Ideal utilization of forest resources for sustainable society

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The amounts of new wood used for housing construction and wood wastes from demolished buildings were calculated using various scenarios of wood recycling. Increase in reuse rate was found to be effective to reduce the total amounts of final wastes and the use of new wood materials.

Keywords: wood waste, C&D waste, wood recycling, reusing

I. INTRODUCTION

I-A. Present states of wastes in Japan

Waste disposal is a serious social issue in Japan. More than 430 thousand tons of industrial wastes were illegally dumped in 1999, of which construction wastes accounted for approximately 70%, and wood wastes amounted to 25%. Based on such backgrounds, the Ministry of Land, Infrastructure and Transport established the "Construction Recycling Law," which aims to recycle 95% of concrete, wood, and asphalt wastes by 2010.

I-B. What wood should do

To attain this percentage of recycling, not only the methods for recycling and disposing of wood wastes existing today but also the methods for utilizing wood should be considered. Wood is the only natural-circulating material among principal construction materials, and is characterized by the storage of carbon dioxide that it absorbed when it was a growing tree. Therefore, to lengthen the period between cutting and disposal is important to reduce the amount of carbon dioxide emitted by human-induced activities. Long periods until wood is disposed of lead to the reduction of wastes and efficient use of another characteristic of wood, which is natural decomposition.

One of the principal factors that make it difficult to recycle wood waste is that construction wastes are usually disposed of as mixtures of materials, which are difficult to separate. From such wastes, only small amounts of recyclable materials can be obtained, and the way to recycle them is limited to chipping. The labor, costs, and energy needed to classify a mixture into components increase as there are more components in the mixture. To solve this problem and to promote recycling, materials should be produced and buildings should be constructed considering the ease of disassembling and recycling. This method will increase the amount of wood that can be recycled and enable the reuse of wood in the form of lumber and multilateral reuse of wood.

This study aimed to analyze changes in the amount of wood demolition waste by using them in various ways.

II. MATERIAL FLOW OF WOOD

We first documented the material flow of wood by integrate statistics and references and conducting interview surveys to understand the present state of the wood use and wood waste(Fig.1).1-3

In 1998, approximately 15 million cubic meters of remainder materials were produced at timber factories, over 90% of which was recycled as pulp,
materials for producing wood composite panels, and fuel. On the other hand, most of the 17 million cubic meters of construction, demolition and package wastes were not recycled but incinerated, landfilled, or dumped illegally. The precise situation is still not clear, and these values contain estimates.

Fig.1. Material flow of wood in Japan, 1998.

III. SCENARIOUS FOR WOOD RECYCLING

We compared the amount of demolition wastes in one year and use of new wood for construction in the next year (the amount of new materials to be used for construction minus the amount of reused and recycled wood), for various methods for recycling/ reusing wood wastes from demolished structures. Three typical scenarios were established and mutually compared. We then investigated the effects of ease of demolishing.

III-A. Assumptions and conditions

The following assumptions were made for our investigation:

1) 11.2 million cubic meters (the amount from demolished buildings in 1998) of demolition wood wastes are produced from wooden houses. The same amount of wood (11.2 million cubic meters) is to be used in the next year to build the same number of new houses as the number of demolished houses.

2) Of newly built houses, 81.2% were built using the Japanese traditional post and beam construction methods, and 18.8% were built using wood-frame construction or panel construction methods. The unit amounts of timber used in each construction method are listed in the Table1.

| Structural lumber | 0.138 (69.1%) | 0.152 (73.5%) |
| Fixture lumber | 0.052 (29.2%) | 0.018 (8.8%) |
| Plywood | 0.010 (4.8%) | 0.037 (17.7%) |
| Wood composite panels | - | - |
| Total | 0.200 (100%) | 0.207 (100%) |

3) Five kinds of timber are used for housing construction: large lumber, medium lumber, small lumber, plywood, and composite panel. The same amounts of large, medium, and small lumber are used for structural members. Fixtures are made of small lumber alone. Although composite panels are not widely used in the wood-frame or panel construction method, the use of composite panels will likely increase, such as for the lining of walls. Therefore, we assumed that 5/6 of the boards used in the wood-frame and panel construction method are composite panels. The conditions and assumptions about the timber used for and produced as demolition wood from houses are summarized in Table2.

<table>
<thead>
<tr>
<th>Table2. Timbers included in demolition wastes and input for construction.</th>
</tr>
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<tbody>
<tr>
<td>Percentage(%)</td>
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<tr>
<td>Large lumber</td>
</tr>
<tr>
<td>Medium lumber</td>
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<tr>
<td>Small lumber</td>
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<tr>
<td>Plywood</td>
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<tr>
<td>Wood composite panel</td>
</tr>
</tbody>
</table>

4) The following constrains are applied for recycling wood chips and reused lumber (Fig.2).

The chips, which are produced from the wood wastes of demolished buildings, are to be used to produce pulp and wood composite panels and as fuel. We assumed that only lumber could be reused.

5) We assumed two cases for the demand for wood waste chips as shown in Table3.

<table>
<thead>
<tr>
<th>Table3. Estimated demand for wood waste chips.</th>
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<tbody>
<tr>
<td>Pulp</td>
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<tr>
<td>D1</td>
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<tr>
<td>D2</td>
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</table>
Case D1 is the status quo. Case D2 was estimated by assuming that recycled pulp would account for 5% of the total pulp used in 1998 and wood composite panels would consist of 50% recycled chips (which were 1% and 33% in 1998, respectively). Demand for fuel was set to be 1.1 times of case D1, according to the government target, which is aiming to make the energy supplied by black liquor and wood waste 1.1 times of the level of 1998 by 2010.7

III-B. Effects of differences in utilization methods of wood wastes

We devised and compared three typical scenarios of recycling.
S1: Wood construction wastes are converted into chips and used as fuel. Those that are not used are disposed of. This scenario assumes that the wastes are not classified while dismantling buildings and are of poor quality.
S2: Wood construction wastes are converted into chips. The chips, from good to inferior qualities, are used as pulp materials, wood composite panel materials, and fuel. This scenario assumes that buildings are dismantled by classifying wastes but do not produce lumber that can be reused. This most resembles the present state.
S3: Of wood construction wastes, lumber is reused. The reuse rate (the ratio of the remaining volume of reused lumber to the original volume) is 0.6 for both large lumber to medium lumber and medium lumber to small lumber. The rest of the lumber, plywood, and panels are converted into chips and used for the three purposes.

III-C. Effects of the facility and method of disassembling

To efficiently reuse lumber, buildings should be constructed so that they are easy to disassemble and be carefully disassembled. This will change the reuse rate and demand for wood wastes. To investigate the effects of these changes, we estimated the amounts of wood wastes and new materials used under scenario S3 and the following conditions:
Reuse rate: 0.8, 0.6 and 0.4
Demands: D1 and D2 shown in Table 3.
These conditions give six combinations, one of which is S3 studied in B.

IV. RESULTS AND DISCUSSION

IV-A. Differences in utilization methods of wood wastes

Figure 3 shows the amounts of wastes and new materials for each scenario.
Comparison between S1 and S2 suggests that use of wood chips for various purposes reduces the amount of waste but does not reduce the amount of new materials. This is attributable to low percentages of wood composite boards used for building houses. S3 showed reductions in both the amount of waste and the input of new materials. Since demand for lumber is high, lumber wastes are highly reused thus reducing the amounts of both wastes and new materials.

IV-B. Effects of the facility and method of disassembling

Figure 4 and 5 show the amounts of wastes and...
Fig. 4. The effect of reuse rate and demand for wood waste chips on the amounts of wastes.

new materials for each combination of conditions.

Difference in reuse rate
For a constant demand, an increase in the reuse rate caused linear drops in both the amount of waste and input of new materials.

Fig. 5. The effect of reuse rate and demand for wood waste chips on the amounts of input of new wood.

Difference in demand
For a constant percentage of reuse, the use of D2 instead of D1 reduced the amount of waste by half but did not affect the amount of new materials much. This was because changes in the demand for chips only affect the amount of new materials used to produce wood composite panels, which are little used compared to the other materials.

Composite effects by reuse rate and demand
Since different demolishing methods produce wastes of different qualities, both the demand and reuse rate are likely to change simultaneously. The effect of a combination was the sum of the two effects. For a reuse rate of 0.8 and demand of D2, the amount of wastes was about 22% of that for S3 (60% and D1). The input of new materials little decreased compared to the reduction in the amount of waste. This is because even if high percentages of lumber are to be reused, used lumber accounts for only a small percentage in the total amount of materials. Also, wood composite panels are used little, accounting for a small percentage in the total amount of construction materials, and do not affect the input of new materials much.

V. CONCLUSION
We investigated the recycling of wood wastes from demolished wooden houses using models.

In our model:
1) Production of good-quality wood chips that can be used for various purposes decreased the amount of wastes.
2) Reuse of lumber as well as recycling of wood wastes to produce chips was effective to reduce wastes.
3) An increase in the demand for chips reduced the amount of wastes but did not greatly affect the input of new materials into wooden houses. This was because wood composite panels were used little in houses.
4) The combination of reuse rate of 0.8 and demand of D2 reduced the waste by 78% from that of 0.6 and D1.

In the further study, the energy and carbon balance for each case should be investigated.

Diverse utilization and large supplies of recycled materials are the quickest approaches to reduce wastes. For example, burning of wastes to produce energy is one approach. However, the idea of disposing huge amount of wastes at once as the source of energy seems to be based on the same concept of mass production and mass consumption. When using wood materials, we should consider that we are borrowing wood from the nature, which should be returned to the earth.
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