Technical Review

Prospects of Steel Structures Adapting to Environmental Change in the Construction Industry

Hisashi HIRATA* Shinichi SAWAIZUMI

Abstract

The increase in environmental changes such as intensified and frequent damage due to natural disasters, carbon neutrality, decline in the labor force population and digitization has led to major changes in the Japanese construction industry. Accordingly, Nippon Steel Corporation has given the highest priority to reinforcing national resilience, construction productivity improvement, carbon neutrality and digital transformation for infrastructure. This report presents the features of steel materials and steel structures that can address these important issues, and the outline and prospects of our approach through the combination of steel materials and solution technologies. Furthermore, the expansion of a series of our solutions is presented.

1. Introduction

In recent years, the environments surrounding us have rapidly changed with the diversification of industrial structures, with changes in people's behavior patterns and sense of values, with responses to global-scale climate changes and carbon neutrality initiatives under the influence of global warming, and with the progress of digitalization. These changes have greatly impacted the environments surrounding the construction industry and have increased the urgency of achieving measures to solve the above issues.

Japan has experienced many natural disasters in the past due to its geographical, topographical, and meteorological characteristics. In recent years, wind and flood damages have become more severe and frequent. As concerns have been lately raised about the possibility of a Nankai Trough Earthquake or a Tokyo Epicentral Earthquake, among others, natural disaster mitigation measures have become more important. Measures are also required to counter the obsolescence of the huge infrastructure stock built during the high economic growth period. On the other hand, the workers to support these initiatives are decreasing in number and increasing in age, and the need to improve the productivity of construction is growing even more. We must also introduce materials and technologies to reduce CO_2 emissions toward the realization of carbon neutrality and must digitize the construction processes with the aid of building information modeling (BIM) and construction information modeling (CIM) among other tools. These issues are becoming more diverse and complex than ever before.

With these backgrounds and issues in mind, we have established the "preparedness for national resilience," "promotion of construction productivity improvement," "contribution to carbon neutrality", and "response to digitalization" as the priority issues Nippon Steel Corporation must tackle. In this paper, we present the features and possibilities of steel as material and of structures constructed of steel and provide the overview and direction of initiatives to solve priority issues by proposing solutions with "steel materials and solution technologies" packages.

2. Issues Surrounding Construction Industry

2.1 Preparedness for national resilience

It has become important to prepare for natural disasters that are becoming more severe and frequent. Various measures have been implemented since the promulgation of the Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry in 2013. These measures include maintaining and strengthening rivers, embankments, dams, retarding basins, etc., for flood control, ensuring the continuity of physical distribution systems for rapid recovery from disasters, functionally strengthening transportation networks from the standpoint of the business continuity plan (BCP), promptly maintaining and managing existing infrastructure systems and putting them into service, and acceleratedly extending the lifespan of old infrastructure systems while in service. In the area of buildings, even after the Tokyo Olympics, many urban redevelopment projects

* General Manager, Civil Engineering, Professional Engineer (Civil Engineering), Construction Products Development Div., Plate & Construction Products Unit
2-6-1 Marunouchi, Chiyoda-ku, Tokyo 100-8071

are now under way, and the construction of logistics facilities, data centers, etc., is booming. We are also required to improve the safety of buildings against megalo-earthquakes and long-period earthquakes and to maintain and strengthen the functions of buildings that serve as evacuation centers in the event of disasters.

2.2 Promotion of construction productivity improvement

In the maintenance of various infrastructure facilities, it is required to reduce the construction lead time for rapid recovery from repeated natural disasters. It is also necessary to reduce the construction cost for efficient redeployment within a limited budget. In addition, with fewer children, more elderly people, and less overall population, skilled engineers and young workers are decreasing in number. The resultant labor shortage poses a serious challenge, especially for the construction industry. The Ministry of Land, Infrastructure, Transport and Tourism aims to achieve a 20% improvement in productivity at construction sites by fiscal 2025. Rationalization and labor saving from design through fabrication to on-site construction are important in this respect. To make the construction industry attractive to young people, it is necessary to develop and introduce technologies for automation, robotization, and digitalization.

2.3 Contribution to carbon neutrality

To achieve carbon neutrality with a total zero reduction in human-caused greenhouse gas emissions by 2050, the Japanese government announced a green growth strategy in terms of both industry and energy policies in 2021. Various initiatives are now underway. In the construction field, it is important to use materials, structures, and fabrication and construction methods whereby CO_2 emissions can be reduced throughout the life cycle of infrastructure. At the construction stage of buildings in their life cycle, the popularization and promotion of net Zero Energy Buildings (ZEB) and net Zero Energy House (ZEH) initiatives are essential to achieve a sustainable society with less use of conventional energy and more use of renewable energy. In the future, the contribution of steel to carbon neutrality will be enhanced by proposals to make the most of the features of steel and steel structures. Among such examples are the evaluation of steel as material in the manufacturing stage and the consideration of the operation life cycle stage of structures with a large impact on the CO_2 emissions in addition to the construction life cycle stage.

2.4 Responses to digitalization

BIM is increasingly used as a tool to improve productivity in the design, construction, and maintenance of buildings. BIM three-dimensionally models a building. In the 3D model, all pieces of information (physical properties, performance, prices, etc.) of the materials used in the building are tied to each other. The parties involved in the construction of the building share these pieces of information to speed up the determination of specifications, to save labor in on-site construction, and to maintain and manage the building. In the civil engineering field, the i-Construction initiative is promoted as part of the measures to improve productivity. The civil engineering field is working together to share the information, optimize the information, and speed up decision making throughout the entire process of design, order, material procurement, fabrication, and assembling by using information and communication technology (ICT) and three-dimensional data. Information sharing, optimization, and early decision-making are being promoted throughout the entire process, including maintenance and management. These initiatives are faced with such problems as compatibility of BIM and CIM data with existing tools used in the design, production, fabrication, and construction stages, but are spreading widely. These issues have been partially resolved. The use areas of the i-Construction technology are expected to expand rapidly in the future. To that end, it will be necessary to apply BIM early and efficiently to the above-mentioned important issues by adapting steel information, design information, design tools, and construction information.

3. Features and Possibilities of Steel and Steel Structures

3.1 Features and possibilities of steel

Steel is a material that has contributed to industrial development in the world. Iron, which is the source of steel, accounts for one-third of the mass of the earth. Its recoverable reserves are overwhelmingly larger than those of other metal resources. Given its availability, the demand for steel is expected to increase by 1.5 to 2 times the current level with global economic growth and regional development. Steel is thus an indispensable material for meeting the increasing growth and development. There is considerable room for us to contribute to the growth and development of the world by constructing various steel structures while making use of the characteristics of steel.

As shown in **Fig. 1**,[1,2] steel has a wider range of strength than other materials and can be expected to ideally have a strength of 10000 N/mm^2 or more. In addition, steel, which is an alloy of iron and carbon, has great potential to offer various other properties, such as weldability, deformation performance, and corrosion resistance, by combining carbon and other elements with manufacturing processes. There is thus a great possibility of utilizing the characteristics of steel to the maximum by proper application technologies.

Steel is produced at mills under strict quality control. It is thus highly dependable in terms of quality and dimensional accuracy and is suitable for working and prefabrication. Steel information at the time of mill production allows effective material traceability in the construction, maintenance, and management stages.

As shown in **Fig. 2**,[3] steel has a recycling system already established and operated. It can be repeatedly regenerated and reused without degrading its properties. Its manufacturing CO_2 emissions are less than those of aluminum, CFRP, and other materials. Steel essentially has high environmental performance in this sense.

3.2 Features and possibilities of steel structures

Steel structures have high structural performance supported by the excellent strength and deformation performance of steel. Prefabrication of structural members helps to save labor and stabilize quality in on-site construction. The possibilities of steel structures in solving various problems in the construction field are presented below.

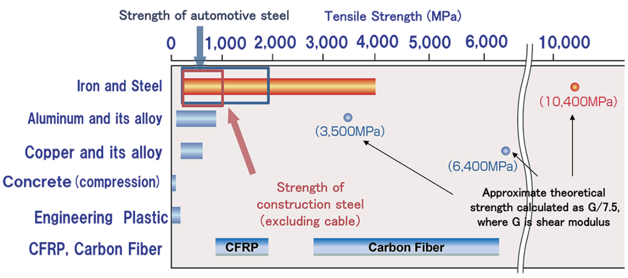

Fig. 1 Comparison of tensile strength of various industrial materials[1,2]

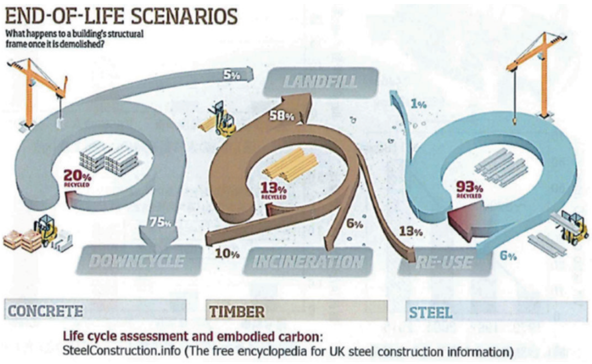

Fig. 2 End-of-life scenarios of concrete, timber, steel[3)]

3.2.1 Preparedness for national resilience

A steel structure is a structural form that makes it easy to fabricate and use members of various cross-sections by taking advantage of the strength and size diversity, workability, and weldability of steel. Optimum member cross sections can be selected to suit the desired performance and constructability of structures. Among such examples are thin and lightweight members that take advantage of high strength steel, and thick and large cross-section members that support large loads. Structural steel members also have performance properties derived from the material properties of steel such as deformability and toughness. The stable performance and quality of steel structures can be secured by combining the high accuracy and quality of members produced at fabrication shops and the welding and other fabrication technologies of the shops with on-site construction technologies.

Construction methods that make use of these features of steel structures can be applied to build structures that are resistant to major floods and earthquakes and to build disaster control infrastructure that suffers less damage and lasts longer. The use of on-site construction technologies that make use of steel structures can contribute to efficient maintenance by using construction methods for steel structures under difficult and constrained conditions adjacent to existing structures. In buildings, steel structure technologies, including steel as well as fabrication and construction, can be used to ensure the performance of extra-thick, high-strength, and large-section columns that bear large axial forces in the lower layers of superhigh-rise buildings and to assure the performance of beam end welds that plastically deform repeatedly during earthquakes.

In the future, we will refine performance evaluation technology and advance design technology, will develop and apply construction methods and structures that make full use of the strength, toughness and other properties of steel in combination with welding and construction technologies, and will consequently contribute to the strengthening of national resilience.

3.2.2 Promotion of construction productivity improvement

Steel structures are highly productive structures. Their members are fabricated at shops and are assembled on-site with less labor and more stable quality. The productivity of steel structures can be further improved by decreasing the amount of steel used and the number of members used, reducing the number of member joints to be connected, and improving the efficiency of member fabrication. The use of high-strength steel for columns reduces the amount of steel used, the thickness of plates used, and consequently the amount of welding performed. The web thickness reduction of H-shaped beams helps to reduce the amount of steel used while maintaining bending performance. Elimination of auxiliary members such as buckling stiffeners helps to reduce the number of members used and to eliminate the machining of member joints to which auxiliary members are to be attached. Large-section members unavailable in existing sizes have been traditionally assembled by welding. Their replacement by rolled or press-formed members is effective in reducing the number of members to be fabricated. Among such examples are hot-rolled H-shaped beams and cold-formed columns. Simplification of member joint details is effective in reducing the labor of machining the ends of members and of joining members and in improving the efficiency of welding tasks common to the fabrication and joining of all members.

A key to on-site construction is the saving of labor in joining (welding or bolting) members. The efficiency of welding joints may be enhanced by automatic welding with robots and by improving welding materials. The size of bolted joints may be reduced by using higher-strength bolts or bolting joints with higher friction. The labor of on-site construction can be saved by reducing the size of steel structures by taking advantage of the strength and other properties of steel and by using prefabricated members. There is still room and possibility for improving construction productivity by using higher-strength materials and advanced joining technologies and by reducing the number of members used.

3.2.3 Contribution to carbon neutrality

Considering the strength of steel, members with the necessary strength can be fabricated from steel in smaller sections and quantities than otherwise possible with other materials. CO_2 emissions in terms of overall steel structures can thus be reduced. We are also promoting the carbon neutrality initiatives during steel manufacture by innovating the steelmaking process and by taking the recyclability of steel into the consideration of CO_2 emissions during steel production. The consumption of material and energy in shop fabrication and on-site construction can be reduced by employing structural specifications created by using the above-mentioned high-strength and high-performance steel and advanced structural design method, by rationalizing welding technologies, by rationalizing on-site work, and by accelerating construction. Accordingly, there is still a lot of room for steel structures to contribute to the reduction of total CO_2 emissions from fabrication through construction to recycling. More improvement may be achieved in this respect.

3.2.4 Responses to digitization

The performance of the members used as columns and beams in steel structures is determined by the performance and cross-sectional shape of steel. The cross-sectional shapes of commonly used hot-rolled H-shaped beams and cold-formed steel pipes are standardized, making it easy to organize them as part of the lineup of member parts in BIM. Steel structures are assembled on the construction site from members prefabricated at the fabrication shop. The prefabricated members can be handled as parts and may facilitate design studies using BIM. The scope of officially approved construction methods may be divided into as structural systems and may be tied to specifications, performance information, and constraint conditions. This procedure may be effective as a means for preventing the erroneous use of construction methods and as a mechanism for design information management during the operation of the construction methods.

4. Proposal and Provision of Solutions by "Steel Materials and Solution Technologies"

Regarding the possibilities of steel structures described in the previous chapter, we have tackled the development of both steel materials and solution technologies (design, fabrication, and construction). Some of the results are already commercialized as "steel materials and solution technologies" packages for building national resilience and improving construction productivity. The details are summarized in the technical papers in this No. 130 issue of the Nippon Steel Technical Report (NSTR). In this paper, we overview the solutions and describe the possibilities of the solutions adapting to carbon neutrality and promoting digitalization.

4.1 "Steel Materials and Solution Technologies" contributing to national resilience and productivity improvement

In this section, we introduce our solutions for the civil engineering and building and housing engineering fields, respectively, to quickly and economically construct buildings and infrastructure structures that are strong and safe against natural disasters.

4.1.1 Civil engineering field

Hat-type steel sheet piles are used in wall structures, such as sea and river revetments, road retaining walls, and temporary earth retaining walls, for the maintenance of various infrastructure facilities. The double wall method using hat-type steel sheet piles is introduced in the technical papers No. 130-05 and No. 130-06. Hat-type steel sheet piles are installed in embankments to form double-walled cores in the embankments. These compact core structures reinforce river embankments and small earth dam embankments as floodplain control measures and tenaciously perform against heavy rain-induced overflows and earthquakes. Combined with a dedicated pressing-in machine, 600 mm wide hat-type steel sheet piles designated SP-J can be installed to construct a temporary earth retaining wall structure with zero clearance from an adjacent structure in a narrow area. Compared with 400 mm wide U-type steel sheet piles available on the temporary construction market, the SP-J hat-type steel sheet piles have a 1.5 times larger effective width and help to shorten the construction period.

Steel pipe piles are used in foundation structures for viaducts like bridges and in wall structures, such as revetments and earth retaining walls. The time and cost of steel pipe construction methods have been reduced by rationalizing construction operations in various construction environments and ground conditions. As actual examples, the Gantetsu pile™ method with high bearing capacity, low noise, and low soil removal, the NS ECO-PILE™ method with high bearing capacity, low noise, low vibration, and no soil removal, and the Gyropress method™ capable of piling in narrow areas and hard soils are introduced in the technical paper No. 130-07. In recent years, we have been putting onto the market the system construction technology that installs steel pipe piles from a temporary platform as required for piling in mountains, harbors, and rivers as shown in **Fig. 3**. This piling method uses steel pipe piles as well as prefabricated steel pipe columns. These members are joined and installed on the site to save on-site labor, shorten the construction period, and ensure work safety.

We have also been applying various fabricated products to tunnel structures. Composite segments with interlocking joints made of special steel shapes are introduced in the technical paper No. 130-11. They are made of steel and concrete and have high strength so that they can be used, for example, where rainwater pipelines are subjected to the high internal water pressure and where tunnels are subjected to the heavy load of aboveground buildings. The composite segment method helps to build smaller diameter tunnels than otherwise possible, to decrease the volume of soil excavated and removed, and to reduce the construction time and cost. This method is used to construct underground rivers and rainwater reservoirs as urban flood control measures and to build shield tunnels in traffic networks. The segment rings are engaged together with interlocking joints to ensure long-term earthquake resistance and durability. The New Austrian Tunneling Method (NATM) is employed to build tunnels through mountains. We provide high-strength and high-performance steel pipes and joint structures for stabilizing the ground in NATM tunnels, as shown in **Fig. 4**. High-strength and corrugated-surfaced steel pipes for increasing bonding strength are supplied as steel pipes to be driven into the crown surface to reinforce the ground at the face of the NATM tunnel. The weight of the steel pipes used can be reduced to improve on-site work efficiency and material transportation efficiency.

The STEEL-C.A.P. method™ is introduced in the technical paper No. 130-10 as technology for rapidly replacing deteriorated decks of road bridges with steel decks. To replace decks in service, it is necessary to save the construction labor and shorten the construction time so that the traffic control time can be minimized. Under this method, steel decks are fastened dry to girders. The construction time can be shortened, the load on the substructure can be reduced with the use of steel decks, and the seismic resistance of the bridge can be improved.

Including these examples and making use of steel and steel structure characteristics, we will continue to develop construction

Fig. 3 Example of structure using steel pipe piles and lateral connection

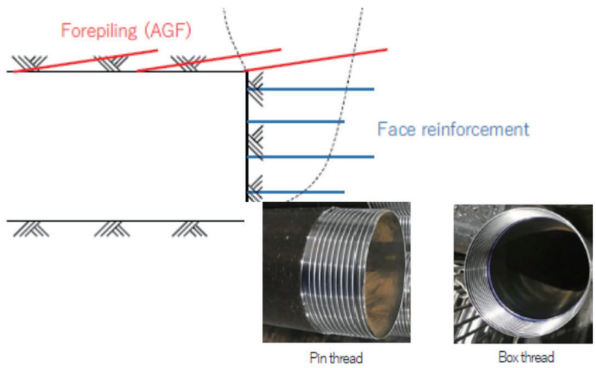

Fig. 4 Schematic drawings of face reinforcement method and thread connection

products, construction methods, and design methods to meet ever increasing performance requirements in the civil engineering field and varying construction environments and ground conditions. There is much room for us to contribute to the maintenance of disaster control infrastructure. The results we have achieved with structure downsizing and on-site labor saving will be combined with the reduction of CO_2 emissions from entire structures and with ICT technology for further improvement in on-site rationalization and productivity.

4.1.2 The building and housing engineering field

Relatively large-scale buildings, such as high-rise buildings, factories, distribution warehouses, and commercial facilities, use large cross-section steel frame members. Large-section H-shaped beams, named MEGA NSHYPER BEAM™, and their design and construction technologies provide solutions to rationalize floor systems including girders and beams by combining hot-rolled H-shaped steel beams up to H-1200 in size with advanced design technology to meet the increasing size and span of high-rise buildings and the increasing floor load of distribution warehouses, data centers, etc. The fabrication of welded H-shaped beams up to H-1200 can be omitted. We have a lineup of methods for eliminating the lateral bracing of girders and for improving the seismic resistance rank of web compactness by combining with buckling design technology. We also have a lineup of highly earthquake-resistant connection construction methods for eliminating the horizontal haunches of beam flanges at beam-column connections in high-rise buildings, etc. Moreover, the welding time can be shortened by reducing the inter-pass temperature and heat input limit when welding beam ends to columns and diaphragms. The large-section hot-rolled H-shaped steel beams described in the technical paper No. 130-13 and their design and construction technologies to maximize their utility value (**Fig. 5**) will increase in importance and sophistication.

Large-section and high-strength steel plates for columns and their welding technologies are described here. The lineup includes high-strength steel plates (490 to 780 N grade) for four-sided built-up box columns as lower layer columns increase in size with the increase in the height and size of urban redevelopment projects. These steel plates accommodate high heat input welding like submerged-arc welding (SAW) of corners and electroslag welding (ESW) of built-in diaphragms during four-sided built-up box column assembly. We have achieved improved fabrication efficiency while ensuring compact column cross-section and high welding performance. The lineup also includes cold press-formed square steel pipes in strengths of 490 to 590 N grade as high axial load bearing columns for upper layer columns and for middle and lower layer columns in high-rise building projects. These steel products help to eliminate the need for fabricating members like built-up box columns. The

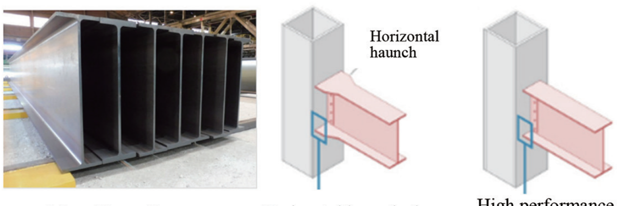

Fig. 5 MEGA NSHYPER BEAM™ and high performance haunchless beam-end connection

performances of cold press-formed corners and through diaphragm welds meet the high performance requirements of high-rise building projects. We are also working to improve the efficiency of diaphragm welds by welding robots, a major step in steel frame fabrication. The use of cold press-formed square steel pipes is expected to continue to expand in the future. Among building steel frame members, columns require the highest degree of fabrication, such as assembling column members and attaching diaphragms to beam joints. The steel materials and solution technologies introduced in the technical paper No. 130-14 are expected to increase in diversity and sophistication. Simplification and labor-saving of the column member fabrication process will contribute to the productivity improvement of building steel frames.

Foundation structures that support the load of the above-mentioned building structures are built by the TN-X method and NS ECO-PILE™ method that combine low noise, low vibration, and low or no soil removal, respectively, with high bearing capacity for construction in urban areas. More recently, we have made it possible to rationally design the foundations in the building field against large earthquakes by taking advantage of the high deformation performance of steel pipe piles. Also, we have developed steel pipe piles strong enough to withstand the horizontal forces of large earthquakes, improved the bearing capacity of piles by filling with concrete, and developed the method of connecting pile heads with prefabricated fittings. These peripheral technologies have made it possible to construct compact foundation structures, shorten the on-site construction time, and improve welding quality.

Lightweight steel sheet members used in low-rise buildings and secondary structures, other than large-scale buildings and steel frame assemblies, are cold formed from 0.35 to 6.0 mm thick steel sheets into arbitrary cross sections and are used in a variety of applications. **Figure 6** shows a steel framed house built by the NS Super-Frame construction method™. We have developed high-performance steel sheet load bearing walls and therefore expanded the application scope of the NS Super-Frame construction method™ to four-story buildings. To make steel framed houses carbon neutral, we are also working to improve their thermal insulation and reduce their net energy consumption to zero. **Figure 7** shows a high-performance steel deck plate for heavy-load floor slabs. It is the first steel deck plate for composite-slab with constant thickness concrete slabs. BIM-compatible floor design support tools are made available for utilization of these high-performance steel deck plates. We have also commercialized a folded steel plate roof construction method (**Fig. 8**) that achieves both wind resistance and constructability. Folded steel plates meet the structural needs of various building parts by making the most of their high forming freedom. Especially when they are used as plane elements such as roofs and walls and their substrates, they have a great impact on their thermal insulation performance. One such example is presented in the technical papers Nos. 130-19, 130-20, and 130-21. Various other applications may also be considered.

As a new approach to steel structures, timber-steel hybrid structures are highlighted in terms of environmental performance and are increasingly used, mainly in public buildings. Fire-resistant timber-steel hybrid columns are shown in **Fig. 9**. A square steel pipe is enclosed with laminated Japanese cedar panels. In the case of a fire, the fire-resistant covering performance of the timber is utilized to ensure one-hour fire resistance performance. The timber-steel hybrid columns also serve as interior materials by utilizing the warmth evoking the appearance of the timber. timber-iron hybrid SMart

Fig. 6 Steel framed house

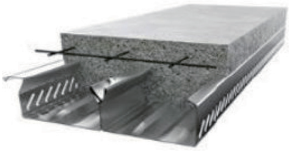

Fig. 7 High-performance steel deck

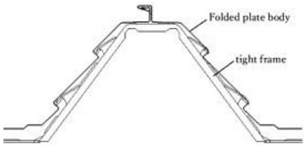

Fig. 8 Fitting-type folding plate

Fig. 9 Application of timber-steel hybrid fire-resistant column

BEAM™ is a hybrid welded light-gauge H-shaped beam whose top flange is integrated with wood for fixing floorboards, for use in large-span timber buildings. The deck plate roof construction method for wooden buildings produces long-span roofs and helps to achieve the elimination of reinforcements like horizontal braces by making use of the excellent in-plane rigidity of the steel plate members. The combined use of steel and timber reported in the technical papers Nos. 130-16, 130-17, and 130-18 is expected to increase from the standpoint of aesthetic appearance and environmental friendliness. As the strength of timber is compensated by the high strength of steel, the timber-steel hybrid columns and SMart BEAM™ floor beams can be used to construct larger wooden buildings with structural rationality.

To meet the diverse challenges and needs of the construction market, it is essential to expand the menu of steel materials. It is also indispensable to augment the advanced design and construction technologies that maximize the performance of steel in various directions according to needs. The steel materials and solution technologies presented in the technical papers Nos. 130-05 to 130-22 are only some examples. We plan to proceed with the development of other new steel materials and solution technologies and sequentially add them to the menu.

4.2 Efforts in carbon neutrality and digital transformation

4.2.1 Contribution to carbon neutrality

The hat-type steel sheet pile/steel pipe pile construction method shortens the construction period and streamlines on-site construction, reducing the number of construction machine operating days and the amount of soil removed. By using high-strength steel plates for building columns, the steel plate thickness can be reduced, and by using MEGA NSHYPER BEAM™ for beams, welding and assembly of large H-shaped steel beams can be omitted. For architectural beams, buckling control technology for H-shaped beams is effective by eliminating stiffeners and thinning the web. These effects not only reduce the cost of steel materials, but also reduce the consumption of energy and secondary materials at construction sites and manufacturing plants, ultimately contributing to a reduction in CO_2 emissions. The thermal insulation measures of the NS Super-Frame construction method™ for low-rise residential buildings can be said to be the initiatives that directly lead to the reduction of energy consumption in the service stage of the building's life cycle during which the building emits the most CO_2 gas. In our future technology development, we think it necessary to take our initiatives by considering not only conventional evaluation indices such as construction cost and time, but also the resultant contributions to carbon neutrality.

4.2.2 Activities for digitalization

BIM and other digital tools can be expected as efficient means for sharing information on the properties of steel and application technology, information on the official approval and use conditions of application technologies, and information on fabrication and construction. We need these pieces of information when we use the steel materials and solution technologies described in the preceding sections.

When we design and calculate a structure, we determine the specifications of its materials, members, and joints while verifying its response to external forces. This design and calculation process as well as optimization determination can be easily automated by computer programs. We have programmed some of the steels and application technologies described in the previous sections and started the initiative for coordination with BIM. We believe that this is an important initiative to reduce the study load of our advanced design technologies and to help our customers to use them for solving many of their problems.

4.3 Nippon Steel's advanced solution ProStruct™ for construction

Nippon Steel has launched ProStruct™ (**Fig. 10**[4)]) as a construction solution brand to meet the various needs of the construction market. ProStruct™ is a series of advanced high-performance and high-use value solutions carefully selected from the above-mentioned combinations of steel materials and solution technologies.

We have developed and marketed large-section shaped steel and high-performance steel materials with excellent strength and toughness. These products and their application technologies that maximize their performance are organized and presented in an easy-to-understand manner as "steel materials and solution technologies" packages under unified names and concepts. In this process, we have considered what contributions our steel materials and solution technologies can make to meet the diversified and complex construction needs of our customers. **Figure 11** shows the four strengths with which ProStruct™ can contribute. In other words, ProStruct™ provides "useful and reliable" solutions for the "rapid and reasonable" construction of "strong and safe" structures against natural disasters and contributes to the realization of an "eco-friendly and sustainable" society through such solutions. At first, we introduced five packages each for the civil engineering and building fields, respectively (**Fig. 12**). Among the packages are a steel pipe pile meth-

ProStruct
Open your future with Structural Steel & Technology
Progress Professional Steel Structure Technology

Fig. 10 Brand name concept[4]

Strong · Safe	Rapid · Reasonable	Useful · Reliable	Eco-friendly · Sustainable

Fig. 11 Brand promise

od for dealing with underground obstacles, an embankment reinforcement method using hat-type steel sheet piles, and a steel beam rationalization method using NSHYPER BEAM™. We will add various packages and maintain ProStruct™ as a toolbox where you can find solutions to solve your construction problems when required. We will also maintain ProStruct™ as a platform for disseminating information on BIM-compliant design tools as well as product and technology information.

5. Conclusions

In this article, we have described four issues: preparedness for national resilience, promotion of construction productivity improvement, contribution to carbon neutrality, which is a new challenge, and promotion of digitalization. We have then deliberated on the possibilities of steel materials and steel structures to meet such issues, our initiatives to put them into practical use, and the directions for our products and technologies to evolve in the future. To meet various issues and needs in the construction field where large environmental changes are taking place, it is essential to combine not only steel materials, but also advanced design, fabrication, and construction technologies. We intend to further augment the solutions that combine the excellent properties of steel materials with the advanced technologies to utilize them.

	ProStruct™ Solutions Combining High Performance Steel with Advanced Structural Technology
Civil engineering structure	Hat-type steel sheet pile × double steel sheet piles for reinforcement of the river dikes
	Hat-type steel sheet pile × Zero clearance method
	Steel pipe pile with helical blades × NS ECO-Pile™
	Steel pipe pile with cutting bits × Gyropress method™
	Steel pipe pile with mechanical joints × Temporary pier structures
	Steel pipe pile with outer ribs × Gantetsu pile™ ※
	Steel pipe pile × TNX™ method ※
Building structure	NSHYPER BEAM™ × Lateral bracing omission construction method
	NSHYPER BEAM™ × Stiffened beam-end web construction method
	NSHYPER BEAM™ × High performance welded beam-end connection for haunchless H-beam flange
	NSHYPER BEAM™ × Efficient welding method with high inter-pass temperature
	HTUFF™ × Large heat input welding method
	NSHYPER BEAM™ × Composite floor slab with unprotected steel beam utilizing membrane action in fire ※
	NSHYPER BEAM™ × Non-diaphragm SRC column to steel beam connection for king post ※
	Cold formed steel HSS column × Hybrid steel column with fire protection using timber ※

※ coming soon

Fig. 12 Packages of steel and construction technology

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Hisashi HIRATA
General Manager, Civil Engineering
Professional Engineer (Civil Engineering)
Construction Products Development Div.
Plate & Construction Products Unit
2-6-1 Marunouchi, Chiyoda-ku, Tokyo 100-8071

Shinichi SAWAIZUMI
General Manager, Building and Housing Engineering
Construction Products Development Div.
Plate & Construction Products Unit