

Building Construction System with Recycled Materials - An Experimental Construction of Residential Plumbing Area-

Naoto Mine

Professor, Department of Environmental Space Design, Faculty of Environmental Engineering,
The University of Kitakyushu, Kitakyushu, Fukuoka, Japan

Hiroki Tsutsumi

Assistant lecturer, Department of Environmental Space Design, Faculty of Environmental Engineering,
The University of Kitakyushu, Kitakyushu, Fukuoka, Japan

Abstract

It is said that the usage period of residential buildings in Japan is shorter than that of Western countries such as the US, UK, France, and Germany. It means that buildings are often demolished to build new houses. The demolition process creates a substantial volume of waste that can not be readily reprocessed. Building materials and components can be recycled and reused to mitigate this problem, however a recycling system has not yet been established. The purpose of this study is to establish a reuse system for building materials. To achieve this purpose an experimental construction was performed with used residential plumbing materials such as bath and kitchen fixtures. In the experimental construction process, the bathroom, kitchen, toilet, and wash basin rooms in an apartment house were assembled and disassembled. The paper describes a process for collecting reused materials and components, and the results of the construction experiment. Work processes and man-hours were analyzed. Man-hours to assemble used materials are approximately 1.5 times that of virgin materials.

Keywords

Building Construction System, Recycled Materials, Housing, Plumbing Area, Construction Experiment

1. Introduction

It is said that the usage period of residences in Japan is shorter than that of Western countries such as European Union or the United States. The Housing Statistical Survey 2003 (Tomozawa, 2002) reported that the housing life time in the UK is 141 years, the US is 96 years, France 86 years, and Germany 79 years. The report stated that in Japan as 30 years. In Japan most old houses are demolished and new houses are built, which produces a lot of waste. The houses built in the '70s will now be rebuilt. The waste produced by demolition has become a serious problem. Many studies have been carried out to reduce construction waste, such as concrete recycling (Kuroda et al, 2002a). On the other hand, there are few studies regarding building finishes and services. This paper describes an experimental construction project using reused building materials and components.

2. Objective and Scope of the Study

The objectives of the study were to reduce construction waste by reusing building materials and components. Authors focused on modular building components such as modular bath units, systematized kitchen units, and other building components that are used for residential plumbing areas. An experimental construction project was conducted to clarify problems that occur during construction when reused materials and components are used. The plumbing area in a house was chosen for the experiment because it is the most complicated area.

In addition to this, a market for reused components must be established to practically realize the reuse of building materials and components. Product liability is another critical issue to address. For these problems authors are planning to make a survey of the current situation in the construction industry.

3. Study Items and Methods

The following are the items and methods of the study.

- (1) To analyze man-hours and problems during construction when reused materials and components are used in the plumbing area in a house.
- (2) To analyze man-hours and problems during demolishing the assembled components that can be reused after the demolition.
- (3) To find out the design method for easy reuse of building components.
- (4) To propose a building system that fits reuse of building components.
- (5) To survey the quality insurance.
- (6) Evaluate establishing a market for reused building materials and components.

Regarding items (1)-(3) an experimental construction was conducted in a laboratory. From the experiment work-study was achieved to analyze work processes, working time, man-hours, and worker's motions. Based on the analysis authors would anticipate the problems during construction. As for the item (4) authors are planning to propose a building system that is easy to disassemble and to assemble when reused components are used in construction. To pick up problems authors will apply "brain storming" to create ideas for a new building system. Regarding the item (5) authors will give a questionnaire survey to manufacturers, contractors, and municipal government to clarify the market problems. As for the item (6) authors will make paper surveys to obtain basic problems. And by using the supply chain management method authors will find out future study themes. This paper describes item (1).

4. Obtaining the Building Components

4.1 Way of Obtaining Used Building Components that are Available for Reuse

Currently there is a strict limitation to obtain used materials and components. As for the wooden structure, used materials can be recycled into particle board, but this is unusual. On the other hand, steel or aluminum has been recycled for a long time. Recent studies regarding the recycling of concrete have been carried out and some of the methods are in use (Kuroda et al, 2002b). However, these are not cost competitive.

Modular components such as bath units, system kitchen units, and bathroom basin units are not typically reused. The reasons are: (1) when the buildings are demolished most of the components are crushed, (2) most of used components are old kinds that people do not want to use, (3) reusable components which are used in show rooms or model houses are not sold in the open market, (4) a quality insurance system has not been established.

4.2 Acquisition from a Waste Process Plant

With the cooperation of the Environmental office of the municipal government of Kitakyushu authors have tried to obtain used building components from a commercial waste process plant.

4.3 Reused Components at the Waste Component Stockyard in Manufacturer

The demolished building components are temporarily stocked at the manufacturer’s yard then transferred to the final waste process plant. Authors got a toilet bowl and kitchen unit from there. The toilet bowl was used in the experiment, but the kitchen unit was not because it was an old style.

4.4 Reused Components from the Demolition Site

Authors obtained information that there was a building demolition site in the city of Kitakyushu. The information was a construction company demolished a modular bath unit that was available to use as recycled components. The demolished modular bath unit was used by a house renovation company. This fact shows that there is building components reuse market that is not open to the public.

4.5 Reused Components from Show Rooms or Model Houses

The building components that are displayed or used in show rooms or model houses are available to be reused. Authors got a modular bath unit, kitchen unit, and bathroom basin unit from the manufacturer. These components were used at show rooms or model houses.

5. Outline of the Experimental Construction

5.1 Outline of the Building Plan for the Experiment

The experimental construction was achieved as a model of “the plumbing area” of an apartment house. A plumbing area plan was drawn based on the reused components that included a modular bath unit, a kitchen unit, a bathroom basin unit, and a toilet bowl. The model of the experiment was a high-rise apartment house constructed in Kitakyushu city in July of 2004. We modified the original plan to make the experiment easier. Table 1 shows an outline of the model plan for the experiment. Figure 1 and 2 shows a plan and a section of the experimental plumbing area.

Table 1: Outline of the experimental construction

ITEMS	DESCRIPTION
Building use	A plumbing area of an apartment house
Partition	Wooden stud and plywood
Floor system	Stud and particle board system
Floor height	2,800 mm
Experimental area	80.0 m ²
Site area	19.2 m ²
Laboratory area	230 m ²
Location of the experimental room	The experimental construction laboratory in the University of Kitakyushu

5.2 Methods of the Work Study

5.2.1 Process Analysis

Process analysis is widely applied for work and method improvement in the manufacturing industry. The work processes have four categories: (1) operation, (2) transportation, (3) delay (stock or idle), and (4) inspection (quantity or quality). Each category has its own symbol, so it's easy to visually recognize the work types. The relationships among each process are connected with flow lines. By using process analysis method for construction it is possible to express multi-trade work visually, which had been difficult to analyze previously. (Mine, 2003)

These processes are categorized following two levels according to the work detail.

- (1) The elemental work unit (e.g., the work element is the basis of work done by single trade):EWP
- (2) The unit work process (the group of EWPs to complete a unit work process): UWP

Figure 1: A plan of the experimental construction

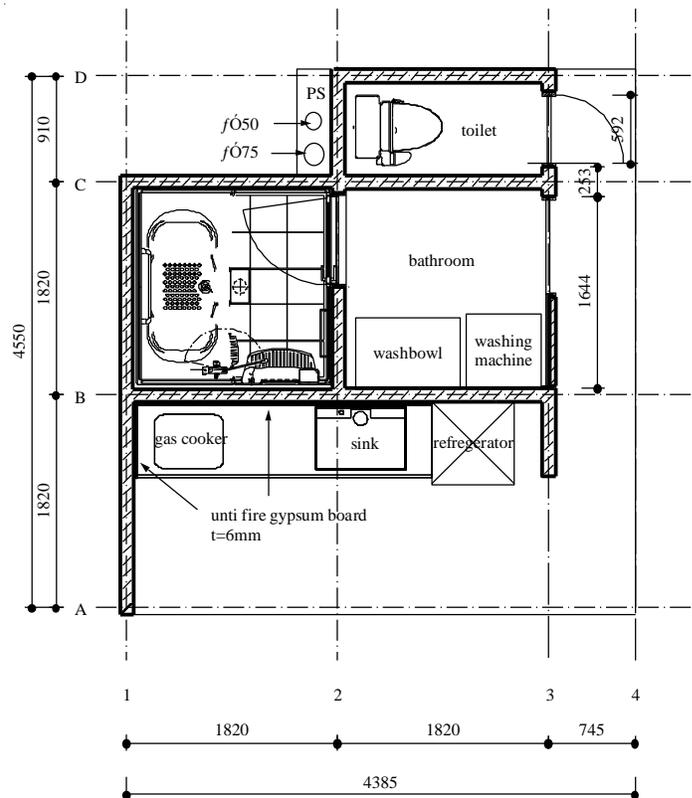
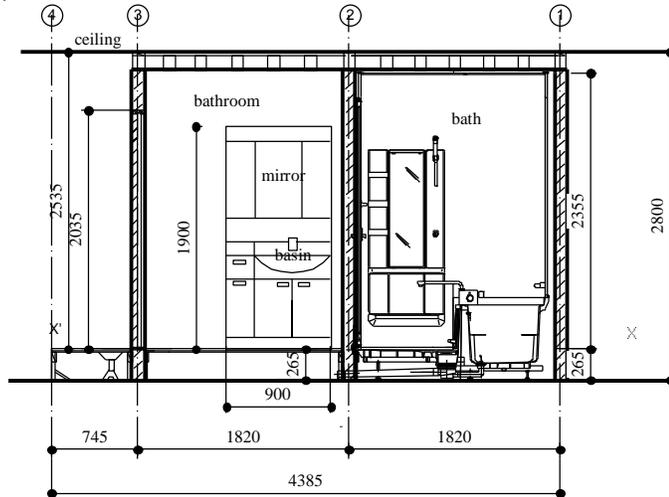


Figure 2: A section of the experimental construction



5.2.2 Measuring Man-hours

The snap reading method (work sampling) was introduced to measure man-hours of each activity. The snap interval was 5 minutes for one sample. In each snap the observer distinguishes each worker's activity and records it in the sheet. One observer measured one to three workers' man-hours. One set of activity is analyzed from start to finish, which includes various kinds of activities.

5.2.3 Recording the Experimental Works

The VCR system was used with a digital handy camera and a time lapse VCR system. After recording the work, the recorded video tapes were converted into DVDs. The records were used for detailed man-hour measurement and motion analysis.

6. The Results of the Experiment

6.1 Activities in the Experimental Construction

The experimental construction includes partition, floor, modular bath unit, kitchen unit, bathroom basin unit, toilet bowl, plumbing for water supply and drain. In addition to these works door installation, wallpaper, and baseboard were also included. Figure 3 shows activities in the experiment.

6.2 The Process Analysis

6.2.1 Entire Process in a House

To obtain the basic data for method improvement and/or development, activities must be distinguished into sub-work such as transportation, inspection, and main work such as operation. These must be expressed as graphically different. The analysis was carried out on primary unit work process in an experiment. Figure 3 shows the entire UWP in a plumbing area. Before all the operation processes there was transportation. To avoid complexity authors expressed only the major processes eliminating minor transportation.



Figure 2: Modular bath unit installation work



Figure 3: Kitchen unit installation work

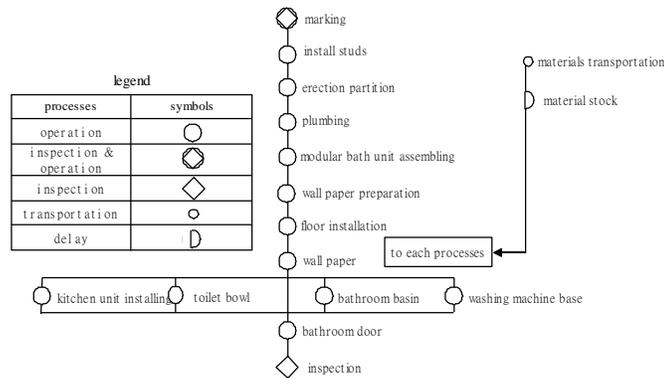


Figure 4: The UWP of entire work in plumbing area

6.3 Analysis of Man-hours

6.3.1 Man-hours of All Trades

Man-hours by processing the data were analyzed that was measured with the snap reading work sampling method. Figure 5 shows the result of the measurement containing the entire project. In the graph hatched bars show activities that are constructed with reused materials and components. As shown in Figure 5 the man-hours of partition wall is the largest. That was 1,555 man-minutes which is 25% of total man-hours. The man-hour of modular bath unit assembling work is 370 man-minutes, and its man-hour percentage of total man-hour is 23%. Kitchen unit is the second large amount that is 225 man-hours, 14% of total man-hours respectively.

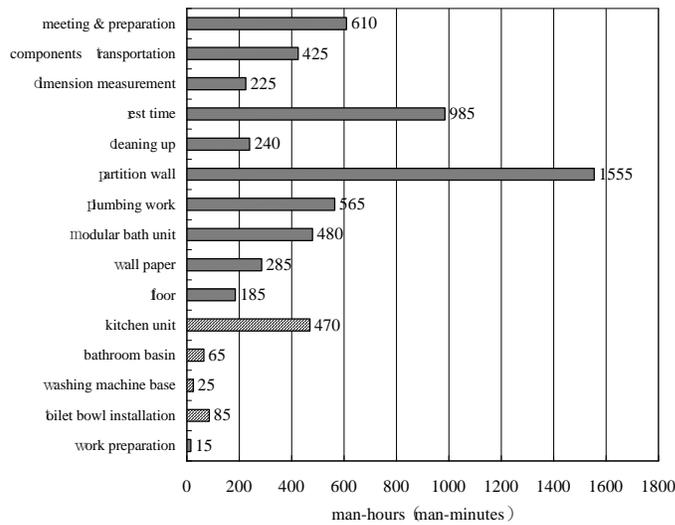


Figure 5: Man-hours of each activity

6.3.2 Man-hours Comparison to Normal Project

In the experiment recycled building materials and components were used. It is logical to compare the data to a normal project. The data provided by the Construction Company A was used as normal project data. In this case, “normal” means that a project used new materials. Figure 7 shows a comparison of the experiment and Company A data. The total duration of the experiment data is 870 man-minutes, and the A company data is 340 man-minutes.

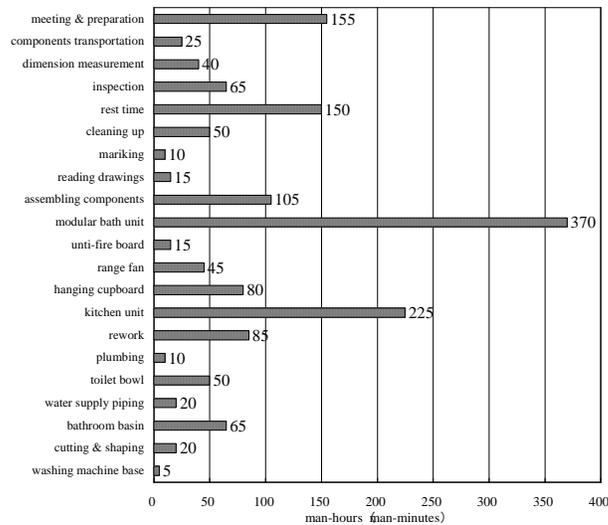


Figure 6: Man-hours of each activity

The total duration of the experiment data is 870 man-minutes and the Company A data is 340 man-minutes. Apparently, the experiment data is larger than that of the Company A data by 250%. As shown in Figure 6 most of the activities in the experiment man-hour except the activity for the washing machine base were larger than the Company A man-hour.

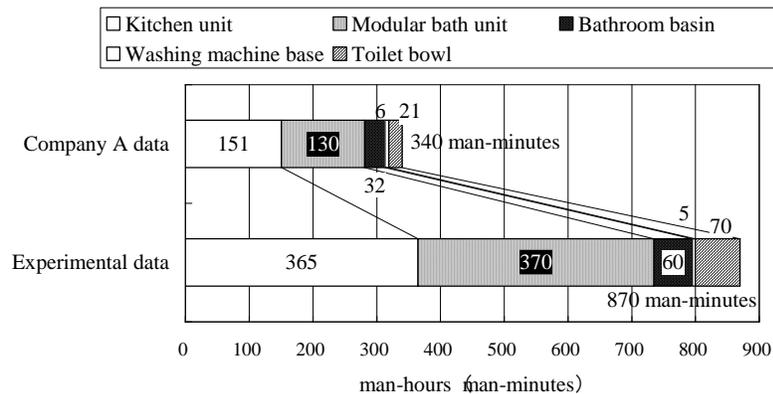


Figure 7: Man-hour comparisons to the normal data.

7. Conclusions

An experimental construction study was carried out to obtain basic data when reused building materials are used for construction in the plumbing area of an apartment house. From the experiment work process and man-hour data were obtained. Through the study, it was confirmed that used materials and components could be made use of in construction. Authors are planning to carry out a similar experiment to advance the study. In addition authors plan a survey of quality insurance and a possibility of establishing reused materials market. The research was funded by the Housing Research Foundation in Tokyo.

8. References

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