DECONSTRUCTION AS AN ESSENTIAL COMPONENT OF SUSTAINABLE CONSTRUCTION

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ABSTRACT

In the hierarchy of actions required for closing the materials loop, protecting the environment, and conserving resources, deconstruction and materials reuse ranks above recycling and just below minimizing the mass of materials used in the built environment. This paper will present an overview of the issues of deconstruction and materials reuse and describe why deconstruction is an absolutely essential for creating a sustainable built environment. The issues covered will include deconstruction tools and techniques, environmental issues and impacts, economics, policy initiatives, building code considerations, and materials reuse markets. An overview of the work of CIB Task Group 39 will be provided, indicating the status of deconstruction and materials reuse in a variety of countries worldwide. Examples of deconstruction and materials reuse activities will be provided from Australia, Israel, Japan, The Netherlands, Norway, the U.K., and the U.S. The future agenda of TG39, to include Design for Deconstruction, will also be addressed.

KEYWORDS:

Deconstruction; materials reuse; resource conservation

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., demolition waste amounts to 92% of the total construction and demolition (C&D) waste stream of 136 million tonnes annually or about 125 million tonnes of demolition that is for the most part landfilled. In the Netherlands, C&D waste amounts to 15 million tonnes per year; however due to a high degree of environmental awareness and government regulation, over 80% of this waste stream is recycled, mostly into subbase for roads.

In general, more careful consideration of the priorities for disposal of materials from demolition and construction operations needs to be put into place to minimize virgin materials extraction and the energy needed to process used materials for further use. Figure 1 indicates just such a scheme and places reduction in materials use at the top of the materials waste processing hierarchy because this produces the most beneficial effect for natural systems. Reuse is just below reduction of materials use and includes both deconstruction and component/materials reuse.

Deconstruction of buildings has several advantages over conventional demolition and is also faced with several challenges. The advantages are an (1) increased diversion rate of demolition waste from landfills; (2) potential reuse of building components; (3) increased ease of materials recycling; and (4) enhanced environmental protection, both locally and globally. Deconstruction preserves the invested embodied energy of materials, thus reducing the input of new embodied energy in the reprocessing or remanufacturing of materials. A significant reduction in landfill space can be a consequence. For example, in the U.S. where C&D waste represents about one-third of the volume of materials entering landfills, a diversion rate of 80% as is being experienced in The Netherlands would preserve increasingly scarce land for other optional uses.

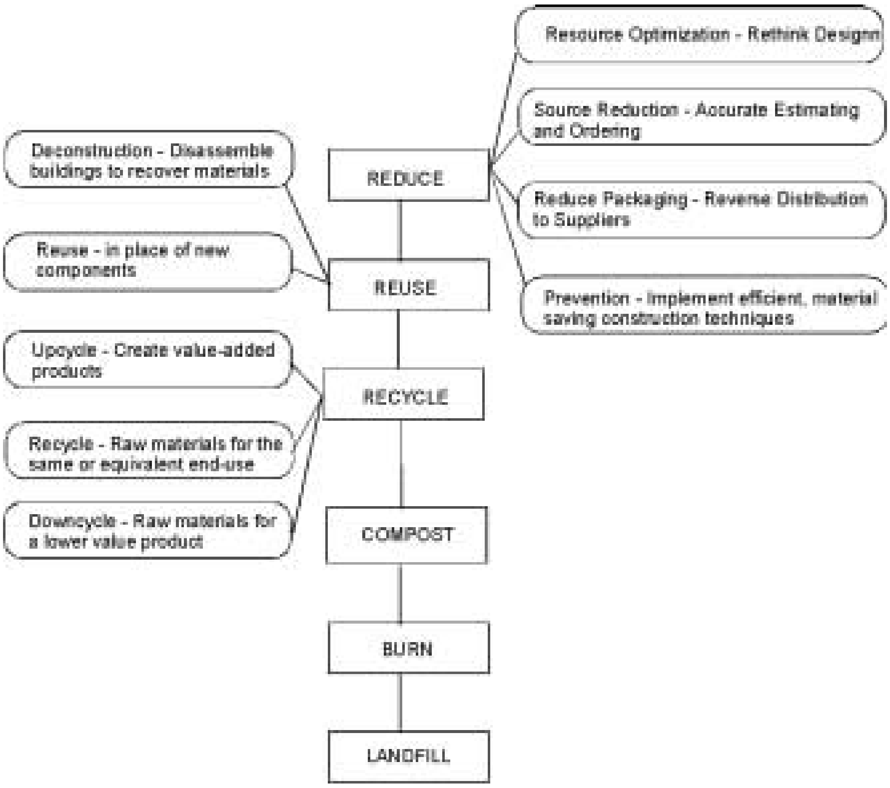

Figure 1 Waste Management Hierarchy for demolition and construction operations

The challenges faced by deconstruction are significant but readily overcome if changes in design and policy would occur. These challenges include: (1) existing buildings have not been designed for dismantling; (2) building components have not been designed for disassembly; (3) tools for deconstructing existing buildings often do not exist; (4) disposal costs for demolition waste are frequently low; (5) dismantling of buildings requires additional time; (6) re-certification of used components is not often possible; (7) building codes often do not address the reuse of building components; and (8) the economic and environmental benefits are not well-established. Again, these challenges generally fit into one of two categories: design or policy.

ESTABLISHING DECONSTRUCTION

Implementing deconstruction is not a simple task. Successful implementation cannot occur without a support structure of government, regulations, and businesses working together toward a joint goal. Deconstruction can result in environmentally sound community economic development through the formation of partnerships between non-profit social service and environmental organizations, government agencies, and the private sector (Catalli, 1997). It is necessary to first educate and train those who are potential deconstructors. Individuals working in the field of demolition are primary targets. In addition to education and training, outlets for the salvaged materials must be created. Deconstruction can supply useful materials to building materials yards, recycling centres and remanufacturing enterprises, which in turn can create additional jobs and community revenues.

Influence Factors

Although the optimal solution for the environment is to salvage all materials, this is not the optimal economic solution for most starting deconstructors. The optimal economic solution results from many factors. Each of these factors changes based on location, building types, and regional markets. The overall economic situation plays a key role in implementation. The economics of the region, economics of the people in the region, and the economics of businesses are all contributing factors. Following money, the influences most often heard by business are regulations, mandates, laws, and incentives. Without a legal or an economic push to reduce, reuse, and recycle, the effort is often ignored. The construction industry, comprised mostly of midsize construction firms, operates under a tight profit margin (usually around 5%). As in most industries, the construction and demolition companies are not willing to jeopardize this profit margin by implementing reuse programs or expanding their demolition practices to deconstruct if the company will not realize an immediate and significant profit. Most businesses feel it is simply not worth the financial risk to be environmentally friendly.

National Availability of Buildings

In looking at the demolition and deconstruction industry it is important to identify the feedstock for this industry. Nationally, regionally and locally building types vary drastically. The building stock also varies based on classification - i.e. industrial, residential, or commercial. Availability of buildings is not the issue so to speak; it is the availability of buildings worth being deconstructed (CIWMB, 1997). Currently it is necessary to be extremely choosy in the selection of a building for deconstruction. Contractors still rely on their old cherry picking rule of thumb to deconstruct only those buildings that appear to have historically high value materials.

Tipping Fees

There is a correlation between regional tipping fees and the efforts of industry to find alternative waste disposal methods. As tipping fees rise, the cost of doing business related to demolition, renovation, and new construction also rises. Inflation and markets also affect tipping fee prices.

While higher tipping fees create more incentives for earth friendly waste disposal alternatives, they are not the only driving factor. There are many areas throughout the nation that experience high tipping fees but show no signs of implementing deconstruction or mandating reuse or recycling. In these regions the tipping fees are simply considered the cost of doing business. As landfills close and tipping fees rise, the construction industry passes the increased expense of waste disposal to the owner of the construction project who in turn passes the extra expense along to society in the form of rent or the new purchase price. Society needs to decide where the money should be spent, either in preserving the environment now or footing a higher bill later.

Feasibility and Market

Determining the feasibility and market for deconstruction plays a key role in its success. A network of businesses must be created to allow for the smooth flow of goods. The product flow of deconstructed materials mimics the traditional flow of materials. Traditionally, materials follow resource extraction, to manufacturing, to marketing and distribution. Deconstructed materials must follow a similar pattern, however in this case, the definition of the stages of flow change. Traditional resource extraction, what we think of as mining, for example, is now changed to physically removing materials - deconstructing - to acquire the valuable resources. When thinking of manufacturing, we think of changing raw materials into desirable products. The new definition of manufacturing in this case is taking the salvaged items and performing repairs, rectification, or adaptation to what society needs. Marketing at this stage is similar to that for new products. A clientele must be established to facilitate the flow of these products back into circulation. Marketing requires not only a supply of these products, but also a need, if not demand, for these deconstructed materials.

Builders must make tradeoffs when it comes to reusing “older” materials. Use of salvaged materials can be both beneficial and detrimental. On the positive side, for example, salvagers may have the option of deconstructing an old factory floor made of solid old growth wood. This product is not only in demand, but valuable and difficult to find in today’s market. At the other end of the spectrum, old plumbing fixtures, such as toilets, may be salvaged. When considering their reuse, it is important to consider the tradeoffs of not selecting a newer low flush toilet. Examining at these choices - saving landfill space or saving water - forcing us to determine the primary concerns of society: How will society choose to allocate its limited resources? How many years of potable water remain? What technological advances may be made that may change society’s conservation focus?

Environmental Policy and Incentives

Without policy favouring sustainability, researchers look to the governments to offer incentives that will begin to sway the construction industry when designing and building for the future. 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 (Kraft, 1997). 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.

Barriers to Implementation

The use of salvaged materials can only be successfully implemented if there are not lower cost new materials that will serve the same purpose. Currently the sale of antique or historical materials is successful. However, the sale of salvaged windows, for example, which may not have the same energy efficiency of new windows, may carry other detrimental environmental affects. The bottom line is that the salvaged materials either need to be less expensive than the new materials or have some characteristic that makes them unique to and interesting to the buyer.

It is necessary to have knowledge, incentives, and coordination. The main problem is the transfer of knowledge. To facilitate this transfer of knowledge, researchers must move slowly to determine the feasibility of existing alternatives. Many environmental strategies are not possible, either as a result of existing regulatory barriers, economic constraints, or lack of public acceptance. Currently, the largest barriers to non-traditional construction and demolition techniques are cost and attitude. The primary concern of business is to make a profit. At the present time, in most regions, it is not cost effective to alter traditional, tried and true techniques. Another challenge is changing the industry's attitude, or more to the point, grabbing the attention of industry long enough to provide them with the appropriate tools to make an educated decision about their building options.

Project time requirements

Project time constraints can limit options with respect to deconstruction. Often by the time the demolition contractor is contacted, the project owner is under a time constraint requiring construction to begin in a matter of days. This time constraint will not allow for the deconstruction process to occur. The deconstruction process requires significantly more time than traditional demolition. Possible alternatives such as mandatory waiting periods for demolition in addition to public announcement/ advertisements and or direct contact with demolition/ deconstruction contractors to increase their awareness of the opportunity could be an invaluable incentive to increase deconstruction.

Salvage Material and Market Variation

Due to the wide variety of buildings available for deconstruction there is a variety of materials produced from this disassembly (Franklin Associates, 1998). The uncertain quality and quantity of this used building materials feedstock means that users cannot rely on a constant and consistent supply. For those willing to use these materials, this inconsistency is a great disincentive.

Market Demand

The market demand for old growth high quality large timbers will always exist, however there is very little existing demand for denailed standard dimensional lumber. The cost of new materials is simply too low to drive the consumer to venture to other markets for building materials - markets such as salvaged materials. It is possible that the new material supply could be subject to a future disposal cost fee as in Europe where manufacturers of products are charged the disposal cost of their packaging materials. In the German automotive industry, the manufacturer is required to "take-back" and properly dispose of the vehicle after use. The major problem with assigning responsibility for product disposal is the change in ownership of building and the rate at which construction companies go out of business.

Land Value

Land value often dictates redevelopment or new development. These efforts should be concentrated in areas where land is scarce and costly, where people are more likely to redevelop than simply develop. Emphasis can also be placed on areas where land is relatively inexpensive. Developing new land results in an infrastructure burden and the unnecessary development of pristine undisturbed land.

Mechanical Properties of Reclaimed Materials

Although public interest in utilizing recycled wood resources is increasing, several technical constraints hinder widespread acceptance. These technical obstacles hinder general acceptance in the marketplace and more specifically, acceptance by building officials at the jobsite. Existing grading rules can be used to grade recycled lumber using the general requirements for sizing, grading, and marking of softwood lumber (Falk, 1999). Neither rules nor standards specifically address the use of recycled lumber or the characteristics that distinguish it from new lumber.

In summary, several key factors influence the successful establishment of deconstruction. In general, European countries, governments, and individuals have some level of environmental literacy. These countries also lack the land needed to simply landfill mass quantities of waste. The lack of space for waste results in high disposal costs and therefore alternatives to traditional disposal are readily accepted. These alternatives tend to be progressive and inventive simply out of financial need and environmental awareness. Unfortunately, these conditions are not present in the U.S. Many factors, in addition to those previously stated, influence the establishment of a successful deconstruction market sector. Factors such as population, tipping fees, existing supporting infrastructure, and building feedstock for deconstruction process all influence the potential for deconstruction.

Designing 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 conceptualise their buildings as being timeless and no designer intends on spending intensive labour creating a building only to be torn down. The designer's perception is that the building will stand forever. Similarly, no contractor believes that his or her structure will be torn down. 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 homebuyers (NAHB, 1997). 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.

INTERNATIONAL OVERVIEW

The initial meeting of CIB TG39 at the Building Research Establishment (BRE) in Garston, Watford, U.K., was held to assess the status of deconstruction in a variety of countries around the world. Country reports were presented from Australia, Germany, Israel, Japan, The Netherlands, Norway, the U.K., and the U.S. Below is a brief summary of deconstruction in a selection of these countries, which represents the differences and commonalities in these locations.

Australia (Philip Crowther, Queensland University of Technology)
The total waste stream in Australia is about 14 million tonnes of which somewhere between 14% and 40% is C&D waste. Deconstruction of 70 to 100 year old timber houses in Australia is a common practice with about 80% of the materials being recovered and reused for renovation and remodelling of existing homes or in the construction of new, replica housing. Additionally the relocation of houses is a common practice, with 1,000 homes being moved in the Melbourne area each year out of a total housing stock of 800,000 units (See Figure 2). For residential structures it is estimated that between 50% and 80% of materials are recovered in the demolition process. The recovery of materials from commercial buildings is significantly lower with a total recovery rate of about 69% (58% reuse and 11% recycled). In Australia up to 80% of concrete is processed to recover the aggregates for reuse in construction. For modern housing, the emergence of new systems of prefabricated buildings allows the potential deconstruction of the housing stock in the future. EcoRecycle Victoria provides guidance for waste minimization in construction and demolition including *Tender Guidelines for Construction and Demolition Projects* and includes the consideration of deconstruction as an element of the tendering process (Crowther, 2000).

Figure 2 Relocation of typical residential structure near Melbourne, Australia (Philip Crowther)

Germany (Frank Schultmann, Deutsch-Französisches Institut für Umweltforschung (DFIU)
The demolition waste stream in Germany is estimated to be about 45 million tonnes per year of which about 25% is concrete and 50% is bricks and stone. Between 1991 and 1999 several case studies on deconstruction were conducted and revealed an exceptionally high recovery rate, in excess of 95% for many structures. Recent studies are looking at deconstruction methods and show that optimised deconstruction combining manual and machine dismantling can reduce the required time by a factor of 2 with a recovery rate of 97%. The Deutsch-Französisches Institut für Umweltforschung (DFIU) in Karlsruhe has several research programs underway that are investigating various aspects of deconstruction. One of these is the process of auditing an existing building for its deconstruction potential for the purpose of predicting the cost of dismantling the building versus the value of the

extracted materials. Computer models have been developed to assist in this process and cover both the technical and economic aspects of deconstruction (Schultmann, 2000).

Israel (Amnon Katz, Technion - Israel Institute of Technology)
The amount of construction waste in Israel is estimated to be 350 to 700 thousand tonnes per year. Deconstruction activity is currently relatively low due to the type of construction (reinforced concrete frame with plastered concrete block walls), small number of structures to be demolished, and the lack of willingness of the public to accept second hand materials. Design for deconstruction initiated the development of a 4-story pre-cast parking garage that can be dismantled and relocated according to market demands. The need to relocate army camps has also initiated careful planning for deconstruction of existing buildings in closing camps to maximize reuse of the building elements (Katz, 2000).

Japan (Mikio Futaki, Building Research Institute- Ministry of Construction)
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. The waste disposal and recycling system in Japan is based on ‘The law concerning waste disposal and public cleanliness’ which was passed in 1970. Starting in 1988, substantially stronger waste reduction and recycling laws were introduced and additional laws were passed between 1991 and 2000. The major law addressing recycling was passed in 1993 (The law concerning the promotion of recycled material use: Ministry of Health and Welfare) and new government policies based on this law were enacted.
For buildings beyond a certain minimum size, selective dismantling to recover specific materials such as concrete, asphalt, timber and wood products is required. It is expected that these requirements will expand and recycling will increase in the future (Futaki, 2000).

The Netherlands (Bart te Dorsthorst, Ton Kowalczyk, Koen van Dijk and Pauline Boedianto, Delft University of Technology)
C&D waste in The Netherlands is generated at a rate of 14 million tonnes per year. Strict government regulations ensure that about 80% of these materials are reused in other construction, generally in creating materials for road base. The Dutch Government passed a law on the first of April 1997 which in short states that “...dumping of reusable building waste is prohibited,” thus forcing even higher rates of recovery. Reusing components of existing buildings is hampered by two factors. First, the building stock is comprised largely of reinforced concrete structural materials that are difficult to take apart and for disassembly they must be sawn apart. After disassembly, the recovered component must undergo testing prior to its direct reuse as a slab, column, or beam in a new building. Second, recovered components such as brick are costly to remove and process and are therefore not competitive with new products. Efforts are underway to begin the process of informing architects and other actors in the construction industry about the potential for designing buildings for deconstruction The Dutch authority promotes development of demountable precast concrete elements instead of conventional cast-in-place structures. Figure 3 shows a demountable precast concrete system (Dorsthorst, et al., 2000).

Norway (Lars Myhre, Norwegian Building Research Institute)
Total C&D waste in Norway is about 1.5 million tonnes per year of which 978,000 tonnes is demolition waste. In the Oslo region, between 25% and 50% of this waste stream is estimated to be recycled or reused (See Figure 3). Significant private and public initiatives are underway with a goal of reducing the C&D waste stream by up to 70%. The GAIA group of architects is promoting perhaps

Figure 3 The MXB-5 demountable precast concrete system with dry-mounting method

the most ambitious plan for including design for deconstruction in planning. They established the "Building System for Reuse" or BfO system which decouples building systems, eliminates the uses of composites, and relies on traditional, locally produced building materials and well-known simple technology. The BfO system includes 88 standard wood and concrete components that can be assembled into a wide variety of configurations. The ability to easily assemble and dismantle the components also allows the capability of easily changing or reconfiguring the building to meet the user's needs over time. A follow on project that takes advantage of the BfO system is called ADISA or Assemble for DIS-Assembly and consists of 45 standardized components with space planning based on a module of 600 mm. Presently a pilot project at the Prestheia eco-village is building 19 dwellings using the ADISA system (Myhre, 2000).

Figure 4 Disassembly of log house in Norway

United Kingdom (C. McGrath, Building Research Establishment; S.L. Fletcher, Sheffield University; H.M. Bowes, University of Salford)
Within Europe as a whole C&D waste amounts to some 180 million tonnes each year with only about 28% being reused or recycled. Throughout the UK 53 million tonnes of C&D waste are produced annually with approximately 24 million tonnes of inert C&D waste being recycled. Construction waste comprises inert and active wastes that if mixed, will incur the higher landfill tax rate (£11/tonne). Separated wastes can incur lower landfill tax rates (£2/tonne), are much more suitable for recycling and reuse, and can become an asset rather than a liability. The introduction of the landfill tax in 1996 has contributed to a big increase in the number of fixed and mobile crushing and recycling sites. Estimated at fewer than 100 sites in 1994 there are now thought to be more than 400 of these sites. Approximately 3 million tonnes of C&D waste is reclaimed as shown in Table 1.

Table 1 - Size of reclamation industry and market (U.K.)

Sector	**Sales £ million**	**Employment**	**Tonnes 000's**
Architectural antiques			
Stone	17	2100	71
Timber	4	1100	7
Iron & steel	4	800	7
Clay	1	800	2
Ornamental antiques			
Stone	16	1170	22
Timber	36	1740	22
Iron	9	1000	9
Clay	1	100	1
Reclaimed materials			
Timber beams	42	3600	137
Timber flooring	29	2960	105
Clay bricks	31	4300	457
Clay roof tiles	63	3600	316
Clay and stone paving	19	1300	694
Stone walling	29	2450	1118
Salvaged materials			
Iron and steel	11	2800	77
Timber	36	7800	383
Antique bathrooms			
Sinks, baths, taps, WCs	41	1900	1
TOTAL	**389**	**39520**	3430

Reclamation involves less processing, greater employment and is often a more efficient use of resources than recycling. Therefore if deconstruction was a standard process, it would in turn increase the amount of materials being reclaimed and have many benefits for new construction and society (McGrath, et al., 2000).

United States (Charles J. Kibert, Abdol R. Chini, and Jennifer Languell, University of Florida)
Deconstruction and materials reuse in the U.S. is highly decentralized and growing rapidly, especially in areas of the country where construction and demolition waste disposal fees exceed $50 per tonne. The main actors at present are the federal government and non-profit organizations. The federal government, while in the process of closing excess military bases, is including deconstruction as an alternative to demolition for removal of older buildings. Dimensional lumber and wood beams have historically been the most prevalent materials used in the construction of homes and the wood in pre-World War II housing is of particular interest due to its high quality. The U.S. Forest Products Laboratory has been engaged in research efforts to re-grade western lumber extracted from buildings

so that it can be re-certified for new construction. A similar effort has been underway at the University of Florida to re-grade Southern Yellow Pine, the most common source of wood in the southeast U.S. Figure 5 shows progress in the deconstruction of a church in Gainesville, Florida as part of a research project by the Centre for Construction and Environment at the University of Florida to assess the economics and techniques of deconstruction (Kibert et al., 2000)

Figure 5 Deconstruction of a Unitarian Church in Gainesville, Florida

CONCLUSIONS AND RECOMMENDATIONS

As its primary purpose, 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 that comprise the structure. Deconstruction is emerging as an alternative to demolition around the world. 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 in ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. CIB TG39 is in the process of conducting a 4-year study of deconstruction and coordinating an exchange of information among research organizations and practitioners around the world.

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