Sustainable buildings and steel

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More than 90% of steel products used in Japan are recovered as obsolete scrap, and more than 40 million tons of steelmaking materials, about 40% of total steelmaking materials consumed in Japan, are provided by steel scrap. Because of its ease of separation and melting over other materials, steel is a material that is extremely suitable for recycling use.

Meanwhile, steel is extensively used for frames, envelopes and other building components and thus is a major structural material alongside wood and concrete.

This paper describes how steel can contribute to the construction of sustainable buildings through maximum use of its excellent performance — recyclability.

Keywords: Steel, Building, Recyclability, Sustainable

I. INTRODUCTION

In Japan, steel is widely used in building construction for structural frames, envelopes and other structural members. The annual trend in new building construction starts in terms of total floor areas by structural type is shown in Fig. 1. Steel-structure buildings, alongside wooden buildings, account for the largest share in the total floor areas, reaching a little less than 70 million m² in fiscal 1999.

Buildings are demolished at the end of their service life and generate waste. Construction waste accounts for about 20% of the total industrial waste in Japan (about 400 million tons/year) and about 40% of the total disposal amount (84 million tons/year).¹ Recycling of construction waste remains low in Japan — only 65% for waste concrete and 40% for waste lumber. Further, illegal disposal of waste poses social problems. Annual average illegal disposal amounts to 390,000 tons, of which waste concrete, lumber and other construction waste account for nearly 90%.

To meet the situation and curtail such illegal disposal, the Ministry of Land, Transport and Infrastructure plans to impose duty on recycling use in and after June 2002 pertaining to waste concrete, lumber and asphalt.

On the other hand, steel differs from concrete and lumber — most steel materials, at the end of their service life, are recycled as scrap. In this sense, steel is a material that is more eco-friendly than other construction materials.

In addition, the service life of steel can be extended by the provision of galvanizing and other appropriate corrosion-protection measures. Also, development of the construction method that can meet the changes of the life cycles of buildings and reuse the structural members will allow the improvement of service life of buildings and the mitigation of the environmental burdens such as reduction of energy use at the production stage of structural materials.

In this paper, how steel can contribute to the realization of sustainable buildings by making the maximum use of the excellent recyclability offered by steel is discussed.

II. RECYCLABILITY OF STEEL

The current trend in recycling of iron and steel products in Japan² is shown in Fig. 2.

Steel is produced in basic-oxygen furnaces and electric furnaces using pig iron, produced from iron ore, and scrap as the steelmaking raw material. Annual consumption of steelmaking raw materials amounts to a little more than 100 million tons, and production of crude steel amounts to about 90 million tons. Steel products are used for containers, automobiles, shipbuilding, machinery, building construction and civil engineering. Steel products used in building construction amount to 20 million tons annually.

At the end of their service life, steel products

are recycled as the steelmaking material. Steel products used for containers are recycled in an extremely short period, those for automobiles after about 10 years, and those for building construction and civil engineering after 25~30 years. At present, the accumulated stock of steel products in Japan is about 1,200 million tons.

Some of the scrap thus recycled, about 4 million tons/year, is exported mainly to Southeast Asian nations and used as steelmaking material in electric furnaces.

As introduced above, steel products are recycled after their respective service lives, forming a highly effective recycling chain for not only domestic but international markets.

Fig. 1. Building construction by type of structures (in terms of floor areas).

Fig. 2. Recycling of iron and steel products in Japan (FY1998).

III. IMPROVEMENT OF SERVICE LIFE

The average service life of houses in Japan is about 25 years, which is much shorter than the 50 years in the U.S. and 75 years in Europe. Two major reasons for this are that the service life of framing members is short due to Japan's climatic conditions — high temperature and humidity, and that the housing function cannot follow the change in lifestyle due to the radical upheavals in society.

In Japan, steel products are extensively used as the structural frames of houses. This type was developed as industrialized houses in the 1960s. Recently, steel-framed houses, in which frames of wooden 2x4 houses are replaced by steel frames manufactured from galvanized steel sheets of approximately 1 mm thickness, are showing increasing construction (Fig.3.). As for a service life of steel-framed houses, it has become possible to make quantitative assessment by means of the corrosion test of steel sheets themselves,³ the measurement of the corrosion environment of entire houses and other approaches. As a result, a service life of 75 years in the Housing.

Performance Guarantee System has been certified for steel-framed houses, provided they are constructed using galvanized steel sheets of Z27 (coating mass: 275 g/m² or more on both sides), prescribed in the Hot-dip Zinc-coated Steel Sheets and Coils (JIS G 3302).

As an attempt to maintain the function of dwellings in line with the changes of lifestyles, the SI building⁴ (Fig.4.) is cited. It is a building which aims at prolonging the service life of the entire structure by separating at the building design stage the structural frame (S: support) having a service life of 100 years or more and the exterior and housing units (I: infill) that are remodeled at 10~30 year intervals.

Attempts are also being made to reuse structural members beyond their service life. Figure 5 shows a building in which column-column or column-beam connections are joined by means of "fitted joint", instead of the conventional welding or high-strength bolt joining. In the building, round steel tubes are used as columns and rectangular steel tubes as beams, and rings and curved plates are attached at the tube ends with which columns and beams are connected. Details

Fig. 3. Steel-framed house.

Fig. 4. Support/infill (SI) system structure.

Fig. 5. 3-storied photo studio building constructed using the "fitted joint" method.

Fig. 6. Details of "fitted joints".

of the fitted joint are shown in Fig. 6. Adoption of the fitted joint allows not only labor saving in construction but also easy demolition of buildings and easy reuse of structural members.

As discussed above, application of steel having excellent durability, development of the construction method that can meet the changes in lifestyles and the reuse of structural members promote the improvement of service life of buildings, which will lead to the relative reduction of CO₂ emission and other environmental burdens in the stages of building construction, demolition and waste disposal.

Figure 7 shows the results of the analysis of the relationship between CO₂ emission from building construction and the service life of buildings, taking a 7-story apartment building (total floor area: 4,000 m²).⁵ According to the analysis results, it is possible to reduce CO₂ emissions by half, if the service life can be extended from 25 years to 100 years.

IV. CONCLUSION

In Japan, industrial waste from the construction industry accounts for about 20% of total industrial waste in terms of tonnage, and accordingly recyclable steel products are expected to be increasingly used as construction materials. To this end, promotion of research on eco-friendly steel products for building construction is quite important to ameliorate the environmental burden of the construction industry.

Fig. 7. Relationship between service life of buildings and CO₂ emission from building construction.

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REFERENCES

- ¹Recycling Promotion Conference on Construction By-products.
- ²Monthly Iron and Steel Statistics, the Ministry of Economy, Trade and Industry.
- ³Y. Sakumoto, H. Nomura, M. Matsumoto, A. Ninomiya, T. Miyao and Y. Sakamoto, Experimental Study on Durability of Galvanized Light-Gauge Steel Shapes, Trans. of Arch. Inst. of Japan, Vol. 540, 2001, pp. 133-140.
- ⁴Next-generation house : SI21, The Iron and Steel Institute of Japan.
- ⁵M. Iwata, H. Dohnomae and Y. Hisamatsu, Scenarios for Life Cycle Environmental Burden Reduction of Architectural Steel Structures and Their Evaluation, Trans. of Arch. Inst. of Japan, Vol. 533, 2000, pp.167-173.

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