for other types of waste. Stricter control of the waste handling according to the Pollution Law has contributed to significantly reduce illegal dumping which was considered as a problem before. The Ministry of Environment has delegated some local councils the power to develop local regulations on building and construction waste. The councils can require that the builder shall produce an overview of the waste amounts that will be generated during the building and construction works, and to develop a plan on how this waste shall be handled. Oslo is one of the councils having developed such local regulations on waste, and the results have been promising with regard to reuse and recycling of heavy building waste. The Ministry of Environment therefore plan to delegate this power to develop local waste regulations to all local councils in Norway.

8.3 Creating standards for deconstruction and materials reuse

The Planning and Building Act shall ensure that building and construction works are executed correctly and technically safe. Supplementary to the act, there are technical regulations that regulate building and construction works and the products used in buildings. A main goal of the act and the regulations has been to improve the quality of the building process. All building and construction projects, including demolition projects, should be executed by approved enterprises. There are strict requirement on the skills and qualifications of the persons involved in the process, and the requirements for documentation have been significantly enhanced.

The need for long-term perspectives and environmental concerns are emphasised. In the technical regulations, for instance, it is stated that:

> *"The life of works shall in all phases, i.e. execution, usage and demolition, be managed with a reasonable load on resources and environment, and without worsening quality of life and living conditions. Materials and products for use in construction works shall be manufactured with justifiable use of energy and with the aim of preventing unnecessary pollution. Construction works shall be so designed and executed that little energy is consumed and little pollution is caused during the life of the works, including demolition." (§ 8.1)*

The Working Conditions Law from 1977 shall ensure the safety, health and welfare of the employees. There are several regulations under this law. One regulation (Byggherreforskriften) instructs that the builder shall ensure that safety, health and working conditions are taken care of in all stages of the building project. The builder is responsible for the handling of materials on the building site, the storing and removing of waste [5]. Another regulation instructs works involving contact with asbestos. This regulation directs that only specially trained employees are allowed to handle asbestos or products containing asbestos.

8.4 Legal issues

Charges and taxes

There are local charges for delivering waste on disposal sites. These charges are levied to cover the full costs of establishing and running sites. The charges may therefore vary between the different local councils in the country.

A national tax on depositing waste was enforced in 1999. The tax is 300 NOK (35 USD) per ton of organic or unsorted waste. If the waste is incinerated, a basic tax of 75 NOK per ton and a supplementary tax of 225 NOK per ton applies. The supplementary tax is reduced according to the degree of energy recovery. If the waste is incinerated without energy recovery, the tax will be 300 NOK per ton, which is similar to the tax for depositing unsorted waste. The national tax is intended to stimulate waste reductions, increased material recovery and utilisation of the energy content of the waste.

9.0 BARRIERS AND OPPORTUNITIES FOR DECONSTRUCTION

DISCUSSION

Behind the concept of deconstruction lies the need for reducing the overall resource consumption in the society. Deconstruction promotes resource efficiency by focusing on reuse and recycling of materials and components. Deconstruction includes several issues, such as:

- the reuse and recycling of the waste materials currently being generated,
- the use of reused and recycled products in the construction of buildings,
- the design of buildings for future dismantling and optimum reuse and recycling of the materials and products used.

The primary focus in Norway with regard to deconstruction efforts is short-termed on reducing the total amount of waste being disposed of. Reuse and recycling are promoted since it contributes to reduce the amount of waste being disposed of, and not because it contributes to reduce the overall resource consumption in the society.

Statistics show that Norway in many ways lies behind many other European countries with regard to reuse and recycling of building and construction materials. Only a small share of the total building and construction waste is being reused or recycled in Norway. There might be several reasons for why recycling and reuse are less practised in Norway than in other European countries. Lack of market for reused and recycled products is probably one important reason.

To be cost-efficient, recycling plants must treat a certain volume of building waste. Such a volume may be difficult to achieve many places in Norway since the country is sparsely populated. The population of 4.45 million people is spread over a total land area of 324,000 square kilometres. The corresponding population density of 13 persons per square kilometre is close to 20 times lower than in for instance Germany and United Kingdom [11]. Long transportation distances in Norway also contribute to increase the costs of reusing and recycling building and construction waste.

Land is expensive in central parts of Europe. This gives an important economic incentive for reusing and recycling waste instead of using land for waste disposal sites. In Norway, in contrast, the costs of establishing waste disposal sites may be taken to be lower since there is still much available space left. This contributes to make waste disposing more economic attractive than reuse and recycling.

Norway has good supply of natural resources like gravel, rock and timber, in contrast to many other countries where the supply is more limited. The good supply may have contributed to reduce the attention around resource efficient handling of building and construction waste in Norway.

By introducing the national tax on waste disposal in 1999, the authorities are now trying to promote reuse and recycling of waste instead of disposing. With regard to buildings, however, and the measures taken to reduce future waste volumes, this tax will have limited influence due to the effect of discounting. Most buildings have long services lives. The present value of waste disposal costs occurring 50 or 100 years into the future is close to zero for ordinary interest rates. This way, there are almost no economic incentives in designing and constructing buildings that are suited for future reuse and recycling. It is consequently a fundamental problem that discounting in cost-benefit analyses does not favour design for disassembly and future reuse and recycling of buildings. Other than economic instruments should therefore be applied to promote long-termed reuse and recycling in the building sector.

Many promising deconstruction initiatives are taken in the building and construction trade, and there are signs indicating that the general awareness about deconstruction related issues is increasing in the population. The demolishing of a 15-storey office block in the centre of Oslo in April 2000 can for instance be used as an example of the public's interest in deconstruction. The building that was demolished was the first high-rise building erected in Norway (in 1960), and it was the highest building ever demolished in Scandinavia. Using 75 kg of dynamite, it took 4.5 seconds to take the building down. More than 10,000 people had appeared on the scene to see the building go down, and the demolishing was headline news in most media.

Information technology and internet solutions opens for easily organisation of the trading of used (and new) components. If a system for reusing building materials and components was widespread implemented in the building and construction market, it would significantly contribute to reduce the overall resource consumption and waste volumes. In the work towards such a system, the ADISA principles developed by GAIA architects may serve as an inspiration and example on how the building and construction industry could be organised in a more sustainable way.

CONCLUSIONS

The share of the building and construction waste that is being recycled or reused in Norway is currently rather low, and Norway is far from being an international leader with regard to deconstruction related issues.

The annual production of building waste has been estimated to be about 1.5 million tons, whereof about 70 % concrete and brick tiles and 14 % wood. The waste from the construction of bridges, ports, roads, railroads, airports etc. has been estimated to be 22 million tons, or eight times the building waste. The construction related waste is however not considered as a large environmental problem since it predominantly consists of non-polluted soil and rock and more represents a space problem than a pollution problem.

The handling of building waste is regulated through several laws and regulations. In compliance with the Pollution Law, some local councils have been delegated the power to develop local regulations on building and construction waste. Oslo has been one of the councils, and results so far are promising. The Planning and Building Act with the corresponding Technical Regulations put strict requirements on the skills and qualifications of the persons involved in the building process, and the requirements for documentation have been enhanced.

There are local charges for delivering waste on disposal sites. These charges are levied to cover the full costs of establishing and running sites. A national tax of 300 NOK per ton for depositing waste was enforced in 1999. The tax is intended to stimulate waste reductions, increased material recovery and utilisation of the energy content of the waste.

Several initiatives have been taken by the trade and the authorities to promote reuse and recycling of building materials. Amongst these are NORSAS - a national competence centre for waste and recycling, and EcoBuild – a five year action programme which aims to contribute to environmental improvements in the building and real property trade, and the achievement of national, environmental goals. Furthermore, two trade organisations (BNL and TELFO), are developing a national action plan for building and construction waste.

Several projects with focus on reuse and recycling have been initiated. The GAIA architects have developed the ADISA principles which is a building system adapted for future replacement, reuse and recycling of materials and components. Some of the ideas and principles behind ADISA are now being used in the design of an eco-village outside Kristiansand.

RESIBA is another interesting project. The aim of this project is to make recycled aggregate to a competitive product, and to bring Norway up to the same level as rest of Europe with regard to the use of recycle based building materials.

Pilestredet Park is a project established to convert an old hospital area in Oslo city into a small town with nearly 1,000 apartments, a college with many students, and a number of offices and shops. Pilestredet Park shall be a leading example on sustainable urban development. There are strict requirements with regard to reuse and recycling of the demolition materials. At least 90 % of the waste materials generated during the building and construction works shall be recycled, and maximum 10 % of the total demolition waste is allowed to be deposited as waste. The construction of a “Reused House” will be a show-case project at Pilestredet Park.

The primary focus in Norway with regard to deconstruction efforts is short-termed on reducing the total amount of waste being disposed of. Reuse and recycling are promoted since it contributes to reduce the amount of waste being disposed of, and not because it contributes to reduce the overall resource consumption in the society.

Statistics show that Norway in many ways lies behind many other European countries with regard to reuse and recycling of building and construction materials. But, many promising deconstruction initiatives are currently taken in the building and construction trade, and there are signs indicating that the general awareness about deconstruction related issues is increasing in the population. Hopefully, the deconstruction examples referred to above can serve as an inspiration and contribute to increase the reuse and recycling of materials and components in the building and construction trade.

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REPORT 8
THE STATE OF DECONSTRUCTION IN TURKEY
(TECHNICAL REPORT ON DECONSTRUCTION FOR TURKEY)

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ABSTRACT

An in depth study of the Turkish laws, acts, regulations, standards and official contract documents related to construction and demolition works; environmental issues; health and safety standards; waste disposal; recovery of building materials, and recycling has revealed that as far as policies are concerned, Turkey has adopted them in almost all relevant fields. These documents were obtained from the officials and/or from the web-sites of the Ministry of Environment; the Ministry of Development and Settlements; Ministry of Works; Ministry of Culture; major municipalities; Turkish Standards Institute (TSE- Turk Standartlar Enstitusu); State Institute of Statistics (DIE – Devlet Istatistik Enstitusu); and various experts/professors from the Middle East Technical University (METU).

Since Turkey is aiming to enter the European Union it is updating or revising its laws and regulations as well as adopting new ones, in order to facilitate its membership. Turkish laws governing most aspects of construction and demolition works exist but, unfortunately, they are not applied stringently due to a lack of checks and resources. Same is the case with recycling waste and waste disposal; the regulations are there but the resources to enforce them or awareness of their existence is missing.

Lack of data also acts as a deterrent in the dissemination of information and assessment of the state of affairs. The DIE does not have the resources to collect all necessary data at regular intervals. Although, a database for the construction sector exists, which is updated regularly, data for building demolitions and rubble disposed is not tabulated from the building permits, which are the only source of the data for new buildings. In short, the information and regulations exist but the resources for enforcement are very limited.

KEYWORDS: Used building material; C&D waste; Rubble; Turkish Standards Institute; DIE, Turkey National Report on Sustainability.

1.0 INTRODUCTION

Conventionally, buildings in Turkey are constructed with a reinforced concrete structure, plastered and painted masonry walls and timber fenestration. Floor finishes are terrazzo or ceramic tiles while plumbing pipes and conduits for electric wiring are embedded in the masonry walls. Buildings constructed with such materials are not easy to deconstruct; while the type and amount of recoverable building material and components is limited.

Nevertheless, partial deconstruction has always been as much a part of Turkey’s traditions as has been construction. Examples of reused building components can be seen at most of the historical sites and old settlements. Even the centuries old Ankara citadel has pieces of ancient Roman structures in between the stone blocks of the fortifications; for instance, you can see sections of marble columns or blocks with Roman script and/or carvings at many locations on the stone wall. Turkish people are known for their frugality, and a capacity for 'making do' with limited resources. It is therefore not surprising that each large city has its share of used building materials outlets. These outlets are owned and run by the demolition contractors themselves. In Ankara almost all of the demolition contractors yards are located on the same main road, on the other hand, in Izmir and Istanbul they are widely dispersed in the city. In fact, in Istanbul some contractors relocate their yards to areas where new informal settlements are mushrooming; the squatters being their biggest clients.

The number and the size of the demolition contractors' yards, which are also the used building materials' outlets, is an indication of the amount of demolition going on in the country. All building components, apart from rubble, that are recovered from a demolished structure are sold at these yards. The rubble is disposed in landfills or any place deemed convenient by the driver of the disposal lorry. Since the municipalities charge dumping fee according to the amount of material to be dumped, records for excavation soil or demolition rubble are not tabulated separately. Although, some statistics for industrial waste are available, they do not encompass construction or demolition wastes.

1.1 Waste Impact of the Construction Industry

According to Turkey's "National Report on Sustainable Development 2002", the type of industrial waste in Turkey as a developing country is not much different from the type of waste encountered in the developed countries of the world. In order to quantify the amount and composition of industrial waste and to investigate the resultant environmental problems, the DIE as well as certain local governments and industrial organizations (such as: the Union of Chambers of Commerce, Industry, Maritime Trade and Commodity Exchanges of Turkey; Chambers of Industry of Istanbul and Kocaeli) have conducted independent studies to develop industrial waste inventories for the period of 1991-1995. Although the industrial waste inventories of the manufacturing sector for 1994-1997, prepared by the DIE, did not cover the entire country, it is the only legitimate waste statistics data bank that exists in Turkey. Besides the Industrial Waste Statistics of the DIE, the Ministry of Environment has also concluded a detailed industrial waste inventory project in 2002, which encompasses the Marmara, the Mediterranean, and the Western Anatolia Regions

Waste generated by the construction industry has not been accounted for in the statistics for industrial or household wastes. Since data for waste produced or disposed of by the construction industry has not been collected by any of these agencies, the impact of waste from construction industries is also not known.

1.2 Waste statistics; percentage of C&D waste reused, recycled, or landfilled

The State Institute of Statistics (DIE) collects and publishes different types of data regularly. Decision about the type of data to be collected depends upon the demands of the various ministries [1]. Two types of databases that may be of use to architects and the construction industry are the Construction and the Environmental statistics. Construction statistics comprise of data related to building contractors/firms, new/renovated buildings, and cost indices. On the other hand, information with regard to buildings being demolished or dismantled is not gathered. Only buildings demolished by fire have been accounted for, as this data is collected from the reports filed by the various Fire Departments in the country.

Environmental statistics cover such areas as air and water pollution, and solid waste disposal. Data for solid waste is further divided into household and industrial waste categories.

Although, air and water pollution statistics are published on a monthly basis, the "Household Solid Waste Composition and Tendency Survey" was conducted in 1993 only and the "Municipal Solid Waste Statistics" were collected for the year 1991.

An analysis of the manufacturing and/or industrial sector waste inventories of 1994-1997 published by the DIE, as well as data on the composition of industrial wastes by sectors and the amounts disposed, yields the following conclusions:

• In Turkey, the manufacturing sector generates over 13 million tons of industrial waste annually.

• Approximately 57 % of this amount is disposed.

• Approximately 30 % of the disposed wastes are taken to municipal dumping grounds and the remaining 70 % are disposed of in uncontrolled and unregulated manner.

This means that close to 5 million tons of industrial wastes are being dumped each year in the country without proper regard to environmental and human health issues, and thus creating significant problems. The most recent data on the distribution of industrial waste by sectors and the methods of disposal are given in the Figure 1. As can be seen here, metals, chemicals, and food industries are producing most of the industrial wastes [2]. It should be noted that even though the definition for 'industrial solid wastes' includes the term 'stone and soil' the statistics for such waste belongs to mineral waste from the mining sector only. Data for 'construction debris' has not been collected so far.

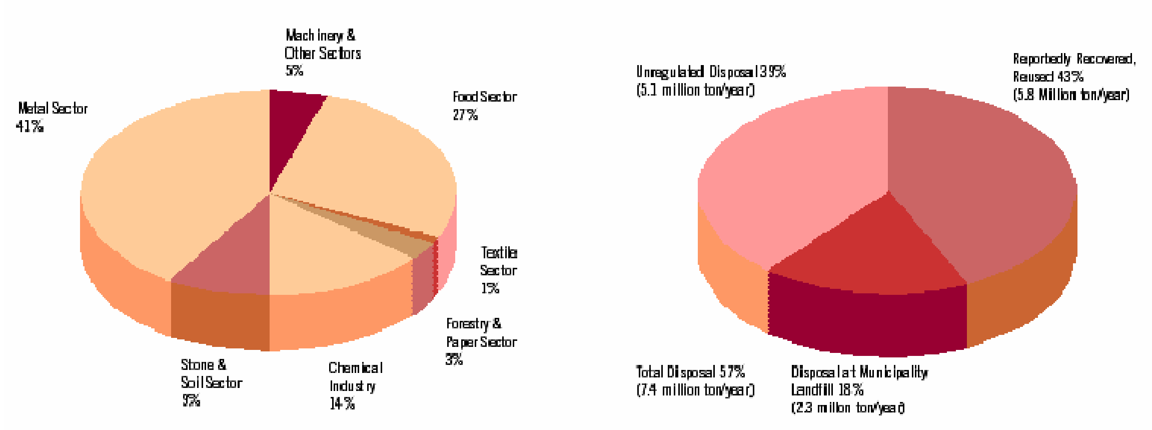

Figure 1 Industrial Waste Production by Sectors, Removal and Disposal Methods in Turkey. Source: Turkey's National Report on Sustainable Development.

2.0 DEMOLITION AND DECONSTRUCTION TECHNIQUES, MACHINERY AND TOOLS

All over Turkey, buildings are constructed with reinforced cement concrete (RCC) skeleton structures or bearing wall structures, with masonry wall partitions, therefore, it is not possible to deconstruct them totally. Building components or material to be recovered from a building are dismantled manually and removed from the site before demolition work starts on the empty shell. Most of the demolition work is also done manually, which is time consuming and expensive. The demolition contractors do not consider it worth their while to salvage brick or masonry blocks, therefore, the structure is reduced to rubble as fast as possible. The resulting mound of rubble is left behind on the site, to be removed later by the building contractor (Figure 2).

Figure 2 Rubble from the demolished building in a residential district of Ankara, has been left behind on the site.

2.1 Planning issues for demolition and deconstruction

The Ministry of Development and Housing has prepared a ‘Technical Contract for Demolition and Dismantling’, which covers all technical aspects of such works. This document requires the demolition contractors to:

- prepare a demolition action plan in view of the structural typology;
- take stringent precautions for human safety and reduce environmental pollution;
- use proper scaffolding, machinery and tools;
- employ trained workers;
- recover as much building material for reuse or recycling as possible; and
- store the recovered material properly until removal from site.

Although, demolition contractors may be required to follow these guidelines when they bid for public works, they do not feel obliged to abide by them in private projects.

2.2 Demolition techniques, methods and machinery

As mentioned earlier, demolition is done manually with the help of sledge-hammers and pick axes. Sometimes pneumatic drills and excavating machines are also used. If fenestration and other fixtures are to be sold, they are dismantled; otherwise they too are knocked down. The glazing is broken and removed and then the timber fenestration is sawed and pulled out for firewood. Subsequently, a top-down technique is adopted where the roof slab is demolished first with pick axes. Non load bearing walls are knocked down next, with sledgehammers or even excavators. The concrete structure is demolished with bulldozers. If the building is higher than 2 floors, the top floors are demolished with all the aforementioned machinery and tools until it is reduced to a skeleton low enough to be bulldozed.

2.3 Deconstruction techniques, methods, and tools

Deconstruction is done manually, and since it is an expensive and time consuming process, the demolition contractors choose to recover only those building components which have a resale potential. They use crowbars, hammers and de-nailers to dismantle fenestration, door sets, built-in cabinets and cupboards, and other fittings. Very rarely, old brick is recovered from the building, provided the mortar has deteriorated with time and the bricks can be loosened with crow-bars.

The number of workmen employed can vary from as many as fifteen to as few as five, depending upon the size of the structure to be demolished. In the case of a standard squatter house (called a 'gecekondu' in Turkish), which is a single storey building consisting of 3 to 5 rooms, time taken by the demolition contractor to recover re-saleable material is only one day. Three workers are required to take down the roofing tiles and another two are employed in removing fenestration and timber components. This can be achieved during the first half of the day, while the rest of the day is spent in dismantling the timber roof structure and other fixtures. If the building skeleton is made up of reinforced concrete, the steel reinforcement is also removed for recycling [3].

2.4 Worker training and safety

The Ministry of Works has adopted strict measures for workers training, safety, health and employment conditions, which are enforced through laws, bye-laws, rules and regulations. These measures cover all the different aspects of the various types of works. For instance, the rules and 'Regulations for Health and Safety of Construction Workers' include the health and safety issues for construction as well as demolition workers. These regulations also stipulate that trained workers be used for dangerous jobs; however reality has it otherwise, as construction and demolition contractors are known to employ only unskilled labor for most manual work.

3.0 DESIGN FOR REUSE

Although, used building materials are not a novel commodity in Turkey, its buyers are usually squatters who cannot engage the services of qualified professionals to design their houses. On the other hand, home-owners/builders who employ architects usually want to use new and fashionable materials. For this reason, reuse of building components is not popular with the construction industry. Moreover, very few architects are aware of the presence of used building materials outlets, let alone the difficulties of recovering building components from demolitions. It is not surprising that they are not cognizant of the need to design for reuse.

3.1 In situ building reuse

In-situ reuse of buildings is fairly common; this is usually brought about by the change in use-patterns of urban districts. As the central business districts (CBD) expand, residential districts are assimilated into commercial districts. Apartment blocks are converted to office blocks, multi-level shopping centers, or even hospitals. If the conversion requires a major renovation project, the owners have to obtain permits from the municipality concerned. On the other hand, if the change in function is catered for by non-structural interior changes only, permission is usually not sought. Since data for change in building function is gathered from renovation permits, it is not representative of the true situation. Nevertheless, data for modified buildings published by the DIE in the 'Building Construction Statistics' for the year 2000 is presented in Table 1 below.

Table 1 Buildings modified for a different use after alterations and repairs.[4]

Old Use	New Use					
	Residential	Commercial	Industrial	Medical/ Cultural/ Social	Other	Total
Residential	-	45	0	1	5	51
Commercial	105	12	3	1	4	125
Industrial	1	3	-	0	1	5
Medical/ Cultural/ Social	0	0	0	-	0	0
Other	43	35	0	0	1	79
Total	149	95	3	2	11	260

Source : DIE Construction Statistics 2000.

3.2 Moving buildings to new sites for reuse

Construction materials and methods being what they are, as a rule, buildings are not relocated in Turkey. However, one incidence has been reported so far where two mosques belonging to the Seljukid period were moved from their original location in Pertek, Tunceli, to a distance of 22km away, in a bid to save them from being drowned in the waters of the proposed Keban Dam. The mosques were built of stone blocks, which locked into place without mortar; these blocks were numbered and removed to the new site. However, the dome could not be shifted in the same manner since it was built with brick and mortar; any attempt to dismantle the bricks intact, failed. The original domes had to be replaced with new ones after the mosques were relocated. Since most of the brickwork was damaged in the dismantling process, only 35% of the original building could be moved successfully.[5]

3.3 Benefits of component reuse

Used building components are in great demand by low-income groups who cannot afford to purchase new materials in order to construct or repair their houses. Most of these buyers are often squatters who want to build additional rooms or a whole new house in an informal settlement. Sometimes, people are also forced to buy second hand fittings and fixtures to replace old and damaged ones out of a need to match the period, design, colour or style with the existing scheme. Nevertheless, as far as the buyers are concerned, the main benefit of component reuse is purely financial. Sophisticated issues of ecology, life cycle impacts or embodied energy do not, in any way, encourage people to buy used building material and components.

3.4 Damage during extraction

As mentioned earlier, buildings in Turkey are constructed with reinforced concrete structures and masonry walls rendered with sand and cement plaster. In addition, doors and window frames are anchored to the walls with the help of concrete infill, and tiles are laid in a bed of cement concrete mortar. This widespread use of concrete is a deterrent to the recovery of building components and, therefore, to deconstruction. In order to remove fenestration and door sets with minimal damage, the adjacent walls are chipped off around the anchors first to release the frame. Likewise, ceramic sanitary ware that has been made watertight at the interface with cement grout is chipped during the dismantling process, while ceramic tiles are usually broken and discarded.

3.5 Component re-certification requirements

The Turkish Standards Institute (TSE) certifies all manufactured construction material after it has been tested in its labs. This certification is mandatory for all materials in order to maintain acceptable production standards, and also to allow for the inclusion of such material in the Building Codes. The Turkish Building Codes do not list any recycled or used building material as, to date, no such material had been awarded a quality certificate [6].

4.0 ENHANCING MATERIALS RECYCLABILITY

Recycling of building materials is a very new concept in Turkey. It is only after the devastating earthquake of 1999 in the Marmara region, that some attention has been paid to the vast amount of building debris accumulated from the collapsed and demolished buildings. Initially, some of this debris had been dumped into a nearby lake but later, the task of recovering it from the lake and crushing it into aggregate, was undertaken by the municipality. The crushed rubble was to be used as hard core for road building.

Waste recycling is recommended and encouraged by the Ministry of Environment. The Regulations for solid waste disposal go so far as to dictate that recycled materials should be preferred to new ones. However, the waste referred to in the regulations belongs to industrial processes or packaging only. As yet, there has been no mention of recycling C&D waste. According to the National Report on Sustainability,

> "Waste management is one of the major components of the implementation of the sustainability principles. Industrial waste management requires that wastes caused by industry, production and services be managed for the protection of environmental and human health by reducing the loss of raw materials used in manufacturing. Reducing the amount of waste at the source, waste recovery and recycling, as well as implementing appropriate waste disposal techniques are among the basic components of sustainable development."

4.1 General issues of materials recycling (upcycling, downcycling)

On the domestic scale, there has been significant progress made in the field of solid waste recovery and recycling over the past decade. The efforts of local governments and the NGOs have helped to raise public awareness on waste recovery and recycling and a number of projects have been initiated to separately collect paper, plastics, metal and glass components of household waste. Moreover, recycling plants exist for all types of recyclable municipal solid waste, which employ high level technologies.

On the industrial level, however, Turkey is trying to promote the "clean production" technologies in order to prevent waste and thereby increase efficiency in production, reduce costs and ensure conservation of natural resources. In this regard research and development projects were launched in 1996 by the Scientific and Technical Research Council of Turkey (TUBITAK) and were conducted in cooperation with the World Bank and the Technology Development Foundation of Turkey (TDFT).

R and D projects have demonstrated that clean production procedures entail changing raw materials and/or production technologies. Unfortunately, these procedures are generally unacceptable from the standpoint of the companies' management policies and financial concerns. Therefore, the second best alternative for clean production was considered to be recycling of water in factories or recovery of energy from waste heat. Additionally, it is recommended that an autonomous "cleaner production institute" be set up to develop and accumulate further knowledge in this field and ensure easy and cost-effective access to relevant technologies. Industries are also encouraged to obtain quality standards such as ISO 9001 and ISO 14001 in order to increase their exports, especially since these standards will also help with the implementation of clean production technologies, waste minimization, and recycling procedures at the factories [7].

4.2 Recycling issues for specific materials (concrete, metals, plastics, glass, etc.)

As mentioned in the previous section, some household waste like metal cans, glass bottles, plastic containers, packaging and paper products are being recycled. The same is the case for industrial waste but not C&D waste. It has been observed that paper sacks, broken glass, steel off-cuts and aluminum is collected for recycling. Waste wood is usually used as fuel, unless the pieces are large enough for reuse. Concrete recycling is unheard of, however, concrete rubble from earthquake damaged structures was crushed for use as hard-core in road building. Usually, concrete or masonry rubble is dumped.

4.3 Deconstruction as a method for increasing materials recyclability

The construction industry does not feature as one of the solid waste producers in the Industrial waste statistics, which goes to show that waste produced by this sector is not being given its due importance. Measures to reduce C&D waste stream or to recycle such waste can only be taken if there is a realization of its impact on the environment. This impact can only be quantified if the amount of C&D waste produced annually was known. In order to adopt measures to improve recyclability, it is imperative that the producers and consumers of building materials and components are made aware of this phenomenon.

Demolition contractors, who are also the used building material retailers, deconstruct the building only to the extent whereby they can recover materials they can sell; further efforts are not financially feasible. Hence, they do not ponder on deconstruction as a method to improve recyclability; re-useability and therefore, re-saleability of a component is their only driving force.

5.0 ENVIRONMENT, HEALTH AND SAFETY

According to the National Report on Sustainable Development 2002, during the past few years there has been an increase in industrial training programs related to work safety, environmental management systems, quality assurance, and in-service training. These programs have been initiated by the Union of Chambers of Commerce and Industry, stock exchanges, Small and Medium Industry Development Organization (KOSGEB), the Quality Association (KALDER), universities, and research institutions.

There are various types of social security organizations. About 28 % of the workforce is registered with the Social Security Agency (SSK – Sosyal Sigortalar Kurumu), 12 % with Bagkur (the social security agency for self-employed workers and employers), and 10 % with the Civil Servants Retirement Fund. However (Emekli Sandigi), approximately 50 % of the workforce is not registered with any social security organization. The number of actively employed persons covered by the social security system was 9.5 million in 1997, which rose to 12.2 million in 2001.

Meanwhile, there is a growing tendency to employ workers who are not members of trade or labor unions, and to use subcontractors for some jobs instead of having workers on the payroll. This state of affairs is a direct result of high social security premiums and increased liabilities of companies. For this reason, unregistered employment continues to be a major problem in the country. Likewise, unregistered immigrant workers are another problem area in the labor market. The number of " immigrant workers" employed in the informal sector, without any residence and work permits, is estimated to be approximately one million people. [8]

5.1 Structural evaluation, fall protection, job hazard analysis, and other safety issues

None of the demolition contractors interviewed in Istanbul, Ankara or Izmir provinces employ the services of structural/ civil engineers to assess the building to be demolished, for a safe demolition strategy. Also, demolition workers were not seen wearing protective helmets on the job-sites. A top down approach helps to mitigate accidents, on the other hand, safety procedures are mostly instinctive. Only one contractor owned up to the fact that serious or fatal accidents do occur occasionally; however he avoided giving further details. Nevertheless, it is not the lack of concern for human safety but more so an over-confidence in their expertise that leads the workers to ignore safety measures.

The Turkish Labor Law holds the employers responsible for the health, safety and training of the labor force. It also outlines the working conditions and procedures to be adopted for construction, as well as demolition works. The Regulations for Construction Workers Health and Safety promulgated by the Ministry of Development and Settlement are extremely comprehensive and encompass all related issues. Additionally, Section 5 of these regulations deals only with safety measures to be adopted for demolition works [9].

5.2 Hazardous Waste Disposal

The Ministry of Environment has adopted stringent measures for dealing with hazardous waste materials, including asbestos and lead based paints. These regulations require industries to submit regular reports on their hazardous waste production and its disposal procedures; failure to comply results in heavy fines. However, the management of industrial wastes, except those sent to municipal landfills, still remains as an important problem since the only licensed facilities for industrial waste treatment have been built in the context of the Izmit Integrated Environment Project. These facilities comprise of a hazardous waste incineration plant and a hazardous waste landfill, for proper disposal of solid and liquid wastes produced by industries and households in the region. They have an annual hazardous waste burning capacity of 35,000 tons and close to one million cubic meter hazardous waste storage capacity.

Despite the fact that the existing capacities of industrial waste disposal and recycling facilities are not sufficient to meet national demands, and that more than 2.5 million tons of hazardous waste is produced annually, existing facilities do not receive sufficient amounts of waste for disposal or recycling. The main reasons for this are insufficient controls and the fact that industrial organizations are not prepared to meet the high costs of waste disposal. Over the last three years, some small-scale facilities have acquired "temporary licenses", particularly for the recycling of motor oil and solvent wastes. However, the legal control mechanisms regarding the quality of the recycled substances and the disposal of wastes at these facilities are also not adequate. [10]

6.0 ECONOMICS OF DECONSTRUCTION AND MARKETING OF USED BUILDING MATERIALS

In Turkey, the demolition business is a considerably lucrative source of income in larger cities, which are also the major sites of such demolition works. Demolition companies exist in all large cities of Turkey. Bentderesi, a main road in old town Ankara is the address of the demolition contractors' yards, where construction material and components recovered from buildings they had pulled down are stored and sold. In Istanbul they are situated in Ümraniye, Günesli, Arnavutköy, Altinsehir and Mahmutbey. There is great similarity in the demand and supply patterns of this enterprise in the cities of Istanbul, Izmir and Ankara. Furthermore, their clientele too hails from identical strata of the population. For instance, customers of demolition waste like doors, fenestration, bathroom fittings and hardware are usually squatters, while, timber joists and planks are mostly bought by building contractors for form-work or scaffolding. Once in a while, this merchandise is also in demand for renovation and restoration projects. [11]

All of the demolition companies in Turkey concentrate mostly on recovering timber components from the buildings they demolish. For reasons mentioned in section 3.4, bricks and floor or wall tiles are rarely recovered intact from the structure. In fact, brick is usually dumped in landfills. The demolition teams focus on recovering only those materials from the structure which provide the highest margin of profit, such as: boards, rafters, battens and joists, steel reinforcement, aluminum components, corrugated roofing sheets, roofing-tiles, iron grill-work, doors, fenestration, bathroom fittings and fixtures, pipes, built-in cupboards, kitchen cabinets and sinks (Figures 3 to 5).

Figure 3 Second hand merchandize displayed on the pavement outside a used building materials outlet in Ankara.

It was further determined that lack of space in the yard may also be a deciding factor for dumping some demolition material that may ordinarily have a market value. Such material is usually bulky and the profit it is expected to bring in, does not justify the space it occupies.

Hence, yard owners prefer to stock up on materials that not only bring in a quick profit, but that also take up less space.

Figure 4 Fenestration on display in a used building materials outlet in Istanbul.

Figure 5 Sanitary ware, terrazzo and roofing tiles and other used building material for sale in a demolition contractor’s yard in Izmir.

Used building materials are usually bought by urban squatters to build illegal settlements, which are also referred to as 'informal' housing. In fact, the demolition contractor’s main clients are these illegal builders. Consequently, the supplier of the used building materials, who happens to be the demolition contractor, and the consumer who is a squatter, prefer to keep their business dealings private. They do not look kindly upon inquisitive researchers trying to assess the economics of deconstruction, as any information may lead to their connections with the growing squatter-settlements. For this reason the author, who to her knowledge is the only researcher in this field in Turkey, has not been able to elicit enough information from the parties concerned, in order to fully assess the economics of deconstruction. Nevertheless, the presence of a large number of demolition companies involved in the material recovery business is ample proof of the feasibility of deconstruction in Turkey. As one dealer of such material claims “if it were not a profitable business we would not be opening shop here every day”.

6.1 Assessing the economics of deconstruction

Demolition companies take on three to four large demolition projects per year and they may spend four or more weeks to complete the work, depending on the size and complexity of the project. Demolition contractors estimate the amount of timber and tiles they can recover from the roof of a building according to standards set by the Ministry of Works. Likewise, these standards are also referred to while calculating the amount of reinforcement steel that may be recovered from the demolished structures. However, experience has taught them that the amount of reinforcement actually present in the building is always significantly less than the stipulated amount. Nevertheless, all iron and steel elements are recovered from the rubble, since they can be recycled completely and therefore, fetch a good price.

The demolition companies usually make a hundred percent profit on each contract, in spite of the fact that they sell the demolition waste material very cheaply. In order to provide a rough idea of these remarkably low rates, prices of various demolition materials were collected and catalogued in Table 2. These materials are listed in the first column while their size, and price in terms of US dollars is quoted in columns two and three, respectively.

Table 2 Sale Price of Demolition Materials (March 1999-February 2001).

Material	Size	Price in US $
Roofing Tile	Standard unit	$0.05 - $0.08
Brick	Standard unit	$0.03 - $0.04
Door with frame	Standard unit	$17 - $27
Galvanized steel door set	Standard unit	$30 - $40
Fenestration (glazed-3-bays)	2m x 1.2m	$20 - $35
Fenestration (un-glazed-2-bays)	0.8m x 1.2m	$10 - $17
Galvanized steel windows	2m x 1.2m	$10 - $23
Kitchen Sink - ceramic	Standard unit	$6
Kitchen Sink – s. steel	Standard unit	$7 -$8
Wash-basins - white	Standard unit	$5 -$8
Wash-basins - white	Small	$3 -$5
Wash-basins - colored	Without pedestal	$10 -$12
Wash-basins - colored	With pedestal	$15 -$20
Bath-Tubs	Standard unit	$17 - $27
Shower tray	Standard unit	$7 - $10
Iron grill-fencing: balcony	0.9m x 1.0m	$4 -$5
Wrought-iron staircase	14 steps	$60
Boiler	As scrap iron	$0.05 /kg
Galvanized iron sheets	0.9m x 2m or 0.9m x 2.5m	$2
Timber grade 1	5x10x400	$1.33 - $2.00
Timber grade 2	10x10x400	$2.67 - $4.00
Timber grade 3	Varying sizes	$0.05 /kg

6.2 Assessment models

Due to a lack of accurate information, it has not been possible to develop any assessment models with regard to the economics of deconstruction.

6.3 Deconstruction assessment tools

Deconstruction assessment tools have not been developed so far.

6.4 Life cycle costing of deconstruction

Life cycle costing has not been done in the field of deconstruction.

6.5 Materials Reuse Businesses

Materials reuse businesses exist in all major cities of Turkey. It is believed that even in Ottoman times, reused material was in great demand and care was taken in recovering and storing such material for later use. All the demolition contractors interviewed in the cities of Istanbul, Ankara and Izmir have claimed that theirs is a family business that has been passed down from father to son. As mentioned earlier, in Ankara almost all used building material yards are located along the same road, while those in Istanbul and Izmir are scattered in different parts of the city. In fact, the ones in Istanbul sometimes change their location to follow their clients.

According to the demolition contractors interviewed, three types of contract may be undertaken depending on the estimated market potential and/or the re-sale value of recovered construction material. If the estimate is high, the demolition contractor tenders a bid for the job. If low, it is the other way around and a negotiated sum in favor of the contractor is agreed on. The third is a no-fee, break-even type of contract where neither party reimburses the other. Needless to say that since the owner of the building to be pulled down is a former squatter he is not bothered with the legality of his business. Hence, neither is permission sought before pulling down the building nor is a contract actually drawn between the parties concerned; it is more or less a gentlemen's agreement.

It must be pointed out here that with the exception of a few, owners of demolition yards were not too keen to discuss the details of their business; in fact some did not even want to answer questions regarding their merchandise when they discovered that the author was not a prospective buyer. This reticence on their part stems not only from the fear of the tax men but also the hostile municipality inspectors who look upon their businesses as a source for cheap building material that encourages mushrooming of squatter housing. It is also one of the main reasons that receipts of payment for second-hand building materials are not issued to the buyers, especially since they are squatters.

6.5.1 Role of demolition contractors

Demolition contractors have always played a very important role in the low-cost housing sector. After the end of the Ottoman era, the Turkish Republic gave due attention to town planning and building regulations, which prohibited the construction of squatter settlement. However, there was one law that gave indirect protection to the squatters; the '*gecekondu*' law provided amnesty to an illegal building that was constructed overnight. Thus, *gecekondus* started mushrooming in and around all major urban centers.

In order to build a house quickly and cheaply, the squatters needed ready made building components. This is where the demolition contractor came in; his yard was also a used building materials outlet. He not only supplied them with ready to use cheap building material like roofing, doors and windows, but also refrained from divulging their activities. Once the roof was put up, their one room house was safe. The demolition contractor could be depended upon to supply them with the bathroom and kitchen fittings and fixtures when they could afford them. The construction of a squatter house is an ongoing process where a room is added when the need arises, or when enough funds have been accumulated. This ensures an almost lifelong relationship between the squatter and the demolition contractor.

6.5.2 Do-It-Yourself (DIY) outlets

As a rule, DIY outlets do not stock used building materials. However, some antique dealers have been known to supply antique/used ornaments from demolished buildings, like door knobs, fire grates, grill work, electrical fittings, wash basins and tubs etc.

6.5.3 Industry associations (e.g. Used Building Materials Association in N. America)

As remarked earlier, used building materials suppliers are also the demolition contractors. Although, it is a very old trade in Turkey, and trade associations are an integral part of Turkish traditions, the demolition contractors have not yet organized themselves into an association.

7.0 DESIGN OF BUILDING AND COMPONENTS FOR DECONSTRUCTION

Buildings or their components are not designed to facilitate deconstruction. The introduction of fast action glues and adhesives has speeded up the assembly and construction process. Concrete mortars and grout also aim to improve durability and weatherproofing; however, these measures are detrimental to the deconstruction process. There was a time that carpenters prided themselves on their demountable joinery, and stone masons were adept at mortar free block masonry. However, these trades and techniques have died out now, and time is the essence in any enterprise. Products are designed for ease and speed in assembly; if the design also allows for easy disassembly, it is usually unintentional.

7.1 Design techniques for allowing component extraction by disassembly

Design techniques that allow the extraction of an individual component have not been developed so far. The interface between building components is designed for durability, which is unfortunately equated with permanence.

7.2 Design of components for disassembly

The only field of construction where design for disassembly has been given importance is prefabricated exhibition structures or disaster housing. Both types of buildings are temporary in nature. Furthermore, these buildings are made with modular configurations; the modules themselves are designed as a complete unit, i.e., a wall panel comes fitted with the fenestration which is not to be removed when the house is dismantled.

7.3 Parallels in other industries

Structures for the weekly local markets or exhibitions may be considered as shelters designed for deconstruction. Such structures are disassembled easily because they are built with steel members that have been screwed together. Sometimes extruded aluminum profiles are also used to make up the structure. It should be noted here that conventional building material is not used to construct these shelters, therefore, the design techniques can not be replicated for building construction.

8.0 POLICY, REGULATIONS, STANDARDS, LIABILITY

According to Turkey's National Report on Sustainable Development 2002, most of the environmental legislation in Turkey has been put into effect during the past decade. Following are the seven regulations, which are considered vitally important:
- Environmental Impact Assessment Regulations,
- Solid Waste Control Regulations,
- Hazardous Waste Control Regulations,
- Air Quality Control Regulations,
- Water Pollution Control Regulations,
- Waste Control Regulations and
- Hazardous Waste Control Regulations.

An overall assessment of the Turkish environmental legislation indicates that during the past two years, the concept of sustainability was clearly included in the laws and regulations put into effect. Moreover, the Ministry of Environment is taking further legal measures to prevent and control environmental pollution. In this regard, the existing legislation is being reviewed as part of the efforts to harmonize them with the EU legislation. It is hoped that this step will contribute substantially towards achieving the goals for sustainable development. It has also been noted that the existing problems in achieving these goals are related to the present infrastructure, and can be summarized as follows:
• Difficulties in implementing the rules and regulations pertaining to air, water, soil, and solid wastes, due to bureaucratic difficulties and lack of infrastructure. A major problem stems from the inadequacy of treatment plants and/or lack of technological options that would ensure meeting the limits put forth in the relevant regulations.
• The absence of appropriate systems and facilities for the disposal of industrial and hazardous wastes, and the insufficiency of mechanisms developed to meet the operational costs of existing plants constitute an extremely important problem. [12]

8.1 Government policy supporting deconstruction
Although there is no specific policy concerning deconstruction of buildings, it is supported indirectly through bylaws and regulations. For instance, the 'Technical Contract for Demolition and Deconstruction' issued by the Ministry of Development and Housing puts great emphasis on recovering as much building material and components as possible, from a building that is to be demolished. It also lays down rules for proper storage and cartage of the recovered material.

8.2 Building codes
Building codes do not include any reference to recycled or used building materials. Nor are there any codes assigned to deconstruction works/ processes. Additionally, efforts to give deconstruction its due importance through inclusion in the building codes are non-existent. Likewise, nothing has been done so far to include used building materials in the list of approved building materials prepared and maintained by the Ministry of Housing and Development.

8.3 Creating standards for deconstruction and materials reuse
According to Turkey's National Report on Sustainable Development 2002, the identification of wastes generated by industries, waste minimization, measurement and control of the use of raw materials and energy consumption, and ensuring the proper disposal of waste, constitute

the main principles of "environmental management systems." ISO 14001 international standard and the "Responsible Care Program" for the chemical industry, which is implemented in Turkey since 1993, represent improvement of efficiency in industrial establishments by means of environmental management systems. The extension of ISO 14001 practices to the construction and demolition industries is essential for promoting deconstruction of buildings and materials reuse in new construction.

8.4 Legal issues

The existing environmental legislation can be extended to cover issues related to deconstruction, and recycling and reuse of building materials. However, it will be necessary to educate the parties concerned, in environmental issues pertaining to demolition of buildings and solid waste generation during construction and demolition works.

9.0 BARRIERS AND OPPORTUNITIES FOR DECONSTRUCTION

A detailed survey of the current state of affairs related to deconstruction in Turkey, which is based on information elicited from demolition contractors and Turkish legislation, has revealed that the opportunities for deconstruction by far outbalance the barriers in this field. The local tradition of reusing just about any commodity has been instrumental in the establishment of a thriving market for used building materials. However, the profile of buyers of such material and lack of certification of used materials can be enumerated as the biggest barriers in promoting deconstruction.

In Turkey, cooperatives have played a major role in promoting and supporting various rural and industrial sectors. Such an establishment would also benefit the demolition businesses greatly. Were they to get together to form such a cooperative, it could easily help the members maintain a catalogue of material available at each yard. Better still, these yards could specialize in certain components or fixtures only and the cooperative could step in to collect and distribute building material from the demolished structures. To date, all but one yard owner sell all types of material recovered from the demolished buildings; the only exception specializes in brick. Establishing a web-site through the cooperative and putting the inventory on-line will make the purchase of second hand material less of a hassle and also more accessible by advertising the available stock. **[13]**

On the other hand, much still needs to be done to improve the quality of merchandise and attract the more sophisticated clients. For instance, cartage and storage conditions need to be improved and second hand components and fixtures must be graded into categories for standardization.

9.1 Consumer tastes

Buyers of used building materials are usually low-income groups, hence, such material is commonly identified with low-quality housing. The more affluent classes are misled into believing that new materials are necessarily more durable and, therefore, more desirable. In order to keep their profits high, housing developers have to choose finishing material that is fashionable and, therefore, brand new; this rules out used materials. Meanwhile, commercial buildings are being built with steel, granite and glass, in keeping with the sleek hi-tech image; such material cannot be bought from used building material outlets.

9.2 Lack of design for deconstruction strategies

Due to a lack of relevant statistics, the environmental impact of C&D waste is not common knowledge. Consequently, designers and builders are not concerned with the fate of their buildings; they build them for posterity. However, reality has it otherwise, and buildings are doomed to redundancy. If these issues are introduced into the curriculum for design education, it will be possible to overcome the existing lack of strategies for design that facilitates deconstruction.

9.3 Lack of tools and training

The current deficiency of tools is due to the ever-present lack of resources. If design for deconstruction is promoted, this lack of tools may to some extent be countered. On the other hand, the lack of training is more crucial not only from the point of view of maximizing material for reuse and recycling, but also from the point of view of the deconstruction workers' health and safety.

9.4 Lack of markets for used components

The task of promoting second hand building materials itself is not at all formidable, since there already exists a market for such materials in all major cities of Turkey. If buildings were designed with the aim of ultimate deconstruction, it would be possible to recover more building material with the least amount of damage. The value of used building material depends on its condition; if such material could be recovered in an almost new state, it would be possible to sell it with more ease to a wider market.

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REPORT 9

TG39 – UK Country Report on Deconstruction

James Hurley & Gilli Hobbs

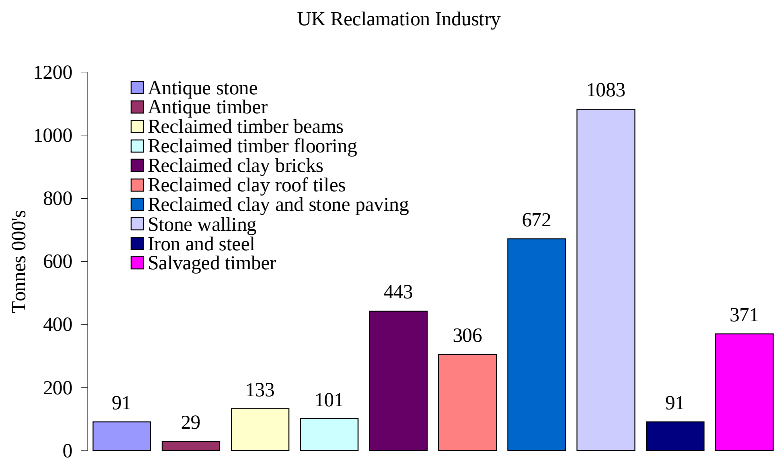
1. Introduction

1.1 UK construction industry

It is estimated that the UK generates around 94 million tonnes (Mt) per annum of core construction and demolition (C&D) waste, which excludes approximately 40 Mt of mixed waste including inert fines, timber, metals, plastics and packaging. A recent survey suggests that 92% of the inert C&D waste is being recycled or beneficially reused, but at best this is being down-cycled. Timber and timber packaging is estimated to be 7.4 Mt per annum but for the rest of the materials are little understood. Recent estimates suggest that only 934,000 tonnes of this is being recycled per annum, mostly up-cycling into new product.

The level of knowledge on the amounts, types and location of C&D material is at best an informed and extrapolated guess. This is not surprising, as there has been little opportunity to benchmark this waste stream. Despite this, it is commendable that an estimated 3.3 million tonnes of architectural and ornamental components are salvaged each year in UK for reuse (Figure 1). Similarly, that as much as 35 million tonnes of recycled aggregates are recycled into mostly low-grade applications and an unknown quantity of steel is recycled back into production. However, there are large volumes of potentially reusable components other than core C&D and ornamental antiques that are currently sent to landfill and lost to the system only to be replaced with similar components.

Figure 1. UK Reclamation in 1998



1.2 UK demolition waste

Limited studies at BRE (not including infrastructure and roads) have identified that demolition waste is mostly composed of concrete, ceramics, furniture, timber, metal, plastic, electrical goods and miscellaneous materials and components. The results for each of the six buildings audited by BRE are aggregated in the Figures 2-3 below to show the overall variation between the types of wastes being generated and the reuse / recycling potential for the key demolition products. Naturally the variation in materials will be determined by the construction type but the reuse/recycling potential will be as much about how the materials were bound together as well as the quality and condition of the materials. These are most important indices to record during the audits in order that appropriate decisions can be made. Figure 2 shows that the most common materials were hard, inert fractions such as concrete, stone and ceramics. Timber was also significant in some buildings and, when considered, the furniture, furnishings and fixtures could also be of significant size.

Figure 2. Variable percentage quantity of materials from the six case studies

	Multi-storey housing	Prefab Housing	Factory	Multi-storey offices	Factory	Hospital
Ceramic	2.3		9.3	1	16	67
Metal	3.1	0.4	2.8	1.5	2	1
Furniture	2.3			59.9	1	
Plastic	0.6	1.1		1.7		1
Concrete	86.8	85.2	86.5	34.1	78	12
Timber	3.5	7.7	1.4	1.8	2	19
Miscellaneous	1.4	5.6			1	
Total	100	100	100	100	100	100

Figure 3 shows that there are substantial opportunities to reuse as well as recycle. Despite this fact the great majority of materials will be down-cycled and neither up-cycled nor reused. Although recycling is much more preferable than combustion or landfill, we should continue to find greater opportunities to reclaim and reuse key demolition products where possible and account for this both economically and environmentally.

Figure 3. Variable percentage potential for reuse / recycling for the six case studies

	Multi-storey housing	Prefab housing	Factory	Multi-storey offices	Factory	Hospital
Reusable	2.9	69.9	6	41.8	12	74
Recyclable	89.9	23.9	89	27.3	86	24
Combustion	5.3	1.3		3.4	2	1
Inert landfill				17.1		
Non-hazardous landfill	1.2	4.9	5	10.4		1
Hazardous landfill	0.7					
Total	100	100	100	100	100	100

Separation at the actual point of waste generation is the most appropriate form of management. It is preferable to separate hazardous or undesirable substances from the rest of the waste stream to avoid contamination and to ensure they are disposed of in an appropriate manner.

2. Demolition and Deconstruction Techniques, Machinery, and Tools

The demolition industry has undergone major transformation within the last 20 years. Traditionally it has been a labour intensive, low skill, low technology, and poorly regulated activity, dealing mainly with the disassembly and demolition of simply constructed buildings.

More recently, it has followed the trend of all major industries and mechanised the process by replacing labour with machines. This is because of the increased complexity in building design, the financial pressures from clients, health and safety issues, regulatory and legal requirements and advances in plant design. The industry now employs fewer, but more highly skilled operators and very expensive specialised equipment. Traditionally, much of the demolition contractors' income was from the sale of salvaged and recycled materials. Today income is mostly generated from the contract fee - demolishing as quickly and as safely as possible. Nevertheless, substantial amounts of materials and components are recovered or reclaimed but for mostly down-cycled or not used to its fullest potential (Figure 1).

Figure 4. Demolition of structures following soft strip

Older buildings of non-complex construction e.g. Victorian structures are generally simpler to demolish, at least until toxic materials like asbestos is found. Components often have an aesthetic or antique value which results in them being salvaged. As the complexity and size of buildings has risen so have the technical demands placed on contractors taking them down safely. Research from University of Salford[1] reveal that demolition techniques are now not only numerous but also varied in their technology, application, cost and speed. Traditional methods such as the steel ball are being rapidly replaced by more modern methods as the emphasis changes from masonry and brickwork to concrete and steel structures.

There are eight factors which affect the choice of demolition method. Any one building will be subject to a unique combination of these factors.

1. *Structural form of the building*. What are the technology and materials involved in its construction?
2. *Scale of construction*. A large building may make a complex method economic, while a small building could be demolished by hand.
3. *Location of the building*. Access for plant can affect the choice of equipment for a demolition. (This is related to point 4.)
4. *Permitted levels of nuisance*. Noise, dust and vibration tolerances will vary from site to site.
5. *Scope of the demolition*. Some methods are not suitable for partial demolition.
6. *Use of the building*. A contaminated structure will be treated differently to an ordinary residential terrace.
7. *Safety*. Of operatives, the public and environment.

8. *Time period*. A spokesperson for the NFDC says “given the time we could recover most things during demolition, but clients want to see a rapid return on their investment.

The first six of the above factors are concerned with the physical aspects of the building to be demolished; its technology and materials, size, location, site, use and the scope of the demolition required. The final two factors are an indication that the characteristics of the building are not the sole consideration when deciding on a particular demolition method. The incorporation of the time factor shows that the contractual conditions can have an effect on choice, whilst the inclusion of safety aspects points to the influence of wider issues such as legislation, and the environment. It is suggested that three more factors should be added to the initial group of eight. The suggested additions are again concerned with issues unrelated to the physical attributes of the building.

9. *The proposed fate of the building materials and components* once the structure is demolished will probably affect the choice to some extent. Some of the methods available, for example, explosives, merely reduce a building into manageable size pieces taking little or no account of the separation of materials. Clearly such methods would be unsuitable for a project where a high degree of reuse of individual components was specified.
10. *The culture of the demolition firm carrying out the work* will to some extent condition their choice of method for dealing with a particular problem. A firm that is familiar with a specific method or equipment is more likely to apply that expertise if possible than search for another solution. If the problem falls outside the boundaries of their previous knowledge, they could then be forced into examining other options.
11. *Monetary cost*. If a method would place a heavy burden on the contractor, without presenting any other advantages it is unlikely to be chosen. Similarly a client will probably let a contract on the basis of the least cost option, although this is slowly changing as more clients look for the best value option, which may not always be the cheapest initially.

There will usually be several methods of tackling a demolition, all of which have various merits relating to the factors above. It may not be a case of ‘right’ or ‘wrong’ methods, just alternative options based on different assessment of the relevant factors in a case. One of the objectives of this report is to identify the factors relevant to the choice of demolition methods in a particular case, and determine the influence that decision has on the eventual reclamation of materials. In the main, the demolition process relies on one of eight basic methods; pulling, impact, percussion, abrasion, heating (or freezing), expanding, exploding or bending. Figures 5, 6 & 7 show the various methods of demolition technique in tabulated form.

Figure 5. Traditional methods of Demolition

Method	Tools/Equipment required	Application suitability	Preparation /procedure	Comments
By Hand	Portable tools including: crowbars or mattocks pneumatics drills power saws	Now reserved mainly for high and inaccessible areas, or architectural salvage	Demolition proceed in a top-down fashion, floors in buildings are removed prior to demolition to prevent premature collapse due to weight of debris collection	Oldest method Labour intensive and slow Expensive if labour costs are high Debris is easily segregated for salvage purposes Possible safety implications of working at height.
Pulling	Wire Rope Vehicle to provide pulling power	Brick or masonry structures	Remove all stabilising components e.g. pipework, beams and lintels Detach from adjacent buildings Set rope around section of brickwork and drag to collapse	Causes dust nuisance Time consuming if uncontrolled collapse occurs Destabilised for a period before demolition – safety implications.
Impact	Demolition ball between 0.5 and 2.0 ton suspended form a crawler crane	Fairly large, brick, masonry, concrete or r.c.	Remove floors as per hand Buildings > 30m high should be reduced by hand before using ball. Detach from adjacent	Widely used in European countries Produces noise, vibration and dust Can be set to drop weight vertically onto floors and foundations
	Pusher arm (extended arm and steel pad fitted to tracked vehicle)	Normally brickwork	Arm is positioned at top of wall and forward motion applied	Popular in late1970s More controllable and versatile then demolition ball Restricted in terms of height of wall to be demolished
Percussion	Hammer: hydraulic or pneumatic: handheld or vehicle mounted	Concrete, brickwork, masonry and steel. Capable of partial demolition	Involves repeated impact	Pneumatic hammer is smaller and lighter, but noisier than hydraulic Both produce persistent noise
	Hydraulic breaker, four or five types available		Jaw-like attachments break or cut concrete and steel by holding and crushing into sections	Produces small size materials, no need for secondary crushing before use as recycled aggregate Reasonable cost

Figure 6. Demolition using Explosives

Method	Application suitability	Preparation /procedure	Comments
Borehole Charges	Concrete, brickwork and masonry, not suitable for narrow members	Place in pre-drilled holes	Shock waves from powerful explosives can be transmitted over great distances by some ground conditions e.g. clay and by airwaves Risk of flying debris Produces medium sized materials that may require further crushing before use as recycled aggregates
Lay-on charges		Placed in contact with structure and contained with sandbags or clay	
Concussion charges	Enclosed structures e.g. tanks	Bulk charge placed within structure	

Figure 7. Newer Methods of Demolition

Method	Tools/Equipment required	Application suitability	Preparation /procedure	Comments
Expansion/bursting: Static	Buster with wedges	Concrete or masonry	Mechanical wedges forced into pre-drilled holes and expanded by hydraulic pressure	Create noise and dust at drilling stages, otherwise nuisance free. Slow. Good for working in close proximity to other buildings.
	Chemical expansive agent	Cannot be used for narrow structural members, r.c. or pre-stressed concrete	E.g. Injection of unslaked lime composite mixed with water into predrilled hole, hydration of mixture causes expansion which splits surrounding material	
Dynamic	Explosives, high-pressure water, gas pressure		Apply to pre-drilled holes	
	CARDOX		Liquid carbon dioxide in metal tube inserted in pre-drilled hole, heated by electric filament, causes expansion	
Abrasive	Hammer drill, hand operated, or vehicle mounted	General	Reduces concrete to dust using rapidly rotating and hammering bit	Vehicle mounted hammer drill used for the destruction of mass concrete
	Diamond boring machine	Drilling concrete	Diamonds form abrasive interface	Quite slow and expensive

Figure 7 (continued). Newer Methods of Demolition

	Diamond disc cutter	Capable of cutting r.c.		
	Diamond wire saw	Cuts around circumference of concrete sections		Noisy, but produces little dust or vibration
	High-pressure water jet	Can be used to cut cement grout to release components	250-300 Mpa water jet forced through small nozzle can cut plain concrete. Addition of particles of steel allows it to cut through r.c.	Expensive in comparison to other methods. Uses large quantities of water
Heating	Thermic lance (metal tube, approx. 3m long containing aluminium alloy or iron alloy rods	Reinforced concrete	Tip of lance heated to 1000C oxygen fed to tip produces flame 2500C, can melt reinforcing rods and concrete	Cutting of some materials can cause toxic fumes
	Fuel Oil Flame		Combustion of mixture of kerosene and oxygen gas produces flame to melt concrete	
	Argon-hydrogen/Argon-nitrogen plasma, and carbon dioxide laser beam		Development stage (Kasai 1998)	Specialist use only
	Heating and peeling using electrical conductors		Drill holes to reveal rebars, attach electrical conductors to induce current through the rebars, causes heating which dries out surrounding concrete so it peels	Little noise or dust after drilling stage. Could use microwaves to dry out concrete, omits use of drilling but expensive
Cryogenic		Reinforced concrete, steel framing	Quick-freezing steel in a restricted area makes it brittle	Time consuming, limited use and expensive
Bending	Jack-up	r.c. horizontal members	Application of point force upwards against floor slab induces bending and shearing forces into slab designed for down loading only	Developed in Japan, rarely used.

4. Component Reuse and Enhancing Materials Recyclability

The BRE material experts (timber, steel, masonry, concrete) were each asked to comment on recycling activities in their chosen discipline. Their individual responses are included below.

Concrete & Masonry Products

Concrete constitutes the greatest proportion of construction waste in the UK and around much of the world but traditionally little of this has been reused, or even reclaimed. The concrete that has been reused has been restricted to use in low-quality sub-base or foundations, although a small amount is now crushed and used as aggregate, mainly in bases and back-fill. This form of recycling is known as down-cycling, whereby the value of the material is down graded despite being recycled. Up-cycling into higher grade applications or reuse is preferred. Concrete can either be cast on site (in-situ) or in a factory and then delivered to site ready to be installed (precast). Precast concrete therefore lends itself to the possibility of being removed from a structure and reused on a different structure either in the same location or elsewhere. In-situ concrete can also be reused but is usually tied into the rest of the structure with reinforcement and therefore can not be easily removed. The concrete precast industry has annual sales in the UK of £1.6 billion and employs over 20,000 people. The largest market share of the concrete precast industry is taken up by masonry blocks, paving slabs/ blocks, roof tiles, pipes and floor units.

There are four main masonry techniques:

- Irregular shapes and sizes chosen and placed by hand to achieve interlocking (e.g. dry stone walls).
- Medium to large blocks cut to precise sizes and placed using a grid pattern with little or no mortar.
- Small to medium bricks/blocks in a few sizes assembled in a grid pattern where inaccuracies are filled with mortar (normal brickwork).
- Irregular shapes and sizes packed apart and bonded together with mortar.

Only the fourth method relies on mortar for stability because in masonry structures mechanical interlocking is of paramount importance. But there are many fixtures, fittings and joints that are also important to different types of brick and blockwork.

In the UK the most popular building method is concrete foundations and floor, concrete block inner skin with a cavity wall and brick and cement mortar outer skin. The most popular method of connecting these two skins is stainless steel wall ties. These come in many different designs and depend on the type of wall. For example there are slope tolerant, movement tolerant, symmetrical, asymmetrical, shear, slat and slip wall ties.

Reuse of concrete products

The key concrete products such as masonry blocks, paving slabs and building blocks have no fixtures, fittings or joints and therefore lend themselves to be easily dismantled and reused. Concrete roof tiles are simply nailed to roof purlins and so can easily be removed without damaging the tile itself. Concrete pipes are joined together using fixed or loose elastomeric seals. If a pipe run is dismantled then this seal would be discarded but the actual concrete pipe could be reused with a new seal. The problem with precast floor units is that they are usually fixed in place by pouring concrete or mortar in-situ between the edges of the units, usually with steel reinforcement to tie all the units in place. It is therefore very difficult to dismantle the units without damaging them.

Not many concrete products are actually designed to be reused as manufacturers would rather you bought new ones, but some can still be reused. One unique type of concrete products is temporary concrete crash (safety) barriers. These are sometimes rented out by a contractor from the suppliers and are then returned to the manufacturer when they are no longer required. They are then either cleaned and reused, or disposed of if they are faulty. Many products can be reused but are not designed *specifically* to be reused, such as kerbs and flags, paving, roof tiles, lintels, sills and copings. If they were designed with deconstruction and reuse in mind then the design would not be very different to what it is.

However, some concrete products could be reused with only a slight alteration in their design. Although this would probably increase the initial price of the product, the whole life costs could be reduced. Example products include:

- Sea & River Defence Units
- Pipes & Drainage
- Water Treatment & Storage Tanks
- Railway Sleepers
- Agricultural Products
- Fencing
- Cladding & Structural Wall Units
- Staircases & Stair Units
- Floors: Beam & Block
- Floors: Hollowcore, Composite & Double Tee

Of the *key concrete products*, masonry blocks, paving slabs and blocks and roof tiles require little alterations to their design in order for them to be able to be reused. Similarly, pipework can be easily dismantled, the problem being getting to the pipework to do it. Floor units would require the most alterations to their design in order for them to be deconstructed and reused, especially to their fixing and jointing method.

No matter what the practical or physical possibilities are, it still has to be economic to deconstruct and reuse the component. Additional problems with concrete products are dimensional (most UK structures are one-off designs), physical or practical. The concrete products with the main share of the market (masonry blocks, paving slabs and blocks and roof tiles) require no alteration to their design, just an economic market for their reuse. Some other concrete products need just a small design alteration to enable them to be deconstructable and reusable, but a market for them would still be required for it to be economic to do so. Some concrete products will also never be reused due to their location in a structure and the difficulty in recovering them (e.g. piles and pipework).

Standards and specifications

There are no current standards relating to the specific deconstruction and reuse of concrete structures in the UK. Guidance has been published on the demolition of concrete structures by several trade organisations (PTI - 1992 and NFDC - 1997). Significant guidance also exists on the reuse of crushed concrete as aggregate in new concrete (e.g. BRE Digest 433, 1998). However, some guidelines have recently been published in Germany on the reuse of concrete elements. The *Guideline for the Circulation of Prefabricated Component Parts made from Concrete, Reinforced Concrete and Prestressed Concrete* (Building Inspectorate, 2001) presents guidelines on how to assess a concrete component for different parameters and suggests both destructive and non-destructive tests to measure there suitability for reuse (Figure 8).

The technical parameters of the prefabricated parts calculated according to the provisions of the Guideline (above) must be established for the prefabricated parts by means of a relevant certificate issued by an expert, or expert agency. The certificate must be issued only on completion of all the tests. The certificate must contain the parameters required to prove load-bearing strength, fitness for use and durability as the basis for structural load bearing design. Use-specific tests may be conducted where the intended reuse of the prefabricated parts has already been established.

Guidelines of this type are essential for both promoting and assisting the reuse of concrete components. If the reuse of concrete components is going to increase in the UK then similar guidance will be essential. This is especially true if more complicated concrete elements, such as reinforced concrete load-bearing beams are to be reused, as well as the less complicated concrete elements such as paving slabs and roof tiles.

New concrete and masonry products and tests are specified according to British Standards (BS). For example, *concrete material quality* is tested as cubes and in beams to:

- BS 1881: Part 116: 1983 - Method for determination of compressive strength of concrete cubes
- BS 1881: Part 118: 1983 - Method for determination of flexural strength of Aggregates used in concrete to:
- BS 882: 1983 - Specification for aggregates from natural sources for concrete

British Standards are soon to be replaced by European Normative Standards (ENs), but the BS codes will run in parallel for a few years as Member States adopt the ENs. For example, concrete structures in UK are designed to BS 8110 - Structural use of concrete which will be replaced by Eurocode 2.

Building and Planning control

There is no mention of deconstruction in building or planning controls in the UK at the moment, but minimum *de factor* standards are laid down for the recycling of aggregates in concrete (BRE Digest 433, 1998). Quite recently the Highways Agency have been requested to include the specification of recycled aggregates in road maintenance and rebuild where deemed economically viable. This would more often than not include quality controls such as those developed by DETR (now DTI) Quality Control for Recycled Aggregates (1998). Similar controls could be put in place to encourage or ensure that all deconstructable options are considered before planning permission or a licence for demolition is granted. Targets for local authorities could also be set for a minimum number or percentage of buildings which have to be audited before they are demolished, or for the minimum number of elements and components which need to be recycled or reused. Even if these minimum thresholds were very low, they would at the very least raise awareness within the local authorities and perhaps encourage sustainable markets that can grow.

Deconstruction tools and techniques

Most commercial concrete buildings are cast in-situ concrete frames and therefore need to be destructively demolished. The concrete elements are therefore unlikely to be reused in their original form, and at best could be crushed down and the steel and crushed concrete recycled.

Concrete frames incorporating pre-cast concrete beams are simpler to deconstruct if the joints are simply supported. However, these joints are frequently cast in place, usually with a concrete or mortar that is stronger than the actual beams themselves. One barrier at the moment is that no standard jointing system exists and the joints are not designed with deconstruction in mind, although new and innovative jointing methods are being developed.

Fixtures, fittings and joints between concrete components obviously have a major influence on whether a component can be removed from a structure, and therefore reused. The most commonly used precast concrete products (masonry blocks, paving slabs and blocks) have no fixtures, fittings or joints and therefore lend themselves to be easily dismantled and reused.

The main barrier to any concrete products being deconstructed and reused is an economic one. The cost of each individual unit (e.g. a tile or paving slab) is so low that it is usually more cost effective to buy new ones, especially in bulk. Another major barrier is a dimensional one. Most orders for structural units in the UK (beams, columns etc.) are for one-off bespoke structures with unique dimensions. The components therefore, have to be specially made for that particular structure and will not dimensionally fit a different structure, unless the new structure has been designed with this in mind which is rare, if not non-existent.

More use of precast, modular building and standardisation would be beneficial for increasing the opportunities for deconstruction, especially for repetitive buildings such as offices, prisons, hotels etc. The UK is behind many of the European countries on these issues, especially in the concrete industry. Precast companies in the UK at present have to construct new concrete moulds for virtually every new structure that they produce, as most of then are one-off bespoke designs. Standardisation of orders and products is minimal.

Physical barriers and problems that need to be addressed also exist due to pre- and post-tensioned beam/floors, jointing systems, the natural ageing of concrete, reinforcement corrosion and the presence of coatings. All these issues need to be investigated and guidance produced in relation to deconstruction and reuse. Not many concrete products are actually designed to be reused, as manufacturers would rather you bought new ones, but some can still be reused. Many products can be reused but are not designed *specifically* to be reused, such as kerbs and flags, paving, roof tiles, lintels, sills and copings. If they were designed with deconstruction and reuse in mind then the design would not be very different to what it is at present.

However, although many of these items could be reused, contamination is often an issue as the aesthetics of these components are usually very important. Kerbs, flags and paving can all become contaminated with pollutants such as petrol, chewing gum or other materials which can stain the concrete. The cost it then takes to clean these elements usually negates the benefits of re-using the components.

Some concrete elements could also be reused with only a slight alteration in their design, such as sea defence units, water treatment/storage tanks, railway sleepers, fencing, cladding, staircase units and flooring units. Although this would probably increase the initial price of the product, the whole life costs could be reduced. Unless there is a financial incentive to do so however, this is unlikely to happen. This is where more comprehensive guidance could be provided and where fiscal incentives (taxes or subsidies) could have a real effect upon the market place.

Material tests to verify durability / specification

The main problem with reinforced concrete as a reusable construction material is that it naturally deteriorates with time due to carbonation, although techniques (such as coatings) can be used to extend this finite lifespan.

No specific standard tests have been developed in the UK for the assessment of reclaimed concrete elements that are to be reused in their original form. However, many standard tests exist to assess the strength, quality and durability of reinforced concrete which could be used together to provide an assessment of the condition and the potential life-span of a concrete element. A potential problem is that many of these tests require a sample of the concrete to be taken (e.g. a core) and the total cost of the range of tests required may negate any financial benefits of reusing the element. Also, many of the problems encountered with reinforced concrete are not immediately apparent and are 'hidden' within the element e.g. reinforcement corrosion. Full-scale load testing is also possible although it is often destructive and is likely to be prohibitively expensive. However, an approximate (and therefore cheaper) assessment could be made of the quality and strength of the element and the element used in a lower-grade application (with a higher factor of safety).

Standardisation

The concrete industry is increasingly moving towards the use of more standardised components in order to increase productivity and reduce costs and this will in turn increase the potential for deconstruction and the reuse of concrete components in the future. Greater speed of construction, fewer defects, higher quality and lower costs are all being demanded by construction clients. Traditional forms of construction and supply chains are struggling to meet these demands. These issues can be addressed with the aid of standardisation and modularisation. This in turns aids deconstruction and reuse.

Steel and Composite Products

Introduction

Of the 700 million tonnes/year of global steel production, almost half is recycled from scrap. Steel is unique among major construction materials in that it always contains recycled content; it is completely recyclable at the end of its product life and may be recycled without loss of quality. Nevertheless a potentially significant amount of steel is not recycled.

There is a potential for increasing the amount of steel which is recovered or recycled from demolition sites. Demolition contractors do not have any particular problems with steel or concrete buildings, the two materials being easy to separate providing the right machinery is available. These two materials are the basis of most buildings and demolition firms are highly skilled at demolishing and separating them. The main steel elements are removed first and overhead magnets above the concrete crushing plants extract the rest of the steel [reinforcement]. Design for deconstruction is particularly appropriate for steel structures as the working life of the building elements is generally well in excess of the design lifetime of the building.

Steel products and components are widely used in the construction industry both as structural framing elements (beams, columns, bracing) and as non-structural systems (cladding, access stairways, gantry cranes). Steel is also widely used in conjunction with other construction materials. Typical examples would be the use of steel reinforcement to concrete structures or composite construction where the steel and concrete together provide an optimum solution in terms of utilising the strengths of both materials. Steel webs may also be used in engineered timber products where long spans are required. In the UK steel framing has over 50% of the market share for multi-storey buildings. Of these many of the most recent are steel-concrete composite buildings. It will be sometime before these buildings come to the end of their working life. Consideration should be given now to the possibilities for end of life disassembly (dismantling with recycling in mind), deconstruction (dismantling with reuse in mind), recovery (for recycling) and reclamation (for reuse). Similarly for new-build projects, deconstruction should be considered at the feasibility stage as common design criteria.

Standards and Specifications

The main steel products used in multi-storey construction are hot rolled products to BS 4360:1990 and BS EN 10025:1990. These documents specify the mechanical properties for specific grades of steel. They also refer to inspection and testing. Although there is no specific reference to products recovered from existing buildings the methods of inspection and testing are relevant to either new or existing products. There are no specific national or international standards relating to the disassembly, deconstruction or demolition of steel structures. Design standards make no reference to the reuse of steel members from demolition of existing buildings. Proposals have been drawn up by the Steel Construction Institute and BRE to develop a model specification.

In order for opportunities for the deconstruction and reuse of steel as a construction material to be realised, it is essential that deconstruction is incorporated into the design/feasibility stages of new construction projects. A section in the relevant European design codes (EC3 and EC4) or the appropriate national code (BS5950) on deconstruction would be a useful step in the right direction. The provision of increased tolerances and the use of slotted holes could allow for the movement required during deconstruction. The use of common design procedures within the European Community will lead to an increased use of standardised connections and structural members.

Standardisation will help to provide the financial incentives required in order to encourage deconstruction and reuse. A reduction in the nature and type of building components will simplify the design of tools for deconstruction and will simplify classification.

The corresponding documents for the supply and specification of cold-formed steel are BS2989 and BSEN10142. Mechanical properties and appropriate test methods are specified. As with hot rolled steel the inspection and testing can be applied to steel reclaimed from existing buildings as well as new product. Some mention of this in the standards would provide an incentive for reuse as opposed to recycling. The increased use of light gauge steel construction and modular construction provides a significant opportunity for deconstruction. Prefabricated construction provides a more suitable environment in which to incorporate connections that can be easily deconstructed. Current European research is concerned with the development of novel jointing systems for light gauge steel with particular emphasis on automated assembly. Some consideration of the potential for deconstruction at this stage of development would be useful.

Building and Planning Control

There are no specific restrictions imposed by Building Control or Planning authorities on the use of steel reclaimed from existing structures or from demolition sites. Building Control will require evidence that elements reclaimed from one project are capable of meeting the requirements for the new application. This relates to methods for verifying performance in terms of load carrying capacity and durability. For steel elements, as long as they have not been highly stressed (inelastically) and do not show any visible signs of plastic deformation they are capable of being reused even for structural applications. Any out of plane deformations such as buckling in the web of column sections could lead to instability in use. A useful source of information on this topic is "Appraisal of existing iron and steel structures" published by the SCI which gives information on methods of investigation and guidance on calculations for checking structural adequacy. A system of in-situ non-destructive testing would be of benefit in encouraging reuse of structural elements.

CPD legislation will provide an accessible data source relating to the form of construction which can be used to inform the decision making process at the end of the working life of the building. Education for local authorities and other planning bodies on the potential for deconstruction could provide an opportunity for regulators to consider whole life costing for a project to include the environmental benefits of deconstruction and reuse of steel products.

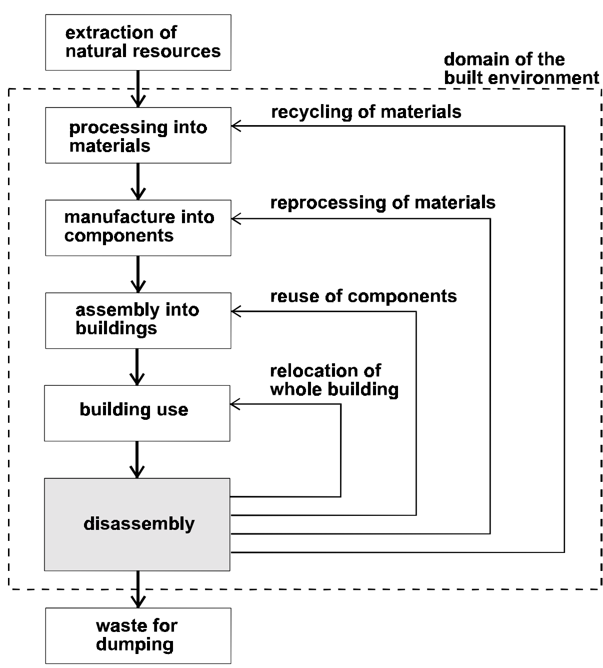
Timber products

Overview

Timber is a versatile, strong and adaptable material both in its raw form as wood and as a range of products. Timber has been used in construction throughout history primarily due to its relative strength, ease of use and fixing and the fact it is a readily available natural resource. Although the ease of fixing and modifying timber components during construction has proved popular with builders, for instance notching and drilling joists for services, these types of modification turn a generic joist of uniform section into a joist that is tailored specifically for the building it is installed in. Similarly nails, screws and other types of fixing locally damage the timber rendering it in some cases unsuitable for reuse when that component is deconstructed. It can, and is however available for recycling.

The number of different products produced from timber is immense. For example, using different combinations of board makeup, coverings and wood fibre lengths (veneers, blocks chips strands or short fibres) it is possible to produce over 5,000 different types of board product, each with different performance characteristics and potential end-use applications. Wood products can also be re-engineered for different applications for instance the use of cardboard construction for internal doors. Surprisingly DIY is the largest market for timber and timber products. Market sectors for renovation, packaging, temporary works (formwork, scaffolding, etc.), joinery, floor and ceiling joists and fencing also have significant market share in descending order of volume.

Deconstruction strategies for material reuse and recycling were clearly summarised by Crowther as reproduced below:



The tiered strategy is closely linked to the environmental impact of demolition waste timber as greater degrees of reprocessing generally produce greater environmental impact. The most environmentally friendly option and the ultimate target for construction materials is the reuse of components without modification, or even the reuse of whole buildings due to the lightweight structure of timber buildings.

Since the demolition and even deconstruction process can cause damage to timber, the suitability of timber for reuse will depend on the robustness of the timber component to withstand damage during removal from the building and demolition site. This suggests that larger section timber such as joists, studs beams, columns, purlins and trusses will be more suited to reuse whilst smaller sectional timber such as battens and joinery may be recycled or used as a fuel source. However there is a large amount of overlap whereby all timber components may be reused depending on their value. So far the salvage industry has focused on architectural and antique timber components that require a high value of return for the relatively small quantities involved for economic gain. Since sustainable reclamation will only occur if it is economic to do so the following drivers will need to increase the scope of timber that is reclaimed:

- Cost of sending timber to landfill
- Increased use of high value timber products in construction (engineered timber such as Gluelam, LVL, I-beams, Metal-web beams)
- Better tools and techniques for deconstruction
- Increased use and further development of reprocessing techniques such as finger-jointing and laminating
- Standards for grading re-claimed timber
- Process and economic studies to help provide market confidence
- Development of routes to market
- Increased client demand for re-cycling and reuse in construction, renovation and DIY.

Housing provides the main market for timber in construction and will generally last longer than industrial and office buildings (average age of housing stock in the UK is about 90yrs compared to 50yrs or less for offices). This probably accounts for the greater quantities of timber construction waste compared to demolition waste. Because of the short length of timber in construction waste and the damage incurred (holes, notches) during deconstruction, both C&D timber waste will require some form of re-processing to produce useful lengths of timber. Automated methods developed for the sawmilling industry such as defect cutting and finger jointing can be applied to timber waste to produce long lengths of reusable timber. Holes in the timber, following the removal of nails and other fixings, may need to be ‘plugged’ in a similar manner to plywood before the timber is reused. All of the techniques for re-processing can adopt existing technology that is already developed for the sawmilling and joinery industries.

Standards and specifications

Current standards for the use of sawn timber in construction focus solely on virgin material stock. Since the majority of large section timber will be structural the governing standards for reuse as a structural material may well be:

- BS5268 – Structural use of timber
- BS4169 – Glue-laminated structural members
- BS 6446 – Specification for manufacture of glued structural components of timber and wood based panels
- BS EN519 –Machine stress grading of timber
- ENV 1995-1 – Eurocode 5. Structural design of timber structures.

Although reclaimed timber is not specifically included in the scope of these standards they could be extended with minor additional application rules. The main effort would be the assignment of a strength class to the reprocessed reclaimed timber. This normally required extensive testing of over 300 pieces of timber for a new species. Once grade stresses have been established for that species timber made be graded and stamped for structural use using automated grading machines. This method of assigning strength classes could be adopted for reused timber on a case by case basis through Certification and later by creation of a specification standard for reprocessing and grading of reclaimed timber.

Another potential system of grading and specifying reclaimed timber for structural purposes could include a %-based 'penalty' that is imposed on a reclaimed timber element in comparison to a new timber element. The penalty would relate to established Tables that are currently used to determine the dimensions of structural timbers needed for a given span or distance. For example, a span of 3 metres between two walls could require that a new timber floor joist is of 125mm x 50mm or a timber ceiling joist is 100mm x 50mm (this is an example and not specifically true to the Tables). However for the same distance where reclaimed timber is used, there could be a 20% penalty imposed so that the dimensions of a reclaimed timber floor joist would need to be 150mm x 60mm or a timber ceiling joist is 125mm x 60mm. On a similar thread, the 'penalty' could also be graded so that the greater number of lightning shakes, knots and damage/repair that a reclaimed timber element has the greater the %-based penalty would be e.g. the penalty could be 50% rather than 20%. For the moment this is an idea without substance but could provide a simple method for adopting established specification Tables.

Building and planning control

Due to the various types of degradation associated with reused timber, Local Authorities will probably require evidence that reclaimed timber meets the requirements of Regulation 7 to the Building Regulations (England & Wales) 2000. This is commonly achieved for other material types through Certification although the use of an independent checking authority adds extra expense to process of reusing timber structurally. Reuse of timber as a non-structural grade may avoid this expense but poor appearance could limit the reuse to low value joinery or packaging material.

Deconstruction tools and techniques

There are relatively few tools and techniques tailored to the deconstruction of timber structures and building components. The Code of practice for demolition BS 6187-2000, recommends that timber structures should either be demolished by deliberate collapse methods or deconstructed. Due to the quantity and difficulty in removing connectors in timber structures, deconstruction techniques can be time consuming. How to balance this time with revenue gained and market demands is the challenge to the industry and us all.

Many timber components that are reclaimed from existing structures contain nails and screws that must be removed or made safe for handling before reuse or recycling. This is currently done by hand which can be time consuming and generally only proves to be economically viable for high value items such as large section beams. Many lower value components such as small section joists and studs will need to be free of nails and screws if they are to be reused or recycled e.g. chipping for the production of board products. Nailed and screwed connections are often used in virgin wood to attain the codified values for shear and pullout. It may be suggested that larger diameter nails or reduced capacities should be adopted for the reuse of structural timbers.

‘Plugging’ of the timber as described previously, may provide similar performance characteristics for timber connectors although this would need to be demonstrated. Whatever option is chosen for fixing reused timber, research is required to establish basic rules for reuse performance.

Material tests to verify durability/specification

There are two main methods for establishing the grade and hence suitability of timber for use in construction:

- Visual grading
- Machine stress grading

When structural timber is produced at the sawmill, some pieces can be as much as eight or more times stronger than others of the same size and species. This is due mainly to the differences in density of the fibre material and the presence to a greater or lesser extent, of defects such as knots and sloping grain.

One of the major disadvantages of visual stress grading is that it is rather inefficient in that wood structure and density that influence strength cannot be sufficiently taken into consideration by visual inspection. Another disadvantage is that economic restraints do not allow for a slow deliberate examination of each piece and hence only a rough estimate can be made of even the more obvious defects such as knots and sloping grain. The grading rules therefore have to be set conservatively.

There are no current grading rules for stress grading reused timber, either by machine or visually. These rules would need to be established if timber is to be reused structurally. Since the majority of timber in buildings will require some reprocessing to produce useful timber, grading of the reclaimed timber will need to be carried out. Reprocessing machines such as those for finger-jointing are expensive to install on an industrial scale. Some sawmills in the UK are currently 'tooling-up' for finger-jointing waste timber from the saw log, thus turning waste into higher value products. This initiative should be encouraged and extended to the reprocessing of reclaimed timber.

Once grading rules have been established for reclaimed timber, other performance requirements for durability, dimensional tolerance and the performance of fixings can be readily established within existing codes with little alteration or guidance required beyond that which is already provided.

Standardisation

Sectional sizes of timber used in construction are already standardised as described in BS 4471. This provides the basic sizes of timber after sawing although due to the potential distortion of timber these may change slightly with conditioning. Different sizes of timber can also be obtained by either re-sawing or processing. Processed timber is commonly of two types:

- Regularised
- Planed

Regularised timber is process so that its thickness or depth is uniform throughout its length. Planed timber is commonly used in the construction of timber frame wall panels where studs are machined on all four faces to produce timber with a sectional tolerance of ±0.5mm. With finger-jointing and laminating techniques reclaimed timber can easily be reprocessed to produce the same standard sizes of timber currently available. This type of processing may be required for timbers that have been coated with paints, varnishes or other materials, whereby the coated sections are machined from the timber leaving a regularised or planed finish.

5. Environment, Health and Safety

Demolition Code of Practice BS 6187: 2000

This British Standard concerns the process of demolition from initiation, through planning, to the execution stages. The new version of BS 6187:1982 is essentially a re-write which takes into account the advances in technology and equipment that are available to the demolition industry. The application of new techniques and the effect of new legislation that has been introduced, particularly health and safety, and environmental legislation, including the Construction Design and Management (CDM) Regulations 1994, the Construction (Health, Safety and Welfare) Regulations 1996 and the Environmental Protection Act 1990 have been taken into account. The document is written for all – including Clients - involved in demolition (which include partial demolition) projects and gives emphasis to responsibilities from concept stage to completion, starting with clients. The Standard addresses the safety of both those engaged in the demolition process and also those members of the public who may be affected by the demolition activities.

The new edition of BS 6187 has been expanded to cover project development and management, site assessments, risk assessments, decommissioning procedures, environmental requirements and facade retention. Deconstruction techniques are considered, including activities for reuse and recycling. Principles relating to exclusion zones, their design and application have also been added.

UK local government policy and procedures

Building Control procedures make sure buildings are constructed to meet all requirements of the Building Regulations, ensuring that products used are fit for their purpose in terms of structural performance, fire performance, thermal and sound insulating properties etc. The Building Regulations have no requirement that buildings should incorporate recycled components or that building components should be recyclable at the end of the building or component life. Recovered building components from demolition will also have to meet the requirements of the regulations in terms of structural performance, fire resistance etc.

HSG Health and Safety in Demolition Work

The Health and safety Executive (HSE) is currently revising a series of health and safety guidance for construction. This draft guidance document - currently a working document on Health and Safety in Demolition Work - is to:

> "Help all those involved in the demolition process, from client and designer to contractors and individual workers, to identify the main causes of accidents and ill health and to explain how to eliminate the hazards and control the risks".

This guidance is being developed alongside other relevant pieces of regulation and guidance so as to improve the business of demolition and deconstruction. Complementary documents include BS6187-2000, Construction (Design and Management) Regulations 1994 (CDM) and a range of other laws and guidance including:

- The Health and Safety at work etc. Act 1974
- The Management of Health and Safety at Work Regulations 1999
- The Construction (Design and Management) Regulations 1994
- The Construction (Health Safety and Welfare) Regulations 1996
- The Provision and Use of Work Equipment Regulations 1998
- The Lifting Operations and Lifting Equipment Regulations 1998
- The Control of Substances Hazardous to Health Regulations 1999
- The Control of Asbestos at Work Regulations 1987
- HSG 213 *Introduction to Asbestos Essentials*
- HSG 210 *Asbestos Essentials Task Manual*
- HSG 189/2 *Working with Asbestos Cement*
- HSG 189/1 *Controlled asbestos stripping techniques for work requiring a licence*
- L28 *Work with asbestos insulation, insulation coating and asbestos insulating board*

The document includes various sections and it is not intended to reiterate them here, rather to indicate the nature of the content and relationship to the above documents. The sections of the document include:

- The roles & responsibilities of the client, designer, planning supervisor, principal contractor, site supervisor and contractors
- Preparing for demolition work including gathering information, the tender period and planning site work
- Working safely including safe systems of work, induction and supervision, the site environment and ensuring stability
- Process and techniques including preliminary activities, remote demolition, controlled collapse, dismantling and partial demolition
- Health risks
- Training & competencies

Health and safety issues

The demolition of buildings is mostly covered by existing health and safety legislation. Some of the international standards mention concrete specifically (PTI, 1992 and NSI, 1989). Special care also has to be taken with pre- and post-tensioned beams and slabs. Adequate factors of safety and modified strength classifications need to be used to ensure that any concrete elements which are reused are well within their load-bearing capabilities. Guidance, test methods, strength classification and certificates of conformity are essential for making the concrete elements safe to reuse and for giving potential designers and owners the confidence to use them.

For the reclamation of structural steel members for reuse, existing techniques are generally remote. Beams and columns are either partially or totally flame cut or, alternatively cut using shears attached to a modified excavator. Bolts are rarely removed prior to recovery. Hence most of this material is recovered and recycled. Methods to promote an increase in the amount of steel to be reused are likely to involve removal of bolts from areas where access and space is restricted. This is likely to involve a greater risk of injury to operatives where machines are not available. The development of new tools, techniques and working practices is an essential pre-requisite to deconstruction and reuse of steel elements.

Safety on demolition sites has been a major factor in current trends for demolition techniques, especially for steel and concrete structures. The once, dominant track loader and crawler crane and drop ball have been replaced by excavators with long reach booms to distance the operator from the building being demolished. This trend of taking personnel out of potentially dangerous situations and providing machines for dismantling (for recycling) buildings is likely to increase and may be extended to soft strip applications. Specialist tools and attachments to excavators and mini-excavators increase the scope of dismantling and deconstruction operations and can provide additional safety for operatives. These may be developed specifically for timber frame structures.

Environmental issues

Contamination may prove to be a significant barrier to reuse. The use of sprayed products for fire protection may mean that removal and disposal of potentially hazardous materials may make deconstruction uneconomic. However, standard coatings on steel products do not represent a barrier to recycling. Galvanised and painted steel is recycled. The fillers in the paint are organic and are burned off, the pigments, which are resistant to high temperature, are removed with the waste products. Corrosion of existing structural sections may also provide a significant barrier to reuse. Although members may be perfectly capable of fulfilling the design function in terms of strength and stability, the measures required to provide an aesthetically pleasing finish may prove uneconomic.

Timber is perhaps the most sustainable and renewable construction material available, encouraging its reuse can only improve upon the already exemplar performance. It is well known that timber absorbs CO_2 from the atmosphere and sequesters it as stored carbon in the built environment. If the timber is later burnt or composted, CO_2 is released back into the atmosphere greatly increasing the life cycle impact of the use of timber on the environment. The longer that carbon sequestered in timber is stored in the built environment the lower the environmental impact.

6. Economics of Deconstruction and Marketing of Used Building Materials

Landfill tax

The landfill tax was introduced on 1st of October 1996 and it applies to waste that is disposed of in licensed landfills. Exemptions for the tax have been provided for dredged waste, mineral waste from mines and quarries, and wastes arising from the clearance of contaminated sites. Exemptions also apply to inert materials that are used for landfill restoration or filling former quarries. The tax seeks, as far as is practicable, to ensure that the price of landfill fully reflects the impact which it has upon the environment. It provides an incentive to reduce the waste sent to landfill sites and to increase the proportion of waste that is managed at higher levels of the waste hierarchy.

There are two rates of tax, a standard rate of £14 per tonne (as of April 2003) for non-hazardous and a lower rate of £2 per tonne for inert wastes. The levy for non-hazardous waste currently rises at £1 per tonne per annum but this is set to rise by £3 per tonne per annum as of April 2005 to around £35 per tonne in 2013. From this it can be seen that the cost of disposing of waste to landfill is likely to substantially increase in the future. The money raised from the tax has been used in some part to encourage the use of more sustainable waste management practices and technologies. For this, the landfill tax credit scheme was established to permit up to 20% of the taxes collected by landfill operators to be used for the purpose of implementing social and environmental projects complying with specific approved objects in the regulations.

Aggregate Levy

In April 2000 the Treasury agreed to introduce an Aggregates Levy of £1.60 per tonne on primary aggregates from April 2002. Secondary and tertiary aggregates will not be subject to the levy, which should encourage a greater use of recycled aggregates in low- to high-grade applications. £58.6 million will be used for a Sustainability Fund that will support various initiatives including developments, improvements and R&D within the industry, its facilities and its impacts to the local populations. The funds will be distributed through a number of organisations including the Waste Resources Action Programme (WRAP), the DTI Construction Innovation and Research Programme, DTLR Clean up Programme and a Freight facilities Grant who will all oversee the management and approval of the fund and projects. However, until the aggregate tax is implemented and the fund structure agreed, there is little benefit in speculating the outcome.

Reclamation Valuation & Environmental Quantification

In order to appreciate the potential to reuse and recycle there is an urgent need to include a value of the various costs for demolition, deconstruction and soft strip. This should include costs for both plant and staff time. This will not be an easy task and will require weightings for geographical and technological variations. There is also an environmental cost to consider that is even more difficult to ascertain. The reclamation valuation surveys herein were undertaken by Salvo (who represent the reclamation industry) and attempt to provide indicative revenue for materials and components that could be reclaimed for reuse. Similarly, the environmental quantification provided by BRE provides an indication of the environmental rewards to be realised from reusing and recycling. Reclamation valuations and environmental quantifications were undertaken for two of the case studies; Whipps Cross University hospital and Nestle factory. A number of assumptions were made for the studies. The common assumptions were:

- All reclaimed items have been removed from the building without damage, and not been damaged during any transport or processing to enable reclamation.
- The installation of reclaimed items has involved the same environmental impact and wastage of materials as the installation of new items.
- The service life of reclaimed items is the same as new items.
- Most reclaimed items have been removed from site, taken to a separate site to be processed and stored, and then transported to a new development.
- All transport has been based on UK Government Transport Statistics providing typical loads and distances for different materials.

The aim of the environmental quantification is to quantify the environmental rewards for reusing or recycling construction materials, as opposed to allowing post-demolition materials to enter the waste stream and using newly manufactured construction materials. The assessment was undertaken using the BRE Environmental Profiles Methodology, which uses a level playing field approach to assess environmental impacts over the whole life cycle. The assessments therefore take account of any environmental impacts associated with transport, manufacturing and processing, maintenance and replacement, and disposal at the end of life. These are based on typical UK scenarios. The BRE Environmental Profiles Methodology measures 12 Environmental impacts:

Climate Change	Acid Deposition	Ozone Depletion
Human Toxicity to Air	Low Level Ozone Creation	Fossil Fuel Depletion
Human Toxicity to Water	Ecotoxicity to Water	Eutrophication
Minerals Extraction	Water Extraction	Waste Disposal

For this study an overall measure of the environmental impact known as Ecopoints was used. 100 Ecopoints is equivalent to the overall environmental impact of one UK citizen over 1 year. The study also provided a measure of Embodied CO_2 in terms of the hectares of Amazonian rainforest that would be needed to sequester the same amount of CO_2 from the atmosphere. This study has taken the amount of carbon sequestration provided in the Intergovernmental Panel on Climate Change (IPCC) report for selectively logged rainforest in Amazonia of approximately 2.5 tonnes of Carbon per hectare per year. Interestingly, a hectare of sustainably managed English oak would also absorb 2.5 tonnes of carbon per hectare per year.

Figure 9: Overall reclamation valuation and environmental quantification for WCUH

	Reclamation Valuation				Environmental Quantification		
ALL PRODUCTS (m^3)	STTOD - sold to the trade, own dismantling	STTG - sold to the trade at the gate	SOS - sold on SalvoWeb	RVO - reuse value on-site	Ecopoints	Hectares pristine Amazonian rainforest per year	Hectares heavily logged, sustainably managed rainforest per year
24,515 m^3	£456,995	£2,107,442	£6,952,402	£4,227,529	119,121	2,516	1,060

As an example of what can be achieved, Figure 9 provides a summary for WCUH. These show the economic potential for 24,515 m3 of key demolition products that could realise an income of between £456,995 - £6,952,402 depending on the form of deconstruction used. Avoiding landfill disposal by reusing or recycling the KDP could save a further landfill tax charge of £34,000 which could easily triple by the end of the project. This would also reduce the estimated 3,064 lorry journeys required for the disposal of the demolition waste and minimise the number of lorries required to deliver new materials to site. These benefits may be used to complement any planning applications that are required. Similarly, reuse and recycling can help realise environmental rewards that are similar to the environmental impact of 1,191 people over 1 year or the amount of carbon sequestered by 1,060-2,516 hectares of rainforest. Figure 10 provides individual examples of the 39 KDP audited at WCUH

Figure 10: Reclamation valuation and environmental quantification for select KDP

	Reclamation Valuation				**Environmental Quantification**		
PRODUCT	**STTOD - sold to the trade, own dismantling**	**STTG - sold to the trade at the gate**	**SOS - sold on SalvoWeb**	**RVO - reuse value on-site**	**Ecopoints**	**Hectares pristine Amazonian rainforest per year**	**Hectares heavily logged, sustainably managed rainforest per year**
Leaded cupola (intact)	-£32,000	£0	£24,000	£80,000	0	0	0
Dressed red rubbers (brick)	£2,800	£7,000	£18,200	£5,600	263.2	6.44	2.716
Handmade reds (brick)	£452,696	£1,810,783	£5,885,045	£2,716,175	85106.801	2082.40045	878.229755

In order to appreciate the detailed value in Figures 9-10 above, a brief description for one of the KDP is explained. Handmade red bricks are quite commonly used in the pre-1920's buildings at WCUH. The value of one handmade red brick dismantled by the demolition team to sell off-site will be only 5p, whereas to dismantle it and sell it to the trade on-site will be 20p. Sold via the Salvo website it is estimated that each of this type of brick could fetch 65p; to replace a new brick being used for the new hospital is 30p. It is estimated that approximately 9-million handmade red bricks are available for reuse with an economic potential between £0.5-million and £5.9-million. These are significant figures to consider.

The approximate environmental quantification -or reward- for adopting reuse of the handmade red bricks on- or off-site is significant. Each of the handmade red bricks is equal to 0.0094 Ecopoints – the impact of one UK citizen over 50 minutes. Similarly, one brick is equivalent to the Carbon sequestered by 0.00023 hectares of pristine Amazonian rainforest or 0.000097 hectares of heavily logged, sustainably managed rainforest over one year. The potential environmental rewards for reclaiming and reusing the handmade red bricks from WCUH is equivalent to the environmental impact of 851 people over 1 year or between 878 - 2,082 hectares of pristine / sustainable logged rainforest per year.

Process mapping

However, to realise the potential to reuse and recycle there is an urgent need to value the various costs for demolition, deconstruction and soft strip for both plant and staff time. This is not a simple task and will require weightings for geographical and technological variations. There is also an environmental cost to consider which is even more difficult to ascertain. Recently, BRE has been undertaking process maps of the demolition process for both the Department of Trade and Industry (DTI) and the Waste and Resources Action Programme (WRAP) projects using the baseline principles of the Calibre tool. The following provides a brief insight into the process mapping of the soft strip process at the former Nestle factory in Norwich.

Many items were removed, including partitioning panels, cupboard doors, single doors double doors, wardrobes, shelves, doorframes, architectural timbers, handrails, unique wardrobes and skirting boards. Steel shelves were also removed and used for storage of the items removed from the building. All nails were removed from items. Doors were also removed in one of two ways, firstly with all the fixings attached, secondly with all the fixings removed. At all times the disturbance of asbestos panels was avoided.

Process mapping provide a better understanding of the barriers and opportunities to deconstruct and helps to clarify the roles and responsibilities of participants, having real-time feedback of activities involving all levels of staff. It also helps to identify and eliminate disruptive patterns and process bottlenecks, thereby improving site organisation and developing more expedient design solutions. The process mapping helps the process become more efficient, more competitive, and more predictable in the delivery of the product and improves performance. The following table shows select results of the process mapping and average times.

Type	Dimensions (m)	Volume (m3)	Average Time (min)	Staff	Equipment
Partitioning Panel	2.9 x 1.2 x 0.05	0.17	12	2	Screw driver, steel bar
Other Panels	2.9 x 1.2 x 0.05	0.17	3	2	Screw driver, steel bar
De-nailing	1.5 x 0.060 x 0.010	0.0009	0.5	1	Pillar
Cupboards doors	0.685 x 0.520 x 0.025	0.54	4.5	1	Screw driver
Single door With fixings	1.9x0.640x0.045	5	5	1	Screw driver

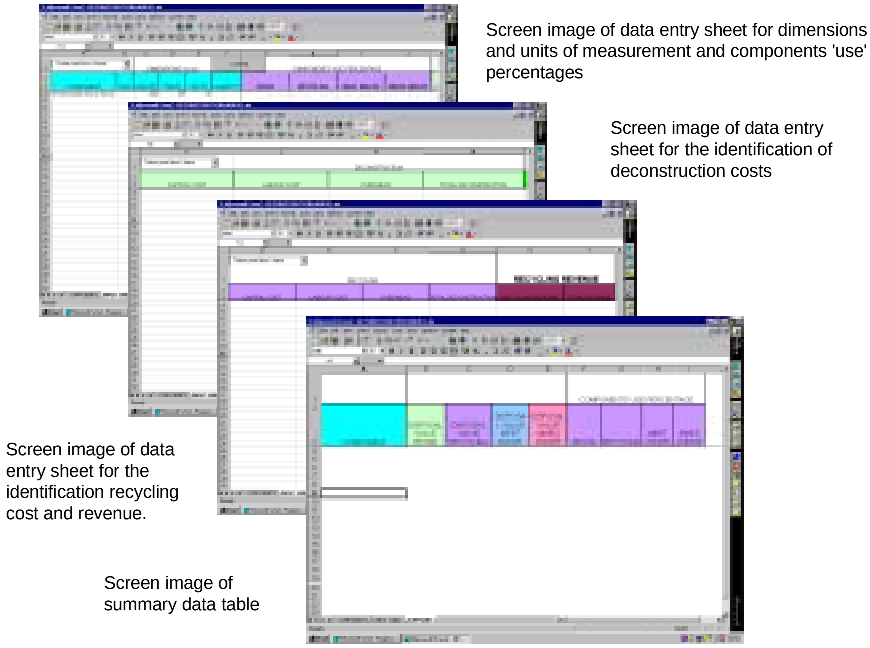
Yet what is the additional cost of adjusting the process? How is it we can choose one process over another and what value should we place on that change? BRE has recently developed a procedure and cost model to make an economic assessment of the cost and benefits of deconstruction and reuse of building materials. Discussions with industry highlighted that, whilst the principle of the model and that the procedure are sound, significantly more development and research is required to create a model that would add value to the industry.

The foundations of the cost model are based on basic principles of economic theory. Economics is a study about how scarce resources are allocated in a world where there are constant demands. Factors of production are usually classified into four different groups of entities; Land, Labour, Capital and Enterprise. The deconstruction cost model adopted an approach based on the economics of allocation of scarce resources, and created a methodology that can measure the quantities of scarce resources that have to be employed to deconstruct and then reuse construction components and materials in a way that can maximise the economic value added.

The model uses costs and prices as a method to rank the various ways to deconstruct and opportunities for re-sale of the building components. Prices are used to perform the allocation system, as they provide the information and incentives needed to make rationale economic decisions in order to arrive at the optimum outcome. A prerequisite of a tool is that it is capable of ranking decisions based on a defined measure. The cost model fitted this description as it attempts to rank alternative approaches to deconstructing a component- the defined unit of measure is cost. A more complex model could include benchmark prices that each factor of production can command, typical costs for deconstruction, including for example, typical labour rates, and cost of hiring capital. A more complex model would add value if it also considered how influences such as building design, construction methods, location, infrastructure would affect the cost and income earned by deconstruction and reuse. A predictive cost model for deconstruction and reuse of materials can be developed but it needs to be practicable and usable.

The model creates a systematic approach for identifying and summing the costs of deconstruction products, and add value to the Whole Life Cost (WLC) arena by creating a better understanding of the costs and revenues incurred when a KDP has reached the end of its (current) economic life. Maximising the disposal value of a component may have significant cost savings for the construction industry clients. Including the disposal value in WLC calculations of an asset help ensure that procurement of construction products are chosen which offer best value.

Figure 11: Screen Dumps of the Deconstruction Cost Model (included in previous paper)



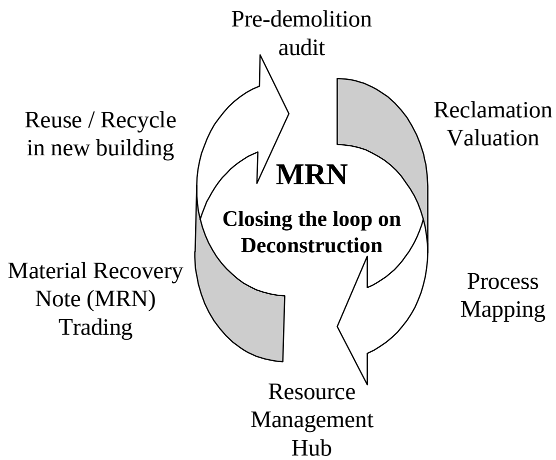
The cost model is one possible way to assess the economic benefits of reusing salvaged buildings rather than sending them to landfill.

Funding Change – Material Recovery Notes

Material Recovery Notes (MRN) are an idea, a potential opportunity to extend the principles of packaging recovery notes (PRN's) to reclaimed materials. It is well known that the PRN system has helped to develop the recycling industry; the MRN system could provide similar assistance to the reclamation industry. However, this is merely an idea arising out of the industry's apparent willingness to develop the reclamation and reuse of construction materials if there is sufficient demand, supply, time and collaboration. The MRN system could provide this framework.

The MRN system would aim to close the loop on deconstruction and minimise the level of demolition to materials earmarked for recycling, composting, recovery of energy or landfill (including inert supplies which are a necessity). The MRN system would also help the WLC model to accommodate multiple life materials rather than one-life accounting. Despite best efforts, WLC models are lacking sound, reasonable data for their models, hence the urgent need to gather this information before we unnecessarily demolish our historic buildings and architectural products and resign them to landfill or at best down-cycling as crushed or chipped materials. The MRN system would be able to capitalise on pre-demolition audits, reclamation valuations, environmental quantification and process maps described in this paper. Figure 12 shows the basic principles of the closed loop approach.

Figure 12: The MRN - Closing the Loop on Deconstruction



To support the MRN system a key demolition product template should be developed, whereby the information gathered on a particular product could be advertised in advance of, or following, the deconstruction process. Vital information from the pre-demolition audit, reclamation valuation, environmental quantification, process mapping, WLCcomparator, risk analysis, method statement, specification, cost and comparable revenue could be made available to potential purchasers. Once a purchase was made the MRN trade would be completed along with the environmental rewards.

The MRN system and key demolition product template is not entirely a new concept as the reclamation industry has been trading architectural and antique products and materials for many years. Salvo has played a significant role in the development of this trading and quality control and it is anticipated that a national resource management hub will align itself, and capitalise on, existing and developing systems. However, it is necessary to consolidate all this information under one umbrella and draw upon the range of information, regulation and specification to assist trading and reuse of suitable products and materials. In this way it will be possible to provide a portal to engineers, architects, specifiers and clients in need of reassurance that they are making sound business decisions that the City and insurers will approve.

The collective nature of these tools constitutes a valuable advance in determining how clients can appreciate the nature, make-up and value (economic and environmental) of their structure prior to demolition. In itself, this paper does not answer all the questions or provide a complete analysis of the potential to deconstruct and reuse construction materials both on- and off-site. What it does provide is an incentive to identify KDP and their potential/value for reuse, and what are the environmental rewards in terms of Ecopoints and sequestered CO_2 from hectares of Amazonian rainforest. Together, this information provides a sound foundation to build on and offer opportunity where it exists.

7. Design of Buildings and Components for Deconstruction

Lack of design principles

There have been few investigations undertaken in UK to understand the principles of design for deconstruction and reuse. Various other industries such as the car and munitions industries have invested in automated and mechanized systems for deconstructing their product at the end of its life. However, this has not been the case for the construction industry until quite recently. Currently, Buro Happold and CIRIA are completing a government-funded study on Principles of design to facilitate deconstruction for reuse and recycling (due to be published mid 2003). It is not the intention of this paper to reproduce what will eventually be published, merely to provide an indication of what the document will include.

The CIRIA paper will identify the huge variety of materials and types of products used in buildings which requires many different approaches to designing for deconstruction but are often generic in particular styles. Generally speaking, the paper will take each building element and consider the following three options:

Steps to maximise end-of-life value at deconstruction

Assuming that reuse after deconstruction is the first consideration, it will be vital that the condition of the element is as good as possible. This will favour using elements that can be cleaned, maintained and serviced, as appropriate, by taking various steps to maximise end-of-life value at deconstruction. This will maximise the remaining life in a component when it is removed by deconstruction and minimise the degree of reconditioning required to prepare it for gaining certification of an appropriate level of technical performance. Maintenance and careful protection of components during their life can make recycling easier and improve end-of-life value.

Design for reuse after deconstruction

Designing for reuse after deconstruction will require that the element can be removed from the building with as little damage as possible. A suitable deconstruction sequence must be planned appropriate to the time when the component is likely to be removed.

Design for recycling after deconstruction

Designing for recycling after deconstruction will generally differ little from designing for recycling after demolition. It is most likely that recycling after deconstruction will occur when certain components have been removed and salvaged for reuse after construction, leaving others that cannot be reused and can only be recycled. Alternatively, it may be that the process of deconstruction may significantly increase the likelihood of materials being clean and separable and, hence, better suited to recycling.

Design for deconstruction

To design a masonry building for deconstruction it is necessary to look to the past for inspiration. When buildings were built with solid walls and lime mortar was used to hold the bricks or stones apart then it was possible to deconstruct and reuse the building materials. Whilst cement mortars continue to be used and cavity wall construction necessitates the use of block work and wall ties there will remain a major barrier to deconstruction.

The ease with which timber products can be removed or dismantled during deconstruction will influence their suitability for deconstruction. This is often reliant on the type and number of connectors used in the construction. Nails and staples for instance are more labour intensive to remove, cause more damage to the timber and require a greater number to achieve a sufficiently strong connection. The use of bolts, dowels, screws or pressed metal plate connectors greatly improves the deconstructability of components.

Glazing can cause a particular problem for deconstruction of windows although modern double glazed units are much improved through the elimination of putty seals. Glazing bars are also prone to damage due to their small cross section. In general, small cross sectional timber will be more likely to get damaged during dismantling and will be less suited to deconstruction.

The obstacles to deconstruction outlined above are considerable. They include economic, technical, logistic and social factors. Given the current market for steel products and the relatively low cost of the material these obstacles can only truly be overcome by thinking about reuse at the initial design phase. Certain types of connections such as fin plates or cleats would be more amenable to recovery and reuse than larger more rigid connections such as welded joints or large end plate connections. Certain areas of the steel construction industry are more amenable to design for deconstruction than others. The increased use of pre-fabrication in the light gauge steel frame industry is one area where deconstruction techniques could be readily adopted. The increased use of modular construction and pre-fabricated wall and floor units mean that it is both practical and economically feasible to either re-site an existing building or use the components in a new building. Design for deconstruction is not however solely an issue for the designers of buildings. The development of suitable tools for the safe and economic removal of structural elements is an essential pre-requisite of the more widespread adoption of deconstruction.

8. Policy, Regulations, Standards, Liability

Studies by the BRE have shown that there is an array of current and proposed legislative, fiscal and policy frameworks affecting the C&D industry, and that this will become ever more stringent in the future. Initiatives such as the European waste catalogue, community wide waste management plans, national waste and sustainability strategies, the landfill directive, national acts of parliament and proposed European lists and tests will assist in the development of a normalised but adaptable system of waste management within the EU. Most of these policies need to be adopted between 2004-2008 so there are challenging times ahead. In UK, these initiatives are to be encouraged by current and proposed fiscal measures including the landfill tax (£14 per tonne in 2003), the aggregate tax (£1.60 per tonne in 2003), the sustainability fund, the landfill tax credit scheme and funds for R&D from both government and private sources.

Current and future legislation will be a key driver in sustainable waste management. It will challenge industries to manage their resources effectively and efficiently. There are obvious advantages and opportunities for the waste management industry too, with clients and main contractors requiring material waste management strategies for particular types of materials and sites. The following sections describe the European and UK legislative, strategic, fiscal and policy issues that may have an impact on C&D waste.

With regards to the demolition industry and deconstruction, most of these regulations will apply either directly (e.g. CDM Regulations) or often indirectly (e.g. Packaging Regulations). Although some of the regulations do not specify demolition plant or machinery (e.g. ELV Directive) or electrical components and tools (e.g. WEEE Directive), it is believed that EU Decisions will be eventually taken to this effect. The following is, therefore, only an introduction to the growing wealth of legislation, fiscal measures and policies that will have an impact on the way demolition is undertaken and what processes will need to be introduced to comply.

Current EU waste management and legislation

Waste Hierarchy

The waste hierarchy (Figure 13) provides a theoretical framework, which should be used as a guide for ranking waste management options. All options in the hierarchy should be considered for each type of waste and which cannot be reasonably separated out. The UK Government advocates the use of the waste hierarchy as a guideline following the options of reduce, reuse, recycle, recover and finally disposal.

Figure 13: The Waste Hierarchy

Precautionary Principle

The precautionary principle was defined by the UN Conference on Environment and Development, in the Rio Declaration as:

> "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

The principle involves taking precautions now to avoid possible environmental damage or harm to human health in the future, even although the scientific basis for taking the precautions may be inconclusive.

Polluter Pays Principle

The polluter pays principle states that the polluter should bear the full cost of the consequences of their actions. The potential environmental and human health costs of producing, treating and disposing of waste should therefore be reflected in the price of products and the charges associated with collection, treatment and disposal of wastes.

Proximity Principle

This suggests that waste should generally be managed as near to its place of origin as possible. It recognises the fact the transportation of wastes can have a significant environmental impact and economic cost. Where the best practicable environmental option (BPEO) for a waste is at the lower end of the waste hierarchy, this can be justified where the environmental impact and/or cost of transport to a distant waste management facility outweighs the benefit of recovering the waste. The mode of transport as well as the distance should be considered. Clearly, the treatment and disposal of waste as near to the source as possible depends on the quantities and types of waste arising on a regional and local level and the location of the facilities. The application of the principle will therefore vary according to the waste concerned, the volume and the potential environmental impact of the method of waste disposal and mode of transport. There also has to be a balance between the proximity principle and economies of scale. In some cases, economies of scale may mean that some specialist recovery or disposal operations may be located far from the point where the waste arises.

Self-sufficiency Principle

The self-sufficiency principle sets out that as far as practically possible, waste should be treated or disposed of within a sensibly defined region where it is produced. Regional Technical Advisory Bodies have been set up in UK to provide specialist advice on options and strategies for dealing with the waste that will need to be managed within each region. The preferred option or strategy will be reflected in the Regional Planning Guidance for local authorities. This is of significance for waste planning authorities as they cannot consider the needs of their own areas in isolation. Waste management options and solutions may sometimes cross-planning areas, as well as regional boundaries. Indeed, in some circumstances, local options for the management of some types of waste may not be available. Planning guidance states that each region should provide facilities with sufficient capacity to manage the quantity of waste that they expect to have to deal with in that area for at least ten years.

Overview of EU C&D waste management

There are increasing restrictions on the disposal of active (mixed) C&D waste in Europe that ought to increase the amount of mono landfills for future recovery. Current mono landfills containing only C&D waste are very limited. Despite a range of Council Directives and Decisions, there is still no common theme. The recent Landfill Directive provides the necessary measures to address the lack of a common theme, and encourages reuse and recycling of components and materials through various means including growing disposal costs. It also calls for a consensus on the types of landfill sites to be inert, hazardous or non-hazardous.

Subsidies to assist this change are few and far between, however a positive response has been witnessed by member states implementing waste management plans. In some member states, these plans have served to set targets and increase levels of reuse and recycling. In others, there is a growing wealth of information available to help them improve performance.

There is increasing use of tools to facilitate change including waste exchanges to transfer reclaimed components, but the network required to market the materials is predominantly patchy. Funding from the EU and member states helps support R&D in new techniques and technologies, and more recently dissemination of established knowledge.

In April 2000 a working document produced by the C&D waste project group described the measurement of the C&D waste stream in member states, and detailed the aims and instruments that are likely to improve C&D waste management. The document also includes a selection of recommendations which member states need to consider when developing their own waste management policies. It is interesting to note that in Scotland, the Scottish Environmental Protection Agency (SEPA) has targeted C&D waste as a priority waste stream and great efforts are being made to minimise and manage this large volume of waste more efficiently and effectively.

Working group on sustainable construction

As one of the fourteen priority actions for improving competitiveness within construction, a Working Group on Sustainable Construction was established in 1999 which included three Task Groups, one of which was TG3 on C&D waste management. The main function of TG3 is to provide a document of recommendations on how to improve C&D waste management through improved planning, prevention and reclamation. One of its main findings was that “optimal separation of C&D waste must take place to maximise recovery of material for reuse and recycling.

The scope of the document focused on the whole construction process including design, pre-construction, construction, demolition, reuse, recycling, final disposal, research and education. Its output was to make recommendations to three core sectors of construction, building on and making use of both the Symonds report and the Priority Waste Stream report. These three core sectors are Industry, Member states and their public authorities, and the European Commission. The recommendations are suitably lengthy and incorporate other requirements of industry and member states that include:

- Waste management plans for C&D waste
- Design for deconstruction, reuse and recycling
- Annual reports
- Appropriate management of hazardous wastes
- Environmental assessments of manufactured materials and products
- Education to the whole supply chain about waste prevention and reclamation
- And many more, relevant recommendations

European waste management plans

Member states are requested to provide waste management plans to facilitate self-sufficiency, reduce movements of waste materials and establish inspections of disposal and reclamation. Reports to the Commission by individual States are submitted every three years, and agglomerated into a single report by the Commission thereafter. Annexes of Waste Categories (Annex I), Disposal Operations (Annex IIA) and Recovery Operations (Annex IIB) are included in the Landfill Directive.

European Waste Catalogue

The European Waste Catalogue (EWC) came into force in January 2002 through an amendment to the Duty of Care regulations. It applies to all wastes in Europe whether for disposal or reclamation, and is a harmonised, non-exhaustive list using common terminology across the Community. However the inclusion of a material in the EWC does not mean that it is a waste, only when the relevant definition is satisfied is it considered waste. The EWC identifies 20 broad categories of waste and over 800 waste types based on the process, giving rise to the waste. It will take effect on August 31st 2002 in the UK under the Landfill Directive regulations where the classifications will replace the simple waste identification system on the Duty of Care transfer note.

Hazardous wastes 91/689/EEC & 94/904/EC

Member states are required to implement controlled management of hazardous waste. These indicate the appropriate means necessary to collect, transport, store and manage hazardous wastes. These are defined in Annexes covering generic types of hazardous waste including pigments, paints, resins, and plasticizers, and properties of waste which render them hazardous including oxidising, harmful, carcinogenic and corrosive substances, as well as substances that yield damaging leachates or ecotoxic risks. In 2001, the hazardous waste list created by EC Decision 94/904/EC was incorporated into the EWC.

Current UK waste management and legislation

UK law

Prior to 1972 there were minimal controls over the disposal of wastes. The Public Health Act 1848 was the first attempt at national legislation in the UK. It was this Act which created the term "Statutory Nuisance" in relation to any accumulation or deposit which was prejudicial to health or a nuisance. The Act enabled local government to take action on behalf of the public. Between 1848 and 1936 a series of Acts were enacted before the consolidating Public Health Act 1936. This Act gave local authorities the powers to police and inspect waste arisings. It also gave authorities the power to remove household and trade waste and to inspect for, and require the removal of, noxious materials.

The Environmental Protection Act 1990

The Environmental Protection Act 1990 (EPA 90) was the culmination of a long period of discussion of amendments to environmental law. The Act covers a wide range of environmental topics, not all of which are relevant to waste management. Part I of the Act introduced the system of Integrated Pollution Control (IPC) which is applicable to the release of pollutants to air, water and land from certain processes, establishing the important new criteria of Best Available Technology Not Entailing Excessive Cost (BATNEEC). Part II of the Act deals specifically with the deposit of waste on land (most waste management activities fall under the provisions of Part II). Many of the provisions of the EPA 90 have been implemented by Regulations made by the Secretary of State for the Environment.

The Environment Act 1995

The Environment Act 1995 established the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA). The creation of the Agencies represented a major step towards truly integrated environmental management and control, as they brought together the regulators responsible for Integrated Pollution Control, water management and waste regulation. The 1995 Act makes numerous amendments to EPA 90 and other environmental statutes. Many of these amendments relate to the powers and duties of the regulators, who now have greater scope to take preventative action when there is a likelihood of pollution.

Scottish National Waste Strategy

In May 2000 the Scottish Environment Protection Agency (SEPA) published the Scottish national waste strategy. It contains proposals for meeting the targets in the Landfill Directive as well as covering wider issues of waste reduction, reclamation and recycling and the planning of waste management facilities. The main objective of the waste strategy is to achieve integrated waste management system and services. The strategy also identifies four priority waste stream projects; newsprint, tyres, future (WEEE etc) and C&D waste. The latter C&D project will require the development of a C&D Waste Action Plan that will reflect three key objectives and tasks:

- comprehensive review of volume and location of C&D waste
- levels of C&D waste reclamation, key players and barriers to reuse
- future management and market development of C&D waste

The Scottish national Waste Strategy is the only Strategy in UK that has focused attention on C&D waste and identified it as a priority area. This will be watched closely by other Nations to see how its successes can be translated into their own Strategies.

Draft Welsh Waste Strategy

The Welsh Assembly aim to introduce by early 2002 a final Wales Waste Strategy to supersede Waste Strategy 2000 for England and Wales. Key policies include a waste elimination led strategy, segregation of waste at source to be encouraged and the development of recycling and composting markets in Wales. It is consulting on the option to set targets for the reuse and recycling of C&D waste. C&D waste was the largest controlled waste stream in 1998/99, in Wales. A consultation paper was issued in July 2001 entitled *Managing Waste Sustainably* by the National Assembly of Wales. It asks the question, should targets be set for the reuse and recycling of C&D waste in Wales in advance of any Directive and at what level should they be set. The final Wales Waste Strategy should be released soon.

Northern Ireland Waste Strategy

The Northern Ireland Waste Management Strategy was issued by the Department of the Environment in 2000 and offers a long-term vision for the future development of waste management practices in Northern Ireland. It also provides the necessary framework required to deliver the strategy. It emphasises the development of local markets for C&D waste and recovered timber, but does not specify a target for these wastes. Similar to the other National Waste Strategies, the Northern Ireland Strategy addresses all waste streams including commercial, industrial, municipal and C&D waste but does not focus sufficiently on C&D waste as it does on municipal waste.

UK Waste Strategy 2000 (England and Wales)

The DETR published a statutory waste strategy for England and Wales in May 2000. This strategy describes the government's vision for managing waste and resources better. It sets out the changes needed to deliver more sustainable development. The strategy stresses that the quantity of waste produced must be tackled by breaking the link between economic growth and increased waste. The main theme of the strategy is 'where waste is created we must increasingly put it to good use – through recycling, composting or using it as a fuel'. The strategy also recognises the need to develop new and stronger markets for recycled materials. To address this, a major new Waste and Resources Action Programme will be set up. This Programme will deliver more recycling and reuse, help develop markets and end-uses for secondary materials, and promote an integrated approach to resource use.

Special Waste Regulations

The Environment Agency (EA) was established in 1995 under the Environment Act. The EA is a regulatory body ensuring that waste management legislation is complied with. If a waste contains a substance that is classed as an irritant at a concentration of 20% or over, it may be classed as a Special Waste. Special Wastes include asbestos, acids and pesticides etc. There are some definitions of the form in which the special waste is present to consider. For example glass fibres are considered an irritant and therefore a special waste, but in the form of glass reinforced plastics (GRP) the EA does not class the material as a special waste.

The current Special Waste Regulations are undergoing a major review, which will simplify some procedures. However, a re-designation of 'special waste' to 'hazardous waste' will reveal more types of waste covered under the new regulations. It is expected that the new regulations will take effect in early 2003 as the Hazardous Waste Regulations. The two Regulations identify all hazardous wastes with those items not currently designated special waste such as fluorescent tubes becoming hazardous wastes when the new regulations take effect.

Sustainable Construction Strategy

The need to reduce waste at all stages of construction was central to the message of *Rethinking Construction* the 1998 report of the Construction Task Force on the scope for improving the quality and efficiency of UK construction. Improving the efficiency of the construction industry is a key objective for the Government, as set out in its strategy for more sustainable construction ‘Building a Better Quality of Life’. The strategy published in April 2000, identifies priority areas for action, and suggests indicators and targets to measure progress. It sets out action that the Government has already taken, further initiatives that are planned, and highlighted what others can do. The Government will use the strategy as a framework to guide its policies towards construction, and will encourage people involved in construction to do the same.

The sustainable construction strategy emphasises the importance of reducing waste at all stages of construction by focusing on the need to consider long term impacts of design, construction and disposal decisions so that materials and other resource use is optimised. The strategy encourages the industry (including clients) to consider refurbishment or renovation as an alternative to new buildings and structures. It highlights the need to avoid over-specification in materials and the scope for standardisation of components.

EU Directives already adopted into UK legislation relevant to deconstruction

European lists and tests

Annex II of the Landfill Directive requires that a uniform waste classification and acceptance procedure was to be completed by April 2001. This is still ongoing, but interim leachability limits have been set and awaiting the final criteria from the Technical Adaptation Committee (TAC). The TAC effectively decides whether a waste can be disposed of in an inert, hazardous or non-hazardous landfill. In the interim, preliminary waste acceptance procedures are used to separate inert, hazardous and non-hazardous wastes into groups. Eventually this uniform European list will assist member states to define national lists that individual landfills will use to define site-specific lists. A three-level hierarchy to characterise and test wastes will also be required to validate that waste entering a landfill meets these lists. This hierarchy will include an initial test, an annual test and an at-the-gate test for all loads. It is early days in the development of these lists and tests and there is much scope to influence the final outcome.

Directive on Environmental Liability

The European Commission (EC) has been considering the introduction of a Community-wide scheme of environmental liability since 1989, following a draft Directive issued on civil liability for damage caused by waste. This Directive on Environmental Liability was finally adopted by the EC in January 2002, following a White Paper issued in February 2000 and a Working paper on the likely approach in July 2001. The proposals are aimed at the prevention and remedying of environmental damage to water, land and biodiversity. The regime would be based on the principle that the polluter should bear the cost of damage they cause to the environment, or of measures to prevent imminent threat of damage.

The Landfill Directive 99/31/EC

The Landfill Directive was adopted by UK in 2002 and will be introduced in July 2004. The Directive defines three classes of landfills: hazardous, non-hazardous and inert waste, basically banning co-disposal of waste that is currently a common form of practice in UK. The following wastes will be banned from landfill:

- explosive, oxidising or flammable wastes
- infectious clinical waste
- tyres (whether whole or shredded)
- liquid wastes, except those suitable for disposal at an inert waste site.

The aim of the Directive is to provide measures, procedures and guidance to prevent or reduce negative effects to the global environment and all its cycles from landfilling of waste during the whole lifecycle of the landfill site. All waste except for inert waste is to be pre-treated before landfilling. The Environment Agency (EA) is currently consulting on definition and application of pre-treatment. It is expected that by mid 2007 at the latest, no waste will be able to be collected and taken to landfill without some weight reduction being applied through source segregation or sorting at a waste transfer station. The Directive states that hazardous waste may only be landfilled in a hazardous waste site and therefore rules out co-disposal which must cease by 2004 at hazardous waste sites. There are some exceptions, for example asbestos can be disposed in a licensed non-hazardous landfill provided that it is contained in a separate cell.

The Landfill Directive will require a greater proportion of wastes to undergo some form of waste pre-treatment involving mechanical waste separation and sorting procedures followed by composting, anaerobic digestion, thermal treatment and other processes. The time-scale for the introduction of some of the necessary changes in treatment capacities is relatively short. Treatment applies to new landfills from July 2001, landfills classed to receive hazardous waste from July 1004 and all others by July 2009.

Incineration of Waste Directive

The aim of this directive is to prevent or limit the negative effect on the environment and resulting risks to human health from the incineration and co-incineration of all types of waste. Limits are set concerning levels of emissions to air, water and soil. Residues from the incineration process will be minimised in their amount and harmfulness and recycled where appropriate. The directive has to be transposed into national legislation by December 2002 and will apply to all new installations thereafter. It will also apply to all existing installations from December 2005.

All incineration processes should comply with the Incineration of Waste Directive. An operator dealing with demolition waste would have to ensure that the material was burnt properly without exceeding any of the set pollution limits. Should demolition waste be sent to a Municipal Waste Incinerator (MWI) then it would probably need to be well mixed with other waste to ensure operation within the combustion envelope of the incinerator and to prevent emissions that may swamp the pollution abatement system.

At present, the apparent environmental benefits of energy recovery by burning plastic in a waste incinerator are likely to be outweighed by significant disbenefits. Burning plastic waste limits the amount of biodegradable household waste such as paper and cardboard that can be processed. This means that more biodegradable waste goes to landfill, where it breaks down to form methane and carbon dioxide. Although much of the methane can be collected and used as fuel, a large proportion escapes into the atmosphere. Methane is known to be about 25 times more potent as a greenhouse gas than carbon dioxide. Unless plastic waste is burnt as a direct replacement for oil or gas, the environmental effects are negative.

Electrical and Electronic Equipment Directives

There are three EU directives in preparation concerning the management of electrical and electronic equipment:

Waste Electrical and Electronic Equipment (WEEE) Directive - This directive focuses on the management of waste electrical and electronic equipment (WEEE) and sets out measures for collecting end-of-life electrical and electronic equipment for recovery, recycling and reuse. The objectives of the WEEE directive are the prevention of WEEE, and increasing the reuse, recycling and other forms of recovery of WEEE in order to reduce the disposal of waste and encourage resource efficiency. It also aims to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, particularly those involved in the treatment of WEEE. The directive proposes recovery targets of between 70% and 80% by an average weight per appliance and reuse and recycling targets of 50 to 75% depending on the category of the WEEE. The targets are due to be reviewed five years after the directive comes into force in 2002, with implementation in the UK 18 months later.

Restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) Directive - This was originally intended to form part of the WEEE directive but has now been made into a separate directive. The main objectives are to protect soil, water and air from pollution caused by the current management of WEEE, and to reduce the harmfulness of WEEE[12]. The environmental risks associated with the waste stream are not properly dealt with by current waste management practice. The directive states that by 1 January 2008 new electrical and electronic equipment put on the market must not contain lead, mercury, cadmium, hexavalent chromium, or brominated flame-retardants. The RoHS directive is expected to become law in 2002 with implementation in the UK 18 months later.

Electrical and Electronic Equipment (EEE) Directive - The proposal for a directive on the impact on the environment of electrical and electronic equipment (EEE) is only at an early draft stage with a draft working paper released in February 2001. This proposed directive focuses on the original electrical and electronic equipment rather than the waste. It aims to minimise the impact of electrical products over their whole life cycle, making them eco-friendly in their design, production, use and end-of-life disposal. This working paper sets out manufacturing and design requirements that have to be followed for products that are to be sold in the EU. Manufacturers of EEE will have to perform an assessment of the environmental impact of a product throughout its lifecycle, and use this to design the product with an optimal balance between environmental and other factors. The result of the analysis will be an ecological profile of the product describing the significant environmental impacts, prioritising those which can be influenced through product design.

Nearly one million tonnes of WEEE are discarded every year in the UK. Due to their hazardous material content, electrical and electronic equipment can cause environmental problems during the waste management phase if not properly pre-treated. Current data on the recycling of WEEE suggests that about 49% by weight of all WEEE is sent to a recycling process.

Proposed recommendations for construction and demolition waste

The European Commission wishes to introduce a recommendation (a non binding measure) for C&D waste with the aim of improving the management of the C&D waste stream by following the waste hierarchy, giving preference to prevention over reuse, material recycling, energy extraction and lastly disposal. It will aim to reduce the impact of C&D waste on the environment whilst better utilising natural resources.

The recommendation will also encourage the substitution of hazardous substances in new buildings and make sure that waste from construction (bricks, glass, wood etc) is sorted at the point of generation. It would also include proposals for recycling targets set initially at 50 to 70% by 2005 and an increase in landfill charges. It is thought that the European Parliament would prefer binding legislation rather then just a recommendation. So far progress has been very slow. If adopted, this recommendation / legislation will have a significant impact on the demolition industry which supplies the construction sector.

9. Barriers and Opportunities for Deconstruction

Introduction

There are a number of areas where the Government may influence design and planning strategies at an early stage. These include fiscal incentives such as the maintenance of a fixed price for recovered steel products or increased costs for waste disposal through the landfill tax. Incorporation of deconstruction techniques into material specifications and design codes on both a National and European level would focus the minds of designers and manufacturers. Education of the long-term benefits of deconstruction techniques for regulators and major clients would provide the necessary incentive for the initial feasibility stage. Design for deconstruction is not, however, solely an issue for the designers of buildings. The development of suitable tools for the safe and economic removal of structural elements is an essential pre-requisite of the more widespread adoption of deconstruction.

A recent study by BRE has shown what the industry has known for decades; that there are key factors that affect the choice of the demolition method and particular barriers to reuse and recycling of components and materials of the structures. For the former, most factors are physical in terms of the nature and design of the building along with external factors such as time and safety. Future factors to consider may well include the fate of the components, the culture of the demolition contractor and the ‘true cost’ of the process. For the latter, barriers to uptake include the perception of planners and developers, time and money, availability of quality information about the structure, prohibitively expensive health and safety measures, infrastructure, markets quality of components, codes and standards, location, client perception and risk.

The demolition industry is already very knowledgeable about recycling components of a building which have a fiscal value. The market for these items is very competitive and the demand and supply for the different items is constantly changing. This makes it very difficult for the demolition companies to plan and budget in advance. A more stable market and perhaps a guaranteed minimum price for each type of component would aid greatly in this process. The main barriers in the UK to the increased use of deconstruction methods within construction include:

- Lack of information, skills and tools on how to both deconstruct and design for deconstruction.
- Lack of a large enough established market for deconstructed products. A similar scheme to the BRE’s Materials Information Exchange would assist this.
- Lack of design. Products are not designed with deconstruction in mind.
- Reluctance of manufactures, which always prefer you to purchase a new product rather than to reuse an existing one.
- Composite products. Many modern products are composites which can lead to contamination if not properly deconstructed or handled.
- Legal obstacles. Allocation of risk and responsibility has to be considered when using ‘second-hand’ components. Adequate factors of safety and certification also have to be considered.
- Joints between components are often designed to be hidden (and therefore inaccessible) and permanent.

The main opportunities which require development include:

- The design of joints to facilitate deconstruction.
- The development of methodologies to assess, test and certify deconstructed elements for strength and durability etc.
- The development of techniques for reusing such elements.
- The identification of demonstration projects to illustrate the potential of the different methods.

The greatest benefit will be achieved by incorporating deconstruction issues into the design and feasibility stage for all new construction. Each case can then be judged on its merits in terms of the potential cost of recovery and recycling or reclamation and reuse of steel construction materials.

Opportunities for steel deconstruction

The demolition industry is already adept at recovering and recycling steel materials even where they are used with other construction materials such as concrete. The increased use of light gauge steel for industrial, commercial and residential use provides the potential to increase the quantity of structural members that can be reused. For key steel products, beam sections and column sections can be reused where it is economically viable to remove the members without causing significant damage to the connected ends. The lighter gauge steel units such as metal floor decking or floor joists are in general easier to remove without causing too much damage because they are often screw fixed as opposed to being bolted.

Certain areas of the steel construction industry are more amenable to design for deconstruction than others. The increased use of pre-fabrication in the light gauge steel frame industry is one area where deconstruction techniques could be readily adopted. The increased use of modular construction and pre-fabricated wall and floor units mean that it is both practical and economically feasible to either re-site an existing building or use the components in a new building.

Barriers to steel deconstruction

The obstacles to deconstruction are considerable. They include economic, technical, logistic and social factors. Given the current market for steel products and the relatively low cost of the material these obstacles can only truly be overcome by thinking about reuse at the initial design phase. Certain types of connections such as fin plates or cleats would be more amenable to reclamation and reuse than larger more rigid connections such as welded joints or large end plate connections.

Reuse of steel members will have an impact on the working conditions for demolition contractors. In particular there will be health and safety implications in working close to connections between beams and columns. There are technical difficulties in removing individual sections where steel is used in conjunction with other materials. This is particularly significant in composite steel-concrete construction where the beams are connected both to the supporting columns and to the floor slab. The separation of profiled steel decking from the underside of the concrete floor slab is a difficult operation although evidence from fire tests suggests debonding occurs at high temperatures.

Contamination may prove to be a significant barrier to reuse. The use of spayed products for fire protection may mean that removal and disposal of potentially hazardous materials may make deconstruction uneconomic. Corrosion of existing structural sections may also provide a significant barrier to reuse. Although members may be perfectly capable of fulfilling the design function in terms of strength and stability the measures required to provide an aesthetically pleasing finish might prove uneconomic.

Opportunities for timber deconstruction

There are many timber products used in buildings that if deconstructed could be reused in new build or renovation with little modification required. For example large timber beams, railway sleepers, timber doors, flooring and windows are all currently reused to some degree through the salvage industry. The common link between these products is the high quality of timber or high value of the product which ensure profitability for relatively low volumes of re-sale. Products that may have sufficiently high re-sale value and quality for a reuse strategy include:

- Timber framed walls
- Trussed rafters
- Traditional cut purlins and rafters
- Internal doors
- External doors
- Floor and ceiling joists
- Floor coverings
- Garden structures
- Windows
- Large timber structures

Since weathering or damage incurred during deconstruction may be undesirable for re-sale, some products may require re-processing:

- Tiling battens
- Floorboards
- Fencing
- Garden structures
- Cladding
- Fixtures and fittings

Although reuse of waste timber may not be economically viable at the moment, increasing the value of timber components and making them more suited to deconstruction may help reduce the amount of timber waste in the future. There are already timber components on the market that help to achieve this such as:

- metal webbed beams
- I-beams
- laminated veneer lumber (LVL)
- other glue laminated timber products

These products have superior performance to ordinary structural timber and some have greatly reduced sensitivity to damage during installation due to the provision of holes for services to pass through. Their increased product value and reduced damage through the construction process improve their suitability for deconstruction with minimal reprocessing. Encouraging more value added timber products in construction will help to ensure that future deconstruction practices are economically viable.

Barriers to timber deconstruction

Deconstruction for reuse is a very laudable philosophy for reducing the life cycle impact of the built environment although it is still a very immature practice. Many of the barriers to its uptake have not yet been addressed in the timber and construction industry despite fiscal measures such as the landfill tax. Although timber is readily chipped for recycling or burnt for energy production, there are still large amounts of timber being sent to landfill. This has to be a problem of material segregation. Without fiscal measures to increase the segregation of timber from other waste materials, recycling and reuse strategies cannot be implemented. The impending Landfill Directive may go some way to alleviate this by imposing source segregation prior to landfill.

Technologies and techniques for deconstructing timber structures, structural elements and joinery need to be improved to improve the cost of this activity and improve safety levels for operatives particularly for manual handling. One key technology that needs developing is the automated removal of nails and screws. Other ‘bolt-on’ technology may also be required for reprocessing reclaimed timber such as:

- metal detectors for grading machines to avoid damage to rollers
- automated finger jointing and laminating machines to produce standard sizes of reused timber of any length.
- automated sorting of waste timber into different section size categories using 3D laser scanning.

Once the timber waste has been converted through reprocessing into high value structural timber it will require re-grading. Grading rules for reused timber are not currently available and will need to be established, as described previously, for use of this timber resource.

Opportunities for concrete deconstruction

Some of these concrete products are already sometimes reused, such as:

- Kerbs and flags
- Vehicle safety/crash barriers
- Lintels Sills & Copings

- Paving slabs and blocks
- Roof Tiles
- Garden Products
- Tunnel Linings

Of the *key concrete products*, masonry blocks, paving slabs and roof tiles all offer excellent opportunities for deconstruction and reuse. The opportunity for reusing pipework is small, the major problem being the cost of excavating and recovering the pipework. It is possible to recover and reuse flooring units, depending on the type of fixing and jointing used- if an in-situ joint is used then the potential is low. However, whatever physical or practical opportunity exists it will only be exploited if there is an economic gain for doing so, which is the main barrier at the present time for the deconstruction of concrete products.

Barriers to concrete deconstruction

The main barrier to more concrete products being deconstructed and reused is an economic one. No matter what the practical or physical possibilities and opportunities that exist, it still has to economic for the individual or organisation involved to deconstruct and reuse the component. Additional problems with concrete products are dimensional (most UK structures are one-off bespoke designs), physical, or practical.

The concrete products with the main share of the market (masonry blocks, paving slabs and blocks and roof tiles) require no alteration to their design, just an economic market for their reuse. Some other concrete products need just a small design alteration to enable them to be deconstructable and reusable, but a market for them would still be required for it to be economic to do so.

These problems can all be overcome with adequate research and development and the production of sufficient guidance, standards and where necessary, legislation.

Many products can never be reused in their original form (for various reasons) such as:

- Foundation Units & Piles (virtually impossible to remove from the ground)
- Pipes and associated products (as above)
- Bridge Beams & Gantries (dimensional, safety/risk and jointing problems)
- Frames, Beams & Columns (as above)
- Multi-storey car parks (as above)

One major barrier is a dimensional one. Most orders for structural units (beams, columns etc) are for one-off bespoke structures with unique dimensions. Therefore the components have to be specially made for that particular structure and will not dimensionally fit a different structure, unless the new structure has been designed with this in mind which is rare, if not non-existent.

Other *physical* barriers include (depending upon the type of concrete product):

- Pre- and post-tensioning beam/floors- dangerous to de-stress
- Joints often mortared or glued or tied together with reinforcement
- Blockwork is usually mortared together, which therefore requires cleaning
- Concrete ages naturally due to- carbonation, weathering, colour change, cracking and chemical effects (such as sulphate attack, ASR and DEF)
- Reinforcement corrosion can occur
- Coatings (either cosmetic or protective) can deteriorate due to ageing, weathering and mishandling

Other *practical* barriers include (depending upon the product):

- Lack of information, skills and tools exist on how to both deconstruct and design for deconstruction
- Lack of big enough established market for deconstructed concrete products
- Lack of design- products not designed with deconstruction in mind, generally designed to last a 'lifetime'
- Reluctance of manufactures- always prefer you to purchase a new product
- Composite products- many modern products are composites which can lead to contamination if not properly deconstructed/handled
- Legal obstacles- allocation of risk and responsibility when using 'second-hand' components, factors of safety
- Joints between components are often inaccessible

Barriers to masonry deconstruction

Many barriers have already been mentioned above. The cost of time it takes to take down bricks by hand and stack and clean them for reuse is enormous. Thankfully for traditional bricks, tiles and slates there is a market for this. The only barrier apart from cost to the traditional building being deconstructed is where modern repairs have been done and cement mortar used or other contaminant materials, such as glues or modern building materials. The main barrier to deconstruction of modern building is the method of construction. Cement mortar cannot be cleaned off bricks and blocks so if they are to be deconstructed at all their use can only be aggregate.

Survey results on General opportunities and barriers

The following information was collated as part of University of Sheffield PhD research[2] from in-depth exploratory interviews with demolition experts. These experts were members of the NFDC, IDE, UK Research Organisations, and private consultants. Through interviews, knowledge and opinions where sought about the current state of the industry and potential design changes that would help increase the reuse and recycling potential of buildings, their components and materials. The conclusions of this in depth study are presented below.

Perception

Demolition is in fact the start not the end of most building projects, particularly on inner city or brownfield sites. As such it needs to be fully integrated with the future works program, not as it often seems, perceived as an obstacle to be quickly overcome before building can commence. When presented with a brief to design a building, most architects start with the visualisation of a clear site and end with the newly constructed building. If reuse and recycling is to be encouraged there is a pressing need to change this approach and include the demolition phase. Projects should start with the demolition phase and consider its incorporation into the new building and end with the potential for the components of this building to be included within the next redevelopment.

Time and money

Time is inextricably linked to money, both in terms of that allowed for the demolition contract as a whole and as the deciding factor as to any material's fate. No time to dismantle reuseable materials simply means no materials for reuse. Due to developer pressure the main emphasis is now on demolishing in as speedily as is safely possible. As such demolition contracts have generally reduced from six months to six weeks duration. If more time was available then reuse and recycling might increase but the bottom line is economic; labour is expensive and new products are now cheap. In some isolated cases demolition firms have offered two very different tender fees, the difference being due to recycling. The first for say a million pounds and down in six weeks and the second for a hundred thousand pounds and down in six months with the demolition contractor making up the difference from salvaging as many components and materials as possible.

Information

All interviewees suggested that information should be more prominent. The emphasis here being on the quality not quantity of information available to the demolition contractor. This should include:

- As built drawing records
- Records of all changes to the building
- Asset registers showing what is in the building and its recycling potential
- Identification of potentially hazardous materials
- Details of prefabricated components plus fixing and carrying points
- Labelling of materials.

CDM regulations are starting to improve this situation. We live in a society that is increasingly geared towards and driven by information and this is equally relevant to the building profession. Quality information can speed up both the pre-tender and main demolition contract, and allow pre-determination of waste and recycling routes.

Demolition experts' opinions

The following points summarise demolition experts' opinion on specific issues regarding their activities. The points reflect a consensus of opinion.

Health & Safety

Health and safety legislation is becoming tighter all the time. It has resulted in safety standards being raised across the industry but possibly has had a detrimental effect on reuse and recycling as working practices become more restricted. Working at height or in dangerous places, removing slates from a roof for example now requires full scaffolding and boarding out. This is prohibitively expensive and so most contractors would try and use more remote methods which usually imply less separation and selection of individual materials resulting in reduced amounts reclaimed.

Landfill tax

The landfill tax has had a mixed response within the industry. Initially its implementation caused contracts to stall as those involved worked out who was to pay. The price differential between inert and non-inert waste has encouraged some additional reuse and recycling, with any extra costs being on the whole passed on to the client. The EU report proposes that relying solely on landfill tax or primary aggregate tax would not achieve high recycling rates. It reasons that the taxes would have to be set at politically unacceptable levels before they changed the behaviour of building professionals, particularly in areas with easy access to landfills or quarries.

Barriers to reuse and recycling

All interviewee's identified a number of barriers to reuse and recycling, these are summarised below.

Legislation & regulation

As discussed above legislation & regulation is not only pressurising the demolition phase of a contract it also appears to be currently inhibiting the amount of material reused or recycled.

Infrastructure, markets, quality & standards

Due to the lack of infrastructure, fluctuating share prices and inconsistent quality of reclaimed components and recycled materials, contractors are wary of utilising them and customers are dubious about buying them. The main issues of reclaimed components and recycled materials include:

- *Perception*. Willingness of client, public etc to accept them
- *Quality*. Reliability, safety and liability in event of failure
- *Quantity*. Insufficient quantity, intermittent supply and unreliable markets.
- *Standards*. The construction industry is traditionally 'conservative' in nature, and has a tendency only to use specifications that have been tried and tested over considerable periods of time. For the use of reclaimed components and recycled materials to increase, there is a need to develop performance-based specifications 'fit for use or purpose'. This places emphasis on identification of the properties and qualities required of materials appropriate to intended use.
- *Definition of Waste*. There must be a redefinition of the term Waste. Many components and materials which nobody intended to discard and which require little or no processing before reuse are being treated by Regulators as waste.

Location

The location of a site affects the demolition contract in a significant way. It basically controls the type of demolition carried out. For inner city or urban sites full protection from the surrounding area must be provided. Strict site operation times, noise, dust, space and transportation guidelines will be placed on the contractor. This usually results in a more controlled, slower demolition but one in which the time considerations are paramount and space on site is at a premium.

Client perception and risk

The perception of demolition as a public nuisance does not help the image of recycling. Clients, in an effort to minimise adverse publicity, will usually desire the demolition phase to be as rapid as possible. For the positive perception of reuse and recycling to grow the benefits need to be sold to the client, perhaps through green marketing.

Particular problem elements

Complex designs, the lack of foresight as to the eventual demolition, the bonding of dissimilar materials and contamination of waste streams are the main issues e.g.:

- Buildings with pre-stressed and post tensioned beams, cantilevers and undercrofts have all recently been demolished. In all these cases the demolition process was more onerous due to the presence of these complex structural components.
- Composite materials, loose and bonded insulation particularly in permanent shuttering, cladding panels and large glass curtain walling all make the demolition task more difficult.
- Polystyrene boards used in foundations and to provide the voids in hollowcore concrete beams and floor units make recycling the concrete very arduous (in the past the voids where formed using bags filled with air).
- Steel and concrete present no particular problems, and they also have well-established reuse or recycling loops. However contamination in concrete is an issue. Steel mixed with concrete is easily separable with magnets but the likes of timber must be separated first, as it is impossible to do this after crushing as the timber splinters.
- Fire cladding if bonded to the steel makes it more difficult to isolate, most contractors preferring the more jacket types of fire cladding.
- Asbestos and asbestos cement components and lagging need to be removed from structures prior to demolition and treated accordingly as special wastes.

- Components and materials that have been contaminated above acceptable level need to be removed prior to demolition, stored separately and then decontaminated before reuse, recycling or landfill. Alternately treated accordingly as hazardous wastes.

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IP 14/98	Blocks with recycled aggregate: beam and block flooring
IP 7/00	Reclamation and recycling of building materials
Digest 447	Waste minimisation on a construction site
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REPORT 10
DECONSTRUCTION AND MATERIALS REUSE IN THE UNITED STATES

By A. R. Chini and S. F. Bruening

Abstract: The demolition of buildings produces enormous amounts of debris that in most countries results in a significant portion of the total municipal waste stream. Deconstruction – the systematic disassembly of buildings in order to maximize recovered materials reuse and recycling - is emerging as an alternative to demolition around the world. While the process of demolition often leads to the mixing of various materials and contamination of non-hazardous components, deconstruction is actually the source separation of materials. This paper will present an overview of the issues of deconstruction and materials reuse in the United States. The issues covered will include waste impact of the construction industry, deconstruction tools and techniques, economics of deconstruction and marketing of used building materials, materials reuse businesses, and barriers to deconstruction.

Keywords: Construction and Demolition Waste; Deconstruction; Landfilling; Materials Reuse; Repair; Sustainable Development

1.0 INTRODUCTION

The demolition of building structures produces enormous amounts of materials that in most countries results in a significant waste stream. In the U.S., construction and demolition (C&D) waste is about 143 million metric tonnes (MMT) annually that is for the most part landfilled. Deconstruction may be defined as the disassembly of structures for the purpose of reusing components and building materials. The primary intent is to divert the maximum amount of building materials from the waste stream. Top priority is placed on the direct reuse of materials in new or existing structures. Immediate reuse allows the materials to retain their current economic value

Deconstruction of buildings has several advantages over conventional demolition and is also faced with several challenges. The advantages are an increased diversion rate of demolition debris from landfills; "sustainable" economic development through reuse and recycling; potential reuse of building components; increased ease of materials recycling; and enhanced environmental protection, both locally and globally. Deconstruction preserves the invested embodied energy of materials, thus substituting recovered existing materials for the input of embodied energy in the harvesting and manufacturing of new materials.

The challenges faced by deconstruction are significant but readily overcome if changes in design and policy occur. These challenges include: existing buildings have not been designed for dismantling; building components have not been designed for disassembly; tools for deconstructing existing buildings often do not exist; disposal costs for demolition waste are frequently low; dismantling of buildings requires additional time; building codes and materials standards often do not address the reuse of building components; unknown cost factors in the deconstruction process; lack of a broad industry identity with commensurate standardized practices; buildings built before the mid-1970's with lead-based paint and asbestos containing materials; and the economic and environmental benefits that are not well-established.

Generally the main problem facing deconstruction today is the fact that architects and builders of the past visualized their creations as being permanent and did not make provisions for their future disassembly. Consequently, techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at institutions around the world, and government policy is beginning to address the advantages of deconstruction by increasing disposal costs or in some cases, forbidding the disposal of otherwise useful materials. Designing buildings to build for ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. The objective of this paper is to provide information about building deconstruction and materials reuse programs in the United States.

1.1 Waste Impact Of The Construction Industry

The construction industry contributes an incredibly large amount of waste to the municipal solid waste stream (MSW) in the United States each year. Quantifying This annual waste production is an inexact science. To date, the most thorough attempt to estimate the total tonnage of Construction and Demolition (C&D) debris was made by Franklin Associates of Prairie Village, Kansas. Their work, titled *Characterization of Building-Related Construction and Demolition Debris in the United States*, was developed for the EPA in 1998 and produced a reasonable estimation of tonnage of waste generated through residential and non-residential demolition, renovation and construction for the year 1996. The following work is an estimation of the tons of debris produced during the year 2000. The techniques used to derive these numbers are the same as those used in the Franklin Associates report. The numbers utilize easily accessible U.S. Census information for the year 2000 combined with research statistics taken directly from the Franklin Associates Report (1998).

Estimated Generation of New Residential Construction Debris

The techniques used to estimate the amount of debris generated per year by the residential construction industry are as follows:

1. Estimate the total dollars of new residential construction put in place during the year 2000:

This value was found by adding the total value of Private New Housing Units to Public Housing and Redevelopment (Current Construction Reports C-30, 2002).

Private New Housing Units	\$265,047 million
Public Housing and Redevelopment	\$ 4,308 million

2. Estimate the average cost of residential construction per square foot for the year 2000:

This number was found by dividing the total value of residential construction put in place by the total sq. ft. of new construction put in place. The most current values obtained for these variables were for the year 1998. To adjust the 1998 numbers to 2000, the values were projected from 1988 to 1998 to 2000 proportionately (Construction and Housing, 2002).

	1988		1998		2000
Value (billion \$)	116.2	(48%)	173	(9.6%)	188.6
Total Mill. Sq. Ft.	2,181	(33%)	2,902	(6.6%)	3093

The percentages in the first column were given numbers and the numbers in the second column were in extrapolation based on a two year interval, rather than the ten year interval.

Value of Construction put in place (million \$) / Total Square Feet of Construction put in place (2000) = *188,600/3,093 = \$61/ft^2 (\$675/m^2)*

3. Estimate the Total Square Feet of New Construction for the year 2000

This number is found by dividing the Total Dollars of new residential construction from the first problem (\$269.355 billion) and dividing it by the estimated cost per square foot of residential construction (\$61/sq. ft.)
\$269.355 / \$61/sq.ft. = 4.416 billion ft^2 (410 million m^2)

4. Estimate the average residential construction waste generation per square foot

The Franklin Associates report uses *4.38 lb/ft^2 (21.5 Kg/m^2)* of waste generation in their calculations. This number coincides with recent reports that a 2000 square foot (187 m^2) house produces 8000 lbs (3630 Kg) of debris so this number was kept for calculations.

5. Calculate total generation of debris by the residential construction industry for 2000

This number is found by multiplying the total square feet of new construction by the debris generation per square foot and dividing that number by 2000 to get tons.

(4,416 x 4.38) / 2000 = 9.67 million tons (8.8 MMT) of debris generation (2000)

Estimated Generation of New Non-Residential Construction Debris

The techniques used to estimate the debris generated per year by the non-residential construction industry are as follows:

1. Estimate the total dollars of new non-residential construction put in place during the year 2000

This value was found by adding the total values of private non-residential construction, public industrial, public educational, public hospital, and public other (Current Construction Reports C-30, 2002).

	(2000)
Private Non-Residential	$208,241 million
Public Industrial	$ 1,157 million
Public Educational	$ 49,814 million
Public Hospital	$ 4,135 million
Public Other	$ 29,151 million
	$292,498 million

2. Estimate the average cost of non-residential construction per square foot for the year 2000

This value was found by dividing the total value of non-residential construction put in place by the total square feet of new non-residential construction put in place. The most current value obtained for these variables were for the year 1998. To adjust the 1998 numbers to 2000, the values from 1988 to 1998 to 2000 were projected proportionately. (Construction and Housing, 2002)

	1988		1998		2000
Value (billion $)	97.9	(37%)	134	(7.4%)	143.9
Total (Million sq. ft.)	1,413	(12%)	1,581	(2.4%)	1,619

Value of construction put in place / Total square feet of construction put in place (2000) = *143.9 / 1.619 = $88.88/ft^2 ($958/m^2)*

3. Estimate the total square feet of new non-residential construction for the year 2000

This number is found by dividing the Total Dollars of new non-residential construction from item no. 1 above ($292,498 million) and dividing it by the estimated cost per square foot of non-residential construction ($88.88/ft^2)

$292.498/ $88.88/ft² = 3.29 billion ft² (305 million m²)

4. Estimate the average non-residential construction waste generation

For the purpose of this paper, the Franklin Associates estimation of *4.02 lbs/ft² (19.6 Kg/m²)* was used.

5. Calculate total generation of debris by the non-residential construction industry for 2000

This number is found by multiplying the total square feet of new non-residential construction by the debris generation per square foot and dividing the number by 2000 to get tons.

(3,290 x 4.02) / 2000 = 6.614 million tons (6 MMT) for the year 2000

Estimated Generation of Residential Renovation Debris

The techniques used to estimate the amount of debris generated per year by the residential renovation industry are as follows:

1. Estimate the total dollars spent on improvements and repairs for the year 2000

This value was obtained by adding the amount spent on improvements for the year 2000 to the amount on repairs (Expenditures for Improvement and Repairs, 2002).

Improvements	$110,739 million
Repairs	$ 42,236 million
	$152,975 million

2. The Franklin Associates report provides the following estimates in their report for the year 1996

Estimates for Remodeling	**Million jobs**	**Tons/job**	**Million Tons**
kitchens (minor)	1.25	0.75	0.937
kitchens (major)	1.25	4.50	5.625
baths (minor)	1.80	0.25	0.450
baths (major)	1.20	1.00	1.200
additions	1.25	0.75	0.938

Replacements	
Concrete from driveway replacements	13.000 tons/year
Asphalt roofs	6.800
Wood roofs	1.400
Heating and A/C replacements	1.574
Kitchen remodeling	6.562

Bathroom remodeling	1.650
Additions	0.938

3. Estimate the percent increase in debris generation from 1996 to 2000

Because of the lack of available information regarding this subject, the information available was used and extrapolated using a price conversion factor from 1996 to 2000 to calculate a plausible inflation percentage to apply. This begins with a price index conversion factor from 2000 dollars to 1996 dollars: Conversion Factor = 0.886.

This conversion factor can be used to compute how much the expenditures in 2000 ($152,975 million) would be equivalent to in 1996: 1996 expenditures = 0.886 x $152,975 = $135,537 million.

The actual expenditures in 1996 on renovations was $114,300 million. Using the value that the 2000 expenditures would equate to in 1996 and the actual expenditures for 1996, we can obtain an approximate percentage increase in the amount on renovation. This percent increase could be applied to the number of jobs and thus the amount of waste generation.

($135,537 - $114,300) / $114,300 = 18.6%

4. Apply the increase to the jobs and tonnage provided in the Franklin Associates report

	1996	2000
Concrete from Driveway Repl.	13.000 (18.6%)	15.418
Asphalt Roofs	6.800 (18.6%)	8.065
Wood Roofs	1.400 (18.6%)	1.660
Heating and A/C Repl.	1.574 (18.6%)	1.867
Kitchen Remodeling	6.562 (18.6%)	7.783
Bathroom Remodeling	1.650 (18.6%)	1.957
Additions	0.938 (18.6%)	1.112
TOTAL	*31,924 million tons*	*37.862 tons (34.5 MMT)*

Estimated Generation of Non-Residential Renovation Debris

The techniques used to estimate the amount of debris generated per year by the non-residential renovation industry are as follows:

1. Estimate the total dollars spent on non-residential improvements and repairs during the year 2000

This value was found by interpreting the proportion of dollars spent on non-residential renovation to dollars spent on residential renovation to be the same for the year 2000 that it was in 1996. The Franklin Associates report assumed this proportion to remain constant enough to use it for 1996, so it will also be used in this calculation:

($100,400 / $114,300) x $152,975 = $134,372 million

	1996	2000
Non-Residential renovation	$100,400	$134,372
Residential renovation	$114,300	$152,975
TOTAL	$214,700 million	$287,347 million

In following with the methodology of the Franklin Associates report, the amount of debris produced in non-residential renovation will be assumed to be directly proportional to the amount produced in residential renovation. Because the amount spent on non-residential renovation was approximately 87.8% ($134,372/$152,975) of that spent on residential renovation, it will be assumed that the amount of waste produced in non-residential renovation is also 87.8% of that produced in residential renovation.

(0.878 x 37.862) = 33.243 million tons (30.218 MMT)

Estimated Generation of Residential and Non-Residential Demolition Debris

In their work for the EPA, *Characterization of Building-Related Construction and Demolition Debris in the United States*, Franklin and Associates estimated that approximately 245,000 residential building and 45,000 non-residential buildings were demolished in 1996. The numbers were computed by averaging the available U.S. Census numbers from the years 1984 to 1995. Because U.S. Census demolition statistics were discontinued as of 1995, it is not currently possible to calculate a reasonable national approximation of demolition statistics.

For the purposes of estimating annual waste for the year 2000, the same numbers were used for residential and non-residential demolition debris as those used in the Franklin Associates report. The first reason for doing this was the aforementioned lack of current demolition statistics. Additionally, because the Franklin Associates used an average of the years1984 to 1995 for their 1996 estimate, they assumed that there is not an upward trend associated with time in the number of demolitions taking place. If there is, it is quite possible that it would be offset by the rise in environmental awareness and tipping fees during that time. Thus, the following estimation of residential and non-residential demolition debris is taken directly from the Franklin Associates report.

Residential Demolition Debris	
Number of demolitions (2000)	245,000
Average size of demolished residence	1396 ft^2
Estimated waste generation per foot	115 lb/ ft^2
Total	*19.7 million tons (17.9 MMT)*

Non-Residential Demolition Debris

Number of demolitions (2000)	45,000
Average size of demolished residence	13,299 ft^2
Estimated waste generation per foot	173 lb/ft^2
Total	*50.4 million tons (45.8 MMT)*

Table 1. Summary of Estimated Building-Related C&D Debris Generation, 2000 (Million Tons)

	Residential	**Non-residential**	**Totals**
<u>*Construction*</u>	9.670	6.615	*16.285* (10%)
<u>*Renovation*</u>	37.862	33.243	*71.104* (45%)
<u>*Demolition*</u>	19.700	50.400	*70.100* (45%)
TOTALS	*67.232* (43%)	*90.257* (57%)	*157,489 (100%)*

Note: 1 Million Ton = 0.91 Million Metric Ton (MMT)

Thus, according to the calculations above, the total C&D waste generated for the year 2000 was approximately 157.5 million tons (143.3 MMT). This represents a 16% increase in waste production in the industry over the four-year period from 1996 to 2000. Because many of the numbers used in the above calculations are based on assumed progressions and extrapolation of previous years, the accuracy of this estimate is unknown.

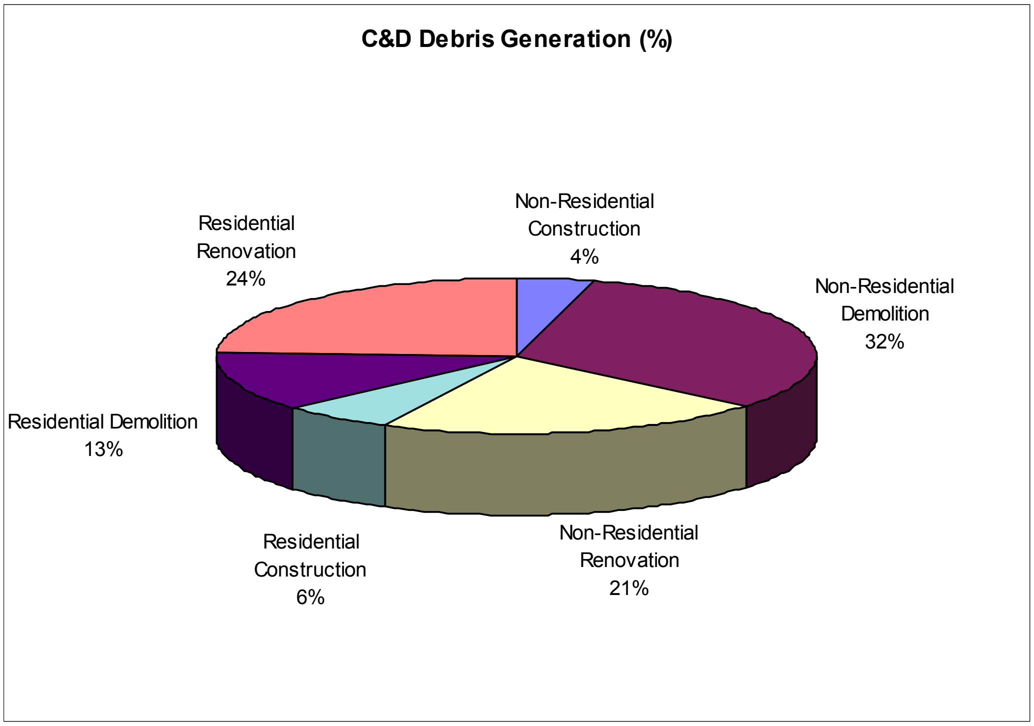

Figure 1. Construction and Demolition Waste Generation in 2000

1.2 Waste Statistics

According to the debris generation statistics from the previous section, the demolition industry (renovation and demolition) produced more than 140 million tons of waste in 2000. This equates to 90% of all C&D waste for the year. This statistic conveys the importance of deconstruction as a method for recovering reusable building components. The EPA estimates that 35 to 45 percent of this debris is sent to Municipal Solid Waste (MSW) landfills or unpermitted landfills, and 20 to 30 percent is reused or recycled (Franklin Associates). For the purposes of this discussion we will assume that 75% of C&D waste is currently landfilled and 25% is recovered for recycling and reuse.

Table 2 establishes estimated quantities of materials bound for C&D landfills, MSW and unpermitted landfills, or recovery. It can be seen from this table that more than 115 million tons of construction and demolition waste was landfilled in the year 2000. Of this, over 90 million tons resulted directly from demolition and renovation waste.

Table 2. Estimated Quantities of Materials bounds for C&D landfills, MSW and permitted unpermitted landfills, or recovery.

	C&D Landfills (40%)	MSW Landfills, Onsite Management, Unpermitted Landfills (35%)	Recovered	Total
Residential				
demolition	7.880	6.895	4.925	19.700
renovation	15.145	13.252	9.465	37.862
construction	3.868	3.385	2.418	9.670
Non-Residential				
demolition	20.160	17.640	12.600	50.400
renovation	13.297	11.339	8.311	33.243
construction	2.646	2.315	1.654	6.615
Total	62.996	55.121	39.372	157.490

The potential C&D waste diversion due to deconstruction is astounding. For example, let us quickly consider a conservative scenario in which the United States could reach a deconstruction rate of 75,000 out of the estimated 290,000 buildings that were demolished in the year 2000. These demolitions generate approximately 70.1 million tons of debris (see Table 1). Assuming that 75% of demolition debris is landfilled (the number is probably quite higher), then approximately 52.5 million tons of demolition debris was landfilled in 2000. Let us say, for the sake of argument, that we deconstruct 75,000 of those buildings that would be otherwise destined for demolition. And let us say that we achieve a 75% recovery rate on these buildings. This would result in an approximate recovery of 9 million tons of waste from these 75,000 buildings. 9 million tons of demolition debris diverted from the waste stream with the potential to be reused and recycled, thus reducing the necessity to extract virgin materials from the earth. This would be a 17% decrease in demolition debris to be landfilled. Keep in mind that this is a conservative scenario and does not account for possible reuse of renovation debris. The potential waste diversion through wide scale deconstruction is actually much higher.

2.0 DECONSTRUCTION STRATEGIES, MACHINERY, AND TOOLS

2.1 Planning Issues for Deconstruction

There are numerous logistical issues to take into account when considering deconstruction as a building removal method. Steps must be taken to assure the owner that the building is a good candidate for deconstruction, that adequate time is available for the deconstruction, that the proper environmental assessments and permits have been obtained, that all hazardous materials have been accounted for, and that the right contractor for the job has been hired. These issues are identified and explored in the following discussion.

Building Inventory

The first decision to be made in the deconstruction planning process is whether or not the target building is a good candidate to be deconstructed. Not every building consists of the right components and is in the right physical condition to be disassembled for material salvage. The decision whether or not to deconstruct can be facilitated by a detailed inventory of the building's components. The detailed inventory serves to identify the cost effectiveness of deconstruction. This inventory can be made by anyone with knowledge of building construction techniques. A builder, architect, structural engineer, or a materials inspector would good candidates. Advice from someone who has an understanding of the materials salvage market may also be helpful. "A detailed building inventory requires inspection of every component, focusing on its condition and the manner in which it is secured to the structure" (Deconstruction: EPA, 2003). The inventory serves to identify construction methods and fasteners, as well as hazardous materials, which have a direct affect on economic feasibility. Table 3 outlines building characteristics that are generally present in highly deconstructable buildings.

Table 3. Characteristics of highly deconstructable buildings

Favorable Characteristics for Cost-Effective Building Deconstruction

1) *Wood framed buildings using heavy timbers and unique woods such as Douglas fir, American chestnut, and old growth southern yellow pine. These components are often found in buildings that were constructed before World War II.*
2) *Buildings that are constructed using high value specialty items such as hardwood flooring, architectural mouldings, and unique doors or electrical fixtures.*
3) *Buildings constructed with high-quality brick and low quality mortar. These will be easy to break-up and clean.*
4) *Buildings that are generally structurally sound and weather tight. These buildings will have less rotted and decayed materials*

(A Guide to Deconstruction, 2000)

Provide Adequate Time

Deconstruction is by nature a labor intensive process. It is estimated that the deconstruction of a building, depending on its extent, takes at-least two times and up to ten times as long as the demolition of the same building. Frequently, when a building needs to be removed it is because the owner of the property has another intended use for the property. In this scenario time is of the essence. Careful consideration should be taken to make sure that all parties are willing to sacrifice the time to properly deconstruct the building.

Permitting and Environmental Assessments

Most jurisdictions require demolition permits to remove a building. In many areas the permit is the same whether it be for deconstruction or for demolition. Only in areas where deconstruction has become established does it require a separate permit. The permits are generally not difficult to obtain. However, certain steps will often be required before the permit will be issued. "Approval of the demolition permit will often be linked to disconnection of electrical power, capping of all gas and sewer lines; and abatement of hazardous materials such as lead and asbestos" (Kibert et al, 2000). In areas where implementation of deconstruction is of high priority, lag time may be required before demolition will be allowed. The purpose of this is to eliminate the discrepancy between the speed of demolition and the time consumption of deconstruction, thus creating an incentive to deconstruct.

An environmental assessment should be made on the site in order to identify hazardous materials. "For commercial properties, it is the responsibility of the property owner(s) to make reasonable efforts to identify hazardous materials on the site prior to demolition or deconstruction. Reasonable efforts include a thorough visual, noninvasive inspection of all aspects of the site and structures by individual(s) trained in environmental assessment" (Deconstruction Training, 2001). Many commercial owners employ a consulting firm to conduct this environmental assessment. This provides tangible evidence that reasonable efforts were made to identify hazardous materials. There are no such requirements for residential property owners. Materials Hazards include lead-based paint and asbestos, underground fuel storage tanks, and electrical transformers or their components containing polychlorinated biphenyls (PCB) (Deconstruction Training, 2001).

Hazardous Materials Abatement

The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) both have federal regulations governing the management of asbestos containing materials (ACM) and lead-based paint (LBP)in buildings. OSHA worker protection requirements for both ACM and LBP are tougher on deconstruction than demolition because the exposure is much greater. EPA disposal regulations do not distinguish between deconstruction and demolition.

Contracting Process

The most important step for the owner in the deconstruction planning process is choosing a contractor. The owner should carefully draft a Request for Proposal/Invitation to Bid to solicit key information from Bidders. A deconstruction contractor must have an in depth understanding of demolition, construction, and the efficient flow of materials. Table 4 provides helpful suggestions concerning the selection of a deconstruction contractor.

Table 4. Tips for selecting deconstruction contractor

Contractor Selection
1) Match the capabilities and approach of the contractor to the characteristics of the building. Large buildings (more than three stories) and small masonry buildings will probably require heavy machinery for safe and cost-effective structural salvage. Light-framed, smaller building can often be most cost-effectively disassembled with manual labor. *2) Require the submittal of a Resource Management Plan which outlines how the specified material recovery goals will be achieved.* *3) Specify separate goals for reuse and recycling, and consider giving reuse greater relative weight.* *4) Provide as much assistance as possible to reach the material recovery goals. For example, provide a list of reuse and recycling strategies/outlets located near the site.* *5) Divide the building removal into separate contracts, e.g., hazardous material abatement, building disassembly, processing of materials, and final site restoration. Some contractors may specialize in one of these areas.* *(A Guide to Deconstruction, 2000)*

In order to tip the balance of feasibility in favor of deconstruction, partnerships are often a preferable option. Joint ventures between not-for-profit organizations, resident-owned businesses, developers, and private general contractors can make a deconstruction project cost effective. The following case study (see Table 5) examines the successful use of joint ventures in building deconstruction by the Hartford Housing Authority.

Table 5. Joint Ventures Case Study

Case Study: Joint Ventures – Hartford Housing Authority
Hartford, Connecticut

With partial funding through a HUD HOPE VI grant, the Hartford Housing Authority and a private developer joined forces with Manafort Brothers, Inc., a private demolition contractor, to deconstruct two buildings at Stowe Village. With years of experience in the deconstruction and salvage business, Managort was key to the success of the project. Nine public housing residents were trained during the project and remained in the Laborer's International Union of North America. The project turned out to be so successful that the city of Hartford has identified other buildings for deconstruction and provided a warehouse for storage of materials
(A Guide to Deconstruction, 2000)

2.3 Deconstruction Techniques, Methods, and Tools

Deconstruction can take a variety of forms. A building is a candidate for complete structural disassembly when a large portion of the materials have potential for reuse. Not all deconstruction projects involve complete disassembly of the building. A deconstruction project could fall within the category of a complete structural disassembly, a small soft-stripping project, or an individual assembly project.

Soft-stripping involves the removal of specific components of the building before demolition. For example, in a structurally weak building that does not have much salvageable material, only a few items may be desirable enough to salvage before demolishing the remainder of the building. Good candidates for soft-stripping include: plumbing or electrical fixtures, appliances, HVAC equipment, cabinets, doors, windows, hardwood, and tile flooring (A Guide to Deconstruction, 2000).

While the entirety of the building may not be worth deconstructing, certain assemblies within the building may be. Perhaps the rafters in an old building are of high quality heavy timbers and thus command a high salvage value. In scenarios like this, particular building assemblies may be targeted for removal before the building is demolished. Rafters, floor joists, wall framing members, and sheathing materials may be of size and condition to warrant salvage (A Guide to Deconstruction, 2000).

The chronology of the deconstruction process is of utmost importance. The proper sequence of disassembly increases jobsite safety and efficiency and protects salvageable materials from unnecessary damage. Whole building deconstruction can be broken down into the five basic steps listed in the Table 6.

Table 6. Deconstruction basic steps

5 Basic Steps to Building Deconstruction

1) *Remove the trim work, including door casings and moldings.*
2) *Take out kitchen appliances, plumbing, cabinets, windows, and doors.*
3) *Remove the floor coverings, wall coverings, insulation, wiring, and plumbing pipes.*
4) *Disassemble the roof.*
5) *Dismantle the walls, frame, and flooring, one story at a time.*

(Deconstruction Training, 2001)

Having the proper tools and equipment on hand on a deconstruction project will decrease material damage and make the worker's jobs much easier. Project managers should carry an inventory checklist of tools on site. In addition to the traditional, tools and equipment are now being developed for the specific purpose of facilitating efficiency in building disassembly. These products, the pneumatic Nail Kicker and various shaping and surfacing machines, will be discussed later in this paper.

Deconstruction Sequence

The first step in removing a piece of material for salvage is to identify how that piece is fastened within the building. An understanding of how materials are installed is paramount in being able to uninstall them without damage. The following deconstruction sequencing is used for a basic residential structure. The piece by piece deconstruction of the buildings closely follows the five steps outlined earlier in this section. After each step in this process all nails should be removed and the materials should be sorted, stacked, and cleaned.

- Cabinet Removal
- Light Fixture Removal
- Window Removal
- Door Removal
- Floor Coverings
- Roof Deconstruction
- Wall Deconstruction
- Floor Deconstruction

2.4 Worker Training and Safety

Just as in the construction industry, efficiency and safety on the jobsite are of paramount importance in deconstruction. Training of workers in the areas of deconstruction techniques and field safety measures has a positive overall effect on the project.

Increased labor productivity reduces labor costs on the project. It also reduces project completion time, which is a barrier to the establishment of deconstruction. Similarly, minimizing workplace accidents has a reduction effect on long term costs for the deconstruction agent/contractor. In deconstruction, which by nature is a small profit margin industry, all possible cost reductions can be the difference between whether the project is cost-effective or not. Deconstruction workers should receive basic worker training, large equipment training, hazardous materials training, fall protection training, and, in some cases, rescue procedures training.

Basic Worker Training

The deconstruction process is generally more labor intensive and less technologically advanced. The skill level required to get the job done is not high. However, a well-planned, coordinated effort is required to complete a deconstruction project efficiently and cost-effectively. Workers should be trained in the use of the necessary hand and power tools, they should be made familiar of the various building materials and fasteners, and they should be taught construction techniques and the construction process. "Knowledge of construction techniques and the construction process will assist in the 'reverse construction' of the structures" (Kibert et al, 2000). Increased efficiency is not the only positive effect of this basic training. Combined with the experience of the actual deconstruction, this training provides workers with marketable skills that could lead to future careers in related industries. Table 7 provides a case study in worker trainig.

Table 7. Worker training case study

Case Study: Peoria Housing Authority

The JATC, a cooperative committee comprised of representatives from the PHA, local labor unions, and the Contractors' Association, formed to provide construction training to public housing residents. The 2,000 hour program, which includes 160 hours devoted to deconstruction, provides workers with training in all aspects of building maintenance and repair.
The removal of building components offers trainees the opportunity to develop skills in a variety of areas:

- *Reseal toilet tanks and replace parts*
- *Replace faucet assemblies*
- *Repair refrigerator evaporator fans*
- *Replace range burners and igniters*
- *Replace burners in boilers*
- *Refinish cabinets and doors*

All of these are marketable skills that would merit consideration for employment with plumbing contractors, carpenters, or as a freelance handyman.
(A Guide to Deconstruction 11)

Large Equipment Training

Deconstruction does not generally require the operation of much large equipment. The exception to this is the forklift. The forklift is an important machine in deconstruction. It is used in the movement of building components around the jobsite, generally from the building to the storage area. In order to minimize job place accidents, care must be taken to be sure that all drivers of forklifts are properly trained. The Occupation Safety and Health Administration (OSHA) states, "Only drivers authorized by the employer and trained in the safe operations of industrial trucks or industrial tow tractors shall be permitted to operate such vehicles. Methods shall be devised to train operators in the safe operation of industrial trucks" (Deconstruction Training, 2001). There are multiply types of forklifts and workers must be certified to drive each forklift they operate.

Hazardous Materials Training

Workers should go through some formal training regarding hazardous materials such as lead-based paint (LBP) and Asbestos containing materials (ACM). This training is an essential job safety measure due to the potentially high levels of exposure that workers can experience on deconstruction projects. Raising worker awareness of proper handling techniques greatly diminishes the potential for exposure and related problems. For example, the University of Florida Center for Construction and Environment requires that all of its deconstruction workers attend an 8-hour ACM and LBP awareness training course (Guy Reuse and Recycling 9). This course is provided by the University of Florida's Center for Training, Research and Education for Environmental Occupations (TREEO Center) and is in compliance with OSHA's asbestos section 29 CFR 1926.1101 and lead section 29 CFR 1926.62.

Fall Protection and Rescue Procedures

Maintaining a reasonable level of jobsite safety is not only an economic and legal issue. Maximizing jobsite safety should be looked upon as a moral obligation. "A typical day in the construction industry in the United States will see one to three workers die from falls in the workplace. Falls are the leading cause of injury in the construction industry" (Deconstruction Training, 2001). OSHA requires employers to train workers who might be exposed to fall hazards on the use of fall protection equipment and rescue procedures.

It is required by OSHA that prompt rescue of fallen employees be provided for. It is important that emergency rescue procedures be established before work on the project has begun. Despite adequate precautionary procedures to avoid injurious falls, the nature of the industry dictates that accidents will occasionally occur. Steps must be taken and procedures established to protect the victim and rescuers in event of a fall.

3.0 WHOLE BUILDING REUSE

3.1 In Situ Building Reuse

Deconstruction should only be considered when adaptive reuse of the building is not an option. When a building reaches the end of its useful life, renovating the structure for reuse is always preferable to taking it down. In-situ building reuse is the modification of a building on site to be used again, generally for a similar purpose. Often times, such as when a business goes under, a building may simply be abandoned. Or a military base may close down, leaving hundreds of buildings with no purpose. In either of these situations the building may be in excellent overall condition and the location may be ideal. All too often such buildings simply go to waste. They rot away and are later demolished. Reuse of these buildings is an economical way to alleviate this problem. Not only that, but reuse minimizes the structure's impact on the waste stream, preserves its structural integrity, creates cheap infrastructure for the community, and often creates jobs, helping to stimulate the local economy. Any building whose useful life has come to an end and remains in relatively good condition is a potential candidate for reuse. Table 8 outlines factors that should be considered when analyzing the potential of a building for reuse.

Table 8. Factors influencing the potential of a building for reuse

Factors Influencing a Building's Reuse Potential

- *The structure should be in good condition. The extant of work required to revive a rotted through building would cause it to not be cost-effective.*
- *Should the building remain on site? If the land on which the building sits would better serve another purpose, deconstruction or moving the building to a new site for reuse (as discussed in the next section) may be a more feasible option.*
- *Structures of historical value should be considered very carefully for reuse in order to preserve architectural styles that are no longer in use.*
- *Generally the building should be converted for a similar use. It would obviously not be cost-effective to convert an old barn into an airport.*

Military base closings have provided numerous examples of successful in-situ reuse of buildings. Table 9 is a case study that explores the planned reuse of military barracks as part of the Fort Ord Pilot Deconstruction Project. These barracks are ideal for in-situ reuse as an affordable housing neighborhood. Their characteristics strikingly resemble the favorable factors listed in the above table. Their reuse will be for a similar purpose as their original use, as residences. This will serve to make the conversion simple and economical. Additionally, the layout of the site is already ideal for use as a small neighborhood and the unique architecture of the barracks and site are considered to be worth preserving.

Table 9. In-situ reuse of military barracks

Case Study: Fort Ord Pilot Deconstruction Project

A group of forty-six barracks on the closed military base is to be converted for use as a colony of artist's studios with living quarters, public serving galleries, and educational buildings. The buildings will be converted to be used for a similar purpose as that for which they were originally built. This simplifies the project, making it more economical. Living quarters will be converted to artists' studios with living quarters and family housing, mess halls converted to public serving galleries, etc. The layout of the site is ideal for use as a small, quaint community.
The benefits of the reuse of these barracks are numerous. Compared to deconstruction, which was also implemented in other areas of Fort Ord, in-situ reuse is a more effective way to minimize waste generation from the barracks. Additionally, the minimal conversion necessary serves to minimize the cost and maintain the architectural integrity and "character" of the site and structures, and the project will provide the art community with affordable housing and a stimulating congregating area.
(Congleton, 2003)

3.2 Moving Buildings to New Sites for Reuse

The end of a building's useful life does not necessarily equate to the end of a building's structural integrity or physical usefulness. Occasionally, a building's useful life can end because it is no longer practical at the site on which it sits. For example, a barn on an old farm may be in excellent structural condition. However, if that farm is being developed into a shopping center, than the barn is no longer of good use on that site. In the case of a situation like this, removal of the entire building for reuse in another area, perhaps for another purpose, may be the best option. A building is generally a good candidate to be moved if the site is no longer accepting of that building and the building is in good shape or represents cultural, architectural, or historical significance.

Figure 2. Relocation of a barn for adaptive building reuse

The most important factor influencing the potential movement of a building to a new site is the old site's capacity to accept the building. A building should only be moved if there is a problem with it being where it is. Perhaps the building was originally built on a site which will not, due to its geology, sufficiently support the building. For example, a house built on a sink hole may be an excellent candidate for movement to a new site. Alternatively, the site may no longer be used for the purpose which is served by the building in question, thus necessitating a move. The barn example above exemplifies this situation.

Also contributing to the potential movement of a building are its physical characteristics. Of particular importance are buildings of high historical, architectural, or aesthetic significance. People, by nature, want to preserve those things that represent memories of times and places. Historically significant buildings serve a similar purpose as old photographs. They embody and preserve past cultures and ideologies. It is for this reason that there is a growing trend of people who prefer to renovate, restore and refurbish old houses into their homes in order to connect with more gracious elements of past living and secure a "slice of history".

Figure 3. Moving an entire building to preserve its historical/architectural value

Of course, the environmental benefits of moving a building, as opposed to deconstructing or demolishing it, should not be ignored. Moving the building to a new site serves to reduce, if not eliminate, the amount of waste generated by that building. The following case study (Table 10) examines Barn to be Home, a company that specializes in moving barns to new sites to be converted into homes.

Table 10. Moving barns to be converted into homes

Case Study: Barn to be Home

Barn to be Home's mission is to build partnerships and networks between individuals with antique structures to preserve and those who wish to utilize these structures for adaptive building reuse. Barn to be Homes specializes in the relocation and adaptive of reuse of "America's vanishing agricultural icon, the Barn." They are a licensed general contractor that can also provide design and structural engineering services for the barn to home conversions.
(Barn to be Home 1)

3.3 Benefits of Component Reuse

The world today is facing the reality of the impacts of over-consumption and environmental abuse. This realization will hopefully result in a shift from environmentally detrimental business practices to those that minimize environmental impact. Deconstruction and component reuse represents such a shift. The reuse of deconstructed building components, as opposed to the landfilling of demolished building components, presents obvious environmental advantages while maintaining comparable, if not favorable, economic characteristics. The benefits of component reuse can be described not only by their environmental and economic benefits, but also by their social and historical benefits.

Environmental Benefits

Without a doubt, the most important benefits provided by the reuse of deconstructed building materials are those they provide to our environment. Each timber that is reused is one less timber to be landfilled. Component Reuse diverts large volumes of Construction and Demolition Waste from landfilling. This preserves precious landfill space. Table 11 shows recovery rates for various deconstruction projects throughout the United States (Kibert et al, 2000). Recovery rates for lightwood framed construction are discussed in a paper by Chini and Nguyen (2003).

Table 11. Recovery rate for various deconstruction projects

Location	Case Study	Reuse/Recycling Rate
San Francisco, CA	Presidio	87%
Fort McCoy, WI	USArmy Barracks	85%
San Diego, CA	US Navy Motor Pool Building	84%
Marina, Ca	Fort Ord	80-90%
Twin Cities, MN	Army Ammunition Plant	60-80%
Baltimore, MD	Four Unit Residential housing	76%
Port of Oakland, Ca	Warehouse	70%
Minneapolis, MN	Residential Building	50-75%

The reuse of building components reduces the demand for newly manufactured materials. This reduction in manufacturing would in turn lead to less energy consumption in the manufacturing process and a reduction in the extraction of raw materials from the earth. Less material extraction and manufacturing means less associated pollution. For example, the reuse of a large old-growth timber means that that quantity of raw material need not be extracted from the earth, transported to a manufacturing plant, cut, milled, treated, packaged, and transported to a storage facility. The associated energy consumption and pollution would thus be eliminated. Table 12 looks at the amount of lumber available for reuse in the United States.

Table 12. Lumber available for reuse

Case Study: Lumber Available for Reuse in the United States

The March 2002 article Wood-Framed Building Deconstruction, made an educated guess of the amount of lumber available for reuse. The purpose of this was not so much to come up with an exact number as to portray the astounding waste reduction possibilities of deconstruction. The following variables were assumed in the calculations:

1) *An average of 13,000 Board Feet of lumber used in framing the average home.*
2) *245,000 homes demolished annually*
3) *25% loss during extraction*
4) *The average size home demolished is half the size of today's homes*

Based on these assumptions, it was estimated that 1.2 billion board feet of lumber could be reused annually if deconstruction were implemented in place of demolition. This is large reduction in the waste stream. Note that these calculations assume that the average demolished house is half the size as today's average house. This is probably not accurate and thus their estimation could be quite small.
(Falk, 2000)

Finally, deconstruction necessitates an inspection for hazardous materials. The subsequent disposal of these hazardous waste materials reduces airborne asbestos, lead particles, and dust in the atmosphere that would be created through demolition (Macozoma, 2001).

Social and Economic Benefits

Setting the substantial environmental benefits aside, deconstruction is a cost-effective alternative to demolition. Numerous studies have shown that, although total costs are generally higher, the resale of materials on deconstruction products makes deconstruction a cheaper option than demolition. Table 13 shows an economic summary of a deconstruction project conducted by the Powell Center for Construction and Environment (PCCE) in Gainesville, Florida (Guy, 2003). This table gives a cost comparison of deconstruction versus demolition on the project. Notice that overall costs for deconstruction, after material salvage, were less than 30% of demolition costs.

Table 13. Deconstruction versus demolition cost for a residential building

	Total Net Demolition			***Total Net Deconstruction***		
COSTS ($)						
Permit	*50.00*			*50.00*		
Asbestos Survey	*1200.00*			*1200.00*		
Asbestos Abatement	*740.00*			*740.00*		
Disposal	*5873.67*	***96.67 tons***		*1344.01*	***22.12 tons***	
Toilet	*63.00*			*63.00*		
Supplies	*10.00*			*637.93*		
Labor and Equipment	*3504.36*			*8469.38*		
Total costs	*11441*	***5.68 per SF***		*12504*	***6.21 per SF***	
REVENUES ($)						
Salvage	*0.00*			*9415.00*	***4.67 per SF***	
Total Net Costs	*11441*	***5.68 per SF***		*3089.32*	***1.53 per SF***	

Deconstruction creates more employment and training opportunities for low-skilled workers than does demolition. This brings jobs and career opportunities into the community, which stimulates the local economy. It has been estimated that for every landfill job created, resource recovery creates ten. The skills learned in deconstruction are marketable in the construction industry. In showing workers how to take a building apart, they learn how the building is put together.

Deconstruction and component reuse stimulate the economy through the creation of a salvaged materials market. This market provides the opportunity for the development of small businesses. Of course, the availability of cheap building materials is a cost savings to the community in its own right. Particularly in low income areas, deconstruction results in the availability of high quality used building materials that may not otherwise be affordable.

According to Macozoma (2001), other economic benefits of deconstruction include but are not limited to:

- Cost saving from avoided transportation and disposal costs of C&D waste.
- Delayed capital expenditure for the development of new landfills due to extended lives of existing landfill sites.
- Delayed closure costs for existing landfills.

- Cost savings from avoided procurement costs of virgin materials.
- Improved financial performance of the construction industry due to reduced energy and pollution costs.

Historical Benefits

The reuse of old building components serves to preserve architecture and craftsmanship that is no longer available today. Deconstruction serves to preserve this architecture and craftsmanship through salvage and resale. Often times, items of historical significance command a high price on the salvage market because they are in high demand by collectors.

Many of the woods and heavy timbers used in building construction before 1950 are now in short supply. Many of the materials used in the construction of buildings during the days of old-growth harvest are unavailable from any other resource today. This creates a strong demand for such materials on the salvage market. These materials are generally considered to be of higher aesthetic quality (and thus of higher value) than the lumber produced today.

3.5 Component Recertification Requirements

Component recertification, particularly lumber re-grading for structural use, has become a hot topic in the deconstruction industry. Quality control is crucial in the trade of lumber products. The grade stamp on lumber verifies the quality of each piece of lumber. Currently, existing grading rules can be used to grade salvaged lumber. However, these rules do not specifically address salvaged lumber. Rules governing the evaluation of severe drying, nail holes, and other salvaged lumber specific defects are lacking (Falk, 2000). Current grading procedures are time consuming and expensive. Grading of salvaged lumber, other than in very large quantities, is not cost-effective. Another problem is that certificate requirements typically require that an entire batch of graded material be given one grading certificate. This limits the sale to one order (Falk, 2000). Because the extent to which salvaged lumber defects and their affect on its strength are somewhat uncertain, grading agencies are hesitant to give it their stamp of approval. When they do, they minimize risk by downgrading the lumber or restricting it from particular applications. The Southern Pine Inspection Bureau, which is the grading agency that governs the state of Florida, uses a disclaimer stating, “they do not re-grade wood to be sold and used for structural lumber” (Kibert et al, 2000). These issues create a barrier to the implementation of deconstruction by raising costs and reducing the possible applications of salvaged wood. In addition, structural salvaged lumber would draw a much higher price on the market than non-structural wood. Currently, steps are being taken to develop a nationally recognized salvaged lumber re-grading system.

The USDA/Fs – Forest Products Laboratory is in the process of developing a certification for used wood materials (Grothe, 2002). The implementation of this certification process would alleviate this barrier to deconstruction dramatically. They are using mechanical testing to develop engineering data showing the strength qualities of salvaged lumber and how it is affected by warp, knots, bolt and nails holes, etc. These tests are ongoing.

4.0 ENHANCING MATERIALS RECYCLABILITY

4.1 General Issues of Materials Recycling

In a perfect world, the term recycling would describe a process in which raw materials achieve an endless useful life. Each conversion for reuse of the material would have future reuse possibilities designed in. Michael Braungart, of McDonough Braungart Design Chemistry, describes this process, “Korean rice husks used as packaging for stereo components are now being reused as building insulation. After use as insulation, the rice husks can be used again as bricks” (Cannell, 2000). It is true that nothing can be used forever. The passing of time eventually renders all materials useless. However, the concept of an endless useful life potential for raw materials is achievable. “Closed-loop” recycling should be the end goal of the recycling industry in order to maximize the usefulness of virgin materials and minimize the necessity to extract them.

Currently, the recycling of materials frequently does not allow for future use of the material after the initial conversion. When lumber extracted from deconstruction or demolition site is ground into mulch and poured into somebody’s back yard, the useful life of the material is extended and that quantity of virgin materials is preserved. However, the possibility for future use after that is virtually eliminated. Processes such as this, which we usually call recycling, are not actually recycling at all. The process of reducing a raw material’s quality, potential for future uses, and economic value, is called downcycling. The process of reusing a material for similar uses, thus maintaining the possibility for reuse again later, is recycling. The process of increasing the material’s quality, potential for future use, and economic value is called upcycling.

Downcycling

Downcycling currently holds an important position in our society. Most forms of recycling today are actually down-cycling. Currently, the technology is not available to recycle most products in such a manner that they are not degraded in some way. As long as this is the case, downcycling will be the best means of maximizing the useful life of raw materials and minimizing extraction of virgin materials. The recycling of paper, on the surface, appears to be a closed-loop cycle. In reality, however, it is not. Inks cannot be reused and are disposed of as waste sludge. The paper fibers are reduced in length and their strength is reduced. New fibers must be added to reinforce the paper’s strength. Thus it is not a closed-loop recycling system. Downcycling should be the last option in the recycling contingent. Whenever possible, techniques utilizing a higher level of sustainability should be incorporated.

Upcycling

Upcycling, as stated earlier, is a process in which the material's quality, potential for future reuse, and economic value is increased during the conversion process. Upcycling maximizes the lifecycle of raw materials. The above mentioned example of the Korean rice husks exemplifies the upcycling ideology. The husks are used as packaging material, a low value product. From there they are used in building insulation, a slightly higher value product. And from that point they become bricks, an even higher value product. Additionally, the bricks have the potential for further recycling down the road. The value of the raw material, the rice husks, is increased for us, the users of the material, at every stage. Upcycling is the ideal form of conversion of materials for reuse due to its high level of environmental and economic impact.

4.2 Recycling Issues for Specific Materials

Nearly all building materials have the potential for reuse following their initial useful life. Although reuse possibilities are available for building materials following demolition, deconstruction maximizes this potential because it allows these materials to be recovered with the least possible amount of damage. Additionally, the organizational nature of deconstruction involves sorting separate materials, which further facilitates reuse opportunities. Wood, steel, concrete, carpet, brick, plastics, and drywall all have high reuse potential.

Wood

Every year in the United States over 42 billion board feet of lumber gets dumped into landfills (Falk, 2003). Reuse of wood recovered from demolished and deconstructed buildings is an important means of reducing this landfill burden. It is estimated that for every 2,000 square feet of wood floor recovered, an estimated 1 acre of woodland is spared from being cleared (Falk, 2003). With the exception of scrap steel, wood products have the highest recoverability level of any building materials. This is due to the large amount of recoverable wood in the deconstruction and demolition market. Additionally, the ways in which wood can be reused are numerous.

"The spectrum of wood-based waste that might be converted to housing products includes full-sized used lumber salvaged from razed buildings, wood resulting from building demolition, old wooden pallets, scrap wood from new construction sites, preservative-treated wood waste from treating facilities and building construction, old wooden utility poles of railroad ties, wastepaper, yard trimmings, and wood fiber found in the sludge produced by paper mills" (Falk, 2003). This proliferation of available materials makes wood products an important piece of the waste diversion puzzle. Wood products can be recycled for direct reuse in similar applications, they can be downcycled into mulch, or they can be upcycled into more valuable items, such as custom cabinetry or furniture.

Many wood products can be recovered and reused directly, with little or no processing necessary. Currently, recovered structural timbers are in high demand in the United States because of their lack of availability from any other source. Virgin stocks were overexploited during the years of heavy logging and have yet to recover. People value the timbers for their aesthetic quality and historical significance. Additionally, dimension framing lumber can be recovered and reused as is. The market for recycled dimension lumber is still a fledgling industry. The reuse applications for recovered lumber are currently limited due to a lack of standardized grading requirements (Chini and Acquaye, 2001). This should change with the establishment of grading requirements. Once the structural uses of recovered dimension lumber are established, the demand will increase exponentially. Reusing recovered wood products in similar applications extends the lifecycle of the product because it maintains the potential for further recycling down the line.

Concrete

Currently, applications for used concrete involve downcycling the materials for use as a lower quality product. For example, concrete can be crushed up into a small aggregate and used in asphalt or new concrete. Currently, no commercial uses of recovered concrete involve upcycling of the material to a higher quality material with high future recyclability.

Steel

The North American steel industry is far ahead of any other building material industry in its use of recycling to conserve raw materials and create economic opportunity. "Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States for one year and every ton of steel recycled saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone" (Fact Sheet, 2003). The steel industry's overall recycling rate is nearly 68% (Fact Sheet, 2003). This includes the recycling of cans, automobiles, appliances, construction materials, and many other steel products. All new steel products contain recycled steel.

There are two processes for making steel. The Basic Oxygen Furnace process, which is used to produce the steel needed for packaging, car bodies, appliances and steel framing, uses a minimum of 25% recycled steel. The Electric Arc Furnace process, which is used to produce steel shapes such as railroad ties and bridge spans, uses nearly 100% recycled steel (Fact Sheet, 2003). Every steel product you purchase contains recycled steel in it, so by buying it you help to close the recycling loop.

Brick

The preferred method of recycling used bricks is to remove them undamaged and reuse them directly. The only current method used commercially to enable used bricks to be made suitable for reuse in their original form involves cleaning the old mortar from the bricks by hand (Masonry Recycling, 2003). A small blunt hand axe can be used to knock the mortar from the bricks. The problem with this is that it is extremely difficult to remove modern Portland cement based mortar from bricks using the technique described above. Thus only old bricks are generally cleaned and recycled by this method. There are however, studies in progress involving the use of pressure waves to break the bond between the mortar and the bricks. This may become a viable solution and create more brick recycling opportunities in the near future. There are currently studies ongoing concerning the use of crushed brick in road base. The results have been inconclusive to this point.

Asphalt Roof Shingles

Between 8 and 12 million tons of roofing shingles are manufactured annually in the U.S. (Schroeder. 2003). Around 65 percent of these shingles are used for re-roofing. Thus, between 5 and 8 million tons of old waste shingles are produced annually (Schroeder 6). Currently, the most practical use for used asphalt roof shingles involves grinding up cuttings to be used in asphalt road paving. Though this is a form of downcycling of the material, it manages to divert material that would otherwise be headed for the landfill. The following case study examines the use of recycled roof shingle clippings in roadwork in the state of Minnesota Table 14).

Table 14. use of recycled roof shingle clippings in hot-mix asphalt

Case Study: Use of Recycled Roof Shingles in Roadways in Minnesota
Benefitting from a public-private partnership between local asphalt producer Bituminous Roadways and the Minnesota Office of Environmental Assistance, Minnesotat road crews are using a 5% roofing shingle byproduct in hot-mix asphalt. This recycled aggregate reuses the cuttings from shingles composed of paper or fiberglass mat. The resulting high performance asphalt is suitable for a variety of residential paving and reconstruction applications. Used roofing (tear-off) shingles are not yet allowed in these applications.
(Schroeder, 2003)

Carpet

The United States carpet industry produces about 1 billion square meters of carpet per year. Of this approximately 70 percent is used to replace existing carpet; this translates into 1.2 million tons of carpet waste produced annually (Schroeder 5). Most carpet is downcycled by being ground up and used as a component in other products (i.e. building insulation, asphalt pavements, and Portland cement concrete). The following case study examines BASF's use of upcyling to increase the recyclability and economic value of used carpet (Table 15).

Table 15. Upcycling used carpet

Case Study: BASF Savant – Upcycling Carpet Fiber *In the 1990's BASF developed a carpet material called Savant, made from nylon 6 carpet fiber. Nylon 6 carpet fiber is a material that can be easily depolymerized into its precursor, caprolactam. The heat used in this process can be largely recovered, and caprolactum, in turn can be re-polymerized and made again into nylon 6, thus creating a closed-loop recycling process. Because it is made of this nylon 6, Savant can be recycled and used again and again. In response to this technology, BASF has created a carpet take back program in order to recover old nylon 6 carpet. Rather than being downcycled into a material with less value, the used nylon is upcyled into a product of greater quality.* *(Braungartand McDonough, 2003)*

Plastics

Plastics recycling is now an established national industry. According to the 2000 State of Plastics Recycling, nearly 1700 companies handling and reclaiming post-consumer plastics were in business in 1999. This was nearly six times greater than the 300 companies in business in 1986. The primary market for recycled PET bottles continues to be fiber for carpet and textiles and the primary market for recycled HDPE is bottles. However, *Recycled Plastic Products Directory* (Recycled Plastic, 2003) lists over 1,300 plastic products from recycled content, including waterproof paper products and even plastic lumber for structural applications. New ASTM (American Society for Testing and Materials) standards are paving the way for plastic lumber that could be used in framing, railroad ties, and marine pilings (State of Plastics Recycling, 2000). The use of recycled plastics for such applications could mean longer life and less maintenance, which translated to lower cost over the life of the product.

The limiting factor in the plastic recycling industry is currently the supply of raw materials that feeds the industry. Because of the maturation of the industry and the fact that nearly every major community has already implemented plastic recycling programs, growth has slowed. There was only a 4% increase in the pounds of plastic collected in 1999 compared with that of 1998 (State of Plastics Recycling, 2000).

4.3 Deconstruction as a Method for Increasing Materials Recyclability

Demolition results in a non-homogenous heap of damaged materials. The recyclability of these materials is thus reduced by the demolition process itself. There is a positive correlation between the proliferation of building demolition in our country and the proliferation of downcycling of materials. Direct reuse and upcyling of building materials generally requires that they be recovered in good condition. Demolition frequently damages building materials to the point that their only usefulness lies in being downcycled to less valuable materials. This reduction of the recyclability of the materials serves to reduce their economic value, increase their future negative effect on the waste stream, and increase the future necessity of raw materials extraction to take their place.

Deconstruction, on the other hand, serves to increase the recyclability of raw materials. Deconstruction results in numerous piles of homogenous building materials with minimal damage. This is because time and care are taken in recovering and sorting materials with as little negative effect on their quality as is humanly possible. The two factors unique to deconstruction that increase the recyclability of building materials are its organizational nature and the lack of damage incurred by the materials during the recovery process.

Sorting

The organizational nature of deconstruction increases the recyclability of the materials within the building. Should the same building be demolished by wrecking ball, the resulting trash heap would most easily be disposed of by hauling to a landfill. The individual components would have to be sorted after demolition in order to address their individual potential for recycling. This extra cost serves as a deterrent to recycling for demolition contractors. Deconstruction, by nature, requires the removal and sorting of individual building components. Piles of brick, wood, roof shingles, drywall, and other materials can then be recycled based on their own properties.

Recovering with Minimal Damage

Great pains are taken during the deconstruction process to recover building materials with minimal or no damage. Methods for efficient and safe extraction of materials are improving daily. Deconstruction improves materials recyclability by creating a supply of used building materials that are in good condition. This supply would not exist on any large scale without deconstruction. For example, structural timbers recovered from deconstruction can be reused in similar applications. This means that their potential for recycling will be available further on down the line. Conversely, structural timbers that have been destroyed by demolition only serve to be mulched up or sent to the landfill. Bricks recovered through deconstruction can be cleaned and sold for reuse, protecting their future recyclability. Bricks recovered from demolition would in far too poor of condition to be reused. Their only potential would be for being ground up and used in lesser applications. To sum it up, deconstruction increases material recyclability by creating the opportunity for material reuse and upcycling, whereas demolition promotes downcycling and landfilling.

6.0 ECONOMICS OF DECONSTRUCTION AND MARKETING OF USED BUILDING MATERIALS

6.1 Assessing the Economics of Deconstruction

There are two levels of economic assessment of the feasibility of deconstruction. Regional economic potential must be assessed in areas where the implementation of deconstruction on any substantial level is being considered. On a smaller scale, site economic assessments must be made when considering an individual building for deconstruction.

Assessing Regional Economic Potential for Deconstruction

For the potential deconstruction contractor/agent, many factors must be assessed when choosing a region to implement deconstruction on a large scale. Not all regions provide the right mix of scenarios that make deconstruction, from a business standpoint, economically viable. The region's building stock, reuse market, and level of public sector involvement all play a key roll in whether deconstruction can thrive, or even survive, in the area.

The most important factor to be considered when assessing the economic potential of a particular region is its building stock. "Building deconstruction, like demolition, depends on the availability of buildings that will form the feedstock for the industry" (Macozoma, 2001). In order for deconstruction to be a favorable operation, the region must contain a large number of buildings available for removal. Not only this, but the buildings must be suitable for deconstruction. For example, a city with a large number of vacant buildings containing a rare type of high quality wood would be an excellent candidate for implementation of deconstruction. The large number of deconstructable building would provide the necessary business opportunities while the value of the recovered wood would provide the necessary resale income to make the business profitable. Other factors affecting the deconstructibility of a building will be discussed in the next section.

The level of development and new construction activity in an area can affect the available building stock for deconstruction. High development requires land. This can often mean that a substantial number of older buildings could become available for removal.
A thorough examination of the local reuse market is necessary when determining a region's economic potential for deconstruction. "The supply and demand of salvage building materials can determine the success or failure of building deconstruction" (Macozoma, 2001). In order for deconstruction to be implemented in a given area investment will have to be made into used building material businesses and material storage facilities. This will provide the distribution points necessary for resale of materials. The local demand for used products must be high enough to offset the cost of developing these distribution centers. Export markets and large metropolitan areas provide the most consistent demand for used building materials (Grothe and Neun, 2002).

Used Building Material Retail Operations (UBMRO's) are an essential element in the economic feasibility of deconstruction (Grothe and Neun, 2002). If UBMRO's are already established or can be established in an area where deconstruction is being considered on a full scale level, the chances of successful implementation are greatly increased. Non-profit UBMRO's provide deconstruction agents with outlets for their salvaged materials when the up front cost of a private retail operation or material storage facility is prohibitive (Grothe and Neun, 2002). In areas with a high supply and demand for high price salvaged materials, the deconstruction agents themselves may succeed in developing UBMRO's.

On-site sales is an equally important means of selling salvaged building materials. Time constraints are usually the limiting factor when selling materials on-site. However, many sites lend themselves well to this means of distribution. An ideal deconstruction site for on-site sales would be one located in a high traffic area and selling low cost materials (see Table 16).

Table 16. On-site sales of salvaged materials

Case Study: On-Site Sale of Building Materials from Deconstructed Building
901 State Road 301, Gainesville, Florida

This house was deconstructed by the Powell Center for Construction and Environment, led by Bradley Guy. The house was located at the corner of a shopping center site in a high traffic, high visibility area of town. There was room on all sides of the site for laying out materials and the locale was a low-income neighborhood, which facilitated the sale of cheap building materials. The site was entirely cleared of salvaged materials by the last day of the project and sales netted $4,613.
(Guy, 2003)

A key issue in an economic assessment of a particular region's deconstruction potential is the level of involvement of the public sector. Government programs supporting deconstruction can do wonders in getting the ball rolling, which is quite possibly the most difficult step in the deconstruction development process.

State and local funding supporting deconstruction can be the difference between success and failure for the industry. Funding of non-profit UBMRO's and community service worker programs greatly reduces costs incurred by deconstruction contractors. Incentives supporting deconstruction need not only take place in the form of financial aid. Kibert et al suggest that incentives for deconstruction be developed in the form of disincentives for disposal. "By creating an environment not conducive to wasteful practices an incentive is created to waste less" (Kibert et al, 2000). Examples of disincentives suggested by Kibert et al include mandates that all demolition companies attend deconstruction seminar and raising the cost for demolition permits while lowering the cost of deconstruction permits.

Community developed job training programs are being implemented in many cities around the country. These programs are a blessing in more ways than one. At one level they provide low cost labor to the deconstruction industry. Time saved on finding labor and money saved per labor hour increase the chances of deconstruction succeeding in the area. On another level the increased job opportunities serves to stimulate the local economy. The U.S. Department of Health and Human Services summarizes the importance of deconstruction training programs by stating, "Building deconstruction offers new opportunities for career and new enterprises and provides an excellent training ground for employment in the wider construction field where there are serious and growing shortages of trained workers throughout the United States (Grothe and Neun, 2002).

Because deconstruction success rides heavily on the sale of used building materials, local perception of these materials can be a make or break factor. Poor public perception can negatively affect the materials resale market, which would negatively affect the profit potential of deconstruction. A thorough discussion of consumer tastes and perceptions will be given in later sections.

Site Economic Potential for Deconstruction

A potential deconstruction site must be evaluated for economic feasibility before any action takes place. At this point it is assumed that the decision has already been made to exploit the region's economic potential. Thus regional issues will not be considered in the following discussion. This discussion will focus on the site itself and its economic potential for deconstruction.

An individual building's economic feasibility for deconstruction, disregarding social factors such as environmental concerns, is decided by its cost comparison with demolition. A contractor's decision in many cases will be decided purely by comparing the net incomes of the two removal techniques.

In almost all cases, the cost of deconstruction is higher than that of demolition. This is due to the labor intensive nature of deconstruction. However, the salvage value regained in deconstruction often makes it more cost effective than demolition. Because the labor intensive factor of deconstruction is somewhat unavoidable, it is important to focus on minimizing other factors in the cost to make it more competitive. Minimizing costs and maximizing salvage value of building materials is essential to maximizing the potential of deconstruction. Having well trained workers, as discussed before, can have a major impact on overall cost. A high level of safety, also discussed before, reduces overall costs of deconstruction projects. These factors, however, are organizational factors that do not affect the potential of the site itself. Factors affecting economic potential of the site include its architecture and composition, project time constraints, and site accessibility. Table 17 shows that deconstruction, when conducted correctly, can be more profitable than demolition (Deconstruction:EPA, 2003).

Table 17. Comparison between demolition and deconstruction costs

Cost Savings with Deconstruction: Presidio Building #901		
9,180 Sq. Ft. Wood Construction		
Labor	($33,000)	
Equipment/Disposal	($12,000)	
Administration	($8,000)	
Total Expenses	($53,000)	($16,800)
Material Salvage Value	$43,660	
Net Cost	($9,340)	($16,800)
Savings	**$7,460**	

Deconstruction, as a rule, is a longer process than demolition. In the cut throat world of development and construction, time is money. "The long process of getting demolition permits often cuts into the time needed to deconstruct a buildings; once a permit is secured, developers are under pressure to demolish the building as soon as possible to make up for financial losses incurred while waiting for a permit" (Deconstruction Training Manual, 2001). When site development is on a tight schedule, deconstruction may be ruled out without any economic assessment being made.

As discussed previously, buildings that would be a good choice for deconstruction should exhibit the following characteristics:

1) Wood framed buildings using heavy timbers and unique woods such as Douglas Fir, American Chestnut, and Old Growth Southern Yellow Pine.
2) Buildings that are constructed using high value specialty items such as hardwood flooring, architectural moulding, and unique doors or electrical fixtures.
3) Buildings constructed with high quality brick and low quality mortar.
4) Buildings that are generally structurally sound and water tight. These buildings will have less rotted and decayed materials.

(A Guide to Deconstruction, 2000)

The above mentioned structural characteristics enhance the resale value of the project. High quality wood timbers are of particularly high value because over harvest has created a supply shortage in the United States. Also of high value are items with historical significance. High levels of lead based paint and asbestos containing materials increase costs on deconstruction projects due to laborious removal policies.

The accessibility of the site directly affects the labor time to deconstruct the building. How much labor involved in the deconstruction, as previously discussed, directly affects the profitability of the project. An open site that with easy entrance can drastically minimize labor costs, whereas a congested, wooded site can greatly increase labor costs. An open site allows for a more manageable work flow during the deconstruction. Workers can move more freely, materials can be removed and store more easily, and disposal vehicles can better access the site. A congested site has the opposite affect.

A thorough economic assessment of the site allows the deconstruction agent/contractor to make an educated decision on whether to bid on the project. The building's assessment can be used to give it a rating, which can be used in deciding whether to proceed. A thorough discussion of deconstruction assessment tools can be found in the following section.

6.2 Deconstruction Assessment Models / Tools

As discussed previously, a preliminary assessment of the economic feasibility of deconstruction is necessary before any other action is taken on the project. It is possible that the project may not possess the necessary characteristics for cost-effective deconstruction. Assessment models and tools for this purpose range from informal site visits to complex computer programs. An assessment of deconstruction potential can be made via an informal site visit, visually assessing the qualities of the building. On a slightly more thorough level, a detailed building inventory may be taken and analyzed to determine the economic potential of the project. Recently, computer models have been developed to determine the feasibility of deconstruction projects. This section provides a detailed discussion of these three assessment tools.

Site Visit

A cheap, informal means of assessing the economic potential of a deconstruction site is a site visit. The site visit should be conducted by the deconstruction agent or someone knowledgeable in construction processes and factors affecting deconstruction potential. During the site visit, the characteristics of the site that affect deconstructibility are visually observed. Based on these observations, a decision can be made as to whether the project should be pursued. The factors observed during the site visit are summarized in the chart below. Although quick and inexpensive, a site visit is not a thorough means of assessing economic potential. The lack of a thorough financial analysis of the materials in the building increases the risk of economic loss. It is recommended that a site visit be conducted in conjunction with a detailed building materials inventory, as discussed in the next section.

Building Materials Inventory

"The most important part of assessing the feasibility of deconstruction for a structure is a detailed inventory of how and of what the building is made" (Macozoma, 2001). A detailed building materials inventory is an invasive technique whereas each type of material in the building is identified, quantified, and assessed for its condition and method of installation. These factors can have a substantial impact on the cost-effectiveness of salvage. Invasive inspection of the structure not only serves to identify hidden layers of salvageable materials but also aids in the identification of hazardous materials, which may not have been visible during the initial site visit.

An initial site survey combined with a detailed building materials inventory is the recommended approach for accurate economic assessment of deconstructibility. However, the downside to a handwritten assessment in this manner is the time required. It has already been established that a major barrier to implementation of deconstruction is it's time consuming nature. The extent to which the length of the deconstruction process can be minimized is key to its success. Developing a spreadsheet, hand calculating materials, salvage values, labor costs, and preparing a final analysis is a laborious process that increases the cost of deconstruction and delays the project.

Computer-Based Deconstruction Feasibility Tool

As previously stated, the downside to a thorough building material inventory assessment is that it can be very time consuming for those performing the assessment to develop and organize the spreadsheets, quantify the materials and their salvage values, and make an accurate final analysis of deconstruction potential. To solve this problem, Bradley Guy of the University of Florida's Powell Center for Construction and Environment has developed a computer software program that can quickly estimate both potential salvage value and deconstruction costs. This step-by-step program will assist in making a rapid assessment of economic potential and facilitate "pre-sales" of materials before the deconstruction process begins. Economic variables such as local labor and disposal costs can be easily manipulated using the program to determine the optimal use for the building (Guy, 2003).

6.5 Materials Reuse Businesses

Do-It-Yourself (DIY) Outlets

Construction and Demolition (C&D) waste is produced at many levels. Although the demolition of huge commercial structures puts a large strain on the waste stream, emphasis should also be placed on the reduction of waste created on a smaller, individual basis. Private homeowners, contractors, and handymen take part in home improvement projects and small-scale demolitions and deconstructions all across the country everyday. Each individual project may not produce a large amount of waste. However, taken as a whole, a large amount of waste is contributed to the waste stream by these types of projects.

Salvaged building materials centers provide an outlet for handymen, homeowners, and contractors to unload unwanted building components without throwing them away. These unloaded materials in turn create a supply of affordable building components that can be reused by other individuals. This opportunity for cyclical use of materials serves to reduce the landfilling of C&D waste and ease the demand for raw materials extraction. The weekend do-it-yourselfer benefits from the availability of cheap materials for repair work and small projects that do not require the use of new, more expensive materials.

Individuals donating used building materials will benefit from tax-deductions at many outlets.

The following two case studies examine two different types of do-it-yourself outlets. ReSource 2000 is a for-profit business based on the resale of donated building materials (Table 18). The Used Building Materials Center in the Monroe County Landfill is a non-profit exchange center based on creating a cyclical movement of materials that avoids landfilling (Table 19).

Table 18. Resource 2000 – a for-profit do-it-yourself outlet

Case Study: ReSource 2000
Boulder, Colorado

ReSource 2000 is a used building materials outlet that obtains used components and resells them in their sales yard. Homeowners and contractors are encouraged by ReSource 2000 to take it upon themselves to donate their unwanted building materials, rather than just throw them away. Besides the obvious environmental and social benefits associated with the donation of unwanted building materials, individuals benefit from the fact that materials donated to ReSource 2000 are tax deductible. ReSource 2000 has given deconstruction materials large-scale donaters deductions ranging from $2,900 to $65,000 dollars. ReSource 2000 encourages the donation of lumber, plywood, sheetgoods, roofing, doors, windows, light fixtures, cabinets, fencing, hardware, plumbing, ducting, insulation, and brick. ReSource 2000 then sells these materials at affordable prices to builders and do-it-yourselfers.
(ReSource2000, 2003)

Table 19. Used Building Materials Center – a non-profit exchange center

Case Study: Used Building Materials Center
Monroe County Landfill, Indiana

Located at the Monroe County Landfill in Bloomington, Indiana, the Used Building Materials Center provides a "swap-and-trade" opportunity for do-it-yourselfers and contractors to unload or obtain used building components. The motto at the Used Building Materials Center is, "Take what you can use … drop off what you can't." Construction and demolition waste makes up 40 percent of the total waste disposal in the Monroe County Landfill. The Used Building Materials Center was developed at the landfill after officials recognized the need to minimize the environmental impact of construction waste.
(Used Building Materials Center, 2003)

Industry Associations

Because it is often slow, inconvenient, and expensive to advertise and store used building materials, the tendency of the average owner or demolition contractor has always been and still is to landfill those materials, with no potential for resource conservation and reuse. At the same time, there is a growing consumer need for materials that are less expensive and/or environmentally friendly. Young, rapidly expanding industries such as the deconstruction industry and the used building materials industry frequently need the help of external forces in order to efficiently bridge the logistical gap between building materials recovery and building materials resale. A number of associations currently exist whose purpose is to bring companies together in order to promote networking, information exchange, lobby for government support, and improve the efficiency of the industry. The following non-profit organizations are working to establish a global network for the deconstruction and used building materials industries.

Used Building Materials Association (UBMA)

The Used Building Materials Association (UBMA) is a non-profit, membership based organization that represents companies and organizers involved in the acquisition and/or redistribution of used building materials. They represent for-profit and non-profit companies in Canada and the United States that acquire and sell used building materials. The UBMA also represents companies that process and recycle building materials such as concrete and asphalt. Their mission is to help companies gather and redistribute building materials in a financially sustainable way (Used Building Materials Association, 2003).

Construction Materials Recycling Association (CMRA)

The Construction Materials Recycling Association (CMRA) is an association devoted exclusively to the needs of the rapidly expanding North American construction waste and demolition debris processing and recycling industry. Those needs include (Construction Materials Recycling Association, 2003):

- Information exchange on issues and technology facing the industry including a listing of available literature on relevant topics.
- Campaign to promote the acceptance and use of recycled construction materials including concrete, asphalt, wood, and gypsum, among others.
- Provide information and support to the C&D recycling industry's side of important issues that affect recyclers.
- They represent the industry at trade shows and other industry functions related to C&D recycling in order to raise the visibility of C&D recycling.

Reuse Development Organization (ReDO)

The Reuse Development Organization (ReDO) is a national and international tax exempt, non-profit organization promoting reuse on every level. ReDo was created to fill an informational void in the reuse industry. ReDo is providing education, training, and technical assistance to start up and operate reuse programs, while working to create a national reuse network and infrastructure. ReDO's mission statement: To promote reuse as an environmentally sound, socially beneficial and economical means for managing surplus and discarded materials (Reuse Development Organization, 2003).

Reusable Building Materials Exchange

The Reusable Building Materials Exchange is a website that provides a convenient way for contractors, home remodelers, reuse businesses, and other interested persons to easily exchange small or large quantities of used or surplus building materials. This web-site increases the efficiency and cost-effectiveness of the industry by providing a vehicle by which to sell used building materials to the public.

Once registered, sellers can create and post their own listings. Each listing will contain a description of the materials along with the name and telephone number of the seller. Buyers can browse the listings of materials wanted or available in several material type categories (e.g. lumber, masonry, doors, windows), and they may browse on more than one category at a time. The actual transactions are carried out directly between the interested parties (Reusable Building Materials Exchange, 2003).

7.0 DESIGN OF BUILDINGS AND COMPONENTS FOR DECONSTRUCTION

With existing buildings containing so many useful materials it is important that these materials be accessible for reuse after the building has exceeded its service life. When considering buildings as a future source of raw materials designing for disassembly is a key element in material retrievability. Additional issues are material durability, desirability and longevity. Materials must be durable if they are to be used over several service lives.

By definition deconstruction is an age-old concept of reusing existing structure components to create new facilities. However, designing for deconstruction from a practical standpoint is a difficult concept to grasp. Designers conceptualize their buildings as being timeless and no designer intends on spending intensive labor creating a building only to be torn down. The designer's perception is that the building will stand forever. Similarly, no contractor believes that their structures will be torn down. Designing and building structures to be taken apart run counter to these professionals' principals. Marketability is always a concern in construction. Many products today are not produced with recycling in mind, just the selling cost.

Manufacturers today focus on generating the least expensive product for the short term. A return to traditional materials and methods means incorporating products and building techniques, which have stood the test of time and are still preferred by home buyers. For example, a vinyl window specified at the time of deconstruction may not be worth reusing or recycling.

Design for Disassembly has been used most frequently in Europe in response to Extended Producer Responsibility (EPR) laws that require companies to take back and recycle their products. The automotive industry pioneered techniques for disassembly that the construction industry can employ. There are currently no EPR laws in the U.S., but private industry may be forced to change its practices as landfills overflow and tipping fees rise.

7.1 Design techniques for allowing component extraction by disassembly

Case study – Dibros Corporation

For an example of potential design changes that could facilitate disassembly a Florida builder was interviewed regarding designing for deconstruction. Dibros principals Miguel Diaz and his son Luis A. Diaz are among many builders in the Gainesville, Florida location. Dibros, in order to make their development more attractive to potential homebuilders, has committed to developing a "neighborhood" using the concepts of New Urbanism. New Urbanism also stresses "traffic calming" through street design and takes the focus away from the automobile and puts the focus on the people. This concept also mixes retail and light commercial businesses with housing. Dibros began planning their community as most builders do, by surveying the land and then planning roads and lots accordingly. However, Luis Diaz decided that instead of having the design dictate the layout, he would let the land dictate the design. Dibros created a Computer Aided Drafting (CAD) plan of the land and marked trees, which ultimately determined the layout of roads, lots and common parks. From the start, this community was developed in a nontraditional manner. Additionally Dibros is interested in new, innovative, environmentally friendly construction materials as well innovative construction techniques.

Components of a Dibros Home

For the purposes of deconstruction, it is important to look at the typical components of a home built by Dibros. Listed in Table 10 are the highest cost items in a typical Dibros home.

Table 10 Highest cost items in a typical Dibros home.

Description	Total Cost ($)	Description	Total Cost ($)
Roof and Floor Truss System	7826	Building Panels	2064
Lumber	6939	Welded Steel Railing / handrail	1920
Wall Covering	5733	Appliances	1901
Stem Wall Concrete	2888	Roofing	1562
Siding	2846	Paint	1357
Drywall	2428	Interior Doors	1226
Framing Hardware	2262	Plaster Stucco	1196

After reviewing this list for items, which warranted further research we eliminated items such as paint and stucco which from a deconstruction standpoint have little value. Further investigation of these components shows the highest cost item, the Roof and Floor Truss System, to be the most expensive item. The trusses are constructed of engineered wood in Melbourne, Florida. The builder agrees that purchasing from a local producer would be less costly. However, Space Coast Truss provides them with excellent quality control. Lumber is the next highest cost category. These components will be further investigated to determine the feasibility of reuse or recommendations for an alternative material.

Foundation Systems and Flooring

The foundation system is a concrete slab and for the house that was examined the finished floor was Hartco wood flooring. Hartco Flooring is a 3/8" glue down laminated wood flooring with true wood layers. It should be noted that flooring and floor covering are subject to physical abuse from feet and heavy objects, and, as the lowest spot in a room, they tend to collect dirt, moisture, and other contaminants. A good flooring material should be highly durable to reduce the frequency with which it must be replaced, and it should be easy to clean. At the same time, softer surfaces may be preferred for reasons of comfort, noise absorption, and style, setting up a potential conflict for the designer. There are also raw material and manufacturing impacts to be considered with many types of carpeting and other floor coverings.

Concrete Slab

The acceptance of concrete slabs comes from a purely marketability standpoint. It takes less time and cost to install. After the service life of the home, the concrete slabs may be reprocessed. The broken concrete can be sent to a ready mix concrete plant that can incorporate crushed concrete (used as aggregate) back into the concrete manufacturing process. The crushed concrete is most often not immediately reused except when it is crushed on site and used as a temporary road base.

Alternative flooring methods are addressed below as to their deconstructibility.

- Carpet systems, including carpet pads and carpet adhesive, have been identified by the EPA as a potential source of indoor air pollution. Although carpet recycling is technologically difficult due to the contaminants and multiple components of used carpet, some companies now have extensive recycling programs. Carpet padding has long been made of recycled materials and is extremely recyclable. One problem with carpet is that it will hold dirt and pesticides, creating a unhealthy environment. The life expectancy of carpet on slab is reduced due to the harsh backing concrete offers.

- Thin wood flooring composites are glued down. Any attempt to remove it will lessen the quality of the material, making it less desirable for reuse. It is essential to ensure the adhesive is not toxic or in any way harmful to the environment for disposal purposes. These products do not take excessive abuse and will not permit numerous resurfacings.
- Ceramic and porcelain tiles have high embodied energy but their durability makes them environmentally sound in the long run. Some high quality ceramic tile incorporates recycled glass from automobile windshields. As a floor covering, tile is durable and recyclable.
- Linoleum cannot be reused and does not contain any recycled content.

Concrete is less forgiving to both the human body and the materials that cover the slab. Concrete slabs can have other problems: cracking from settling and major demolition is required to repair utilities under the slab.

Crawl Space
In comparison to the concrete slab on grade, a crawl space provides many deconstruction options. The construction time and cost are higher but it may provide less maintenance concerns compared to a concrete slab. The alternatives for coverings are the same as for a concrete slab except the following:

- Wood flooring over a crowd space is a return to traditional tongue and groove wood that has always stood the test of time. It does not require excessive resurfacing, provides a cleaner surface, and is more forgiving to the human body and other materials. The quality of floor temperature is also easier to control.
- Area rugs can be incorporated which protect the wood and provide a more favorable environment. Wall-to-wall carpeting can be used with an extended life expectancy. Crawl spaces provide easier and cleaner coordination of utilities, not to mention easier access for maintenance. The space can also be incorporated into a passive cooling system throughout the facility reducing consumed energy.

Framing
Dibros currently uses southern yellow pine framing. Using wood versus steel framing in structures depends on personal preference can benefit either side. From a deconstruction standpoint wood and steel both have advantages and disadvantages.

Wood
Wood is a renewable resource if it is purchased from a sustainably managed forest. This is more difficult than it may initially appear. The process of following the lumber from forest to mill to manufacturer is not easy and is costly. It should be noted that it takes approximately 40 to 50 trees to construct a 2000 square foot house [7]. From a deconstruction standpoint there is a potential to immediately reuse some of the wood salvaged from the site. The wood that cannot be immediately reused may be recycled.

Steel
Although steel is manufactured using a finite resource, it is the most recycled material in North America. Steel framing members contain at least 28% recycled content and generate as little as one cubic yard of recyclable scrap [20]. Steel framing requires approximately 30% more labor to construct than a typical wood framed home. To immediately reuse steel framing members, they must be deconstructed with great care to avoid warping, twisting, or bending during disassembly. Even though the steel may not be available for immediate reuse, all of the steel can be recycled.

Wall Finishes
Dibros currently uses gypsum drywall in 4'*12'*½" sheets with a texture finish veneer plaster.
A disadvantage of drywall is the large amount of waste generated during construction. Drywall generates about 15% of all construction waste and represents the highest percentage by weight of waste in residential construction. For a typical 2000 square feet home, 2000 pounds or five cubic yards of waste is generated. This equates to one pound of waste per square foot of building. Recycled gypsum drywall is available and is becoming more prevalent in the U.S. Specific types of drywall for fire rating and moisture resistance contain products, which can prevent recycling. In addition to the large quantities of waste created in the construction process, drywall has little to no value with respect to material recovery. The drywall acts more as a barrier to the materials that deconstructors are trying to retrieve.

Roofing
Dibros currently uses asphalt roofing shingles. Roofing provides one of the most fundamental functions of the building, shelter. Roofs must endure drastic temperature swings and experience long term exposure to ultraviolet light, high winds, and extreme precipitation. Durability is critical in roofing because a failure can mean serious damage not just to the roofing itself, but to the entire roofing system, building, and its contents. This type of damage multiplies the economic and environmental cost of less reliable roofing materials. Roofing can also have a significant impact on cooling loads. The use of lighter colored, low-solar absorbency roofing surfaces is one of the key measures in life cycle energy costing associated with a home. All roofing options do not allow for immediate reuse and comparisons of the various options are listed below.

Asphalt
Asphalt roofing is the most affordable initial cost option for roofing. Its service life can range from 10 to 30 years depending upon the grade of tile purchased. As far as deconstruction is concerned, the tile may not be immediately reused nor is it readily recycled. Manufacturers publicize the recycling of asphalt roofing in road mix designs, however, the Florida Department of Transportation does not use asphalt roofing in their paving operations. Research is being conducted to incorporate asphalt roofing into mix designs. However the roofing the FDOT is using is waste from the manufacturing process, not waste from the roofs of homes. FDOT reports there is simply too much

contamination and inconsistency in the “take-offs” to use this waste when trying to create a predictable mix design.

Metal
Options for metal roofing include galvanized steel, aluminum, and copper. Metal roofing is an alternative to the common problems experienced with traditional roofing shingles. Metal roofing does cost more initially than a typical shingle or tile roof, but it is actually cheaper because of its longer service life, approximately 3 times that of a shingle roof. In addition to the longer service life, metal roofs have fewer maintenance requirements, provide a better appearance, and a greater value for homes [21]. Because of their low maintenance and long life, steel roofing systems can ultimately be one of the lowest cost roofing materials [22]. The benefit related to deconstructibility of metal roofs is the well-established metal scrap market. Even in regions of the U.S. where there is no deconstruction infrastructure there will often be scrap metal dealers.
Aluminum is also one of the most valuable materials to recycle.

Wood
Wood shingles may not be immediately reused, but may be readily recycled. The expected life of a wood shingle roof, however, is only 15 to 20 years. Building codes require that wood shingles carry a specific fire rating which affects their make up and recyclability.

Polymer Materials
There are a variety of new products on the market made from recycled polymers. One product is made from asphalt and recycled baby diapers, which has the appearance of slate and includes a 50 year warranty. With this composite type material, reuse or re-recycling will be very difficult.

Tile / Concrete
Clay and concrete tiles are also an option where hail is not a serious threat. Both of these roofing options offer excellent service lives. Local availability of these products is an issue due to their relatively high weight, which could result in higher transportation costs. Tile and concrete roof tiles can be deconstructed and the material can be crushed and used in new concrete as aggregate or as roadbase.

Slate
Slate is one of the most durable roofing options with an expected lifespan of over 100 years.
This roofing material is also very expensive yet desirable. Slate is reusable if it is not cracked.
Pre-manufactured nail holes reduce the amount of waste created.

Siding
Dibros currently uses a combination of Hardiplank and concrete stone, depending upon the customer’s specifications.

Vinyl
Vinyl siding has a 20 year warranty because of its innate durability and flexibility. It is installed with nails or other fasteners that increase the labor associated with deconstruction. Vinyl offers low maintenance and it does not need to be painted or stained. However its recyclability is questionable since heating of vinyl produces hydrochloric acid (HCl). Recycling of vinyl results in downcycling, meaning that existing vinyl siding will not be recycled into vinyl siding again, but a product lower on the product cycle chain.

Wood
Wood is a traditional material, just like brick, but unlike brick, it will require more maintenance and has a shorter life. Life expectancy is shorter because of the possibility of termites and weathering. In addition, wood requires continuous upkeep, maintenance, and painting. If wood is properly maintained it may be removed and reused. Removal could be facilitated through the use of screws versus nails.

Hardiplank™
Hardiplank™ is an extremely durable composite made of portland cement, ground sand, and cellulose wood fiber. This product offers a 50-year warranty and is resistant to humidity, rain, and termites. Hardiplank™ is potentially 100% recyclable. However, there is no current recycling process in place.

Brick
Brick offers the best immediate re-use potential. Locally produced brick and stone are long lasting, low maintenance finishes that reduce transportation costs and environmental impacts. Molded cementitious stone replaces the environmental impact of quarrying and transport of natural stone with the impacts of producing cement.

Design for Deconstruction – Some Recommendations
There are four elements in designing for deconstruction:
1. Reuse existing buildings and materials – It is possible for new buildings to be designed facilitate the reuse of existing materials from existing structures
2. Design for durability and adaptability – Longevity is determined by the durability of materials, quality of construction, and by the buildings adaptability to changing needs. Durability needs to be properly balanced with adaptability. Different material life spans must be factored into the design.
3. Design for disassembly
4. Use less material to realize the design

8.0 POLICY, REGULATION, STANDARDS, LIABILITY

Environmental Policy and Incentives - National

There are very few policies in place on a national level that mandate environmentally friendly construction, buildings, designs, and materials. Without policy favoring sustainability, researchers look to the governments to offer incentives that will begin to sway the construction industry when designing and building for the future. Currently there are few incentives, and those that are offered are not nearly enough to persuade business to invest the extra money in designing for the environment. The U.S. EPA runs a program that started in 1992 called Design for the Environment. This program forms voluntary partnerships with industry, universities, research institutions, public interest groups, and other government agencies. The program attempts to change current business practices and to reach people and industries that have the power to make major design and engineering changes. Their ultimate goal is to incorporate environmental considerations into the traditional business decision-making process.

The U.S. Department of Energy, Office of Pollution Prevention, has begun a Pollution Prevention by Design project in an attempt to help engineers, designers, and planners incorporate pollution prevention strategies into the design of new products, processes, and facilities. The problem facing the industry is not the invention, or innovation, but the education and implementation of new techniques and concepts.
Existing Federal Laws and Executive Orders, which pertain to the construction industry, are primarily focused on energy conservation. The following is a listing of these regulations in place:

- Energy Policy and Conservation Act (EPCA of 1975)
- Resource Conservation and Recovery Act (RCRA of 1976)
- National Energy Conservation Policy Act (NECPA of 1978)
- Comprehensive Omnibus Budget Reconciliation Act (COBRA of 1985)
- Federal Energy Management Improvement Act (FEMIA of 1988)
- Energy Policy Act (EPACT of 1992)
- Executive Memorandum ("Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds")
- 10CFR435
- 10CFR436
- Executive Orders: 12759, 12843, 12844, 12845, 12856, 12873, 12902

Over the past two decades, public concern and support for the environmental protection have risen significantly, spurring the development of an expansive array of new policies that substantially increased the government's responsibilities for the environment and natural resources. The implementation of these policies, however, has been far more difficult and controversial. Government is an important player in the environmental arena, but it cannot pursue forceful initiatives unless the public supports such action. Ultimately, society's values will fuel the government's response to a rapidly changing world environment that will involve severe economic and social dislocations in the future. Environmental policy is difficult to predict, the U.S. is moving from a nation that exploited resources without concern for the future to one that must shift to sustainability if it is to maintain the quality of life for present and future generation. If green plans were proposed in the U.S., they would survive the political process [27]. Several states have already implemented their own progressive environmental policies that are stricter than Federal regulations.

Incentives - Two major changes in federal policy are also creating major opportunities for deconstruction: the demolition of public housing under the HOPE VI programs and the conversion of closed military bases across the U.S. If deconstruction were employed in conjunction with demolition to remove public housing across the country, as well as other public and private sector structures, communities could reap substantial environmental, economic, and social benefits for their residents, at little or no additional cost compared to traditional demolition.

Forty-four states and the District of Columbia have set solid waste diversion and/or recycling goals. Several states are beginning to insist on environmental preservation. Blatant disregard for the environment is no longer tolerated. One example is the California Resource Recovery Association, which is actively pursuing manufacturer responsibility legislation.

The California Resource Recovery Association

- *If it can't be assimilated into the environment, then it can only be leased*
- *Anything not biodegradable/recyclable is tagged with its constituents and manufacturer*
- *Mandated deposit laws for certain materials*
- *Mandatory separation of wastes*
- *Mandatory procurement of recycling products for public projects*
- *Product disposal borne at manufacturer level, "advanced disposal fees" for manufacturer wastes*
- *Advanced fees mean that disposal is calculated upfront as part of the costs of producing the product and is internalized by company.*
- *This is like pollution permits, whereby quotas could be traded between those with product stewardship and those without, this would be called a "processing fee"*
- *Eco-labeling and materials labeling is consistent.*
- *Product made with minimum recycled content requirements.*

Federal Government Support

Several federal government agencies demonstrated support for deconstruction by providing financial and technical assistance to pilot projects across the country. The U.S. EPA supported the Riverdale Housing Project. The EPA provided grant funding to the National Association of Home Builders Research Center, the Green Institute, and the Materials for the Future Foundation. In addition to the financial support, the EPA has also provided technical assistance on deconstruction projects. The Department of Health and

Human Services' (HHS), Office of Community Services, The Department of Defense, Office of Economic Adjustment, and the U.S. Department of Agriculture's Forest Products Lab (FPL) have all contributed to the deconstruction research effort. The FPL has been evaluating the grades and strength characteristics of used lumber and timber. They are working cooperatively with lumber grading agencies to develop grading criteria and grade stamps for used lumber.

Case Study: Implementation
Location: Hartford, Connecticut

The City of Hartford, Connecticut, has set aside funding from a state demolition grant to deconstruct 350 abandoned buildings as part of a program to develop deconstruction service companies that train workers for skilled employment.

9.0 BARRIERS TO DECONSTRUCTION

9.1 Consumer Tastes

The successful implementation of deconstruction relies on successful resale of recovered building components. If materials cannot consistently be marketed and sold in a timely manner, it is virtually impossible for deconstruction to be profitable. For this reason, consumer tastes and perceptions concerning used and recycled building materials is often a barrier to the successful implementation of deconstruction. According to *Recycled Construction Product Market (2003),* the most influential persons regarding the purchase of used and recycled building materials are the planners, the builders, and the consumers.

Planners

Architects and landscape architects have the potential for impacting the use of used building materials in new construction. Although architects tend to be more open to the use of used and recycled materials than builders, their perception overall appears to remain negative. Brand or manufacturer loyalty poses one barrier to expanding the use of used and recycled building materials. Currently, architects are more likely to specify a particular product from a product line or manufacturer they trust than to establish a non-brand specification which allows used materials to fill that specification (Recycled Construction Product Market, 2003).

Builders

Builders and their subcontractors play an important role in the selection of construction materials. In an industry whose motto is, “If it was good enough for my father, it is good enough for me,” the movement towards new products is slow (Recycled Construction Product Market, 2003). This attitude reflects real worries in construction, where products that are not up to high standards of quality and safety can cause disastrous accidents. For this reason, builders are the market segment that is slowest to accept used and recycled building materials. Table 20 lists contractors' view of the salvaged building materials.

Table 20. Contractors' view of the salvaged building materials

Contractors' Negative Perception of Recovery and Reuse of Building Materials

Contractors view the use of reused and recycled building materials negatively for the following because they perceive them to have the following characteristics:

- *Dimensional Problems: Contractor's view finding used materials that fit into a pre-dimensioned space as more difficult than purchasing a new product.*
- *Inconsistency in Supply: Contractor's perceive the inconsistent availability of the right quantity and size of used materials as inconvenient.*
- *High Risk: Due to the high personal risk involved when something goes awry in the construction process, builders are reluctant to trust used and recycled products.*
- *Poor Quality: It all boils down to the overall perception that used and recycled materials are of lesser quality than virgin materials.*
- *Expensive: Contractor's tend to view reused and recycled materials to be overall more expensive than virgin materials.*

(Grothe and Neun, 2002)

Consumers

Those people purchasing commercial and residential construction, as well as those renovating buildings, are extremely important in driving the environmentally sound construction movement, including the use of recycled and reused building materials. The prevailing attitude remains that reused and recycled building materials are "substandard but environmentally friendly." Many architects and builders have admitted that they would use more used and recycled products if their clients directed them to do so (Recycled Construction Product Markets, 2003).

Suggestions

Though definitely on the rise, perceptions of reused and recycled building materials must be improved in order for the long term profitability of deconstruction to increase. The following aspects of the industry and consumer perceptions must be addressed in order to rectify the many doubts consumers have concerning recycled and reused building materials.

- **Information Availability –** Aided by the numerous industry associations discussed and increased publicity, information accurately explaining the benefits of recycled and reused building materials has become much more accessible over the last few years. However, as a whole, public knowledge concerning these products is too low. The natural increase in available information and networking that will occur naturally as the industry grows should help to rectify this problem.

- **Overcoming the Perception of Risk –** Because of the perception of risk, products must show they perform as well or better than virgin products. Component recertification processes must be refined and standardized before this can occur. Additionally, recycled products should be tested and certified in order to offset the high-risk aversion of the industry.

In the end, the increased use of reused and recycled building materials is in the hands of the architects, builders, and consumers that use them. Slowly but surely, perceptions have become increasingly positive over the last few years. The natural trend towards increased social and environmental responsibility, along with the maturation of the deconstruction industry, will aid in the effort to improve perception of reused and recycled building materials. This will increase the profitability of the building materials salvage market, making deconstruction a more desirable business alternative.

9.2 Lack of Design for Deconstruction Strategies

The aim of design for deconstruction is for the next generation of buildings to be more efficiently disassembled at the end of their useful lives. More efficient disassembly implies a process that is quicker, causes less damage to recovered building components, and is safer for the workers involved. The problem facing the industry today is that the benefits of design for deconstruction will not be realized until many years from now. Currently, the lack of design for deconstruction in the buildings that are coming to the end of their useful lives is a major barrier to efficient and profitable deconstruction (Chini and Balachandran, 2002).

Buildings that are approaching the end of their useful lives today were not built with deconstruction in mind. Deconstruction is a fledgling industry, much younger than the houses being deconstructed. There are several aspects of design for deconstruction that are currently hindering the materials recovery process. These are lack of kept construction records, abundance of hazardous materials, use of adhesives to hold fasten building components, and lack of labeling of labeling building components.

Construction Records

Today, buildings to be deconstructed do not contain of the original construction information. This lack of information drastically decreases the speed and efficiency of the deconstruction process. The presence of blueprints, materials lists, location of wiring systems, and photographs of connections used in the construction of the building would aid in the planning and implementation of its dismantling (Guy, 2001).

Abundance of Hazardous Materials

Government policies concerning hazardous materials abatement are higher for deconstruction than they are for demolition. This is due to the higher exposure levels for deconstruction workers. These stringent policies increase the cost and time necessary to complete a deconstruction project. Additionally, hazardous materials drastically increase the salvageability of building components. Design for deconstruction will focus on limiting the presence of hazardous materials.

Use of Adhesives

The use of various glues and adhesives in the installation of building materials may increase the stability of those building systems but it serves to decrease the efficiency of the deconstruction process and increase the likelihood of damage during extraction. This is particularly true with glue use on wood products and the grouts used in masonry construction. The glues previously used in wood construction tend to cause splitting and cracking of the wood during extraction. Certain mortars used to bond bricks are not conducive to later separation and cleaning of the bricks. It is only possible to clean bricks that are bonded with soft lime mortar. Those bricks that are bonded with Portland cement based mortar cannot be effectively separated and cleaned.

Currently, it is not standard practice for building components to be labeled before installation. The recovery process is slowed by the necessity to identify the components makeup, how it was fastened, what kind of chemicals may or may not be present, etc… Design for deconstruction will identify issues involving labeling of building components to speed up the deconstruction process.

9.3 Lack of Tools and Training

*Tool*s

The successful large scale implementation of deconstruction in the United States is contingent upon increasing the efficiency of the deconstruction process. Currently, time constraints pose a legitimate threat to the growth of the deconstruction industry. In the construction industry, where time is of the essence, the extra time involved to remove a building via deconstruction, as opposed to removal through demolition, may be a deterrent. Additionally, time is money in the construction industry. The level of efficiency on any project is directly proportional to its profitability, deconstruction must become a more profitable industry if it is to implemented on any substantial level.

Several factors are limiting the efficiency of the deconstruction process. As discussed earlier in this chapter, the lack of design for deconstruction has a negative effect on its efficiency. However, the benefits of designing buildings for disassembly will not be felt until the useful lives of the next generation of buildings have expired. There are other factors affecting the efficiency of deconstruction that can be and are being improved right now. One of the major factors affecting the efficiency of the deconstruction process is the current lack of tools available that stimulate the speed of deconstruction while minimizing the damage incurred by recovered materials.

To date, the tools used during the deconstruction process have generally been the same hand tools used in the construction process. These tools were not designed with the efficient, safe disassembly of buildings in mind. For example, crow bars are frequently used tools on deconstruction sites for prying apart building components such as wooden planks. However, a crow bar was designed to pry apart wooden planks without damaging them. Consequently, the planks are often split during extraction. This damages the wood, reducing its reusability and thus its resale value. Tools must be developed that facilitate the speed and safety of materials recovery during deconstruction while at the same time minimizing the damage incurred by those materials.

The following case study examines a tool that has already been developed to speed up the deconstruction process. The Nail Kicker, developed by Reconnx, is used to remove nails from wood (table 21). According to Reconnx, at a labor rate of $7.50/per hour, a $439 Nail Kicker powered by a $350 air compressor pays itself off.

Table 21. Reconnx Nail Kicker – a new tool for deconstruction

Case Study: Nail Kicker by Reconnx   *The Nail kicker is a handheld pneumatic denailer, similar to a nail gun, that kicks nails out of lumber without destroying the wood. The Nail Kicker serves to increase the speed and automation of the usually labor-intensive task of deconstructing wood-framed buildings. By minimizing the damage caused to the wood, the Nail Kicker also increases cost-effectiveness of lumber salvage and reuse. The Nail Kicker is up to 4 times faster than pulling nails with the back side of a hammer. It can kick nails byg and small out of plywood, flooring, and even 2x materials.*   *(Reconnx, 2003)*

Another company that is designing tools to increase the efficiency of deconstruction is Auburn Machinery, Inc. of Auburn, Alabama. Auburn Machinery is developing planning machines that resize waste lumber into standard sizes, while at the same time removing unwanted paint and chemicals from the surface of the wood (Table 22).

Table 22. Auburn Machinery Wood Recovery machine

Case Study: Auburn Machinery, Inc. ***Auburn, Alabama*** *Auburn Machinery is developing machinery for planning and ripping serves to resize and resurface non-uniform recovered wood products. These machines also serve to remove lead-based paint or other unwanted chemicals from the surface of recovered wood. Additionally, Auburn is developing material handling devices that aid in the sorting, stacking, and labeling of recovered products. The goal of these products it to promote the efficient transformation of recovered wood into usable products.* *(Auburn Machinery, Inc., 2003)*

Training

The implementation of deconstruction as a widespread building removal technique remains slow while the knowledge of its potential benefits is rising rapidly. One reason for this may be that builders and demolition contractors are reluctant to pursue that which they are not familiar with. The lack of deconstruction training available is thus a barrier to its growth as an industry. Development of programs that promote deconstruction of buildings as an alternative to traditional demolition by training contractors how to effectively dismantle structures with the purpose of reclaiming materials will facilitate the full-scale implementation of the deconstruction industry. One such program is already being developed. ReSource 2000, a program developed by the Boulder Energy Conservation Center, has begun a program aimed at training contractors about the deconstruction process.

9.4 Lack of Markets for Used Components

The economic structure of the deconstruction industry requires that the recovered materials be sold in order to achieve any level of profitability. Thus, access to salvaged materials markets is a critical element to the successful implementation of deconstruction. At this juncture, a lack of markets for used building materials is a barrier to deconstruction. The strength of the used building materials market in a given area is directly related to the area's local attitude toward used building materials and the population and location of the area.

As discussed earlier in this chapter, perception of low value of salvaged building materials remains a problem in the construction industry today. This perception of low value has a direct influence on the demand for salvage materials. Thus, the presence of negative perception has an adverse affect on the market for used components. As time passes, the continued effort of the deconstruction industry to educate the public on the benefits of using salvaged building components will serve to alleviate this issue.

Large metropolitan areas tend to support the strongest used building materials markets. There is obviously a positive correlation between the size of a city and its demand for consumer goods. Additionally, the available building stock for deconstruction will tend to be greater in highly developed areas such as large cities. The following case study examines the used building materials market in Milwaukee, Wisconsin, where implementation of deconstruction has been very successful (Table 23).

Table 23. Used building materials market in Milwaukee, Wisconsin

Case Study: Used Building Materials Market – Milwaukee, Wisconsin

Milwaukee has been very successful thus far in its local efforts to implement deconstruction. One of the major factors in Milwaukee's success has been the well developed used materials market in the area. Milwaukee itself is a decent sized city. Additionally, Milwaukee is closely located to the large Metropolitan areas of Chicago, Illinois and Madison, Wisconsin. This has facilitated the smooth distribution of used building materials. Milwaukee's public perception of used building materials is high due to the high level of public education concerning the benefits of deconstruction and materials salvage. Milwaukee public officials have been very supportive of deconstruction activity and have developed guidelines for recovered wood in residential and commercial buildings.
(Grothe and Neun, 2002)

Export Markets in border and port cities create an additional market for used building materials (feasibility). These markets have the capability to increase the consumer base for deconstructed materials exponentially. The following case study examines the export market for used building materials in Miami, Florida (Table 24).

Table 24. Export market for used building materials inMiami, Florida

Case Study: Export Market for Used Building Materials – Miami, Florida

Export of used building materials is a strong market in the Miami area, and exporters were identified as a major customer group for recovered materials. Several used building materials markets in the Miami area sell approximately half of their material to exporters from Central American and Caribbean countries. One exporter to Belize sends a truck to purchase materials from a used building material retail operation on a monthly basis. Top selling items include windows, doors, iron bars, awnings, shutters, cabinets, toilets, and sinks.
(Grothe and Neun, 2002)

So far in this discussion it has been established that large, port cities with high public perception of used building materials have the most healthy markets for used materials. Then problem facing the deconstruction industry at this point is that the majority of towns in the United States do not enjoy this combination of characteristics. A major focus of the construction industry must be to network together those areas that may not be able to establish strong reuse markets with those that can. The use of the internet creates an additional medium to obtain and sell used building materials. "Internet sales have the potential to change existing market relationships by allowing end users to purchase materials at reduced prices from sources other than their traditional supplier" *(Grothe and Neun, 2002).* Currently, Internet sales are more conducive to the sell of high-end salvaged building materials because of the intensely high demand for these goods, particularly high-quality structural timbers. Low-end materials do not benefit as well from the internet because added shipping and processing fees tend to negate the money saving benefits of these materials. The following case study examines the Used Building Materials Exchange, an internet site aimed at providing an international network of salvaged materials distributors (Table 25).

Table 25. Used Building Materials Exchange website.

Case Study: Used Building Materials Exchange *The Used Building Materials Exchange is an internet site created to facilitate the movement of used building components. Members of the website can post listings, similar to classified ads, advertising the components that they are selling or those that they are looking to obtain. Generally, a listing for would identify the component for sale, the price, the name of the seller, and the seller's contact information. The advantage of the Used Building Materials Exchange is that facilitates the globalization of the building materials reuse market.* *(Used Building Materials Exchange, 2003)*

CONCLUSIONS

Deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the materials. Deconstruction is emerging as an alternative to demolition in the US and around the world. Techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at several institutions, and some government agencies are realizing the advantages of deconstruction over demolition by funding research in area of deconstruction and materials reuse. In addition, young, rapidly expanding industries on deconstruction and used building materials are forming to efficiently bridge the logistical gap between building materials recovery and building materials resale. A number of associations are formed to bring companies together in order to promote networking, information exchange, lobby for government support, and improve the efficiency of the industry.

Designing buildings to be built in ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. The first international conference on deconstruction and materials reuse was organized by the Powell Center for Construction and Environment at the University of Florida on May 7-10, 2003 in Gainesville, Florida. This conference was an excellent forum for exchange of information among research organizations, practitioners, manufacturers, and used building materials businesses around the world. The conference Proceedings (CIB Publication 287, 2003) includes thirty six papers that address the key technical, economic, environmental and policy issues needed to make deconstruction and reuse of building materials an alternative to demolition and landfilling.

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