The Necessity for “Two Step Separation”

to Recycle Construction and Demolition Waste

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Abstract:
Construction and demolition waste amounts to 20% of all the industrial waste in Japan and it accounts for more than 70% of all illegal dumping. One of the reasons is that the spread of so called ‘mince demolition’ using construction machinery and consequently a lot of mixed construction waste which is difficult to separate is discharged. Here we present the idea of Two Step Separation of construction waste and demonstrate its efficiency is adopted for the all construction waste in Fukuoka prefecture as case study.

Keywords: separation of construction waste, recycling, illegal dumping, recycling center

Introduction
Although there are many factors which prevent the recycling of construction waste, one of the main reasons is that various materials which are used in the construction industry are mixed when buildings are demolished. To promote the recycling of construction materials, and to especially reuse materials as resources, it is necessary to separate construction waste thoroughly. Last year, the Construction Material Recycling Law (CMRL) was passed by the National Diet. The main points are as follows. the figure is not yet decided as of Dec. 20, 2001

a) The construction materials specified to be recycled are concrete, wood, and concrete with asphalt
b) The scale of construction to which the demolition with separation is obligated:
   Floor area of the construction: More than 80 square meters
c) The scale of the newly-built construction (except for buildings which are only repaired) is obligated:
   Floor area of the construction: More than 500 square meters
e) Construction concerning civil-engineering structure
   The construction fee: More than 100 million yen
f) The 1st clause of article nine of the Law:
   To impose on construction companies who contract demolition or construction, to separate specified construction materials from other construction materials when they carry out demolition or construction.

This law imposes a duty on the contractor of construction or demolition to separate specified items on-site, and to carry them to a recycling center. It is the first time that a regulation which imposes a penalty on contractors who do not carry out the separation of materials during construction and demolition has been established. It is our opinion that the law for promotion of recycling of construction waste is epoch-making. But the three items specified this time are considered as the first group of materials to be considered. Even though it is only three items, many problems have been pointed out by construction and demolition contractors. Moreover it is inevitable that the number of specified items to be separated on-site by the law will increase further. Plaster board and vinyl chloride pipes and joints are
already seen as the additional candidates for future inclusion.

In addition, this Construction Material Recycling Law imposes waste separation on the demolition of buildings which have a floor area of more than 80 square meters. As for the enforcement of CMRL, most standard-scale houses in Japan will be obliged to be demolished using the separation guidelines. There are many contractors who feel it will be difficult to easily separate materials while demolishing buildings, since at this time, few constructors know about the method of demolition with separation by hand, and feel that to separate materials adequately they will have to use a lot of time and workers. Therefore, it is assumed that a lot of demolition-constructors will not perform the demolition with separation and instead discharge mixed construction waste. As a result, it is inevitable that illegal abandonment will increase further than in the present.

On the other hand it is true that there are many items which can be recycled into usable materials by separating them thoroughly at a single material base. In this paper we will investigate detailed items which should be separated in two stages, first at construction demolition sites and secondly at waste recycling plants.

Chapter 1 Definition of Two-Step-Separation

To explain the necessity of the two-step-separation concept, fig. 1 shows the relationship between the economic worth of construction materials and time.

No resources become valuable raw materials until we have put a certain amount of energy into their mining, generation, transportation, and so on. their value is then raised to the product level after we invest a lot of energy into construction, transportation, processing, and assembly. A product’s value falls little by little as it is used. If this product is discharged as mixed waste, it will become valueless at the moment it is discharged. If the cost of disposal is expensive, the product’s value will fall greatly to a negative worth value. Thus, in order to raise the economic value from the minus level to the level of a product again, it is necessary to input immense energy. At this point it can be seen that it is very difficult for the construction waste recycling field to be marketable. It is necessary to separate construction waste at the construction demolition stage, because it is not necessary to use a lot of energy to recycle materials which still have positive value economically by an on-site separation of construction waste. To promote resource saving and a Resource Circulation Society, we need to raise the economic value of materials which are at the minus level by “Two Step Separation” or a two step separation process. Even if today’s economic value is minus, if the materials could be separated into a single kind of material, it would be possible to stock them until the material becomes valuable in an “artificial mine” or

Fig. 1 The relationship between economic worth of construction materials and time
Thus, to separate construction waste effectively, not only construction demolition sites (1st-step-separation), but also recycling plants need to cooperate with each other. It is necessary to establish a system by which, after separating waste as much as possible at the demolition site, items which cannot be separated in the 1st-step are re-separated. Although CMRL requires constructors to separate the waste at the demolition site only, today, middle processing institutions have already been separating construction waste. To promote re-materialization effectively, we need to establish a system to allot each role of separation at both construction demolition sites and middle processing institutions.

The definition of “Two Step Separation”:
To separate construction waste in two steps
step 1: newly-building and construction demolition sites
step 2: middle processing institutions

Chapter 2 The items to be separated at construction and demolition site: the 1st-step of separation
2-1 Hearing investigation of a composite middle processing institutions
There is previous research regarding separation on construction sites for recycling. (By prof. Yashiro, Tokyo Univ.) Separation by machine at a middle processing institution etc. was not mentioned by the previous research. Since separation for recycling is now already performed in the middle processing institutions as well, if we separate waste on construction/ demolition sites, separation efficiency will be greatly improved. Because of this, we propose the separation of items in a two-step-separation, and confirm its effectiveness through the investigation of middle processing institutions in Japan.

We researched today’s problems and received items in middle processing institutions which deal with construction waste. One of the biggest problems is to separate mixed construction waste in middle processing institutions, this is an economic problem as well as a technological one. It is difficult to separate mixed waste crushed into small pieces, which cause problems by clogging the crushing machine.

The purpose of this research is to grasp concretely which items should be separated in which stage of separation. According to the preparatory research we listed 15 items which should be separated for recycling in Table 1.

Table 1 15 items which should be separated in the recycling process (from preparatory research)

| Material Recycling |
|--------------------|
| Recycling and processing facilities |
| Stocking |
| Thermal Recycling |
| An electric power plant by incineration |
| Heat recovery |
| To sell electricity |
| Final disposal site |

| Valuables separated at sites |
|-----------------------------|
| Mixed waste |
| Valuables |
| Composite facilities for separation |
| Resources |
| Flammable Material |
| Nonflammable Material |

| A range of considered items in CMRL |
|-----------------------------------|
| Glass wool |
| Plaster board |
| Concrete |
| PET plastic bottles |
| Packing materials, solvent vessels |
| Blue sheets |
| Waste Rubber |
| Vinyl chloride products |
| Stainless steel products |
| Copper products |
| Aluminum products |
| Plywood, Laminate wood |
| Wood (bare wood) |

| A range of considered items in Two-Step-Separation |
|---------------------------------------------------|
| Window glass |
| Glass wool |
| Plaster board |
| Concrete |
| PET plastic bottles |
| Packing materials, solvent vessels |
| Blue sheets |
| Waste Rubber |
| Vinyl chloride products |
| Stainless steel products |
| Copper products |
| Aluminum products |
| Plywood, Laminate wood |
| Wood (bare wood) |

Fig. 2 Definition of two-step-separation
We added 14 items in Table. 2 to confirm the importance of the separation of these items. 28 items (except for earth dug out of a construction site) which should be separated or not are listed in Table. 3. We chose composite middle processing institutions which were newly-built or rebuilt within three years and supposed to have the most up-to-date technology and facilities for construction waste separation as an investigation subject.

Table. 2 14 items which should be separated for recycling (from literature research)

| Items                                      |
|--------------------------------------------|
| Fluorescent pipe                           |
| Tiles, Asbestos                            |
| Sanitary Ceramics                          |
| Reinforcing bar, Steel frame               |
| Waste Asphalt                              |
| Earth dug out of a construction site       |
| FRP                                        |
| Waste steel                                |
| Fibrous board, Particle board              |
| Waste fiber of carpets and curtains        |
| Tatami                                     |
| Curing paper                               |
| Waste paper                                |
| Corrugated cardboard                       |

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Table. 3 28 items in questionnaire.

| Waste Glass and pottery                  |
|------------------------------------------|
| Window glass                             |
| Glass wood                               |
| Fluorescent pipe                         |
| Plaster board                            |
| Tiles, Asbestos                          |
| Sanitary Ceramics                        |
| Reinforcing bar, Steel frame             |
| Waste asphalt                            |
| FRP                                      |
| Plastic PET bottles                      |
| Blue sheets                              |
| Packing materials, solvent vessels       |
| Waste Rubber                             |
| Vinyl chloride products                  |
| Waste steel                              |
| Stainless steel products                 |
| Copper products                          |
| Waste Lead                               |
| Aluminum products                        |
| Plywood, Laminated wood                  |
| Fibrous board, Particle board             |
| Waste (bare wood)                        |
| Waste fiber of carpets and curtains      |
| Tatami                                   |
| Curing paper                             |
| Waste Paper                              |
| Corrugated cardboard                     |

The contents of questions regarding the 28 items are as follows:
1. To separate or not at the construction and demolition site
2. The reason to separate
   a) It is impossible to separate at middle-processing institutions.
   b) It contained a lot in mixed waste.
   c) It causes a malfunction of the separating machine.
   d) It has high value, if it is separated.
   e) others.
3. The reason not to separate
   a) Easy to separate by machine.
   b) The quantity is small.
   c) Not in demand.
   d) Not valuable, even if it is recycled.
   e) others.

After a request by telephone, we sent the questionnaire by fax to 17 middle processing institutions, and asked them to return it by fax. We received the answer from 11 institutions. The answering rate was 64.7%.

2-2 The necessity to separate on the construction and demolition site
According to our investigation, 28 items were categorized into six groups. Items from group one to group three are items to be separated on the construction and demolition site as the 1st step.

Group 1 Items to be separated on construction and demolition site, because these are worth to recycling.

| Items                                      |
|--------------------------------------------|
| Wood (bare wood)                           |
| Plastic PET bottles                        |
| Waste paper                                |
| Stainless steel products                   |
| Copper products                            |
| Waste Lead                                 |
| Aluminum products                          |
| Plywood, Laminated wood                    |
| Fibrous board, Particle board              |
| Waste (bare wood)                          |
| Waste fiber of carpets and curtains        |
| Tatami                                     |
| Curing paper                               |
| Waste Paper                                |
| Corrugated cardboard                       |

These are the items which should be separated at the construction and demolition site, because they are worth recycling, and recycling market them exists. Although PET bottles are ordinary waste, the quantity is large in the construction field, and there is a possibility to cause trouble at processing facilities.

Group 2 Items which is difficult to remove from mixed waste, or have problems to separate by machine.

| Items                                      |
|--------------------------------------------|
| Packing materials, solvent vessels         |
| Waste lead                                |
| Curing paper                              |

These cause problems such as blocking the crusher, since it is also difficult to remove all of the items at a separating line by hand; they should be separated at the construction and demolition sites.

Group 3 Items which should be separated on site for other reasons.

| Items                                      |
|--------------------------------------------|
| Vinyl chloride products                    |

Vinyl chloride causes dioxin problems, and requires special management during incineration.
Chapter 3 The items to be separated at the separating plants: the 2nd step of separation.

3-1 Investigation of recycled construction waste

Here we will show the results of the questionnaire regarding the situation of construction waste which can be accepted by recycling plants or products manufacturers, namely the situation after the separation of construction waste. According to the investigation, we set up a plan for the separation and stock of 28 items, which are possible to be recycled. We examined four items which are common as construction materials, waste steel, waste aluminum, waste glass, waste plastic in this research except for waste wood, and waste concrete, which are already designated items to be separated.

Next we examined the effectiveness of two-step-separation through a case study. The case study area we chose is in the Hibikinada area in Kitakyusyu, Fukuoka prefecture which was designated as EcoTown by the Ministry of Economy, Trade and Industry for the first time in Japan. The subjects are manufacturers which may possibly accept recycled construction waste in the Kitakyusyu area. The categories of manufactures are as follows.

Waste steel; Blast furnace works, and Electric furnace works.
Waste aluminum; aluminum refinery.
Waste glass; Glass product maker, Tile maker, Road construction (for roadbeds).
Waste plastic; Plastic product maker, Steelworks, Thermal recycling institutions.

The answering rate was 73%. The subjects of investigation are shown in table 4.

Table 4 The number of companies in investigated industry in Kitakyusyu, Fukuoka circumference company

| Materials of construction waste | Usage | Types of industry | Number of investigation |
|---------------------------------|-------|-------------------|------------------------|
| Waste steel                     | Raw material of steel manufacture | Steel works | 4 companies |
| Waste aluminum                  | Raw material of aluminum refinery | Refinery | 12 companies |
| Waste glass                     | Raw material of glass manufacture | Glass factory | 9 companies |
| Waste concrete                  | Coke Alternative material | Steel works | 4 companies |
| Waste paper                     | Fuel | Thermal Recycling facilities | 2 companies |

The total 65 companies.

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According to the questionnaire we will explain about the acceptable recycling conditions of each material.

**Waste steel:**

The standard of acceptable condition is a collective standard determined by the Japan Steel Recycling Industry inc.. According to this collective standard, the kinds and qualities of steel to be accepted for recycling are decided. According to the standard, electric furnace works accept various kinds of steel. They buy steel in good condition and bad condition regularly. Blast furnace works who usually use iron ore, or virgin materials also accept heavy waste steel in good condition of HS or H1 class.

**Waste aluminum:**

The value of waste aluminum is decided by the quality of aluminum multiplied by a yield rate. The quality is based on the contamination of alloys and other different materials. The manufacturers ask for the same kind of materials as they use. For example, a manufacturer accepts waste aluminum of only JIS6063. The yield rates alter according to the degree of contamination of other materials and oxidation. The lower the quality, the more difficult the recycling. The contamination is categorized in two Groups, one is inflammable, the other is a different kind of metal. The quality of aluminum with two different kinds of contaminants or more is less valuable.

**Waste glass:**

The acceptable condition of waste glass as roadbed materials is that which has no harmful contaminants, and conform to a standardized scale. Transparent glass and frosted window glass is recyclable. Glass with copper wire is difficult to crush and is unacceptable. The acceptable condition of glass as glass products materials is colorless glass with no contamination and glass cullet with a standardized scale.

**Waste plastic:**

The acceptable condition as a material of thermal recycling in steelworks and coke substitutes is that with no contamination. Any kind of plastic is acceptable, but PVC and FRP should be eliminated as coke substitutes. Usually, most plastic from construction waste is in bad condition, and unusable as raw material for plastic products. Vinyl chloride pipe and joint are recycled with returning routes established. Its acceptable condition is material with no contamination, washed, and cut to a certain length.

3-2 The condition of recyclable construction waste. Fig. 4 shows acceptable conditions of construction waste from the view point of the manufacture.

The number of manufacturers from our investigation which accept construction waste as materials are shown in table. 5.

![](table.png)

Table. 5 The number of manufacturers to accept construction waste as materials.

According to table. 5, there are many manufacturers who accept waste steel and waste aluminum now. On the other hand, there are many manufacturers who will accept waste glass and waste plastic in the future. To accept waste glass and waste plastic, ideal conditions of acceptance are required. Next we show the recyclable conditions of each material.

**The condition of recyclable waste steel**

The condition of recyclable waste steel of construction waste based on the acceptable condition of researched steelworks is categorized into nine types. Heavy...
are one the type of waste steel. Waste steel is categorized by the existence of contaminants. Waste steel with contaminants is first crushed (by shredder) which eliminates them. The quality is decided by the amount of remaining contaminants. The order of quality is rated from AS to A, B, C. (Steel cans and thin steel plate are also processed in the same way.) Waste steel with no contamination is cut into pieces. The quality is based on the figures of each waste, the order of quality is from HS to H1, H2, H3and H4. Heavy is mainly from construction waste, and one of the best qualities of steel waste. Especially HS and H1 are acceptable at steel blast furnace works.

The condition of recyclable waste aluminum
The condition of recyclable waste aluminum is categorized into six types. The type of waste aluminum accepted by manufacturers is based on the products that the manufacturers produce which accept aluminum. Especially, some manufactures can only recycle aluminum sash (JIS6063) and electric wire (JIS1060). A large amount of aluminum sash is discharged from construction and demolition sites. Other types of aluminum alloys should be separated according to the contaminated metal. Aluminum alloys with more than two kinds of metal should be separated by the type of the metal to recycle.

The condition of recyclable waste glass
The condition of recyclable waste glass (cullet) is categorized into four types. The waste glass discharged from construction waste is not recycled today. But, if it is separated into four types, colorless, with color, with other contaminants, and low quality (with dirt and scratches), it can be recycled. Colorless glass is accepted by several glass manufactures, color glass is accepted by tile and glass manufactures, glass with contaminants or low quality glass can be recycled as roadbed materials.

The condition of recyclable waste plastic
The condition of recyclable waste plastic is categorized into six types. It is difficult to recycle waste plastic in the same way as waste glass, because it is discharged in mixed condition and there are various kinds of waste plastic. It is possible to recycle if it is separated into six types, vinyl chloride pipe, FRP, compound plastic, each kind of plastic (Each kind of plastic, condition separated to PP, PE, PA, PVC and PS), mixed plastic (mixed condition of PP, PE, PA, PVC and PS), and low-quality plastic (impossible to remove contaminants or damaged a lot). Vinyl chloride pipe, and each kind of plastic is accepted by several plastic manufactures. Mixed and low quality plastic can be accepted as materials for thermal recy-
clinging. FRP, compound plastic should be stocked to the time when it is possible to recycle.

**Chapter 4 Examination of reduction of construction waste by two step separation**

4-1 The outline of a case study

We here examine the effect of the two step separation process through a case study. Today, in Fukuoka Prefecture, various measures of recycling are taken at the prefectural government level as an ECO-TOWN (which is the city to promote the Environmental Technology selected by the Ministry of Economy and Industry. Kitakyushu and Omuta in Fukuoka-prefecture were chosen). As a part of its enterprise, the recycling plants in which construction waste is received are now being planned. Because of this, we chose Fukuoka Prefecture as the case area. We chose the Kitakyushu Hibikinada area which is the first ECO-TOWN designated city in Japan as a recycling position and assumed the amount of construction waste according to the quantity of the whole of Fukuoka Prefecture. Through this, the rate of improvement of recycling and the amount of waste as mixed waste was examined. it is our purpose to grasp the effect of recycling when the Two Step Separation defined in Chaper 2 is performed. On a concrete target, we calculated how much the amount of discharge of mixed waste can be reduced and how much the rate of recycling increased when Two-Step-Separation is performed.

Three kinds were set up as a model case, the Present condition model, The model after the construction recycling law was enforced (This is considered as B model below.), and the model when a two-step-separation which we suggest is performed (This considered as C model below).

4-2 The flow of calculation of the case study

1. The quantity of the construction waste carried into a recycling factory directly from the construction site.

2. The quantity of the mixed waste carried into a middle processing institution from the spot

First, we calculate the present quantity of one and two, according to the calculation method which multiplies floor area by the discharge field unit. In the present condition model, since there is no middle processing institution which receives construction waste, we assume all of two as waste in which the last disposal is carried out.

Next, we calculate the weight of each item contained in mixed waste according to the calculation method which multiplies the weight of mixed waste by the composition rate.

In the B-model and C-model, the quantity of the waste which is recycled increases, and the quantity of waste which is carried into a middle processing institution decreases by separation at the construction site. So the quantity of new separation items at construction sites is carried out.

3. Weight of the items removed from mixed waste by the manual separation line

4. The weight of the items divided into recycling and the last disposal by machine separation

We consider that separation in a plant is divided into a manual separation line and a machine separation line. It is assumed that all of the four items contained in group IV in chapter 3 are recoverable with a manual separation line. But with machine separation, not all of the valuables are recoverable so we calculate it by the method of multiplying the amount of injections by the recovery rate of every item. In addition, the rate of recovery rate, including the conventional manual separation is used in c-model.
4-3 Reduction of the amount of mixed waste discharge.

The quantity of mixed waste calculated in the present condition model is about 540,000t. The value is calculated according to the premise that all wooden low layer residences are discharged as mixed waste. When the construction recycling law is enforced and new separation at the construction site is carried out, the amount of mixed waste discharge is reduced to 43% from 63%, 20% more mixture waste is reduced, if 17 items of separation in the construction site proposed this time are carried out.

In Fukuoka Prefecture, especially in Kitakyushu-shi in which there is an abundance of reclaimed land, since the last disposal expense in Fukuoka Prefecture is very cheap compared with that in other prefectures there are very few middle processing institutions which receive construction waste. In order to raise to 80% or more, the rates of construction waste recycling, many middle processing institutions have to be constructed.

The quantity of middle processing institutions can be decreased by increasing the items of separation at the construction site.

4-4 Increase of the rate of recycling

According to the construction waste survey which the Ministry of Construction performed in 1995, the rate of construction waste recycling in Kyushu is 38%, and is very low, compared to the national average of 58%. The rate of recycling in Fukuoka Prefecture calculated at this time is about 40%, and it is thought that this is quite accurate. If the three items of separation at the construction site are enacted as the construction recycling law is carried out, the rate of recycling can be increased to 67%. Furthermore, when a sufficient number of middle-processing institutions are built, it increases to 77%. In the proposed model, this is 80% and it can be said that the effect of the rate of recycling can also increase sufficiently.

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