A Reuse Management Model of Building Steel Structures Using Information Technology

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Summary
Considering a reuse flow, the author proposes a reuse management model for building steel structures using information technology. In the process of selecting structural members, the structural designer discusses with the owner whether or not reusable members should be used. When utilizing reusable members is decided, the structural designer accesses the database managed by IT engineering to select appropriate reusable members. The constructor places orders for reusable members with fabricators, and for new members with manufacturers. Careful demolition is necessary in order to preserve structural members as reusable members. The owner of the building to be demolished requests the demolition contractor to do so. After demolition, members collected for reuse are inspected for their quality and kept in the responsible fabricating contractor's storage until used.

Keywords: Environmental burden, Building steel structure, Information technology, Management model, Design, Construction, Demolition, Reuse, Reusable member

1. Introduction
Although extending service life is the most crucial element in reducing the environmental burden of building steel structures, there are a number of buildings that should be demolished for physical, architectural, economic, and social reasons. When building steel structures had to be demolished, their structural members were scrapped for recycling. This iron and steel recycling, however, is now at a turning point, because of the time-consuming scrapping process and management problems at electric furnace manufacturers. This has given rise to the need for considering the implementation of an alternative measure of reuse whose market has not yet been developed. The reuse of entire buildings, or at least reuse at the structural members, is extremely effective for limited-term and short-life buildings that are beginning to find demand. Scrapping steel structural members requires energy for melting, and this melting process causes substantial CO₂ emissions. Meanwhile, reusing structural members requires only ancillary energy for demolition, transportation, and adjustments, causing less environmental burden.

When promoting reuse targeting general steel structures, it is indispensable to take a cross sectional view of the build-to-order construction industry and to make full use of information technology via the Internet [1]. More specifically, an information network is essential to secure the quality and quantity of reusable members as well as to provide such members of specified quality at designated locations and times without delay.

This paper proposes a management model that can be generally applied for reusing building steel structures using information technology. Citing a case of mid-rise steel building structure and using the proposed model, this paper also examines the viability of the model from the viewpoint of economic efficiency.
2. Reuse Flow of the Building Steel Structure

A reuse flow diagram of the building steel structure is presented in Fig. 1. The diagram shows the flows of software, or information, and hardware, or material (reusable members in this particular case). The dotted line shows the information flow and the continuous line, the material flow. Reusable members circulate via the database (hereinafter referred to as the DB) through a series of cyclic operations: design, fabrication, construction, maintenance, demolition, and storage.

![Reuse Flow Diagram]

*Fig. 1 Reuse Flow*

2.1 Designing & fabricating flow

In the designing phase, structural designers access the DB to select appropriate reusable members. Reusable members in the DB do not necessarily have to be limited to those demolished and kept in storage. When reusable members alone cannot fully meet the quantity requirements, new members are used.

In the fabricating phase, reusable members are used alone or with new members. Some adjustments are made to the ordered reusable members on site or at the factory to convert them into final member products that meet the specified requirements. Reusable member stocks are placed under centralized management as information in the DB, but the actual members are kept in regional storage facilities.

2.2 Construction & maintenance flow

In the construction phase, the constructor orders structural members selected by the structural designer based on drawings and specifications. In construction, reusable members are used either alone or with new members. In the maintenance phase, when earthquake damage is seen in structural members while the building is in service, or when the intended use of the building is altered, a decision is made to repair the building for recycling or to demolish it.

2.3 Demolition flow

The building owner decides the post-demolition policy of the structural members. After deciding to demolish the building and use the structural members as reusable members, the performance information of such members is registered in the DB. During this process, the performance of these members is evaluated to judge their availability as reusable members. In order to use the members as reusable members, more careful demolition and sorting are required. Collected members are classified for reuse, recycling, and disposal flows depending on their degradation.
3. Reuse Management and Information

In order for the reuse management to be economically viable, the author proposes the model presented in Fig. 2 (hereinafter referred to as the reuse management model). The reuse management model here indicates an overall system developed to facilitate reusing building steel structures using information technology. The model consists of the following three fields: management, design, and stock. The role of information in establishing a reuse business can be clarified by characterizing the reuse flow described in Section 2 with these three fields, facilitating building the DB.

Fig. 2 Recommendation of Reuse management Model

3.1 Management field

Business management, which occupies a central position in the reuse management model, is responsible for managing the reuse business and controlling information technology (hereinafter referred to as IT) engineering and reusable member fabricators. IT engineering is responsible for evaluating reusable member performance. IT engineering also creates a system for unified management of reusable member information (hereinafter referred to as the reuse system), and builds and maintains the information DB on reusable member performance. The reuse system is utilized over the Internet to provide DB access to an unspecified number of designers. The reusable member information in the DB is constantly updated. Reusable member fabricators are responsible for fabricating and storing reusable members. They also test the quality of reusable members and put all relevant information into the reusable member DB possessed by IT engineering. This is collectively characterized as the management field.
3.2 Design field
In the design field, the architect designs a building in response to the owner’s request, and the structural designer selects the structural members. In the process of selecting the members, the structural designer decides if reusable members should be used. When utilizing reusable members is decided, the structural designer accesses the DB managed by IT engineering to select appropriate reusable members. Next, the owner requests the constructor to construct the building. Based on drawings and specifications, the constructor then places orders for reusable members with reusable member fabricators, and for new members with new member fabricators. New members are manufactured as always. The constructor obtains prior consent from the owner and designer to use new members when reusable members are unavailable due to design alterations or changes in the demolition timing of target buildings from which reusable members are expected. Thus, in the design field, reusable member fabricating contractors can process reusable members in addition to new members, and increased business options become available to them.

3.3 Stock field
Careful demolition and sorting is necessary in order to use structural members as reusable members. After demolition, the members collected for use as reusable members are inspected for their quality and kept in the responsible fabricator’s storage. The performance data of the reusable members kept in storage is put into the DB possessed by IT engineering. In utilizing reusable members, business management obtains complete data on the buildings from which reusable members are expected, including the construction sites, demolition times, and quantity of structural members, in order to comprehensively assess reusable members storage sites as well as economic efficiency. This is positioned as the stock field. DB utilization concerning the performance of target building steel structures provides building owners with increased business options.

4. Simulation Using Reusable Members
The author conducted a simulation of the reuse management model proposed in Section 3 to verify the possibility of the general application of the model, and assessed the results. Only economic efficiency, the most basic evaluation measure, was used as a criterion for assessing the simulation results.

4.1 Cost of reusable members
For the purpose of comparing economic efficiency, construction expense was determined through discussions between the author and nine specialists from a range of business fields including trading, system engineering, steel fabricating, construction, steel structure demolition, and housing manufacturing (Table 1). The discussions were based on statistics [2][3].

<table>
<thead>
<tr>
<th>Table 1 Construction Expense Breakdown</th>
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<tbody>
<tr>
<td>When new members are used</td>
</tr>
<tr>
<td>Yen/ton</td>
</tr>
<tr>
<td>Steel</td>
</tr>
<tr>
<td>Storage</td>
</tr>
<tr>
<td>DB</td>
</tr>
<tr>
<td>Transportation</td>
</tr>
<tr>
<td>Fabrication</td>
</tr>
<tr>
<td>Erection / Assembly</td>
</tr>
<tr>
<td>Total</td>
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Construction expense generally changes with changing market condition, however, in this study, the total construction expense when new members are used was first set at 200,000Yen/ton, which was then broken down into individual expense items. The new steel product expense was set at 70,000Yen/ton. The subtotal of the erection/assembly, and field temporary works expenses when new or reusable members are used was set at 50,000Yen/ton. The steel product expense when reusable members are used is set at 35,000Yen/ton, half the new member expense.

When information on reusable member performance becomes clear, and there is a method for evaluating the information, quality management costs may be added to the expense items, in which case there may be increases in steel product, storage, and DB building expenses. These possibilities, however, are not considered in this study.

As for transportation expense, an average of short and long distance transportation expenses was adopted. When structural members need fabricating in order to be used as reusable members, the expense of transportation from the fabricator to the job site is set at 10,000Yen/ton. When structural members do not require fabricating, the transportation expense from the storage site to the job site is set at 5,000Yen/ton whether or not fabricating is necessary. Although transportation expense varies depending on the volume of building structures to be stocked and the storage site set up taking regional characteristics into consideration, an average value is adopted here. The expense of fabricating reusable members when necessary is set 20,000Yen/ton lower than that of fabricating new members.

The simulation has assumed that a building construction method facilitating demolition and dismantling had already been developed. It was also assumed that adequate measures had been taken to protect steel members from rust so that they would be able to maintain their expected performance, and in the fabricating phase, the length of reusable members could be altered freely by welding or cutting.

4.2 Simulation model

The model targeted for simulation is a two-way rigid frame structure used for a mid-rise steel building structure (apartment complex) [4].

The structure adopts column members (H:350-800×250-300×9-16×14-26) and beam members (H:250-500×175-300×7-12×11-18). Reusable member stocks are assumed to have been registered in the DB built by IT engineering. Type A is a 7-story (above ground) structure (Story height: 2750 mm; X-direction span 6000 mm × 6; Y-direction span: 7500 mm, 4600 mm), and the steel weight is 203 tons. In Types B to F, variations of the basic Type A structure, the story height and spans in the X and Y directions of Type A are altered. Approximately 10 percent of the length of the structural members is altered to meet the owner’s demands concerning floor area and story height.

As for mid-rise steel building structures to be newly designed, the structural designer accesses the DB possessed by IT engineering to select appropriate reusable members based on drawings prepared by the architect entrusted by the building owner. Type T1 and Type T2 are variations of Type A in which either the story height or span is altered in approximately 5%.

4.3 Examination

The simulation results of the mid-rise steel building structure are presented in Table 4.

<table>
<thead>
<tr>
<th>Construction expense Yen</th>
<th>New members</th>
<th>New members 26% + Fabricating required 74%</th>
<th>New members 34% + Fabricating required 66%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Type T1 (Span: +300 mm)</td>
<td>45,840,000</td>
<td>40,750,000</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td>(89%)</td>
<td></td>
</tr>
<tr>
<td>Type T2 (Story height: +150 mm)</td>
<td>42,940,000</td>
<td>---</td>
<td>31,600,000</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
<td></td>
<td>(74%)</td>
</tr>
</tbody>
</table>
In Type T1, the 74 percent use of Types A to F products specified as reusable members, and the 26 percent use of new members can be achieved. This enables an 11 percent cost reduction compared to 100 percent new member use. In Type T2, the 66 percent use of Type A to F products, and the 34 percent use of new members are possible. A 27 percent cost reduction is possible in types where the story height is altered.

5. Conclusions

This paper examined the viability of reuse management of building steel structures utilizing information technology. For this purpose, a simulation of a mid-rise steel building structure (apartment complex) was performed using the reuse management model. The simulation results revealed the following:

(1) The author proposed the reuse management model considering the reuse flow. The role of information for creating the viable reuse management model becomes clear, making it possible to build the DB.

(2) An information network created over the Internet makes it possible to remove geographical and temporal restrictions.

(3) In construction, fabricators are able to fabricate reusable members in addition to new members. Hence, increased business options become available to fabricators.

(4) Building owners are able to obtain increased business options by utilizing the DB concerning the structural performance of the building to be demolished.

(5) The reuse management model is economically viable, and thus can be generally applied.

(6) Economic efficiency increases with the decreasing amount of reusable member fabricating.

(7) A 15 percent cost reduction becomes possible when a large stock of reusable members is available, compared to 100 percent new member use when all members need fabricating. A 40 percent cost cut also becomes possible when no fabricating is needed.

The economic efficiency of business management was assessed using the business management model presented in this paper and focusing on a mid-rise steel building structure (apartment complex). The assessment did not cover other structure types, but it is believed that the results obtained from these structures would be basically the same. The author would like to take up the issue of establishing a method for evaluating the performance of reusable members as the theme for their future study.

In anticipation of building steel structures expected to be demolished in the future, the author would also like to further their study efforts towards creating a market for reusable members by prior establishment of the reuse management described in this paper.

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References


