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STEEL CONSTRUCTION TODAY & TOMORROW

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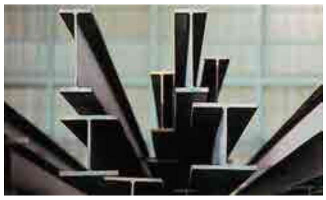
【 *k a n* 】

"環 (*kan*)" in Japanese, or ring or circulation in English

In terms of LCA (a methodology for assessing the environmental impact of a product at all stages of its service life), steel's performance is predominant—steel is repetitively recycled for reuse in a circulation ring. This issue, No. 46, covers the topics relating to LCA and steel's high environmental friendliness.

Special Feature: LCA and Recycling of Steel Products



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The Japan Iron and Steel Federation

Japanese Society of Steel Construction

Examination of LCA for Steel Structures in the Field of Construction

Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation

In Japan, studies are underway regarding the introduction of LCA (a methodology for assessing the environmental impact of a product at all stages of its service life) into the bidding system for domestic public works projects and into green procurement regulations (Act to Promote the Procurement of Eco-Friendly Goods and Services by the State and Other Entities).

In concert with this, the Committee on Environment-friendly Steel for Construction of the Japan Iron and Steel Federation has started initiatives to establish methods of assessment that are relevant to the high environmental performance of steel products, such as taking into consideration the mitigation of environmental impacts offered by the rational use of blast furnace and electric arc furnace methods in recycling and by the use of high-performance steel products. Further, the committee is promoting activities toward the wider application of eco-friendly steel construction products. Additionally, in order to promote a deeper understanding of the high environmental performance of steel structures, the committee annually holds its "Green Steel Seminar" targeting those working in construction.

As part of this effort, the Japanese Society of Steel Construction established in 2010 a "Working Group to Examine the LCA of Steel Structures in Construction," composed of leaned persons, steelmakers and steel users. The working group collects information, studies LCA methodologies in the field of construction, and examines how to apply LCA to steel products. In 2014, the working group organized its study results.

The results of the working group's activities were reported at the 4th Green Steel Seminar under the theme "Recent Initiatives toward the Improvement of Social Infrastructures and Life Cycles—the Predominance in Recycling of Steel Products in Construction." This event was held by the Committee on Environment-friendly Steel for Construction on November 27, 2014 (refer to the table and photo below).

The current issue, No. 46, of *Steel Construction Today & Tomorrow* introduces a partial outline of the activity results reported at the Green Steel Seminar; at the same time, it describes the initiatives toward global environmental preservation promoted by the Japanese steel industry. ■

A List of Lecture Themes and Lecturers at 4th Green Steel Seminar

Keynote lecture: Recent Trends and Future Directions Involved in LCA	Matsunori Nara, Dr. Eng. Professor, Department of Computer and Media Engineering, Tokyo University of Science, Suwa
Methods to Treat Structural Steel Members Left Behind	Dr. Yoshikazu Shinohara Group Leader, Eco-energy Group, National Institute for Materials Science
Introduction of LCA Approaches to Take Account of Recycling Effects of Steel Products and Simulation Examples	Tomohisa Hirakawa Vice Chairman, Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation
Assessment Approaches for Environmental Influence Caused by Use of Steel Products	Dr. Minoru Fujii Senior Researcher, Eco-city Systems Research Program Project Leader, Environmental Urban Systems Section, Center for Social and Environmental Systems Research, National Institute for Environmental Studies

Fourth Green Steel Seminar held in November 2014

Examples of and Future Tasks for LCA Models in Japan

Matsunori Nara: After graduating from the Department of Architecture and Building Engineering, Tokyo University of Science in 1975, he served as a lecturer of that department in 1990. He then became a professor of Department of Mechanical Engineering, Tokyo University of Science, Suwa in 2002 and assumed his current position as a professor of the Department of Computer and Media Engineering, Tokyo University of Science, Suwa in 2014.

by Matsunori Nara, Dr. Eng.
Professor, Department of Computer and Media Engineering, Tokyo University of Science, Suwa

LCA at a Glance

The standardization of life cycle assessment (LCA, or assessment of the environmental impact of a product at all stages of its service life) started in 1993 at the International Organization for Standardization (ISO). In 1997, the ISO published: ISO14040: Principles and Framework for LCA, ISO14041: Goal and Scope of Definition and Inventory Analysis and ISO14049: Examples of How to Apply ISO14041.

In Japan, the Life Cycle Assessment Society of Japan, a joint industrial-public-academic organization, was established in 1995 to promote LCA studies. In 2007, the Japanese Society of Steel Construction initiated studies of LCA for steel products and steel structures. Triggered by the establishment in 2009 of the Act to Promote Procurement of Eco-Friendly Goods and Services by the State and Other Entities (Ministry of the Environment), the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) began an examination of LCA for public works. Currently, while a number of theoretical studies and case studies on LCA are underway, efforts are also being directed toward the collection of inventory data.

In the construction industry, a multi-layered system is in place to receive and construct individual projects involving multiple companies, and this has made it difficult to collect inventory data. However, this problem has been solved through joint research between MLIT's National Institute for Land and Infrastructure Management and the Japan Society of Civil Engineers; as a result, it is now possible to conduct inventory analysis (LCI: life cycle inventory) even for public works projects. LCI is a hybrid-type of inventory data that is prepared by the combined use of input out tables (matrix of production and transactions by industry) and accumulated data; its application allows implementation of LCA for materials, construction methods and structures by setting CO_2 emissions and expenditures as assessment parameters.

Tasks Involved in LCA Relevant to the Recycling of Steel Products

Certain difficulties remain in implementing LCA in the construction field. Among the specific issues that have been pointed out are the restricted range of LCA to the life stages of materials manufacture and construction; the priority placed on CO_2 emissions and the insufficient assessment of other environmental impacts (relating to trade offs, integrated parameters, etc.); and the non-quantification of the effects produced by the repeated recycling of steel products and other materials.

It is probably thought as only natural that steel products, after reaching the end of their service life, are repeatedly recovered as scrap and are recycled again and again. Actually, however, in contrast to the performance of other materials, this characteristic of reusability—which reduces the material's environmental impact—is peculiar to steel and deserves special mention. In other words, while most materials are recycled in a cascading flow, steel and other metallic materials can be horizontally recycled.

Another advantage that steel recycling has over other products is that steel can easily be separated from other materials using magnets in the recovery process. In cases when metals other than steel are used in combination with different metals or materials, it is often difficult to separate these metals and materials, and there are cases when recycling cannot proceed smoothly.

In the field of construction, steel products are independently used in the construction of steel-frame structures and are frequently used together with concrete in reinforced-concrete (RC) structures. However, even in RC structures, the steel and concrete can now be easily separated and recovered when the service life has expired. Compared to other metallic materials, steel is recognized as being easily recycled.

Be that as it may, there is currently no established method for appropriately assessing the excellent environmental characteristics of steel products—i.e. that steel is a highly recyclable material that allows for repetitive recycling. Eco Mark and other environmental labeling programs, along with the Act on Promotion of Procurement of Eco-Friendly Goods and Services, support the procurement of these goods and services by appropriately assessing their environmental effect with the goal of creating societies with a smaller impact on the environment.

However, the environmental impact assessment techniques currently in use cannot assess the effect produced by repetitive recycling. The current techniques cannot distinguish between the environmental performance of materials that can be recycled only once and those that can be recycled multiple times. The average person likely understands that, as the number of times of recycling of a material is increased, its resource-saving effect increases and its environmental impact becomes less. In light of this, it is hoped that an environmental impact assessment technique will be developed in the future that will take into account both the ease and potential multiplicity of recycling.

On the other hand, in order to promote the high environmental performance that is peculiar to steel products, it will be necessary to accumulate data confirming the predominant recyclability of steel products and to raise social awareness about this aspect of steel. The iron- and steelmaking processes operated by the Japanese steel industry are regarded as being world leaders in having a low environmental impact. However, this does not mean that efforts to further reduce the environmental impact of these processes are complete, as there is still much room for continued improvement.

An effective step in this direction is to pursue the production of zero-emissions steel that consumes fewer resources and energy, improves waste water and exhaust gas purification, and discharges less waste. Meanwhile, the consumption of non-renewable (exhaustible) resources and energy is not always directly tied to an increase of environmental impact or to a deterioration of sustainability, but there are definitely cases in which the appropriate use of exhaustible resources can mitigate global environmental outcomes.

Case Study of LCA in Bridge Construction

An LCA case study was made of the old Showa Bridge, a highway bridge constructed where National Route 122 spans the Tone River. The LCA was conducted based on the technique reported in the “Development of Environmental Impact Assessment Technology for Life Cycles of Social Infrastructure” by the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism. The main goal of this study was to attempt a lifecycle assessment of an actual structure using the NILIM technique and to compare CO_2 emissions at different stages in the life of a steel bridge.

Trial calculations of CO_2 emissions were made for two lifecycle cases: a lifecycle that conforms to the repair history of the actual bridge (case 1) and a virtual lifecycle that reflects current social needs and current technological levels (case 2). In case 1, the CO_2 emissions were calculated based on the actual service period (44 years) of the old Showa Bridge. In case 2, the CO_2 emissions were calculated assuming the construction of a similar bridge modeled on the old bridge and setting 200 years as the target service period (rebuilt 100 years after construction). Fig. 1 shows the CO_2 emissions for the case 1 lifecycle, and Fig. 2 for the case 2 lifecycle.

The comparison of CO_2 emissions at every life stage of the steel bridge demonstrated that the total emissions at both the design/construction stage and the demolition/recovery stage accounted for more than 90% of the total lifecycle emissions in both cases—suggesting that decision-making regarding the

Fig. 1 CO_2 Emissions in 44-year Life Cycle at Old Showa Bridge (Case 1)

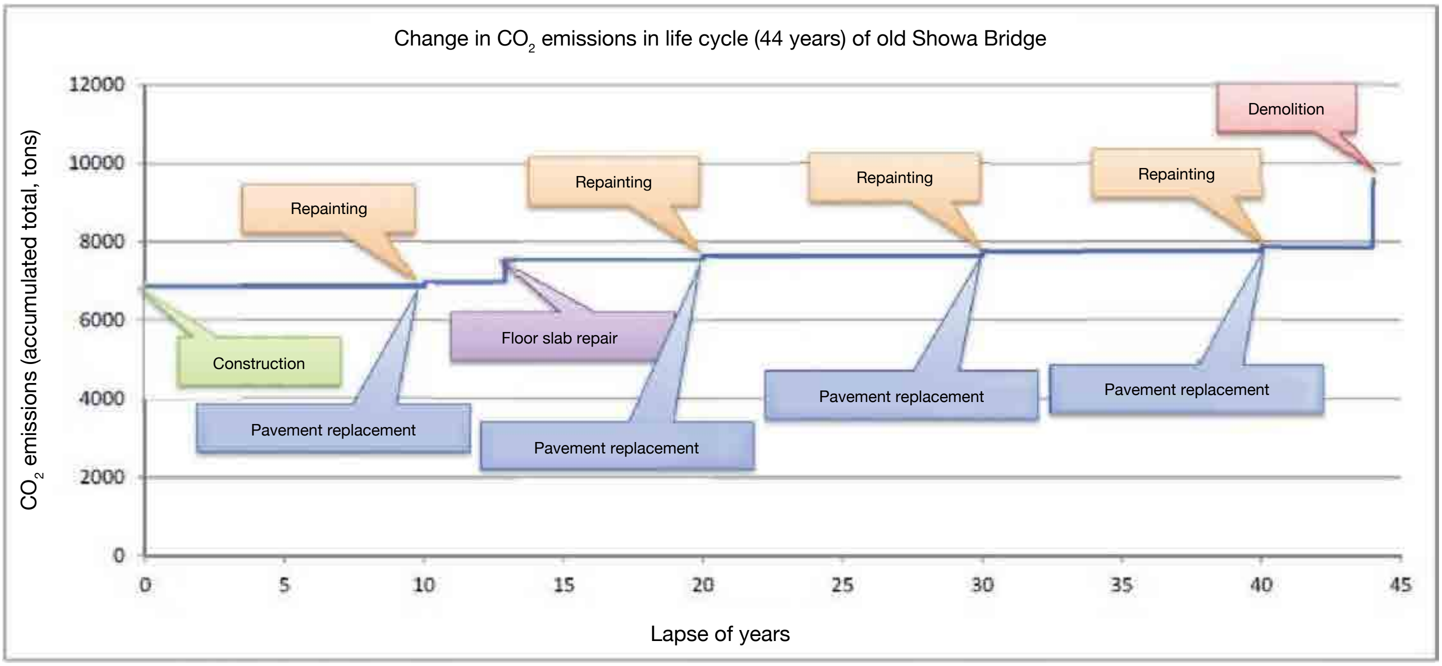
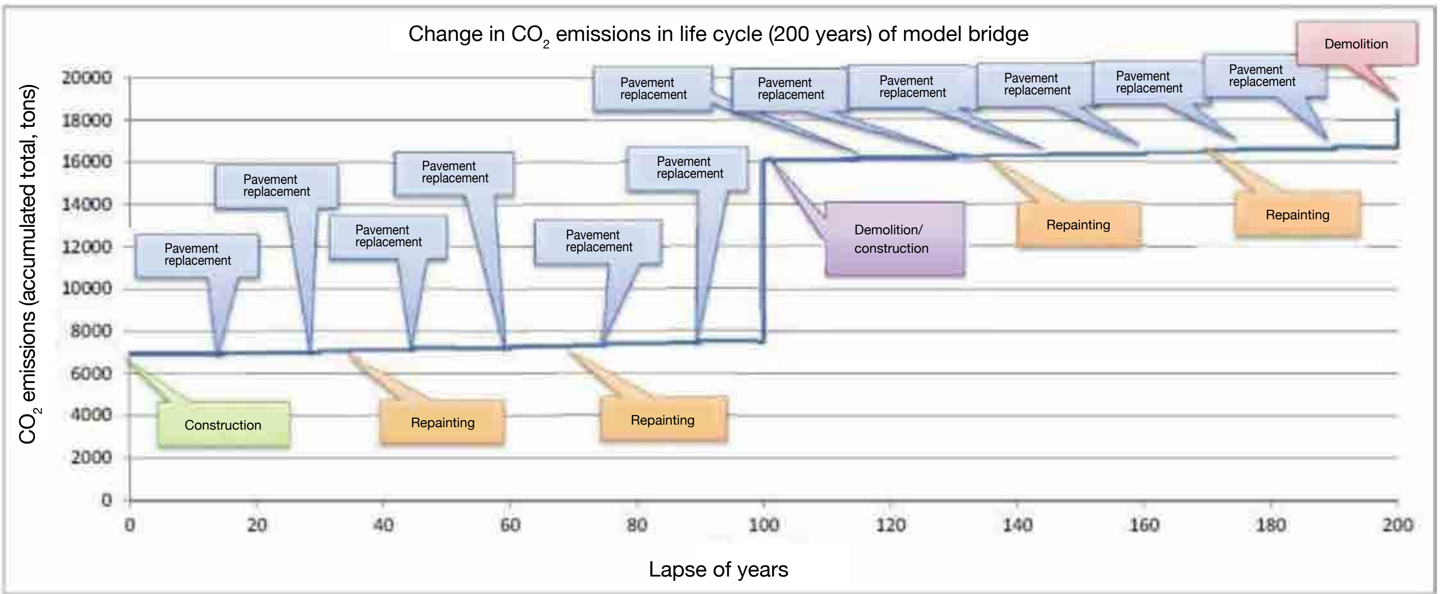


Fig. 2 CO_2 Emissions in 200-year Life Cycle at Model Bridge (Case 2)



selection of materials and construction methods has a strong effect on LCA results. Similarly, while the CO_2 emissions of the maintenance stage were minimal in both cases, the CO_2 emissions of the demolition/recovery stage equaled 25% of the design/construction stage emissions, making it clear that the demolition/recovery stage has a large environmental impact. (Refer to Figs. 3 and 4)

In order to reduce the CO_2 emitted during the lifecycle of a structure, it will be necessary to pay due consideration not only to reducing the environmental impact caused by the production of the construction materials used, but also to making easy the recovery of structural members during demolition and to taking account of recyclability after recovery of the materials used.

Fig. 3 Ratio and Tonnage of CO_2 Emissions in 44-year Life Cycle by Life Stage at Old Showa Bridge (Case 1)

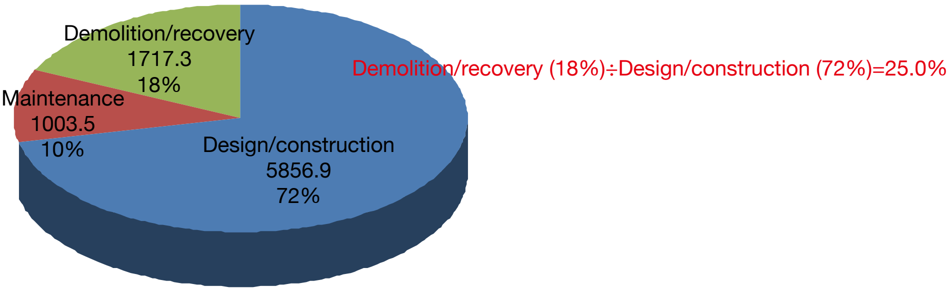


Fig. 4 Ratio and Tonnage of CO_2 Emissions in 200-year Life Cycle by Life Stage at Model Bridge (Case 2)

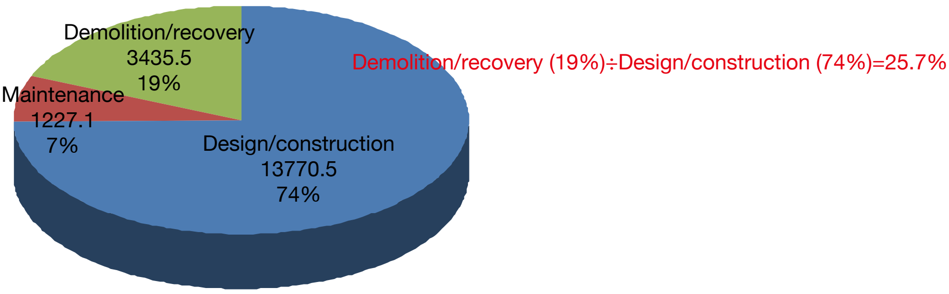
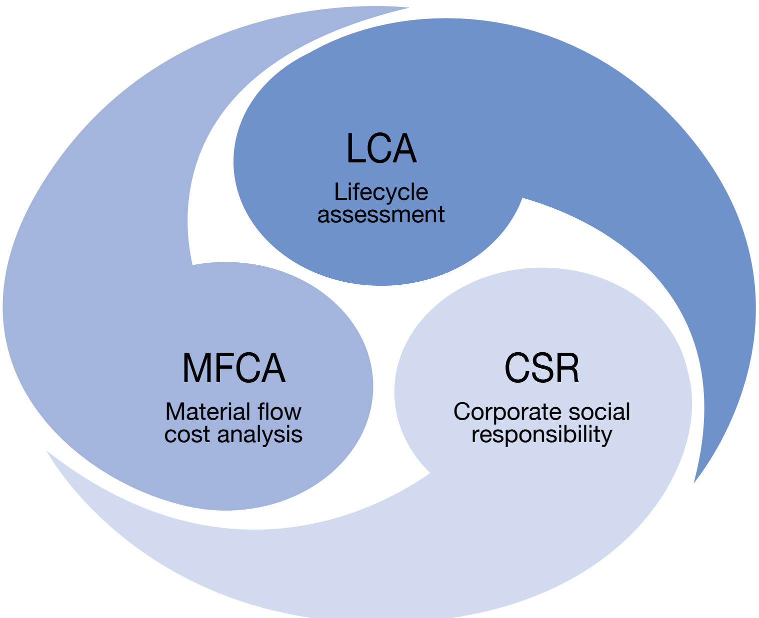


Fig. 5 Striking a Balance between Environment, Cost and Society



Future Directions in LCA

It is considered that in the future the environmental performance of materials will be assessed with a view to "sustainability." The basis for assessing sustainability should consider the use of non-renewable resources and rare materials, long-term planning that takes into account multiple generations, and future forecasts regarding environmental change. Similarly, the environmental performance of steel products will have to be assessed by taking these factors into account.

In addition, it is indispensable for the product to be assessed from the aspect of economic performance. At the market, the product is required to offer not only the high environmental performance but also the economic advantage such as reduction of internally and externally uneconomic products. As regards the economic performance, the environmentally economic performance of products can be assessed by means of the material flow cost analysis (MFCA) that aims at reducing the generation of internally uneconomic materials such as the wastes called the negative product. (Refer to Fig. 5)

As stated earlier, in order to strategically assess environmental impacts, it is required that business operating processes be transparent, that assessment results be scientific and easy to understand for anyone, and that the opinions of the people be fully reflected. From the perspective of making environmental influences easier to understand, LCA is effective and the quantified environmental performance supports of better understanding of LCA by the people. Moreover, the MFCA covering the entire life cycle of the product can serve as a useful means with which the economic performance of products is built-in into the economic system.

Accordingly, as far as steel products are concerned, their performance should be explained in terms of LCA economics. More specifically, the high level of environmental performance of steel products should be indicated with stress placed on their unique advantage: the possibility of repetitive recycling and the resulting cost down. To attain this goal, it will be essential to establish LCA techniques that appropriately assess the environmental performance of steel products, to obtain social consensus by standardizing the techniques in JIS and ISO and, at the same time, to continuously promote studies on the effective use of these techniques. ■

LCI Assessment Methodology for Incorporating the Effect of Steel Product Recycling

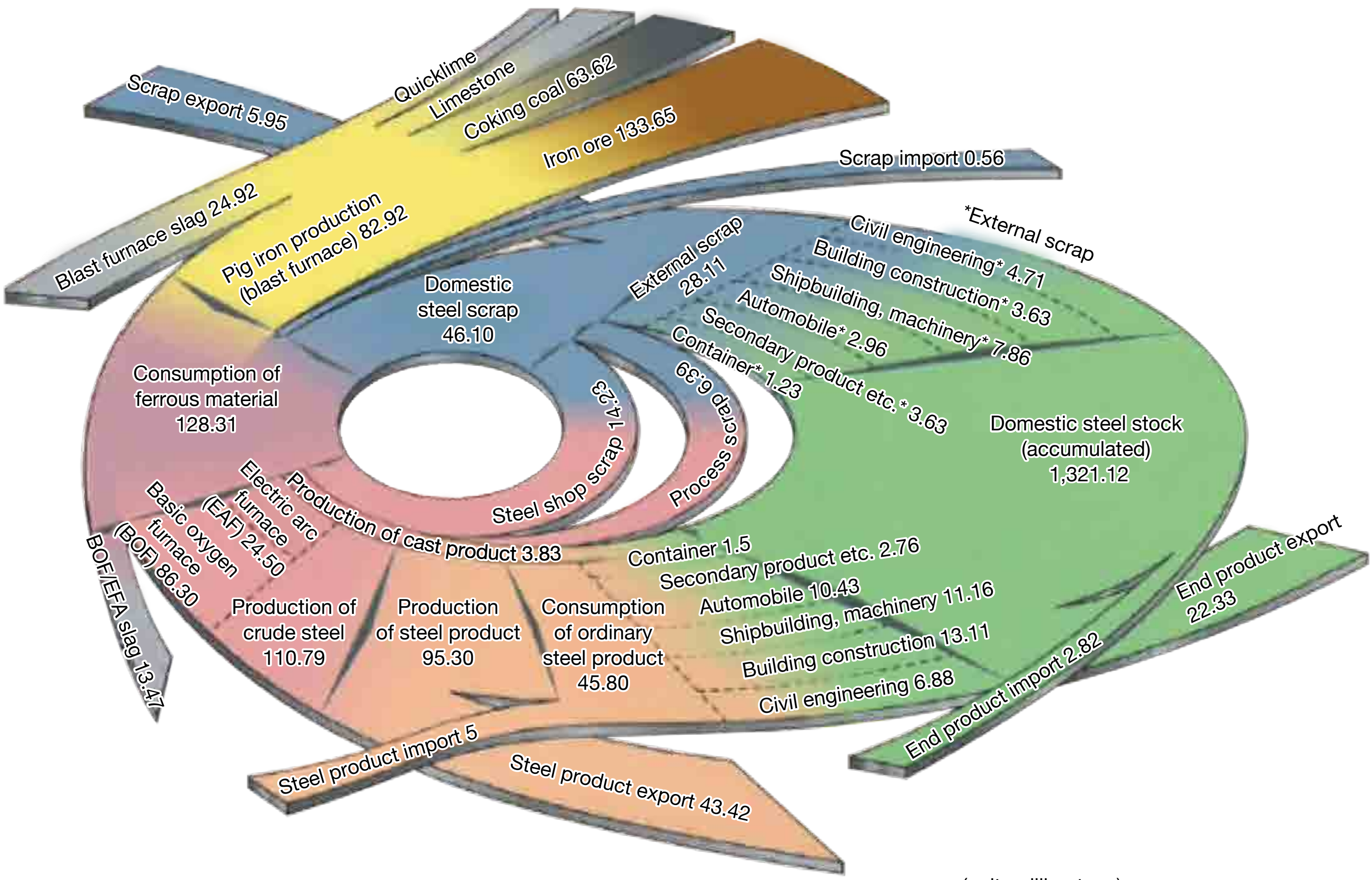
by Tomohisa Hirakawa
Vice Chairman, Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation

The method for calculating the unit CO_2 emissions of steel products (LCI assessment) introduced in this article is based on the methodology proposed by the World Steel Association (worldsteel) [See: "worldsteel (2011)[1]: LCI (life cycle inventory) assessment methodology"]. This methodology clearly distinguishes two types of recycling systems: open recycling and closed (horizontal) recycling.

Table 1 Difference in Recycling by Material

Material recycling	Horizontal recycling	Of recycling systems, the horizontal recycling denotes the process in which a material after recycling is used for the application similar to that before recycling. Ex.: Steel frame, reinforcing bar (structure) → Steel frame, reinforcing bar (structure)
Material recycling	Cascade recycling (Down cycle)	Of recycling systems, the cascade recycling denotes the process in which a material after recycling is used for the application different from that before recycling. Ex.: Concrete (structure) → Concrete (roadbed material)
Thermal recycling		In thermal recycling, scrap, wastes and other materials are incinerated to recover thermal energy, or called the thermal recovery system. (Distinguished from material recycling) Ex.: Lumber, plywood → Fuel source

Fig. 1 Circulation of Iron and Steel Products in Japan (FY2010)



(unit: million tons)

Source: The Japan Iron and Steel Federation

Fig. 2 Concept of End-of-Life Approach (worldsteel 2011)

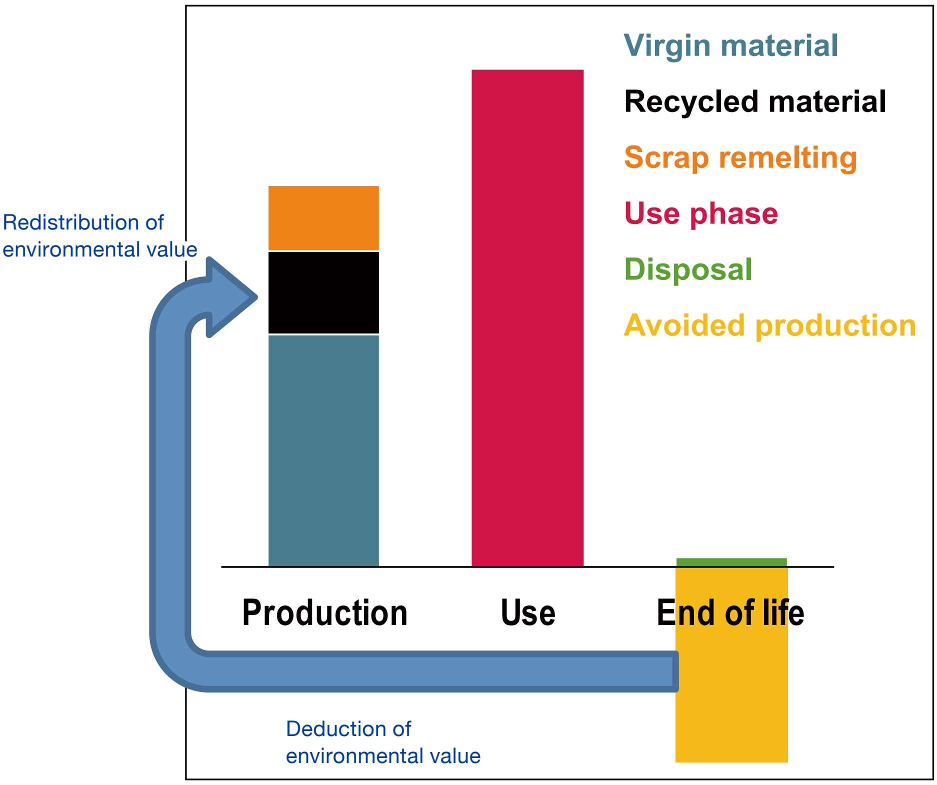
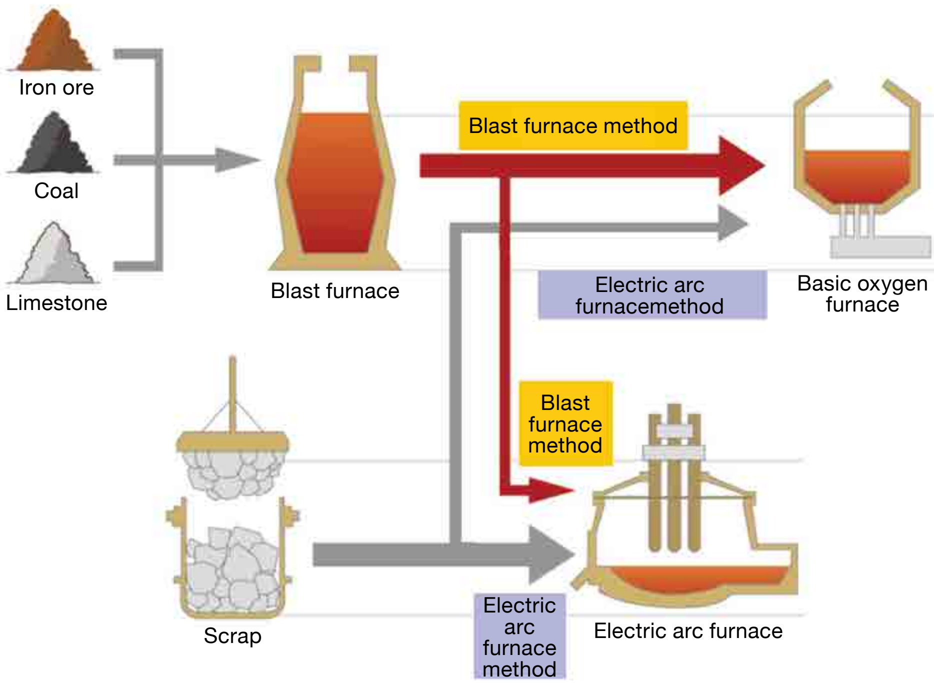


Fig. 3 Relation between Blast Furnace Method and Electric Arc Furnace Method



Open recycling refers either to recycling systems wherein the recovered material is recycled to produce new types of products or it refers to recycling systems (cascade recycling and thermal recycling) wherein the peculiar physical properties of a material are altered. On the other hand, closed recycling denotes recycling systems in which the physical properties of the recycled products do not change and the recycled products can be reused for the same applications as before.

For example, steel structural members such as steel frames and steel-reinforcing bars can be recycled and reproduced as new steel products. The basic physical properties of these recycled products show no change and the products themselves can be used again for the same applications. That is, it can be said that steel products are amenable to horizontal recycling. (Refer to Table 1).

The value of materials used to manufacture steel products that are suitable for horizontal recycling never decreases, even when the materials are subjected to repetitive recycling. And, as these materials circulate through society, they are almost never discarded and never become waste. Fig. 1 shows the state of steel products circulating in Japan.

Concept of LCI Assessment That Considers Recycling Effects

While many approaches are taken in LCI assessment methodologies, worldsteel proposes a methodology based on the “End of Life (EoL) Approach.” In this approach, on the assumption that steel products are suitable for horizontal recycling, the greenhouse gas emissions produced by the manufacture of a steel product are redistributed to the next-generation product, thereby levelling the environmental impact imposed at the production stage. That is, when assessing environmental impacts of steel products, it is a comprehensive approach that eliminates the distinction between products to be produced by melting iron ore (blast furnace products) and products to be produced primarily by melting scrap (electric arc furnace products). Fig. 2 shows the concept of worldsteel’s comprehensive approach.

Relation between the Blast Furnace Method and the Electric Arc Furnace Method in the Production of Iron and Steel Products

Two methods are used in iron- and steelmaking: the blast furnace (BF) method and the electric arc furnace (EAF) method. The BF method denotes a process in which pig iron (molten iron) that is produced in a blast furnace, using iron ore as the main raw material, is then refined in a basic oxygen furnace to produce steel. The EAF method denotes a process in which used steel materials are remelted typically in an electric arc furnace to produce steel, or in which scrap steel is converted into renewed steel in an electric arc furnace.

Fig. 3 shows the relation between the BF method and the EAF method. As shown in the figure, iron ore is not the only material used as a raw material in the BF method, and the materials applied in the EAF method are not restricted to scrap steel. For example, it is common in the BF method to use scrap steel (amounting to about 10~20% of the total load of raw materials used as iron sources), and there are cases in which reduced iron is used as a source material in the EAF method (refer to Fig. 3). That is, it can be understood that both the BF and EAF methods can be used rationally to produce iron and steel products.

Calculation Method for LCI_{EoL} That Takes Recycling Effects into Account

• External Scrap LCI

In calculating LCI_{EoL}, the LCI of external scrap (scrap LCI) is conceived as corresponding to this statement: "Y kg of steel product is produced from 1 kg of external scrap employing the EAF method, and this scrap LCI take overs Y kg worth of LCI of steel product produced employing the BF method." Y indicates the production efficiency (yield) at the stage when steel products employing the EAF method are produced. When the LCI of steel products produced by the EAF method (theoretical value assuming 100% use of external scrap) is defined as Xre, and the LCI of steel products produced by the BF method (theoretical value assuming 0% use of external scrap) is defined as Xpr, the scrap LCI can be defined as follows.

$$\text{Scrap LCI} = Xpr \cdot Y - Xre \cdot Y = (Xpr - Xre) \cdot Y \quad \text{--- ①}$$

• Calculation Equation for LCI_{EoL}

The LCI_{EoL} of steel products can be conceived as the total LCI obtained by deducting the scrap LCI—according to the external scrap recovery rate (RR)—from the steel products LCI (X) that does not take account of recycling efficiency, and further adding (redistributing) the scrap LCI—according to the steel scrap application ratio (S)—during the production of steel products. When organizing the above, the following equation is obtained. The definition of each element used in the equation below is shown in Table 2.

$$LCI_{EoL} = X - RR \cdot \text{Scrap LCI} + S \cdot \text{Scrap LCI} \quad \text{--- ②}$$

From ①, because scrap LCI=(Xpr−Xre)•Y:

$$LCI_{EoL} = X - (RR - S) \cdot (Xpr - Xre) \cdot Y \quad \text{--- ③}$$

• Calculation Examples for LCI_{EoL}

Assuming the case for ordinary steel plates, a trial calculation of the LCI_{EoL} of steel plates was made by giving the assumed value shown in Table 3 for each element used for the LCI_{EoL} equation shown above. As a result, LCI_{EoL} reached 0.76 (kg-CO2/kg). When comparing LCI (X) that does not take account of the recycling effect, while LCI_{EoL} in the BF image decreased: 0.76/1.97→a decrease by 62%, that in the EAF image increased: 0.76/0.66→an increase by 62%. These calculation results can be considered attributable to the fact that, irrespective of whether BF products or EAF products are involved, the environmental impact is levelled by thinly redistributing the greenhouse gas emissions caused by the production of next-generation products that were originally produced from iron ore.

LCI Calculations That Fully Incorporate the High Recyclability of Steel Products

In the civil engineering and building construction fields, the main approach to LCI calculations currently in use is to assess the environmental impact imposed by steel products only from the stage of raw materials procurement and production to the point of their shipment (cradle to gate), which is based on the life stage boundary shown in Fig. 4. Because this approach does not assess LCI through the entire life of steel products, it is essential to employ an approach that takes the recycling effect (end of recycling, etc.) into account.

Currently, the Japan Iron and Steel Federation, under a tie-up with the World Steel Association, is promoting the incorporation into ISO standards of the above-mentioned approach to LCI calculations that takes the recycling effect into account. Further, in accordance with this approach to LCI calculation,

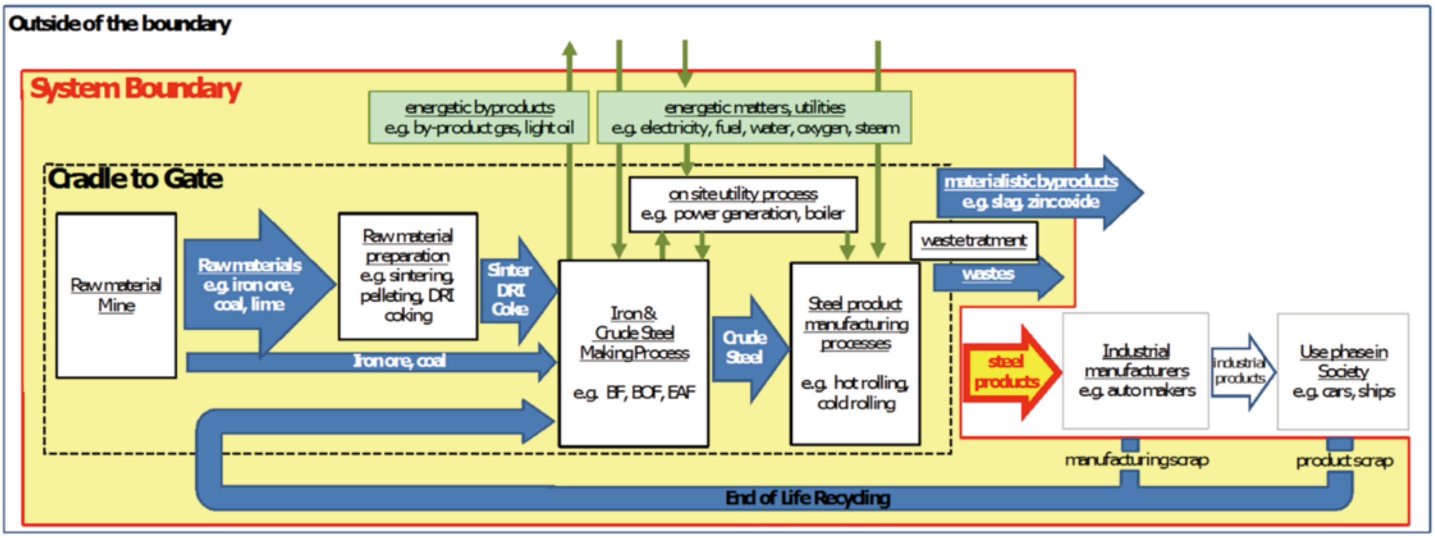
Table 2 Definition of Respective Elements in LCI_{EoL} Equation

Element in equation	Definition
LCI_{EoL}	Steel product LCI (kg-CO2/kg) that takes account of recycling effect; System boundary for LCI calculation of steel products is set to cover product life stages from raw material procurement, production and shipment to external scrap recovery, intermediate treatment, recycling process and scrap LCI; EoL: End of life
Scrap LCI	LCI of external scrap (kg-CO2/kg); External scrap denotes steel scrap recovered from end-of-life end-use product and does not include process scrap and steel shop scrap
X	Steel product LCI (kg-CO2/kg) that does not take account of recycling effect; System boundary for LCI calculation of steel products is set to cover product life stages from raw material procurement to production and shipment (cradle to gate)
Xpr	LCI (kg-CO2/kg) of steel product produced by blast furnace method: On the premise of 0% in scrap application rate
Xre	LCI (kg-CO2/kg) of steel product produced by electric arc furnace method: On the premise of 100% in scrap application rate
RR	RR (recycling rate) in calculation equation for LCI_{EoL} proposed by worldsteel; In its report, RR is shown using the ratio (kg/kg) of the external scrap recovery amount (kg/y) to the external scrap generation potential (kg/y); RR does not cover yielding in steelmaking employing recovered external steel scrap
Y	Production efficiency in electric arc furnace steelmaking (yield kg/kg); Ratio of steel production to external scrap input (more than 1 kg of external scrap is required to produce 1 kg of steel)
S	Application rate of external steel scrap used in iron- and steelmaking process (kg/kg); The equation does not target process scrap and steel shop scrap

Table 3 Example of Trial Calculation of LCI_{EoL}

	X	RR	Xpr	Xre	Y	S	LCI_{EoL}
Steelworks I (Blast furnace method image)	1.97	0.88	2.04	0.47	0.93	0.05	0.76
Steelworks II (Electric arc furnace method image)	0.66					0.95	0.76

Fig. 4 System Boundary for LCI Calculation of Steel Products with EoL Recycling



An entire amount of steel scrap (recovered used steel products) is effectively reused as the material in iron and steelmaking process.

In the recycling process, steel products are easily recovered by use of magnetic force as the scrap, which is used again as the material in electric arc furnace steelmaking.

Nearly an entire amount of steel products applied in respective purposes are recovered as the scrap, which is then used to make renewed steel products.

we are promoting the calculation of LCI values for specific steel products based on production data collected by participating companies and employing this LCI calculation approach. The specific LCI values calculated for each product are targeted for public release in March 2016.

We will be glad if this article proves helpful in promoting an understanding of the unique, high recyclability of steel products and of LCI calculations that fully incorporate this high recyclability. ■

References

1) worldsteel (2011): Life cycle assessment methodology/report methodology report Life cycle inventory study for steel products/Appendix 10: Recycling methodology. Steel Construction Info.: http://www.steel-construction.info/Recycling_and_reuse

Material Stock and the End-of-life Recycling Rate of Steel

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Ichiro Daigo: Associate Professor at Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo. He received Ph.D., M.S. and B.E. degrees from Kyoto University. He has developed many analytical models and tools and pioneered research in Industrial Ecology. His achievement has been published in many academic articles and books.

Steel Stock Accounting

Currently, more than 1,500 million tons of crude steel are annually produced worldwide for use in such diverse fields as bridges, steel towers, buildings, automobiles and machinery. In the 1850s, the invention of the Bessemer steelmaking process enabled the low-cost mass production of crude steel. Over the ensuing 160 years, products manufactured from crude steel have been accumulating within the inventory of manmade products and now form a mass of material stock. Because it is easily recycled, this steel stock offers great potential as a secondary, post-service-life source of steel.

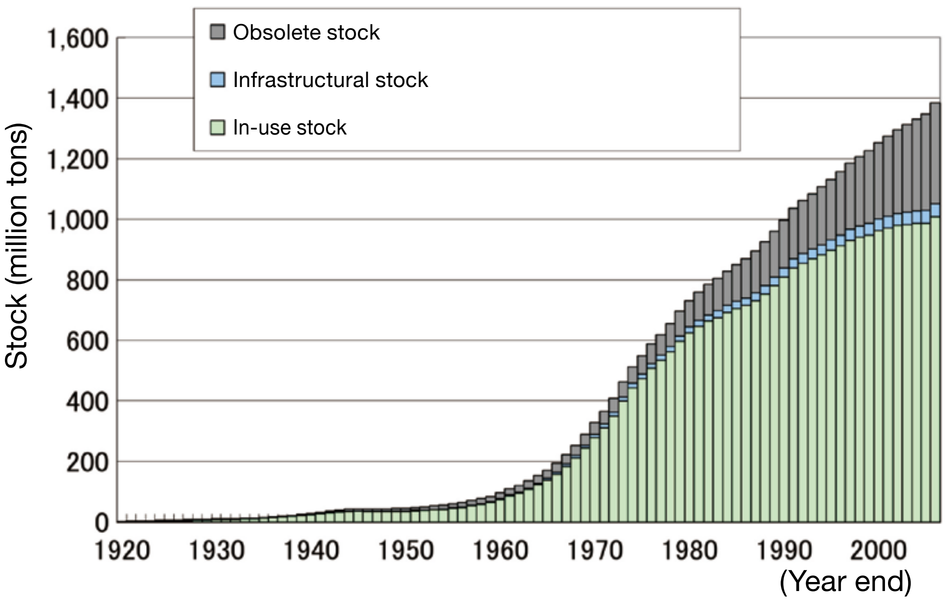
Photo 1 In-use stock of steel

In the beginning of this article, I will simply discuss the concept of material stock consisting of steel products. Steel products have been accumulating within technoshpere as structural members used in the diverse fields mentioned above. These products continue to serve as end-use steel products until their respective service lives expire. While still serviceable, such items are called in-use stock (Photo 1).

If we ask whether or not there are any other categories of steel stock, the academic field of industrial ecology proposes two additional categories: obsolete stock and hibernating stock. Obsolete stock is denoted as stock that has reached its specified service life and fallen out of service, but still exists. Hibernating stock denotes a subset of obsolete stock that has the potential for future recycling, like an animal that awakes from hibernation in the spring.

Fig. 1 shows the transition of accumulated steel stock in Japan. While the infrastructural stock shown in the figure cannot be found in the materials other than steel, it is considered to consist almost exclusively of steel products, and it denotes existing steel stock that is applied in infrastructure having a nearly semi-permanent service period (Photo 2).

Fig. 1 Steel Stock in Japan during 1980 to 2000



Material Flow and Stock Analysis

Roughly two methods are used to estimate steel stock: one is the bottom-up method which counts all existing steel products, and the other is the top-down method which calculates the difference between the input and discarded amounts (called the net addition to stock). The steel stock in Fig. 1 is counted using the top-down method.

The difficulty in this calculation is how to determine the discarded amount. In order to estimate the entire volume of steel stock, in-

Fig. 2 Material Flows of Steel after Discarding as End-of-life Products

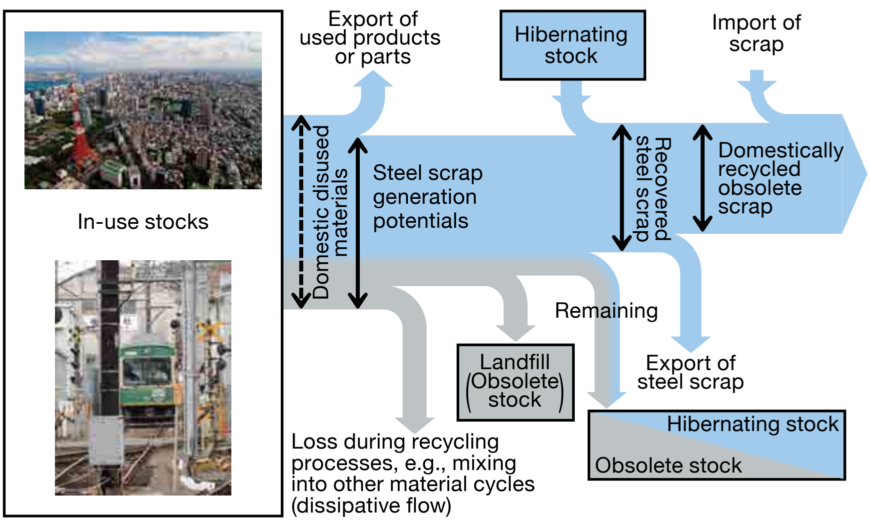


Photo 3 Crush barriers on a disused road as a case of hibernating stock

Fig. 3 Lifetime of End-use Products with a Range of Uncertainty
(Regarding buildings and automobiles, actual lifetimes for them can be obtained by statistics.)

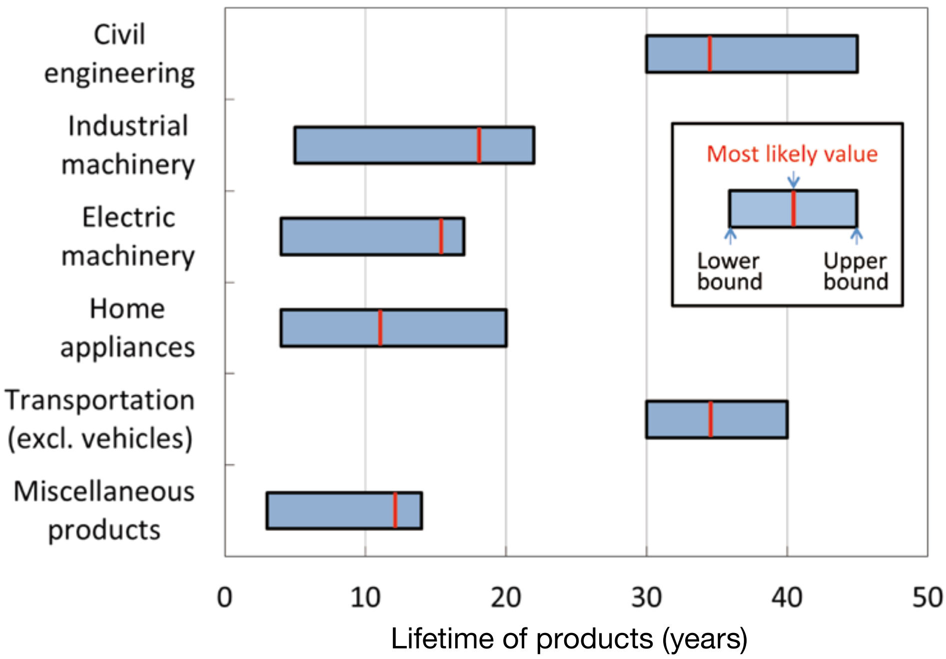


Photo 2 Slit dam as a case of infrastructural stock

cluding both in-use and obsolete stocks, the amount of recovered steel scrap is used as the discarded amount. On the other hand, in order to estimate the in-use stock, it is necessary to count the amount of steel products contained in all end-use products that have exceeded their service life and have been discarded, which can be called as the steel scrap generation potential. The flow amount shown at the right in Fig. 2 is the discarded amounts for the entire stock and the flow amount shown at left in Fig. 2 is for the in-use stock.

While it is difficult to conduct a practical measurement of in-use stock, in-use stock can be estimated by means of dynamic analysis. In the dynamic analysis, the steel scrap generation potential in each year is estimated employing the distribution of the lifetime of respective end-use products (Fig. 3) and the steel input to respective end uses in each year in the past.

Fig. 2 shows the flow of steel products discarded after end of service life (or recovered steel scrap). In addition to the export and import of scrap and used products, loss also occurs within the flow of the recycling process; and, some steel products are subjected to reclamation. Among steel products that remain unrecovered are steel piles used for building foundations that are left in the ground after site demolition, as well as crush barriers installed in front of closed tunnels that have been taken out of service (Photo 3).

Scrap Recovery That Exceeds the Scrap Generation Potential

RR (end-of-life recycling rate) is a variable in the LCI (life cycle inventory) methodology that relates to the recycling effect. Because various definitions are applied pertaining to recycling rates, the end-of-life recycling rate is a term used to distinguish it from other definitions. The end-of-life recycling rate of steel stock is defined as a ratio with the steel scrap generation potential set as the denominator and the recovered steel scrap as the numerator. The values of the denominator and numerator are as described above.

Fig. 4 (a) compares the estimated value of the steel scrap generation potential and the estimated amount of recovered steel scrap in Japan from 1987 to 2010. It is understood from the figure that in each of the two years from 2007 to 2008, the steel scrap was recovered from end-of-life products that had already exceeded its service life before 2007 at levels higher than the scrap generation potential. However, inherent in estimating the scrap generation potential was a range of uncertainty for the lifetime attributed to end-use products as shown in Fig. 3. The resulting maximum and minimum values for these two parameters are shown respectively in Fig. 4 (b) and Fig. 4 (c). Even when this uncertainty is taken into account, it can be concluded that the steel scrap recovered in both 2007 and 2008 exceeded the scrap generation potential for those years.

During the 2007 to 2008 period, both the price of resources and the demand for steel products were high, and thus the high recovery rate is believed to attributable to that, while certain steel products had finished their service life in the past several years, these products left behind were intensively recovered as the scrap in that period.

The following are accepted as factors for the intensive recovery efforts of 2007 and 2008. When steel waste products were generated in suburbs where the recovery costs were high, they were often left behind if they did not pose a legal or safety issue and if the profit from their sale as scrap did not offer sufficient economic incentive for recovery. However, because the price of steel scrap in 2007-2008 was high, end-of-life products that had been left behind in this way as hibernating stock were recovered, which led to the high recovery rates of 2007 and 2008.

High-performance Recoverability of Steel

In the current study, we have obtained much new information. The end-of-life recycling rate of steel products in Japan has been high over the past 20 years or so—more than 80% (see Fig. 5). Further, it is known that the recovery rate greatly fluctuated from about 80% to about 110% depending on the scrap price and the steel product demand in any

Fig. 4 Comparison between the Steel Scrap Generation Potentials and the Recovered Steel Scrap
(in the cases of the most likely value (a), the maximum value (b), and the minimum value (c))

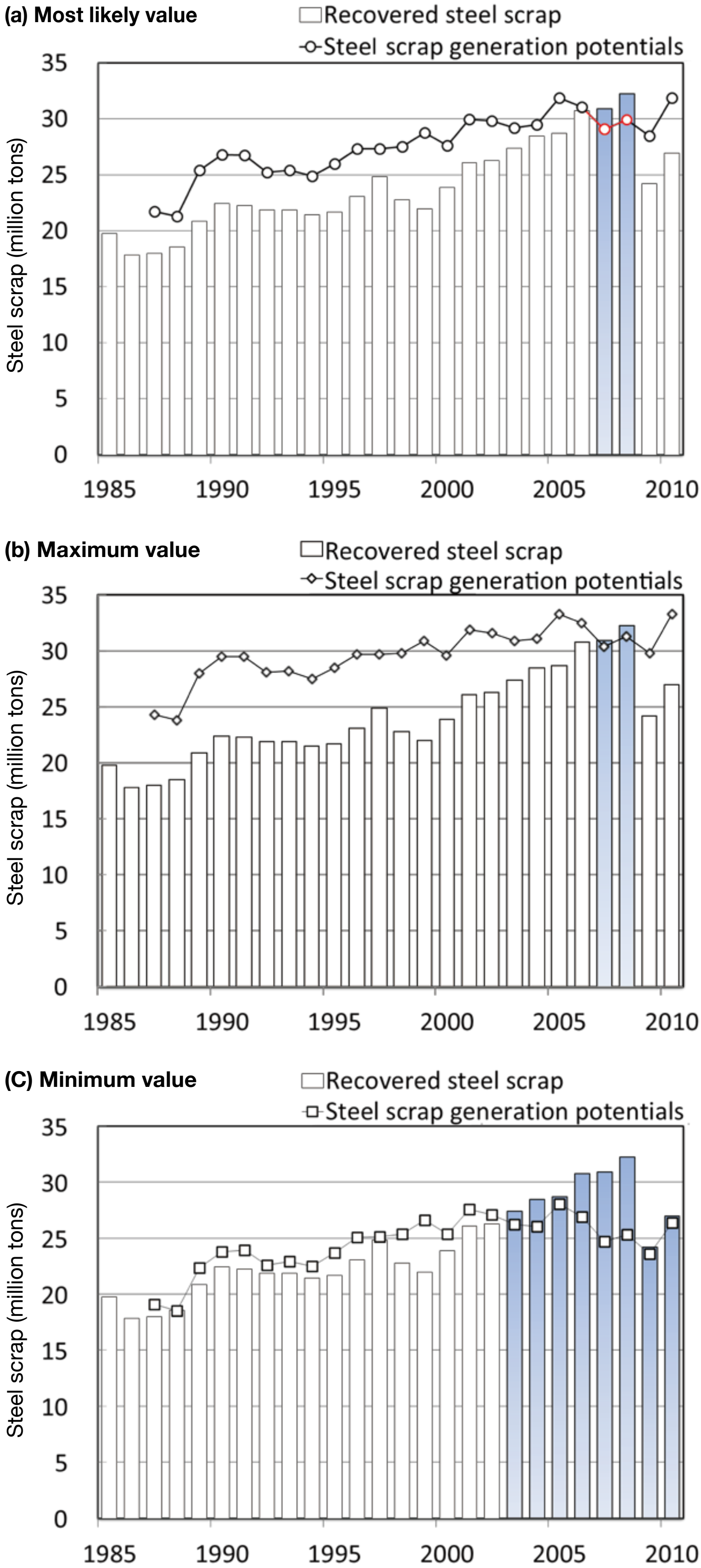


Fig. 5 End-of-life Recycling Rate of Steel in Japan

(The upper and lower bounds show a range of uncertainty.)

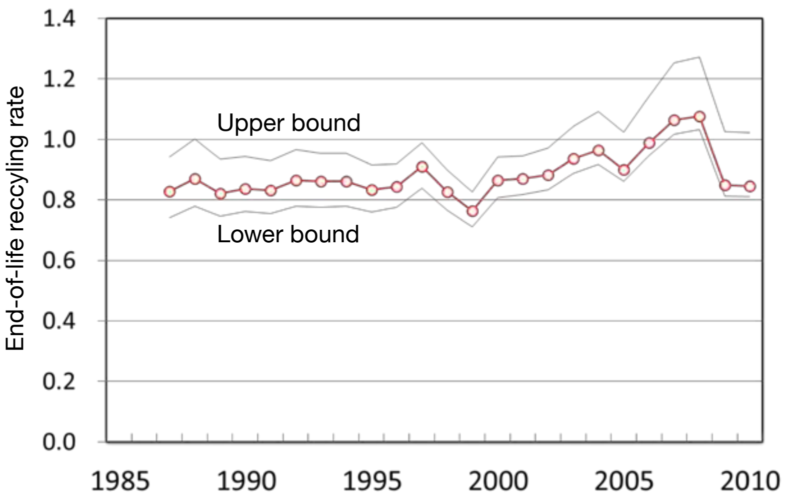
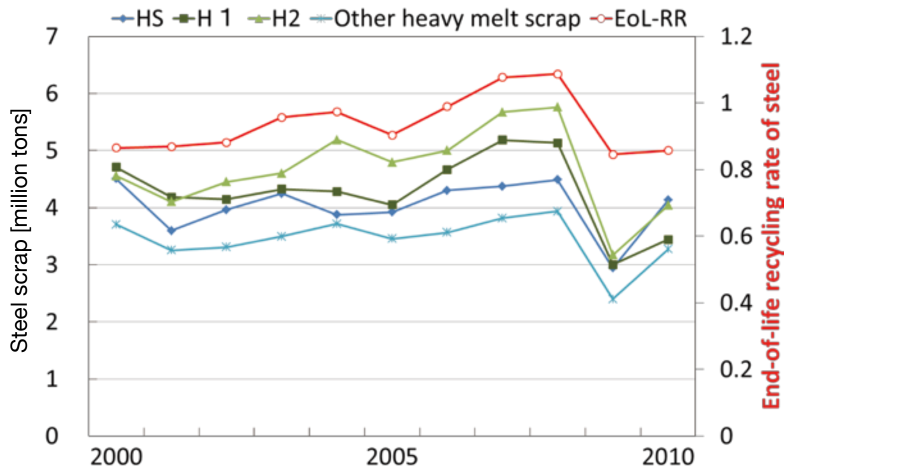


Fig. 6 Amount of Heavy Scrap Recovered by Category relative to its EoL-RR

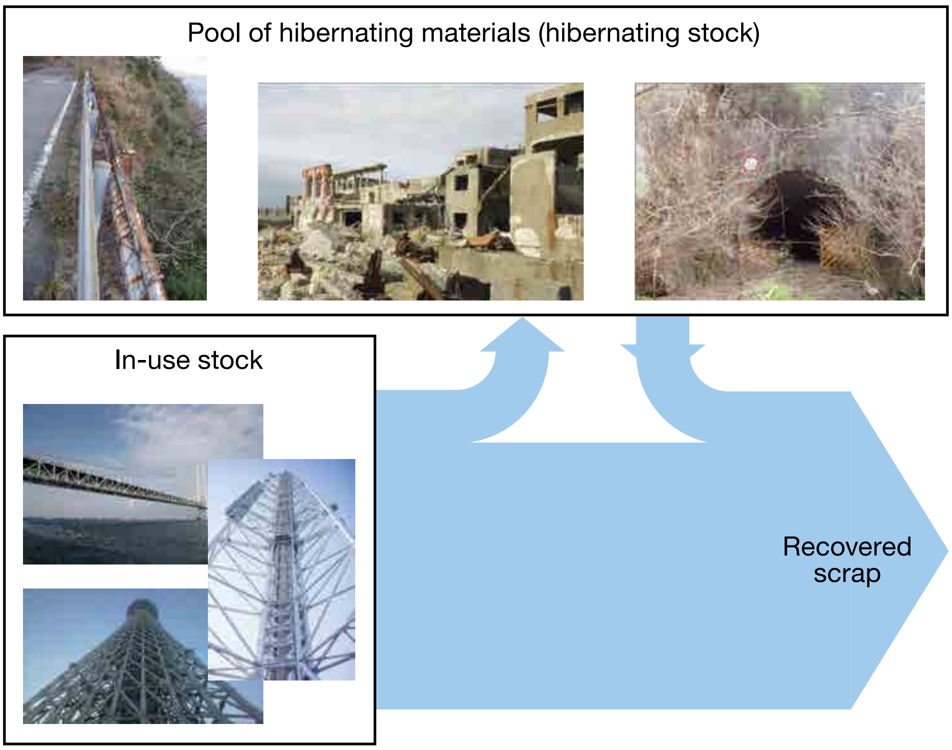


given year. From these sizeable fluctuations, it can be said that the RR, one of the variables in the LCI methodology that pertains to the recycling effect, should not be assessed using the data in a single year; rather, it would be more appropriate to apply an average of the annual values over a longer term. As shown in Fig. 6, it was learned that the steel scrap whose recovery was most dependent on price and/or demand was heavy scrap, particularly low-grade heavy scrap.

In the period when scrap prices were soaring, two specific features were noted: one, even hibernating steel stock is recoverable and, two, the amount of hibernating steel stock thus recovered cannot be disregarded in terms of total recovery (refer to Fig. 7). From the above, just because certain amounts of steel stock are not recovered once does not mean that they cannot be recovered later. Therefore, it can be said that as long as steel stock remains within the inventory of man-made products, it has the potential to serve as a future secondary resource.

Among the major reasons for the high recyclability of steel products are: ease of separation from other materials by means of magnetism, the possibility of removing impurities in the steelmaking process without using electrolysis and the high allowable levels of impurities. In addition, steel products dominate in terms of their high recoverability, including recovery-time buffer from the end-of-life product. ■

Fig. 7 Schematic Illustration of the Role of Hibernating Stock in Recovery Mechanisms



Steel Construction Products Conducive to Supporting an Eco-friendly Society

by Shinji Kitano
Chairman, Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation

Steel: High in Performance, Economy and Recyclability

Steel is the metal that people know best, and more than 90% of all metallic end products are manufactured using steel. An uncountable number of products made from steel are used in our daily lives. Iron accounts for about 30% of the Earth's total weight and are said to be its richest resource. In addition, because iron is magnetic, it can easily be separated from other materials and easily recovered after the end of its service life.

Although a diverse range of new materials have debuted to create an age of materials diversity, iron in particular is a resource-rich material that not only combines the characteristics of performance and economy but also demonstrates high recyclability.

The Japanese steel industry has developed and marketed diverse kinds of eco-friendly products. This article introduces the industry's initiative to promote global environmental preservation and the environmentally friendly steel construction products.

Blast Furnace and Electric Arc Furnace Methods in Iron- and Steelmaking

Steel products use two kinds of steel: basic oxygen furnace steel that is produced at an integrated steelworks where pig iron is produced in a blast furnace using iron ore and coal as the main raw materials; and electric arc furnace steel that is produced in an electric arc furnace using steel scrap as the main material.

In the basic oxygen furnace process, the pig iron (molten iron) that is produced in a blast furnace by reducing and melting iron ore using coal is then refined in a basic oxygen furnace to produce high-grade steel. Meanwhile, in the electric arc furnace process, steel scrap that is purchased from the domestic market is arc-melted and refined in an electric arc furnace to produce specialty steel and ordinary steel.

The steel industry supplies diverse kinds of steel products to society by best matching the process characteristics of the blast furnace and electric arc furnace methods and according to the location of the steel plants and the types of products to be made (Fig. 1).

With the ongoing economic development that is occurring in emerging nations such as China and India, world steel demand is trending upwards in both medium-term and long-term forecasts. Leading up to the 1990s, world crude steel production was in a transition period that averaged about 700 million tons/year, but, entering the 21st century, the scale of production has rapidly risen in the emerging nations, particularly in China, with the result that world crude steel production surpassed the 1,600 million ton-level in 2014.

In such a situation of growing crude steel production, it is noted that the rate of increase in the production of basic oxygen furnace steel considerably exceeds that of electric arc furnace steel (Fig. 2). This is because steel scrap that serves as the raw material for electric arc furnaces is not fully generated unless a certain level of social infrastructure is accumulated. While the international distribution of steel scrap flows from the advanced nations to the developing nations, the amount of scrap that is generated cannot meet all the demand found in the developing nations. Accordingly, because it is impossible to rely solely on electric arc furnaces to meet the currently increasing world demand for crude steel, it is essential to depend on the integrated blast furnace-basic oxygen furnace process to produce and supply the needed crude steel.

Fig. 1 Iron- and Steelmaking Process

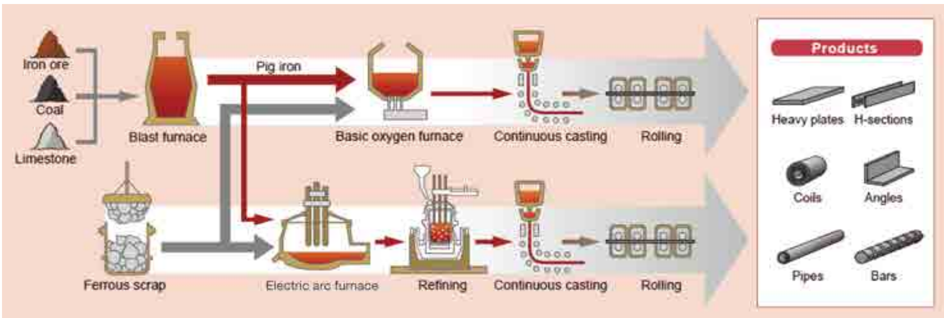
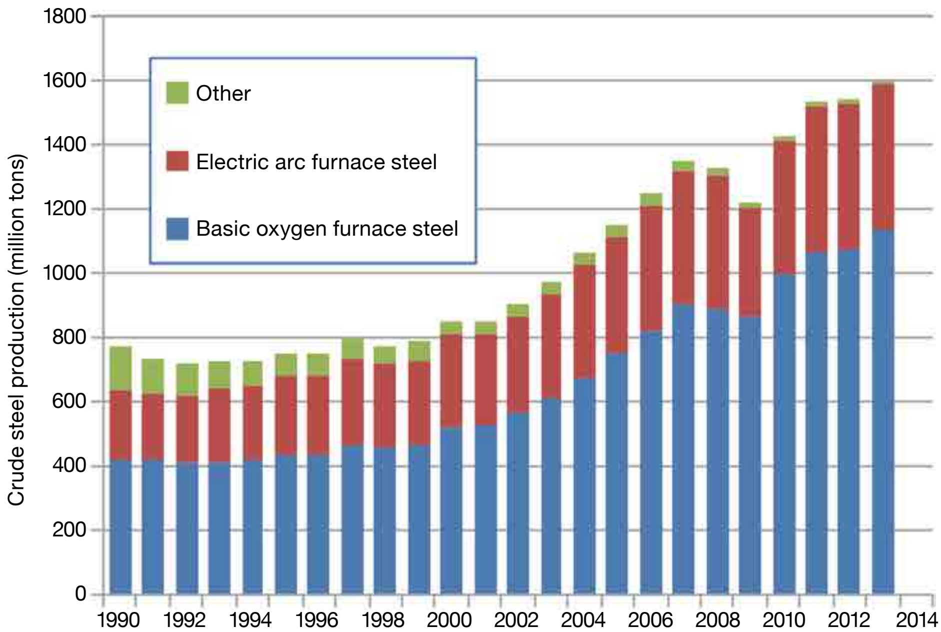


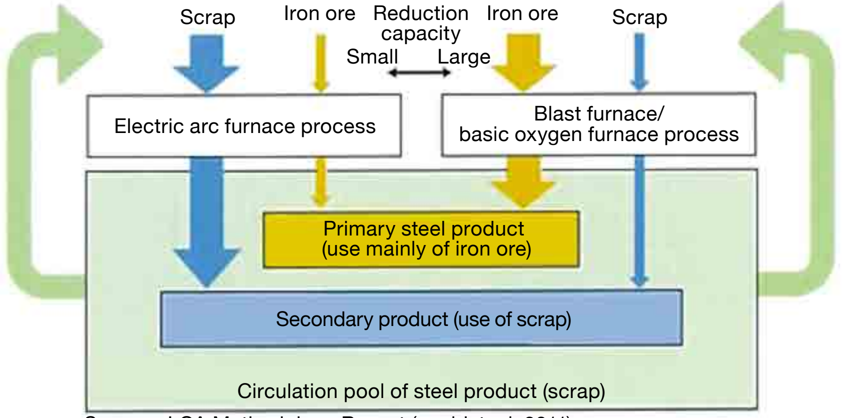
Fig. 2 Crude Steel Production in the World



In the electric arc furnace process, because scrap is melted using electricity, it is noted that CO_2 emissions arising from the electric arc furnace process are less than those of the blast furnace process where iron ore is reduced using coal. However, steel products produced in a blast furnace eventually become obsolete scrap, which is then used as the main raw material in the electric arc furnace process. In this way, it can be understood from a long-term perspective that all the steel products produced, whether in the blast furnace or electric arc furnace process, form an integrated circulation pool. All iron and steel products are subjected to repetitive recycling via this circulation pool (Fig. 3), which contributes to an overall savings of both energy and resources.

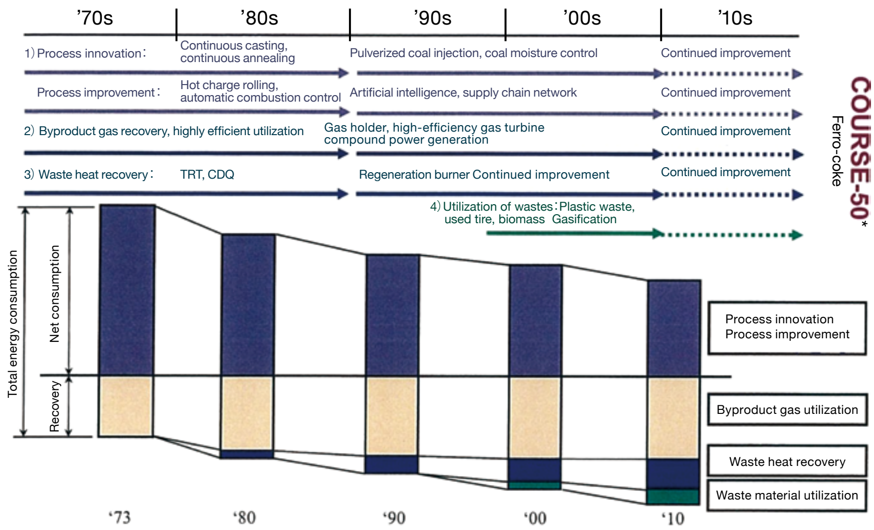
Even when all the iron- and steelmaking processes operating in Japan are switched from the blast furnace method to the electric arc furnace method, this switchover will not lead to a reduction of the Earth's total CO_2 emissions. This is because, in order to balance the resulting decrease in scrap exported from Japan, there will have to be a corresponding increase in the steel produced in other nations using the blast furnace process. In other words, so-called carbon leakage is brought about by increased production that relies on the low-energy efficiency blast furnaces used in other nations, which will naturally lead to an increase in total worldwide CO_2 emissions.

Fig. 3 Concept of Steel Recycling



Source : LCA Methodology Report (worldsteel, 2011)

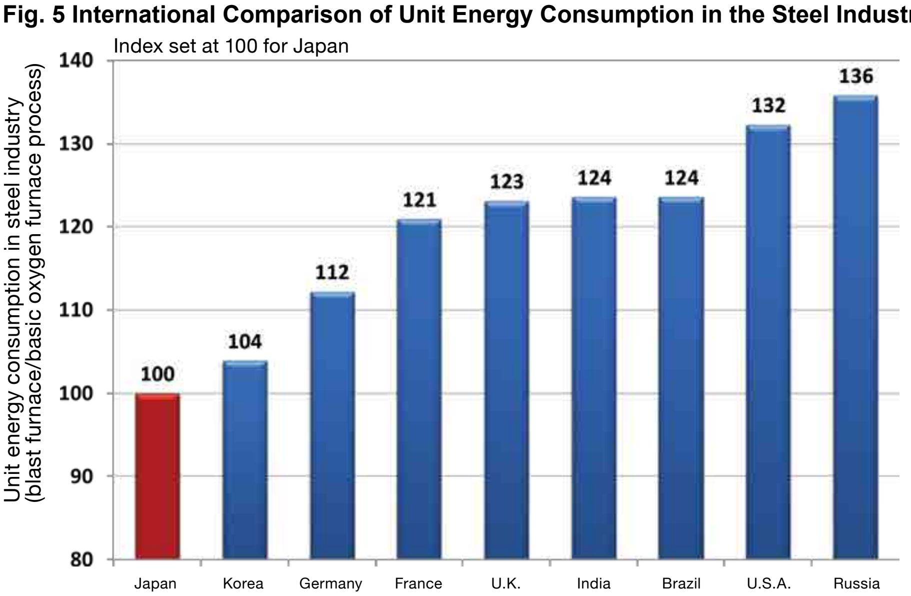
Fig. 4 Major Energy- and Resources-saving Technologies Applied in Steelworks



*COURSE-55: Research project on the technology to reduce blast furnace CO2 emissions and to separate/recover CO2 from blast furnace gas

Source: Commitment to a Low-Carbon Society (The Japan Iron and Steel Federation)

Fig. 5 International Comparison of Unit Energy Consumption in the Steel Industry



Source: Indexing of data in "Estimate for Unit Energy in 2010" prepared by Research Institute of Innovative Technology for the Earth

Steel Industry Initiatives for the Prevention of Global Warming

• Prevention of Global Warming in Iron- and Steelmaking Processes

The Japanese steel industry has actively promoted environmentally friendly iron- and steelmaking operations and continues to do so. Among the comprehensive environmental countermeasures being promoted are the world's most advanced energy efficient production methods, the effective utilization of steelworks byproducts, the preservation of atmospheric and water quality and the forestation of steelworks compounds.

Particular note should be taken of the effective utilization of energy. A great amount of the energy generated as a byproduct of every process at a steelworks is recovered and reused. Byproduct gases generated by coke ovens, blast furnaces and basic oxygen furnaces are recovered and serve as energy sources for other equipment.

Further, other types of energy are also recovered for reuse. For example, the top pressure used in the top-pressure operation of a blast furnace is recovered by means of the top-pressure recovery turbine (TRT) to generate electricity, and the waste heat generated by coke ovens is also recovered by means of coke dry quenching equipment (CDQ). Fig. 4 shows the major energy-saving technologies that have been introduced in steelworks operations in Japan. As a result of sustained efforts made to improve operations, the Japanese steel industry is now the world's most advanced in energy efficiency, as shown in Fig. 5.

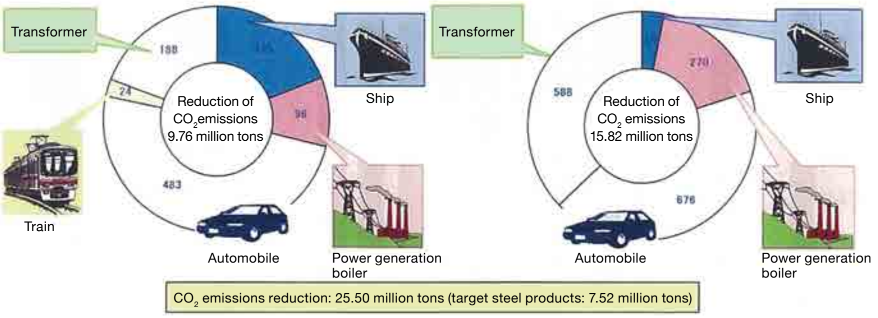
The Japanese steel industry intends not only to continue its efforts to further mitigate global warming but also to disseminate throughout the world the knowledge that it has gained from these initiatives and experience and to positively promote international cooperation in this field.

• Effects of CO_2 Emissions Reduction at the Steel Product Application Stage

Steel products are widely used for diverse application purposes to produce diverse kinds of end products. Most of these end products are used in the efficient mass transport of people and cargo and operate with high energy efficiency, which in turn contributes towards a reduction of greenhouse gas emissions.

The CO_2 emissions suppressed by the use of end products manufactured using the high-performance steel products developed by the Japanese steel industry are estimated to have been 9.76 million tons in Japan in FY2013, and the same end products exported overseas resulted in the suppression of 15.82 million tons (Fig. 6). One of the steel products that enable the highest energy efficiency for end products is high-strength steel sheet for automobiles. The lightweight automobiles brought about by the use of high-strength steel sheet contribute towards improved fuel efficiency. Similarly, high-strength steel plate for shipbuilding also contributes towards improved fuel efficiency. The oriented electrical steel sheets used for transformers eliminate electricity loss, and heat-resistant high-strength steel tubes contribute to improved power generation efficiency.

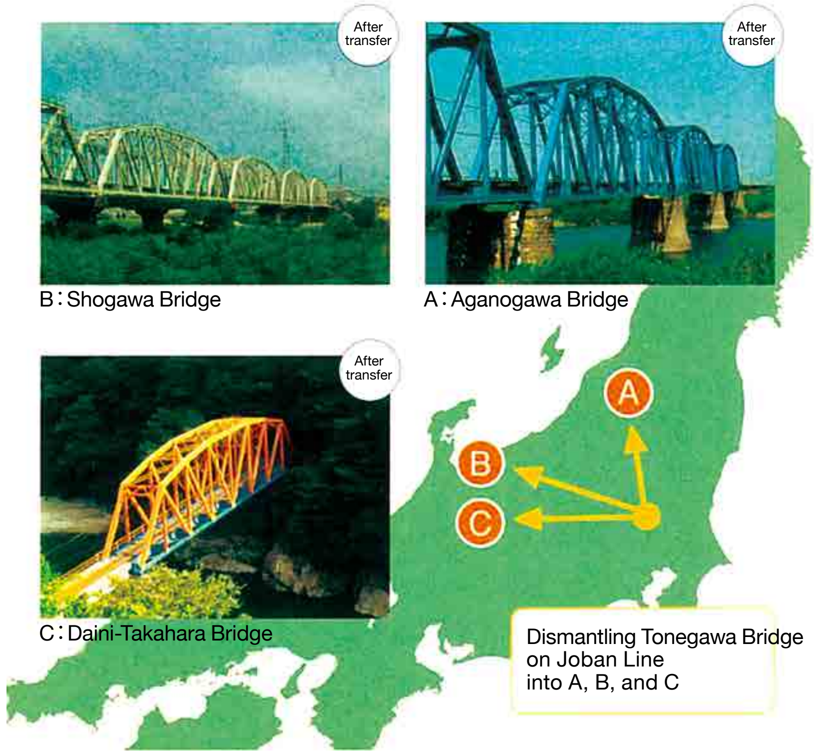
Fig. 6 Effects of CO_2 Emissions Reduction Attained in Five Major End Products (Estimates for 2013)



Source: The Institute of Energy Economics, Japan
*Five steel products of automotive steel sheet, oriented electrical steel sheet, shipbuilding steel plate, boiler tube and stainless steel plate; 3.677 million tons in domestic use and 3.845 million tons for export in FY2013, totaling to 7.522 million tons
*Start of assessment for CO_2 emissions reduction: Domestic use from FY1990, export (automobile sheet and shipbuilding plate) from FY2003, boiler tube from FY1998, and electrical sheet from FY1996

Fig. 7 Case of Demolition and Reuse of Steel Structure (Tonegawa Bridge on Joban Line)

The eight-span Tonegawa Bridge on the Joban Line in Ibaragi Prefecture, constructed in 1916, was dismantled to three sections, each of which is currently reused as the railway bridge in three locations: Aganogawa Bridge spanning Agano River in Niigata Prefecture, Shogawa bridge spanning Sho River in Toyama Prefecture, and Daini-Takahara Bridge spanning Daini-Takahara River in Gifu Prefecture.



Steel Construction Products Conducive to Preserving the Global Environment

• Steel Construction Products Conducive to Lessening Environmental Impacts

In addition to reducing steel usage, steel construction products with increased tensile strength help to reduce global environmental impacts in other ways, such as decreasing construction waste, preserving resources and prolonging the service life of structures and equipment. Specific examples are:

—Reduction of construction waste

Because steel products are recyclable, they produce almost no waste. This advantage not only reduces the cost of waste treatment but also helps to prolong the service life of final wastes disposal site whose securement is threatening.

—Resources savings

Steel is said to be the ultimate eco-friendly material insofar as products made with steel can be easily disassembled, reassembled and repetitively reused. As an example, there is the case of a certain railway bridge that, after being used at one site, was dismantled, moved and reused at three other sites (Fig. 7).

—Prolonged service life of building structures

Steel-frame structures allow large-span construction and have no need of seismic-resistant walls; thus, they are suitable for enlargement and rebuilding. Further, steel-frame structures allow construction of long-serviceable buildings that can flexibly meet future change of building application purposes.

• Steel Construction Products in Harmony with Nature

Capitalizing on the strength, workability and other excellent properties of steel, diverse types of steel construction products have been developed that harmonize with nature. In construction projects that are promoted close to nature, it is important to harmonize with and preserve the natural environment. In this regard, the steel construction products that have been developed thus far have had little damaging impact on original nature and play an inconspicuous but vital role in preserving nature in diverse ways. Further, after the long service life of these products is complete, they are effectively recycled. Specific examples are:

—Water-permeable steel pilings

The application of steel pilings with water-permeable holes allows for the construction of steel pile walls that do not impede existing water flow and give adverse effects on the local ecology and natural environment. The results of analysis show that: in cases when the openings account for 0.4% of the total pile surface area (or 1,000 openings with diameters of 55~70 mm), 80% of the original flow can be maintained. (Fig. 8)

—Steel pile embankments using planting fins

Planting fins hold the soil that serves as a foundation for raising perennial plants. The attachment of these fins to steel pile revetments allows for the greening of embankments in a manner that conceals the steel pile surface without impeding the function of the revetments. (Fig. 9)

—Water-permeable steel dams to prevent sand buildup

Water-permeable steel dams (slit dams) catch boulders and driftwood that are generated during debris flow and large floods. They also allow subsequent mud flows to pass downstream. Further, during normal periods, these dams have no effect on the flow of mountain streams and they permit water and sand to pass freely, thereby allowing the free movement of fish and plant lives. To this end, water-permeable steel dams are able to mitigate violent acts of nature while at the same time leaving nature undisturbed. During normal periods, these dams block the flow of neither earth nor sand, and prevent the drop of the level of riverbeds and the retreat of coastlines so that the ecosystem can be preserved. (Fig. 10)

—Water-impermeable steel dams to block sand

The application of sand and stones obtained near these dam sites as filling materials for the dam barricade (70% or more in Eco-mark certification standard) allows for the construction of dams that do not adversely effect the ecosystem. Further, these dams greatly reduce the volume of waste materials (such as residual sand) that must be removed, which mitigates their environmental impact. (Fig. 11)

Steel Industry Efforts to Tackle Global Environmental Concerns

Measures to treat global environmental concerns will become increasingly important for every industry in the future. To meet this situation, the Japanese steel industry will continue to promote not only further energy- and resources-savings in its production processes but also the development of higher-performance and eco-friendly steel products—with a final goal of contributing to the prevention of global warming and the formation of a recycling-oriented society. ■

Fig. 8 Water-permeable Steel Piling

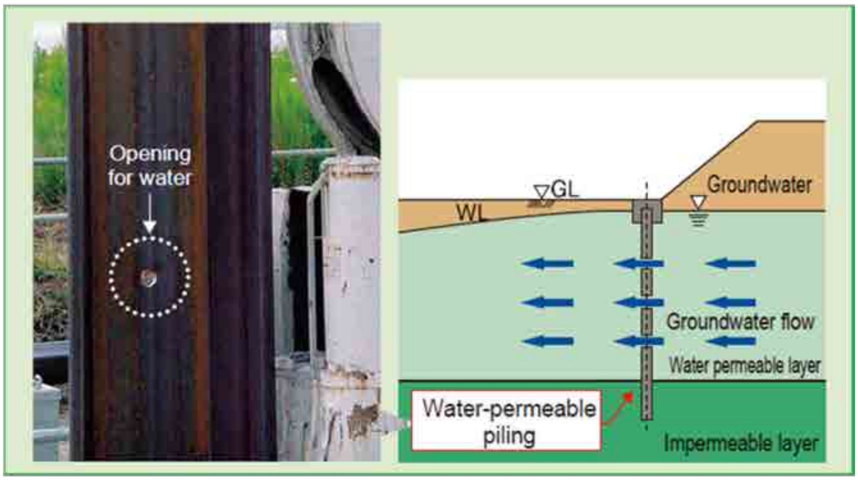


Fig. 9 Steel Pile Embankment Using Planting Fin

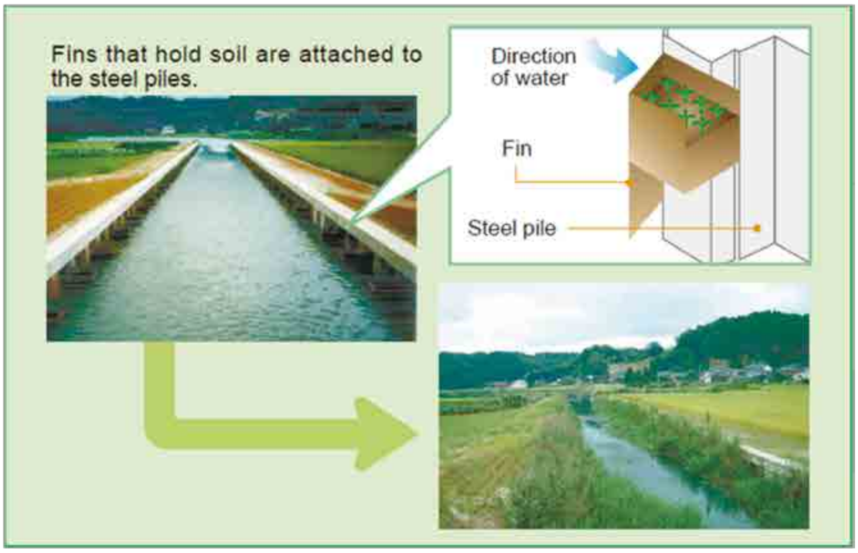


Fig. 10 Water-permeable Steel Dam to Prevent Sand Buildup

Fig. 11 Impermeable Steel Dam to Block Sand

Steel Construction Technologies in Japan

In 2014, at the request of the Ministry of Land, Infrastructure, Transport and Tourism, the Japan Iron and Steel Federation (JISF) compiled a list of steel construction technologies in Japan (in English). The list concisely introduces a total of 27 different types of steel construction technologies and steel materials for use in the fields of building construction and civil engineering so that these technologies and materials might be more readily known and available for use in overseas applications.

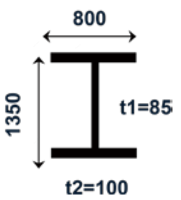
The full contents are available on the JISF website: go to (http://www.jisf.or.jp/en/activity/sctt/index.html) for free public access.

Introduced below are four typical items excerpted from the list.

High-strength Steel for Buildings (SA440, H-SA 700)

SA440 (tensile strength: 590 N/mm^2-grade steel) and H-SA700 (tensile strength: 780 N/mm^2-grade steel) are high-strength steels developed for building construction. Use of these high-strength steels permits downsizing and weight reduction, especially for large-size and extra-heavy sections of steel frames, e.g. steel framing columns for high-rise buildings. These steel materials are also effective in reducing the weight of roof trusses and other heavy members.

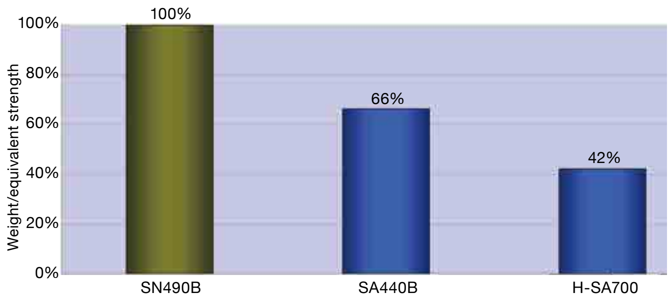
Dimension of Conventional SN490B



Reduced Sectional Dimension of SA440 and H-SA700 due to Higher Strength

	SN490B	SA440	H-SA700
Fy (N/mm^2)	295	440	700
Web Thickness t1 (mm)	85	65	40
Flange Thickness t2 (mm)	100	50	35
Section Area (cm^2)	2578	1711	1085

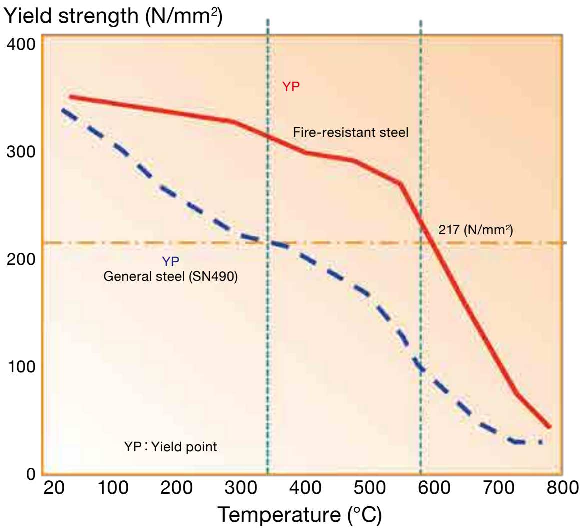
Reduction of Steel Weight Attained by Use of High-strength SA440 and H-SA700



Fire-resistant Steel

Fire-resistant steel exhibits higher strength at high temperatures than do conventional steel building materials. It is guaranteed that at 600°C the proof stress of this material is at least two-thirds the proof stress specified at room temperature. Fire-resistant steel allows the reduced use or elimination of fire protection in the construction of multistory parking facilities and other buildings. This means that such advantages as lower cost, a shorter construction period, and a better working environment can be expected.

High-temperature Performance of Fire-resistant Steel at Elevated Temperatures



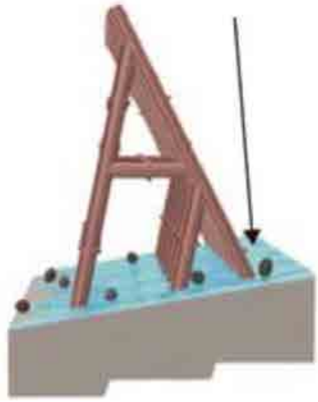
Example of application of fire-resistant steel in multi-story car park

Steel Slit Dams for Controlling Debris Flow

This is a permeable steel slit dam built by joining together steel tubes that have outstanding shock absorption. This structure shows particular concern for the environment, as it is designed not to disturb normal river flow, thus allowing the unimpeded passage of water and inoffensive earth and sand. However, once a debris flow occurs, any offensive matter is certain to be captured.

Control of Debris Flow by Steel Slit Dam

Normal condition：



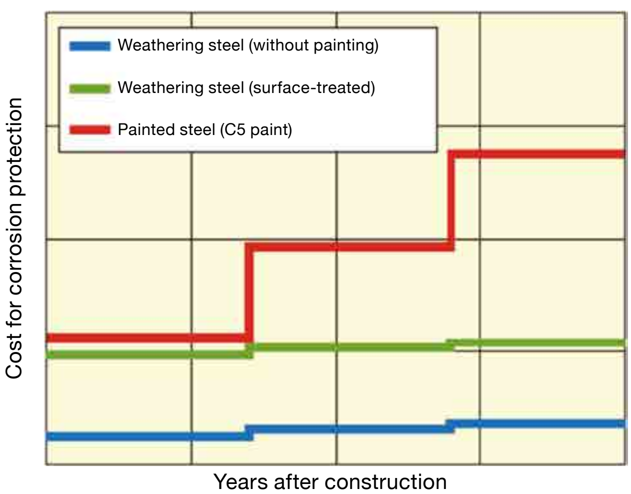
In case of debris flood：

Shift-type structures is designed considering the ecosystem, which does not disrupt river flow.

Weathering Steel for Bridges

Weathering steel forms protective rust on every surface due to the addition of such elements as Cu, Ni, and Cr. This protective coating of rust is tight and homogeneous, and is characterized by an extremely slow rate of corrosion. This property allows weathering steel to serve a long time without surface painting. This leads to reduced maintenance costs for steel bridges.

Image of Lifecycle Cost Reduction in Weathering Steel Bridges



Application of weathering steel bridge in remote mountainous area

Two Seminars Held in Thailand

The Japan Iron and Steel Federation (JISF), in collaboration with the Iron and Steel Institute of Thailand (ISIT), held two seminars in October 2015 in Bangkok. These two seminars were planned as part of government-initiated cooperative projects pursuant to the Japan-Thailand Economic Partnership Agreement.

One was a seminar on steel bridges held October 13 and 14. Four bridge experts, including two dispatched from Japan, gave two lectures titled “Introduction of Steel Bridge and its Advantages” and “The Outline of Suspension Bridge.” The other event held on October 15 was a seminar titled “Waste Management and Byproduct Recycling,” to which two specialists in these fields were dispatched as lecturers from Japan. Both seminars were a success with many participants.

Among other similar cooperative projects in the planning stage are JISF sponsorship in Japan of “Steel Construction Seminar in Japan” and “Newly Recruited and Junior Engineers Training Course in Japan.”

Seminar on steel bridges


Mr. Nattapon Ratanamalee (ISIT)


Mr. Nuttapon Suttitam (ISIT)


Mr. Toru Watabiki (JFE Engineering Corporation)


Mr. Hiroyuki Okada (Nippon Steel & Sumitomo Metal Corporation)

Seminar on the environment and energy conservation


(from left to right) JISF staff, Mr. Noriji Numata (JFE Steel Corporation), Mr. Songwoot Graiparpong (ISIT), Mr. Teruo Furuyama (Nippon Steel & Sumitomo Metal Corporation)

Survey Results for *Steel Construction Today & Tomorrow*

From August 2014 through June 2015 our overseas readers of the periodical *Steel Construction Today & Tomorrow* (English-version) were asked to participate in surveys, as reported in Issues 42 to 44.

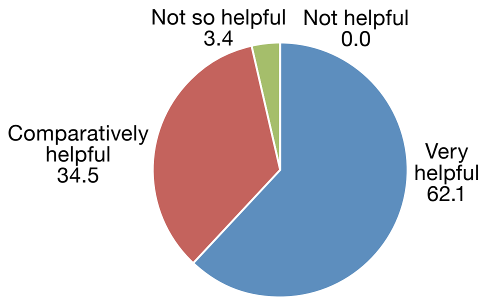
We wish first to express our great appreciation for our readers’ kindness in participating in the current survey. Thanks to your generous cooperation, many useful results were obtained, some of which are introduced below.

Survey respondents numbered 58, with those from Southeast Asia leading the way. Specifically, 97% of the participants said that this periodical is beneficial in their current job; and 88% had experience utilizing steel structures in their current or past jobs. It became obvious that structural steel shapes were the most widely used of all steel-structure materials, mainly in Southeast Asian nations.

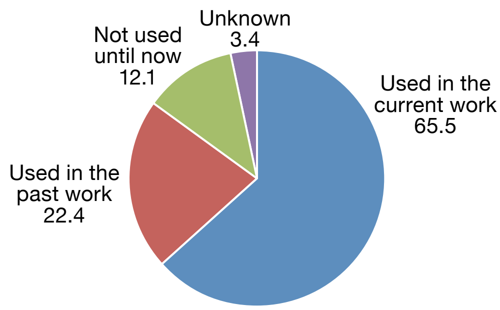
Meanwhile, the primary reason why steel structures were not chosen was their high cost, with the runner-up being the intent of the clients. With regards to themes that readers would like to see taken up in the future, bridges come first, followed by construction, expressways, corrosion protection, earthquake resistance, and railways in that order.

It will be our firm policy to reflect seriously on these survey results when considering future editing plans.

Usefulness of *Steel Construction Today & Tomorrow* for your current work (%)



Is the steel structure used in your current work? (%)



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