Research on Building Waste and Recycling in Kitakyushu
Part 1: An Example of Construction and Demolition Work

Yumiko Ogawa*,1, Toshihide Fukahori2 and Weijun Gao3

1 Graduate School, The University of Kitakyushu, Japan
2 Building and City Planning Bureau of Kitakyushu, Japan
3 Associate Professor Dr. Engineering, The University of Kitakyushu, Japan

Abstract
In this paper, we investigate and analyze the situation of building demolition and construction and the phenomenon of discharging construction waste in Kitakyushu City, Japan in 2002. The amount of construction waste and its processing method are clarified according to the type of structure. An outline of the demolition of a city-owned housing complex has been presented based on statistical data from Kitakyushu City. Furthermore, using examples of housing complexes, we discuss the process of demolition and construction in 2001 and 2002. We also analyze the discharge amount of demolition and construction wastes, the treatment method and the schedule of each demolition construction project, etc.

Keywords: construction waste; demolition and construction; recycle

1. Introduction
Since establishment of the Construction Materials Recycling Act by the Japanese government in May 2002, sorted dismantling of buildings and recycling of construction waste have been obligatory for parties who receive orders for building construction, while the promotion of recycling has received much greater attention in order to establish a recycling-based society. Construction waste accounts for half of all industrial waste and demolition techniques and disposal methods for such waste have gradually improved. In Fukuoka, Japan, in order to promote recycling enterprises, it is aimed to reduce waste material, such as concrete, asphalt, and wood, to zero by the end of 2005.

Some research has been carried out on building material waste and on methods of recycling. Y. Tsunetsugu1) made a comparative study of three scenarios for the recycling of demolition wood waste. K. Yokoyama2) discussed evaluation of low material consumption buildings based on the intensity of resource consumption. Y. Omi3) predicted building material waste and analysis of the effect of recycling in the field of wooden houses. GAO4) presented a model to calculate the energy consumption of residential buildings by using recycled building materials.

However, little research has been carried out concerning the entire process of building demolition. In this paper, using the city of Kitakyushu5) as the investigated area, the condition of demolition and construction in 2002 has been analyzed based on the actual statistical data of construction waste. Furthermore, the conditions and characteristics concerning the demolition, middle processing, final disposal, and recycling of a building have been clarified. Data regarding the amount of construction waste material counted by the Building and City Planning Bureau, Kitakyushu has been used for analysis.

Table 1. Recycling Conditions in 2002

| Construction waste | The amount of construction waste | The rate of resource-recycle |
|--------------------|----------------------------------|-----------------------------|
| Concrete           | 25940.7                          | 70.4                        |
| Wood               | 1045.8                           | 62.8                        |
| Asphalt            | 1521.7                           | 92.1                        |
| Man made wood      | 112.3                            | 80.1                        |
| Sludge             | 2935.6                           | 80.1                        |
| Mixed wastes       | 534.7                            | 2.6                         |
| Metallic materials | 773.7                            | 81.2                        |
| Plastics           | 286.9                            | 5.4                         |
| Paper              | 185.2                            | 8.9                         |
| Asbestos           | 42.8                             | 0                           |
| Another            | 522.2                            | 24.2                        |
| Total              | 33901.6                          | 69.5                        |

(Discharged clay 48855 3m³ | 64.1)

(Received August 30, 2004; accepted July 8, 2005)
discharged by demolition was about 33,900 tons, and
among these, about 22,340 tons have been recycled.
Therefore, the rate of resource-recycling was 69.5%.
Moreover, discharged clay amounted to about 48,850
cubic meters and if this were included, the rate would be
64.1%. If we investigated the recycling of the different
materials, we would find the rate to be 81.2% for metal
waste, 80.1% for man-made wood, 92.1% for asphalt,
62.8% for wood, and 70.4% for concrete, respectively.

2.2 Construction Waste in Demolition and
Construction

Fig. 1 shows the discharged amount of construction
waste per square meter from different types of
construction in 2002, while Fig. 2 shows the treatment
methods for waste from demolition construction in
different types of construction types.

As can be seen in Fig. 2, according to the processing
method of construction by-products, the percentage
of resource-recycling is almost 100% for Reinforced
Concrete construction, and 80% for Steel construction
and Concrete Block construction. Therefore, it can be
concluded that, except for wooden construction, all
construction waste is recycled by more than 80%. In
the case of wooden construction, the main construction
by-products were wood waste or man-made wood,
and the treatment methods mainly serve as recycling,
onerous sale, and incineration disposal. In the case of
the demolition of wooden construction, the percentage
of recycling exceeded 60%, combined with the
amount processed by incineration disposal and onerous
sale, even though the percentage of resource-recycle is
less than 30% of total wood waste.

From Figs. 3 to 5, we have presented the amount of
discharged waste divided by the different materials for
three types of construction, such as Wooden, Concrete
Block (CB) and Reinforced Concrete (RC), by using
data of 2002. For wooden structures, the amounts for
mixed waste and wood waste were about 0.088ton/m²
and 0.08ton/m², respectively. For CB structures,
the main waste was concrete; about 1.66ton/m², while
asphalt was about 0.016ton/m² and wood about 0.04ton/
m². Man-made wood was about 0.017ton/m². For RC
structures the main waste was concrete; about 1.82ton/
m², asphalt was about 0.001ton/m², wood was 0.028ton/
m² and man-made wood about 0.039ton/m².

3. A Case Study on Housing Complex Demolition
3.1 A Case Study on Public Operated Housing in
Kitakyushu City

By the end of April 2003, Kitakyushu City had
approximately 427 housing complexes comprising about
33,340 residences. In Kitakyushu, housing complex
construction reached its peak in the middle of the 1970s,
and from then on construction and rebuilding have
pushed ahead at an almost fixed rate. The life of city-
owned residences is about 40 years. In 2002, demolition
construction had been carried out on five city-owned
housing complexes called H, OT, Y, K, H2, respectively.

An outline of city-owned housing complexes
and their demolition situation in 2002 is shown in Table 2. From this table, it can be concluded that the total amount of construction by-product from the demolition and construction of city-owned housing complexes was 1,061 tons for H housing complex, 2,683 tons for OT housing complex, 6,647 tons for Y housing complex, 6,647 tons for K housing complex, and 1,446 tons for H2 housing complex, while the resource-recycle rates for every housing complex were 100%, 97.5%, 62.2%, 99.8%, and 97.9%, respectively.

3.2 The Outline of the OT Housing Complex

In order to clarify the characteristics of treatment methods for construction by-products, the demolition and construction of city-owned OT housing complexes of Kitakyushu has been investigated in detail, and the process of housing complex demolition and construction in 2001 and 2002 has been analyzed in this paper. Both demolition constructions were located in the OT housing complex (Fig. 6).

Table 3 shows the outlines of these two buildings; and Table 4 shows the treatment methods and disposal amounts of the construction by-product in 2001 and 2002. The waste treatment rate reached about 95.56% in 2001 and 98.87% in 2002. Regarding the treatment method for each construction by-product, no great difference was seen between 2001 and 2002 except for gypsum board, for which the treatment methods were final disposal processing in 2001 and middle processing in 2002, respectively. Furthermore, while there were 11 types of construction by-product in 2001, there were only nine in 2002 as there was no asbestos cement and slate in that year.

3.3 Work Process of the OT Housing Complex

Figs. 7 and 8 show the work process in the demolition and construction of the OT housing complex. Although there was little difference in the treatment method during the demolition construction of the OT housing complex, some differences can be found in the work process between 2001 and 2002.

As for the work process, the processing schedule and daily processing quantity have been investigated. Here, three kinds of by-product (concrete, asphalt, and metal waste) especially have been observed in detail. These three materials were processed on separate days in 2001, but were processed in 2002. Especially in the case of processing concrete; a large amount of concrete waste was transported in a single day. Processing as many construction by-products as possible in a single day can increase work efficiency, and is predicted to lead to the saving of energy consumption concerning transportation.
4. Conclusion

In this paper, the situation regarding building demolition and construction in Kitakyushu was first investigated. An example of building demolition and construction has been analyzed, while conditions related to the transportation of construction by-products was also concluded in Kitakyushu in 2002. The amount of construction by-product and its processing method were clarified according to structural type. Furthermore, by using the OT housing complex demolition construction as an example, the process of demolition construction in 2001 and 2002 has been analyzed. The results can be concluded as follows:

1) The resource-recycling rate for Kitakyushu City in 2002 was about 64.1% in total.

2) According to the processing method of construction by-products, the percentage of resource-recycling is almost 100% for Reinforced Concrete construction, 80% for Steel construction and Concrete Block construction and 60% for Wooden construction.

3) In the case study of housing complexes built between 2001 and 2002, we found that the resource-recycling rate was higher at above 95%.

4) The work process of housing complex demolition between 2001 and 2002 has some different characteristics, while the recent demolition process has shown much greater efficiency than before.
As for further study, serious work is still necessary in order to predict the amount of construction waste accompanying building demolition and construction, and a key factor is the creation of a database regarding demolition and construction by-products. Furthermore, the energy consumption used for resource-recycling, should be analyzed.

References
1) Yuko Tsunetsugu, Masahiko KARUBE and Mario TONOSAKI: Evaluation of the scenarios for recycling of demolition wood waste from residential houses, J. Environ. Eng, AIJ, No. 567, 1-6, May, 2003
2) Keizo YOKOYAMA, Keiichi YOSHIMUTA, Noriyoshi YOKOO and Tatsuo OKA: Evaluation of low material consumption buildings based on intensity of resource consumption, J. Environ. Eng, AIJ, No. 579, 81-88, 2004
3) Yasuo OMI: Extermination of wastes of building materials and analysis of the effect of reusing/recycling in the field of wooden houses; A study on the stock and waste of building materials in/from existing buildings (part 2), J. Environ. Eng, AIJ, No. 584, 107-112, Oct., 2004
4) Weijun GAO: Investigation on energy consumption of recycling and demolition in housing complexes, Journal of housing research foundationno.31, 2004, No. 0324, 251-259

Note 1:
Kitakyushu City has an area of about 485km2 and is located midway between Tokyo, Japan and Shanghai, China. Kitakyushu has thrived as a gateway for trade with Asia since ancient times. Today, Kitakyushu's population of one million continues to reap the benefits of proximity to the Asian continent, and the city has become one of Japan's largest centers for international trade and industry.