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Feature Article

Marking Rule for Steel Properties

Special Topic

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Yamato Konan Building

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Quality Assurance for Steel Products and Marking of Properties in Japan

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Quality Assurance for Steel Products

In steel-structure construction, when the grade of the steel products applied in the construction differs from that specified in the design documents, the completed structure will present serious problems in terms of structural safety, and there may arise situations in which rebuilding is required depending on the situation.

In general, after the shipment of steel products from steelmakers, these products are delivered to steel-frame fabrication plants via steel product distribution companies and intermediate processing companies. In order to verify the quality of the steel products to be applied to the final products manufactured by steel-frame fabrication plants, it is necessary to prepare unified rules for verifying steel product quality at the stage of distribution.

To cope with such a need, the quality verification method called the "endorsement system" has been firmly established in Japan. The quality of steel products can be confirmed by collating with standardized product certificates (mill sheets). However, when steel products are distributed via complex routes, it is likely that the steel products delivered from the steelmaker and a mere copy of the standardized product certificate may not match each other. In order to prevent such a mismatching from occurring, the "endorsement system" is applied. Specifically in this system, the person who confirms whether or not the delivered product matches with the original standardized product certificate implements quality assurance by using the original certificate-equivalent standardized product certificate with his signature and seal, company name/company seal and the delivery date. This system also makes it possible to trace steel products.

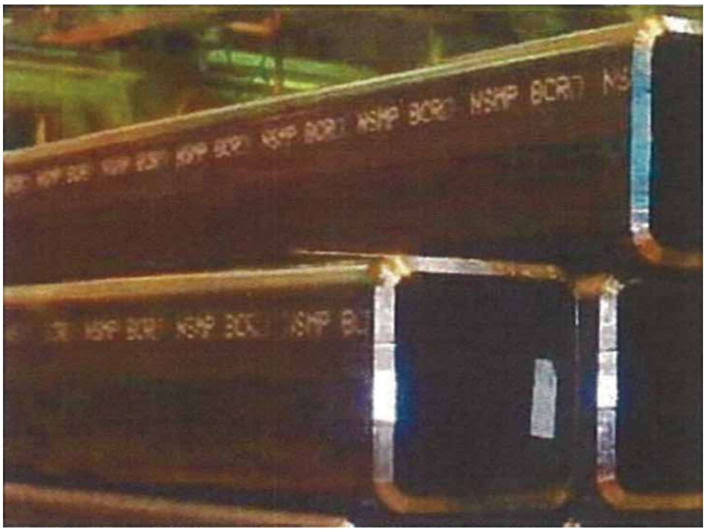
Marking of Steel Product Properties

At the same time, even when the steel products ordered by the steel-frame fabricating plant arrive correctly, misuse is likely to occur when workers at the steel-frame fabrication plant do not correctly understand the grade of the steel products. This makes it impossible to apply the proper fabrication method suitable to each grade of steel products applied in respective fabrication processes. For example, it becomes impossible for the welder to choose the appropriate welding wire and welding method at the welding stage.

At the shipping stage from the steel product maker, the grade of steel products can be understood by collating with the label and stencil pasted on the steel product as shown in Photo 1. However, at the stage of distribution, steel products are subjected to cutting or other secondary processing to manufacture processed products. Further, at the steel-frame manufacturing plant, steel products undergo cutting and fabrication. When steel products undergo cutting and fabrication, it becomes impossible to know the grade of the steel products from the appearance of the fabricated steel members. Accordingly, it becomes necessary to establish a rule required to understand the grade of the steel products delivered from steelmakers by taking a look at these fabricated members.

In Japan, with the aim of marking steel product grades, the Japanese Society of Steel Construction established "JSS (Japanese Society of Steel Con-

(1) Label-attached wide flange beam



(2) Stencil-attached square steel tube

Photo 1 Stage of shipment from steelmakers struction Standard) 4-1971 Marking Rule for Structural Steel Performance with Color Coating" in 1971. JSS 4-1971 was cited in the "Japanese Architectural Standard Specification" published by the Architectural Institute of Japan and the "Specifications for Highway Bridges" published by the Japan Road Association, which led to the wide establishment of JSS 4-1971 as a method for marking the properties of steel products in Japan. Along with the diversification of steel grades and their classes, this standard was revised three times in 1985, 2004 and 2017, and the current version is "JSS I 02-2017 Marking Rule for Steel Properties."

Among the representative marking methods specified in "JSS I 02-2017 Marking Rule for Steel Properties" is a color-coated line indication system. This is the system in which the steel grade marking color is linearly coated on the edge or surface of fabricated members (see Fig. 1). As for the marking colors, two colors are properly used—the strength reference color to be coated in conformity with strength classifications and the supplementary color to be coated to distinguish the grade of the specified product from those of other products. Photo 2 shows its practical application. Incidentally, in the practical marking operation, it is important to mark the steel grade for each piece of a steel product prior to their cutting and fabrication. When marking is performed after cutting, the steel grade may be incorrectly indicated due to a careless mistake.

Unified Rules for Marking Steel Properties

In the economic bubble period starting from the middle of the 1980s, inappropriate design/construction as well as the misuse/mixed use of steel grades at the steel member manufacturing stage came to light, thereby causing social concerns. In order for the required steel products to be correctly applied at all times in steel-structure construction, it is essential that not only steel structure-related industries and companies correctly understand the knowledge and meaning of quality assurance and the marking of steel properties but also that they use these unified rules for the marking of steel properties.

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In the following pages, the full version of JSS I 02-2017 "Marking Rule for Steel Properties" is introduced with the content shown below:

JSS I 02-2017 Marking Rule for Steel Properties

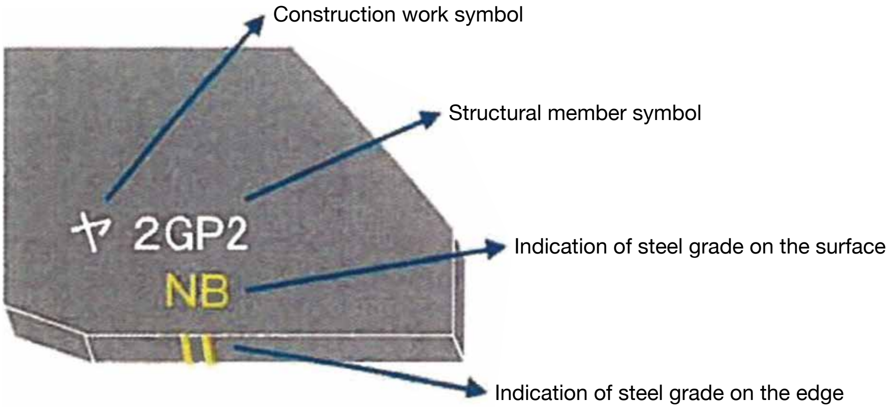
1 Scope
2 Marking Method
 2.1 Steel Grade Indication System
 2.2 Color-coated Line Indication System
 2.3 Colored Character Indication System

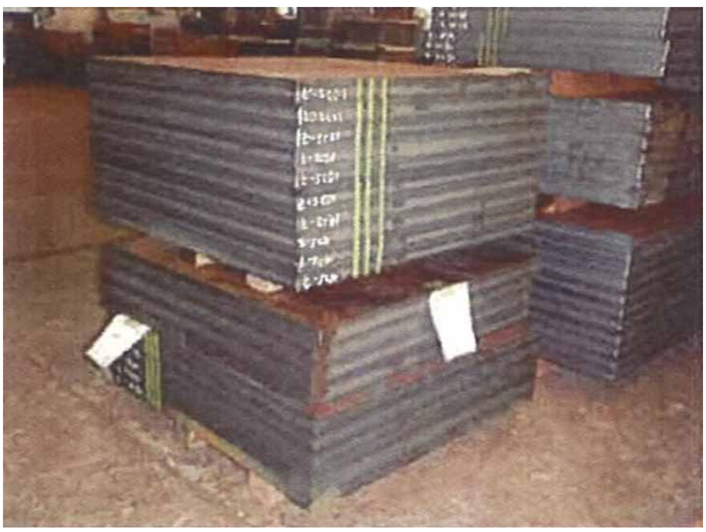
Commentary

1 Scope
2 Marking Method
 2.1 Steel Grade Indication System
 2.2 Color-coated Line Indication System
 2.3 Colored Character Indication System

Appendix

Fig. 1 Color-coated Line Indication System





(1) Steel plate

(2) Through diaphragm and square steel tube

Photo 2 Practical example of color-coated line indication system

Japanese Society of Steel Construction Standard JSS I 02-2017 Marking Rule for Steel Properties

Japanese Society of Steel Construction

1. Scope

In the field of buildings and bridges, steel products shall be applied in which the properties are marked based on JIS standards or their corresponding standards. This standard specifies the method to be used for marking the steel grade (symbol of the grade of steel products) of fabricated members to which shearing and other fabrication methods are provided during the distribution process of these steel products. However, this shall not apply if otherwise agreed between the parties involved in delivery.

The steel grades subject to "Marking Rule for Steel Properties" are as shown in Table 1.

2. Marking Method

The steel grade is usually indicated on steel products such as plates/sheets, shapes and tubes at the stage of shipment from the steel product maker using a label, spraying (stencil) and/or other means. In the case when the indicated steel grade is lost at the stage of distribution of fabricated products to which shearing and other fabrication methods are applied, and the remarking of steel grade is required, marking is provided by the use of any of the steel grade indication system, color-coated line indication system and colored character indication system as shown below.

2.1 Steel Grade Indication System

In this system, characters that indicate the steel grade (symbol of the grade of the steel product) are indicated on the surface or edge of fabricated members by means of hand-writing, stamping, printing, pasting or other corresponding methods. The color of characters is not specified, but a color shall be applied that allows the steel grade to be clearly distinguished.

2.2 Color-coated Line Indication System

In this system, the steel grade marking color is linearly coated on the edge or surface of fabricated members. The marking color is composed of the strength reference color that conforms to the strength classification of the steel products and the supplementary color that is used to distinguish the kind of steel product as required. The strength reference color shall be the color shown by the strength rating of the steel products as shown in Table 2. In addition, the white, blue, silver and black colors shown in the footnotes of Table 2 are used as supplementary colors. Incidentally, the colors are based on the color names specified in JIS Z 8102 (names of non-luminous object colors), and the color specification conforms to JIS Z 8721 (color specification—specification according to three attributes).

Table 1 Steel Grades Subject to JSS I 02-2017 Marking Rule for Steel Properties

Name of standards		Steel grades
JIS G 3101	Rolled steels for general structure	SS400
JIS G 3106	Rolled steels for welded structure	SM400A, B, C SM490A, B, C SM490YA, YB SM520B, C SM570
JIS G 3136	Rolled steels for building structure	SN400A, B, C SN490B, C
JIS G 3114	Hot-rolled atmospheric corrosion resisting steels for welded structure	SMA400AW, BW, CW SMA400AP, BP, CP SMA490AW, BW, CW SMA490AP, BP, CP SMA570W, P
JIS G 3140	Higher yield strength steel plates for bridges	SBHS400 SBHS400W SBHS500 SBHS500W
MDCR 0016	TMCP steels for building structure	TMCP325B, C TMCP355B, C
MDCR 0004	520 N/mm^2 rolled steels for building structure	SM520B-SNB, SNC
MDCR 0017	550 N/mm^2 high-performance steels for building structure	TMCP385B, C
MDCR 0013	590 N/mm^2 high-performance steels for building structure	SA440B, C
JIS G 3444	Carbon steel tubes for general structure	STK400 STK490
JIS G 3475	Carbon steel tubes for building structure	STKN400W, B STKN490B
JIS G 3466	Carbon steel square and rectangular tubes for general structure	STKR400 STKR490
MDCR 0002	Cold roll-formed square steel tubes for building structure	BCR295
MDCR 0003	Cold press-formed square steel tubes for building structure	BCP235 BCP325
MDCR 0012	Cold press-formed high-performance square steel tubes for building structure	BCP325T

MDCR (Market Development Committee Regulation): The Japan Iron and Steel Federation standards

Notes to JSS I 02-2017 Marking Rule for Steel Properties
1) Translated and published by Japanese Society of Steel Construction
2) Translation without guarantee. In the event of any doubt arising, the original standard in Japanese shall take precedence.
3) Send any comment and question about this standard to Japanese Society of Steel Construction (contact details: see back cover).

Table 2 Strength Reference Colors and Color Specifications

Classification of strength rating	Strength reference color (typical color symbol)
400 N/mm² grade	Green (5G5.5/6), white (N9.5)
490 N/mm² grade	Yellow (2.5Y8/12), orange (2.5YR6/13), blue (2.5PB5/6)
520 N/mm² grade	Pink (2.5R6.5/8)
550, 570, 590 N/mm² grade	Purple (7.5P5/12), red (5R4/13)

Supplementary colors:
White (N9.5): Used to mark rolled steels for welded structure
Blue (2.5PB5/6): Used to mark TMCP steel
Silver (N6.5): Used to mark atmospheric corrosion resisting steel
Black (N1.5): Used to mark fire-resistant steel

In the case of marking by means of color-coated line indication with the target placed on steel plates and sheets, marking is indicated linearly on the edge or surface of fabricated members according to the combination of marking colors shown in Table 3. In principle, the indication of the color-coated lines shall be done on the edge, but may be done on the surface.

Table 3 Steel Grade Marking Methods by Means of Color-coated Line Indication and Colored Character Indication (Steel Plates and Sheets)

Steel product			Application		Color-coated line indication		Colored character indication	
Classification	Steel grade		Building	Bridge	Marking color	Indication	Marking color	Indication[*1]
400 N/mm² grade	SS400		○	○	White	1 white line	White	—
	SM400	A	○	○	Green-While	1 green line+1 white line	Green	MA
		B				2 green lines+1 white line		MB
		C				3 green lines+1 white line		MC
	SMA400	AW, AP	○	○	Green-Silver	1 green line+1 silver line	Green	AW, AP
		BW, BP				2 green lines+1 silver line		BW, BP
		CW, CP				3 green lines+1 silver line		CW, CP
	SN400	A	○	—	Green	1 green line	Green	NA
		B				2 green lines		NB
		C				3 green lines		NC
490 N/mm² grade	SM490	A	○	○	Yellow-White	1 yellow line+1 white line	Yellow	MA
		B				2 yellow lines+1 white line		MB
		C				3 yellow lines+1 white line		MC
	SMA490	AW, AP	○	○	Yellow-Silver	1 yellow line+1 silver line	Yellow	AW, AP
		BW, BP				2 yellow lines+1 silver line		BW, BP
		CW, CP				3 yellow lines+1 silver line		CW, CP
	SN490	B	○	—	Yellow	2 yellow lines	Yellow	NB
		C				3 yellow lines		NC
	TMCP325	B	○	—	Yellow-Blue	2 yellow lines+1 blue line	Yellow	TB
		C				3 yellow lines+1 blue line		TC
	SM490Y	A	—	○	Orange	1 orange line	Orange	A
		B				2 orange lines		B
	SBHS400		—	○	Blue	1 blue line	Blue	H[※2]
		W			Blue-Silver	1 blue line+1 silver line		HW[※2]
520 N/mm² grade	SM520	B	○	—	Pink-White	2 pink lines+1 white line	Pink	MB
		C	○	○		3 pink lines+1 white line		MC
		B−SNB	○	—	Pink	2 pink lines		NB
		B−SNC	○	—		3 pink lines		NC
	TMCP355	B	○	—	Pink-Blue	2 pink lines+1 blue line	Pink	TB
		C				3 pink lines+1 blue line		TC
550 N/mm² grade	TMCP385	B	○	—	Purple-Blue	2 purple lines+1 blue line	Purple	TB
		C				3 purple lines+1 blue line		TC
570 N/mm² grade	SM570		—	○	Red	1 red line	Red	Q[※3]
	SMA570	W, P	—	○	Red-Silver	1 red line+1 silver line	Red	W, P
	SBHS500		—	○	Purple	1 purple line	Purple	H[※2]
		W			Purple-Silver	1 purple line+1 silver line		HW[※2]
590 N/mm² grade	SA440	B	○	—	Red	2 red lines	Red	B
		C				3 red lines		C

*1: The character TMC is added in the case of marking TMCP (thermo-mechanical control process) steel for bridge construction.
*2: For higher yield strength steel plates for bridges (SBHS), because TMCP steel is a mainstream grade, H to indicate the steel grade is indicated in the case of marking TMCP steel (HW in the case of marking atmospheric corrosion resisting steel), and Q is added in the case of marking Q (quenched/tempered) steel.
*3: For SM570, the character Q is indicated in the case of marking Q steel, and the character TMC is indicated in the case of marking TMCP steel.

In the case of marking by means of color-coated line indication with the target placed on shapes and tubes, the marking of shapes is provided in conformity with the combination of marking colors shown in the color-coated line indication in Table 3, and that of tubes according to the color-coated line indication in Table 4. For both shapes and tubes, marking shall be indicated linearly on the edge or surface of fabricated members as with plates and sheets.

2.3 Colored Character Indication System

In this system, marking is indicated using the strength reference colors in Table 2 and by means of indicating abbreviated symbols (characters) to indicate the steel grade on the surface or edge of fabricated members. Clearly legible characters shall be applied, and in order to distinguish from other characters, the characters may be enclosed using ○ or □. The practical indication method is shown in the colored character indication in Table 3.

Table 4 Steel Grade Marking Methods by Means of Colored Character Indication (Steel Tubes)

Steel product				Application		Color-coated line indication		
Classification		Steel grade		Building	Bridge	Marking color	Indication	
Circular steel tubes	400 N/mm² grade	STK400		○	○	White	□	1 white line
		STKN400	W	○	–	Green	■	1 green line
			B				■■	2 green lines
	490 N/mm² grade	STK490		○	○	Blue	■	1 blue line
		STKN490	B	○	–	Yellow	■■	2 yellow lines
Square steel tubes	400 N/mm² grade	STKR400		○	○	White	□	1 white line
		BCR295		○	–	Green	■	1 green line
		BCP235	(SN400B)	○	–	Green	■■	2 green lines
			(SN400C)				■■■	3 green lines
	490 N/mm² grade	STKR490		○	○	Blue	■	1 blue line
		BCP325	(SN490B)	○	–	Yellow	■■	2 yellow lines
			(SN490C)				■■■	3 yellow lines
		BCP325T		○	–	Yellow-Blue	■■■	2 yellow lines+ 1 blue line

JSS I 02-2017 Marking Rule for Steel Properties—Commentary

Japanese Society of Steel Construction

1. Scope

Since the revision of JSS I 02-2004 "Marking Rule for Steel Properties" in 2004, JIS G 3140 higher yield strength steel plates for bridges (SBHS) was established. In the field of building construction, new steel products have been developed, which have been established under MDCR (Market Development Committee Regulation) by the Japan Iron and Steel Federation. In the current revision of JSS I 02-2017 "Marking Rule for Steel Properties," the following steel grades were newly added.

- Higher yield strength steel plates for bridges SBHS400 SBHS400W SBHS500 SBHS500W (JIS G3140)
- Steels for building structure SM520B-SNB,SNC TMCP325B,C TMCP355B,C TMCP385B,C
- Cold press-formed high performance square steel tubes for building structure BCP325T

Incidentally, SS490 (rolled steels for general structure), which was conventionally included in the scope, was excluded from the steel grades subject to JSS I 02-2017 because of its rare application in the field of building construction and no specifications as an applicable steel grade in the "Speci-

Commentary-Table 1 Steel Grades Subject to JSS I 02-2017 Marking Rule for Steel Properties (Comparison before and after Revision)

Name of standard	Steel grade		Subject or not subject to JSS I 02-2017
	Former	New	
JIS G 3101 Rolled steels for general structure	SS400 SS490	SS400	SS490: Not subject to JSS I
JIS G 3106 Rolled steels for welded structure	SM400A, B, C SM490A, B, C SM490YA, YB SM520B, C SM570	SM400A, B, C SM490A, B, C SM490YA, YB SM520B, C SM570	
JIS G 3114 Hot-rolled atmospheric corrosion resisting steels for welded structure	SMA400AW, BW, CW SMA400AP, BP, CP SMA490AW, BW, CW SMA490AP, BP, CP SMA570W, P	SMA400AW, BW, CW SMA400AP, BP, CP SMA490AW, BW, CW SMA490AP, BP, CP SMA570W, P	
JIS G 3140 Higher yield strength steel plates for bridges		SBHS400 SBHS400W SBHS500 SBHS500W	Addition SBHS700, 700W: Not subject to JSS I
JIS G 3136 Rolled steels for building structure	SN400A, B, C SN490B, C	SN400A, B, C SN490B, C	
MDCR 0016-2016 TMCP steels for building structure		TMCP325B, C TMCP355B, C	Addition
MDCR 0004-2015 520 N/mm² rolled steels for building structure		SM520B-SNB, SNC	Addition
MDCR 0017-2016 550 N/mm² high-performance steels for building structure		TMCP385B, C	Addition
MDCR 0013-0004 590 N/mm² high-performance steels for building structure	SA440B, C	SA440B, C	
JIS G 3444 Carbon steel tubes for general structure	STK400 STK490	STK400 STK490	
JIS G 3466 Carbon steel square and rectangular tubes for general structure	STKR400 STKR490	STKR400 STKR490	
JIS G 3475 Carbon steel tubes for building structure	STKN400W, B STKN490B	STKN400W, B STKN490B	
MDCR 0002-2017 Cold roll-formed square steel tubes for building structure	BCR295	BCR295	Revision of MDCR in 2017: Increase of size range
MDCR 0003-2017 Cold press-formed square steel tubes for building structure	BCP235 BCP325	BCP235 BCP325	Revision of MDCR in 2017: Increase of size range
MDCR 0012-2017 Cold press-formed high-performance square steel tubes for building structure		BCP325T	Addition

fications for Highway Bridges" in the field of bridge construction. As for SBHS700 and SBHS700W (higher yield strength steel plates for bridges), since both grades show lower records of application, it was decided that the arrangement of marking in their application be commissioned to the parties concerned. As for square steel tubes, while new grades such as UBCR365, BCP385, SHC400 and SHC490 have been developed and put into practical use, common specifications have not yet been established, and thus it was decided that the arrangement of marking in their application be commissioned to the parties concerned.

The steel grades subject to JSS I 02-2017 "Marking Rule for Steel Properties" were increased from 10 grades at its establishment in 1971 and 24 grades at the time of its revision in 2004 to 32 grades in the current revision in 2017. The colors used for color-coated line indication is limited, and thus it has become difficult to settle an indication method common to buildings and bridges.

Meanwhile, the result of surveys of related industry organizations revealed that the most common marking method in the field of buildings is the color-coated line indication system, and that in the field of bridges is the colored character indication system using strength reference colors, and thus the steel property marking method applied in the field of buildings differs considerably from that in the field of bridges. Further it was learned from survey results that rolled steels for building structure (SN grade), higher yield strength steel plates for bridges (SBHS grade) and other steel products specialized for the required performance for buildings and bridges have been standardized under JIS, and that along with the diversification of steel products, the steel grades commonly used in the field of buildings and bridges are limited to rolled steels for welded structure (SM grade). Then, the standardization of independent marking by application was discussed, but it was predicted that there would be some confusion concerning incorrect use and marking of steel products at shearing companies who receive orders for cut sheets and plates from not only the fabricator involved in both buildings and bridges but also the building and bridge construction companies. Based on a comprehensive judgement of this situation and from the viewpoint of preventing confusion, independent standardization by application was not the aim, and it was decided to not aim to mark by application but to maintain the conventional marking system common to both fields.

2. Marking Methods

Three versions of "Marking Rule for Steel Properties" have thus far been published—the Japanese Society of Steel Construction Standard JSS 4-1971 Marking Rule for Structural Steel Performances with Color Coating established in 1971, the revised original draft published in JSSC's bulletin in 1985 and the former version revised in 2004. As to the name of the marking method used in these three versions, various terms such as character indication, color-coated indication, color-coated line indication and colored character indication were used, and the name itself was also changed in these versions. While the changes were implemented in each revision by adapting to the current situation, it was hard to understand the details of revisions, the main text of the JSS and the content of the commentary. To remedy this, it was decided in the 2017 revision that the marking method be classified into three systems—the steel grade indication system, color-coated line indication system and colored character indication system so as to unify the term of marking method.

Meanwhile, for steel products such as plates and sheets, shapes (wide-flange beam, angle, channel, flat) and tubes (circular and square), the steel grade is usually indicated at the stage of shipment from steel product makers by means of labelling and spraying (stenciling). Particularly for rolled steels for building structure (SN grade), there is a case in which marking of steel grade and its class is provided on the surface of steel products. In this process, marking is printed on the surface of steel products at the stage of their shipment from the steel product makers, and because marking remains in the fabricated members after shearing, this marking is accepted as the most reliable and desirable marking system. Further, for steel shapes and other products, there are many cases in which the product label is pasted that indicates the steel grade, cast or inspection number, dimensions and maker's name. However, because a unified indication method for marking the steel grade of these products has not been applied, it was decided that this would not be subject to JSS I 02-2017 as with past JSS versions.

The targets subject to "Marking Rule for Steel Properties" are fabricated members processed from steel products by means of shearing and other processing methods. In the case when the steel grade indication provided by the steel product maker is lost at the stage of distribution of sheared members represented by cut plates and sheets or fabricated members subjected to other fabrication processes, requiring the re-marking of steel grade on these fabricated products, it was decided to mark these members by the use of any of the following three systems—steel grade indication system, color-coated line indication system and colored character indication system.

2.1 Steel Grade Indication System

A system in which the characters to indicate the steel grade (symbols of the grade of steel products) is shown on the surface or edge of the steel products or fabricated members by means of hand-writing, stamping, printing, pasting or other similar methods. All characters to indicate the grade are indicated, not just the abbreviated symbol. While the color used to indicate the characters is not specified, white is mostly applied. At shearing companies and the plants that manufacture various types of intermediate members, hand-writing directly on the fabricated members is frequently applied.

Recently, with the progress of production systems, the dot system and other automated printing devices are being increasingly introduced for use for printing of member symbols and characters, and the wider application of automated printing devices is being desired from the viewpoint of labor-saving and preventing incorrect indication.

2.2 Color-coated Line Indication System

A system in which the color to mark the steel grade is linearly coated on the edge or surface of steel products or fabricated members. This system has been adopted in the Japanese Architectural Standard Specification JASS6 of the Architectural Institute of Japan and has been firmly established within the society. This is the fundamental marking method that can be commonly adopted, not only for plates and sheets but also shapes and tubes.

The common practice is to indicate the grade by means of vertical coating of color lines along the edge. This is a highly efficient system for the marking of cut plates and sheets, because they can be coated at once while piled up. The coating of vertical or horizontal lines on the surface is also available.

With this color-coated line indication system, various kinds of steel grades can be indicated by means of the use of combined colors. The basic concept in color coating is the combined use of strength reference color used to indicate the strength rating and the supplementary color used to distinguish the different steel grades with identical strength as the need arises. Regarding the supplementary color, while silver has conventionally been used only for marking the atmospheric corrosion resisting steel, the frequency of application of supplementary colors has increased since the last revision in which steel grades were increased due to the marketing of rolled steels for building structure (SN grade) and other new products.

In the last revision in 2004, SN grade (rolled steels for building structure) was added, and it was specified that "green + white lines" be used for SN400 grade to distinguish from the "green line" for SM400 grade pertaining to the 400 N/mm^2 grade, and that the "yellow + white lines" be used for SN490 grade to distinguish from the "yellow line" for SM490 grade pertaining to the 490 N/mm^2 grade. In the field of buildings, the frequency of application to SN grade is higher than that of SM grade, and while indication using one color is used for SM400 and 490 grades, two colors to which a supplementary white color is added to the strength reference color is used for SN400 and 490 grades. There were many opinions that the two-color indication would cause more issues, and as a result, the relevant organizations requested that the color-coated line indication system for SM grade should be replaced with that for SN grade. On the other hand, in the field of bridges, SN grade has not been applied, and SM grade is the mainstream grade.

Conventionally, the basic policy was not to change the indication system for existing steel grades. However, in the current revision, based on the present situation in which the SN grade accounts for about 70% of total steel product distribution even if distribution for bridges is included, it was decided that a revision be made to reflect the need in the field of buildings. As a result, the color-coated line indication system for SM grade (rolled steels for welded structure) was changed in the field of bridges, but here colored character indication is the mainstream marking system and the color-coated line indication system shows less application. To that end, it was judged that this change would not have a significant impact.

Incidentally, regarding the "blue color" used for SS490 grade, this was adopted as the marking color for SBHS400 (higher yield strength steel plates for bridges), and in the field of buildings it was also adopted as the supplementary color to indicate TMCP steel.

2.3 Colored Character Indication System

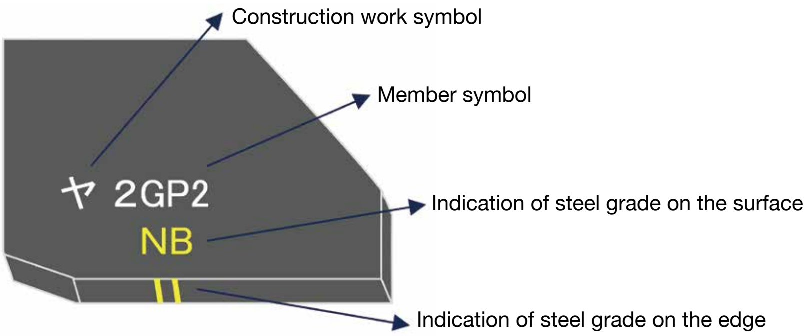
A system in which abbreviated symbols (characters) to indicate the steel grade are indicated on the surface of fabricated members using a strength reference color. Because both member symbol indication and colored character indication happen concurrently, this is a comparatively simple method. In order to make clear that the character indicates the steel grade, the character is frequently enclosed with ○ or □. The colored character indication system shown in Table 3 is the method that indicates the steel grade and detailed grade classification (classes such as A, B, C) as easily as possible. Incidentally, the reason why examples of colored character indication is not shown in Table 4 Steel Grade Marking Methods by Means of Colored Character Indication (Steel Tubes) is that steel tubes are composed of many kinds and thus the standardization of abbreviated symbols (characters) is difficult, and that it was judged desirable to adopt the color-coated line indication system applied to the edge or surface of members or the steel grade indication system with which all characters that indicate the steel grades are indicated.

Recently, there have been cases in which TMCP steel has been applied in place of SM and SMA steels in the field of bridges. In this regard, in the "Specifications for Highway Bridges," the specification of thermo-mechanical processing and linear-reheating straightening for use for non-quenched/tempered steel differs from that for TMCP steel, which has thus required proper marking. Consequently, it was also decided to indicate TMC characters pertaining to TMCP steel under JSS I 02-2017. Two grades, quenched/tempered steel and TMCP steel, are available for SM570 and SMA570, and thus it was decided to indicate a Q in the case of marking quenched/tempered steel and TMC in the case of marking TMCP steel. Also, two steel grades, quenched/tempered steel and TMCP steel, are available for SBHS grade, but because the mainstream grade of SBHS steel is TMCP steel, it was decided to indicate a Q in the case of marking quenched/tempered steel and to require no indication in the case of TMCP steel.

On the other hand, for example, when the detailed grade classification (classes such as A, B, C) of steel products can be judged based on the application standard of the steel grade by plate thickness or the detailed classification of steel grades can be marked by the use of other means, it has become possible to mark the steel grade only by indicating the member and construction work symbols on the surface of fabricated members using strength reference colors. Because this approach can serve both as member symbol indication and steel grade marking, its distinctive feature is high efficiency in marking operations, and thus it can be said that this approach is a kind of color-coated character indication system. Incidentally, when the member symbol can be indicated by the use of white characters printed using an automated printing device, it is impossible to mark by the use of colors, and thus it is necessary to mark using the color-coated line indication system shown in 2.2 above or other means.

JSS I 02-2017 Appendix

Practical Examples of “Marking Rule for Steel Properties”



(In the case of marking SN490B steel plate)

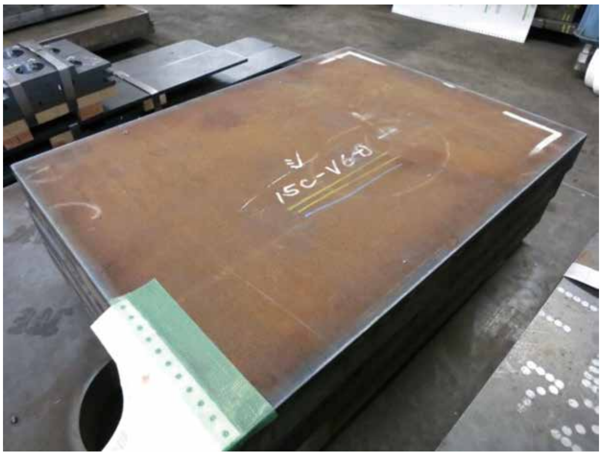
Steel Grade Indication System

SN490B steel plate (hand-written)

TMCP325C steel plate (stamped)

Color-coated Line Indication System

SN490C steel plate (edge)



TMCP325B steel plate (surface)

SN490B wide-flange beam (edge)

BCP325 square steel tube (corner surface)

Colored Character Indication System

SN490C

TMCP355C (enclosed with ◯)

Examples of Steel Products Requiring No Marking

Conditions in which labels and stencils remain in shapes and tubes

Wide-flange beam (attached with label)

Wide-flange beam (with stencil)

Square steel tube (attached with label)

Square steel tube (with stencil)

Achieving Carbon Neutrality in the Japanese Steel Industry

by Toshio Isohara
Chairman, Task Force for Carbon Neutral Steel Advancement, The Japan Iron and Steel Federation

Toshio Isohara: General Manager, Technical Administration & Planning Div., Nippon Steel Corporation. Expert in LCA, product sustainability and low carbonization in steel production. He has various work experience including heads of R&D planning, R&D laboratory and intellectual property. He is also the chair of the Planning Committee for Technological Policy, The Japan Iron and Steel Federation.

Low-carbon Steelmaking with Hydrogen

Steel is produced in extremely large volumes compared to other materials and used as the basic material of various industries. As a result, steel emits at the stage of production as much as 14% of CO_2 (after allocating CO_2 emissions from power generation) of the total emissions in Japan. Thus, reducing its emissions is an urgent issue for the Japanese steel industry.

Steel is generally produced by removing oxygen (reduction) from iron ore using carbon (coal or coke) in the blast furnace-basic oxygen furnace (BF-BOF) process. In the process, CO_2 is emitted as follows.

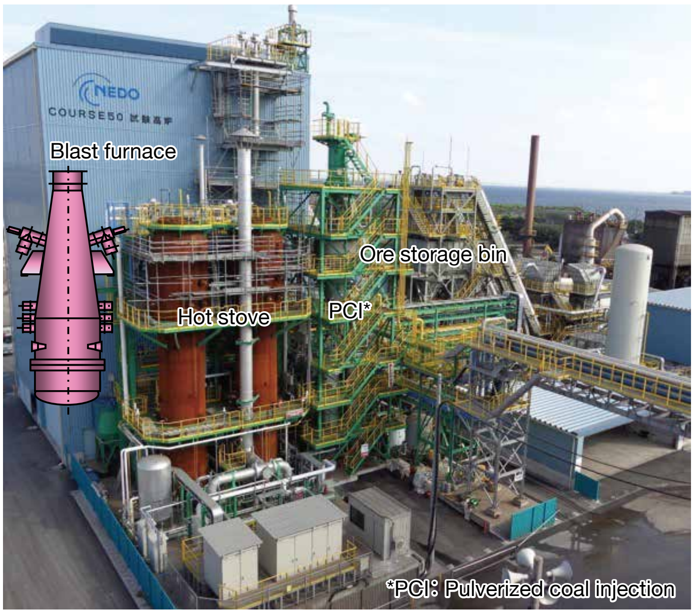
- $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

The carbon intensity in steel production is low compared to those of other materials. However, as mentioned above, the total CO_2 emissions are extremely high because of the huge amount of steel produced. On the other hand, if hydrogen is used in steel production, only water is produced and no CO_2 is generated, as described below.

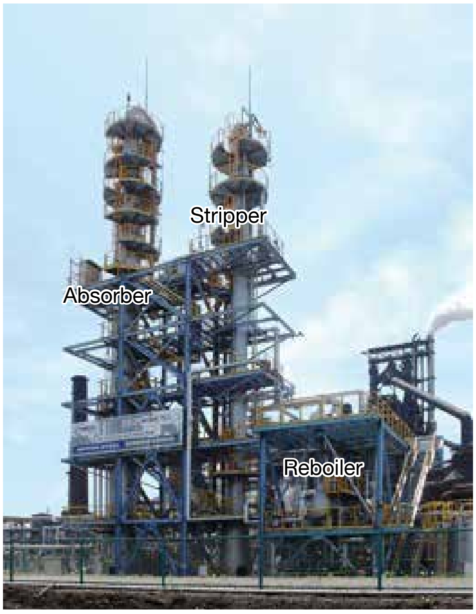
- $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

Japanese blast furnace steel companies have been supported by the New Energy and Industrial Technology Development Organization (NEDO) in the R&D of the COURSE50 (CO_2 Ultimate Reduction System for Cool Earth 50) project. The project is designed to reduce the CO_2 emissions of blast furnaces by 10% with hydrogen, and by 20% with CCUS (CO_2 Capture, Utilization and Storage) resulting in 30% reduction as a total. In 2018, the Experimental Blast Furnace installed at the Kimitsu site of Nippon Steel Corporation demonstrated 10% reduction of CO_2 emissions by means of hydrogen injection. A CO_2 capture facility using a new type of absorbent was also installed near the Experimental Blast Furnace, and a linkage test was conducted (Fig. 1).

Fig. 1 COURSE50 Experimental Blast Furnace (left) and CO_2 Capture Facility (right)

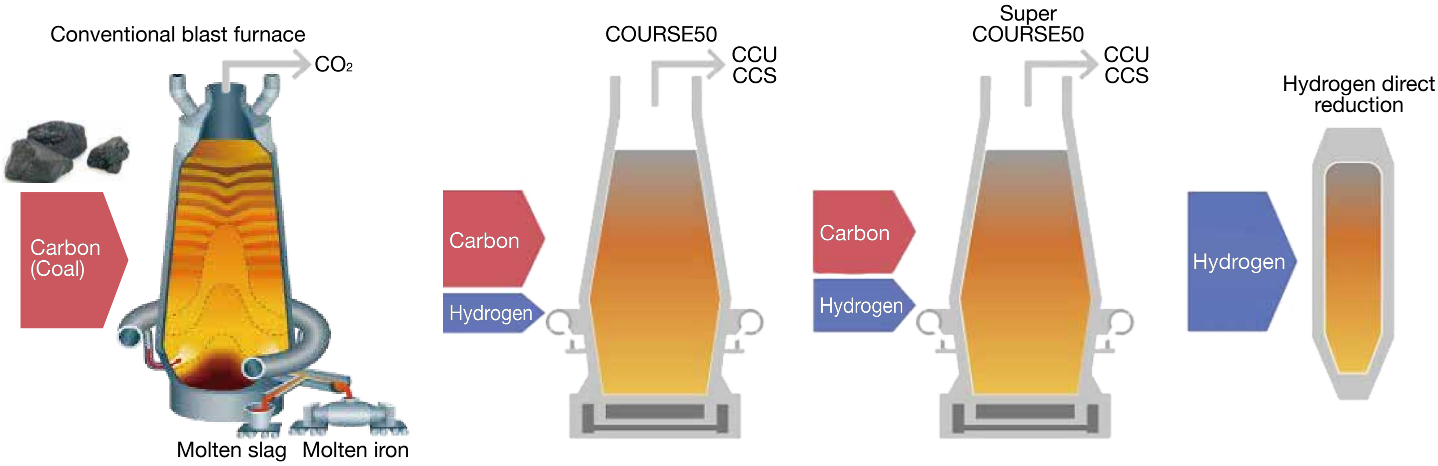


COURSE50
Experimental Blast Furnace
NEDO・JISF：COURSE50



COURSE50
CO_2 capture facility
NEDO・JISF：COURSE50

Fig. 2 Conventional, COURSE50 and Super COURSE50 Blast Furnaces and Hydrogen Direct Reduction Shaft Furnace



Since hydrogen is not currently available in large quantities, COURSE50 assumes the use of hydrogen produced in integrated steel mills during coke production. Assuming that hydrogen will be available in large quantities at low cost in the future, the Super COURSE50 project has also started to inject larger quantities of hydrogen into the blast furnace. Recently, 22% reduction in CO_2 emissions has been demonstrated by injecting heated hydrogen into the Experimental Blast Furnace.

In the blast furnace, solid coke supports the iron ore even at high temperatures and maintains gas ventilation in the furnace. Therefore, the coke amount cannot be zero, and reduction cannot be performed with 100% hydrogen in the blast furnace. On the other hand, 'direct reduction' in which iron ore is made into pellets and reduced with natural gas in a shaft furnace is also used although the production amount is relatively small. The shaft furnace is small in size compared to blast furnace, but it is possible to reduce iron ore using only hydrogen by replacing natural gas with hydrogen. This is called 'hydrogen direct reduction' (Fig. 2). The iron obtained by direct reduction is called direct reduced iron (DRI), which must be followed by melting in an electric arc furnace etc. Furthermore, direct reduction requires high-grade iron ore, produced in less than 10% of the total iron ore, because if the raw material contains a large amount of gangue, a large amount of electricity is required to melt it.

In addition, the reaction of iron ore with CO, main reaction in the blast furnace, is an exothermic reaction and so the reduced iron is melt in the blast furnace. On the other hand, the reaction of iron ore with hydrogen is an endothermic reaction, so heating is required for the reaction (Fig. 3).

As described above, direct reduction using hydrogen has various issues, but it is highly expected as the ultimate low-carbon ironmaking process and various research has started in various countries.

The amount of hydrogen required for steel production is enormous. If all of Japan's current steel production were to be produced using hydrogen, approximately 20 million tons of hydrogen would be required annually. This is equivalent to the entire amount of hydrogen that the Japanese government has vision to supply in Japan by 2050. Since carbon-free hydrogen is expected to be imported, it will be possible that DRI is produced in hydrogen-producing countries and the DRI imported to Japan.

However, hydrogen will be used in various sectors in the future, so it will be important for society to build a hydrogen supply infrastructure to meet these hydrogen demands. In addition, in order to produce steel at the same cost level as current coking coal, hydrogen prices must be lower than the government vision level. However, since there will be a lower limit of hydrogen cost, social acceptance for the increased price of low-carbon steel is also required (Fig. 4).

Fig. 3 Reduction of Iron Ore Using Carbon (left) and Hydrogen (right)

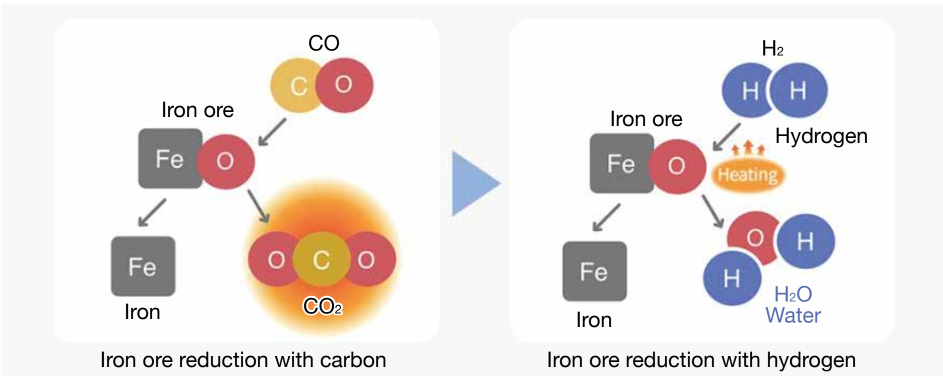
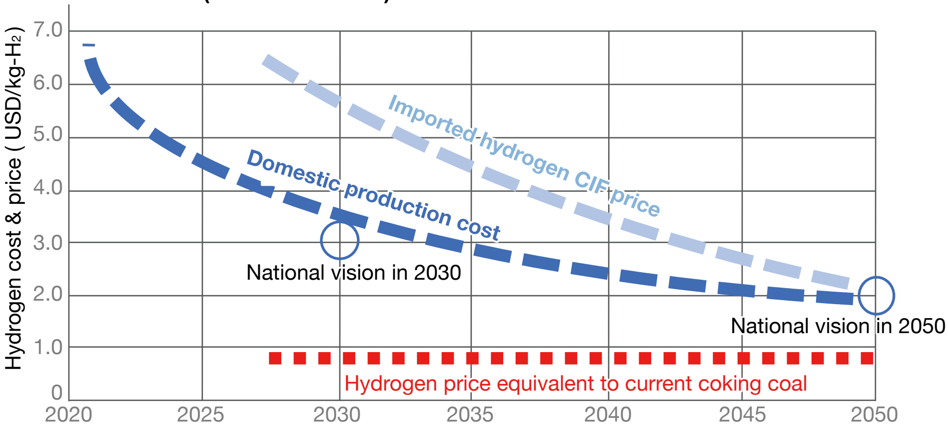


Fig. 4 Hydrogen Cost and Price Visions of the Japanese Government (circles) and Trend (broken curves)



Low-carbon Steelmaking with CO_2 Capture

Conversion of CO_2 into chemicals and minerals or geological storage of CO_2 is another effective means of reducing CO_2 emissions. The challenge of CCUS is the economics of CO_2 capture. In case of CCS, there are additional issues including transportation cost of CO_2 to storage sites often in remote areas, monitoring cost, and social acceptance of the storage.

Biomass is considered a carbon-neutral carbon-based reducing agent because it absorbs CO_2 from the atmosphere through photosynthesis when it is generated. Charcoal, in particular, has a certain degree of strength and can be used in small blast furnaces as a substitute for coke, and has been used in Brazil where forest resources are abundant. On the other hand, it can lead to deforestation and its sustainability can be an issue.

Low-carbon Steelmaking with Scrap

Steel scrap is a useful steel resource that has already been reduced. Currently, one third of the world's steel is produced from steel scrap, and this figure will continue to increase as steel stock increases in the world. The problem of scrap is the contamination of other metals. Steel is a highly recyclable material that can be separated from other metals by means of magnetic sorting, and most of other metals can be easily removed as their oxides (slag) by oxygen refining. However, copper which is widely used in wire harness and core in motors is easily mixed with steel scrap. Once cupper is melted with steel, it is impossible to remove. Contaminated copper degrades the quality of steel and accumulates in steel resources. Preventing copper contamination in scrap is a major issue from the perspective of not only steel resource circulation but also low-carbon steel production.

It is sometimes pointed out that Japan produces as low as about 25% of scrap electric arc furnace steels, which is low carbon emissions in production phase, compared to USA, for example, which produces as high as 60% of electric arc furnace steel. However, in USA, a large amount of blast furnace steel is indirectly imported as final products and used. In Japan, contrary, about 60% of blast furnace steel is exported. As a result, the percentage of scrap used in the steel products used in both countries is about the same. It is important to note that looking only at the producing phase tends to lead missing carbon leakage where carbon is not reduced but only emitted outside the country.

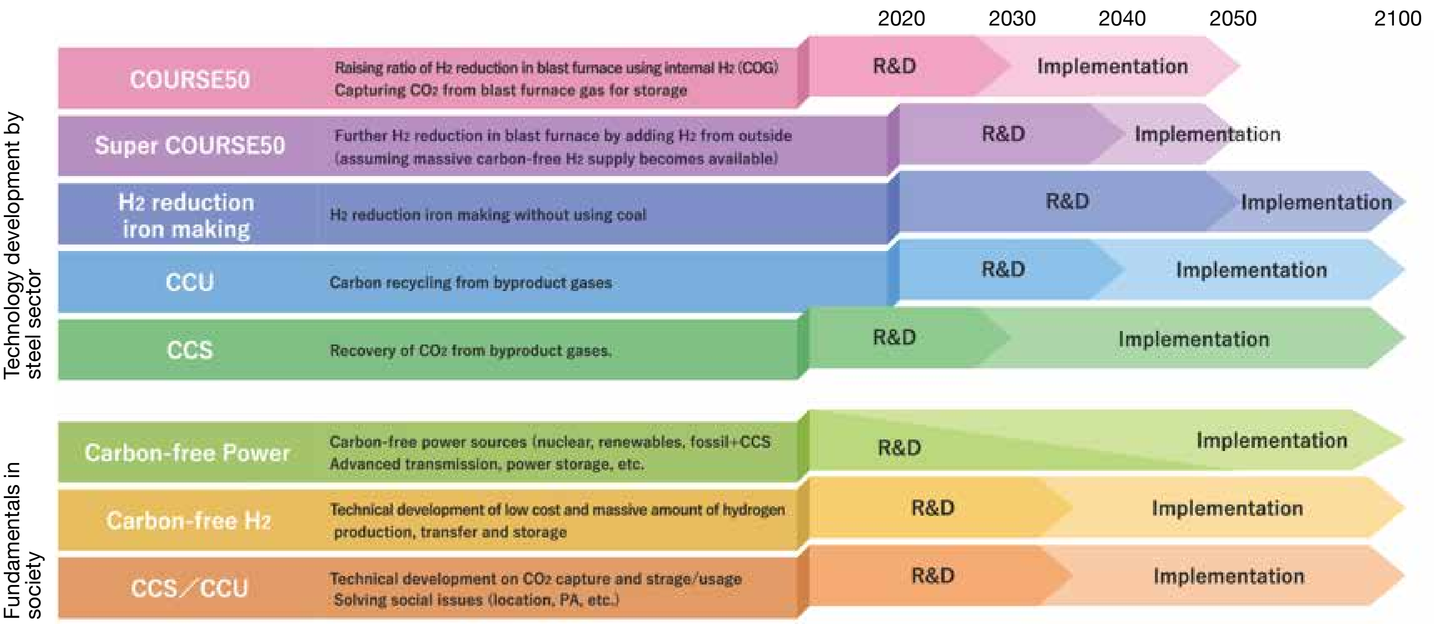
Low-carbon Steelmaking with Electricity

Since carbon emissions from electric power generation will become lower due to increase of renewable energy sources, iron ore reduction by electrolysis might become an option. Boston Metal is attempting to produce molten iron by molten oxide electrolysis. ArcelorMittal is trying to produce iron by electrowinning. Although both of these technologies still have significant challenges to overcome in terms of productivity and large-scale production, they are expected to be highly energy-efficient in terms of direct use of electricity without conversion to hydrogen. Their progress is noteworthy for steel industry.

Low Carbon Roadmap and Challenges

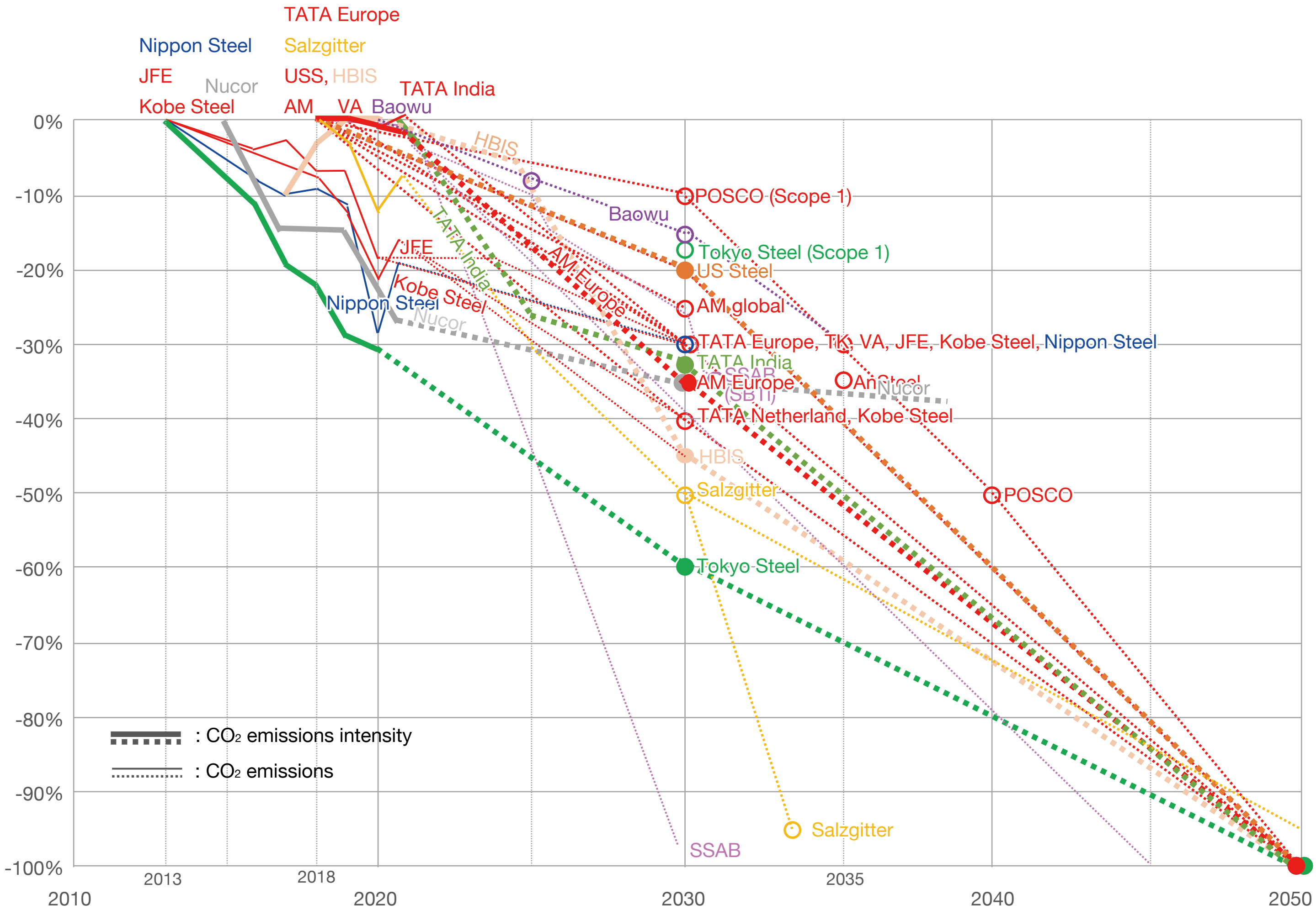
The roadmap to carbon neutrality in steelmaking presented by the Japan Iron and Steel Federation (Fig. 5) indicates that the Japanese steel industry parallelly develops COURSE50, Super COURSE50, and hydrogen direct reduction, while combining CCUS.

Fig. 5. Roadmap of the Japan Iron and Steel Federation to Carbon Neutral Steel



The Japanese blast furnace companies have formed a consortium for hydrogen steelmaking 'GREINS (GREEn INnovation in Steelmaking)' with supports by NEDO as the 'Green Innovation Fund project: Hydrogen utilization in steelmaking processes.' In the project, comprehensive joint studies are being developed including COURSE50, Super COURSE50, hydrogen direct reduction, and advanced electric furnace technologies. In addition, steel producers in the world, including Japan, are challenging to low carbon steel, with targets of reducing CO_2 emissions by around 30% in 2030 and vision of carbon neutrality in 2050 (Fig. 6).

Fig. 6. Roadmap to Zero Emissions by Steel Producers (Scope 1+2)



Yamato Konan Building

—A Double Spiral Structure Enables a Museum and Peripheral Vehicle Passage—

Nikken Sekkei Ltd.

Yamato Konan Building is a 10-story composite logistics building that accommodates a variety of functions, including a home delivery service center, a corporate museum and training facilities. The sloped vehicle path, as well as the sloped museum, wrap around the building's periphery in a "double spiral" design. At upper levels, these slopes are suspended from a steel-framed hat truss structure, while the lower floors are supported by cantilevers. The highly rationalized space also capitalizes on prevailing conditions at the site.

Trucks Traverse the Building's Periphery

The original Yamato Konan Building site featured a collection/delivery center with an attached dormitory for Yamato Transport. The company wished to rebuild it as a futuristic facility on the occasion of the 100th anniversary of the founding of the Yamato Group. Specifically, the project called for the facility to accommodate a training center for human resource development, a corporate museum for public relations, and a café for physically-handicapped employees while retaining its collection and delivery functions. The relatively compact 2,480 m^2 site area required a highly rationalized design to meet all of the client's needs.

The building's 1st to 5th floors are used for loading and unloading, while the 6th floor serves as the entrance for the museum, and the 7th to 10th floors host the office and training center. At the lower floors, the vehicle passage connecting the logistics center and museum wrap around the building in a double spiral. The passages connect to the 50 m-high top floor, as they change function.

In such multi-storied logistics facilities, independently-structured rampways with flat floors to the side are usually provided for vehicles to traverse the upper and lower floors. However, no matter how the rampway is arranged, the passage length remains the same, leaving unused space surrounded by the vehicle passages. To that end, this innovative design allows for flat, wide floors to be arranged in the building center, routing vehicles to the outer periphery.

In order to prevent damage to deliverable goods, Yamato Transport specified a more gradual vehicular passageway gradient than is typically seen. The resulting design allows the vehicle to ascend one level per half length of building periphery, or two levels for every 360-degree "round-trip." As this design still left one level of vacant space between the passages, an additional passage was allocated as a museum exhibition space. (Photos 1 and 2)

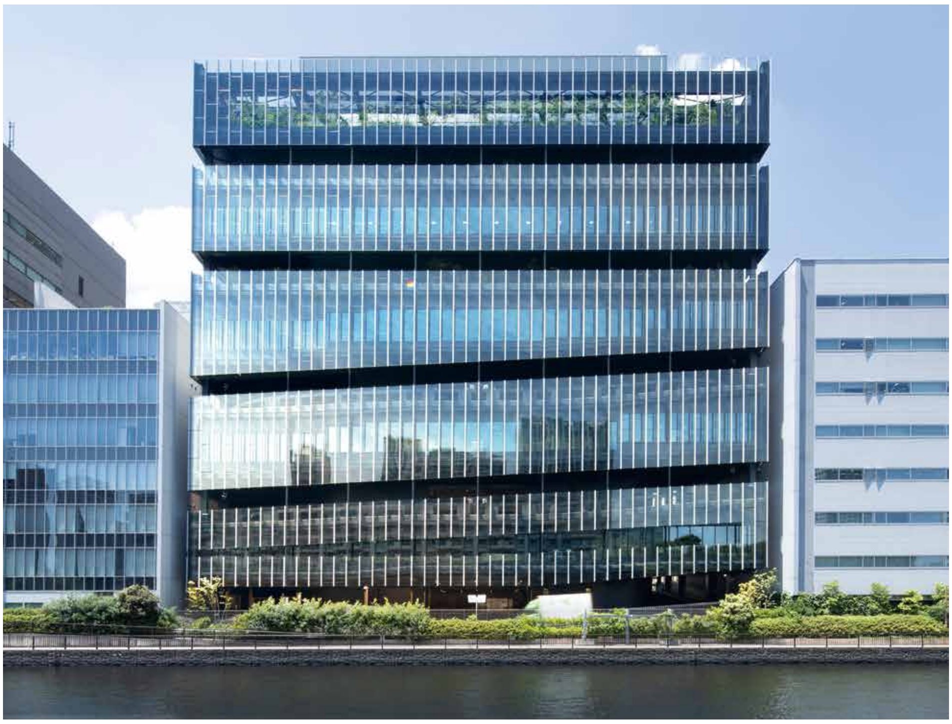


Photo 1 Canal side (east side) view. Arriving delivery vehicles can be seen through diagonally-slatted sections in the glass façade.

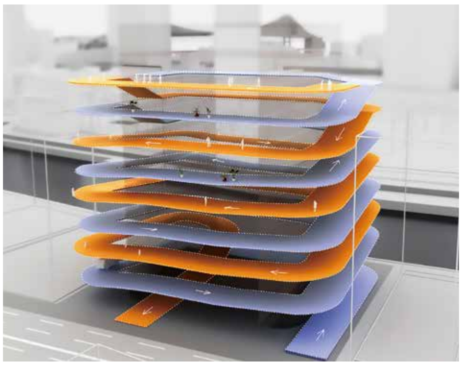


Photo 2 Conceptual model: The blue spiral shows the vehicle passage where the vehicles ascend/descend. The orange spiral depicts the corporate museum.

Bringing Out the Slope from the Flat Space

As the structural performance requirements of the sloped passage and exhibition space differed from the logistics center, office and training facilities, a number of mechanisms were needed to integrate the building's diverse functions.

A 36 m × 27 m flat space was allotted to the building center. A structural frame secures the floor, while the sloping peripheral passageways are supported by cantilevers that protrude from these floor structures. Because the structural plane is essentially identical throughout the building's levels, it was possible to design a well-balanced building, provided that its structural elements were properly arranged.

At first glance, it seemed logical to install columns along the outer periphery. However, it was feared that with the Takahama Canal on the east side of the site and the old seawall on the boundary, providing foundation beams or driving piles near the seawall might destabilize it (the seawall). Thus, the decision was made to support the building structure and the slopes at the periphery from the center.

Piles could have been driven at the front (west side) of the building, the reverse side of the canal. Ultimately, however, no outer periphery columns or structural elements were placed there in order to strike a total building structure balance. Employee and vehicle entrances are also located on this side, so this structural design concept also benefited these circulation plans.

The logistics center required 10-ton trucks to enter from the 1st floor. Taking streetscape and atmosphere improvement priorities into consideration, the rebuild plan allows vehicles to line up at the rear canal side, an aesthetically better solution than the previous layout in which they lined up at the former coastal street side. (Figs. 1, 2, 3, and Photo 3)

Fig. 1 Sectional View

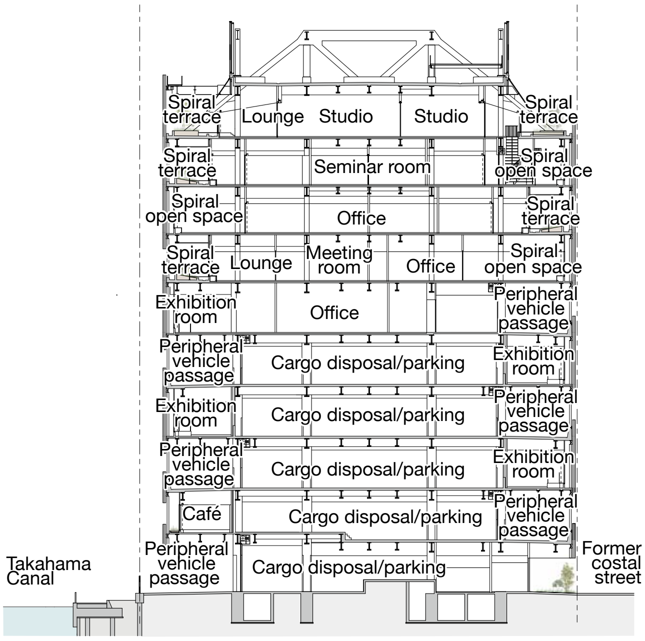


Fig. 2 Plane View

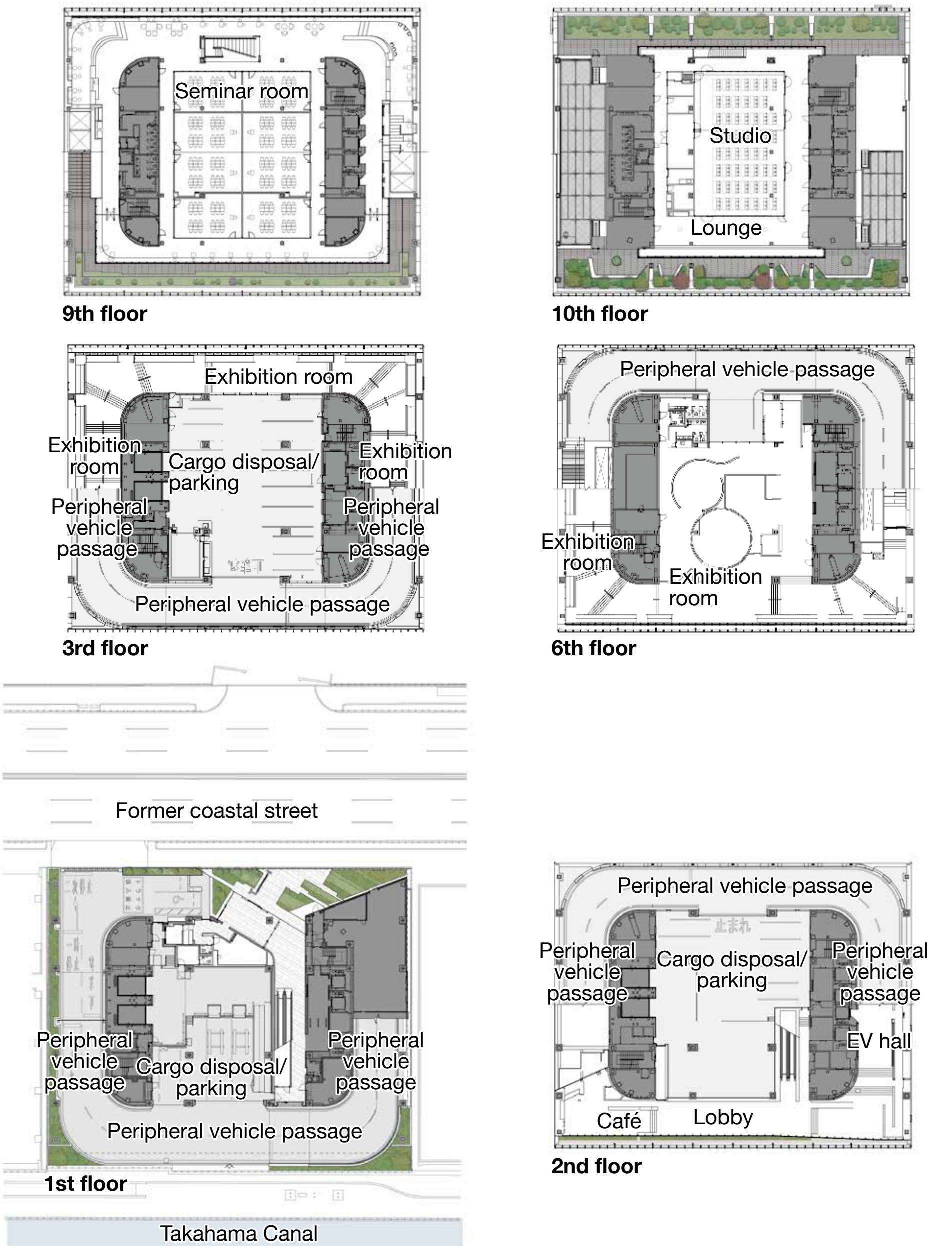
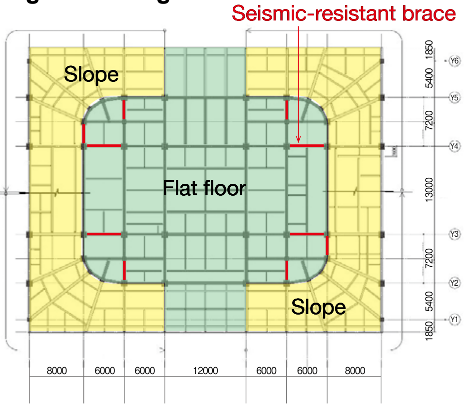


Fig. 3 Framing Plan



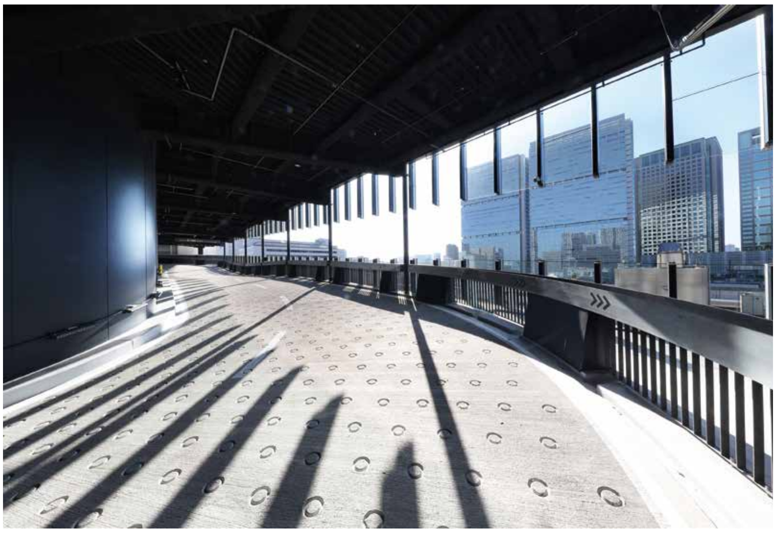


Photo 3 Vehicle passage circumscribing the building's outer periphery

Steel Frame Cantilever and Suspension Structures

The structural performance specifications for the building's lower floors differ from the upper floor specs. Floors 1 to 5 are dedicated to cargo handling; delivery trucks traverse the vehicle passage on the periphery. The corporate museum entrance is on the 6th floor, where guests arrive by elevator. Guests can view the exhibitions while moving down the sloped exhibition spaces between the truck paths. In this way, mobility is maximized for both people and vehicles. The lower floors were treated as a contiguous "mobile zone." A 7.2 meter-long cantilever beam structure supports the periphery at the east-west sides. Beam height is 700~1200 mm.

In order to counter vibration, beams were required to be satisfactorily rigid. Vibration measurements were taken at the existing building and at the newly completed building via rigorous testing; results proved that vibration levels were not problematic. The little overlap between the museum operating hours and the truck operating hours helped to mitigate vibration. Finally, the cantilever beam tips at each floor were connected using 190 mm-diameter steel pipes to counter movement beneath and above the passages.

The 6th through 10th floor area was considered a "quiet zone" due to its designated office and training center use. Nevertheless, measures were also taken here to mitigate vibration. A steel-frame hat truss was installed at the topmost floor, and the upper floor peripheral section was structured by suspending edge columns (composed of 190 mm-diameter steel pipes) from the truss. As previously explained, the mechanisms used to support the building's peripheral structure differ between the mobile and quiet zones. Oil dampers installed on the intermediate floor also help to absorb and neutralize vehicle-generated vibration effects.

Yamato Konan Building is unique in the planar relationship between its center floor and periphery, and in terms of the sectional structural performance differences between its upper and lower floors. Symmetrical architectural floor plans were employed to deal with this. (Fig. 4)

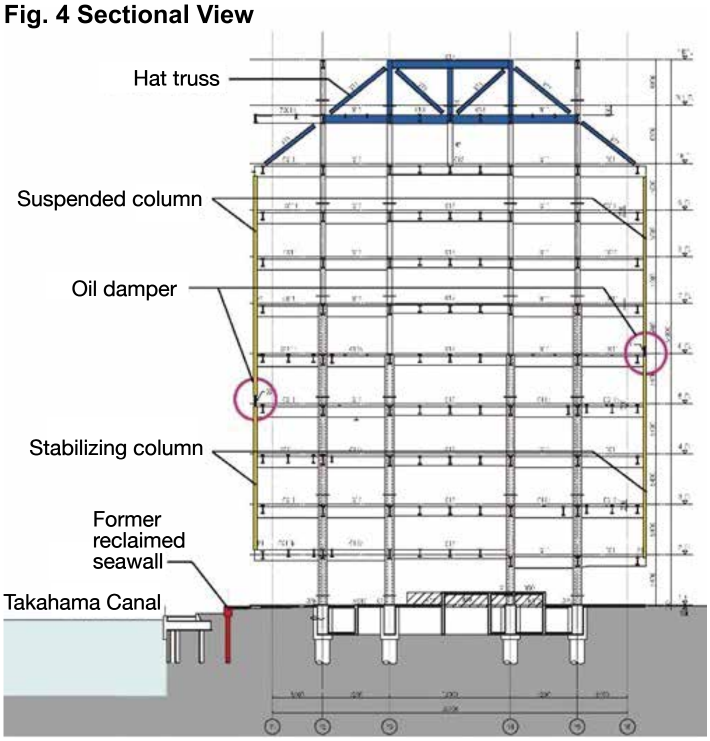
Truss Frame Installation and Slope Gradations

A total of four hat trusses were installed on the top floor. These cross east to south, connecting the building's front and canal sides, where there were no peripheral columns rooted at the lower levels. In turn, columns were placed along the north and south sides (the gable sides) of the building for good earthquake-resistant balance. The hat trusses could only be installed where the floor was flat in order for them to be effective. Therefore, they were placed where the slopes at the canal side and front side flatten for vehicles to enter and exit the cargo space.

The slope rises by one floor halfway around the periphery. A general gradient was applied for the slopes on the north and west sides where there are pillars. For the corners, a gentler (flatter) gradient was applied. Generally speaking, slopes would be made of reinforced concrete. In this project, however, because the lower floors are composed of a 7.2 meter-deep cantilever structure, lightweight durable steel frames were adopted. This structural design accounted for improved member fabrication efficiency -- made possible by applying as much commonality as possible for items such as joint position.

For the vehicle passages, particularly in curved sections, calculating for water gradient and the difference in gradi-

Fig. 4 Sectional View



ents for the right and left sides of truck wheels was tricky.

Slope gradients differ for vehicles and people. The exhibition space (where visitors walk around) employs a combination of slopes and landings based on Japan's Barrier Free Law, which promotes easy mobility and accessibility for the aged and disabled.

The building's center, with stacked flat floors, is the structural core. A seismic-resistant brace was arranged at its four corners to prevent large axial forces onto the diagonal beams. While beams are intricately arranged at these braces, they could still be used as a building service-related shaft space. The architectural design team was tasked to prepare symmetrical floor plans; thus, the structural design team accepted that elements in its purview would also be arranged symmetrically.

Interestingly, the corner sections shown in the framing plan formed a radial state. The indoor ceiling was thus divided into a radial form (as opposed to a more orthodox x-y axis). Perforated ceiling panels of 474 mm width were aligned with space between them to create a fan-like pattern. With perforated materials, slight differences in their spacing did not pose a concern. Panel positioning at the corner sections did pose a challenge, however. Panels were not aligned in a concentric circle but placed on a shifting plane center to honor continuity. The panels were designed to enable final adjustments at the construction site. (Photos 4, 5, 6, 7 and 8)

Photo 4 Top-floor hat truss

Photo 5 Erection of four trusses to the north and east directions

Photo 6 Through the open evacuation door, both the exhibition room and collection/delivery center can be seen, showcasing the intriguing difference between levels and duality of space.

Photo 7 Corner section wall surface construction

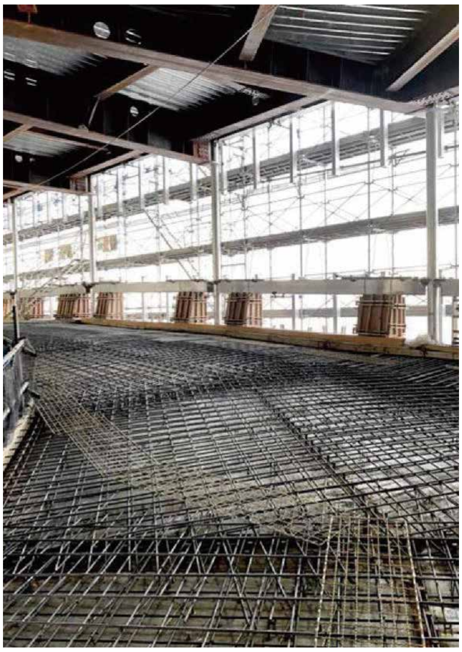


Photo 8 Corner section slope construction

Photo 9 A communication spiral circumscribes the office space, and includes a window side bench.

Upper Floor Use and Changing Applications

The flat spaces in the center of the 7th to 10th floors are home to offices and training facilities. The peripheral vehicle passage at the lower floors turns into outdoor terraces with abundant greenery at higher floors. Meanwhile, the slope that hosts to the corporate museum on the lower floors also serves as conference and employee refreshment areas.

During the height of the COVID-19 pandemic (when social distancing became a priority), the peripheral space was ingeniously utilized as an office space that company employees could use freely. (Photo 9)

The Glass Screen Façade

The glass screens diagonally arranged on the building's periphery allow passers-by to see vehicles as they move through the interior. For the exhibition rooms and other indoor spaces for which functional glass is required, another glaze was added to the interior, forming a "double skin" design. The outer glass assumes the image of a worn scarf, and is single-glazed. Functionally, it reduces some heat load during the summer. This single-glazing is cut diagonally to display the aesthetic value of the cut edge.

In order to reduce costs and the construction period, a 9 m-long glass "belt" was prepared, composed of glass panels, each measuring 1.2 m in width and 2.6 m in height. The belts were arranged by staggering them vertically to make the joints less noticeable. The glass belts appear to have continuous vertical mullions, but they are instead aluminum fittings that cover the edges of the glass panels. The actual load bearing elements lie inside these panels. The connected fittings look, in the end, like mullions, however.

Earthquake resistance is achieved by vertical, independently rocking units, for which necessary space is provided between the glass penels. The façade is split by its glass belts, which allows huge clearances in the event of earthquakes. No displacement is structurally accumulated in the belts, a feature which enhances overall seismic resistance. Open spaces between the belts also serve to ventilate the vehicle passage and terrace areas. (Photo 10)

A Project Where People and Vehicles are Equal

This project piqued our interest with respect to the concept of diversity. We rarely come across a context in which people and vehicles coexist on roughly equal footing. In order to change or create anew such a "non-discriminatory" space, seamless continuity is necessary. With wheelchairs, strollers, and emerging robotics, et al, mobility is consistently related to continuity. We feel that Yamato Konan Building is in the middle of this society-wide trend, and may deserve consideration as a forerunner of this era.

In the end, this project is not an attempt to create a new concept building, but rather the result of a thought process in creating a space to meet client needs; as such, it seems to represent the state of today's society. (Photo 11)

Yamato Konan Building Outline

Location: Minato-ku, Tokyo
Owner: Yamato Transport Co., Ltd.
Main applications: Garage, office, museum
Area Site: 2,482.66 m^2
Building area: 2,242.93 m^2
Total floor area: 19,542.80 m^2
Structure: Steel structure, steel and reinforced-concrete composite structure
No. of stories: 10 stories aboveground
Maximum height: 59.55 m
Eave height: 58.62 m
Architectural design: Nikken Sekkei Ltd
Structural design: Nikken Sekkei Ltd
Construction: Maeda Corporation
Design period: June 2016~February 2018
Construction period: February 2018~September 2019

Photo Courtesy
Photos 1, 3, 6, 9 and 11: Noda Harunori, gankohsha
Photos 2, 4, 7, 8 and 10: Nikken Sekkei Ltd.
Photo 5: Maeda Corporation

Photo 10 Exterior building construction, with a façade composed of small glass aggregates

Photo 11 The top-floor studio and lounge are continuously connected to the terrace.

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