No. 58 December 2019

STEEL CONSTRUCTION TODAY & TOMORROW

http://www.jisf.or.jp/en/activity/sctt/index.html

Feature Article

Recycling and Lifecycle Assessment of Steel Products

Serial Article: Latest Design of Steel Buildings in Japan (4)

GINZA KABUKIZA

Published Jointly by

The Japan Iron and Steel Federation

Japanese Society of Steel Construction

Initiatives to Treat Environmental Issues and Mitigate Global Warming by the Japanese Steel Industry

by Hidekazu Matsubara
Secretary, Committee on Environment-friendly Steel for Construction
The Japan Iron and Steel Federation

Amid growing concerns about global environmental issues, the Japanese government established the Council of Ministers for Global Environment Conservation in 1989. With this establishment, diverse efforts that aim at mitigating global warming have been promoted nationwide. In recent years, in order to work out and propose the "Long-term Low Greenhouse Gas Emission Development Strategies (Long-term Strategies)," which has been required to submit by 2020 in the Paris Agreement of COP21, the "Conference on Japan's Long-term Strategy under the Paris Agreement" was established, which has started examinations involved in the Long-term Strategy.

In light of such movements in Japan and abroad, the Japanese steel industry is promoting various measures that aim at mitigating global warming. One of specific measures being promoted is the "Implementation Plan to Achieve a Low Carbon Society." In addition, staring fixedly at ongoing global warming issues after 2030, the steel industry has worked out the "Vision for Long-term Measures to Treat Global Warming Issues" that aims at realizing its final goal, the production of "steel with no CO_2 emissions in its production process."

The following article introduces the Japanese steel industry's initiatives to treat environmental issues and mitigate global warming that have been promoted so far, and future plans to further mitigate global warming.

Measures to Treat Environmental Issues in Iron and Steel Production

Triggered by the oil crisis that occurred in the 1970s, the Japanese steel industry has promoted various efforts to treat environmental issues involved in iron and steel production, among which are:

- Process improvement measures mainly for the continuation of production processes, such as the introduction of continuous steel casting equipment
- Effective utilization of byproduct gas where byproduct gas generated in iron- and steelmaking processes is recovered and used as energy to operate iron- and steelmaking equipment
- Recovery of waste energy and its effective utilization as a source for power generation
- Introduction of energy-saving technologies developed by capitalizing on the effective utilization of waste materials as resources (Refer to Fig. 1)

The Japanese steel industry has successively introduced these high energy-efficient processes into iron and steel production, thereby attaining a reduction of about 30% of unit energy consumption per ton of steel produced compared to the level in the 1970s. As a result, the industry has realized iron- and steelmaking processes that demonstrate the highest energy-efficiency in the world. (Refer to Fig. 2)

In addition to the efficient energy use mentioned above, the Japanese steel industry has put into effect various kinds of other environmental measures, one of which is the effective use of slag generated in iron- and steelmaking processes. For example, because blast furnace cement produced employing blast furnace slag can be produced without the use of crushing and sintering processes that are used in the production of regular cement, blast furnace cement has a great impact on environmental protection or the reduc-

Fig. 1 Development of Eco-processes in the Japanese Steel Industry

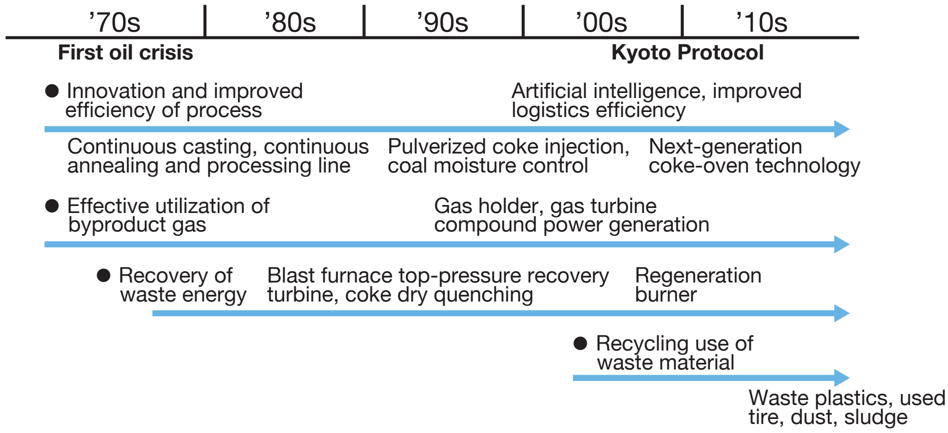
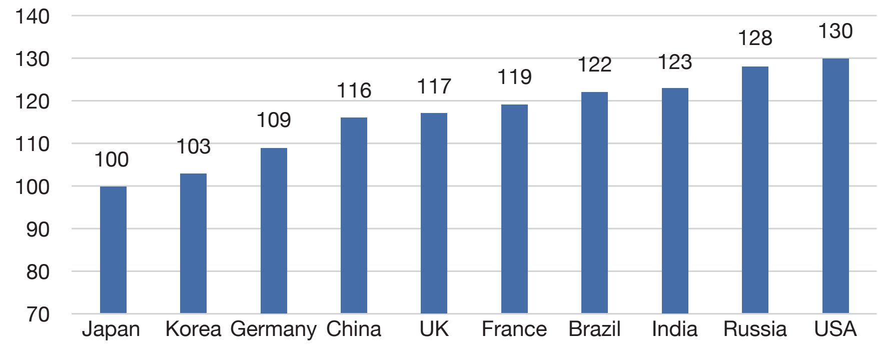


Fig. 2 International Comparison of Unit Energy Consumption in the Steel Industry

Index set Japan as 100 (unit consumption per ton of steel produced)



Source: RITE—Estimate of Unit Energy Consumption for 2015; Conversion to indices by the Japan Iron and Steel Federation

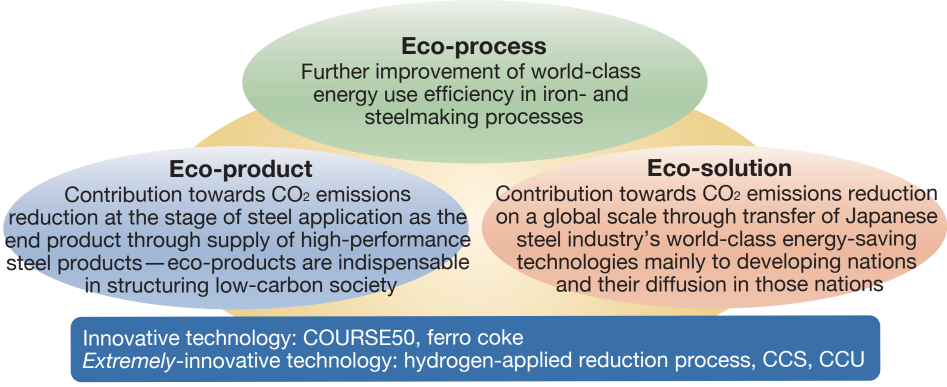
tion of CO_2 emissions during production.

Further, the industry also contributes towards the preservation of not only air but also water quality. Emissions of SO_x and NO_x at steelworks are considerably reduced by the adoption of desulfurization and denitrification equipment. In terms of the vast amount of water used at steelworks, more than 90% of all water use is put back into circulation with the adoption of water quality purification equipment. Capitalizing on these environmental measures, the steel industry contributes toward the improvement of the environment.

Measures to Mitigate Global Warming by the Japanese Steel Industry

Making the most of these world's highest energy-efficient processes, the Japanese steel industry has planned and put into practical use measures to mitigate global warming. Specifically, these measures are promoted based on the "Implementation Plan to Achieve a Low Carbon Society: Phase I (~2020)" that is supported by four core activities: the effective use of three eco-approaches—eco-processes, eco-solutions and eco-products—and the development of the innovative process COURSE50 (CO_2 Ultimate Reduction System for Cool Earth 50). (Refer to Fig. 3)

Fig. 3 Basic Concept for Long-term Measure to Mitigate Global Warming in the Japan Iron and Steel Federation (Three ecos+Innovative technology development)



• Eco-processes

Eco-processes lay out the world's highest energy-efficient processes mentioned above, for which the further improvement of energy efficiency is being promoted. Recently, R&D efforts are being directed towards the introduction of next-generation coke ovens and the enhancement of the operational efficiency of power generation equipment.

• Eco-solutions

Eco-solutions aim at the promotion of energy savings by means of two major approaches: the transfer of energy-saving technologies (BAT: best available technology) developed and put into practical use in the Japanese steel industry to China, India, ASEAN and other nations where the steel industry is achieving remarkable developments; and the effective use of the framework of multinational cooperation programs such as the Global Superior Energy Performance Partnership (GSEP). The Japanese steel industry has contributed towards reducing CO_2 emissions through these approaches on a global scale. (Refer to Fig. 4)

A study made by the International Energy Agency shows that in overseas steel industries there is great potential for energy savings (Fig. 5) that can be achieved by the introduction of advanced energy-saving technologies (most of these technologies developed in Japan). The Japanese steel industry will continue to tackle the development and supply of eco-solutions in the future.

Fig. 4 Transition in International Cooperation Programs to Support Eco-solutions

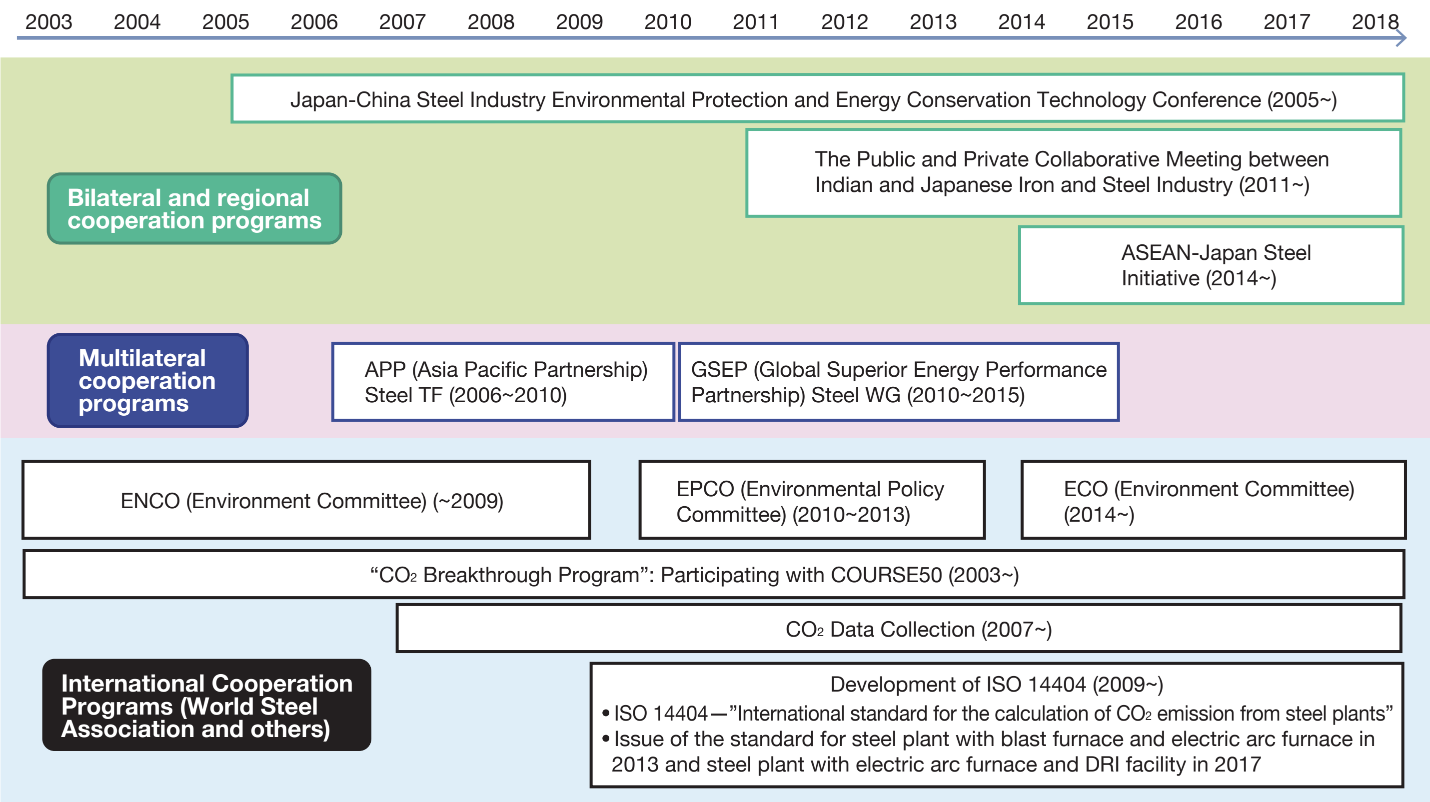
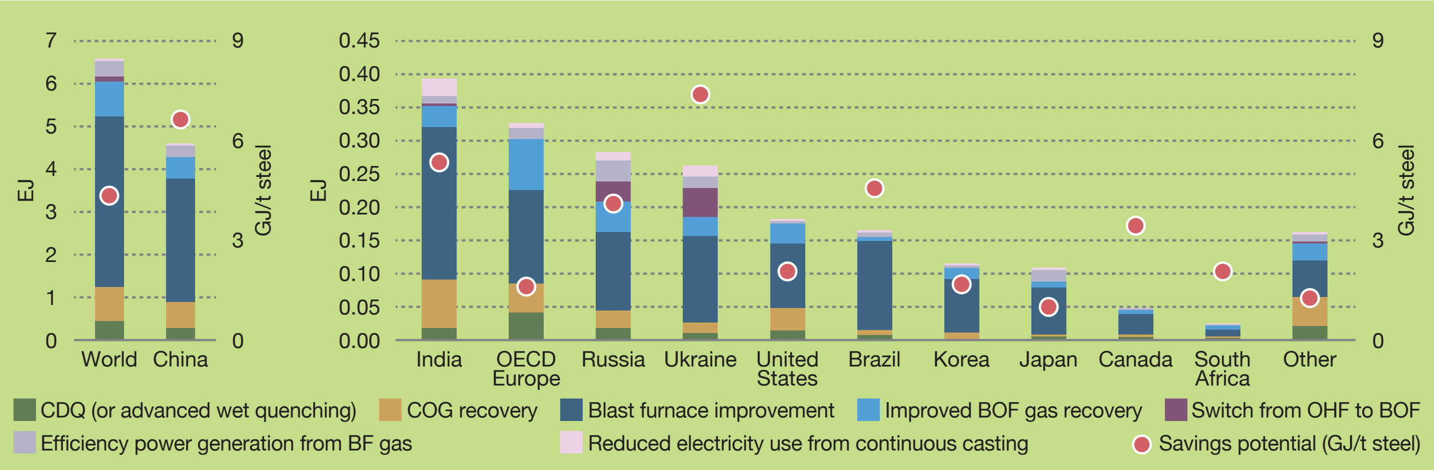


Fig. 5 International Comparison of Energy Saving Potentials in the Steel Industry (2011)



Source: Energy Technology Perspective 2014 of IEA

• Eco-products

Eco-products mean those steel products that allow CO_2 emissions reductions, less environmental burdens, improved fuel efficiency and other approaches in the stage of end products manufactured by the optimum use of the specific performances offered by eco-products. For example, end products manufactured using high-performance steel products contribute toward reducing CO_2 emissions, or eco-products demonstrate eco-friendliness in the application stage. A typical eco-product is high-strength automotive steel sheets. From the 1970s to the present, higher tensile strength has been demanded for automobile steel sheets to meet diverse social backgrounds and needs, or to meet the need for lighter-weight automobiles that allow for improved fuel efficiency. Higher-strength automobile steel sheets developed by the Japanese steelmakers have contributed toward the reduction of CO_2 emissions by lightweight automobiles on a global scale. (Refer to Photo 1)

However, the level of characteristic values achieved in terms of tensile strength or put into practical use by Japanese steelmakers is only 1/2 or 1/3 that of the theoretical value (refer to Fig. 6). Given this, the Japanese steel industry is striving not only to develop higher-strength steel products but also to support future social infrastructure through the development of next-generation steel products to prepare for the arrival of a hydrogen infrastructure. At the same time, the industry is pushing forward with the task of contributing to reduced CO_2 emissions over the entire life cycle of steel products.

In the development of innovative ironmaking processes, R&D efforts are being directed towards two targets: the utilization of hydrogen-reduction of iron ore in the blast furnace process where CO_2 emissions are highest among the iron- and steelmaking processes; and the COURSE50 project in which technological developments are being made with the aim of reducing CO_2 emissions by 30% in iron and steel production by means of the separation and recovery of CO_2. The wider diffusion of COURSE50 put into practical application by 2030 is targeted to be completed by around 2050.

As a means to reduce CO_2 emissions in iron- and steelmaking processes, the Japanese steel industry has worked out the “Implementation Plan to Achieve a Low Carbon Society: Phase II” for 2030. In terms of total CO_2 emissions in the steel industry, Phase II targets higher-level reductions by adding specific reduction targets to be achieved by eco-products, eco-

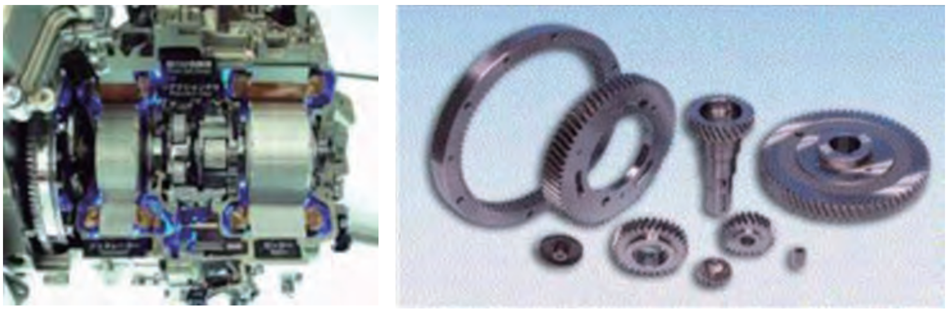
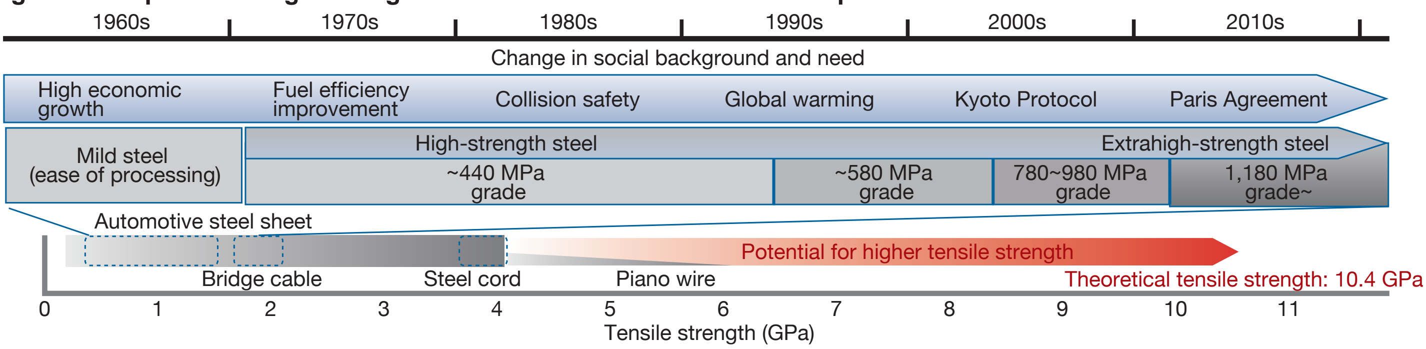


Photo 1 Steel products conducive to reducing CO_2 emissions

- Motors for hybrid and electric vehicles: Improved fuel efficiency, higher output and downsizing of motors attained by the use of high-efficient, non-oriented electrical steel sheet
- Automobile and industrial machinery parts: Multi-stepping, downsizing and lighter weight of transmission gears attained by the use of high-strength gear steel→Improved fuel efficiency

Fig. 6 Development of High-strength Steel Products and Future Development Potential



processes and eco-solutions over those of Phase I (Table 1). In the field of innovative process development, the steel industry has a plan to promote the development of ferro coke, an innovative ironmaking raw material, in addition to COURSE50.

Future Measures to Mitigate Global Warming in the Japanese Steel Industry

The Paris Agreement targets "holding the increase in the global average temperature to well below 2°C above pre-industrial levels." Keeping this statement in mind, it will absolutely be necessary to develop *extremely*-innovative ironmaking technology beyond technologies currently in use as well as innovative technologies which are under development. Given such a situation, the Japanese steel industry is directing its full efforts to the development of COURSE50, ferro coke and other innovative ironmaking technologies towards their practical application by 2030. When these technologies are put into practical use, CO_2 emissions from the use of natural resources are expected to be reduced by 10% from current emissions levels (excluding reductions due to the effect of carbon dioxide capture and storage).

For the moment, the blast furnace method is considered the mainstream method in ironmaking from both an economic and technical perspective, and therefore it will be necessary to promote the establishment of low carbon emissions-type ironmaking technology on the assumption that blast furnaces will continue to be applied in the future. However, it will be impossible to achieve the long-range level of global average temperatures set out in the Paris Agreement with only the use of such measures, which will thus require the development of *extremely*-innovative technologies beyond those currently in development. (Refer to the scenario for the maximum introduction of extremely-innovative technologies shown in Fig. 7)

To these ends, capitalizing on knowledge to be obtained in the development of COURSE50 and ferro coke as the foothold, the Japanese steel industry is promoting three major development challenges: hydrogen-applied reduction process technology that finally allows for zero-emissions from the ironmaking process; CCS (carbon capture and sequestration) in which CO_2 emitted from the ironmaking process is separated, recovered and stored; and CCU (carbon capture and utilization) in which the valuables are formed using CO_2 as the raw material.

Because the hydrogen to be used in the hydrogen-applied reduction process is used not only as a raw material for ironmaking but also as the fuel source for automobiles and other extensive civil sectors, the major precondition is the development and improvement of the technology and equipment to produce hydrogen as a common energy carrier for industrial and social infrastructure. Particularly, the important requisite for the hydrogen used for the production of steel, the basic industrial material, is carbon freeness and the further availability of a low-cost, stable supply. Further, in the practical use of CCS, it will be necessary to solve various tasks beyond technological tasks, such as securement of CO_2 storage sites, social receptiveness, project implementation organizations and the treatment of economic burdens in addition to the development of technology to allow the low-cost transport and storage of large quantities of CO_2. Fig. 7 shows the roadmap towards (scenario for) the development of *extremely*-innovative technologies.

Initiatives towards Sustained Mitigation of Global Warming

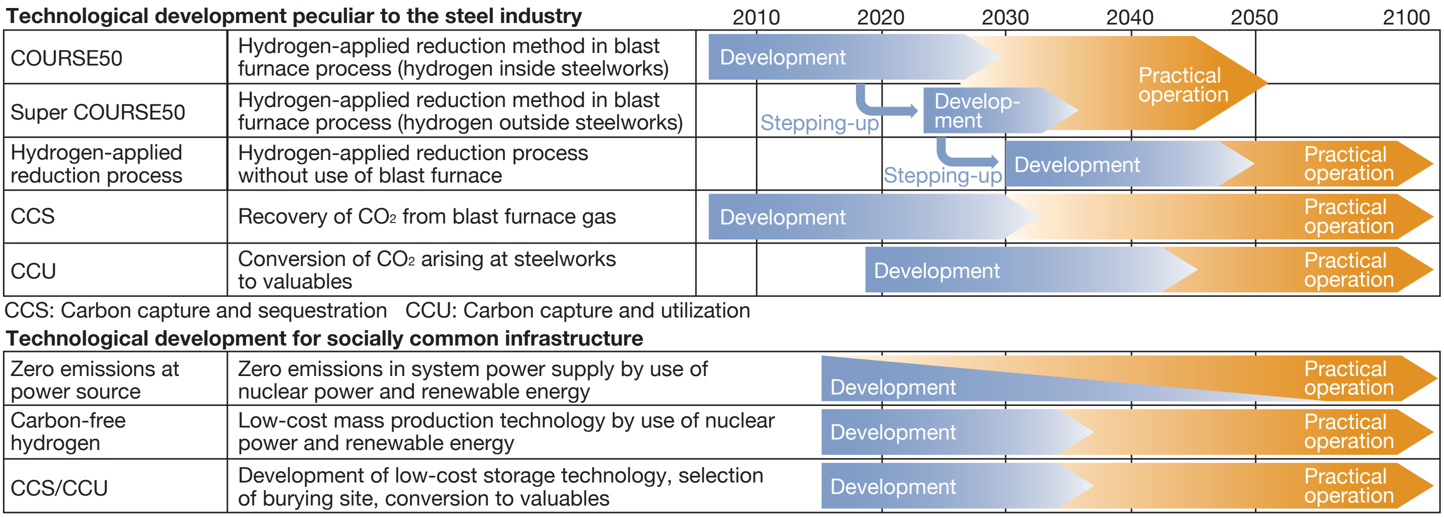
The Japanese steel industry has thus far tackled environmental issues capitalizing on the advanced technologies introduced above. In the future, in order for Japan to attain the medium-range target (2030) stated in the Paris Agreement, the industry will steadily promote the "Implementation Plan to Achieve a Low Carbon Society." At the same time, regarding the long-range target (after 2030) that aims at produce "steel with no CO_2 emissions in its production process," it will sustain its initiatives for long-range global warming mitigation measures that will be obtained through the promotion of eco-products, eco-processes and eco-solutions and the development of innovative technologies. ■

Table 1 Targets for CO_2 Emissions Reduction by the Use of Three Ecos in the Japanese Steel Industry

Implementation of Plan to Achieve Low Carbon Society	Phase I (~2020)	Phase II (~2030)
Eco-process	5,000,000 tons-CO_2* (reduction from BAU)	9,000,000 tons-CO_2 (reduction from BAU)
Eco-solution	70,000,000 tons-CO_2	80,000,000 tons-CO_2
Eco-product	34,000,000 tons-CO_2	42,000,000 tons-CO_2

*Of the emissions reduction target of 5,000,000 tons-CO_2, while concentrating on the reduction of 3,000,000 tons-CO_2 by means of energy savings and other self-efforts, the emissions reduction attained by the increased collection of plastic wastes and other waste materials compared to the FY2005 collection return is to be counted as the emissions reduction return.

Fig. 7 Roadmap towards (Scenario for) Development of Extremely-Innovative Technologies



Standardization of LCI Calculation Methodology for Steel Products and Its Development in Japan

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

Standardization of LCI Calculation Methods with Consideration of Recycling Effect

In assessing the effect on the environment of many products used in our daily life, while attention is liable to be focused on the stage of production and application of these products, it is not always correct to judge environmental performance only in the stages of production and application. Rather, it is important to assess the effect of products on the environment over the entire lifecycle of products that covers processes from the mining of raw materials to the manufacture and application of products and further to recycling after the disposal of used products. That is, lifecycle assessment is important in assessing the environmental performance of products.

Nearly all steel products are recovered as steel scrap after automobiles and other products employing steel products reach the end of their service life. Recovered steel scrap is then reborn as renewed steel products, which are then applied to new end products. This process is repeated for many types of end products many times.

So far, standards have not yet been established to assess environmental burdens over the entire lifecycle, covering even recycling as scrap after the disposal of end products. To cope with such a situation, ISO 20915 "Life cycle inventory calculation methodology for steel products" and JIS Q 20915 "Life cycle inventory calculation methodology for steel products" (hereinafter referred to as the "Standards") have been put into effect, which allow inventory calculations used for assessing the environmental burdens on the entire lifecycle of steel products.

The Standards originate from the LCI calculation methodology prepared by the International Iron and Steel Institute (currently World Steel Association: worldsteel) through organizing the calculation method for the life cycle inventory (hereinafter referred to as the "LCI") in 1997, which takes into account the scrap recycling of iron and steel products, using the Methodology Report published by the Institute. In 2015, the Japan Iron and Steel Federation (JISF) proposed the Technical Committee ISO/TC 17 for the standardization of the LCI calculation methodology, which led to the establishment of ISO 20915 "Life cycle inventory calculation methodology for steel products" in November 2018 and JIS Q 20915 having nearly identical content in June 2019.

While the conventional system boundary (range applied for LCI calculation) used for the LCI calculation methodology generally covers the processes from the mining of raw materials to product shipment, the system boundary in the newly-established Standards covers the processes from the mining of raw materials to product shipment taking into account the recycling effect obtained by scrap recovery and application (Fig. 1). In the case of LCI calculation using the Standards, LCI is obtained by adding LCI (B1) occurring due to scrap input and LCI (B2, minus value) occurring due to scrap recovery to LCI (A) occurring in the processes from the mining of raw materials to product shipment (Fig. 2)

JISF and worldsteel periodically collect from domestic and global steel industries the information on operating results data of their member companies to calculate and make public the average values for global warming potential (GWP) pertaining to major steel products. The GWP data is available at the websites of these two organizations.

In the following three chapters, the

Fig. 1 System Boundaries Used in LCI Calculation Methodology

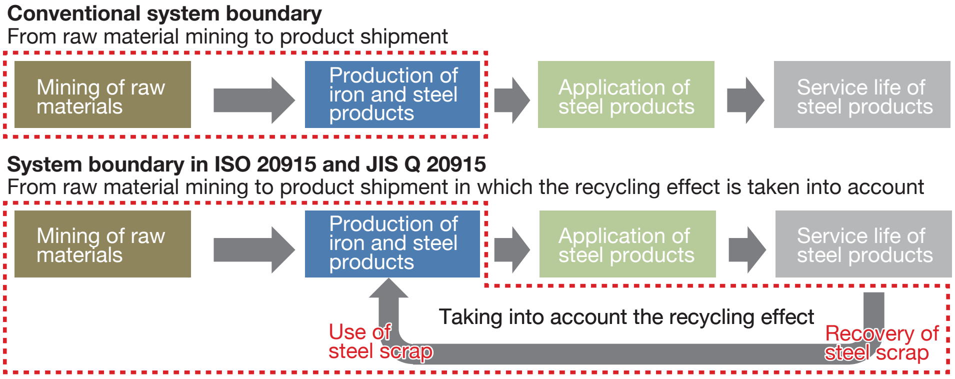
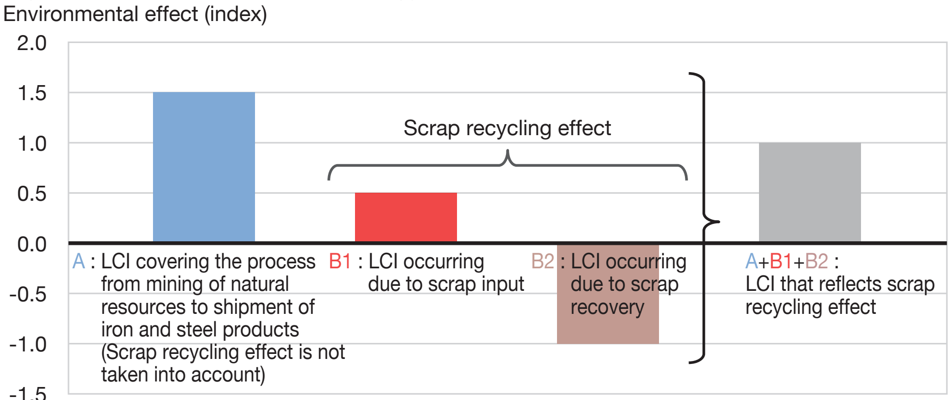


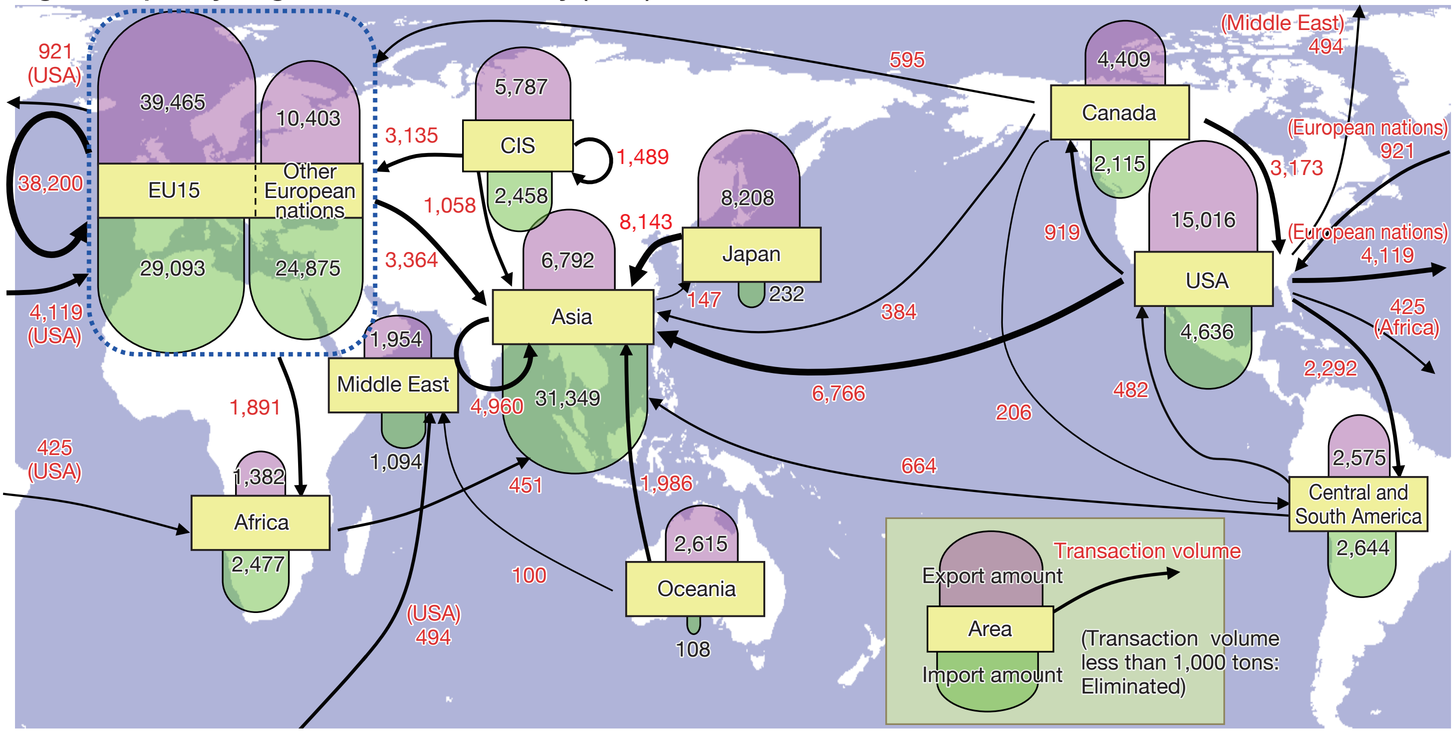
Fig. 2 LCI Calculation Methodology Adopted in JIS Q 20915



Source: "Fig. 3 Concept of LCI Calculation for Steel Products" in JIS Q 20915

Fig. 3 Scrap Recycling under Market Economy (2017)

(unit: 1,000 tons)



Source: International Steel Statistics Bureau, World Steel Association, the Japan Ferrous Raw Material Association

Fig. 4 Environmental Burdens Occurring during Regeneration of Steel Products

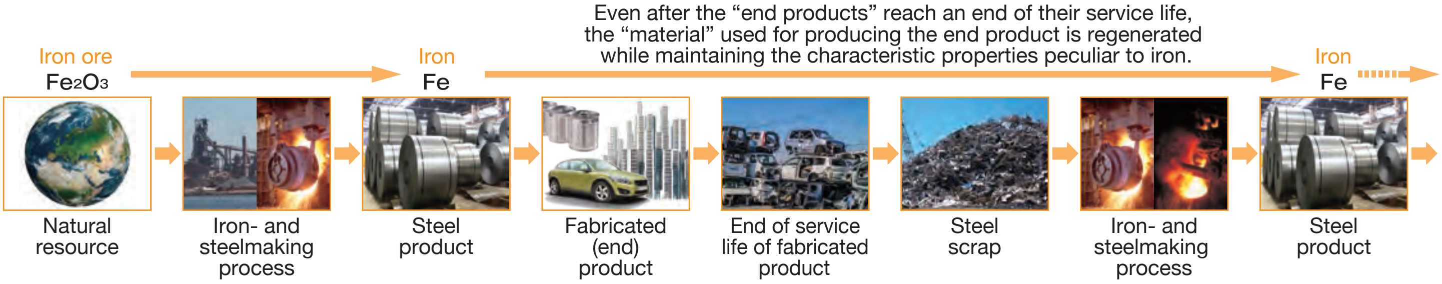


Photo 1 Magnetic separation of used steel products from waste materials

Photo: The Japan Iron and Steel Federation

background for and concept of the Standards are introduced.

Overwhelming Predominance in Terms of Recyclability

The most noteworthy feature of the Standards lies in the full consideration paid to the recycling effect peculiar to steel products. When citing steel’s advantages in terms of recycling, the following five advantages can clearly be seen, which allow closed-loop recycling (any end product and many times) of steel products.

- **Ease of Separation**

As is well known, a magnet attracts steel. Even if steel products are disposed together with other waste, steel is easily separated from disposed waste with the use of a magnet (Photo 1).

- **Establishment of Recycling under Market Economies**

Steel scrap is not the waste material but “the valuable,” and thus steel scrap has already been transacted worldwide based on market principles (Fig. 3).

- **Less Environmental Burdens during Regeneration**

Once iron ore is reduced to iron ($Fe_2O_3 \rightarrow Fe$), the generation of environmental burdens occurring in the subsequent stage of regeneration from scrap to steel can be suppressed to a minimum level ($Fe \rightarrow Fe$), and further it is possible to repeat the environmental burden-free operation in every regeneration process that follows (Fig. 4).

- **Less Quality Deterioration during Regeneration**

At the stage of regeneration from steel scrap to steel, most of the impurities contained in steel scrap can be removed as slag and gas (Fig. 5).

- **Possibility of Regeneration to Diverse Types of Steel Products**

The metallic structure of steel regenerated from scrap is reset at the stage of re-melting the scrap, and steel thus obtained can be processed to various kinds and types of steel products by means of microstructure control employing performance build-in technology (Fig. 6).

Compatible Use of Blast Furnaces and Electric Arc Furnaces

The iron and steel production method can roughly be classified into the blast furnace (BF) method and the electric arc furnace (EAF) method. In the BF method, pig iron is produced mainly from iron ore, and the carbon contained in pig iron (molten iron) is removed using a basic oxygen furnace to produce steel. Meanwhile, in the EAF method, steel scrap is re-melted using arc heat, during which the chemical composition is adjusted to produce steel. Even in the BF method, there are cases in which steel scrap is used from an economical viewpoint, and further in the EAF method, there are cases in which pig iron is used to maintain the quality level of the steel. (Refer to Fig. 9)

Fig. 7 shows the production of steel products around the world since 2000 using the BF and EAF methods. Production employing the BF method is far more than that employing the EAF method, and the BF method surely meets the growing demand for steel products. The reason for this is that, while iron ore can be mined according to the level of demand, the available amount of steel scrap is limited because scrap, so to speak, exudes from the society.

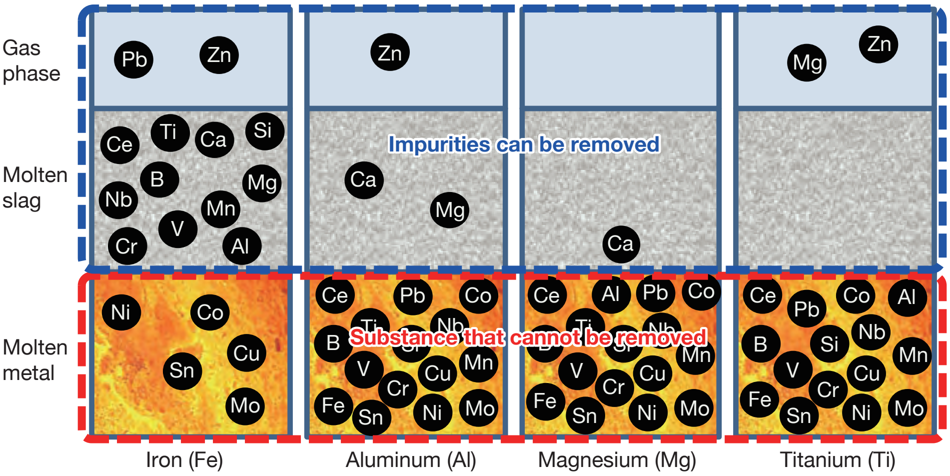
In this way, steel scrap is effectively reused in both the BF and EAF methods while at the same time steadily increasing the steel stock in society by the use of steel products produced from blast furnace-basic oxygen furnace steel. The per-capita steel stock in matured societies in Japan, US and Europe amounts to about 10 tons, but the average per-capita steel stock in the world amounts to only about 4 tons (Fig. 8). For the moment, the age of compatible use of the BF and EAF methods will continue, under which the BF method is expected to play a pulling role towards the growth of social steel stock.

Concept of LCI Calculation of Steel Products

The LCI calculation of steel products is explained by setting the iron ore-derived LCI as Xpr, steel scrap-derived LCI as Xre, scrap recovery rate (recycling rate) as RR and the molten steel yield during regeneration of steel scrap as Y, and further, in order to promote understanding of the concept of LCI, by giving the assumed values prepared by simulating the actual returns in four respective items shown above—Xpr=2.0 (t-CO_2), Xre=0.5 (t-CO_2), RR=0.9 and Y=0.9 (Fig. 9).

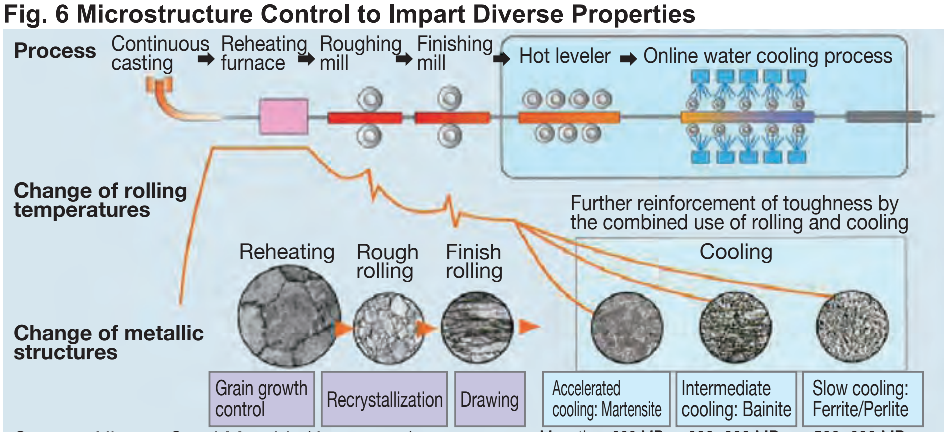
In the situation where both the BF and EAF methods are used in iron and steel production, how should the LCI of steel products be calculated? Should the LCI be calculated for the steel products separately via the BF method or via the EAF method, or via a single linked process covering both methods? Because steel scrap used in the EAF method comes certainly via the BF method in which iron ore is reduced to iron, there is a causal relationship between these two methods, and thus it is impossible to divide the two methods for the LCI calculation. Therefore, these two methods are grasped as a single linked process, and it is very natural to assess the LCI of these two methods employing the average value of lifecycle LCIs of the steel products

Fig. 5 Maintaining of Quality during Regeneration



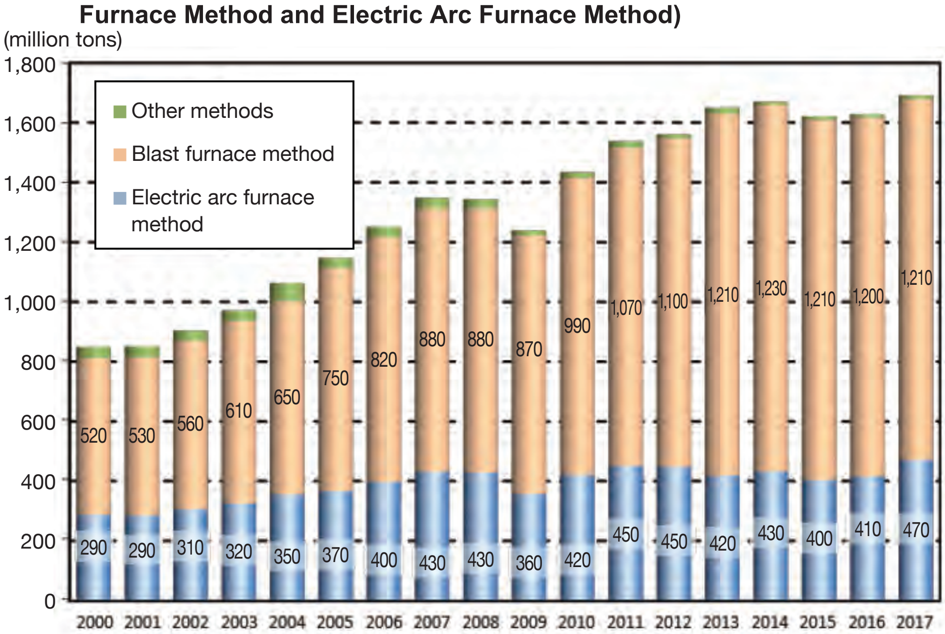
Source: Modification of the "Report 232_269 by Taketo Hiraki et al" submitted at the 23rd Annual Conference of Japan Society of Material Cycles and Waste Management (2012)

Fig. 6 Microstructure Control to Impart Diverse Properties



Source: *Nippon Steel Monthly* (June 2007)

Fig. 7 Production of Steel Products in the World (Steel Products via Blast Furnace Method and Electric Arc Furnace Method)



Source: World Steel Association

(Fig. 10).

Specifically, the LCI is to be calculated for every repetition of recycling, and as a result, the LCI changes from 2.0 (t-CO_2) finally to 0.79 (t-CO_2). In the Standards, this final value (lifecycle average value) is set as the LCI of steel products, as shown in Fig. 11. The Standards specify this final value (lifecycle average) as the LCI of steel products (Fig. 12).

From the concept mentioned above, the LCI calculation can be expressed using the equation LCI=Xpr−RR・Y (Xpr−Xre), but the factor of scrap usage is not taken into account in this equation. That is, it can be said that LCI is identical for steel products produced via either the BF method or the EAF method. By the way, the LCI of steel products is expressed in the Standards as Xpr=A+B1, −RR・Y (Xpr−Xre)=B2. (Refer to Fig. 13)

◆◆◆

Infiltration of LCI Concept for Steel Products in Japan

In order to diffuse and filter the right concept for the LCI of steel products into Japan, JISF is promoting activities that aim at reflecting the right concepts based on JIS Q 20915 in the standards and standard documents in common use in Japan pertaining to environmental burden assessment. As a result, regarding environmental considerations in building construction, the content of JIS Q 20915 has been published in the chapter on steel-frame building construction of the *Guideline for the Management of Building Construction* (2019) supervised by the Minister's Secretariat of the Ministry of Land, Infrastructure, Transport and Tourism.

Further, regarding the Environmental Product Declaration (EPD) based on ISO 14025, JISF has appealed to the Japan Environmental Management Association for Industry so that the LCI calculation methodology based on JIS Q 20915 is subjected to the assessment of EPD, which led to the enforcement in June 2019 of Product Category Rules (PCR) used as the assessment standard for EPD. Triggered by this enforcement, it is considered that EPD acquisition for steel products and secondary products employing steel products will be promoted in Japan. ■

Fig. 10 Concept of LCI Calculation for Steel Products (Lifecycle Average)

$$\text{Average value (t-}CO_2\text{/t)} = \frac{CO_2 \text{ emissions in steel product lifecycle (t-}CO_2)}{\text{Lifecycle production of steel products (t)}}$$

Fig. 11 Concept of LCI Calculation for Steel Products Based on Recycling

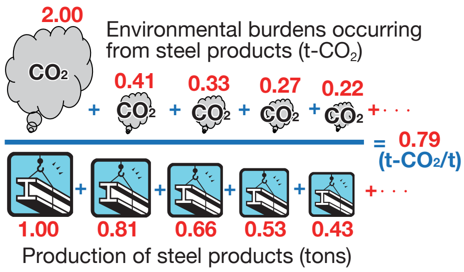


Fig. 12 Number of Lifecycle and Transition of LCI

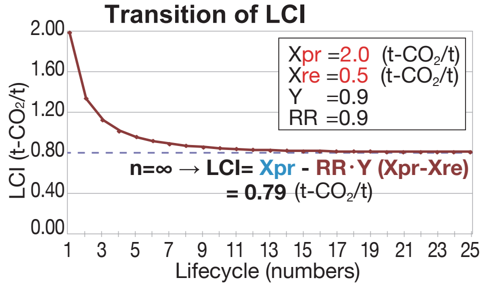
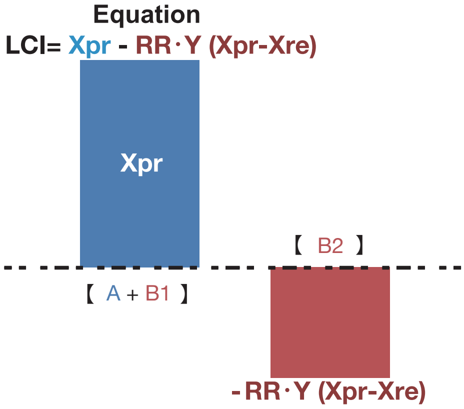
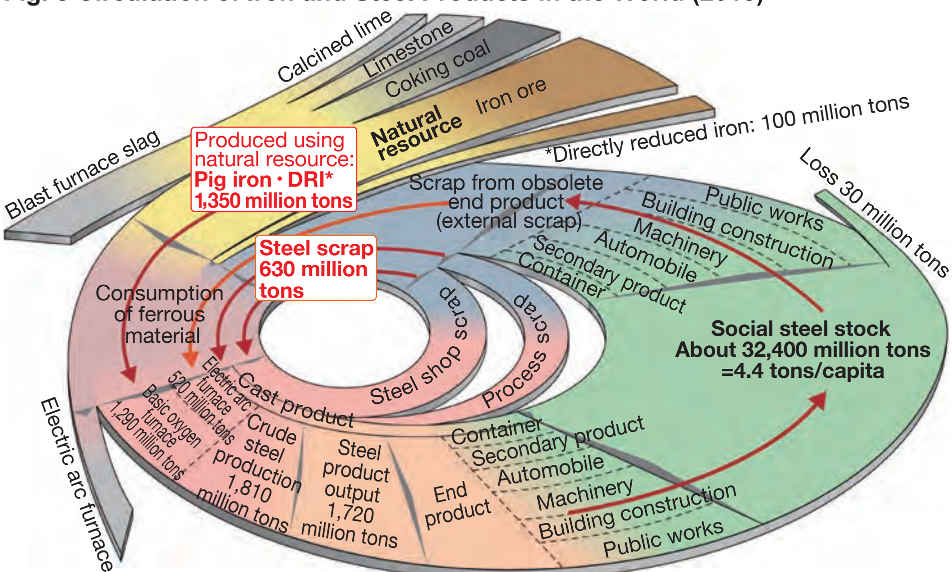


Fig. 13 Relationship of LCIs between Basic Equation and Standards' Equation



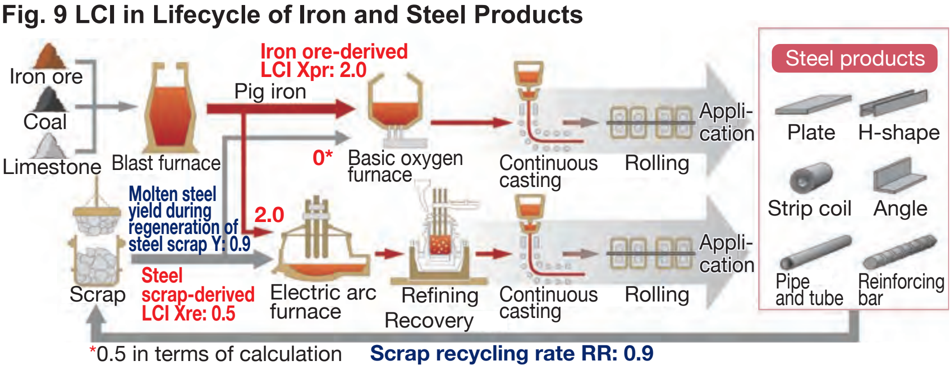
Source of Figs. 9~13:
The Japan Iron and Steel Federation

Fig. 8 Circulation of Iron and Steel Products in the World (2018)



Source: Steel Recycling Research
(World Steel in Figures 2019 and World Steel Recycling in Figures 2014-2018)

Fig. 9 LCI in Lifecycle of Iron and Steel Products



Recycling and the Future of Steel Materials

by Ichiro Daigo and Pasan Dunuwila
Department of Materials Engineering, The University of Tokyo

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.

Pasan Dunuwila: Project Researcher, Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo. He acquired his B.Eng., M.Eng., and Ph.D. (Engineering) from Toyohashi University of Technology, Japan. His research interests primarily lie on the upliftment of economic, environmental and societal well-being of industries through the tools such as Material Flow Analysis, Material Flow Cost Accounting, and Environmental and Social Life Cycle Assessment. His works have been published in several reputed journals.

Introduction

The steel industry has produced more than 1.5 billion tons of crude steel per year since 2010; for example, it has produced 1.63 billion tons of crude steel in 2017. Compared to any other industry that produces metal, environmental impacts associated with steel production is large owing to the vast resources it consumes. Though the blast furnace process in steel manufacture is highly efficient, future steel production has been questionable in terms of the long-term goals of Paris Agreement which specifically desire a drastic reduction in global greenhouse gas emissions by the year 2050. Therefore, from a viewpoint of material life cycle thinking, this article attempts to foresee the future of steel materials and their manufacture.

Global Warming Countermeasures Taken by Steel Industry

The lowest stabilization scenario of International Energy Agency (IEA), i.e., RCP 2.6, allows steel industry to emit 112 billion tons of CO_2 within the 40 years starting from 2011 to 2050[1]. In order to comply with this specified limit, it would be desirable to transform less-efficient processes to more-efficient ones via the countermeasures such as renewal of obsolete equipment. In Fig. 1, the amounts of primary energy consumption to produce a unit amount of crude steel by blast furnace (BF)-basic oxygen furnace (BOF) and electric arc furnace (EAF) processes in different countries are compared. Japan has the lowest energy consuming steel industry and this can particularly be attributed to the high energy efficiency in its steel manufacture[2].

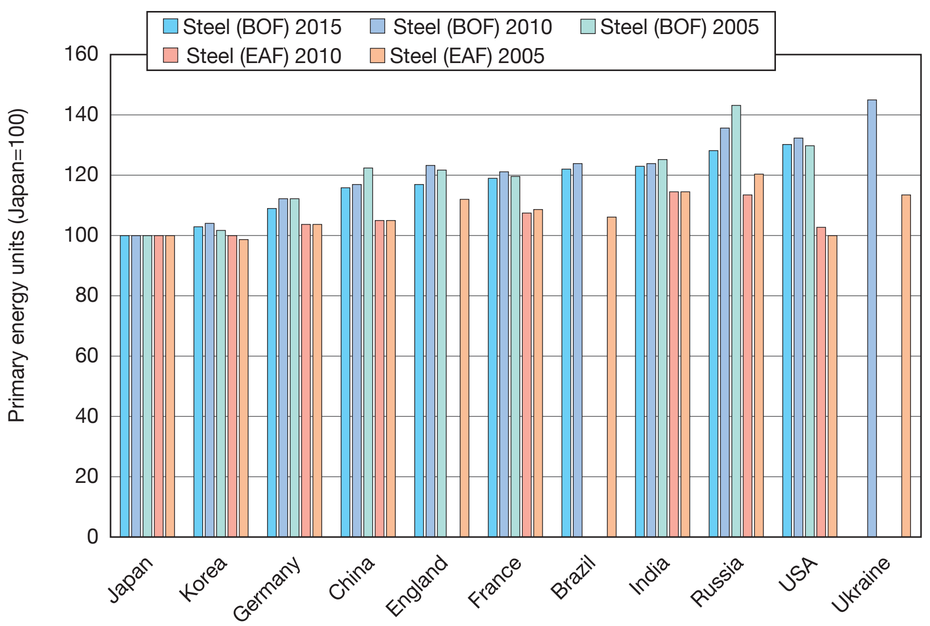
Process technology developments that stem from the national project termed "CO_2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE 50)", and the European Ultra Low CO_2 Steelmaking (ULCOS) program had been prominent in achieving the said status. Therefore, Japan must continue discovering new and innovative steel processing technologies and their dissemination to the world. On the other hand, from a policy standpoint, one must not cause greater emissions elsewhere while trying to optimize a geographically closed-system, and instead, policy makers must consider the regional variations in energy efficiencies.

Steel Stocks and Future Demand

Several estimation models predicting future demand of steel materials have been proposed. One of them is the model termed "Intensity of Use (IU) Hypothesis", in which IU stands for the consumption of certain metal per GDP[3]. As shown in Fig. 2, this IU gets an inverted U-shape as the income per capita increases. Many demand forecasts, including the IU hypothesis, have been extrapolated to the future by analyzing the historical demands (flows) in time series. In recent years, the methods based on material stocks that closely adhere to consumption flows have been proposed and tested.

Lifetime of a product determines how long the steel materials in which

Fig. 1. Comparison of Primary Energy Intensity of Steel by Country (Japan = 100)



belong to in-use stock. Fig. 3 herein depicts the fluctuations in steel stock in Japan[4]. According to that, of the 1.4 billion tons of steel stock, ca. 1 billion tons belong to the in-use stock. Infrastructure-stock or infra-stock (i.e., the amount steel materials exist in semi-permanent infrastructure such as slit dams (see Photo 1), anchor bolts, etc.) constitutes a major part of this in-use stock. The rest can be ascribed to the steel materials that are left behind, such as steel in obsolete (N.B. obsolete stock (see Photo 2) exists in anthroposphere and the steel in which is remains difficult to be collected) and hibernating stocks (N.B. steel in hibernating stock may be collected in the future as a result of price increments, etc.)[5]. This in-use stock in Japan has been saturated since 2000, and similar trends have been reported in other developed countries as well[6].

From a material stock perspective, the curve of the foregoing IU hypothesis can be read as a change of a sigmoidal (S-shaped) curve that saturates toward a certain point on the particular plot. Materials perform their functions when they are used rather than consumed; hence, to better match the relationship between materials and users, it is advisable to explain this phenomenon as a time-series change in the material stock that relies on the amount of material use. Therefore, using the aforementioned empirical rule of saturation tendency, "stock-driven model" has been proposed. To

Fig. 2. Conceptual Diagram of IU Hypothesis

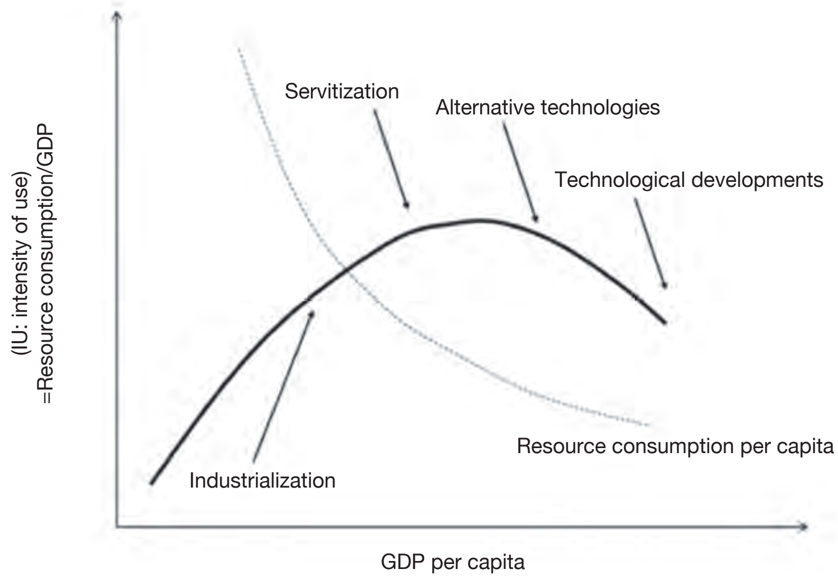


Fig. 3. Trend of Steel Stocks in Japan

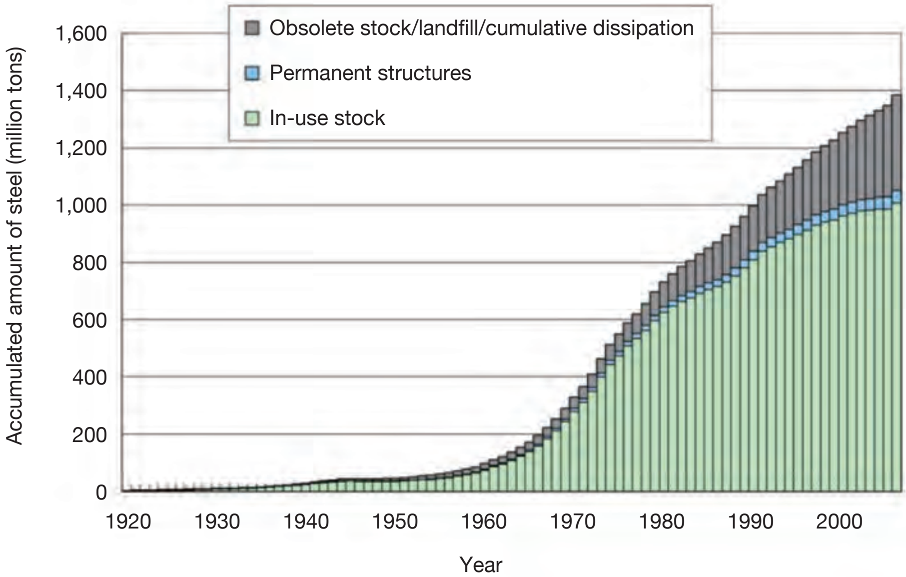



Photo 1 Steel slit dam


Photo 2 Obsolete stock

be more specific, Logistic and Gompertz functions had been deployed to develop the stock-driven models and thereby to forecast the future material stocks[7].

In the models estimating future steel demand, the amount of available scrap is an important factor in quantifying the amount of greenhouse gas emissions. Table 1 summarizes the recent estimates for the steel demands and scarp supplies in both 2050 and 2100. Since these estimates are based on different models and parameters from different sources, values tend to vary. However, Table 1 shows that scrap itself cannot fulfill the future demand of steel even in 2100. The ratio of iron sources reduced from iron ore is estimated to be at least 50% of crude steel production in 2050 and 30% in 2100. Presently there are many countries and regions that would acquire the "developed" status in future; hence steel and scrap would continue to be traded internationally. For instance, surplus of steel scrap in one country would effectively be traded to another country that would have a shortage of iron resources.

Steel Recycling

Steel is recognized as highly recyclable. But then, how many times can steel be used repeatedly? In Fig. 4, we consider that steel materials exist in the states of crude steel, steel products, use, used scrap, etc., and the flows that link the processes in the figure (i.e., Fig. 4) are the transitions between the said states. Therefore, material flow information is referred to as "state transition probability." Assuming that the current pattern of use of steel (material flows) continues forever, a method that evaluates the average number of repeated uses had been developed by applying Markov chain model[8, 9]. Average number of uses here refers to the number of times that steel has been used in domestic products since its initial state (i.e., iron ore), before being exported or dissipated (see Fig. 5). Further, the exported steel can be dissipated or re-exported after being used at the exported destination.

Table 1 Global Crude Steel Demand and Scrap Supply in 2050 and 2100

(unit: billion tons/year)

	2050		2100		References
	Crude steel demand	Scrap supply	Crude steel demand	Scrap supply	
Pauliuk et al. 2013	2.1	1.0	2.6	1.8	11)
Oda et al. 2013*	2.2	0.9	Not applicable		12)
Morfeldt et al. 2015**	2.1-2.3***	0.5-0.6	2.3-2.6	1.6-1.7	13)

* Reference case;
** Results of scenario demand stagnation in 2050;
*** The results of the three scenarios were denoted as a range

Fig. 4. Conceptual Diagram for State Transitions of Steel-material Flows

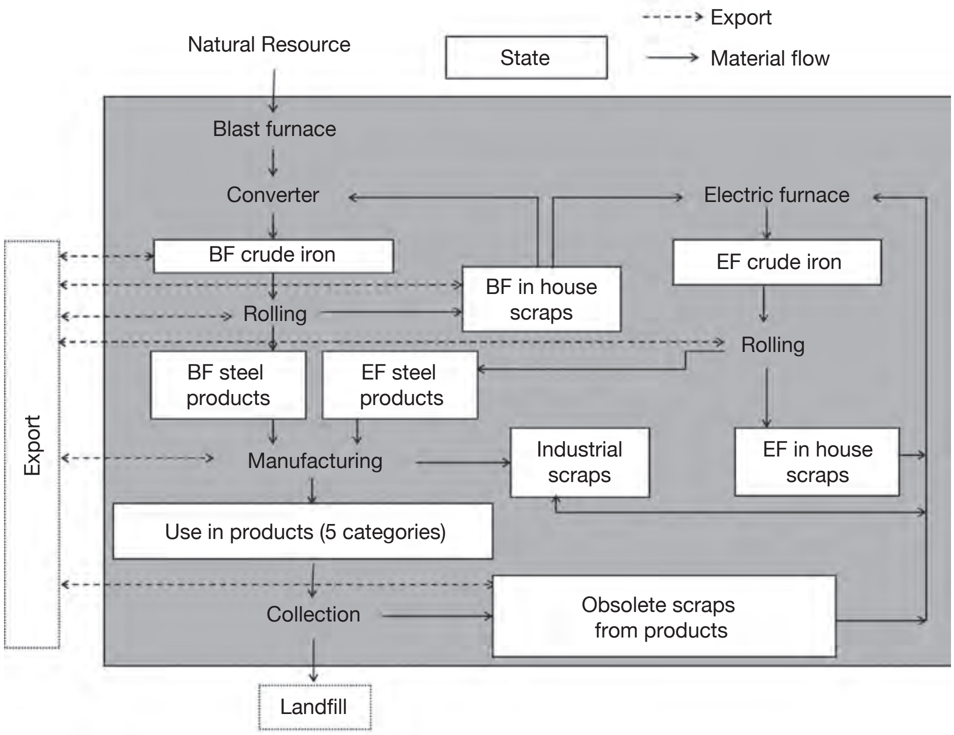
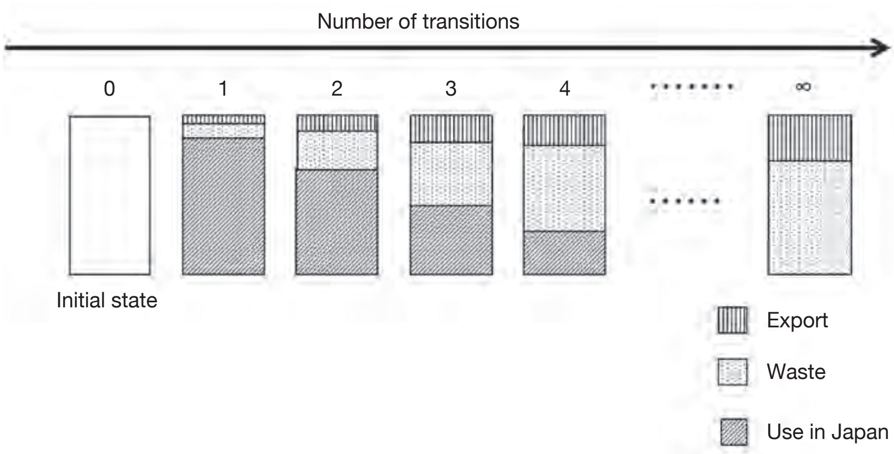


Fig. 5. Conceptual Diagram for State Transitions

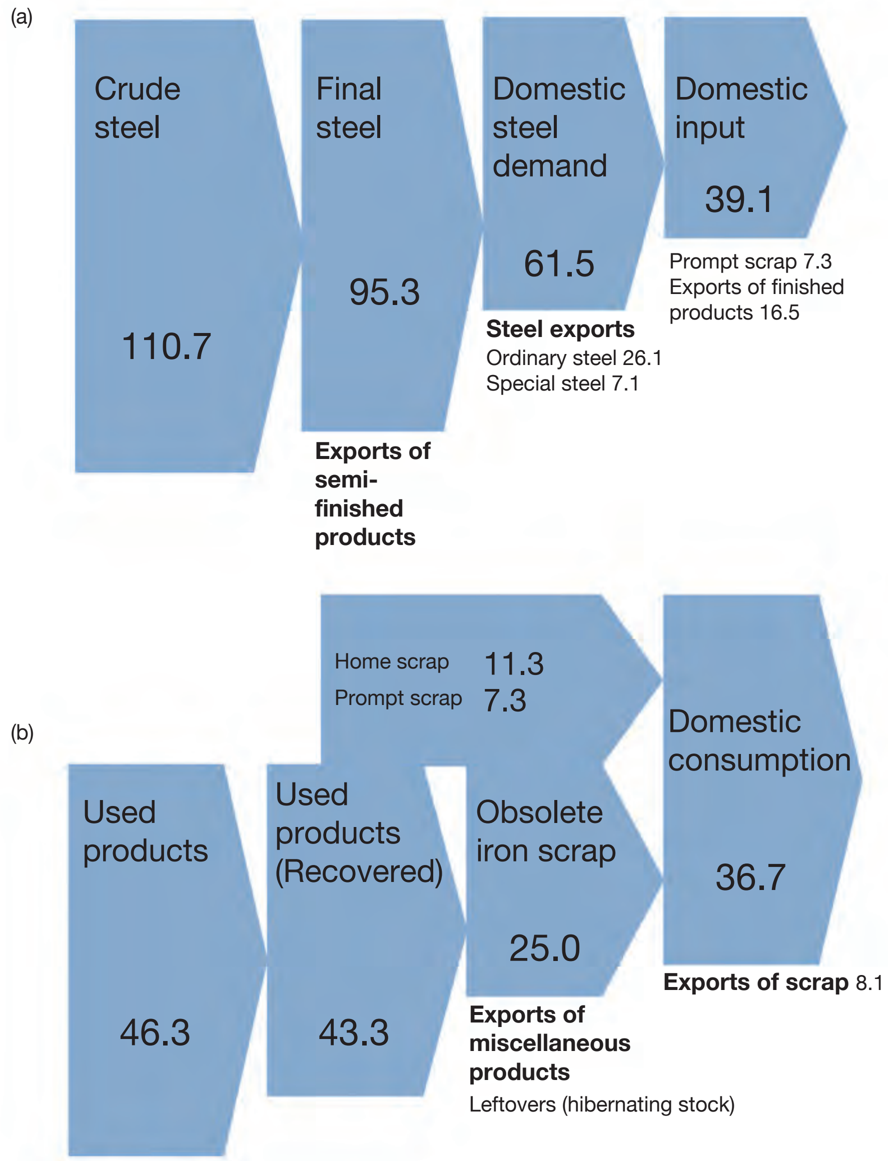


In Japan, as shown in Fig. 6, greater amounts of steel materials and scrap are exported at the time of state transition, so if simply calculated from the material flows, more than 80% of the steel in absorbed state is found to be exported. Here, assuming that the production and consumption patterns of steel materials outside Japan were similar to those within Japan, and based on the flows of steel in Japan in 2005, it could be estimated that steel had repeatedly been used ca. five times in Japan. By applying this model and estimating the global survival rate over time, it was estimated that about half of the newly produced steel materials would still be in use even after 300 years[10]. Therefore, steel materials will benefit many generations to come by continuing to be reborn as different products throughout the world.

Concluding Remarks

In order to reduce greenhouse gas emission in the society, reducing those in the steel industry is a must. Steel materials will be in high demand as they lay foundations for infrastructure that contribute to the social well-being in developing countries. Though steel is highly recyclable, demand of which in the future cannot be fulfilled by the scrap recycling alone; hence, iron is required to be reduced even till 2100. Also, further developments in low-carbon steel manufacture are expected. ■

Fig. 6. Flow Chart for (a) Steel and (b) Steel Scrap (2014, Unit: million tons)



References:

1) International Energy Agency: Energy Technology Perspectives 2014 – Harnessing Electricity's Potential. OECD/IEA, Paris, (2014), 376 pp
2) RITE: Energy intensity in iron and steel sector (January 30, 2018) http://www.rite.or.jp/system/latestanalysis/2018/01/Comparison_EnergyEfficiency2015steel.html
3) International Iron and Steel Institute, Projection 85: World steel demand. International Iron and Steel Institute, Brussels. (1972)
4) I. Daigo, Y. Igarashi, Y. Matsuno, Y. Adachi: ISIJ Int. 47, (2007)1064-1068.
5) I. Daigo, K. Iwata, I. Ohkata, and Y. Goto: Environ. Sci. Technol. 49, (2015) 8691–8696.
6) D.B. Müller, T. Wang, B. Duval: Environ. Sci. Technol. 45, (2011), 182–188.
7) H. Hatayama, I. Daigo, Y. Matsuno, Y. Adachi: Environ. Sci. Technol. 44, (2010) 6457–6463.
8) I. Daigo, Y. Matsuno, K.Ishihara, Y. Adachi: Tetsu to Hagane, 91, (2005) 265-273.
9) M. J. Eckelman, I. Daigo: Ecol. Econ. 67 (2008) 265-273.
10) S. Pauliuk: Resour. Conserv. Recycl. 129 (2018) 81–92.
11) S. Pauliuk, R. L. Milford, D. B. Müller, and J. M. Allwood: Environ. Sci. Technol., 47, (2013) 3448–3454.
12) J. Oda, K. Akimoto, T. Tomoda: Resour. Conserv. Recycl. 81 (2013) 81– 91.
13) J. Morfeldt, W. Nijs, S. Silveira: J. Clean. Prod. 103 (2015) 469-482.

Green Steel Seminar Held

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

The Japan Iron and Steel Federation states how to treat environmental issues arising from iron and steel production as one of the major pillars of its operations. Among the committees to promote measures for the handling of environmental issues is the Committee on Environment-friendly Steel for Construction, which promotes research into environmental performance assessments of construction steel products and activities to enhance understanding of the environmental predominance of these products.

In order to promote understanding of the high environmental performance demonstrated by steel products—conducive to preventing global warming, building a circulation-oriented society and harmonizing with nature, the committee has held the "Green Steel Seminar" every year since 2011 in Tokyo for those working in the field of construction. In November 2019, the committee held its ninth seminar in Tokyo and plans to hold it for the first time in Osaka in December with content similar to that in Tokyo.

The ninth seminar was held under the main theme "Recent Measures to Improve Social Infrastructure and Lifecycle Assessment: High Environmental Performance Peculiar to Steel Products." Specifically, four presentations were made centering on the application of environmental product declaration (EPD), the difference between closed-type recycling and open-type recycling and its reflection in lifecycle assessment (LCA), and LCA methodology by making the most of the recyclability of steel (see the table below). ■

A List of Presentation Titles and Presenters at the Ninth Green Steel Seminar in 2019

Title	Presenter
Application of Environmental Product Declaration (EPD) in Iron and Steel Products	Masayuki Kanzaki Director, LCA Center, Sustainable Management Promotion Organization
Deference between Closed-type Recycling and Open-type Recycling and Its Reflection in the Lifecycle Assessment of Iron and Steel Products	Ichiro Daigo Associate Professor, Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo
Lifecycle Assessment Methodology for Iron and Steel Products Making the Most of Their High Recyclability	Hidekazu Matsubara Secretary, Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation
The Iron Cycle Connects People with the Earth: Steel's Environmental Performance and Recent Trends in the Japanese Steel Industry's Initiatives to Mitigate Global Warming	Yuki Yamamoto Chairman, Committee on Environment-friendly Steel for Construction, The Japan Iron and Steel Federation

(Reference: Scenes of the 2018 Green Steel Seminar in Tokyo)

Introduction of ISO 20915 at the Plenary Session of SEAISI Annual Conference

International Environmental Strategic Committee
The Japan Iron and Steel Federation

The South East Asia Iron and Steel Institute (SEAISI) held its Annual Conference in Bangkok, Thailand on June 16~20, 2019, to which the International Environmental Strategic Committee of the Japan Iron and Steel Federation (JISF) dispatched Dr. Shiro Watakabe, Staff General Manager, Climate Change Policy Group, Technology Planning Department of JFE Steel Corporation. At the Plenary Session II of the Annual Conference, he delivered a lecture that introduced ISO 20915, which was standardized by the International Organization for Standardization (ISO) in November 2018.

He also joined the panel discussion held at the Plenary Session II with the main theme of "value creation in steel industry through circular economy mindset." At this Session, participants made presentations pertaining to the notion of a circular economy. Mr. Wikrom Vajragupta, the chairperson, gave his impressions—"The notion of the circular economy differs by both country and organization, and in the situation in which many ASEAN countries show an excess of imports over exports, yet there are many CEOs who think hard about how to comprehend the circular economy, but the presentations from Dr. Shiro Watakabe and other participants show many informative suggestions."

Following the presentations, there were questions and answers, where Dr. Shiro Watakabe stressed that steel products are the most eco-friendly material from the aspect of lifecycle assessment. He wrapped-up the session stating—"It is ISO 20915 that has made it possible to evaluate steel's recycling effects in a visible method, and I will be very pleased if the main points of my presentation today will filter deeply to relevant persons and organizations in ASEAN nations."

As the last event at the Session, a 30-second video was introduced that was prepared by JISF under the concept "Actually, Steel is Light" in order to make well-known the lifecycle assessment of steel products, scenes of which were taken up in major steel journals in Japan to sensation. In the Session, Dr. Nae Hee Han from the World Steel Association and Mr. Yap Chin Seng, Certification Authority for Reinforcing Steels, United Kingdom also appeared as panelists in addition to Dr. Shiro Watakabe.

GINZA KABUKIZA

—Building a High-rise Office Tower on an Open Space of Traditional Kabukiza Theatre Using a Mid-storey Mega Truss—

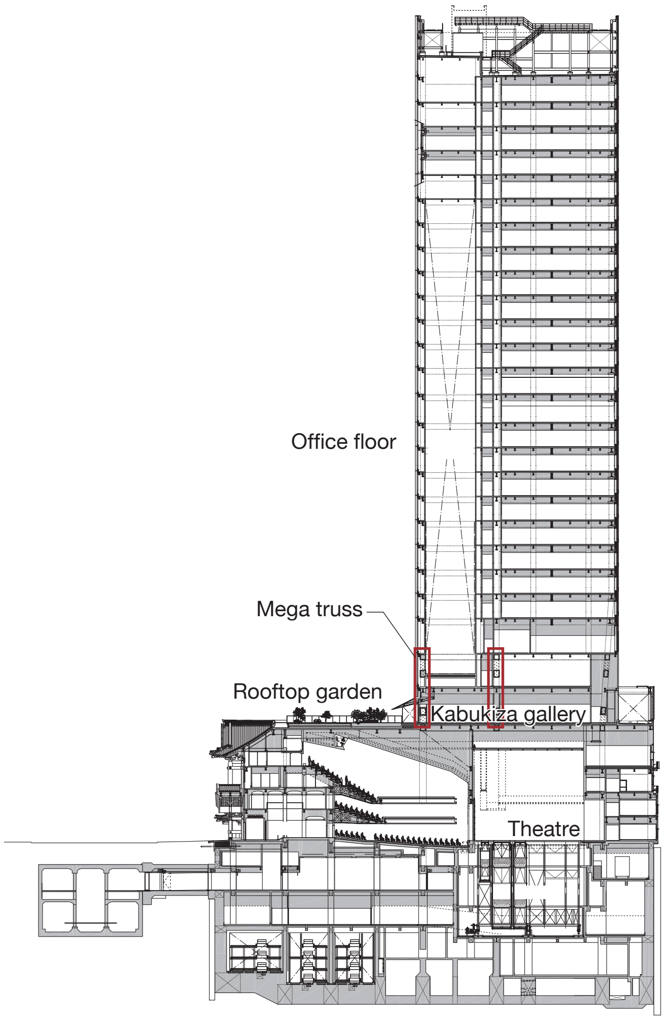
Mitsubishi Jisho Sekkei Inc.
Kengo Kuma and Associates

The Kabukiza Theatre in Ginza, Tokyo, has been reborn as GINZA KABUKIZA, a complex facility composed of the new Kabukiza Theatre and a high-rise office tower, Kabukiza Tower, constructed on top of the Kabukiza Theatre. It has 29 stories aboveground and four basement floors.

We have challenged with the difficult task of recreating a traditional architectural design peculiar to Japanese-style architecture by means of steel structure, which has led to the successful realisation of a lightly-imaged Kabukiza Theatre while at the same time positively incorporating advanced structural technologies. In the switchover section between the theatre and the office tower, the mega truss, a pivotal device in terms of building structure, was arranged not only to produce a column-free wide theatre space but also to support the high-rise office tower constructed on the theatre (Photo 1 and Fig. 1).

Photo 1 GINZA KABUKIZA, a complex facility building where a high-rise office was installed on the Kabukiza Theatre

Fig. 1 Section of GINZA KABUKIZA



Carrying on the Historical Spirit of the Kabukiza Theatre

GINZA KABUKIZA is a reconstruction project for the Kabukiza Theatre, which has a history of more than 100 years. The current reconstruction is its fifth such reconstruction. The former fourth Kabukiza Theatre, completed in 1950, was designed by Isoya Yoshida, a celebrated architect in the field of Japanese-style architecture. Because of some concerns such as growing obsoleteness, insufficient seismic resistance and lack of barrier-free facilities in the former theatre, it became necessary to reconstruct it so as to renew these functions. Further, in order to continue to carry on Kabuki, a Japanese traditional performing art, the Kabukiza Theatre needed to include stable business continuity. To attain these goals, the GINZA KABUKIZA project was promoted as a complex development project in which an office building for lease would be established attached to the Kabukiza Theatre.


Photo 2 Full view of the new Kabukiza Theatre designed by carrying on the former theatre

One major target pursued in the current project was that the history of Kabuki performances loved by everyone needed to be carried into the future, and that new functions that meet the contemporary age needed to be incorporated into the new Kabukiza Theatre. The fourth reconstruction of the Kabukiza Theatre was considered as a compilation of all reconstructions and repairs so far implemented, and therefore the newly-opened fifth theatre has fundamentally carried on the concepts behind the fourth theatre.

However, we think it appropriate that the newly-opened fifth Kabukiza Theatre has not simply carried on the former theatre but has surely succeeded in achieving what everyone hoped from the former fourth theatre. (Refer to Photos 2 and 3, and Fig. 2)

Expression of Wooden Structures Employing Steel Structures

The fourth Kabukiza Theatre was a reinforced-concrete structure, and its exterior section was fundamentally finished with concrete. However, in the current reconstruction project, because the high-rise office tower was to be attached to the theatre, a steel structure was inevitably adopted as the primary material. Accordingly, even if the new theatre was to succeed the former theatre, it was impossible to adopt identical structural materials to those used in the former theatre.

Specifically, in the new theatre, the exterior section was mainly finished by pre-cast concrete (PC) panels fixed to steel framing. Lightweight glass fiber-reinforced concrete was used as the bracket complex, and aluminum members were used for the rafters because the theatre roof had warp and thus the dimension of the structural members applied differed. In this way, suitable members were selected for the right applications.

There arose some fears that the adoption of steel structure would cause the change in image of reinforced concrete-structured former theatre. However, if all structural members used for the new theatre were to be produced by means of the concrete forming method, the construction costs would have soared, and it was further considered that the completed new theatre would not be able to present such a lightweight structural image.

In addition, the architectural design of the Kabukiza Theatre expresses the Japanese traditional wooden architecture, and thus the steel frame+PC panel system adopted for the new theatre, rather than the reinforced concrete system for the former theatre, seems the right choice. Because the wooden structure is assembled by combining every structural piece one by one, it is supposed that the engineers engaged in the construction of the third and fourth theatres by the inevitable use of reinforced-concrete structures faced many difficulties. By such a meaning, just because the difference of the structural materials between the new and former theatres was supported by the maximum use of contemporary technologies, we surely believe that the carrying over of the architectural concepts from the former theatres to the new theatre was successfully attained.

Fig. 2 Section of Theatre Seat Section

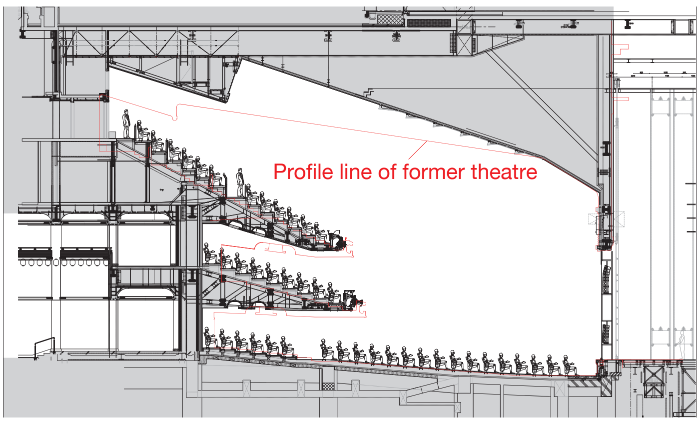



Photo 3 Theatre seats prepared by carrying on the design of the former theatre

Switchover from Lower Theatre Floors to Upper Office Floors

In the reconstruction project for the fifth Kabukiza Theatre, a steel structure was necessarily adopted in order to realise the complex facility composed of the theatre and the office tower. In the theatre section, various devices were incorporated to recreate the wooden architecture using the steel structure. Because the high-rise office tower is right above the theatre, a mega truss system was introduced between the theatre and high-rise tower sections. Specifically, two mega trusses were arranged in the fifth and sixth floors in the switchover section between the theatre and the high-rise office tower to provide the column-free atrium in the four layers of the theatre section and also to support ten columns installed on the south side (theatre front side) of the high-rise tower. (Refer to Photo 4)

Further, in order to smoothly transfer the load from the mega truss to the ground, a wall beam mechanism was provided in the third and fourth basements to support the mega truss, through which the load from the mega truss is dispersed and transferred to the ground.

In the fifth storey of the mega truss floors, Kabukiza gallery and rooftop garden were provided, and in the sixth storey, machine rooms were provided. In this way, the MEP equipment and other facilities used by both the theatre and the high-rise office tower could ingeniously be arranged in the mega truss floors located between the theatre and high-rise tower sections. In the circulation plan for the entire building, an office tower entrance was arranged separately from the theatre entrance, and those working in the office tower change from the elevator for use for the lower floors to the elevator for the high-rise office tower at the seventh floor. The pit for these elevators could be fitted into the mega truss floor.

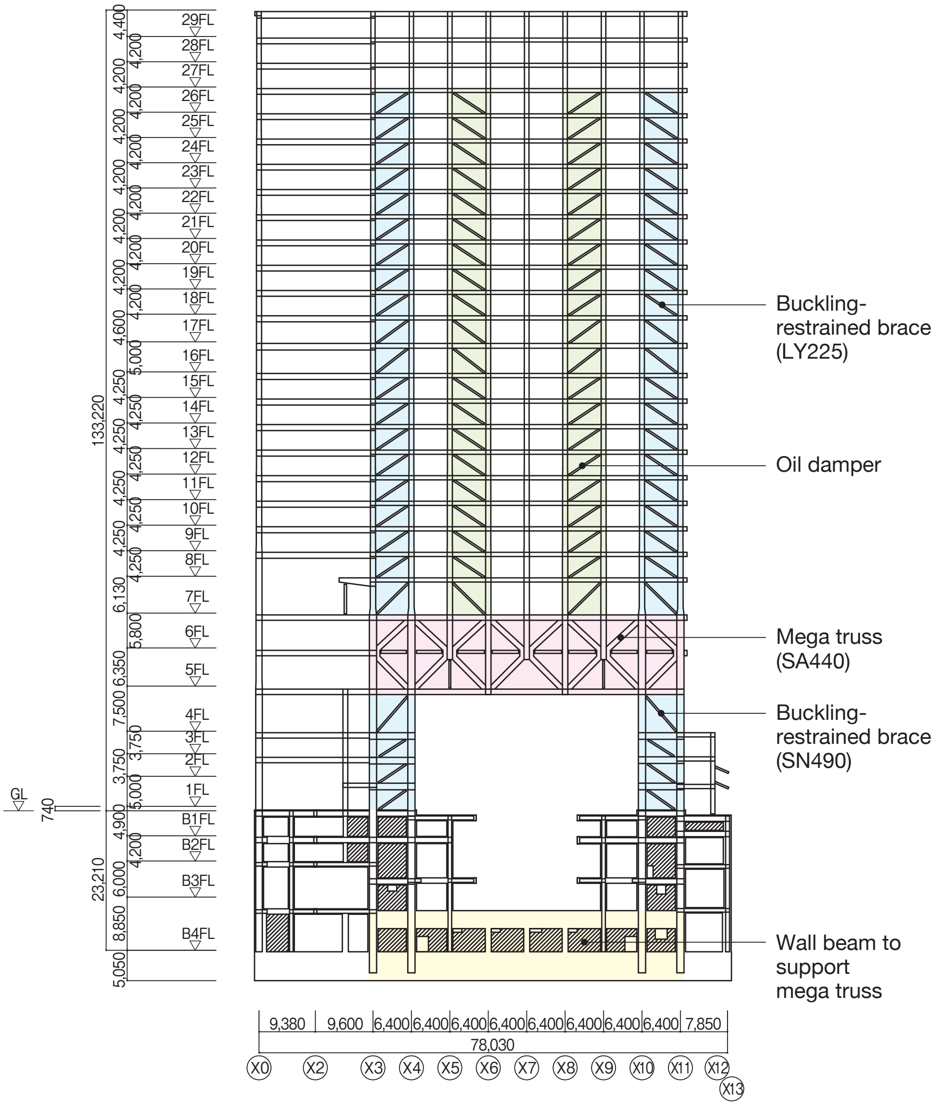
In terms of the architectural design, MEP, structure and other aspects involved in the GINZA KABUKIZA building, we think that the system switchover between the theatre and the high-rise office has successfully been put in effect.

Seismic Design

The significant subject in the structural design stage was the influence on seismic resistance of the column arrangement in which most columns at the south side (theatre front side) are supported using the mega truss in order to treat south-north direction seismic vibrations. While the columns at the north side of the high-rise tower are installed on the ground, those at

Photo 4 Mega truss structure provided as the switchover structure between the theatre and high-rise office tower

Fig. 3 X-direction Framing Elevation



the south side are supported by the mega truss. To that end, repeated examinations on seismic resistance were made employing three-dimensional and other approaches to confirm the seismic safety of the entire building. Particularly for the high-rise office tower, a hybrid response-controlled system was adopted by arranging sets of both buckling-restrained braces and viscous oil dampers. (Refer to Fig. 3)

The buckling-restrained braces were also inserted under the mega truss. As mentioned above, in the current reconstruction project, a structural design was introduced in which the framing structures were clearly divided into those used for the theatre and those for the high-rise office tower. In the low-rise section, because the theatre is located there and many complex frames are applied there, the design was made so that framing deformation is fundamentally suppressed to a minimum level and the framing shows elastic behaviors. That is, the design was made so that the structural section under the mega truss does not cause much plasticization. On the other hand, in the high-rise tower section, the main beam was designed so that some plasticization is allowed to occur during great earthquakes. Well-organized structural designs are adopted for both the theatre and the high-rise office tower.

Mega Trusses to Support High-rise Tower

The mega truss has a span length of 38.4 m and a height of 13 m, and two trusses are arranged at the south side of the high-rise tower (the front side of Kabukiza Theatre). The long-term axial load to be borne by the two mega trusses amounts to 9,000 tons, the highest class of mega trusses applied in high-rise buildings in Japan. High-strength steel (SA-440) is applied for all of upper chords, lower chords and diagonal members having a box section of 900×900 mm. (Refer to Photo 5 and Fig. 4)

Because the mega truss is a large-size member, it is difficult to lift-up the truss assembled on the ground. Accordingly, it was assembled by the use of temporary column while controlling its level by the use of hydraulic jacks (Photo 6). The structural section just beneath the mega truss is the trap cellar of the theatre, and thus it was forecasted in the current reconstruction project that, if the temporary column was installed in the theatre as it is, there would arise some obstacles in the following construction of the theatre. To that end, it was necessary to remove the temporary column quickly after the finish of the installation of the mega truss, which however required special devising in the frame installation above the mega truss.

When the framing above the mega truss is to be installed while supporting the frame load by the use of the mega truss, the mega truss would cause deflection as the load to be borne by it increases, and at the same time the deflection of the frame above the truss would increase. That is, the extra load would be added to the mega truss, which would lead to an irrational design of framings to be installed above the truss.

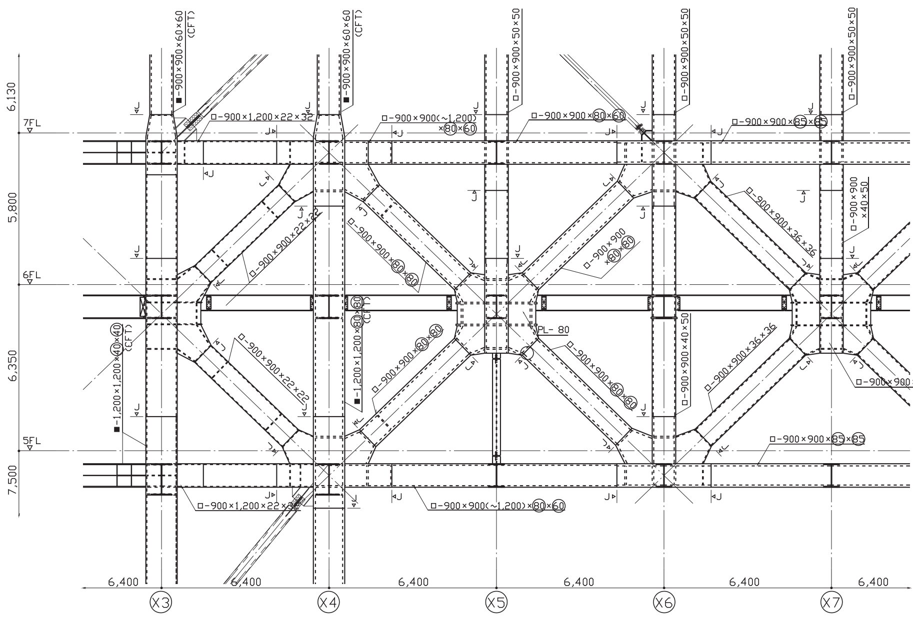
To prevent such adverse effects from occurring, hydraulic jacks was fitted into the column base on the truss upper chord, and framing installation progressed while controlling the vertical displacements of the framings above the mega truss (Photo 7). That is, the following process was adopted: as the assembly of building frames on the mega truss progressed, the mega truss deflected due to the increasing weight of those frames to cause deflection of the frames being installed → the frame deflection was corrected by the use of jacks to maintain the level frame installation → then these processes were repeated to install subsequent frames levelly. The high-rise tower section was constructed while returning the building frames to a level state as if the frame above the mega truss were sitting on the ground.

Photo 5 Mega truss with a span of 38.4 m and a height of 13 m and manufactured employing high-strength steel SA440

Hurdling of Application Limits for Steel Structures

Since both Kabuki actors and fans have exceptional feelings for the Kabukiza Theatre, how they would evaluate the newly-opened theatre was our primary concern. But it has come to be highly reputed. In many cases, people first feel a sense of incongruity in a newly built the-

Fig. 4 Details of Mega Truss Steel Framing



○: SA440C high-strength steel
Unmarked: SN490B rolled steel for building structure

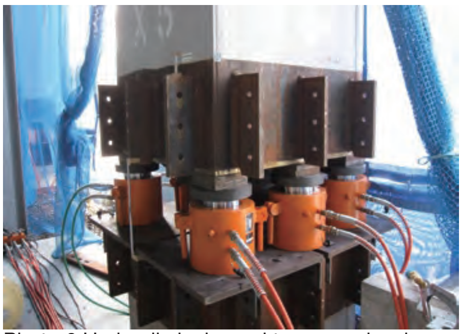


Photo 6 Hydraulic jack used to secure level assembly of frames

Photo 7 Measurement of displacement of frames during installation

atre, but gradually become accustomed to it. The new Kabukiza Theatre, however, has won such a high reputation ever since its completion. We think it uncommon that the new theatre has received such a high public estimation just from the stage of opening of the theatre.

Kabuki actors, fans and other related persons individually have their own image of the Kabukiza Theatre deep in their heart. We now feel happy that we succeeded in reconstructing the theatre to such an extent that it satisfies all of them. The Kabuki audience, meanwhile, consists of a great many regular patrons having an intimate knowledge of the former fourth Kabukiza Theatre. The current fifth theatre resembles its predecessor so closely that merely shifting the position of the theatre's souvenir shops to the reverse side is throwing some of the patrons into confusion.

Moreover, not a few people are unsure that the current theatre was reconstructed, still believing that the fourth theatre was left intact, with only a high-rise tower added behind. To that end, there are even cases where we have been asked if it is true that we entirely tore down the old theatre building for reconstruction. We had a hard time, yet the reconstruction project was exceptionally gratifying. We believe that we have done a good job, by taking advantage of the quality of the joint design team of Mitsubishi Jisho Sekkei Inc. and Kengo Kuma and Associates.

The column-free space provided in the theatre and the mega truss adopted in the construction of the new Kabukiza Theatre have become available only with the flexible application of steel structures. At the initial stage of design, we had some fears about the occurrence of vibrations and noises caused by the use of steel structures, but these concerns were fully solved capitalizing on contemporary architectural technologies. The successful completion of the current reconstruction project is owed greatly to the maximum use of high performance that steel can offer and the all-out effort to hurdle the application limits for steel structures. We accept that the current project can be positioned, in a sense, as a model solution in the application of steel structures. (Refer to Photo 8)

Outline of GINZA KABUKIZA Project

Location: Ginza, Chuo-ku, Tokyo
Project owner: KS Building Capital Specific Purpose Company, Kabukiza Theatre
Development: Shochiku Co., Ltd. (trustee)
Main applications: Office, theatre, shop and parking lot
Area: Site area—6,995.85 m^2
Building area—5,905.62 m^2
Total floor area—93,530.40 m^2
Material: Aboveground—Structural steel
Underground—Structural steel and reinforced concrete
Foundation—Reinforced concrete
No. of stories: Four basements, 29 storeys aboveground, two-storey penthouse
Maximum height: 145,500 mm
Design: Mitsubishi Jisho Sekkei Inc., Kengo Kuma and Associates
Structural design: Mitsubishi Jisho Sekkei Inc.
Construction: Shimizu Corporation
Design term: January 2008 to September 2010
Construction term: October 2010 to February 2013

Photo courtesy

Mitsubishi Jisho Sekkei Inc.
Kengo Kuma and Associates
Taisuke Ogawa/Taisuke Ogawa Shashin Jimusho
Mitsumasa Fujitsuka/Helico
Shochiku Co., Ltd.
Kabukiza Theatre

Photo 8 Traditional tile roof of Kabukiza Theatre and vertically-narrow spaced lattice exterior of Kabukiza Building of GINZA KABUKIZA completed by optimized use of steel structure

STEEL CONSTRUCTION TODAY & TOMORROW

Published jointly by

The Japan Iron and Steel Federation
3-2-10, Nihonbashi Kayabacho, Chuo-ku, Tokyo 103-0025, Japan
Phone: 81-3-3669-4815 Fax: 81-3-3667-0245
URL http://www.jisf.or.jp/en/index.html

Japanese Society of Steel Construction
3F Aminosan Kaikan Building, 3-15-8 Nihonbashi, Chuo-ku, Tokyo 103-0027, Japan
Phone: 81-3-3516-2151 Fax: 81-3-3516-2152
URL http://www.jssc.or.jp/english/index.html

Edited by
Committee on Overseas Market Promotion, The Japan Iron and Steel Federation
Chairman (Editor): Kazuhito Tsujimoto

Published three times per year, **STEEL CONSTRUCTION TODAY & TOMORROW** is circulated to interested persons, companies and public organizations to promote a better understanding of steel products and their application in the construction industry. Any part of this publication may be reproduced with our permission. To download content (PDF format), please go our website at: http://www.jisf.or.jp/en/activitity/sctt/index.html. We welcome your comments about the publication and ask that you contact us at: sunpou@jisf.or.jp.