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.

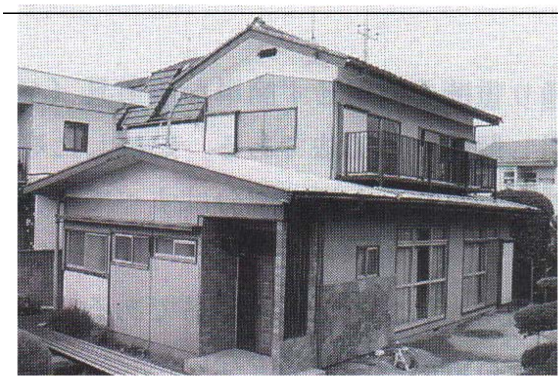
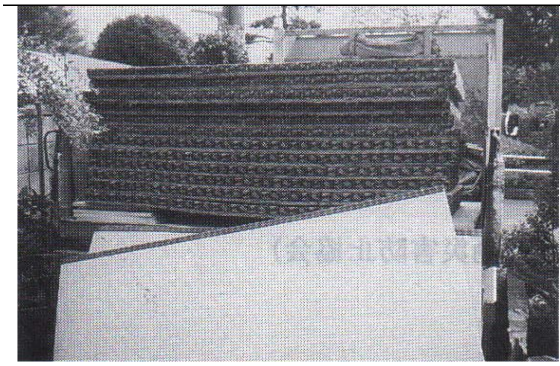
Mechanical demolition combined with manual demolition

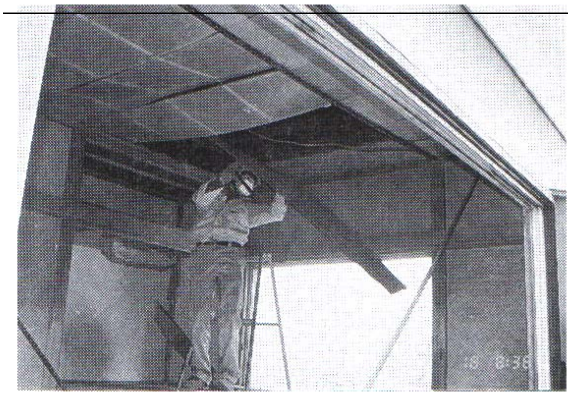
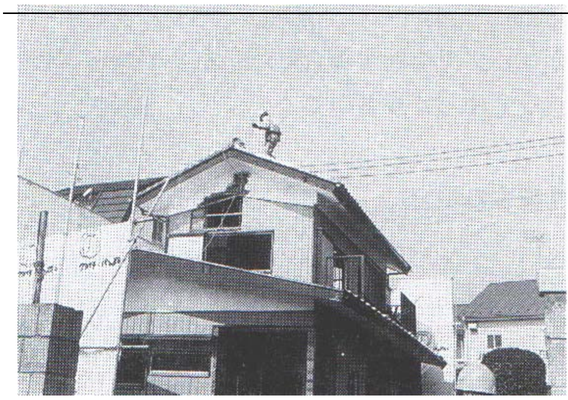
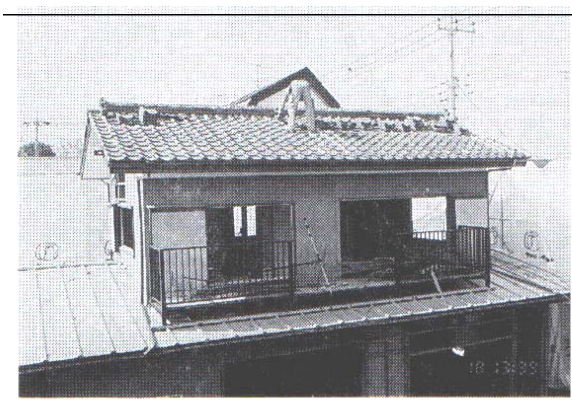
Where direct mechanical demolition is impossible due to site conditions, manual demolition is partially applied beforehand to prepare for mechanical demolition. This is followed by source-segregated mechanical demolition.

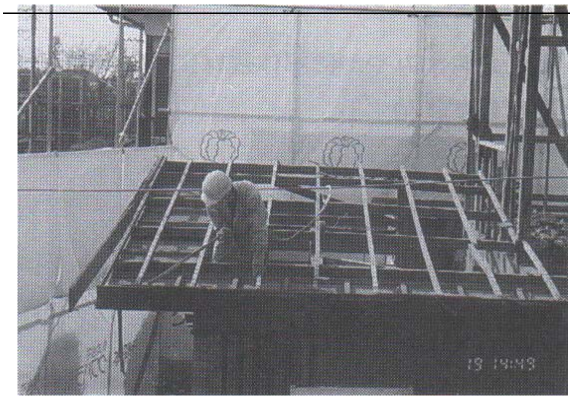
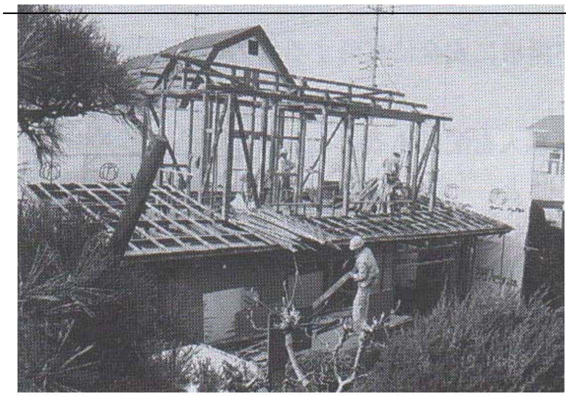
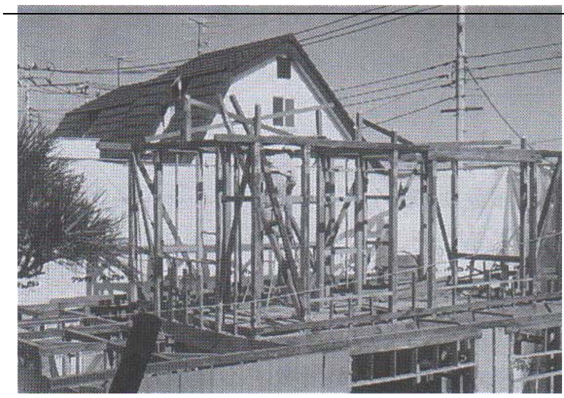
Unsegregated demolition

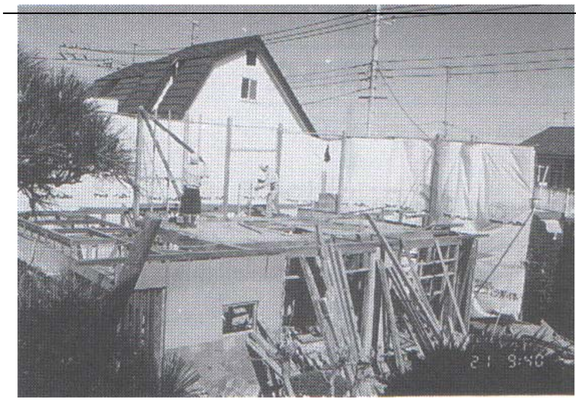
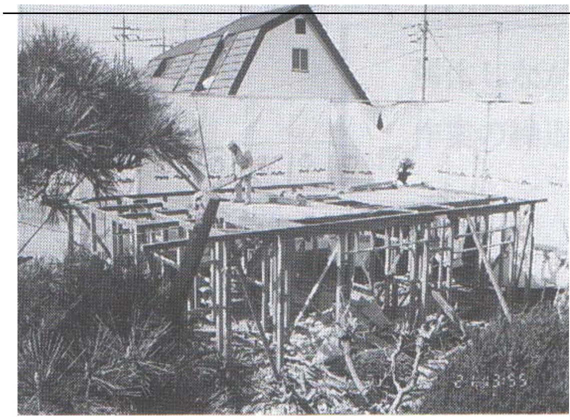
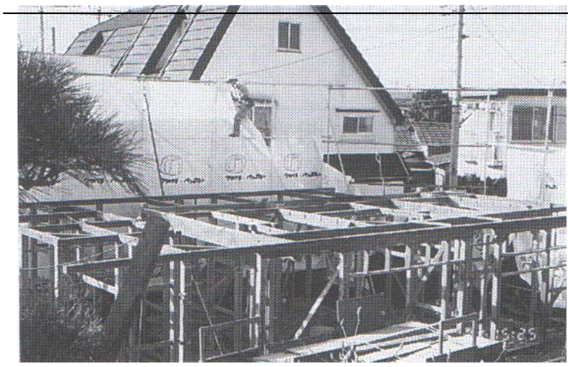
This is a method in which all parts of the building are mechanically demolished together without segregation. This method prevents recycling of waste materials, being prone to cause field burning and inappropriate disposal.

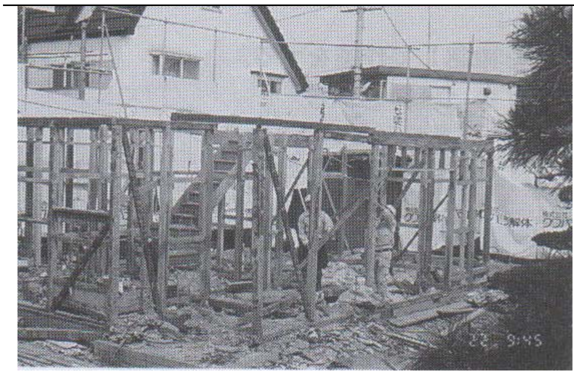
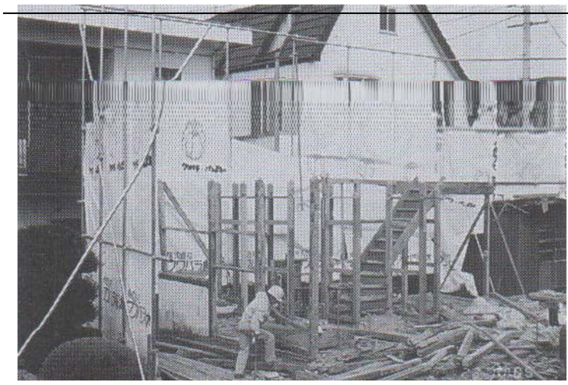
Guideline for manual demolition of wooden buildings

	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.

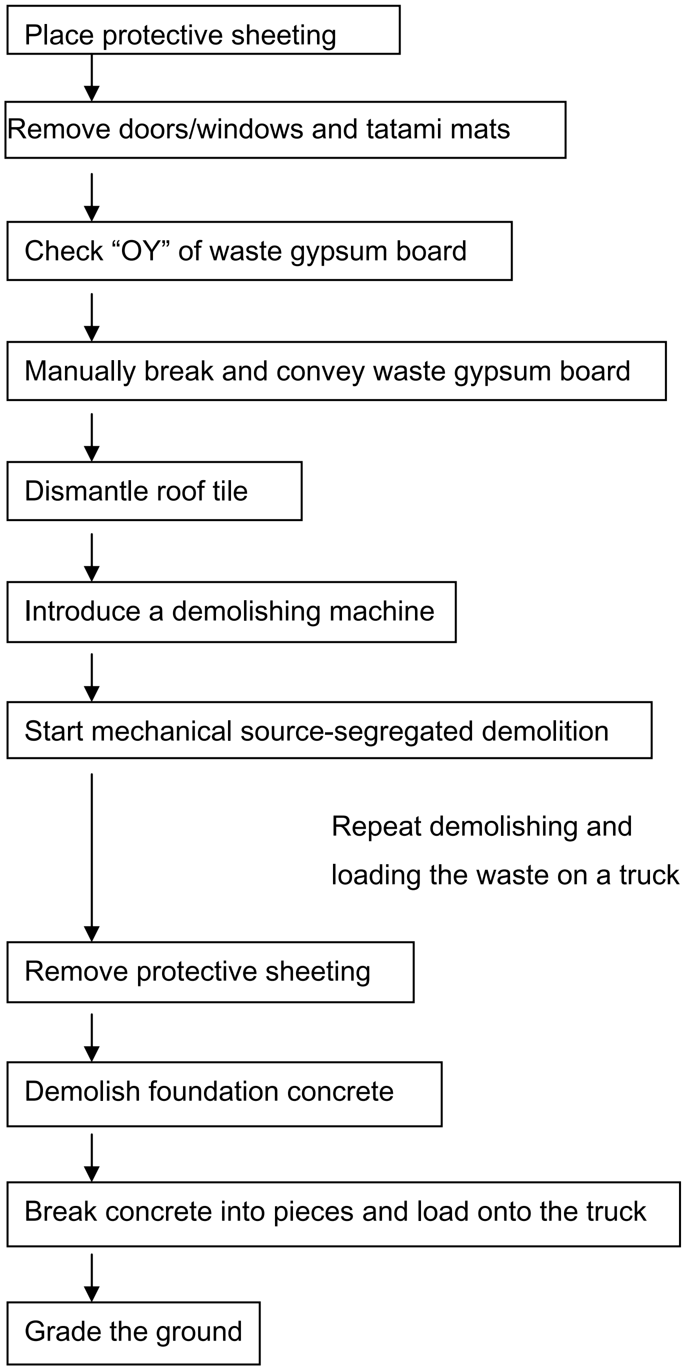
	Safety guidelines for demolition
	**Remove sheathing and rafters** - When dismantling rafters, ridge beams, purlins, and struts, tie the main rope to a beam or other member and use safety belts.
	- When dismantling exterior wall materials at high positions, prepare an adequate work platform. - Rope off 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**

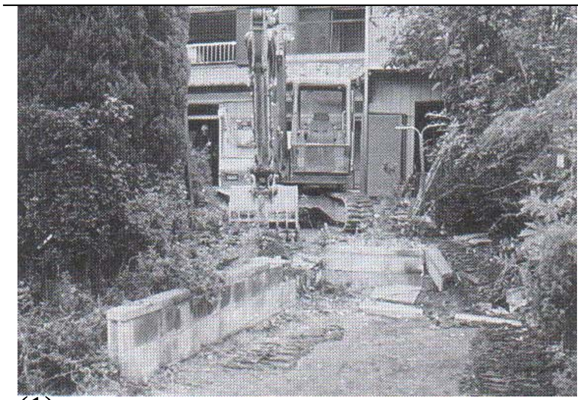
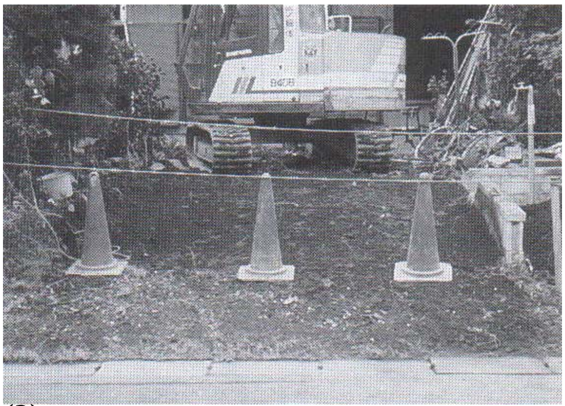
	Safety guidelines for demolition
	**Place new bracing to reinforce the framing before demolition**
	**Dismantle the framing progressively from outside**
	**The end of demolition of wooden building**

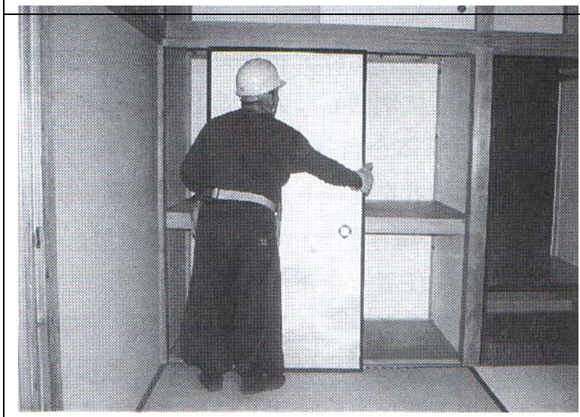
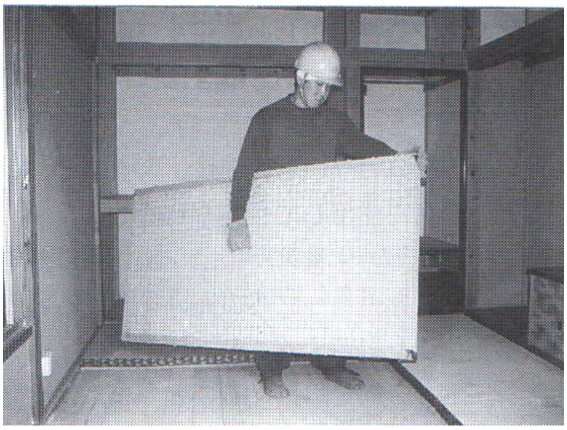
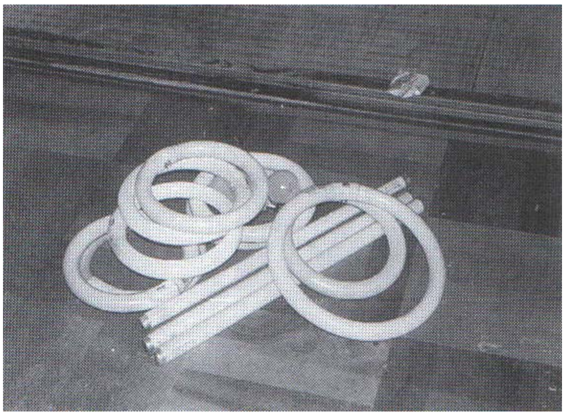
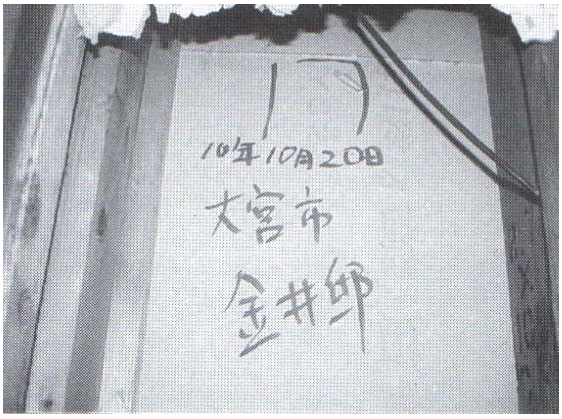
Mechanical source segregated demolition

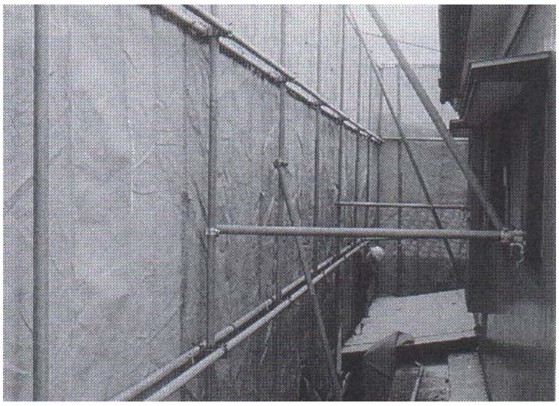
As waste gypsum board was designated as a controlled disposal item as of June 17, 2000, with a 1-year notice, the demolition procedure is changed as follows:



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.



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

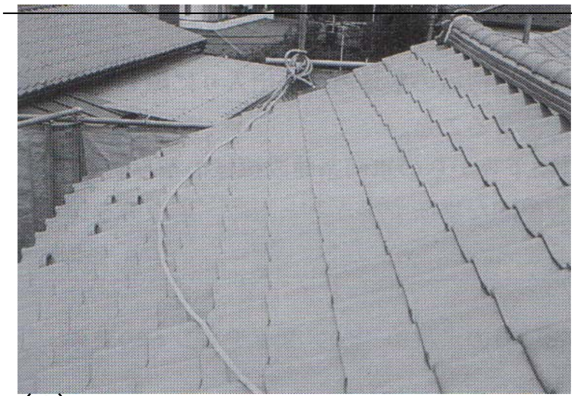
a. Provide equipment for safe lifting and lowering of workers to and from the roof.

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.

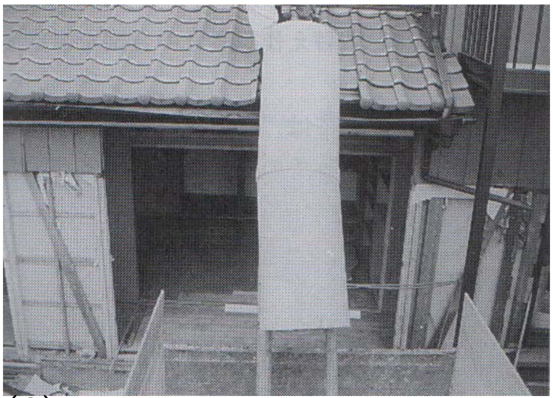
d. When dismantling and conveying tile on the roof, try to walk on the roof tile to keep away from the roof boards or rafters, as they can be rotten.

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.

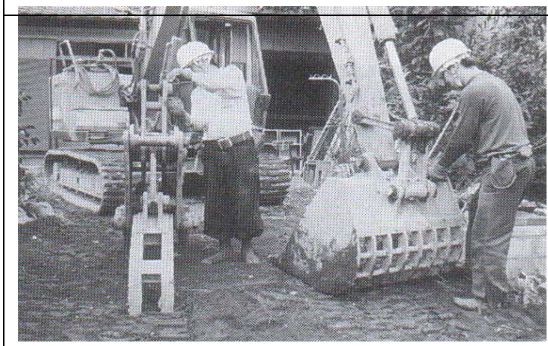
(3)

(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.

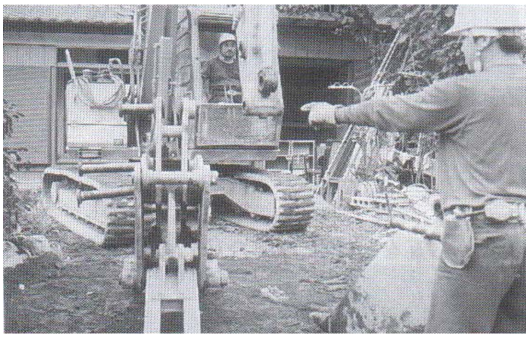
Technical safety guidelines



Bring in a backhoe

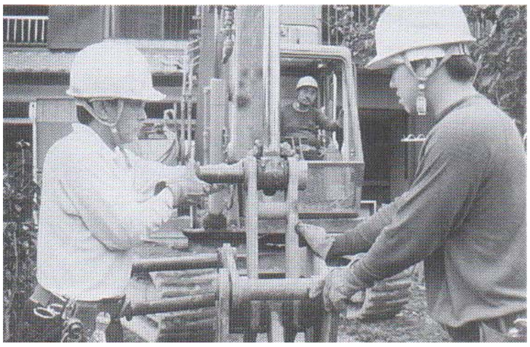
a. When a backhoe moves into or out of the site, place personnel to guide it.

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

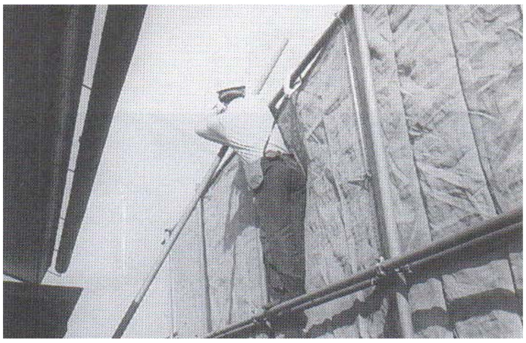
a. Changing the head of the backhoe should be carried out on a flat ground. Make sure that signs are confirmed between the operator and the workers changing the head.



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.



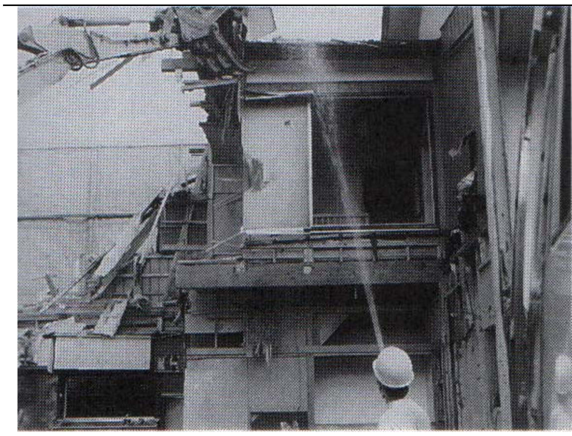
In the case of a two-storied building, replace the temporary enclosure and struts for scaffolding.

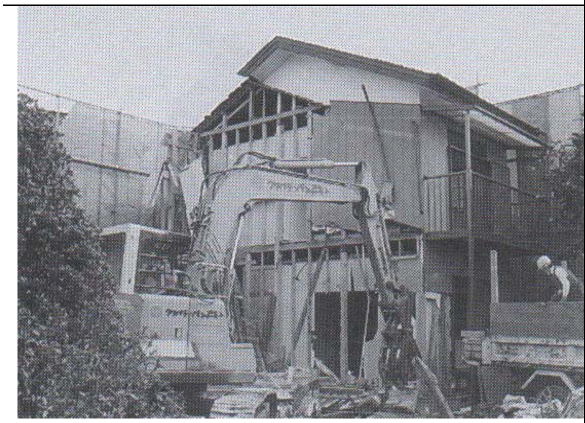
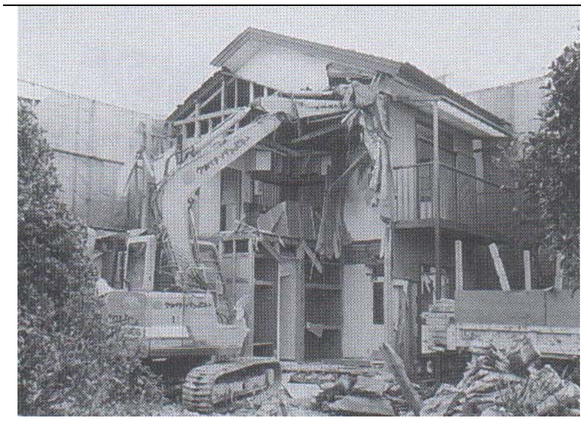
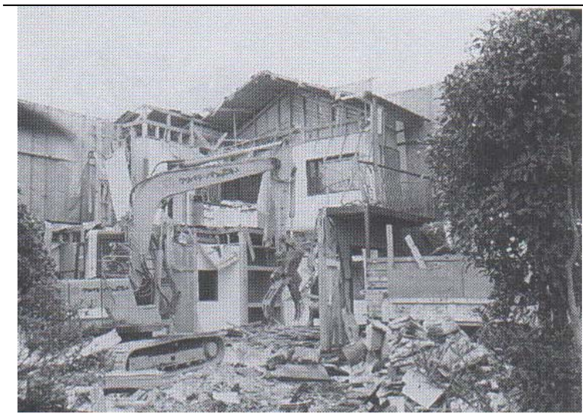
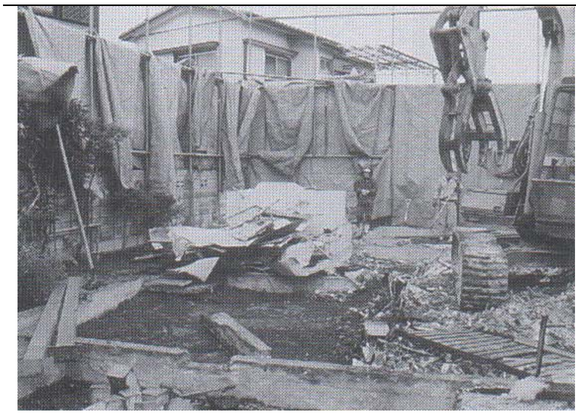
(1) The worker removes clamps wearing a lifeline.

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

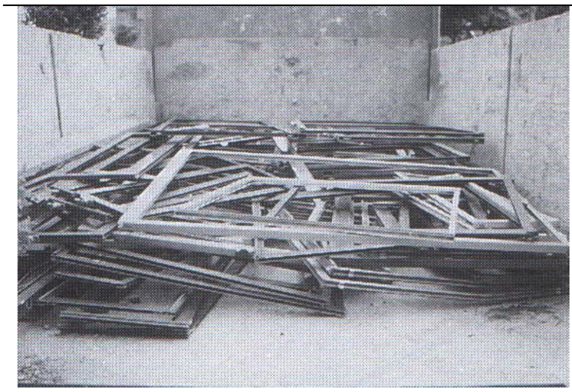
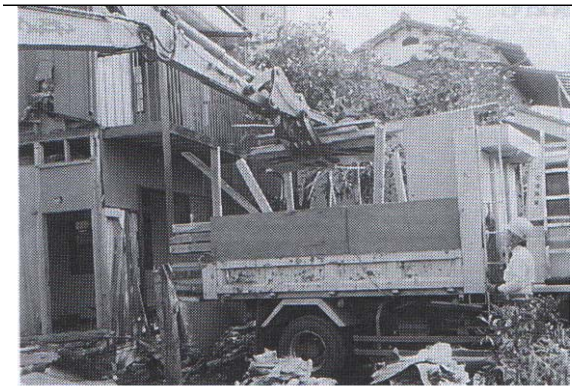
	Technical safety guidelines
	A view of the two-story wooden building.
	A view of the building to be demolished.
	After removing tatami mats, doors, windows, and roof tile, start mechanical demolition.
	Start from the ground floor.

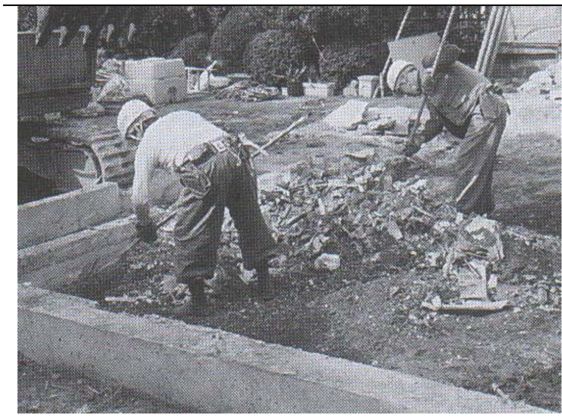
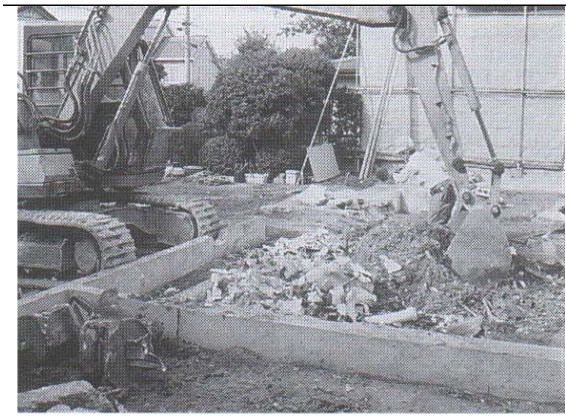
	Technical safety guidelines
	Dismantle the joinery on the first and second floors.
	Demolish the roof of the second floor. While demolishing, load the demolished wood onto a dump truck.
	Grab the roof and demolish progressively.
	

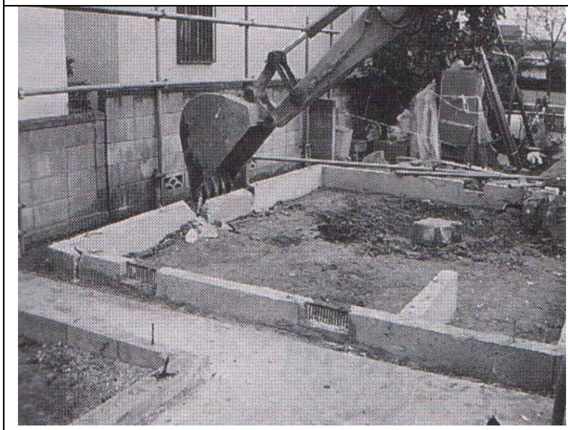
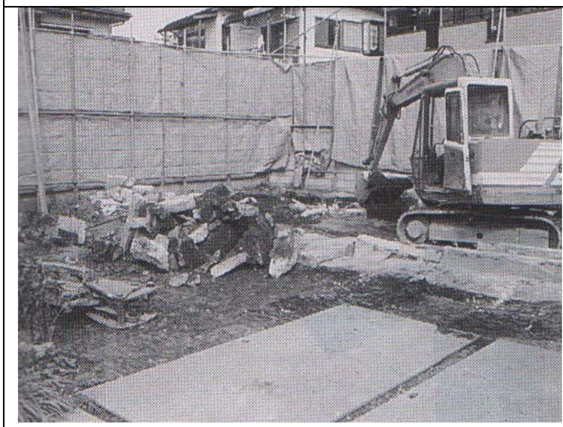
	Technical safety guidelines
	Demolish the roof on the second floor.
	Demolish the roof span by span.
	Spray sufficient water on dusting parts as required.
	When loading demolished members, exercise care not to overload the truck.

	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 19th floor 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).

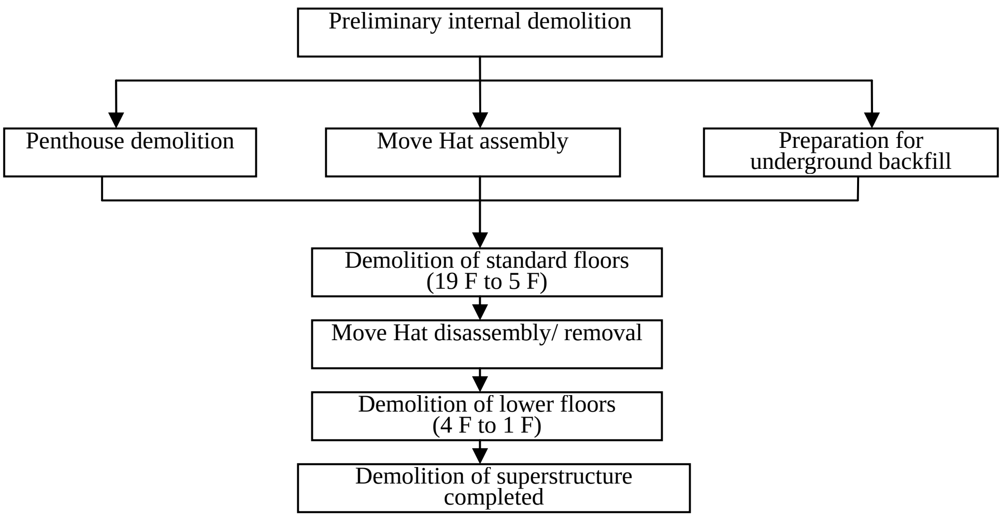


Figure 2 Flow of demolition work

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).

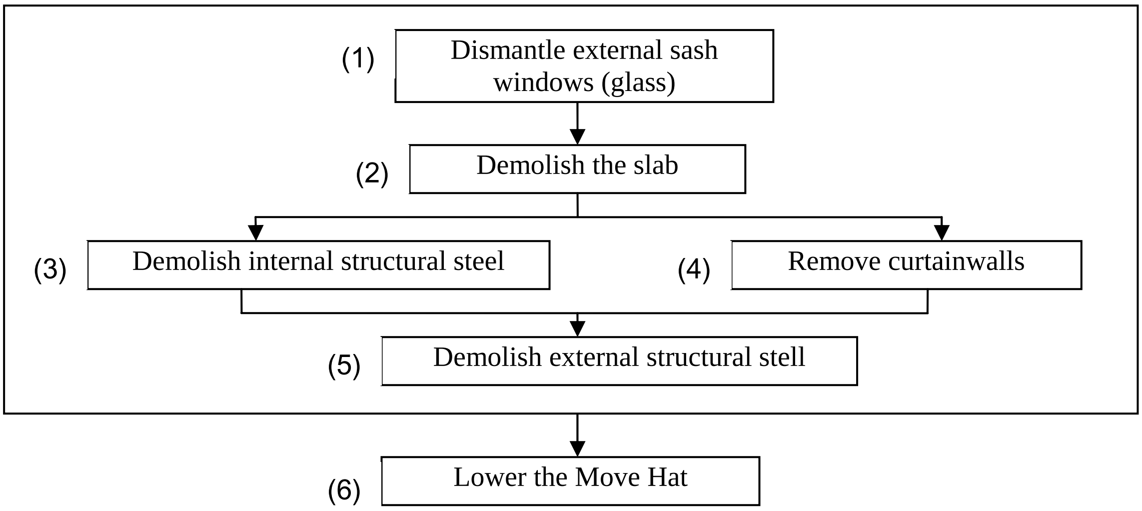


Figure 3 Demolition procedure of structural body

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).

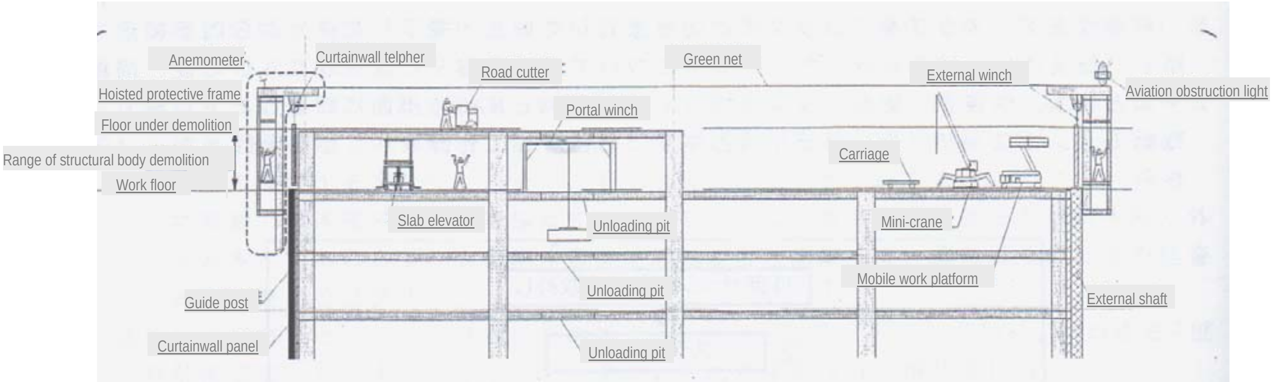


Figure 4 Demolition method (vertical cross-section)

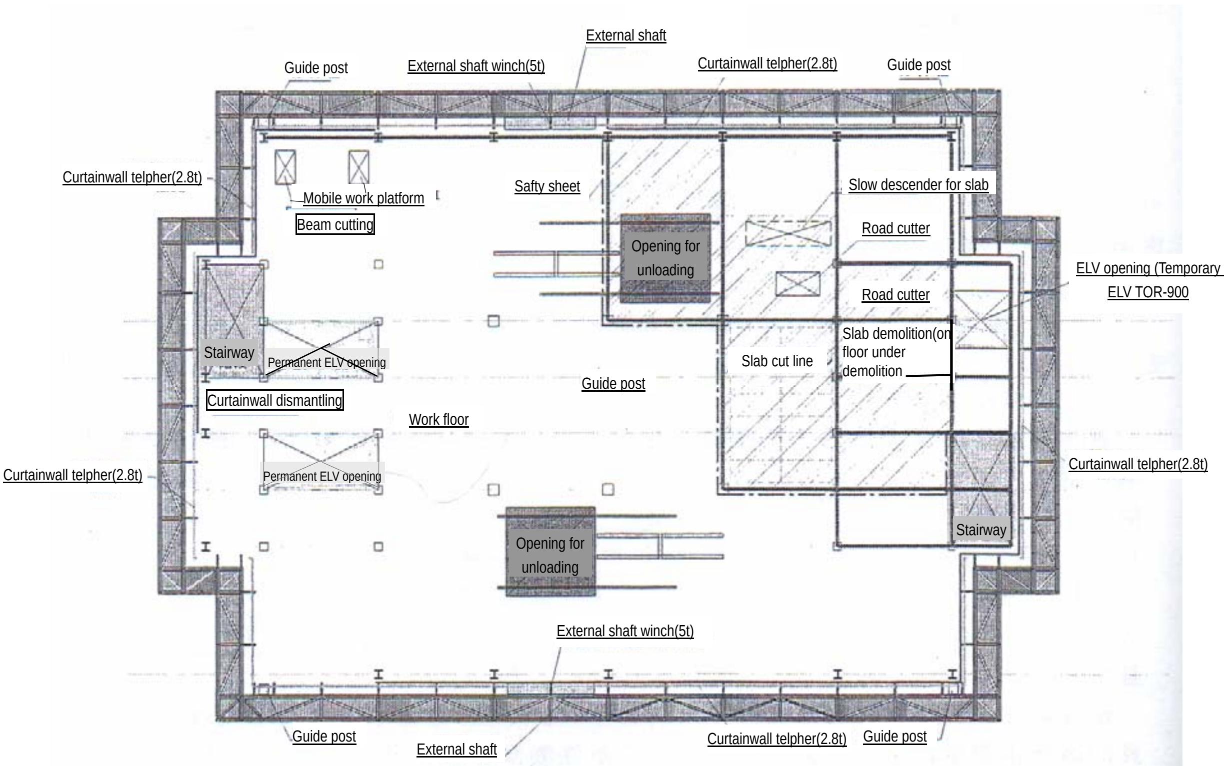


Figure 5 Demoliton method(plan)

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).

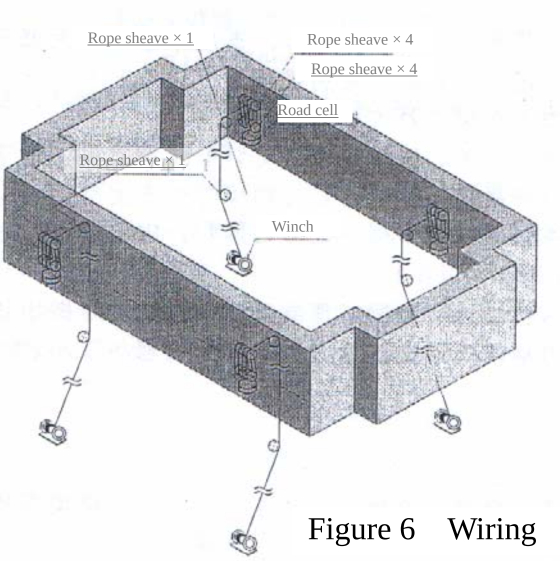


Figure 6 Wiring

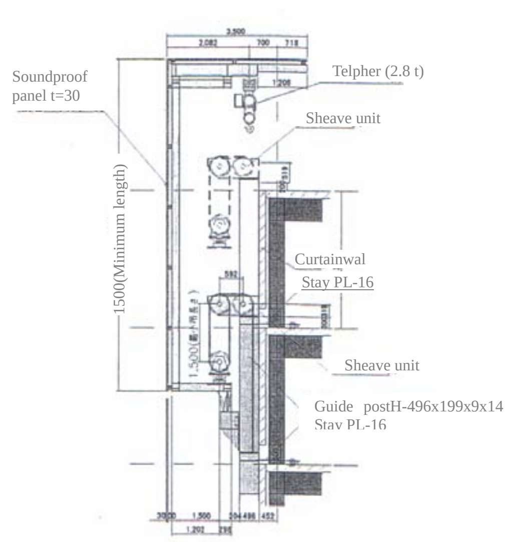


Figure 7 Hoisting system

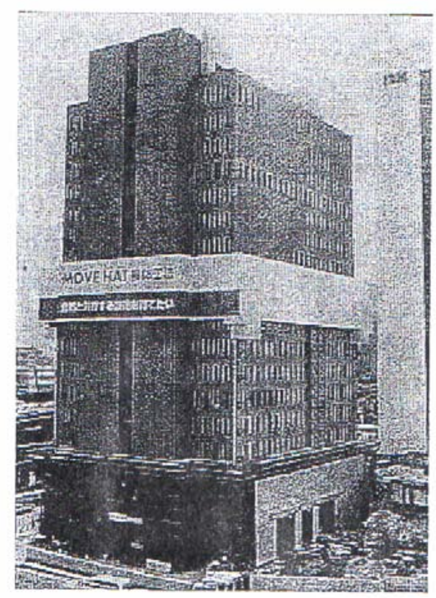


Photo 2 Rising Move Hat

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.

REFERENCE

(Reports)

1 **Japan deconstruction association**, Guideline for deconstruction of wooden buildings (draft), Tokyo, 1998.

2 **Japan Construction Safety and Health Association**, Safety of Wooden Building Demolition.

(Proceedings)

3 **Steel Club (Building Environment Committee)**, Proceedings of symposium sustainable building and steel, Tokyo, 2001.

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.

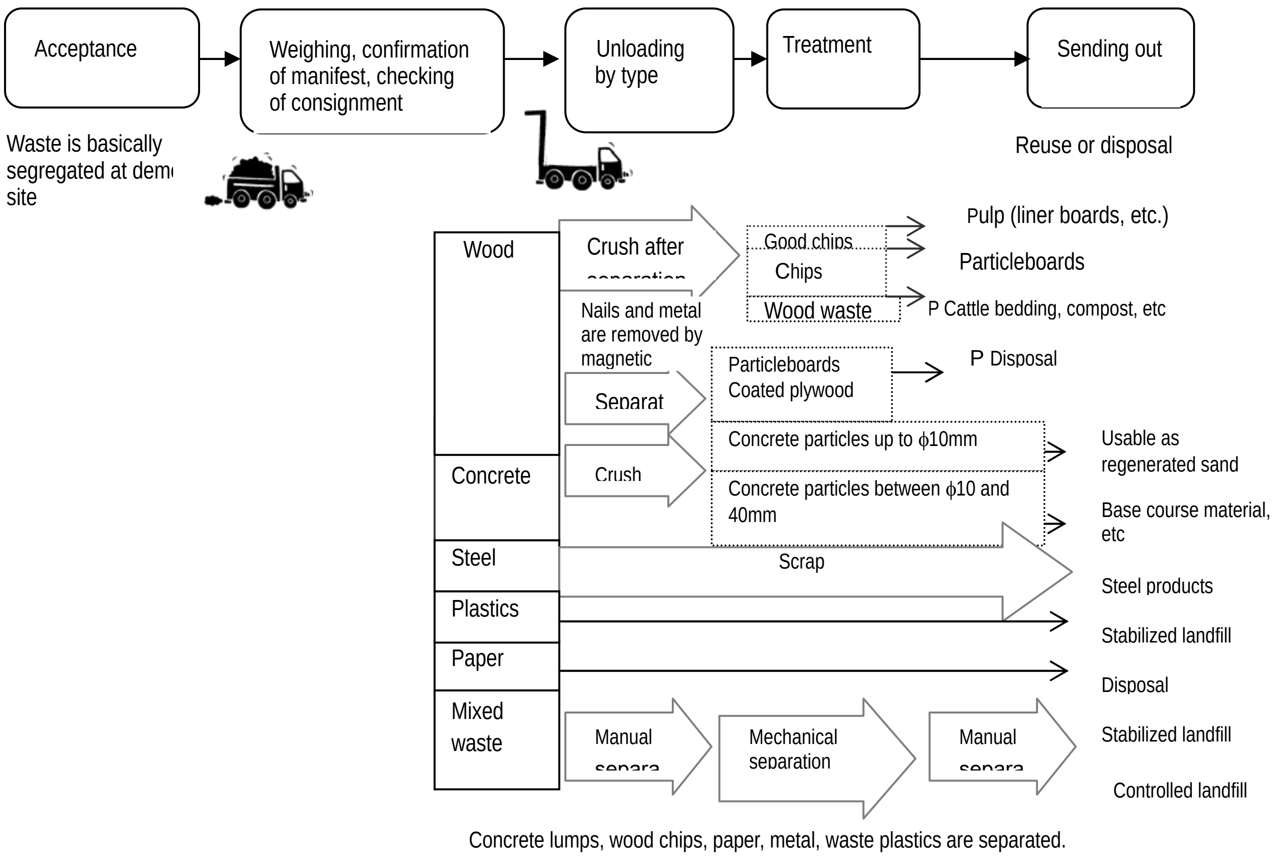


Figure 1　Treatment processes in intermediate treatment plant

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.

<u>The development to construct long life house</u>
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.

<u>The usage of dismantled wastes as resources</u>
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

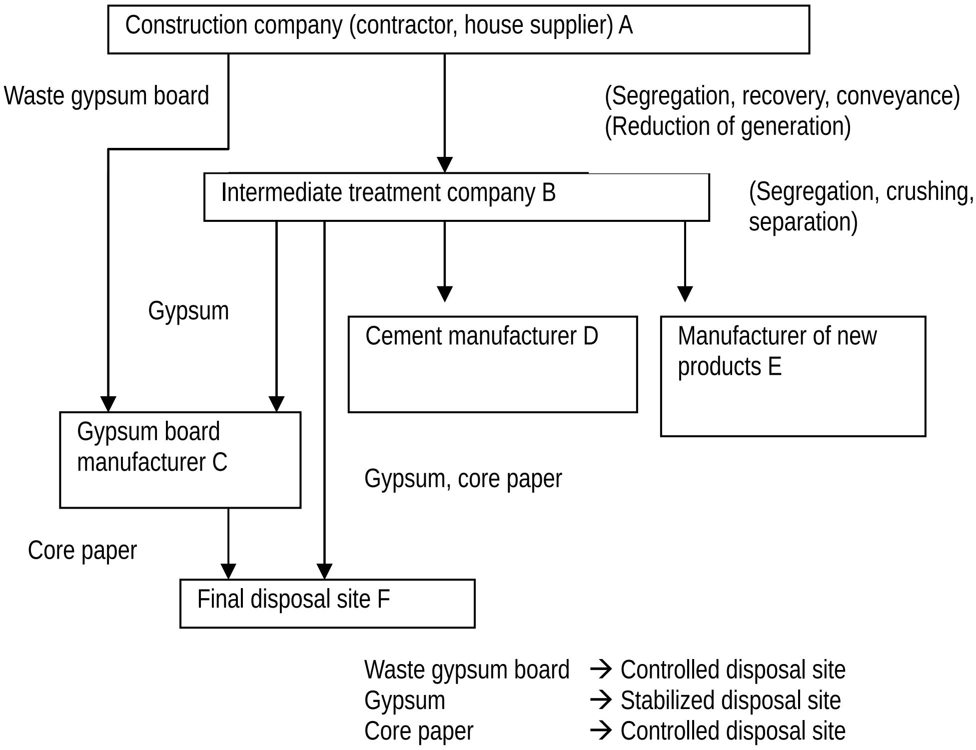


Figure 2 Recovery and disposal flow of waste gypsum board from new construction. [2]

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.

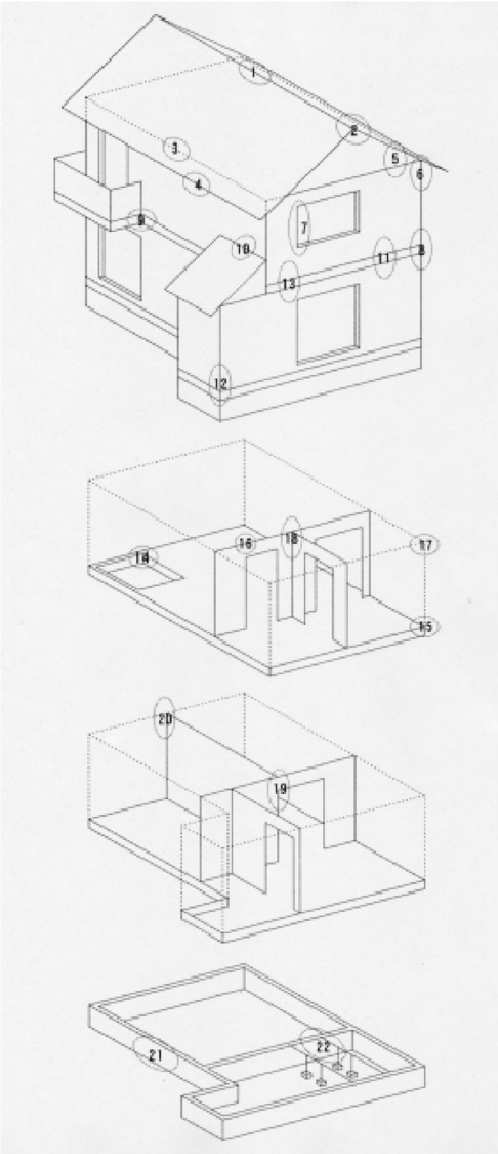

Photo 1 Gypsum boards remove by hand.

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)

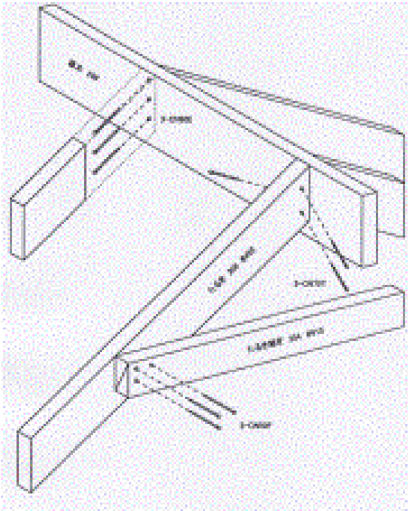
【Construction Method】	**2 by 4 Construction System**		
【Component】	**Rafter /Ridge board**	**【Joint】**	***Rafter – Ridge board***
【Figure】 		**【Design】** ***Rafters are connected to the ridge beam by nail (CN75 or CN90) .*** **【Problem for recycling】** ・ ***Roof structure is deconstructed in the following 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.***	
【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***			
【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..***			

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.

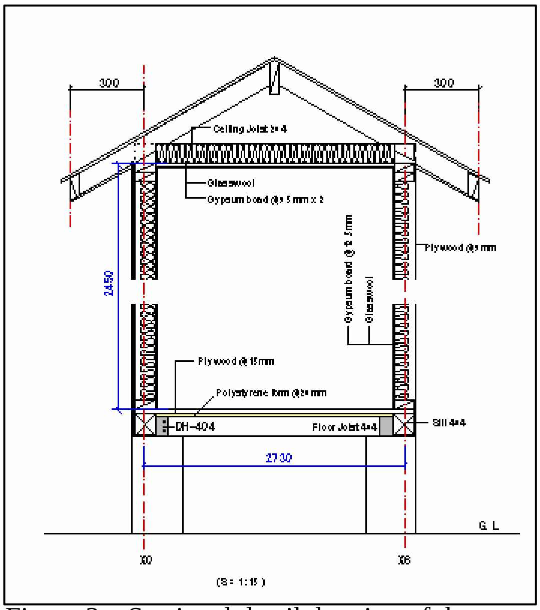


Figure 3　Sectional detail drawing of the test house “Improved”.

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	3hr., 54min.	Remove the gypsum boards (wall)
	13:22-14:56		
	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	2hr., 56min.	Deconstruct the wall framing
	13:08-15:00		
	15:42-16:02		
	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	2hr., 14min.	Remove the gypsum boards (wall)
	15:43-16:30		
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.

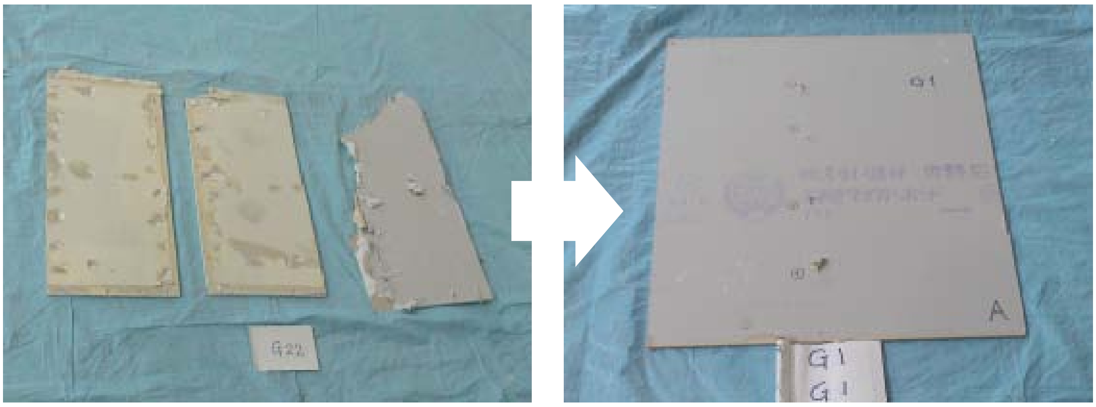


Photo 16　Damage of the gypsum board. Right: “Improved”.
The gypsum board generated from the improved test house is less damaged than that of the gypsum board generated from the benchmark test house.

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

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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).

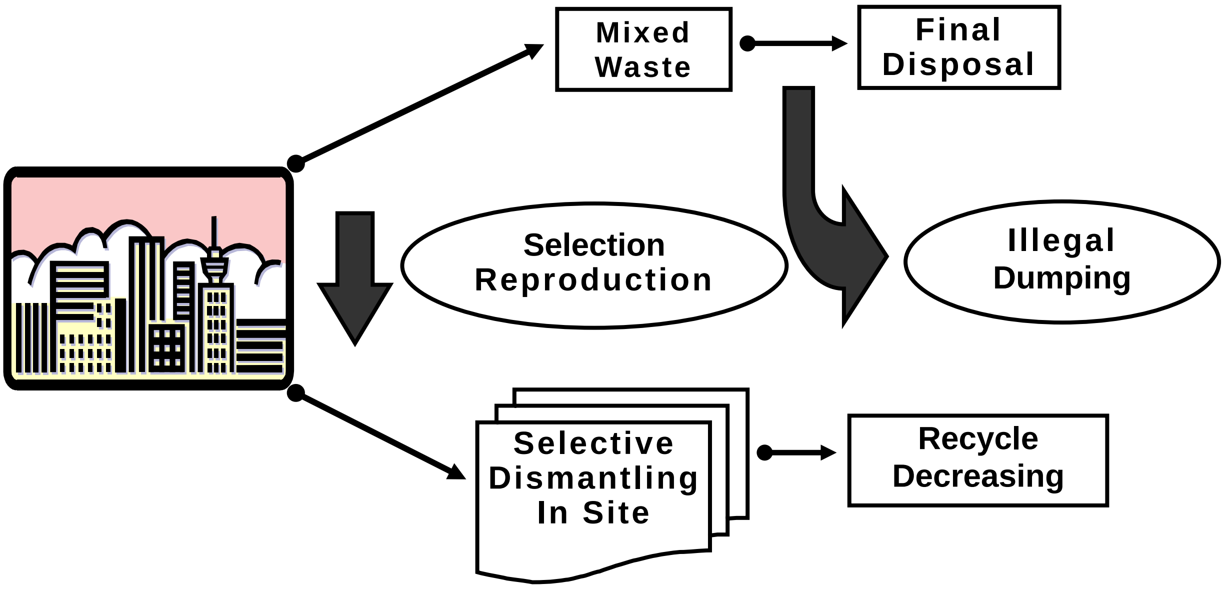

Figure 1 Selective dismantling.

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).

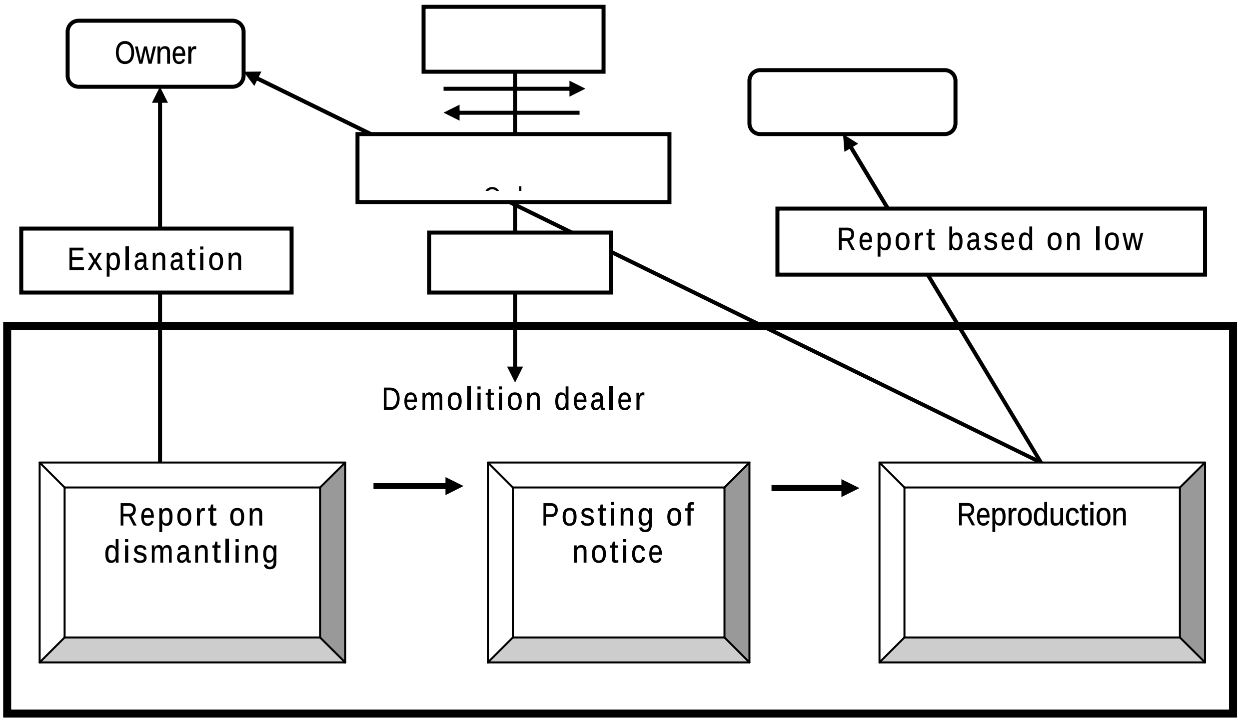

Figure 2 The action to achieve recycling.

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).

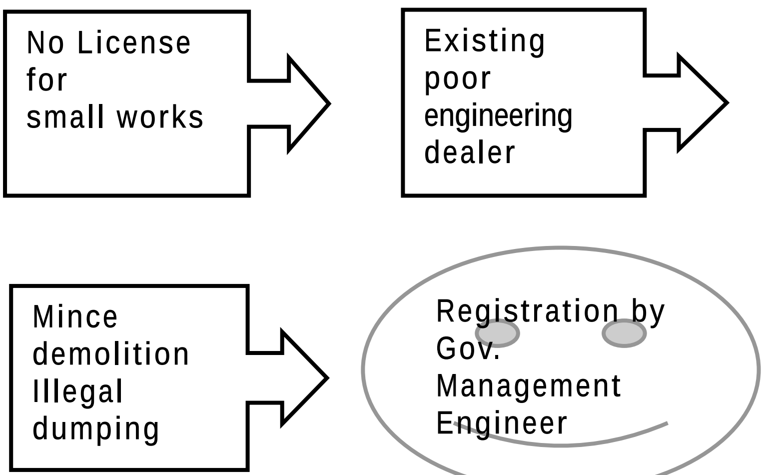

Figure 3 Registration of demolition dealer.

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%.

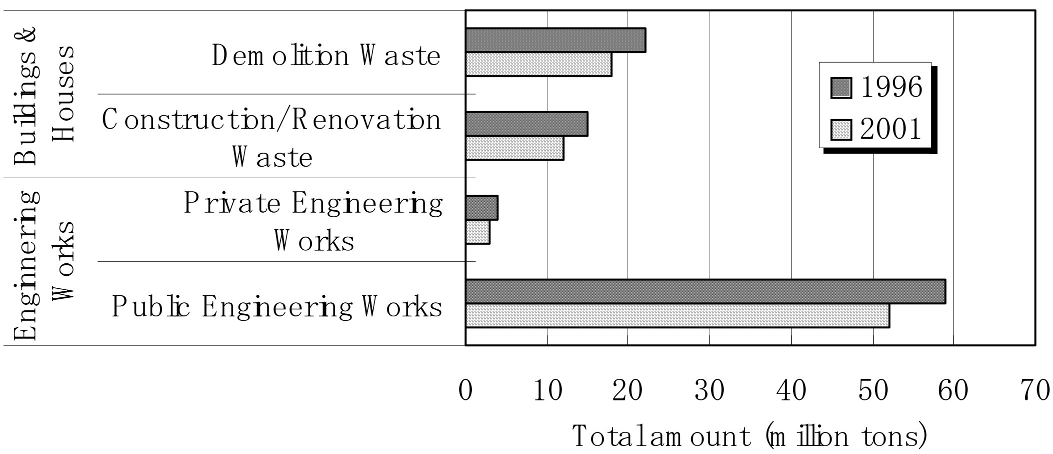

Figure 4 Waste generated from the construction industry in Japan – in the year 1996 and 2001.

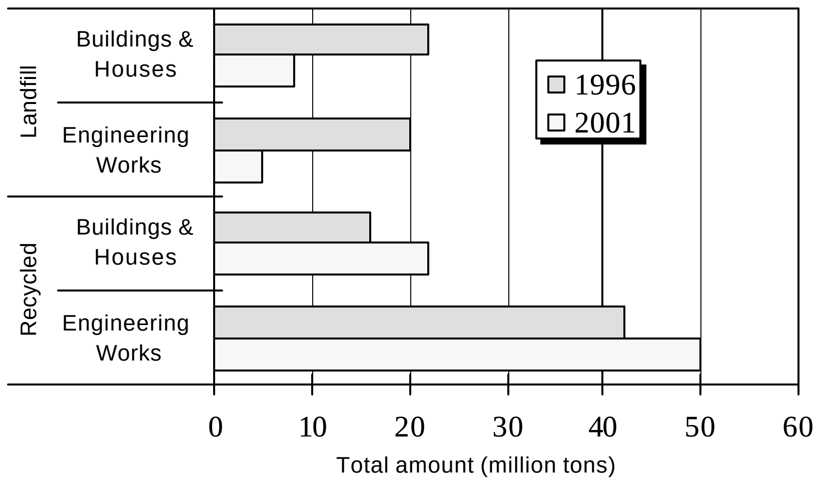

Figure 5 Amount of the waste landfilled and recycled.
Note: Recycle includes reduction by the methods of burning.

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.

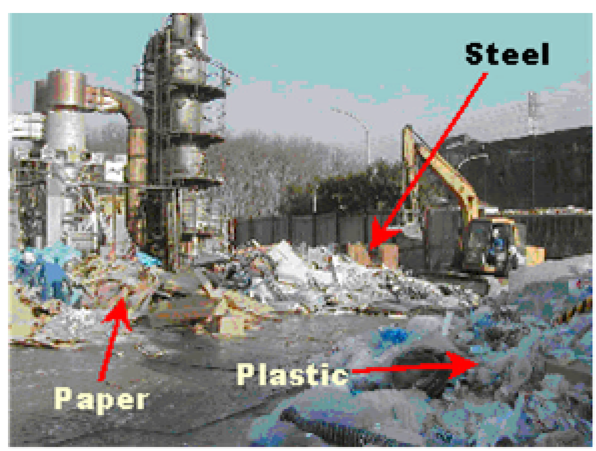

Photo 2 C&D waste.

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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