High Performance Steels
(For Bridge Construction)

Research Group on Steel Products for Bridges
The Japan Iron and Steel Federation

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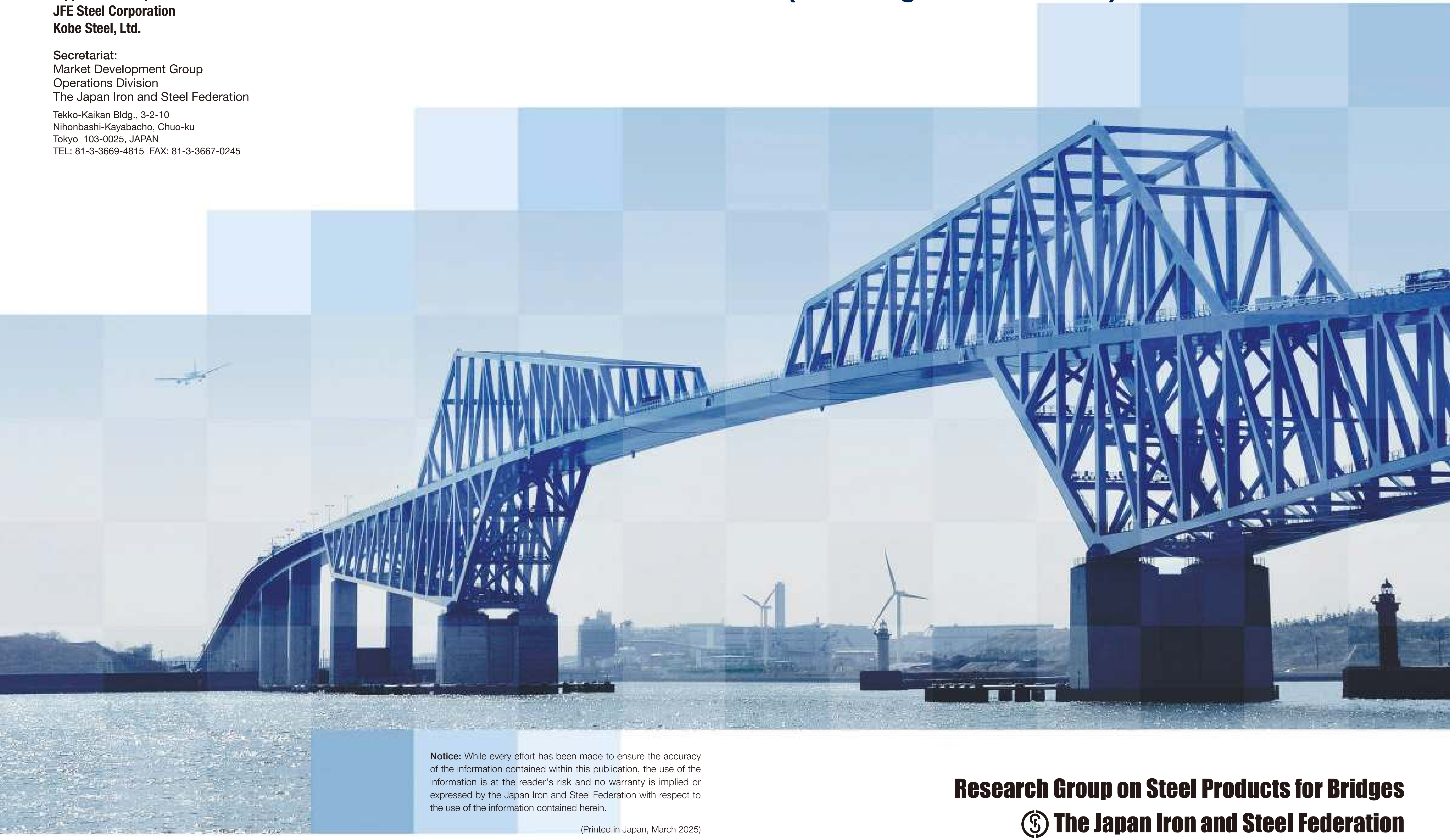

(Printed in Japan, March 2025)

Photo: Tokyo Gate Bridge

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What Is High Performance Steel?

"High Performance Steel" is the designation given to the steel that offers higher performances in tensile strength, toughness, weldability and cold formability and corrosion resistance than those generally used in bridge construction.

Some of these high performance steels have already been specified in the Specifications for Highway Bridges of the Japan Road Association, revised in December 1996. High performance steels thus specified and those for which bridge application is being studied and which have already been put into practical use in fields other than bridge construction are introduced here.

● An important technology, which allows production of high performance steels like high-strength steel grades having tensile strengths of 500 and 600 N/mm² widely applied for steel bridges, is the Thermo-Mechanical Control Process (TMCP). TMCP adequately controls reheating and rolling, and cooling after rolling in steel plate production. The TMCP tech-nology imparts better weldability, higher strength, excellent toughness and improved properties to steel plates. (See pages 36-37)

High Performance Steels: Strength, Toughness and Weldability, Corrosion Resistance, etc.

Materials	Standards	Pages
Steels for Bridge High Performance Structures	SBHS400 (Yield point 400 N/mm² and over) SBHS400W (Yield point 400 N/mm² and over, weathering steel) SBHS500 (Yield point 500 N/mm² and over) SBHS500W (Yield point 500 N/mm² and over, weathering steel) SBHS700 (Yield point 700 N/mm² and over) SBHS700W (Yield point 700 N/mm² and over, weathering steel)	2～7

High Performance Steels: Strength

Materials	Standards	Pages
High-strength steel	HT690 (Tensile strength 690 N/mm² and over) HT780 (Tensile strength 780 N/mm² and over) HT950 (Tensile strength 950 N/mm² and over)	8～9
Steel with constant yield point (Thicknesses: over 40 mm)	SM400C (Yield point 215 N/mm² and over) ➡ SM400C-H (Yield point 235 N/mm² and over) SM490C (Yield point 295 N/mm² and over) ➡ SM490C-H (Yield point 315 N/mm² and over) SM520C* (Yield point 335 N/mm² and over) ➡ SM520C-H (Yield point 355 N/mm² and over) SM570** (Yield point 430 N/mm² and over) ➡ SM570-H (Yield point 450 N/mm² and over) SMA400CW (Yield point 215 N/mm² and over) ➡ SMA400CW-H (Yield point 235 N/mm² and over) SMA490CW (Yield point 335 N/mm² and over) ➡ SMA490CW-H (Yield point 355 N/mm² and over) SMA570W** (Yield point 430 N/mm² and over) ➡ SMA570W-H (Yield point 450 N/mm² and over)	10～11
Steel with narrow range of yield point variation	SN400 (Yield point variation 120 N/mm²) SN490 (Yield point variation 120 N/mm²) SA440 (Yield point variation 100 N/mm²)	12～13
Steel with low yield ratio	SN400 (Yield ratio=Yield point/Tensile strength 80%) SN490 (Yield ratio=Yield point/Tensile strength 80%) SA440 (Yield ratio=Yield point/Tensile strength 80%)	
Low yield point steel	LY100 (Yield point 100 N/mm²-grade steel) LY225 (Yield point 225 N/mm²-grade steel)	14～15
Ultrathick steel plate	Steel plates having high strength and excellent toughness in the range of thicknesses surpassing those specified in the Specifications for Highway Bridges	16～17

*75~100 mm: 325 N/mm² and over **75~100 mm: 420 N/mm² and over

High Performance Steels: Toughness and Weldability

Materials	Standards	Pages
Steel with excellent toughness	❶ Cold forming Charpy absorbed energy* / Radius in cold forming (t: thickness) vE ≥150J ➡ 7t and over vE ≥200J ➡ 5t and over ❷ Meeting the specification required for low-temperature application	18～19
Low preheating steel	Steel having P_{CM} lower than standard ones specified in the Specifications for Highway Bridges	20
Steel for large heat-input welding	Steel applicable to large heat-input welding	21
Steel with lamellar-tearing resistance	Z15, Z25, Z35 (Steel having guaranteed reduction of area in the thickness direction)	22～23

*The value at JIS-specified test temperature

High Performance Steels: Corrosion Resistance and Other Properties

Materials	Standards	Pages
Weathering steel	SMA400W SBHS400W SMA490W SBHS500W SMA570W SBHS700W	24～26
Corrosion resisting steels for repaint term extension	Can prevent corrosion from coating defects compared to conventional steels.	27
Steel for galvanizing	Steel that prevents dull gray surface and cracking due to galvanizing	28～29
Structural stainless steel	SUS304 (0.1% offset proof stress 235 N/mm² and over, tensile strength 520 N/mm² and over) SUS316 (0.1% offset proof stress 235 N/mm² and over, tensile strength 520 N/mm² and over) SUS304N2 (325 N/mm² 0.1% offset proof stress 440 N/mm², tensile strength 690 N/mm² and over)	30
Clad steel	Stainless-clad steel (base metal: carbon steel + clad material: stainless steel) Titanium-clad steel (base metal: carbon steel + clad material: titanium)	31
Longitudinally-profiled (LP) steel plate	Maximum difference in thickness 25~30 mm, maximum taper gradient 4 mm/m, total length 6~25 m	32～33
High-strength steel wire for bridge cables	ST1770 (tensile strength 1,770 N/mm² and over), ST1960 (tensile strength 1,960 N/mm² and over)	34～36

SBHS
(Steels for Bridge High Performance Structures)

Scope

SBHS (Steels for Bridge High Performance Structures) are high-performance steel plates (JIS G 3140) for use in bridge construction. These steels were developed as a result of a joint industry-academia research project and with the primary object of reducing the construction cost of steel bridges.

In terms of strength, toughness and weldability, the performance of SBHS exceeds that of 490 N/mm²-, 570 N/mm²-conventional and 780 N/mm²-grade conventional steel. A good understanding of the high performance offered by SBHS and their effective application will enable the user both to produce rational bridge designs and to conduct more streamlined member manufacturing.

Features

As steel plates produced using TMCP technology, SBHS high-performance steel plates for bridge construction make high strength compatible with high weldability and workability. (For TMCP technology, refer to pages 36~37.)

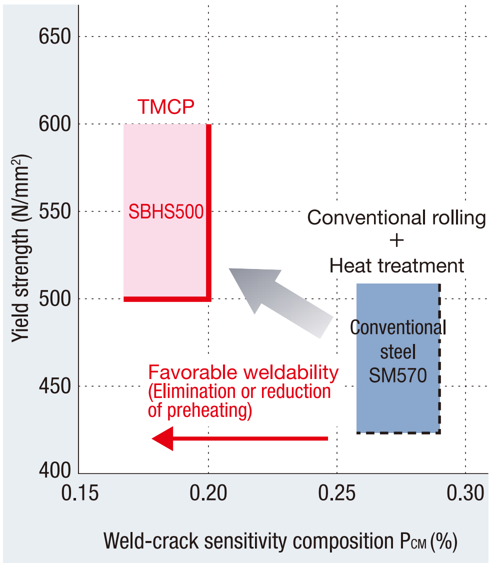
■ Higher Yield Strength than Conventional Steel

- •490 N/mm² grade [SBHS400(W)] : Yield strength—Improvement by 10~23% (+35~75 N/mm²)
- •570 N/mm² grade [SBHS500(W)] : Yield strength—Improvement by 9~19% (+40~80 N/mm²)
- •780 N/mm² grade [SBHS700(W)] : Nearly similar— Improvement by 2~5% (+15~35 N/mm²)

■ Higher Workability and Weldability than Conventional Steel, and the Ability to Eliminate Preheating and to Lower Preheating Temperatures

- •490 N/mm² grade [SBHS400(W)] : No need for preheating
- •570 N/mm² grade [SBHS500(W)] : No need for preheating
- •780 N/mm² grade [SBHS700(W)] : Lowering of preheating temperature (100~120℃→50℃)

Weld-crack Sensitivity Composition P_{CM} (%)



Greater Contribution toward Reduced Steel Weight and Construction Cost

■ Practical Effect Yielded at Tokyo Gate Bridge

(Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism. : *Technoangle* No. 38, October 2005)

○ Reduction of weight of steel products applied: About 3%
○ Reduction of cost for member manufacturing: About 12%

Example in 50 mm-thick steel plate

Property \ Strength rating		490 N/mm²-grade steel		570 N/mm²-grade steel		780 N/mm²-grade steel		
		SBHS400 SBHS400W	Conventional steel (SM490Y SMA490W)	SBHS500 SBHS500W	Conventional steel (SM570 SMA570W)	SBHS700	SBHS700W	Conventional steel (HT780*)
Strength	Yield point (N/mm²)	≥ 400	≥ 335	≥ 500	≥ 430	≥ 700	≥ 700	≥ 685
	Constant yield point	○	△	○	△	○	○	△
Workability Weldability	Excellent toughness	○	△	○	△	○	○	△
	Lowering of preheating temperature	○	△	○	△	○	○	△
Corrosion resistance	Weathering steel spec	○ (SBHS400W)	○ (SMA490W)	○ (SBHS500W)	○ (SBHS570W)	—	○	—

○ Applicable by use of common-specification grade
△ Inapplicable by use of common-specification grade

* HBS G3102 (HT780)

Material Characteristics

Chemical Composition

Unit: %

Grade	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	B	N
SBHS400	≤ 0.15	≤ 0.55	≤ 2.00	≤ 0.020	≤ 0.006	—	—	—	—	—	—	≤ 0.006
SBHS400W	≤ 0.15	0.15~0.55	≤ 2.00	≤ 0.020	≤ 0.006	0.30~0.50	0.05~0.30	0.45~0.75	—	—	—	≤ 0.006
SBHS500	≤ 0.11	≤ 0.55	≤ 2.00	≤ 0.020	≤ 0.006	—	—	—	—	—	—	≤ 0.006
SBHS500W	≤ 0.11	0.15~0.55	≤ 2.00	≤ 0.020	≤ 0.006	0.30~0.50	0.05~0.30	0.45~0.75	—	—	—	≤ 0.006
SBHS700	≤ 0.11	≤ 0.55	≤ 2.00	≤ 0.015	≤ 0.006	—	—	—	≤ 0.60	≤ 0.05	≤ 0.005	≤ 0.006
SBHS700W	≤ 0.11	0.15~0.55	≤ 2.00	≤ 0.015	≤ 0.006	0.30~1.50	0.05~2.00	0.45~1.20	≤ 0.60	≤ 0.05	≤ 0.005	≤ 0.006

Yield Point or Proof Stress, Tensile Strength and Elongation, and Charpy Absorbed Energy

Grade	Yield point or proof stress (N/mm²)	Tensile strength (N/mm²)	Elongation			Charpy absorbed energy		
			Thickness (mm)	Test specimen	%	Test temperature (℃)	Charpy absorbed energy* (J)	Test specimen and its sampling direction
SBHS400 SBHS400W	400 and over	490~640	6 ≤ t ≤ 16	JIS No. 1A	15 and over	0	100 and over	V notch Direction perpendicular to rolling direction
			16 < t ≤ 50	JIS No. 1A	19 and over			
			t < 40	JIS No. 4	21 and over			
SBHS500 SBHS500W	500 and over	570~720	6 ≤ t ≤ 16	JIS No. 5	19 and over	–5		
			t < 16	JIS No. 5	26 and over			
			t < 20	JIS No. 4	20 and over			
SBHS700 SBHS700W	700 and over	780~930	6 ≤ t ≤ 16	JIS No. 5	16 and over	–40		
			t < 16	JIS No. 5	24 and over			
			t < 20	JIS No. 4	16 and over			

*Average value of three test specimens

Welding Materials

Standards of Welding Materials

Welding method		SBHS400,SBHS500, SBHS700	SBHS400W,SBHS500W, SBHS700W
Shielded metal arc welding		JIS Z 3211	JIS Z 3214
Gas metal arc welding	Solid wire	JIS Z 3312	JIS Z 3315
	Flux cored wire	JIS Z 3313	JIS Z 3320
Submerged arc welding		JIS Z 3351 (solid wire), JIS Z 3352 (flux cored wire), JIS Z 3183 (deposited metal)	

Required Performance of Weld Joints

Steel grade	Joint tensile strength* (N/mm²)	Charpy absorbed energy of weld metal	
		Test temperature (℃)	Charpy absorbed energy** (J)
SBHS400(W)	490 and over	0	47 and over
SBHS500(W)	570 and over	–5	47 and over
SBHS700(W)	780 and over	–15	47 and over

*No specification of fracture position
**Average value of three test specimens

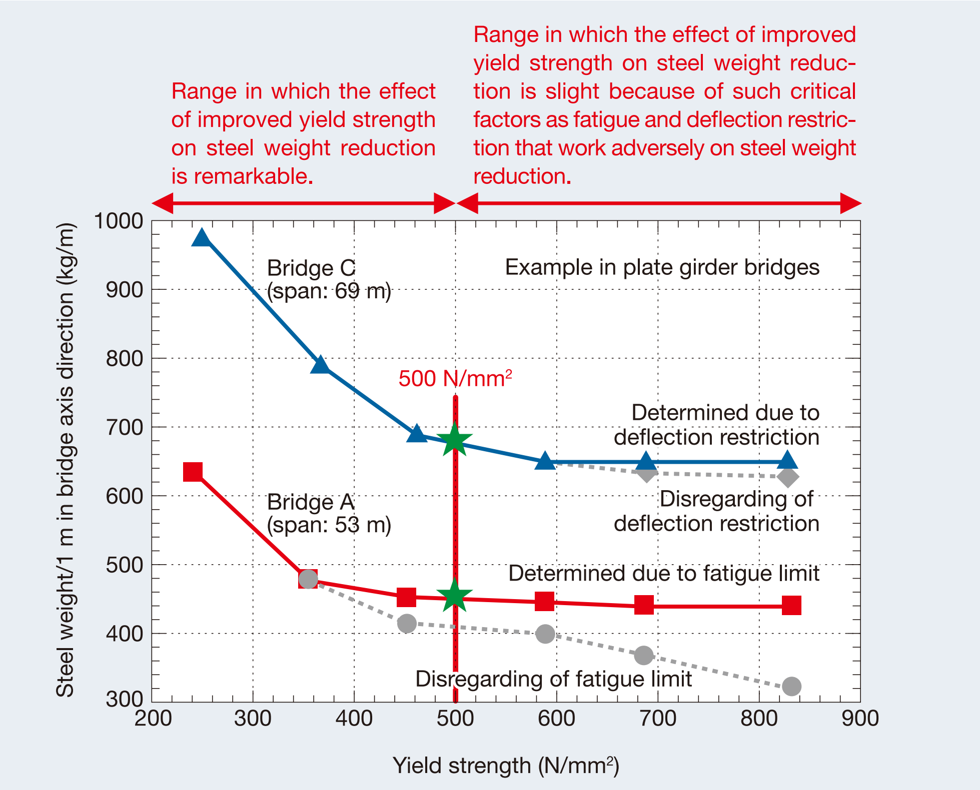
Representative Welding Materials (Example for SBHS500)

Welding method		JIS Specification	Welding position	Symbol
SMAW		JIS Z 3211	All position	E57J16-N1M1U
GMAW	CO_2 gas	JIS Z 3312	Flat, Horizontal	G57JA1UC3M1T
	Ar + 20%CO_2 gas		All position	G57JA1UMC1M1T
FCAW	CO_2 gas	JIS Z 3313	All position	T57J1T1-1CA-G-U
			Flat, Horizontal	T57J1T15-0CA-G-U
			Horizontal fillet	T57J1T1-0CA-U
SAW	Deposited metal	JIS Z 3183	Flat	S58J2-H
	Wire	JIS Z 3351		YS-M5
	Flux	JIS Z 3352		SFCS1

Yield Strength

Relation between Yield Strength and Steel Weight

For plate girder bridges, steel products with yield strengths of 500 N/mm² and under are effective for economical design. This type of steel is also effective in reducing the plate thickness of heavy-gauge steel members.

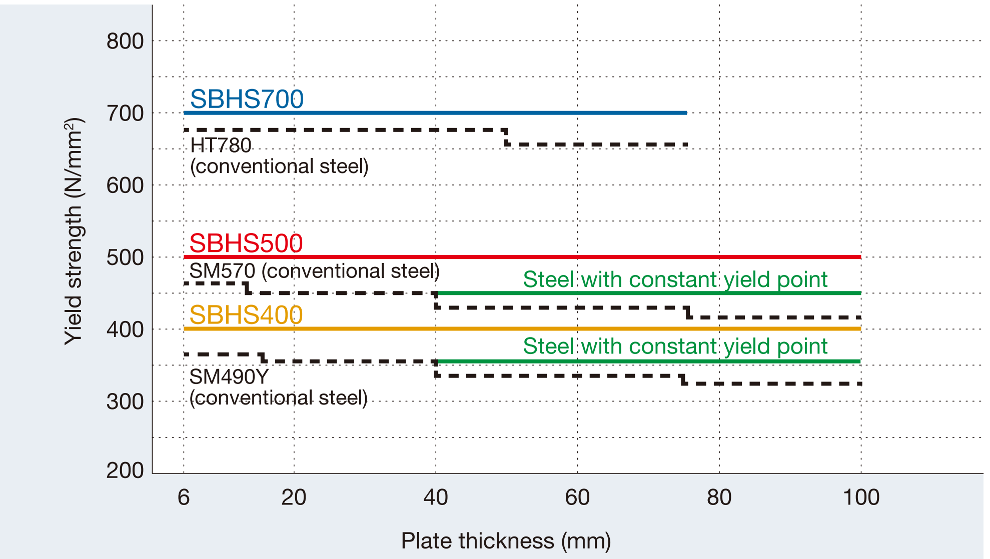


For long-span suspension bridges and cable-stayed bridges, steel products with a yield strength of 700 N/mm² are effective for economical design.

* T. Konishi, S. Miki et al: Possibility for Economical Design of Steel Bridge by Use of High-strength Steel, Proceedings of Japan Society of Civil Engineers, No. 654/1-52, July 2000

Yield Strength of SBHS

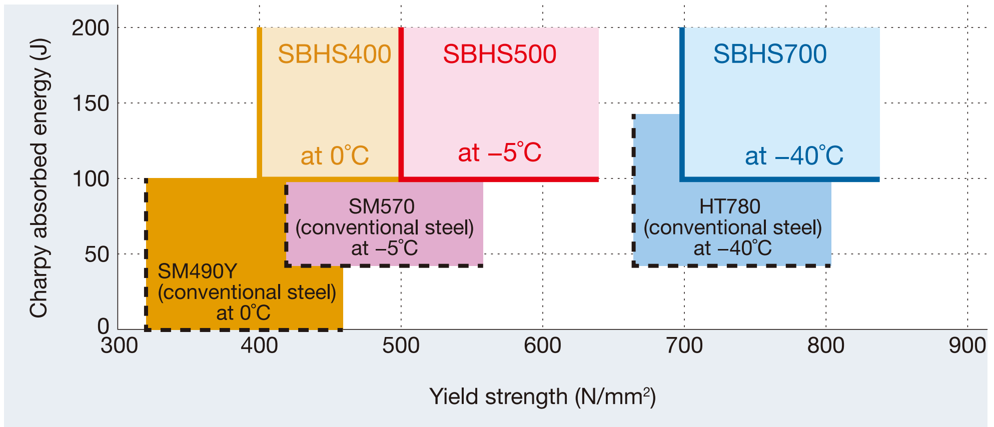
SBHS are available in three yield strength grades (400, 500 and 700 N/mm²) and demonstrate constant yield strength regardless of plate thickness. SBHS manufactured according to weathering steel specifications have the same yield strength as mentioned above.



Toughness

Toughness of Base Metal for SBHS (Example)

SBHS toughness is higher than that of conventional steel and, further, is guaranteed in the direction perpendicular to the rolling direction. SBHS manufactured according to weathering steel specifications have the same toughness as mentioned above.



Lowering of Preheating Temperatures

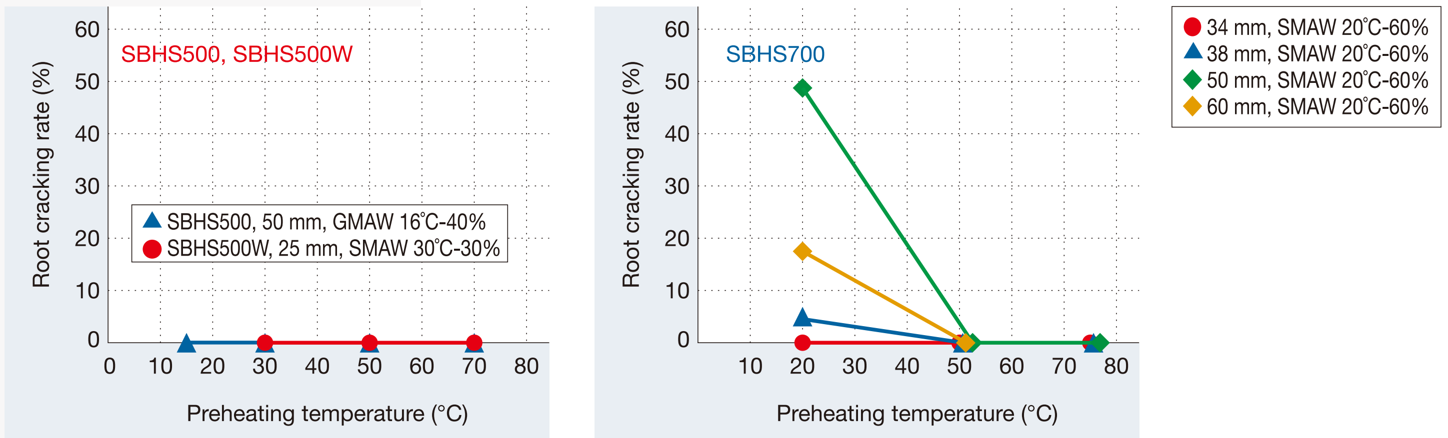
Effect of Lowering of Preheating Temperatures in Shielded Metal Arc Welding (SMAW)

Steel grade	Symbol	Classification		Plate thickness (mm) t ≤ 25	25 < t ≤ 40	40 < t ≤ 50	50 < t ≤ 100
490 N/mm² grade	Conventional steel (SM490Y SMA490W)	Standard P_{CM} (preheating temperature)*	(SM490Y)	0.26 (no preheating)		0.27 (80˚C)	
			(SMA490W)	0.26 (no preheating)	0.27 (80˚C)		0.29 (100˚C)
		P_{CM} requiring no preheating		—	0.24	0.22	
	SBHS400 (W)	P_{CM} (preheating temperature)		≦0.22 (no preheating)			
570 N/mm² grade	Conventional steel (SM570)	Standard P_{CM} (preheating temperature)*		0.26 (no preheating)	0.27 (80˚C)		0.29 (100˚C)
		P_{CM} requiring no preheating		—	0.24	0.22	
	SBHS500 (W)	P_{CM} (preheating temperature)		≤0.20 (no preheating)			
780 N/mm² grade	Conventional steel (HT780)	Standard minimum preheating temperature (°C)**		100			120
	SBHS700 (W)	Minimum preheating temperature (°C)		50 (t≤75)			

* Standard P_{CM}, preheating temperature standard (Japan Road Association: Specifications for Highway Bridges, 2012 Ed.)

** Standard minimum preheating temperature (Honshu-Shikoku Bridge Authority, Steel Bridge Manufacturing Standards, May 1993)

y-groove Weld-crack Test Results (JIS Z 3158)



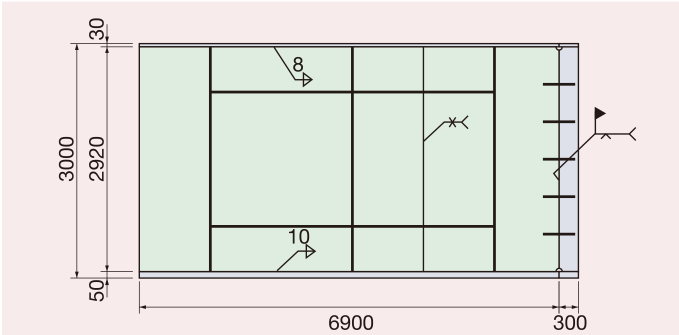
Workability

Workability of SBHS500

Dimension of I-girder Used in Workability Test

Steel grade	Application section	Dimension (mm)	
		Plate thickness	Width × Length
SBHS500	Upper flange	30	500 × 6900
	Web	20	2920 × 6900
	Lower flange	50	700 × 6900
SM490Y	Stiffener	12	

I-girder Manufacturing Drawing (Elevation)



unit (mm)

Manufacturing of I-girder

Outline of Workability Test Results

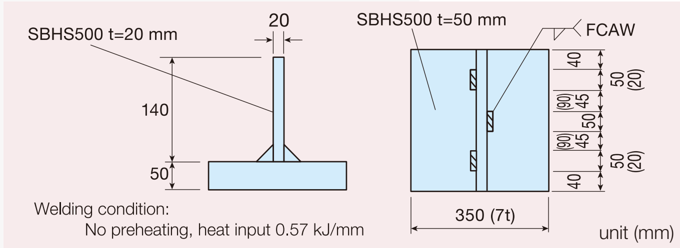
Assessment item	Application section		Comparison with SM490Y	Assessment item/Manufacturing condition
Cutting		t = 50 mm	○	Cut-surface roughness
Boring		t = 50 mm	○	Boring accuracy
Assembly welding		t = 20, 50 mm	◎ [1]	Available assembly weld length: 20 mm
Butt welding	Web	t = 20 mm	○	No preheating; Maximum heat input: 6.1 kJ/mm·T-SAW
	Upper flange	t = 30 mm	○	No preheating; Maximum heat input: 9.9 kJ/mm·T-SAW
	Lower flange	t = 50 mm	○ [2]	No preheating; Maximum heat input: 10 kJ/mm·T-SAW
Fillet welding	Web-Flange		○	No preheating
	Stiffener		○	No preheating
Distortion straightening	Press straightening		○	
	Roller straightening		○	
Site welding	Web	t = 20 mm	○ [3]	No preheating; Maximum heat input: 9.7 kJ/mm·EGW
	Upper flange	t = 30 mm	○ [2]	No preheating; Maximum heat input: 4.1 kJ/mm·CO_2
	Lower flange	t = 50 mm	○ [2]	No preheating; Maximum heat input: 4.1 kJ/mm·CO_2

◎ Excellent ○ Similar

In spite of being 570 N/mm^2-grade high-strength steel, SBHS500 has workability similar to that of SM490Y.

Assessment of Workability of SBHS500

[1] Results of Assessment Test for Assembly Weldability



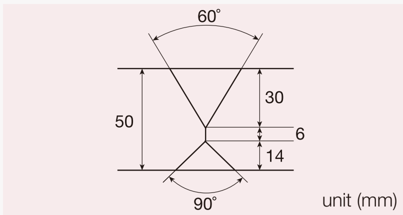
Steel grade	SBHS500		Conventional steel	
PCM	≤ 0.20		≤ 0.22	General
Weld length	20 mm	50 mm	50 mm and over*	80 mm and over
Assessment result	No cracking	No cracking	Provision in Specifications for Highway Bridges	

*In the case when heavier plate thickness is 12 mm and under

Confirmation that no cracks occurred in welds with a weld length of 20 mm during assembly welding (conventional steel: 80 mm and over)

[2] Assessment Results for Effect of Interpass Temperatures

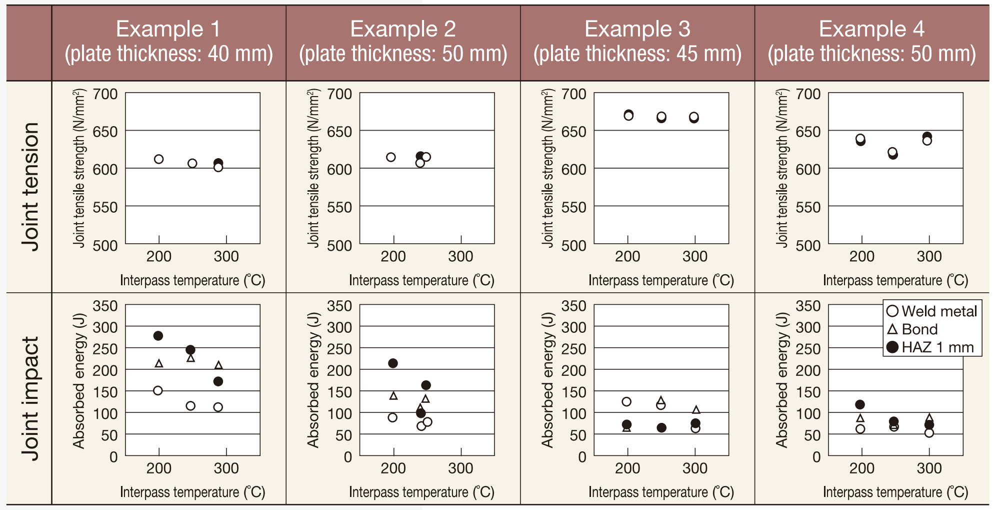
(1) Example in x groove



(2) Example of welding condition

Welding method	Welding side	Layer No.	Electrode	Heat input (kJ/mm)	Interpass temperature (℃)
SAW	1st side and 2nd side	1	–	≤ 5	3 grades ① 200 and under ② 250 and under ③ 300 and under
		2nd layer to final layer	L	≤ 10	
			T		

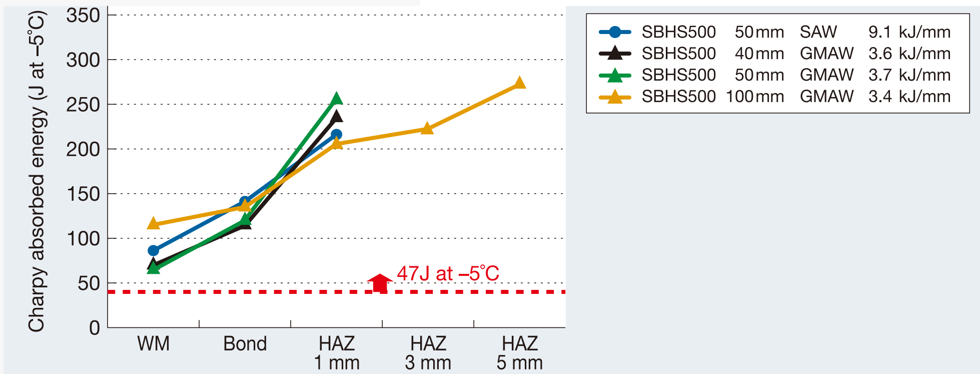
(3) Assessment of Weld Joint Performance



Confirmation of appropriate weld joint performance at an interpass temperature of 300°C and under (conventional steel: 230°C and under*)

*Required performance of weld joint described in HBS (Standards of Honshu-Shikoku Bridge Authority)

[3] Results of Assessment of Weld Joint Toughness



Applicability for large heat-input welding (10 kJ/mm and under) similar to that of SM490Y

High-Strength Steel

Scope

The thickness of plates to be applied can be reduced and structural weight can be decreased through the use of high-strength steel. Many application advantages — such as longer spans, efficient transport and erection, and also efficient fabrication and welding are brought about.

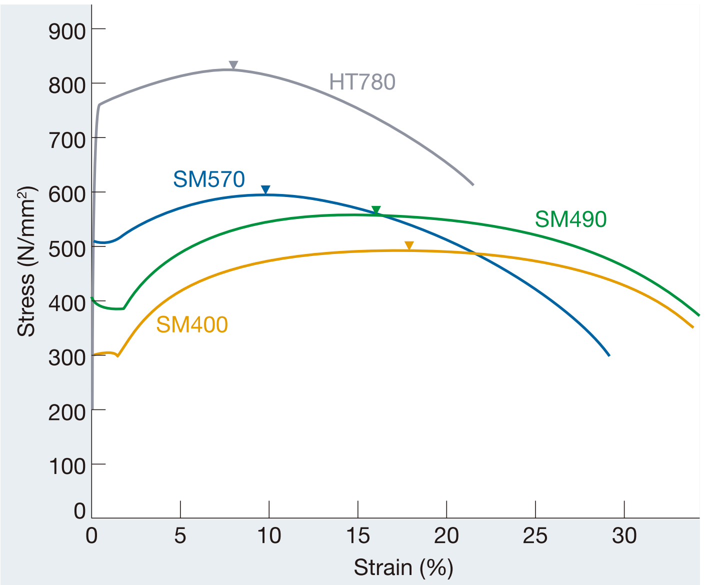
Material Characteristics

Standards for High-Strength Steel

Strength ratings	Standards
Steel of 690 N/mm² grade	HBS G3102 HT70 WES 3001 HW550
Steel of 780 N/mm² grade	HBS G3102 HT80 WES 3001 HW685 JIS G3128 SHY685
Steel of 950 N/mm² grade	WES 3001 HW885

HBS : Honshu-Shikoku Bridge Standard
WES : Japan Welding Engineering Society Standards
JIS : Japanese Industrial Standards

Stress-Strain Curves of Each Grade



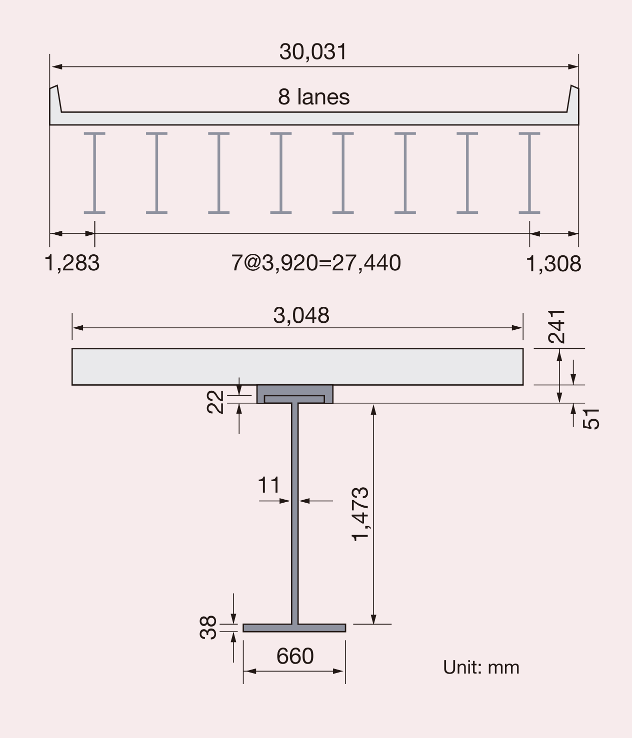
Yield Point, Tensile Strength and Allowable Stress of Each Grade

Grade	Thickness (mm)	Strength (N/mm²)		
		Yield point	Tensile strength	Allowable stress
SS400 SM400 SMA400W	t ≤ 40	235	400	140
	40 < t ≤ 75	215	400	125
	75 < t ≤100	215	400	125
SM490	t ≤ 40	315	490	185
	40 < t ≤ 75	295	490	175
	75 < t ≤100	295	490	175
SM490Y SM520C SMA490W	t ≤ 40	355	490	210
	40 < t ≤ 75	335	490	195
	75 < t ≤100	325	490	190
SM570 SMA570W	t ≤ 40	450	570	255
	40 < t ≤ 75	430	570	245
	75 < t ≤100	420	570	240
HT690	t ≤100	590	690	355
HT780	t ≤100	685	780	—
HT950	t ≤100	885	950	—

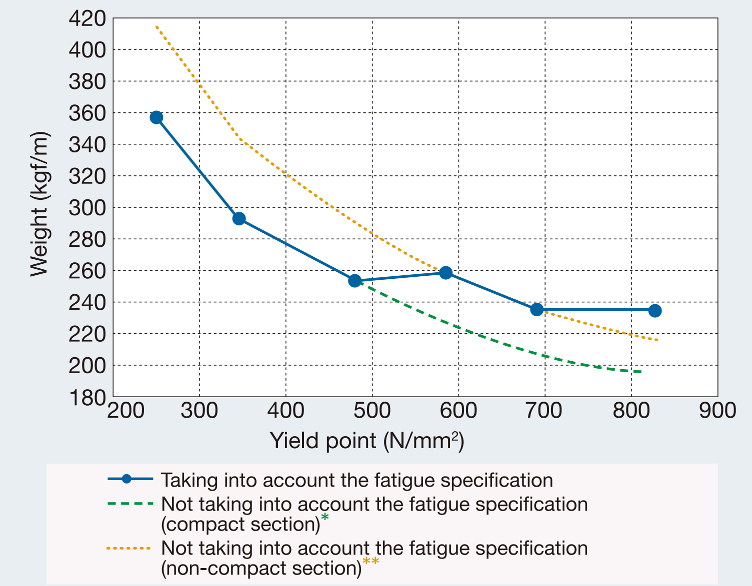
Application Benefits

Trial calculation example based on AASHTO (composite plate girder)
Conditions: Simple girders having 33 m span

Dimensions of the Bridge Subjected to the Study



Relationship between Yield Point and Steel Weight



*Compact section: Heavy-thick section for which sectional plastic deformation is expected in the ultimate state
**Non-compact section: Thin-thick section for which buckling is dominant in the ultimate state
(J. Murakoshi: Applicability of High-strength Steel in Bridges Examined from the Strength Characteristics, Civil Engineering Journal, Public Works Research Institute, Ministry of Construction, 38-2, 1996)

Application Examples

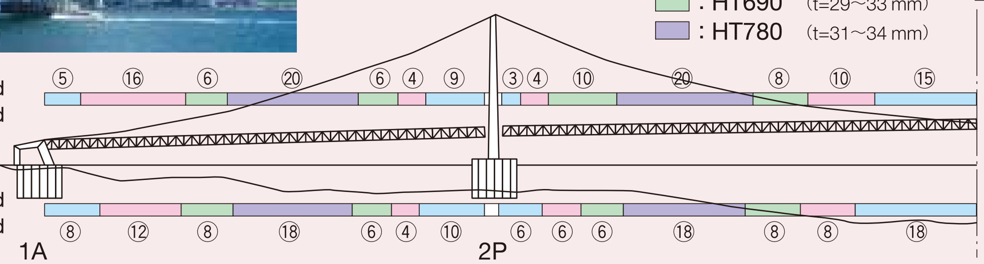
High-strength steel of 690 and 780 N/mm² grades is in wide use in long suspension, cable-stayed, truss and other bridges.

Akashi Kaikyo Bridge

Steel products used for upper and lower chords of superstructure

The figure in ○: Number of panel

: SM490Y (t=25~30 mm)
: SM570 (t=26~33 mm)
: HT690 (t=29~33 mm)
: HT780 (t=31~34 mm)



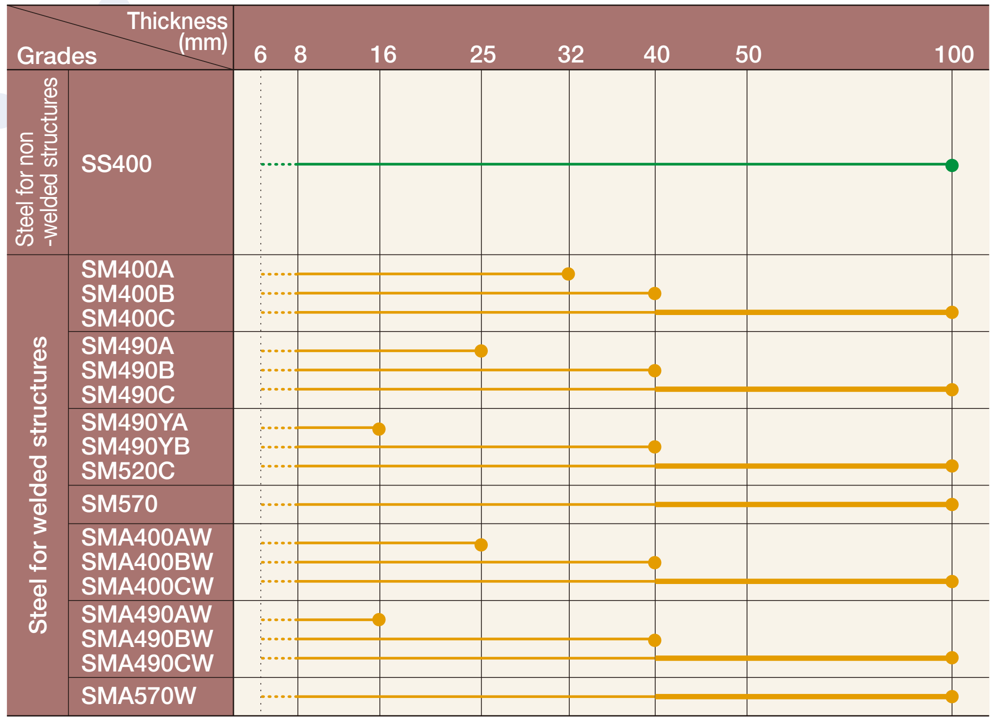
Source: Honshu-Shikoku Bridge Authority

Steel with Constant Yield Point
(Thickness : Over 40 mm)

Scope

As shown below, the applicable thickness has been increased up to 100 mm following the revision of the Specifications for Highway Bridges in December 2002. Under the revision, it is possible to use steel plates of thickness exceeding 40 mm with guaranteed no variation in the lower limits in yield point or proof stress depending on thickness. These steels are called “Steel with Constant Yield Point” and already have rich application records.

Selection Criteria for Steel Grades According to Thickness



Bold line: Steel with constant yield point (-H) can be applied.
(Specifications for Highway Bridges-Part II . Steel Bridges, Japan Road Association)

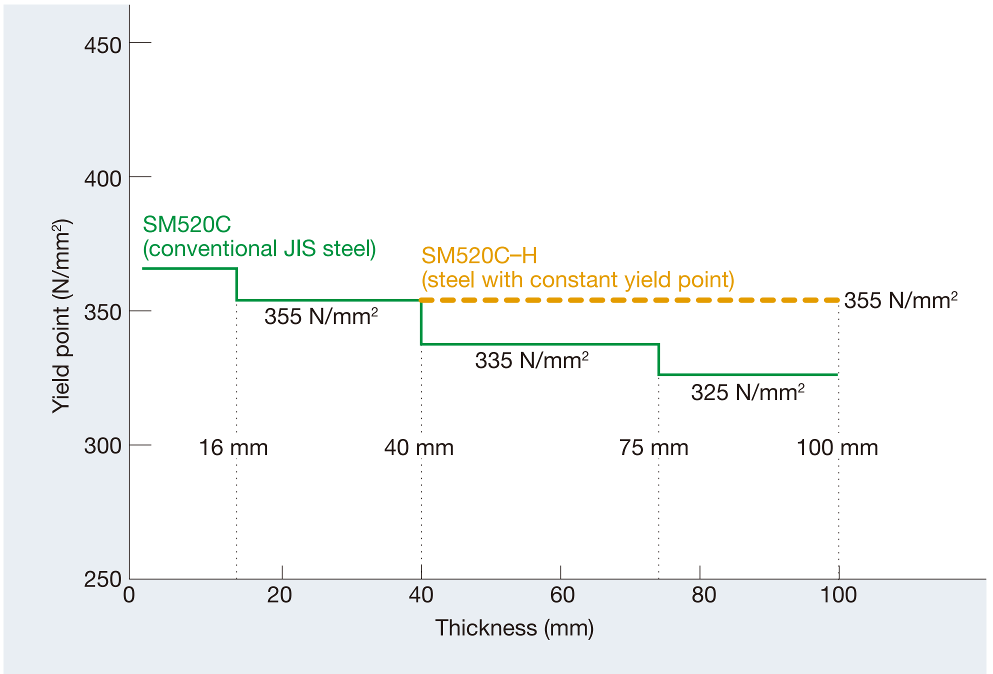
Material Characteristics

The thickness range of steel with constant yield point is 40~100 mm. The steel guarantees the yield point specified for conventional JIS materials with thicknesses not more than 40 mm and the steel designation has the suffix “-H” in addition to designation in JIS.

Comparison of Yield Point between Steel with Constant Yield Point and Conventional JIS Materials

Yield point or proof stress of steel with constant yield point (N/mm²)		Yield point or proof stress of conventional JIS steel (N/mm²)			
Designation	Thickness (mm) 40 < t ≤100	Designation	Thickness (mm) 16 < t ≤40	40 < t ≤75	75 < t ≤100
SM400C–H SMA400CW–H	235 and over	SM400C SMA400CW	235 and over	215 and over	215 and over
SM490C–H	315 and over	SM490C	315 and over	295 and over	295 and over
SM520C–H SMA490CW–H	355 and over	SM520C SMA490CW	355 and over	335 and over	325 and over
SM570–H SMA570W–H	450 and over	SM570 SMA570W	450 and over	430 and over	420 and over

Comparison of Yield Point between SM520C and SM520C-H



Application Benefits

The allowable stress of the steel with constant yield point conforms to the values listed in the table below regardless of thickness, based on the yield point guarantee in the table at left. Steel weight reduction provides an economic benefit and complexity in design can be avoided through the use of steel with constant yield point.

Allowable Tensile Stresses in Axial Direction and in Bending one (N/mm²)

Steel with constant yield point	Thickness (mm)	SM400C–H SMA400CW–H	SM490C–H	SMA490YC–H SM520C–H SMA490CW–H	SM570–H SMA570W–H
	40 < t ≤100	140	185	210	255

Conventional JIS steel	Thickness (mm)	SM400 SMA400W	SM490	SMA490Y SM520C SMA490W	SM570–H SMA570W–H
	t ≤40	140	185	210	255
	40 < t ≤75	125	175	195	245
	75 < t ≤100	125	175	190	240

Steel with Narrow Range of Yield Point Variation and Steel with Low Yield Ratio

Scope

The plastic design is adopted in steel-frame building construction in Japan, and thus the building's safety at a time of earthquake depends largely on the plastic deformation capability of the steel products applied.

Accordingly, for JIS-SN400 (B, C) and 490 (B, C) steels widely used in steel-frame building construction and high performance steel of the 590 N/mm² grade (SA440) for building structures, it is guaranteed that the margin between the upper and lower limits in yield point falls within a narrow range of 120 N/mm² for the SN steel and 100 N/mm² for the SA steel, and further that the yield ratio for both grades is less than 80%.

As a result, these steel products are expected to demonstrate excellent deformation capability at a time of earthquake.

Material Characteristics

Mechanical Properties of JIS-SN400 and 490, and SA440

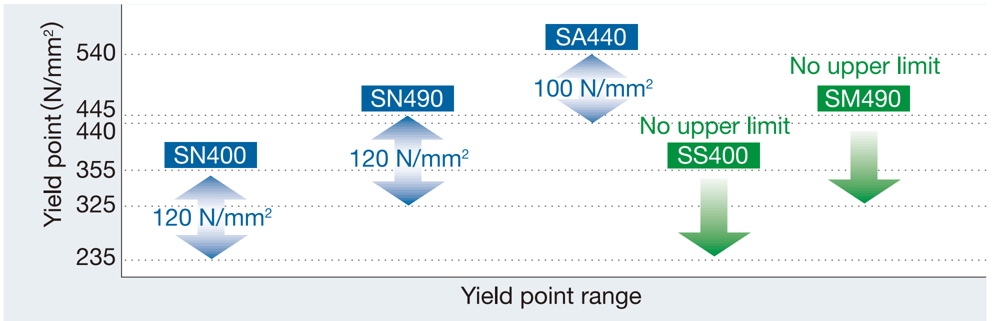
Standards	Yield point or proof stress (N/mm²)		Tensile strength (N/mm²)	Yield ratio (%)	Elongation (%)	
SN400B SN400C	16 < t ≤ 40 235 to 355, incl.	40 < t ≤ 100 215 to 335, incl.	400 to 510, incl	80 and under	No. 1A specimen 16 < t ≤ 50 22 and over	No. 4 specimen 40 < t ≤ 100 24 and over
SN490B SN490C	16 < t ≤ 40 325 to 445, incl.	40 < t ≤ 100 295 to 415, incl.	490 to 610, incl	80 and under	No. 1A specimen 16 < t ≤ 50 21 and over	No. 4 specimen 40 < t ≤ 100 23 and over
SA440B SA440C	440 to 540, incl		590 to 740, incl	80 and under	No. 4 specimen 20 and over	No. 5 specimen 26 and over

Notes
❶ Omission of the standards for SN steel with thicknesses of 16 mm and under
❷ Applicable thickness of SA440: 19 mm to 100 mm, incl.
❸ Yield ratio = (Yield point or proof stress/tensile strength)×100

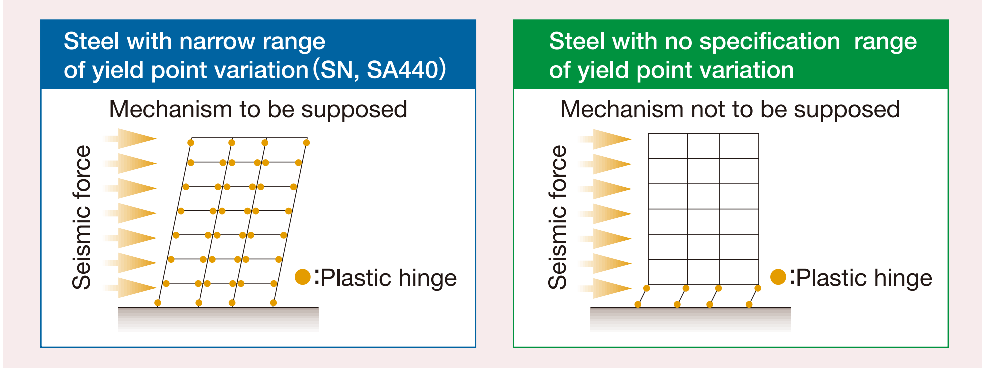
Application Benefits

❶ Steel with Narrow Range of Yield Point Variation

In the case of using this type of steel in building construction, the entire building structure can be expected to show the designed plastic deformation behavior.

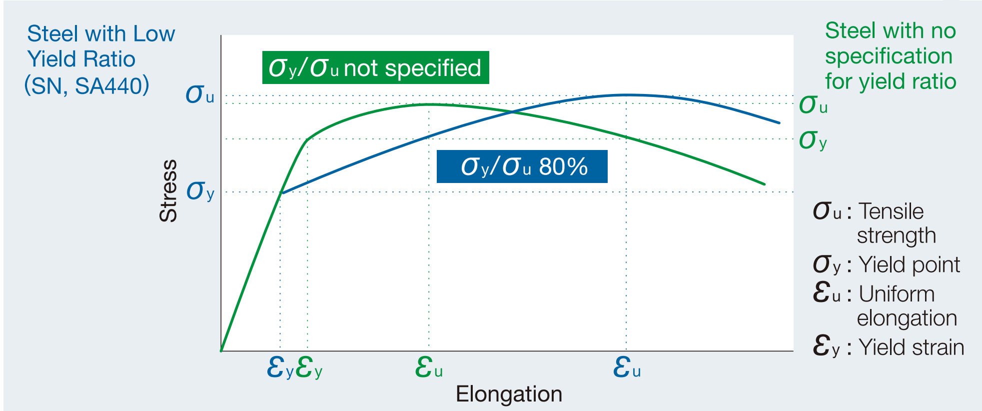


Deformation Behaviors of Structures Employing the Steel with Narrow Range of Yield Point Variation

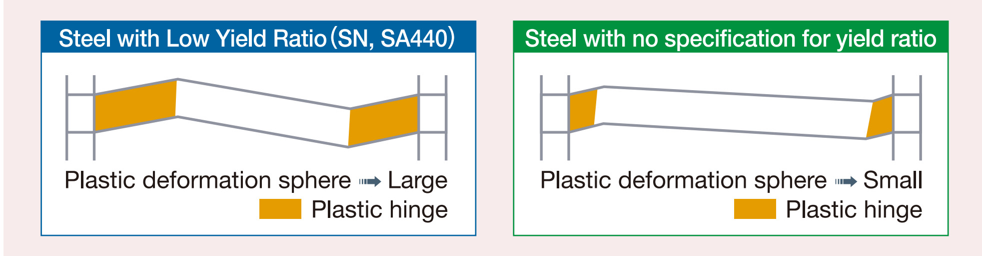


❷ Steel with Low Yield Ratio

In the structural members employing steel with low yield ratio, plastic deformation occurs over a wider range, and as a result these members demonstrate excellent deformation capability.



Improvement in Deformation Capability of Structures Employing Steel with Low Yield Ratio



Low Yield Point Steel

Scope

Low yield point steel features a low yield point, excellent elongation performance (high ductility) and is used in seismic dampers for building structures. Earthquake input energy is absorbed by plastic deformation of seismic dampers employing this type of steel, and thus oscillations of building structures can be reduced.

Material Characteristics

Steels of 100 and 225 N/mm² yield point grades are used for seismic dampers of building structures.

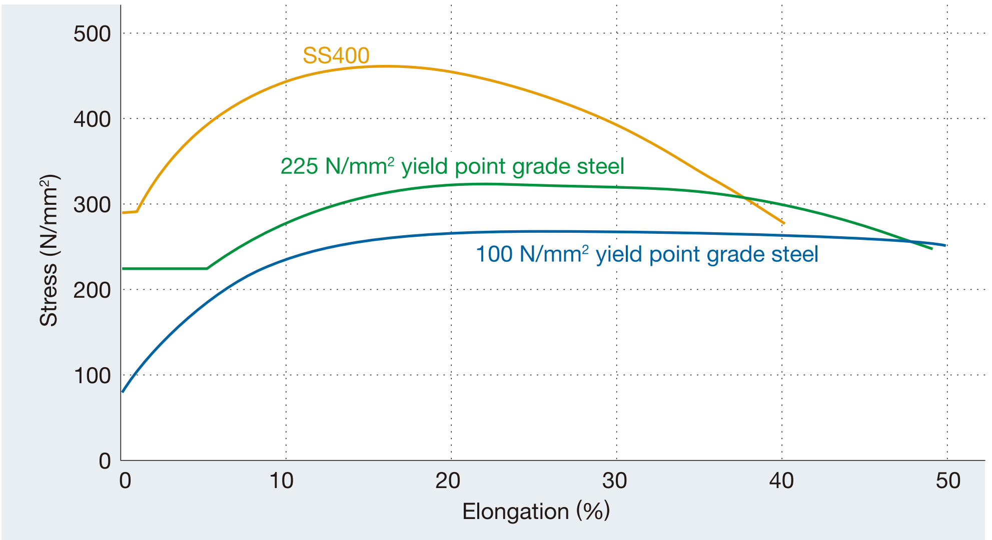
❶ Mechanical Properties

Designation	Low yield point or proof stress (N/mm²)	Tensile strength (N/mm²)	Yield ratio (%)	Elongation	
				Test specimen	(%)
LY100	80～120	200～300	≤60	JIS Z 2201 No.5	50≤
LY225	205～245	300～400	≤80		40≤

❷ Chemical Composition

Designation	C	Si	Mn	P	S	N
LY100	≤0.01	≤0.03	≤0.20	≤0.025	≤0.015	≤0.006
LY225	≤0.10	≤0.05	≤0.50	≤0.025	≤0.015	≤0.006

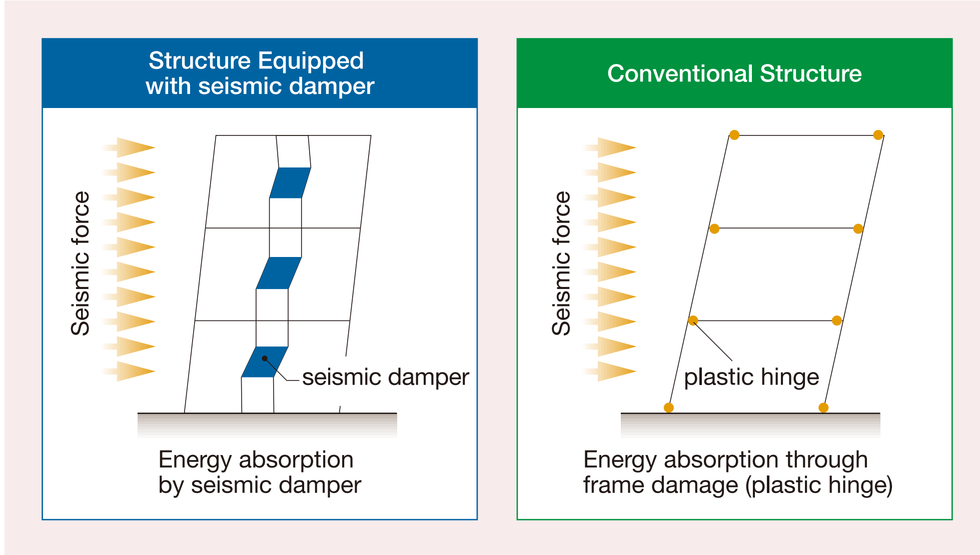
❸ Example of Stress-Strain Curves



Application Benefits

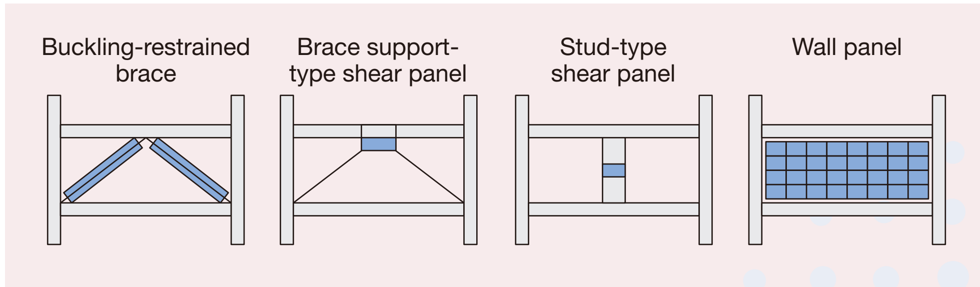
Comparison of earthquake response between a structure equipped with seismic damper and a conventional structure is shown below.

Comparison of Earthquake Response between Structure Equipped with Seismic Damper and Conventional Structure



Application Examples

Building seismic damper application is shown below.



Buckling-restrained brace

Wall panel

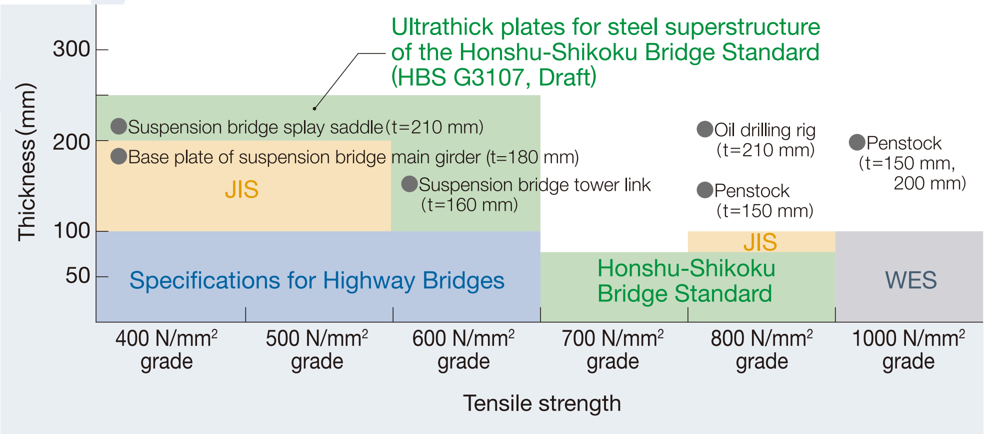
Ultrathick Plate

Scope

Application of ultrathick plates allows construction of larger-size structures. When ultrathick plates are used for bridge structures, the structures can be simplified due to reduction in the number and sectional area of structural members applied.

Material Characteristics

Examples of specified maximum thickness of steel plates in several specifications or standards, and major application examples in steel structures are as follows:

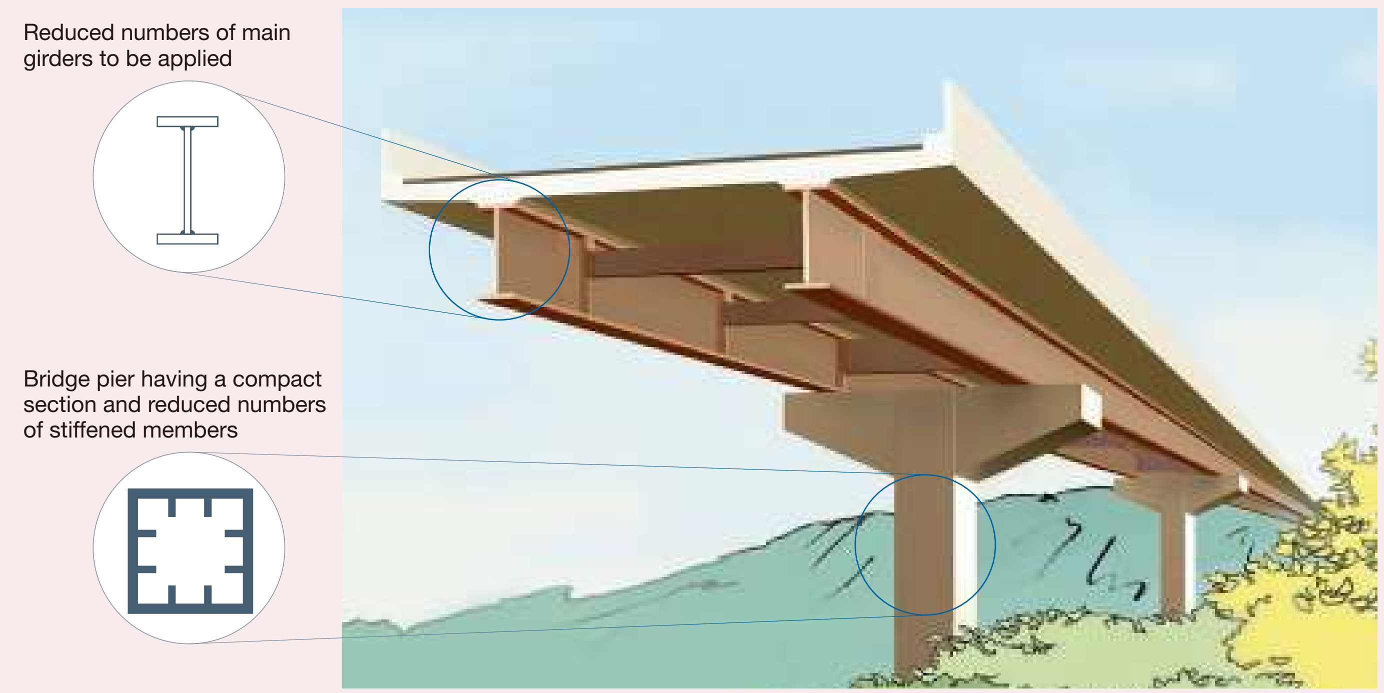


A standard covering ultrathick plates with thickness over 100 mm for bridge applications is prepared — Ultrathick Plates for Steel Superstructure of the Honshu-Shikoku Bridge Standard (HBS G3107, Draft). This standard prescribes ultrathick plates for main tower base plates, splay saddles, tower links and other suspension bridge members.

Application Benefits

- The application of ultrathick plate allows not only compact structural sections but also a reduction in the number of main girders to be applied and the elimination of stiffened girders. The end result is a large numerical reduction in the fabrication processes of bridge members.
- The section's plastic deformation can be expected, and therefore deformation capacity becomes large.

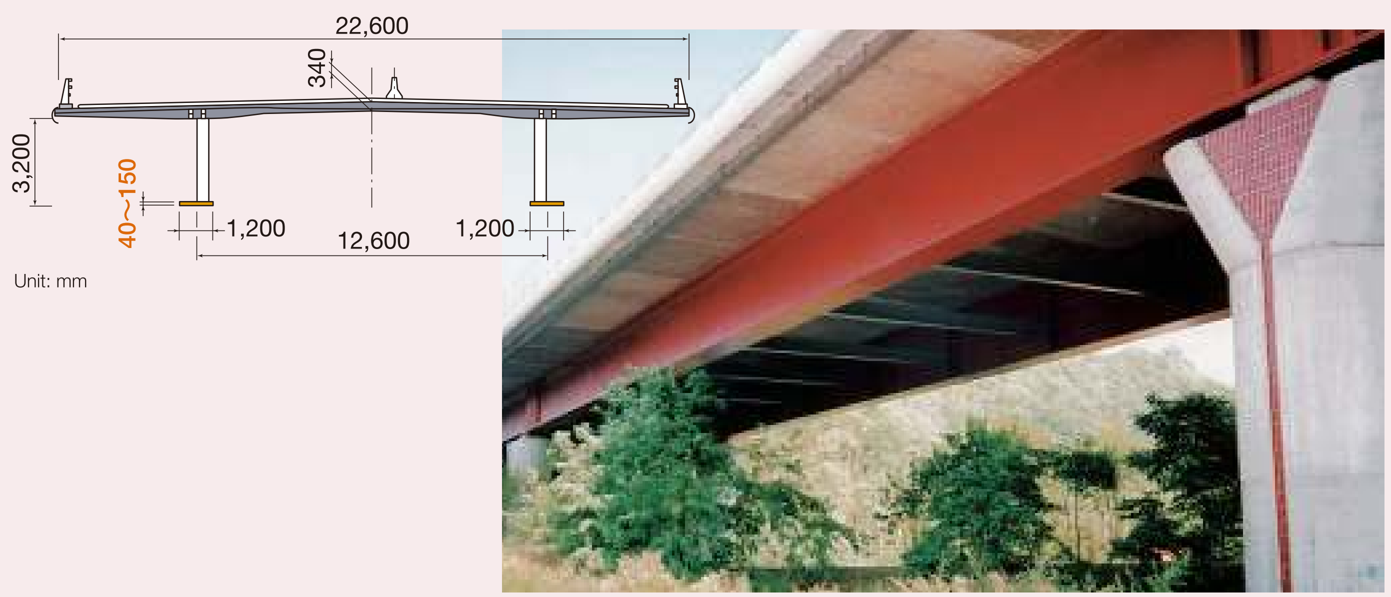
Illustration of Applications of Ultrathick Plate Members



Application Examples

In the United States and Europe, steel plates with thickness over 100 mm are conventionally used in bridge construction.

Application Example in France



Example of application in minimum girder bridges in Japan (Tokai-Oobu viaduct: SM570, maximum plate thickness 75 mm)

Application in Base Plate of Suspension Bridge Main Tower (SS400 t=180 mm)

Courtesy: Honshu-Shikoku Bridge Authority

Steel with Excellent Toughness

Scope

Application of steel with excellent toughness has such advantages as:
❶ Cold forming is possible with smaller bending radius.
❷ Application of steel products can be expanded in cold regions.

Along with progress in production technology, it has recently become possible to manufacture steel plates having excellent toughness.

Material Characteristics

❶ Cold Bending

The section of steel products in which strain occurs due to cold bending poses the problem of toughness decline, and accordingly the Specifications for Highway Bridges prescribe that as a basic rule the inside bending radius should be more than 15 times the thickness.

However, where sufficient toughness can be secured for the section of steel products subjected to cold bending, the Specifications stipulate cold bending within the inside bending radius more than 5 times the thickness. Practically, cold bending restrictions are eased for steel plate for which the following conditions are guaranteed.

- N(nitrogen) content in the steel, 0.006% and under
- vE ≥ 150J* → Inside bending radius ≥ 7t (t: thickness)
- vE ≥ 200J* → Inside bending radius ≥ 5t (t: thickness)

*The value at JIS-specified test temperature

Example of a truss bridge employing square steel tubes with bent sections (Takishita Bridge, Hokkaido)

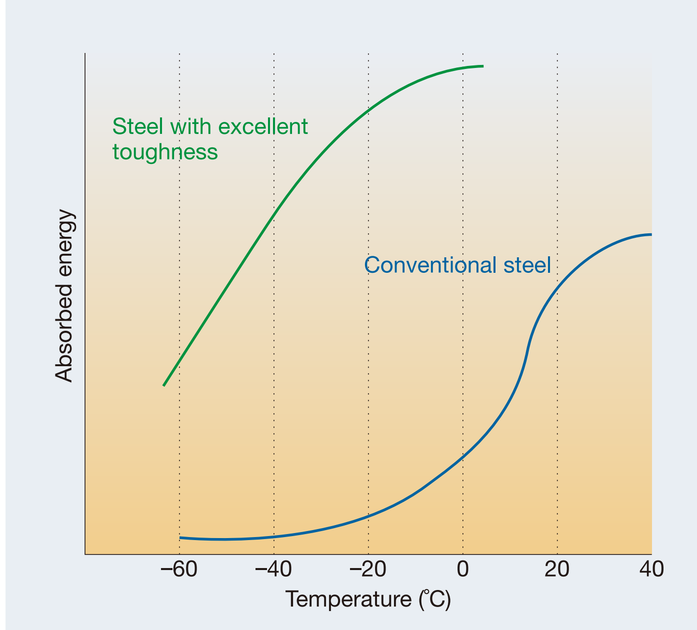
❷ Application in Cold Regions

The toughness of steel products decreases at low temperatures, and therefore countermeasures must be taken against brittle fracture. However, use of steel plates having appropriate toughness poses no problems in their application in cold regions.

Application Examples in Cold Region (Distribution of Lowest Temperatures in Hokkaido)

Source: Guidelines for Design and Construction of Steel Highway Bridges in Hokkaido, Research Committee on Steel Highway Bridges of Association for Civil Engineering Technology of Hokkaido

Example of Comparison in Impact Properties between Conventional Steel and Steel with Excellent Toughness



Application Examples

Cold Bending of the Corner Section

Steel bridge pier

Steel main girder

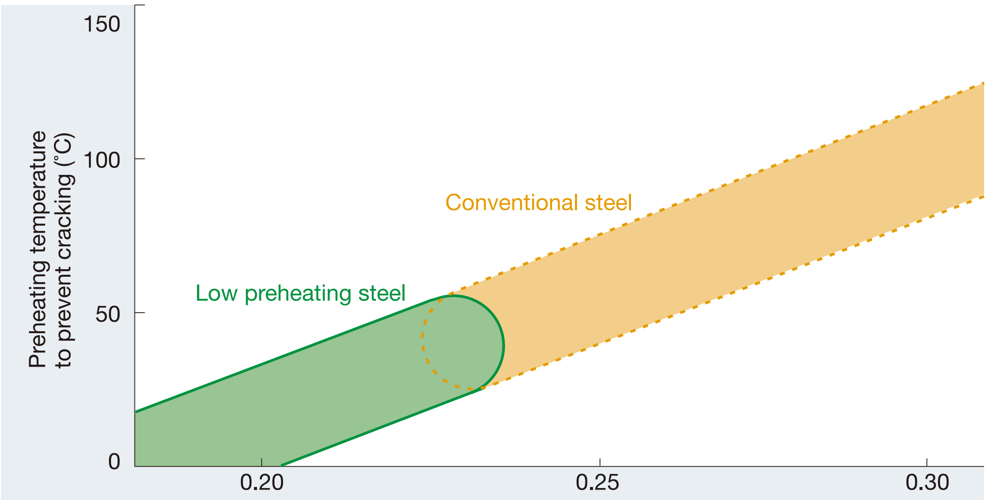
Low Preheating Steel

Scope

As bridge length increases, high-strength steel of more than 570 N/mm^2 in strength rating is increasingly adopted for bridge girders. In bridge construction employing high-strength steel and heavy-thick steel, steel products must be preheated just prior to welding in order to prevent cold cracking of the welds. However, on-site preheating at 100°C or higher presents a heavy burden not only with regard to work control but also for the welding operators. Application of low preheating steel permits reduction or elimination of preheating and incidental work.

Material Characteristics

Low preheating steel is designed with a low cracking parameter of material, and therefore preheating temperature during welding can be lowered.



P_{CM} (%) = C + Si/30 + Mn/20 + Cu/20 + Ni/60 + Cr/20 + Mo/15 + V/10 + 5B

Application Benefits

Application of low preheating steel (low P_{CM} steel) allows considerable lowering of the preheating temperature.

Example of Effect of Lowering of Preheating Temperature in Submerged Metal Arc Welding (SMAW)

Steel grade	P_{CM}	Thickness (mm)			
		t ≤ 25	25 < t ≤ 40	40 < t ≤ 50	50 < t ≤ 100
SMA400 SMA400W	Standard P_{CM} (preheating temperature)	0.24 (no preheating)		0.24 (50°C)	
	P_{CM} requiring no preheating	—		0.22	
SMA490 SMA490Y	Standard P_{CM} (preheating temperature)	0.24 (no preheating)	0.26 (50°C)	0.26 (80°C)	0.27 (80°C)
	P_{CM} requiring no preheating	—	0.24	0.22	
SMA520C SMA570 SMA490W	Standard P_{CM} (preheating temperature)	0.24 (no preheating)	0.27 (80°C)		0.29 (100°C)
	P_{CM} requiring no preheating	—	0.24	0.22	

Standard P_{CM}, standard preheating temperature (Specifications for Highway Bridges, Japan Road Association, March 2012)

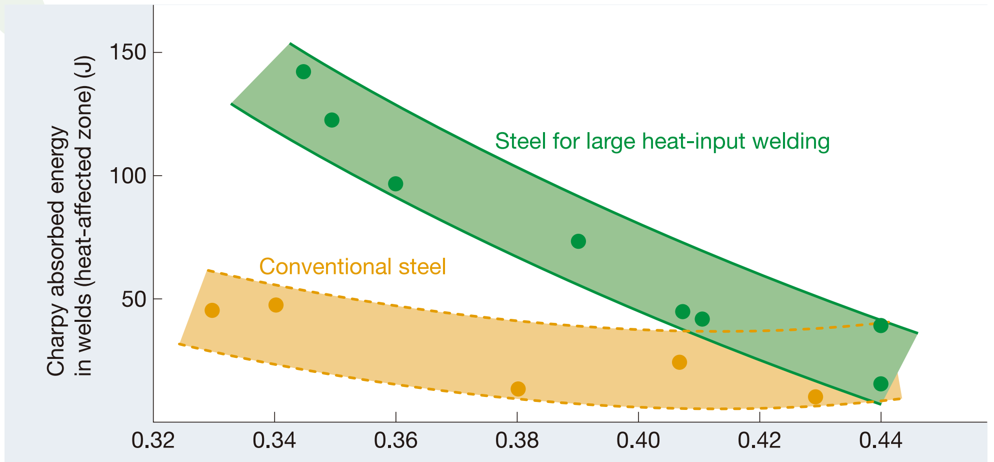
Steel for Large Heat-input Welding

Scope

Along with advancing automation in welding, large heat-input welding is increasingly used. In general, as weld heat-input is increased, weld quality tends to deteriorate. Application of steel for large heat-input welding contributes to improved welding quality as well as higher welding efficiency.

Material Characteristics

Examples of welding qualities are shown below.

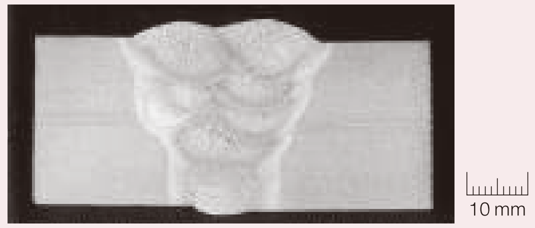


C_{eq} (%) = C + Mn/6 + Si/24 + Ni/40 + Cr/5 + Mo/4 + V/14

Application Examples

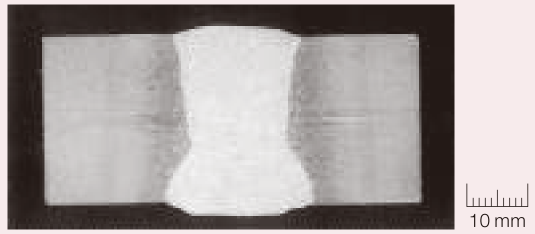
Application of steel for large heat-input welding allows greater reduction in the number of welding passes.

Example of on-site welding of main girder web (Electro-gas welding employing large heat-input welding)



CO_2 shielded gas welding method (7 passes, heat input 30 kJ/cm)

Improved welding efficiency



Example of large heat-input welding joint (1 pass, heat input 150 kJ/cm)

Macroscopic photos showing comparison of weld joint sections

Steel with Lamellar-tearing Resistance

Scope

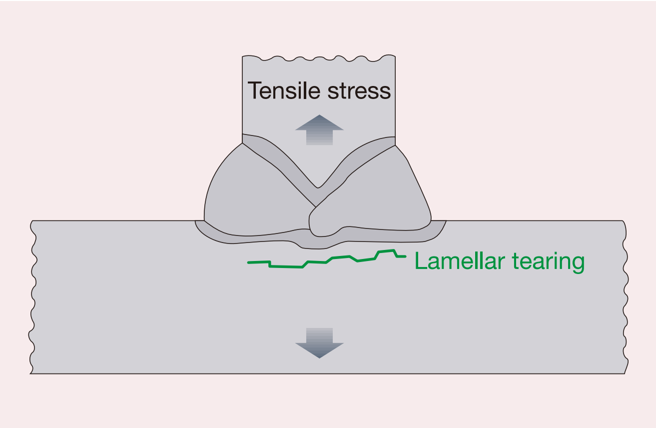
Along with recent trends in the scaling-up and complexity of steel structures, the use of structural members with welded joints that are subjected to large tensile stress in the thickness direction is unavoidably increasing in steel bridge construction from the structural, functional and aesthetic viewpoints. These structural members may suffer from lamellar-tearing after welding. Therefore, the application of steel with lamellar-tearing resistance is recommended in the Specifications for Highway Bridges in Japan.

Material Characteristics

Lamellar tearing is a phenomenon of cracking parallel to the surface of steel plates and can occur in welded joints subjected to tensile stress like cruciform, T- and corner joints. Non-metallic inclusions (mainly MnS) and root cracking can become the initiation site of lamellar tearing.

Although lamellar-tearing resistance can be directly confirmed by the Z-window type restraint weld cracking test, it is generally evaluated by the reduction of area measured by the through-thickness direction tensile test and S (sulfur) content in the steel. Lamellar tearing-resistant steel that guarantees the value of the reduction of area is specified in WES 3008 (Japan Welding Engineering Society Standards) and JIS G3199 (Japanese Industrial Standards), in which the non-metallic inclusions contained in the steel decreases and alloy segregation diminishes.

Illustration of Lamellar Tearing



Relationship between Reduction of Area in the Through-thickness Direction Tensile Test and S Content (WES3008-1990)

Reduction of Area measured by the Through-thickness Direction Tensile Test of Steel with Lamellar-tearing Resistance Specified in JIS G 3199

Class	Average value of three specimens	Value of each specimen	S content (%)	
Z15(S)	15% and over	10% and over	0.010 and under	(To be applied according to agreement between the user and the supplier)
Z25(S)	25% and over	15% and over	0.008 and under	
Z35(S)	35% and over	25% and over	0.006 and under	

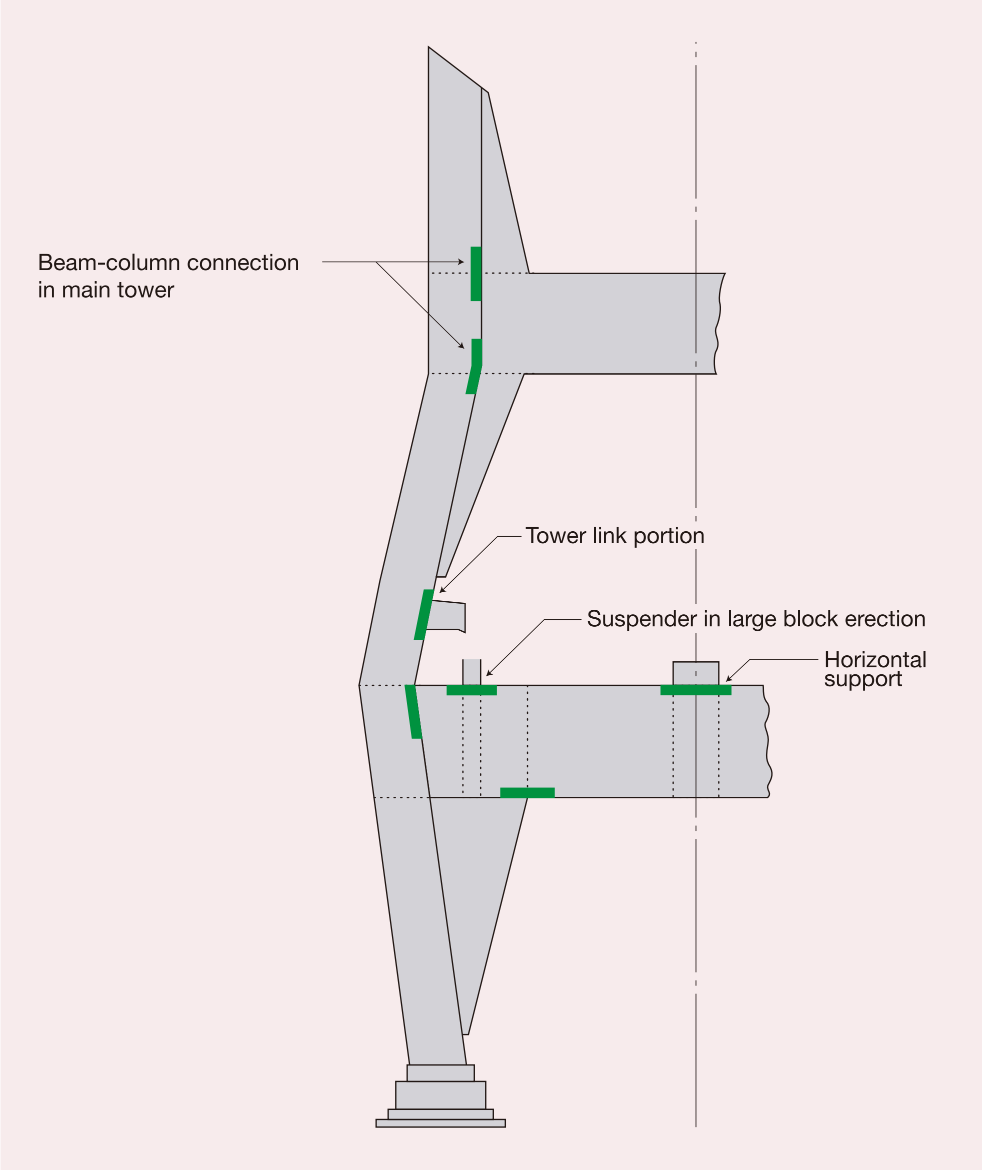
Reference: Classification according to WES 3008.
"S" is attached when S content is specified.

Application Benefits

For welded structural members in which lamellar tearing is suspected, the use of lamellar-tearing resistant steel and appropriate welding procedure can preclude lamellar tearing.

Application Examples

Locations Where Lamellar-tearing Resistant Steel can be Applied



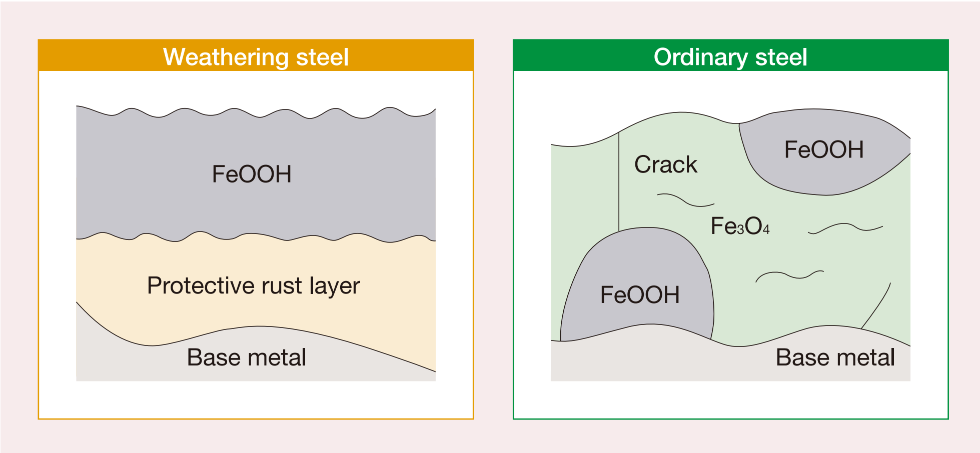
Weathering Steel

Scope

Weathering steel can dispense with painting because of its characteristics that the development of rust is controlled steadily with the lapse of time. As a result, maintenance costs can be significantly reduced.

Rust on Weathering Steel	Rust on Ordinary Steel
● Dense and tightly adherent ● Anti-ion-penetration capability	● Porous and fragile ● Easy ion penetration
Suppresses the development of rust after a certain time lapse	**Corrosion reaction continues and rust develops**

Schematic Drawing of Rust Layers of Weathering and Ordinary Steels Exposed for Long Time



Material Characteristics

Weathering steel for bridge construction is specified in JIS — JIS G3114 Hot-rolled Atmospheric Corrosion Resisting Steels for Welded Structures (SMA series).

Hot-rolled Atmospheric Corrosion Resisting Steels for Welded Structures (JIS G 3114)

Designation	Yield point or proof stress (N/mm^2)						Tensile strength (N/mm^2)	Charpy absorbed energy	
	t ≤ 16 mm	16 < t ≤ 40	40 < t ≤ 75	75 < t ≤ 100	100 < t ≤ 160	160 < t ≤ 200		Testing temperature	Absorbed energy
SMA 400 AW/AP	245 and over	235 and over	215 and over	215 and over	205 and over	195 and over	400 ～ 540	—	—
SMA 400 BW/BP								0℃	27J and over
SMA 400 CW/CP	245 and over	235 and over	215 and over	215 and over	—	—		0℃	47J and over
SMA 490 AW/AP	365 and over	355 and over	335 and over	325 and over	305 and over	295 and over	490 ～ 610	—	—
SMA 490 BW/BP								0℃	27J and over
SMA 490 CW/CP	365 and over	355 and over	335 and over	325 and over	—	—		0℃	47J and over
SMA 570 W/P	460 and over	450 and over	430 and over	420 and over	—	—	570 ～ 720	-5℃	47J and over

Reference: In general, "W" steel is used unpainted or with rust stabilization treatment, and "P" steel is used painted.

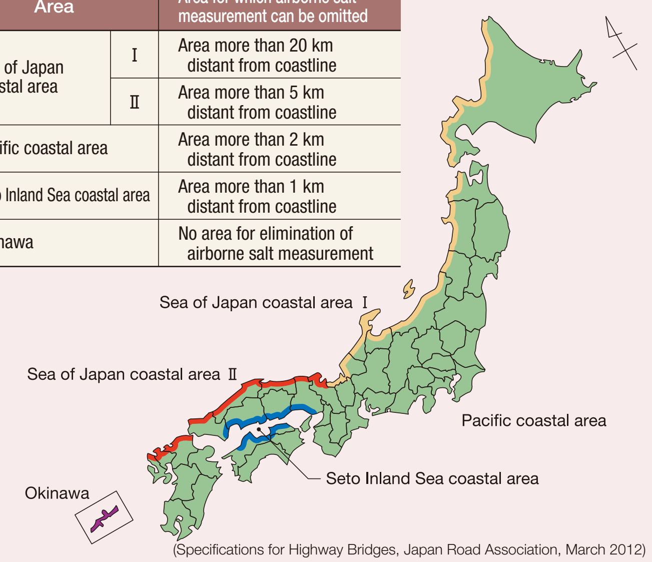
Cautions in the Use of Weathering Steel

❶ Considerations to be made in the planning stage (effect of airborne salt)

- In areas with airborne salt levels at 0.05 mdd (mg/100 cm²/day) or lower, weathering steel can be applied in an unpainted state.
- The following figure shows the standard areas where measurements of airborne salt can be eliminated and unpainted weathering steel can be applied. (Airborne salt measurement method: the dry gauze method specified in JIS Z2381 or the method specified by Public Works Research Institute)

Unpainted Weathering Steel Applicable Areas

Area		Area for which airborne salt measurement can be omitted
Sea of Japan coastal area	Ⅰ	Area more than 20 km distant from coastline
	Ⅱ	Area more than 5 km distant from coastline
Pacific coastal area		Area more than 2 km distant from coastline
Seto Inland Sea coastal area		Area more than 1 km distant from coastline
Okinawa		No area for elimination of airborne salt measurement



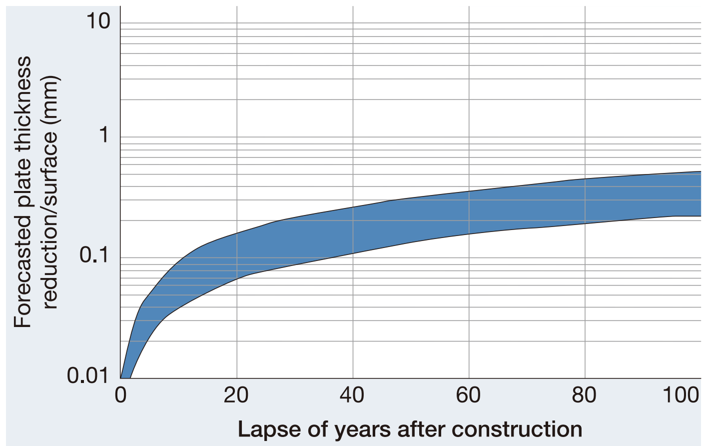
(Specifications for Highway Bridges, Japan Road Association, March 2012)

❷ Diagram for Forecasting Plate Thickness Reduction

In areas where the amount of airborne salt is 0.05 mdd or lower, the forecasted reduction of plate thickness after 100 years of application is minimal.

Plate Thickness Reduction Forecast Curve

(Airborne Salt Level: 0.05 mdd or lower)



(Calculated from test data of joint research by Public Works Research Institute of Ministry of Land, Infrastructure, Transport and Tourism, the Kozai Club and Japan Bridge Association)

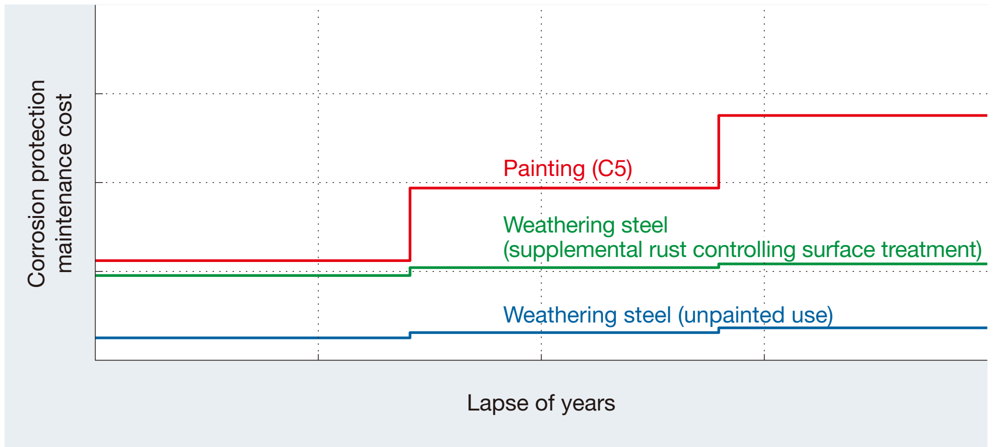
The curve in the above figure shows the range of forecasted plate thickness reduction, based on the horizontal exposure of test specimens between main girders at 22 locations nationwide for 9 years. (The exposure results have also been proved by the results of 17-year exposure tests.)

Application Benefits

Merits of Weathering Steel

- Reduction of lifecycle costs: Repainting can be eliminated.
- Mitigation of environmental burdens: Unpainted steel can be applied.
- Environmental harmonization: The attractive stabilized rust that over time forms on weathering steel surfaces harmonizes well with the natural surroundings.

Image of Lifecycle Cost



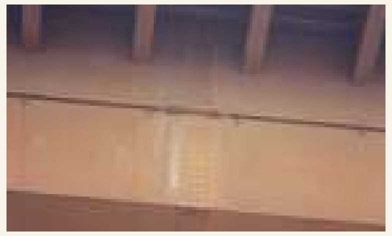
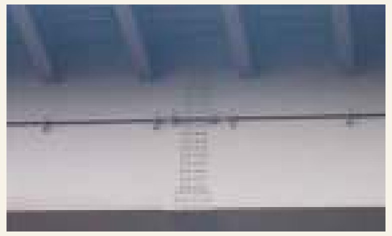
Application Examples

Unpainted Weathering Steel in Bridge Structure (Japan)

Reference: *(Example of secular change)*

At the initial stage of construction, non-uniform rusting can be found, but this changes to a uniform dark brown tone as time passes.

(Example of unpainted use)

Completion	About 2nd month ⇒	About 1st year ⇒	About 28th year
Distant view			
Close-range view			

Reference: *(Ni-type weathering steel)*

In contrast to conventional JIS weathering steel, the newly developed Ni-type weathering steel contains a quantity of nickel as a main element. Ni-type weathering steel is more resistant to airborne salt and has already been put into practical use.

Corrosion Resisting Steels For Repaint Term Extension

Scope

Corrosion resisting steels for repaint term extension comply with Japanese Industrial Standards for structural steel products such as SS (JIS G 3101), SM (JIS G 3106) and SBHS (JIS G 3140). In high salinity environments, they can prevent corrosion from coating defects compared to conventional steels.

Application Examples

Examples of application of corrosion resisting steels for repaint term extension are shown below. These steels had been applied to more than 100 bridges as of March 2024, mainly in high salinity regions such as coastal areas and where de-icing salt is sprayed.

Application of Corrosion Resisting Steels For Repaint Term Extension in Coastal Areas

Courtesy:NIPPON STEEL CORPORATION

Corrosion resisting steels for repaint term extension prevent corrosion and peeling of paint in deteriorated parts. Therefore, they are also effective to apply to parts of bridges where the corrosion environment is particularly severe, and where the coating thickness is difficult to control, such as girder ends, bearings, joints, and member ends.

Steel for Galvanizing

Scope

Hot-dip galvanizing is widely applied as a method of corrosion protection of steel products used for bridge construction. In hot-dip galvanizing, structural members are immersed in a high-temperature galvanizing bath, which poses the following problems:

- Dull gray surface due to galvanizing (surface discoloration)
- Cracking due to galvanizing (cracking due to zinc embrittlement and high strains)

Steel for galvanizing is provided with measures to prevent dull gray surface due to galvanizing and cracking due to zinc embrittlement.

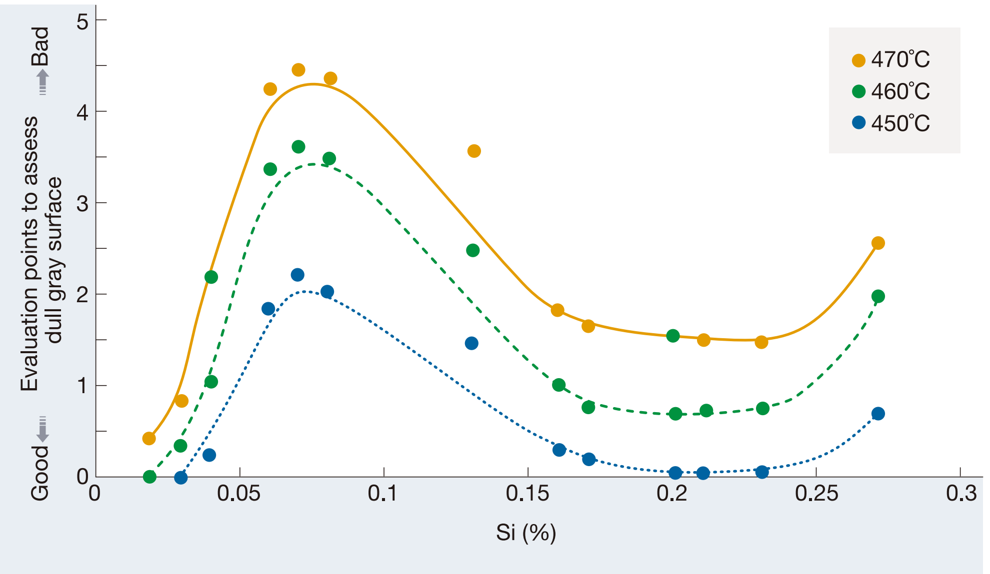
Material Characteristics

❶ Dull Gray Surface due to Galvanizing

Dull gray surface due to galvanizing concerns galvanizing temperatures and the amount of Si included in the steel (see figure below).

The figure shows that control of Si amount to 0.02% and under or 0.15~0.25% will improve the dull gray surface of the steel product during galvanizing.

Relationship between Evaluation Points to Assess Dull Gray Surface and Si Content



❷ Cracking due to Galvanizing

In the process of hot-dip galvanizing, zinc sometimes penetrates into the grain boundary of the heat-affected zone due to weld residual stress and thermal stress, which lowers the grain boundary's strength and causes cracking. This phenomenon is called cracking due to zinc embrittlement.

The relationship between zinc embrittlement of steel products and chemical composition was studied and clarified (see Equation 2). It became clear that in the case of 570 N/mm² grade steel, when the chemical composition parameter, S_{LM400}, satisfies Equation 1, cracking due to zinc embrittlement does not occur.

In the case of 570 N/mm² grade steel: $S_{LM400} \geq 53\%$ ——— ①

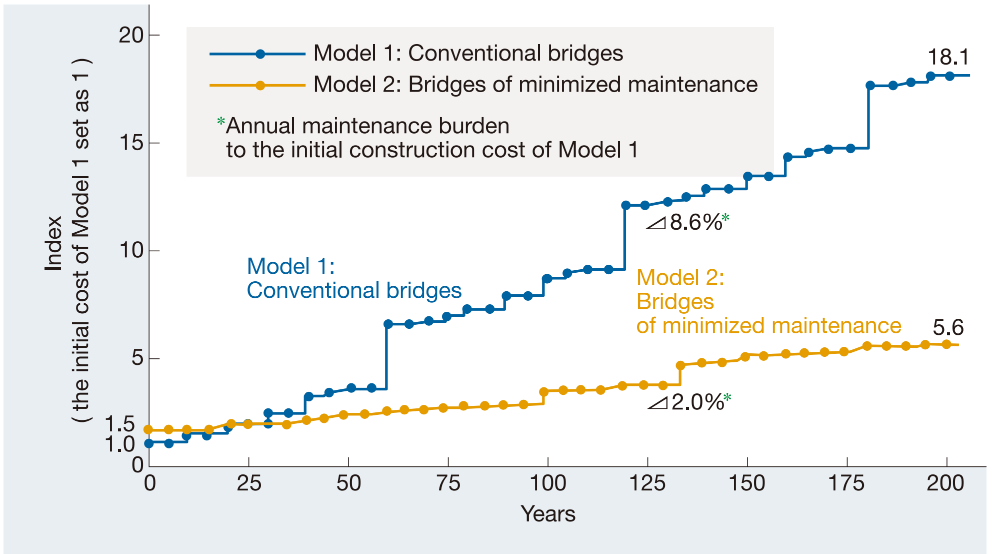
$$SLM400 = 227 - 320C - 10Si - 76Mn - 50Cu - 30Ni - 92Cr - 88Mo - 220V - 200Nb + 200Ti$$ ——— ②

In Equation 2, adjustment of chemical composition to satisfy Equation 1 allows production of steel products in which zinc embrittlement is improved.

Application Benefits

When galvanizing is adopted as a corrosion protection method for steel bridges, maintenance costs such as repainting are greatly reduced, thus leading to the reduction of the life-cycle cost (LCC) of steel bridges.

Example of LCC Assessment



Calculation Conditions of LCC Assessment

	Model 1		Model 2	
Replacement cycle	60 years		200 years	
Painting (coating film)	Chlorinated rubber paint	15 years	Galvanizing	130 years
Repainting	Chlorinated rubber paint	15 years	Zinc spraying	70 years
Slab	RC slab	40 years	PC slab	200 years
Slab maintenance	Partial maintenance after 20 years of service	20 years	Maintenance for joint section	50 years
Support	Steel support	30 years	Rubber support	100 years
Expansion device	Conventional specification	10 years	Minimized maintenance specification	20 years
Pavement	Ordinary asphalt365 and over	10 years	Modified asphalt	15 years
Water-proofing layer	Sheet water-proofing (pavement cycle)	10 years	Sheet water-proofing (pavement cycle)	15 years
Water-proofing layer replacement	Paint water-proofing (pavement cycle)	10 years	Paint water-proofing (pavement cycle)	15 years

(K. Nishikawa: A Concept of Minimized Maintenance Bridges, Bridge and Foundation Engineering, Aug. 1997)

Application Examples

A Bridge Constructed Using Galvanized Members

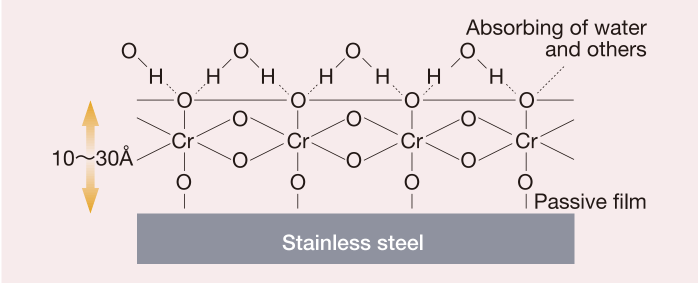
Structural Stainless Steel

Scope

Application of stainless steel makes possible construction of structures having excellent corrosion resistance.

In stainless steel production, more than 12% of Cr, which is liable to oxidize, is added to the steel, which forms a stable passive film on the steel surface. This passive film enhances corrosion resistance of stainless steel. If the passive film is damaged due to surface flaw, it offers an advantage that the film is recovered quickly due to Cr ions.

Passive Film of Stainless Steel

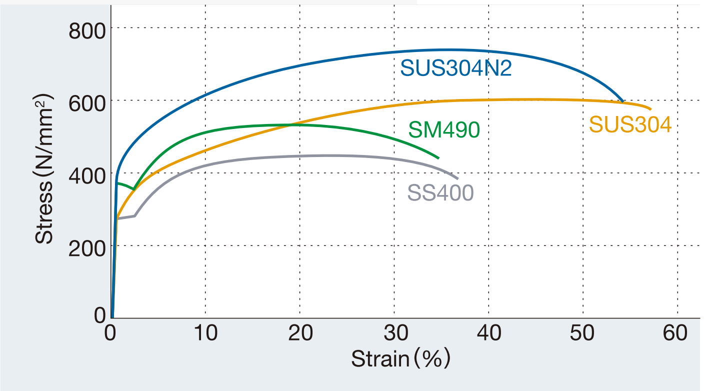


Material Characteristics

There are three kinds of stainless steel, which are used as structural materials:

❶ SUS304 (SS 400 grade strength)
❷ SUS316 (SS 400 grade strength+High corrosion resistance)
❸ SUS304N2 (SM 490 grade strength)

Stress–Strain Curve



Physical Properties of SUS304

Steel	SUS304	Mild steel	SUS304/Mild steel
Density g /cm³	7.93	7.86	1.01
Specific electric resistance μΩ–cm (room temperature)	72	19.5	3.69
Magnetism	No	Yes	—
Specific heat cal /g / ˚C (0~100˚C)	0.12	0.116	1.03
Linear thermal expansion coefficient ×10⁻⁶/ ˚C	17.3	11.7	1.48
Thermal conductivity ×10⁻² cal/cm/sec/ ˚C(100˚C)	3.89	11.9	0.33
Young's modulus E tf /cm²	1970	2110	0.93
Modulus of rigidity G tf /cm²	758	840	0.90
Poisson's ratio	0.3	0.3	1.00

In addition, dual-phase stainless steel (ASTM S82122, SUS329J3L, etc.) having an austenitic and ferritic dual-phase structure has been put on the market. The stainless steel has corrosion resistance similar or superior to that of SUS304 and SUS316 and tensile strength twice that of SUS304 and SUS316.

Application Examples

In building construction, excellent corrosion resistance and decorativeness inherent to stainless steel are attracting much attention and thus stainless steel is finding increasing use as structural members. In addition to building construction, stainless steel is steadily being applied for bridge construction in Europe, the US, and Asian nations.

Courtesy: Aichi Steel Works, Ltd.

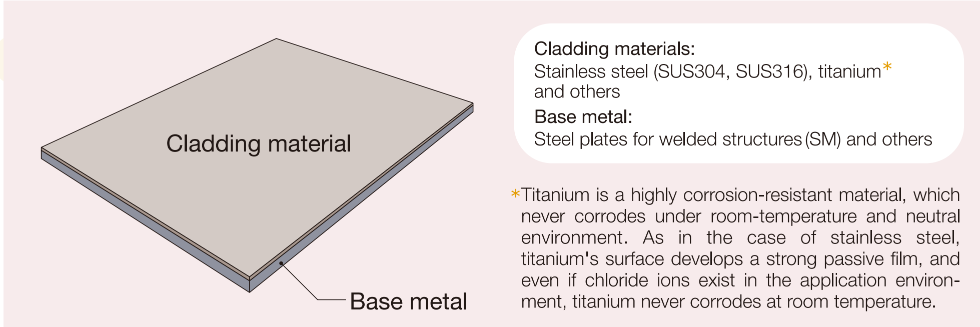
Clad Steel

Scope

Clad steel refers to the product produced by joining steel with different kinds of metals in a layer state. The aim of clad steel is to reconcile excellent function and economy that are not obtainable from a single material.

Stainless steel, titanium and other corrosion-resistant materials are used as the cladding material for steel, in which strength is borne by steel, thus realizing an extremely economical material.

Illustration of Clad Steel



Application Examples

Stainless-clad Steel

This steel already has application records in dam and watergate facilities, but in recent years its application for bridge superstructure is being examined.

Full-scale pilot member of bridge box girder
(Differences in surface luster are due to investigations made on appearance differences by surface-treatment methods.)

Titanium-clad Steel

Titanium is an expensive material, but when titanium is used in the form of titanium-clad steel, future maintenance costs will be greatly reduced.

Example of a steel pier partially covered with titanium clad steel in the splash and tidal zone

LP Steel Plate
(Longitudinally-profiled Steel Plate)

Scope

LP steel plates are produced by changing the thickness in the longitudinal direction. Longitudinally profiled steel plates have become available due to recent developments in plate rolling technology.

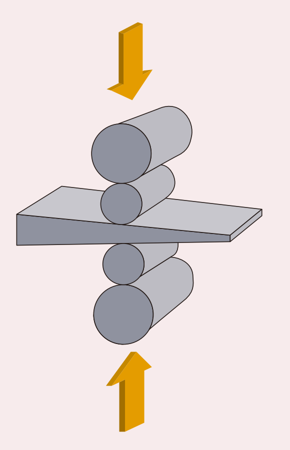
Application of LP steel plates allows cost reduction by eliminating welds and reducing structural weight.

LP steel plates have already been applied in the construction of more than 100 bridges in Germany and France, and are finding increasing applications in shipbuilding and bridge construction in Japan.

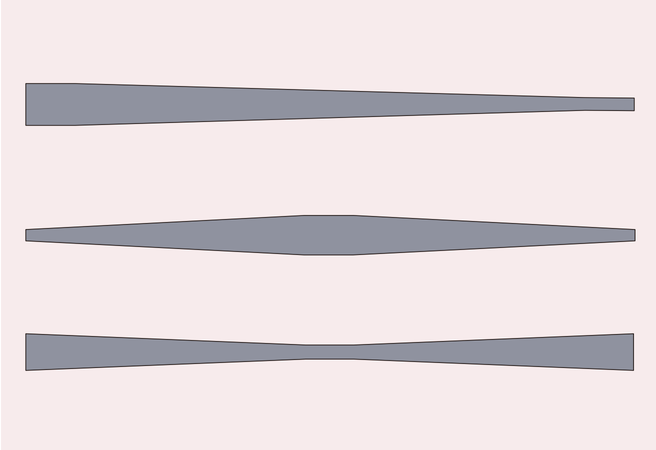
Material Performances

❶ Production Process

LP Steel Plate Production by Rolling



Basic Configuration of LP Steel Plate (Longitudinal-direction Section)



❷ Size Availability of LP Steel Plates

Maximum thickness difference :	**25 – 30 mm**
Maximum gradient :	**4 mm/m**
Minimum thickness :	**10 – 15 mm**
Maximum thickness :	**100 mm**
Total length :	**6~25 m**
Width :	**≥1.5 m**

❸ Applicable Steel Standards for LP Steel Plates

JIS G 3101 SS400, JIS G 3106

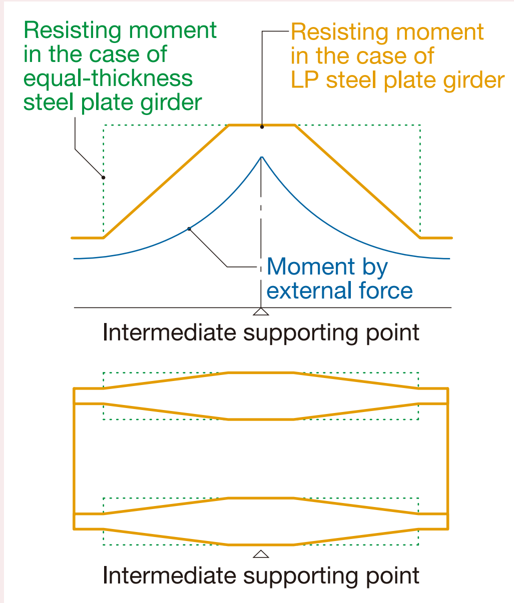
Application Benefits

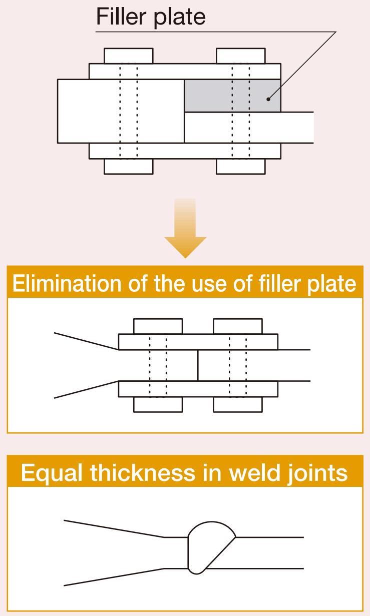
● Rationalized Thickness Composition in Compliance with the Section Force Required

① Structural weight of LP steel plate girders can be reduced, compared to steel girders of equal thickness.
② Application effect is greatly improved for large-section twin-girder bridge.

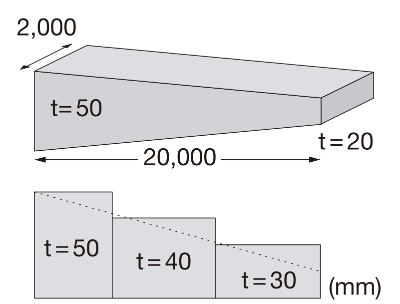
● Equal Thickness in Joints

① Use of filler plates can be eliminated in bolt joints.
② Tapering process is not required for weld joints.





Cost reduction: Trial calculation in Germany



In the case of replacing a plate-joined flange with LP steel plate, it is reported that a cost reduction of 12% was obtained.

(Introduction of Overseas Literature: Application of LP Steel Plate in Bridge Construction, Bridge and Foundation Engineering, September 1989)

Application Examples

An illustration of application of LP steel plates in girder flanges is shown below.

High-Strength Steel Wire for Bridge Cables

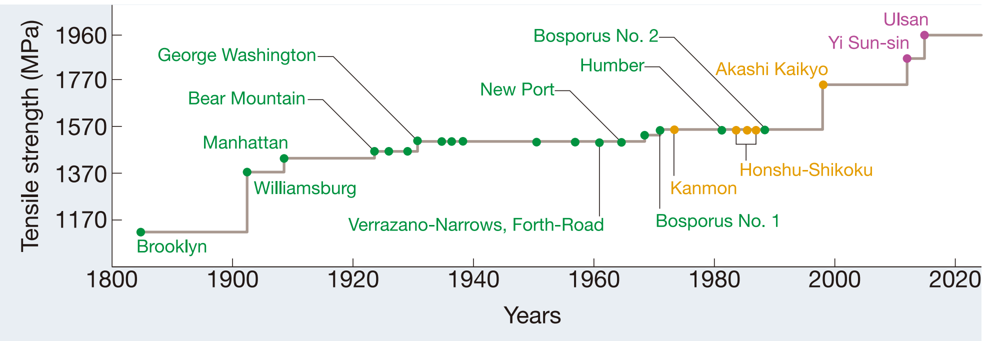
Scope

In long-span suspension bridge construction, as the span length increases, the deadweight of the bridge increases, and cable section increases correspondingly in case of using steel wire of identical strength level.

When adopting high-strength steel wire for the main cables of long-span suspension bridges, the cable section can be made smaller, and efficient erection work, reduction of main tower height and simplified stiffening structure are realized.

For the construction of Akashi Kaikyo Bridge having a center span of 1,991 m, high-strength steel wire having a tensile strength of 1,770 MPa, 200 MPa higher than conventional galvanized steel wire (1,570 MPa) for bridge cable, was developed and put into practical use. In recent years, high-strength steel wire with an even higher strength grade of 1,960 MPa has been developed.

Increasing Strength of Steel Wire for Cables of Various Bridges

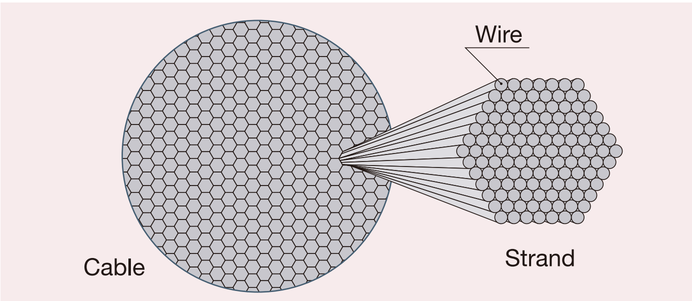


Material Characteristics

In producing steel wire with 1,770 MPa and 1,960 MPa strength grade, low-alloy steel with higher levels of C and Si was adopted as the base material, which improved the tensile strength by 200~400 MPa over the 1,570 MPa grade.

1,770 MPa and 1,960 MPa high-strength wire not only possess high tensile strength, but also demonstrate toughness and fatigue strength, and also exhibit handling efficiency during cable erection that are similar or superior to those of 1,570 MPa grade wire.

Cable Section



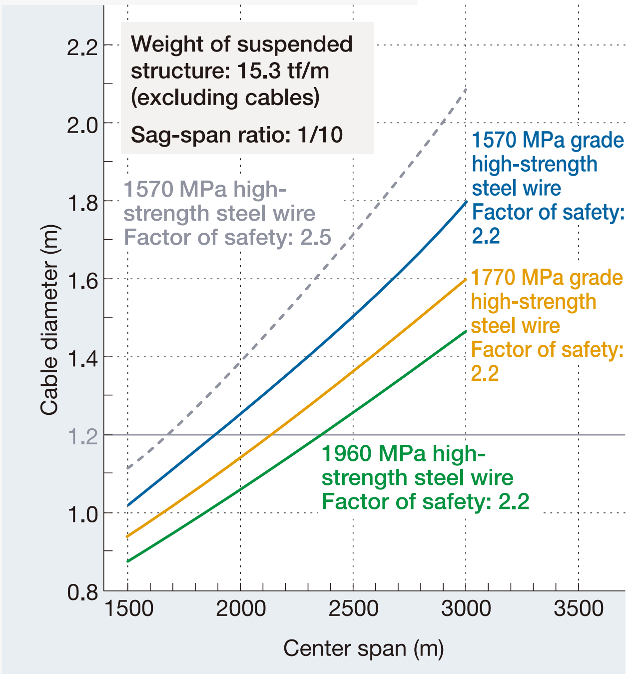
Major Specifications of Steel Wire for Bridge Cables

Item			1570 MPa strength grade	1770 MPa strength grade	1960 MPa strength grade
Material	Main chemical compositions	C (%)	0.75 ~ 0.80	0.80 ~ 0.85	0.90 ~ 0.95
		Si (%)	0.12 ~ 0.32	0.80 ~ 1.00	1.00 ~ 1.20
		Mn (%)	0.60 ~ 0.90	0.60 ~ 0.90	0.30 ~ 0.60
Galvanized wire	Mechanical properties	Tensile strength (MPa)	1570 ~ 1770	1770 ~ 1960	1960 ~ 2150
		Proof stress (MPa)	≥1160 (0.7% total elongation)	≥1370 (0.8% total elongation)	≥1470 (0.2% offset)
		Elongation (%)	≥4	≥4	≥4
		Coils (3d)	No breakage	No breakage	No breakage
		No. of twists	≥14	≥14	≥14
	Amount of galvanizing (g/m²)		≥300	≥300	≥300
	Zinc coat adhesion (5d winding)		No peeling off	No peeling off	No peeling off
	Free ring cast diameter (m)		≥4	≥4	≥4

Note: In the case of wire diameter of 5 mm

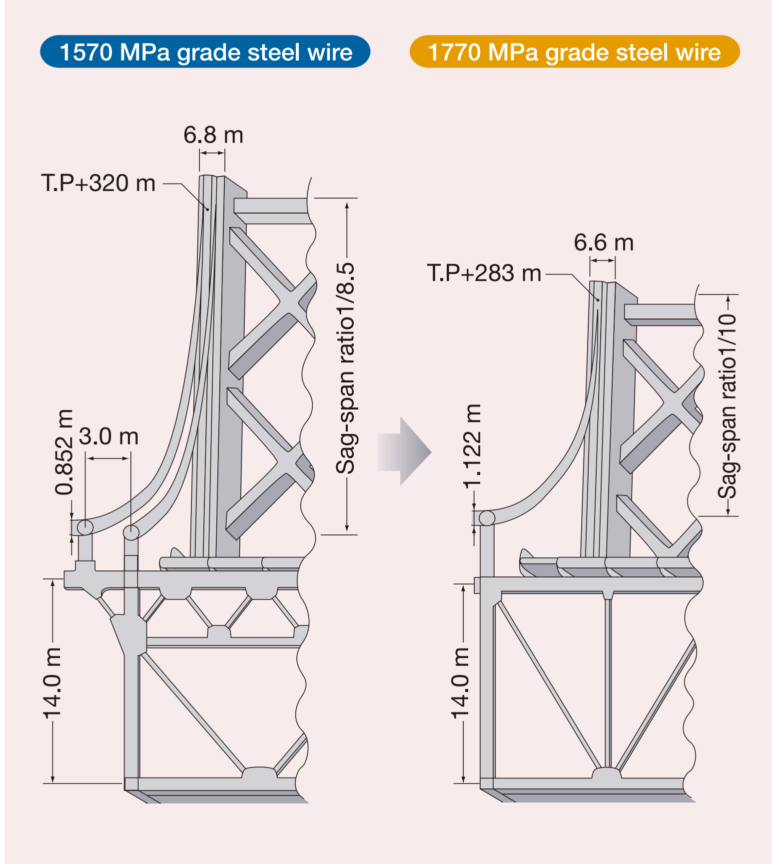
Application Benefits

Trial Calculation of Span Length and Cable Wire Strength for Suspension Bridges



The present maximum limit of cable diameter for suspension bridges is about 1.2 m on account of squeezing performance (to form sound-quality cable with small void ratio by squeezing several hundred strands) and stabilization degrees for fixing hanger ropes to cables.

Example of Change in Bridge Structure due to Higher Strength of Steel Cable (from 1,570 MPa steel wire to 1,770 MPa steel wire)



Application Examples

For Akashi Kaikyo Bridge, 1,960 Mpa steel wire is adopted for the catwalk ropes in addition to 1,770 Mpa steel wire for the main cables.

Akashi Kaikyo Bridge (main cables)

Kurushima Bridge (main cables)

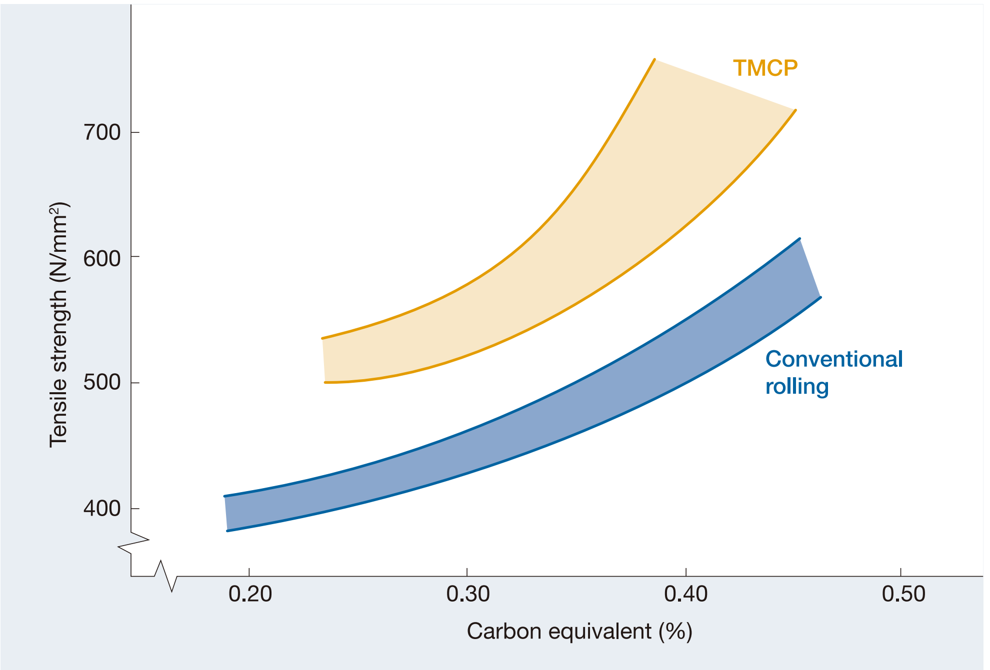
TMCP (Thermo-Mechanical Control Process)

Scope

● What Is TMCP?

TMCP refers to the Thermo-Mechanical Control Process — a steel plate rolling process based on controlled rolling followed by controlled cooling. Application of TMCP technology not only allows a greater reduction of the carbon equivalent (C_{eq}) and the weld crack sensitivity composition (P_{CM}), two important parameters for weldability, but also enables the production of high-strength, high-toughness and other high-performance steel plates.

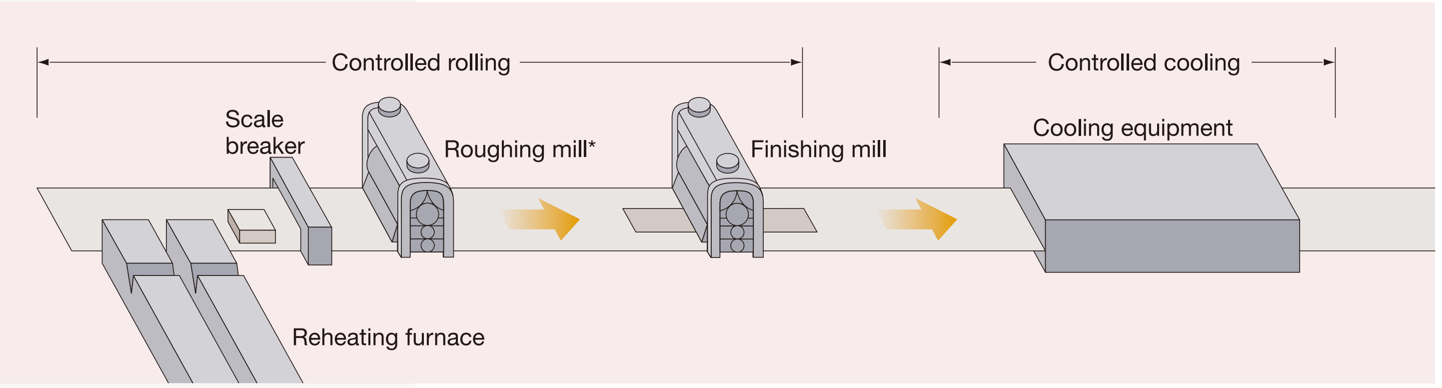
Relationship between Carbon Equivalent and Strength of Steel Plates Produced by the Conventional Rolling Method and TMCP (thickness: 20~30 mm)



● TMCP Equipment

An outline of TMCP equipment is shown below.

Typical Arrangement of TMCP Equipment



*In certain plants, roughing mill is not used.

Features

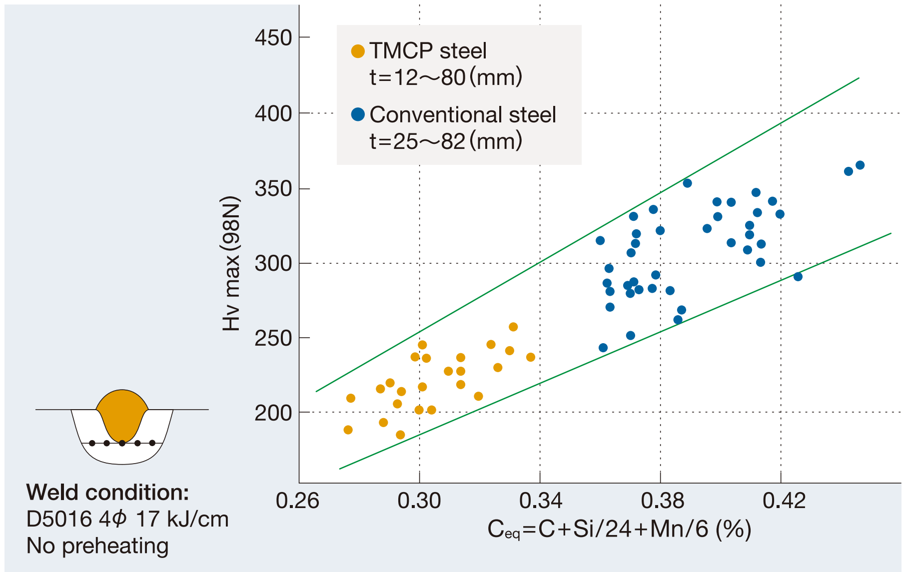
Because TMCP steel plates feature low carbon equivalent and high fracture toughness through proper application of controlled rolling and cooling, these plates offer the following features:

● Features in Terms of Plate Fabrication

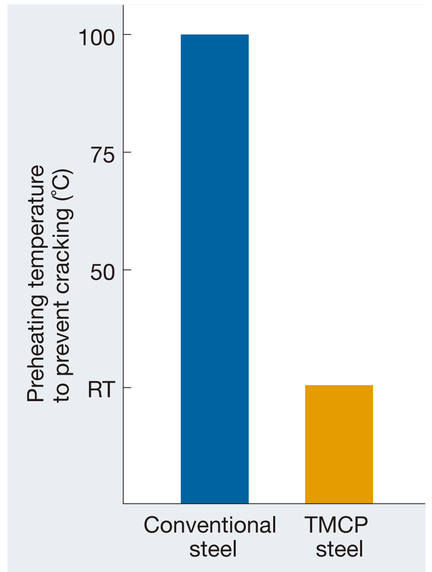
① Outstanding improvement in weldability
② Little change in material performances after gas flame straightening
③ Improvement in notch toughness of HAZ (heat-affected zone) of weld joint
④ Softening in HAZ by large heat-input welding — within the practically allowable range

● Example of Weldability Improvement by Use of TMCP
Outstanding reduction in carbon equivalent leading to excellent weldability

C_{eq} and Maximum Hardness



y-groove Restraint Cracking Test



● Feature of Microstructure

TMCP steel plates have fine ferrite and pearlite structure, compared to conventional steel plates.

Microstructure of 490 N/mm² Grade Steel (× 400)