NIPPON STEEL

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COR-TEN™
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NIPPON STEEL

Steel Plates

COR-TEN™

NET ZERO
NIPPON STEEL
Green Transformation
initiative

NIPPON STEEL CORPORATION

Susa Bridge (Yamaguchi)
Photo: 1992 (3 years after completion)

COR-TEN™

COR-TEN™
is a registered trade name of United States Steel Corporation.

Contents

1 COR-TEN Saving Maintenance Cost

Since 1959 when COR-TEN began to be marketed, this material has served as served as weathering steel (atmospheric corrosion-resistant steel).

COR-TEN has successfully overcome rust, steel's most weakest, by capitalizing on its unique "rust cures rust" function.

When exposed to the atmosphere without painting, COR-TEN begins to rust in the same way as ordinary steel. But soon the alloying elements in COR-TEN cause a protective surface layer of fine-textured rust to form, thereby suppressing corrosion rate.

Capitalizing on this excellent property, COR-TEN can be used without painting, thereby nullifying the commonly held belief that "steel must be used with paint."

But, if paint is applied to COR-TEN, the service life of the paint is prolonged compared to coatings applied to ordinary steel. Accordingly repainting costs are reduced.

Since its development in the U.S. in 1933, COR-TEN has been used in every field where steel is applied, such as bridges, railway vehicle and buildings. Recently, unpainted applications of COR-TEN are attracting attention as being especially suited for resource savings and environmental concerns.

Another growing application of unpainted COR-TEN is in conjunction with rust stabilization treatments on bridges, building exteriors and other structures.

In this way, COR-TEN helps to reduce lifecycle costs (LCC) and environmental burdens in a wide range of applications.

2 COR-TEN Features

Weather Resistance

Because COR-TEN has high weather resistance, it can be used without painting. Unpainted applications not only offer the economic advantage of reducing repainting costs; they also offer aesthetic benefits associated with the calming color of the protective rust.

While weather resistance depends on the product grade and the application environment, COR-TEN's weather resistance is nearly 4~8 times that of ordinary steel.

Paint durability

COR-TEN is paintable in the same way as ordinary steel. In addition, even if a painting defect should occur, COR-TEN suppresses the progress of rust area and, accordingly, prolongs the service life of the paint, thereby reducing repainting costs.

Weldability

While trace amounts of alloying elements such as copper (Cu) and chromate (Cr) are added to COR-TEN to ensure high weather resistance, the carbon content is lowered to provide appropriate weldability. Accordingly, COR-TEN can be welded using either manual, gas-shield or submerged arc welding. In addition, spot welding can be applied to thin-gauge COR-TEN.

Workability

COR-TEN possesses workability (cold forming, hot forming and gas cutting) similar to ordinary steels of same strength.

Reliability

Since 1959 when "COR-TEN" began to be marketed, more than 2.6 million tons of this material have been produced. (2013 end)

3 COR-TEN Weather Resistance

When COR-TEN is exposed to the atmosphere, it develops an initial layer of rust as ordinary steel does. But, as time goes by, this early product gradually converts to a fine-textured rust (protective rust) that tightly adheres to the base metal, providing a protective layer that both protects the base metal and suppresses further corrosion.

Fig. 1 shows the results of exposure tests conducted in an industrial area. It can be seen from the figure that corrosion in COR-TEN is suppressed within 3 to 5 years.

Fig. 2 shows the results of exposure tests in coastal areas. As can be seen in the figure, while the corrosion level of COR-TEN is lower progress than that of ordinary steel, corrosion continues to develop in COR-TEN for a long period. Accordingly, it is necessary to pay due care in the application of COR-TEN in coastal areas.

Fig. 3 shows the results of exposure tests in the U.S. The corrosion in both Japan and the U.S. show the same trend, but the corrosion levels in the U.S. is only about 1/3 to 1/2 that in Japan. This seems attributable to differences in temperature and humidity between Japan and the U.S.

Fig. 1 Exposure Tests in Industrial Areas

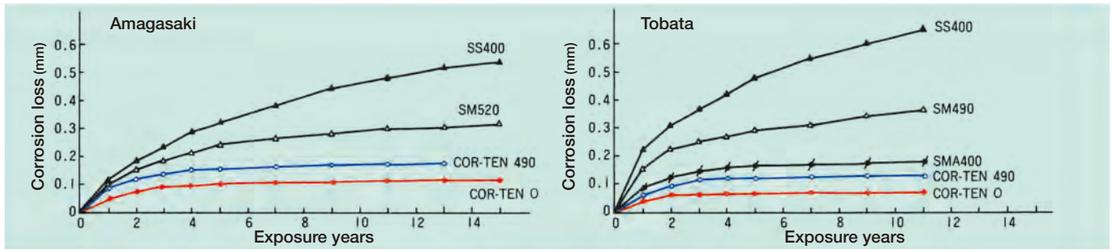


Fig. 2 Exposure Tests in Coastal Areas

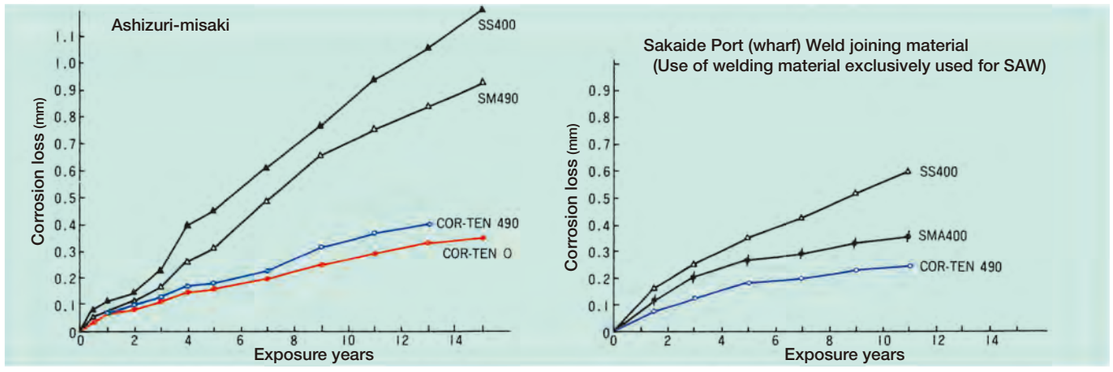
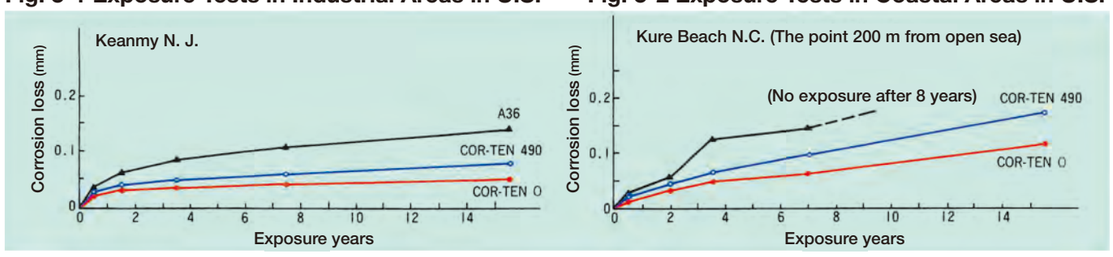


Fig. 3-1 Exposure Tests in Industrial Areas in U.S.

Fig. 3-2 Exposure Tests in Coastal Areas in U.S.

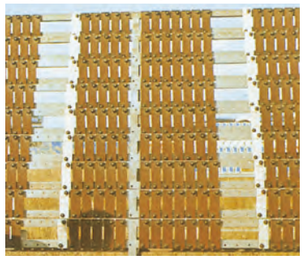


Exposure Test Results

Because a reliable accelerated test method is not available and because the alloying elements used in steel products and the effects of individual application environments are complicated, it is necessary to carry out long-term exposure tests using numerous test specimens in order to judge whether weather resistance is high or low.

COR-TEN was developed in 1933 as a result of long-term exposure tests using 30,000 or more test specimens. Since then, exposure tests and follow-up surveys of existing structures have been continued worldwide to further improve weather resistance. Extensive knowledge has been obtained on the performance characteristics that weathering steel should possess and on the environmental conditions required for weathering steel to fully demonstrate its unique weather resistance. The following offers a summary introduction of such knowledge.

Exposure Tests (without eaves)



It is necessary that steel products include the weather-resistant elements that which contribute to the formation of protective rust

As regards weather-resistant alloying elements, P, Cu, Cr and Ni are widely known. Further, Si, Mo, Ti and V are known as complementary elements used to improve weather resistance in combination with Cu and Cr.

Further, a multiplier effect can be obtained by appropriately combing the use of these elements, and thus higher weather resistance can be obtained by finding the optimum mix of elements from many experiments.

It is necessary for weathering steel to be subjected to repeated wet-dry cycles in the atmosphere in order to form protective rust

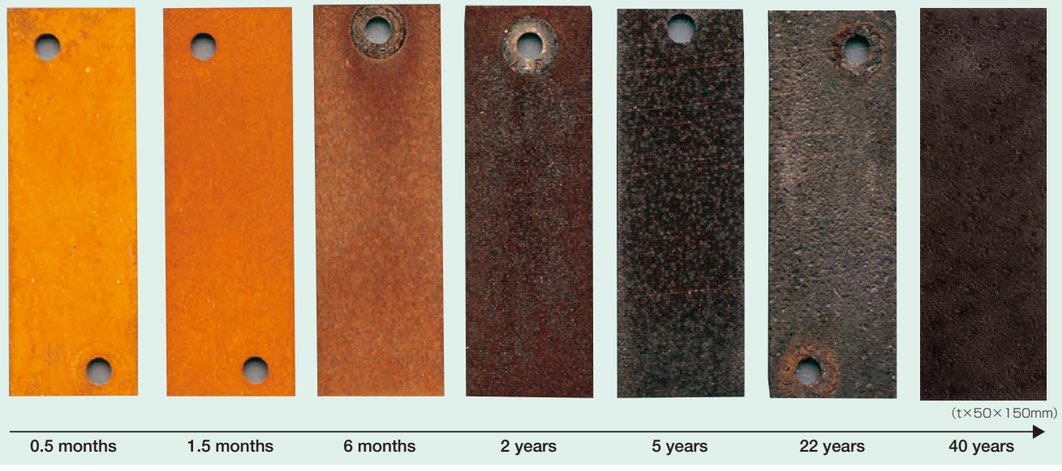
Accordingly, when the surfaces of weathering steel are constantly submersed in water or wet earth, protective rust does not form. Consequently, the application environment such as this prevent the peculiar features of weathering steel from being fully utilized.

Further, protective rust is most likely to form in sections subjected to sunlight and rainfall, but is less likely to form in areas subjected to salts.

Because these environmental effects become clear when steel products are exposed to the atmosphere in an as-rolled state, it is necessary in unpainted applications of weathering steel to pay full attention not only to the select of COR-TEN steel but also to the purpose of its use and to the site where it is to be used.

Secular Changes in Rust Appearance

In the initial stage of application, COR-TEN shows a yellowish appearance. This is followed by a gradual change in the color of the protective rust from brown to a stable dark brown after one to two years in general application environments. Afterwards, the coloration shows no clear change except perhaps to a deeper dark brown.



4 COR-TEN Application Examples

Unpainted use (Bare)

The unpainted application of COR-TEN not only offers economical advantages but, thanks to the calming color of the protective rust, it also demonstrates excellent aesthetic properties. Because of this, COR-TEN is applied in a wide range of fields such as buildings and monuments. Because the initial outflow of rust dirties the surrounding area, it is necessary to fully examine the application site and the purpose for using COR-TEN and to devise a structuring method.

Hokkaido Centennial Memorial Tower (Hokkaido)
Photo: Oct. 1969 (under construction)

Photo: Apr. 1973 (4 years after completion)

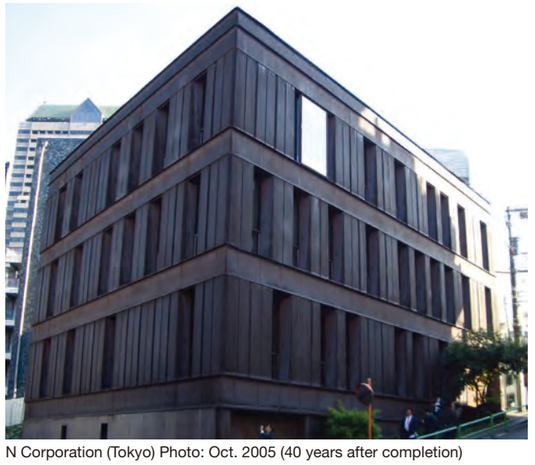
Photo: Sep. 1977 (8 years after completion)

Photo: May 1991 (22 years after completion)

Photo: Jul. 2010 (41 years after completion)

Kanno Museum of Art (Miyagi) Photo: May 2007 (1 year after completion)

Univ. OKAYAMA Pref. Alumni House: June 2013 (at time of completion)



N Corporation (Tokyo) Photo: Oct. 2005 (40 years after completion)

La Chapelle des Pommiers (Normandy, France; floor member; by Kyoji Takubo)
Photo 1999 (at time of completion)

Shimane Museum of Ancient Izumo (Shimane) Photo: Oct. 2009 (3 years after completion)

IRONHOUSE (Tokyo) Photo: Dec. 2009 (2 years after completion)

4 Unpainted use (Complementary Rust Stabilization Treatment)

COR-TEN can be applied without painting (in a bare state), thus reducing the cost of repainting and other repairs. However, there have been expressions of concern during the first year or two when the protective layer of fine-textured rust (protective layer) is forming. These concerns usually referred to adverse landscaping associated with the yellowish color of the initial rust and to the contamination of surrounding areas caused by the runoff of early-stage rust washed away by rainwater. As a result, there have been obstacles linked to the use of COR-TEN in spite of its superior economic advantages.

In order to solve these problems, supplementary rust stabilization treatment was developed.

In the case of Complementary Rust Stabilization Treatment, agents similar in color to rust have been selected on the premise that the agents would be converted to rust in the future. Recently, in order to meet requests for the free selection of colors that harmonize with surrounding colors, Complementary Rust Stabilization Treatment agents to which various colors can be applied.

Because the Complementary Rust Stabilization Treatment agents will eventually be converted to rust, there is a certain period when the color will cease, over time, to remain uniform. When countermeasures are required from a landscaping perspective, it is necessary to apply an easy restoration treatment for surface layer film.

No.2 Hozugawa Bridge (Kyoto) Photo: Sep. 2006 (18 years after completion)

Nagano Municipal Museum of Art (Nagano)
Photo: Jul. 2006
(27 years after completion)

Nagano Municipal Museum of Art (Nagano) Photo: Aug. 1980 (8 months after completion)

Ariake-tennis-no-mori (Tokyo) Photo: May 2007 (20 years after completion)

Viaduct Hokuriku Super-express (Niigata)
Photo: Jun. 2005 (19 years after completion)

World Hall (Hyogo) Photo: Mar. 2010 (26 years after completion)

Nagaragawa Baseball Stadium (Gifu) Photo: Oct. 2011 (22 years after completion)

Arakawa Bridge (Tokyo): Landscape type Complementary Rust Stabilization Treatment (light blue) Photo: Jul. 2007 (6 years after completion)

Steel pier of Kitasaki Viaduct (Aichi): Landscape type Complementary Rust Stabilization Treatment (white) Photo: Jul. 2007 (7 years after completion)

4 Painted use

When COR-TEN is painted, the required number of times that repainting must be conducted can be reduced.

This advantage is believed to result from the fact that, even when corrosion occurs in the base metal due to defects in the painted film or to pinholes, the corrosion progresses slowly and thus the occurrence of blistering and peeling of the paint film is reduced.

By making the most of this advantage, COR-TEN is applied in every field where steel is used–ranging from buildings to railway vehicle, marine containers, storage tanks, industrial machinery and bridges.

Tomari Bridge (Okinawa) Photo: Nov. 2004 (19 years after completion)

Jinbocho Theater (Tokyo)
Photo: Dec. 2007 (0.5 years after completion)

Container

Garbage truck (ShinMaywa Industries, Ltd.)

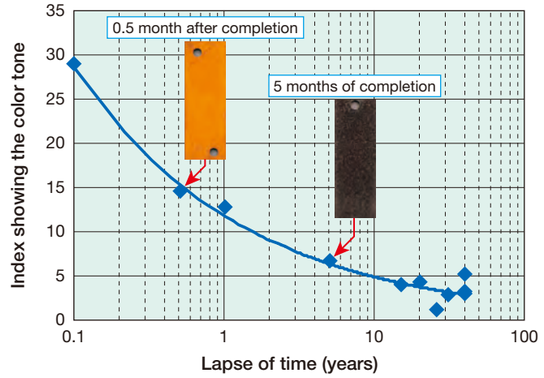
Gosha Inari Shrine (Aichi) Photo: Oct. 2005 (completion)

VINCOR™

VINCOR (**VIN**tage **COR**-ten) is a product to consider the initial color tone with a state of being aged from shipment.

VINCOR is sold by Chikumakozai Co., Ltd (Tel: 81-47-354-5721).

■ By using the index numbers that have a high correlation with colors, the color tone is quantified and reproduced.

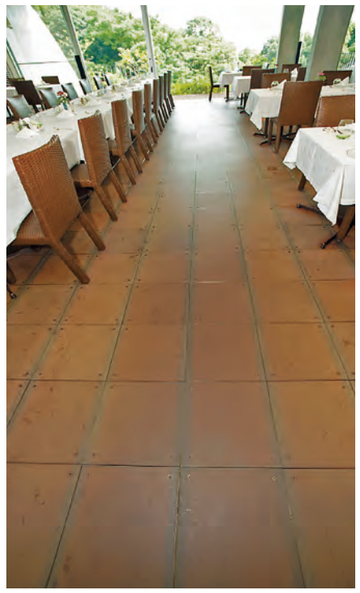


9 years after completion

Partition wall in restaurant

Various Application Examples of COR-TEN

“Stair in the Void” by Minoru Togashi (Yamagata)
Photo: Jun. 2005 (4 years after completion)



Kotohiragu cafe & restaurant “Kamitsubaki” (Kagawa)
Photo: 2009 (2 years after completion)

“Tamasora” by Noe Aoki
Photo: Tadasu Yamamoto

Yokohama Naka Ward Office (Kanagawa)
Photo: Oct. 2006 (23 years after completion)

COR-TEN Specification

Steel Grades and Features

Steel grade	Designation	Applicable thickness range (mm)		Feature	Main applications
Highly weathering steel product	COR-TEN O	Hot-rolled sheet and plate:1.6≦t≦76 Cold-rolled sheet:0.4≦t≦2.3 Shape:6≦t≦38 Bar:5.5≦t≦44		●Because of its high weather resistance, this grade is most suitable for unpainted application.	●Sash, panel and other building exterior members ●Outer plate for rolling stock ●Marine container ●Steel tower, etc
Unpainted specifications For welded structures Weathering steel product	COR-TEN 490A/B/C	Hot-rolled sheet and plate:6≦t≦50 Shape:6≦t≦38		●Because of its high weather resistance, this grade can be used without painting. ●Because of its high weldability and notch toughness, this grade is recommended for use for welded structures.	●Bridge ●Steel frame, steel tower, various platforms ●Crane and other industrial machinery ●Flood gate ●Low-pressure gas holder, water tank and other large-size vessels
	COR-TEN 570	Hot-rolled sheet and plate:6≦t≦50			
General weathering steel product	NAW™ 490	Hot-rolled sheet and plate:1.6≦t≦12.7 Cold-rolled sheet:0.4≦t≦2.3 Shape:3.2≦t≦12.7		●Featuring economical advantage, this grade is recommended for use with painting. ●Because of its high strength, NAW 490 offers a high wet abrasion resistance.	●Column, beam and outer plate of container ●Ready-mixed concrete car ●Small-capacity compressor tank
Ni-type highly weathering steel product	NAW-TEN™12 -400A/B/C -490A/B/C -570	Hot-rolled sheet and plate:6≦t≦100		●Because of its high weather resistance, this grade is most suitable for unpainted use. ●Because of its high weldability and notch toughness, this grade is recommended for use for welded structures. ●The mechanical properties excluding chemical composition conform to those in JIS SMA standards.	●Bridge ●Steel tower ●Building exterior member
Highly weathering steel product	COR-TEN A	Hot-rolled sheet and plate	t≦12.7	●Because of its high weather resistance, this grade is most suitable for unpainted application.	●Sash, panel and other building exterior members ●Outer plate for rolling stock ●Marine container ●Steel tower, etc
Unpainted specifications For welded structures Weathering steel product	COR-TEN B		t≦200	●Because of its high weather resistant, this grade can be used without painting. ●Because of its high weldability and notch toughness, this grade is recommended for use for welded structures.	●Bridge ●Steel frame, steel tower, various platforms ●Crane and other industrial machinery ●Flood gate ●Low-pressure gas holder, water tank and other large-size vessels
	COR-TEN C		t≦25		

Notes:
1) For unpainted uses, COR-TEN O, COR-TEN 490, COR-TEN 570, NAW-TEN™12 are applied.
2) Thicknesses or diameters other than those listed in the above table are subject to the agreement between the orderer and us.
3) Bar includes bar-in-coil. But the diameter of bar-in-coil should be 32 mm or less.
4) The available size range differs depending on the steel grade and size. Please inquire us for every lot of orders.
5) NAW™ and NAW-TEN™ are a registered trade name of NIPPON STEEL.
6) Shapes are constantly not manufactured, so please consult us in advance concerning designations (only A and B) and size selection.

Chemical Composition

Destination	Steel grade	Designation	Chemical Composition (%)									
			C	Si	Mn	P	S	Cu	Ni	Cr	Other elements	ν value
For domestic uses	Highly weathering steel product	COR-TEN O	≦0.12	0.25 ～0.75	0.20 ～0.50	0.07 ～0.15	≦0.035	0.25 ～0.55	≦0.65	0.30 ～1.25	—	—
	Unpainted specifications For welded structures Weathering steel product	COR-TEN 490A/B/C	≦0.17	0.30 ～0.65	0.80 ～1.25	≦0.035	≦0.035	0.30 ～0.40	0.05 ～0.30	0.45 ～0.65	V:0.02 ～0.10	—
		COR-TEN 570	≦0.17	0.40 ～0.65	0.80 ～1.25	≦0.035	≦0.035	0.30 ～0.40	0.05 ～0.30	0.45 ～0.65	V:0.02 ～0.10	—
	General weathering steel product	NAW™ 490	≦0.12	0.15 ～0.35	≦0.90	0.06 ～0.12	≦0.035	0.25 ～0.50	—	—	≦Ti:0.15	—
	Ni-type highly weathering steel Highly weathering steel product	NAW-TEN12 -400A/B/C	≦0.18	0.15 ～ 0.65	≦1.25	≦0.035	≦0.035	0.50 ～ 1.00	0.70 ～ 1.70	≦0.08	—	≦1.20
		-490A/B/C -570			≦1.40						—	
For overseas uses	Highly weathering steel product	COR-TEN A	≦0.12	0.25 ～0.75	0.20 ～0.50	0.07 ～0.15	≦0.05	0.25 ～0.55	≦0.65	0.50 ～1.25	—	—
	Unpainted specifications For welded structures Weathering steel product	COR-TEN B	≦0.19	0.30 ～0.65	0.80 ～1.25	≦0.04	≦0.05	0.25 ～0.40	≦0.40	0.40 ～0.65	V:0.02 ～0.10	—
		COR-TEN C	≦0.19	0.30 ～0.65	0.80 ～1.35	≦0.04	≦0.05	0.25 ～0.40	≦0.40	0.40 ～0.70	V:0.04 ～0.10	

Notes:
A parameter to weather-resistant alloying elements (ν value) is given by the following equation. Unit: mass%

ν value=1/{(1.0−0.16[C])×(1.05−0.05[Si])×(1.04−0.016[Mn])×(1.0−0.5[P])×(1.0+1.9[S])×(1.0−0.10[Cu])×(1.0−0.12[Ni])×(1.0−0.3[Mo])×(1.0−1.7[Ti])}

C. Miki, A. Ichikawa, M. Ukai, S. Takemura, T. Nakayama and H. Kihira: Proposal of Weather-resistant Alloying Parameters and Weather Resistance Assessment Methods, Journal of Japan Society of Civil Engineers, No. 738/1-64, pp 271-281, July 2003

5 Mechanical Properties

Designation	Product	Tension test						*Bending test (180° bending)			**Impact test			
		Thickness or diameter mm	Yield point N/mm²	Tensile strength N/mm²	Elongation: Thickness or diameter mm	Elongation: Elongation %	Test piece JIS	Thickness or diameter mm	Inner radius	Test piece JIS	Symbol	Test temperature °C	Charpy absorbed energy J	Test piece JIS
COR-TEN O	Cold-rolled sheet	t≦2.3	315≦	450≦	—	24≦	No.5	—	—	—	—	—	—	—
	Hot-rolled sheet and plate Shape	t≦20	355≦	490≦	t≦5	22≦	No.5	t≦5	1.0t	No.3	—	—	—	—
					5<t≦16	18≦	No.1A	5<t	1.0t	No.1	—	—	—	—
		20<t≦38	325≦	460≦	16<t≦38	21≦								
		38<t	295≦	430≦	38<t	21≦	No.1A							
						23≦	No.4							
	Bar	D≦38	325≦	460≦	D≦25	20≦	No.2	D≦32	1.5D	No.2	—	—	—	—
	Bar-in-coil	38<D	295≦	430≦	25<D	23≦	No.3	32<D	2.0D		—	—	—	—
COR-TEN 490 A/B/C	Hot-rolled sheet and plate Shape	t≦16	360≦	490～610	t≦16	15≦	No.1A	—	—	—	B	0	27≦	V-notch Rolling direction
		16<t≦40	355≦		16<t	19≦								
		40<t	335≦		40<t	21≦	No.4				C	0	47≦	
COR-TEN 570	Hot-rolled sheet and plate	t≦16	460≦	570～720	t≦16	19≦	No.5	—	—	—	—	−5	47≦	
		16<t≦40	450≦		16<t	26≦								
		40<t	430≦		20<t	20≦	No.4							
NAW 490	Cold-rolled sheet	—	345≦	460≦	t≦2.3	22≦	No.5	—	—	—	—	—	—	—
	Hot-rolled sheet and plate Shape	—	390≦	490≦	t<6	22≦		—	1.0t	No.3	—	—	—	—
					6≦t	23≦		—	1.5t	No.1	—	—	—	—
NAW-TEN12-400 A/B/C	Hot-rolled sheet and plate	t≦16	245≦	400～540	t≦16	17≦	No.1A	—	—	—	A	—	—	V-notch Rolling direction
		16<t≦40	235≦		16<t	21≦					B	0	27≦	
		40<t≦100	215≦		40<t≦100	23≦	No.4				C		47≦	
NAW-TEN12-490 A/B/C	Hot-rolled sheet and plate	t≦16	365≦	490～610	t≦16	15≦	No.1A	—	—	—	A	—	—	
		16<t≦40	355≦		16<t	19≦					B	0	27≦	
		40<t≦75	335≦		40<t≦100	21≦	No.4				C		47≦	
		75<t≦100	325≦											
NAW-TEN12-570	Hot-rolled sheet and plate	t≦16	460≦	570～720	t≦16	19≦	No.5	—	—	—	—	−5	47≦	
		16<t≦40	450≦		16<t	26≦								
		40<t≦75	430≦		20<t≦100	20≦	No.4							
		75<t≦100	420≦											
COR-TEN A	Hot-rolled sheet and plate	≦12.7	345≦	485≦	—	22≦	***50							
					—	18≦	***200							
COR-TEN B		≦100	345≦	485≦	—	21≦	***50							
					—	18≦	***200							
		100 over t≦125	315≦	460≦	—	21≦	***50							
		125 over t≦200	290≦	435≦	—	21≦	***50							
COR-TEN C		≦25	415≦	550≦	—	21≦	***50							
					—	16≦	***200							

*Can be eliminated unless otherwiser orderer specifies
**Applied to steel product with thicknesses more than12 mm
***Test piece Gage length, mm

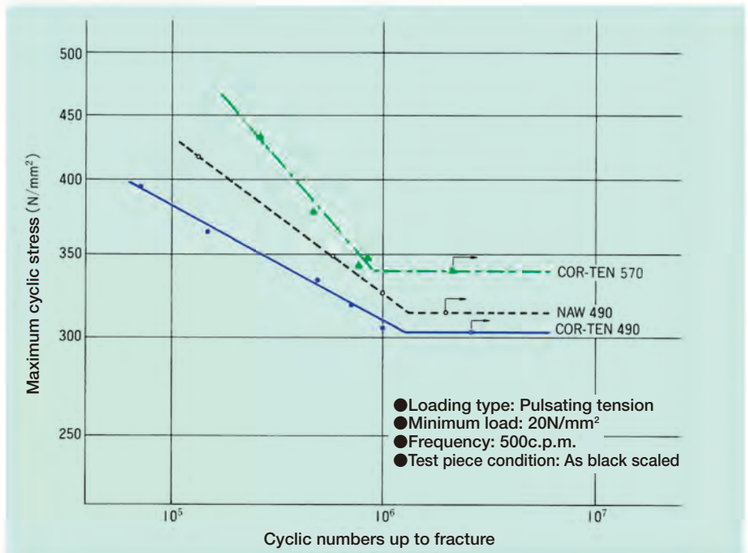
6 COR-TEN Characteristic Properties

Chemical Composition, Mechanical Properties (Example)

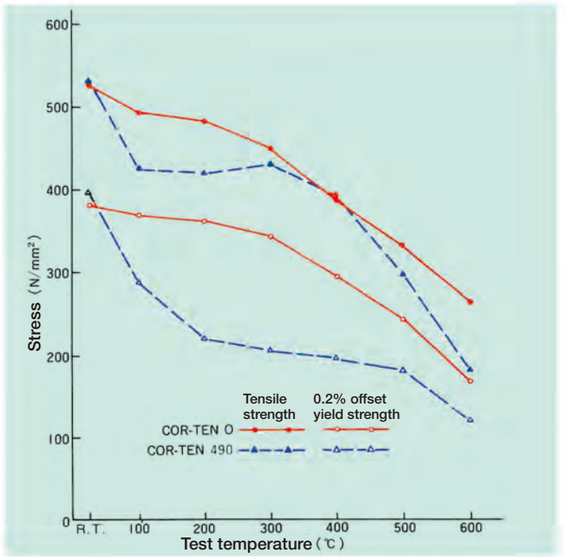
Chemical Composition and Tensile Test Values

Designation	Product	Thickness mm	Chemical composition (%)										Tensile test value			
			C	Si	Mn	P	S	Cu	Ni	Cr	V	Ti	Yield point N/mm²	Tensile strength N/mm²	Elongation %	Test piece JIS
COR-TEN O	Cold-rolled sheet	1.2	0.08	0.45	0.38	0.115	0.018	0.28	0.12	0.60	—	—	345	500	33	No.5
	Hot-rolled sheet and plate	3.2	0.08	0.43	0.40	0.094	0.005	0.28	0.17	0.59	—	—	404	536	35	No.5
		6.0	0.08	0.43	0.41	0.096	0.005	0.28	0.17	0.59	—	—	392	524	27	No.1A
		9.0	0.08	0.44	0.41	0.095	0.004	0.28	0.16	0.61	—	—	382	520	26	No.1A
COR-TEN 490	Hot-rolled sheet and plate	12	0.13	0.26	1.01	0.008	0.006	0.32	0.11	0.46	0.03	—	395	530	26	No.1A
		25	0.15	0.45	0.96	0.019	0.005	0.33	0.12	0.47	0.06	—	385	520	27	No.1A
		42	0.15	0.46	0.96	0.018	0.005	0.32	0.11	0.46	0.06	—	385	520	33	No.4
COR-TEN 570	Hot-rolled sheet and plate	19	0.09	0.35	1.21	0.016	0.006	0.32	0.12	0.50	0.04	—	570	661	36	No.5
		25	0.09	0.36	1.19	0.015	0.005	0.33	0.13	0.53	0.04	—	540	640	28	No.4
		32	0.09	0.35	1.22	0.014	0.004	0.34	0.12	0.52	0.03	—	540	640	27	No.4
NAW 490	Hot-rolled sheet and plate	2.3	0.08	0.20	0.62	0.066	0.004	0.27	—	—	—	0.03	432	547	31	No.5
		8.0							—	—	—		433	535	34	No.5

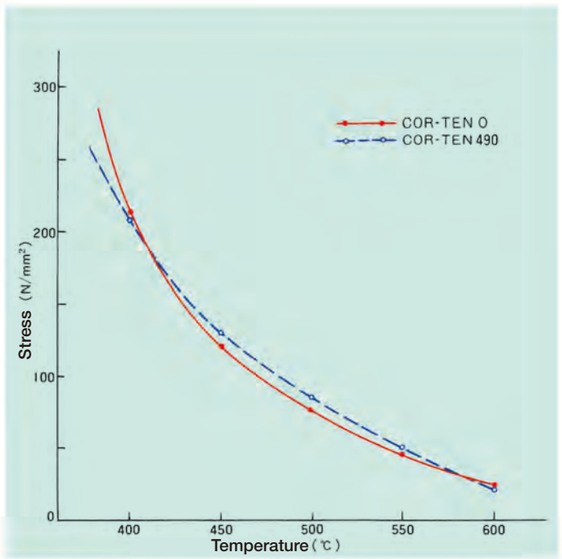
Fatigue Test Results



High-temperature Tension Test Results



Creep Rupture Strength (10^5 hours, estimated)

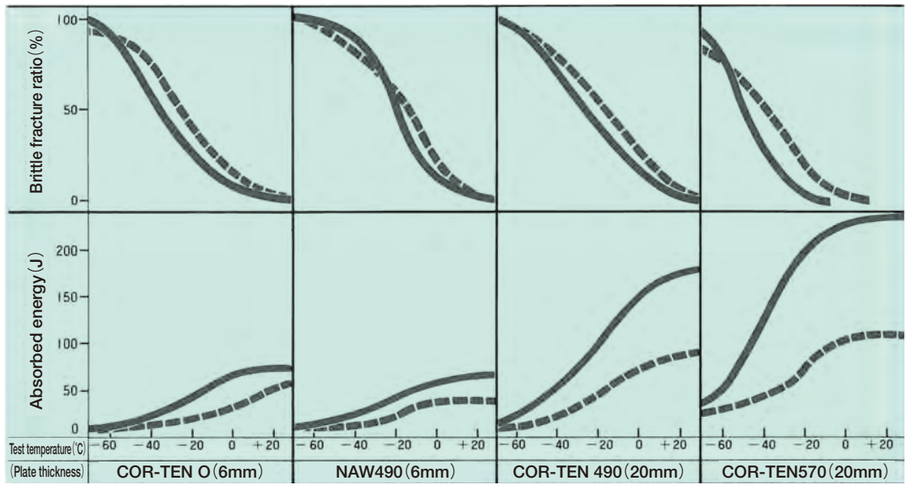


6

Impact Properties and Abrasion Resistance (Example)

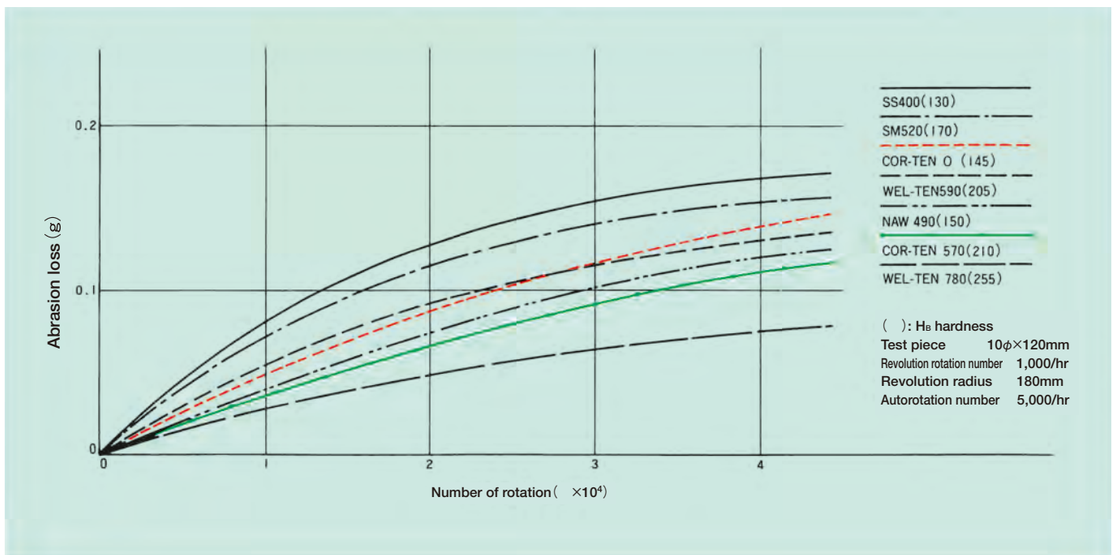
Impact Properties

Charpy Transition Curve (V-notch (Sub-size test piece 5×10 mm in plate thickness of 6 mm))



Abrasion Resistance

Abrasion Resistance to Wet Sand

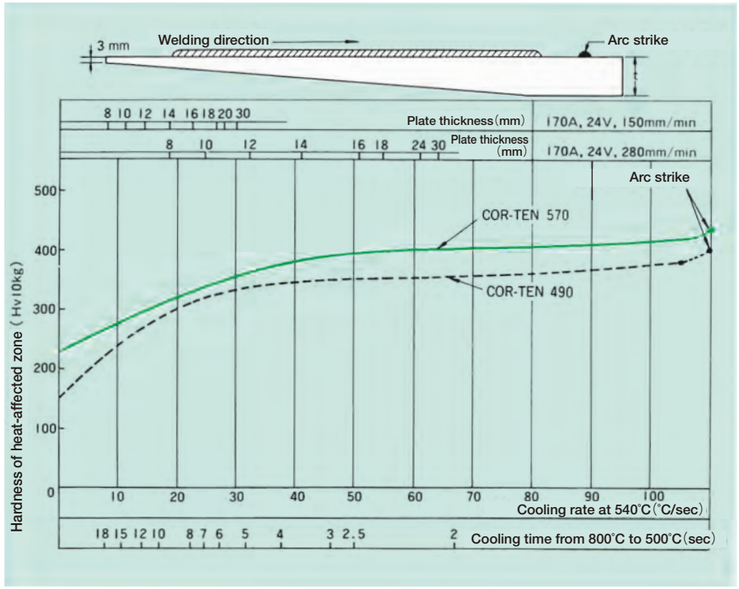


Weldability (Example)

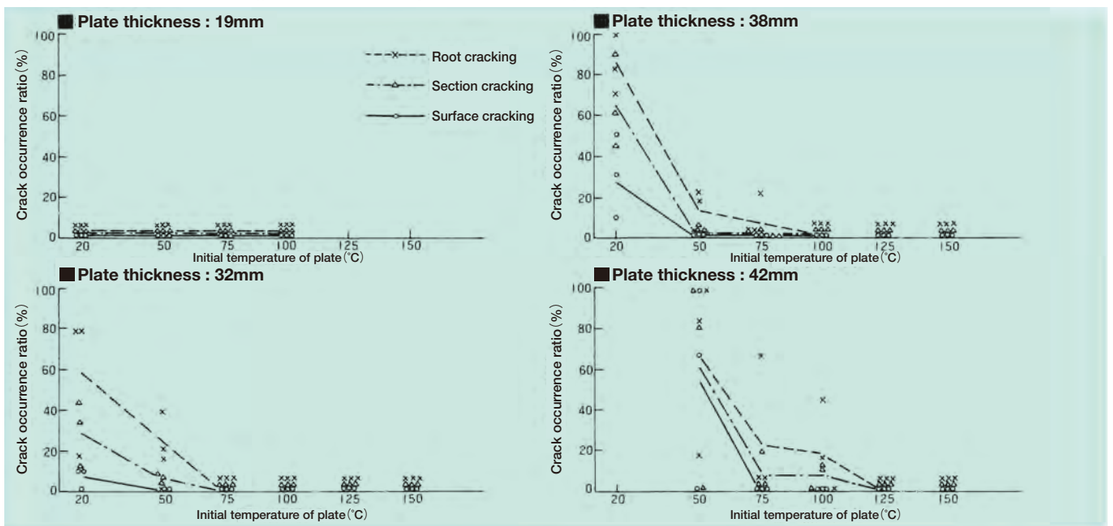
Steels containing P–such as COR-TEN O, NAW 490–are likely to suffer hot cracking during welding and are thus not recommended for use in welded structures requiring heavy-gauge members that are ≧ 13 mm in thickness.

For welded structure applications, it is recommended to adopt COR-TEN 490 and COR-TEN 570 having high weldability. These products are low in hardenability, highly resistant to weld cracking and offer high joint performance.

Taper Hardness Test Results

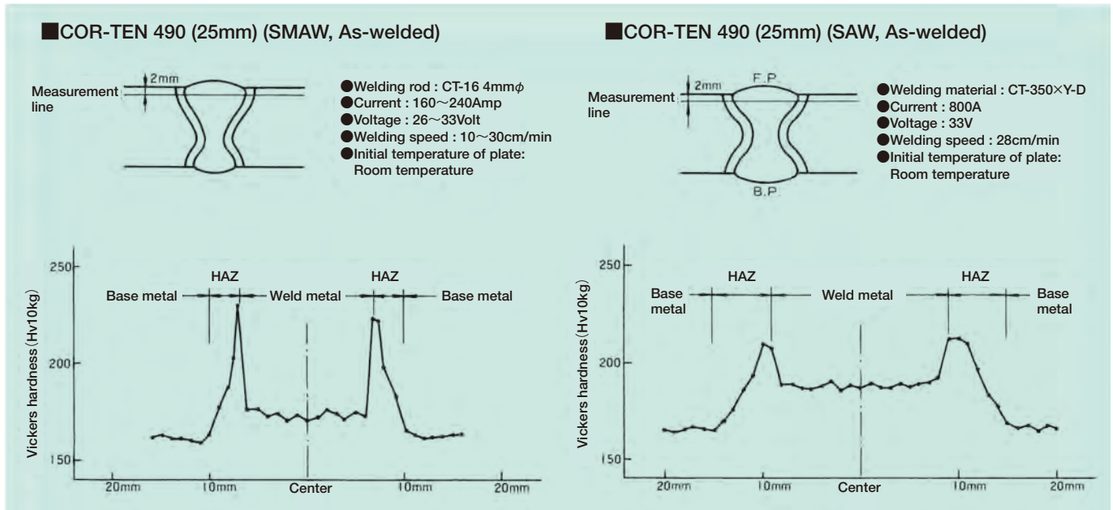


Y-groove Weld Cracking Test Results (COR-TEN 490)

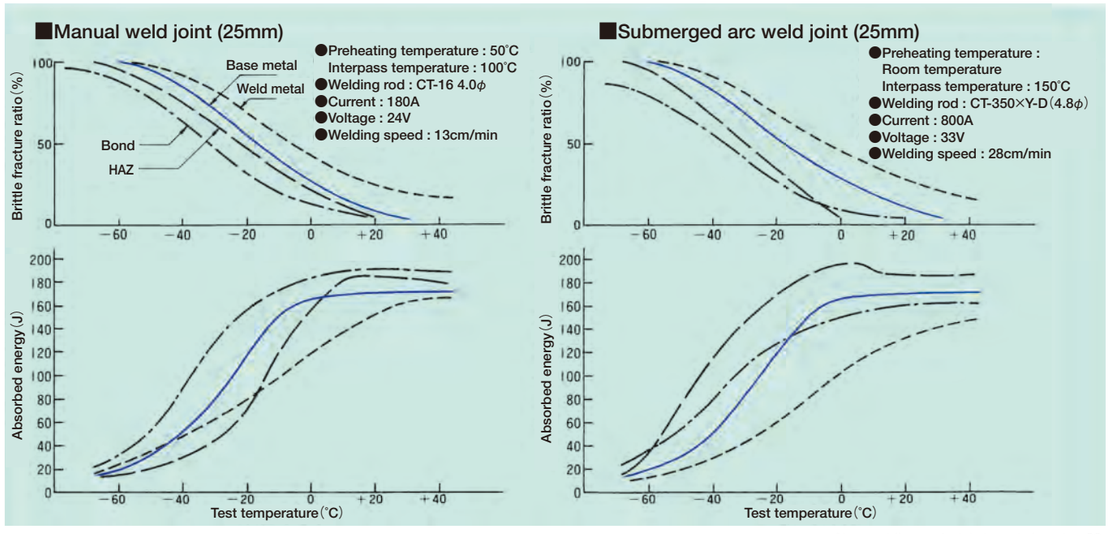


6 Weld Joint Properties (Example)

Weld Joint Hardness Distribution



Charpy Impact Test Results for Weld Joint of COR-TEN 490



New welding materials brand show in p30.

Workability (Example)

■Cold Bending

It is considered that thin-gauge plates of COR-TEN O and NAW 490 are most commonly used with cold bending. When cold bending is applied under the conditions shown in the table below, favorable results can be obtained.

Plate thickness	Minimum inner bending radius
≦1.6	1t
over 1.6, ≦6.0	2t
over 6.0, ≦20	3t

■Drilling and Machining

When drilling and machining COR-TEN 490 and COR-TEN 590, tool damage is reduced and fine finishes are made possible using fabrication speeds slightly lower than those for SM490 and SM570. The standard applicable fabrication speeds are 2/3 the speed used with SS400 for drilling and 3/7 the speed for machining.

■Hot Working

Aside from COR-TEN 570, all grades of COR-TEN steel can be hot-worked in the same way as ordinary carbon steel. Because COR-TEN 570 is quenched and tempered, it undergoes changes in material quality and suffers drops in yield point and tensile strength when hot working is applied at temperatures higher than the tempering temperature. It is recommended that hot working be conducted at temperatures of 600°C or lower.

■Cutting

Both shear cutting and gas cutting can be applied to COR-TEN in the same way as ordinary steel products. In applying gas cutting to COR-TEN 570, the hardness slightly increases near by cutting area. This level of increase in hardness does not exert any appreciable effect on the subsequent fabrication processes, but when preheating and postheating are applied before and after gas cutting, the subsequent cold working is favorably attained.

■Spot Heating and Linear Heating for Stress Relief

Stress relief of COR-TEN can be undertaken by means of spot heating and linear heating. When COR-TEN is heated to relieve stress in the same way as ordinary steel, no deterioration in material quality occurs.

When the heating temperature is elevated beyond 800°C, due care should be taken because the material strength and surface hardness increase while toughness tends to decrease.

It is recommended that COR-TEN 570 be treated in the same way as SM570.

6 Physical Properties (Example)

Elastic Modulus (Unit:N/mm²)

COR-TEN O	19.3～20.7×10⁴
NAW 490	20.5×10⁴

＜20.74×10⁴N/mm²（18℃）＞

Coefficient of Thermal Expansion (Unit:×10⁻⁶/℃)

Temperature range (from room temperature)	Up to 100℃	Up to 200℃	Up to 300℃	Up to 400℃	Up to 500℃	Up to 600℃
COR-TEN O	10.5	11.8	12.8	13.4	13.5	13.6
NAW 490	—	—	13.0	—	—	13.8

＜11.16～11.28×10⁻⁶/℃（20℃）＞

Specific Heat (NAW 490)

Temperature(℃)	50	100	150	200	250	300	350	400	450	500	550	600
Specific heat	0.105	0.111	0.122	0.105	0.128	0.134	0.140	0.145	0.150	0.164	0.176	0.198

＜0.1136～0.1146（20℃）＞

Thermal Conductivity (NAW 490)

Temperature(℃)	cal/cm sec℃	kcal/m hr℃
100	1.34×10⁻¹	48.2
200	1.18×10⁻¹	42.5
300	1.05×10⁻¹	37.8
400	0.94×10⁻¹	33.8
500	0.86×10⁻¹	31.0
600	0.80×10⁻¹	28.8

＜43～52kcal/m hr℃（20℃）＞

Electrical Resistance (NAW 490)

Temperature(℃)	20	100	200	300	400	500	600
Resistivity(μΩ cm)	20.3	23.8	29.4	38.5	50.4	63.6	79.2

＜13.7～15.8μΩ cm（20℃）＞

＜ ＞: Value of “mild steel (C: 0.12~0.20%) specified in Handbook on Mechanical Engineering (The Japan Society of Mechanical Engineers)

7 COR-TEN Joint Materials

Welding Materials

The following welding materials for use with COR-TEN are prepared by NIPPON STEEL WELDING & ENGINEERING CO.,LTD.

Welding Materials and Examples of Characteristic Properties

Designation	Welding method	Brand name	Characteristics	Tensile property			Impact property	
				Yield point (MPa)	Tensile strength (MPa)	Elongation (%)	Temperature (℃)	vE (J)
COR-TEN 490 COR-TEN B	SMAW	CT-03Cr	Weldability is excellent in all positions. For the welding of a thin plate less than 9mm.	500	570	29	0	110
		CT-16Cr	Extra low hydrogen type electrode for welding of medium and thick plates in all positions. Crack resistance and mechanical properties are excellent.	500	560	30	0	240
	FCAW	SF-50W	Diffusible hydrogen content is extremely low and weld metal shows excellent crack resistance. Weldability is excellent in all positions.	500	580	26	0	100
		SM-50FW	Diffusible hydrogen content is extremely low and weld metal shows excellent crack resistance. Weldability is excellent in horizontal fillet welding.	510	590	27	0	74
	GMAW	FGC-55 (P specifications) ※1	GMA welding wire for all positions. Welding of atmospheric corrosion resisting steel (P specifications) for various structural works.	460	570	25	0	180
		YM-55W	GMA welding wire for all positions to be used with CO_2 shield gas. Weldability is good in wide current range.	580	630	27	0	90
	SAW	YF-15B × Y-CNCW	For butt welding.	510	600	27	0	120
		NF-800R × Y-CNCW	For fillet and butt welding.	530	630	26	0	67
COR-TEN 570	SMAW	CT-60Cr	Extra low hydrogen type electrode in all positions. It assures excellent weldability, X-ray properties, crack resistance and mechanical properties.	520	610	25	–18	180
	FCAW	SF-60W	Diffusible hydrogen content is extremely low and weld metal shows excellent crack resistance. Weldability is excellent in all positions.	630	685	22	–5	115
		SM-60FW	Diffusible hydrogen content is extremely low and weld metal shows excellent crack resistance. Weldability is excellent in horizontal fillet welding.	540	620	23	–5	70
	GMAW	YM-60W	GMA welding wire for all positions to be used with CO_2 shield gas. Weldability is good in wide current range.	540	640	26	–5	110
	SAW	YF-15B × Y-60W	For butt welding.	520	630	29	–5	88
		NF-800R × Y-60W	For fillet and butt welding.	511	608	25	–5	68

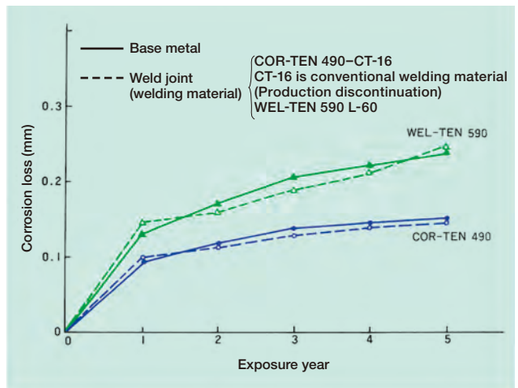
Notes: ※1 FGC-55 is P specifications (Paint). Other materials are W specifications.

- Regarding the welding materials for NAW-TEN series, refer to the catalog prepared exclusively for the series.

Exposure Test Results for Weld Joints

Manual welding test specimens were prepared for COR-TEN 490 and WEL-TEN™ 590 in order to compare the rates of corrosion between these two specimens and base metal specimens (no joints)- the results are shown in the figure on the right. The test results show that the weld joints of both COR-TEN 490 and WEL-TEN 590 have weather resistance similar to the base metal.

WEL-TEN™ is a registered trade name of NIPPON STEEL.



Inquiry: NIPPON STEEL WELDING & ENGINEERING CO.,LTD.
Shingu Bldg., 4-2 Toyo 2-chome, Koto-ku, Tokyo 135-0016 JAPAN
TEL.+81-3-6388-9000 FAX.+81-3-6388-9160
URL.www.weld.nipponsteel.com

Bolt Joints

(1) Weather-resistant High-strength Bolts

F10TW and S10TW, and F10TMR and S10TMR are available as high-strength bolts for use with weathering steel. It is recommended that F10TMR and S10TMR be used with the NAW-TEN series.

For more details, inquire at NIPPON STEEL BOLTEN CORPORATION (Phone: 81-6-6682-3261).

■Applicable sizes: M16～M24

■Chemical Composition (Standard Values)

(mass%)

Material \ Chemical composition	C	Si	Mn	P	S	Cu	Ni	Cr	Al	Mo	B
NWB110	0.20～0.25	0.15～0.25	0.70～0.90	≦0.030	≦0.030	0.30～0.50	0.30～0.50	0.60～0.80	0.040～0.080	—	0.0010～0.0030
NWB110-MR	0.20～0.25	0.15～0.25	0.40～0.60	≦0.030	≦0.030	0.30～0.50	2.50～3.50	—	—	0.15～0.25	0.0010～0.0025

■Mechanical Properties (Standard Values)

Bolts

Mechanical Properties of Test Pieces

Class by mechanical property	Yield strength N/mm²	Tensile strength N/mm²	Elongation %	Reduction of area %
F10TW(S10TW) F10TMR(S10TMR)	900≦	1000～1200	14≦	40≦

Note: The tension test is conducted using JIS Z2201 No. 4 test piece.

Mechanical Properties of Bolts

Class by mechanical property	Minimum tension load kN				Hardness
	M16	M20	M22	M24	
F10TW(S10TW) F10TMR(S10TMR)	157	245	303	353	27～38HRC
Effective section of bolt(mm²)	157	245	303	353	—

Note: The figure in the table shows the minimum tension load that can withstand up to the bolt fracture when the tension test is conducted by inserting the wedge into the bearing surface of bolt and on the condition of no breakage of bolt head.

Nuts

Class by mechanical property	Hardness	Guaranteed load
F10W F10MR	95HRB～35HRC	Same as minimum tension load of bolt

Washers

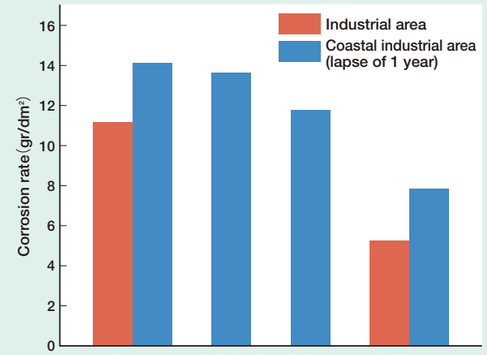
Class by mechanical property	Hardness
F35W F35MR	35～45HRC

■Characteristic Performance Tests

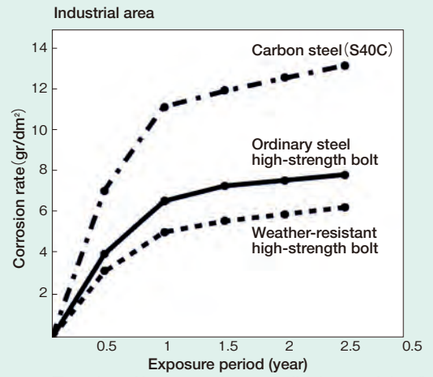
Weather Resistance of High-strength Bolts

The exposure test results (1 year) for various kinds of high-strength bolts are shown in the figure below. It is understood from the figure that these bolts demonstrate high characteristic performances.

Weather Resistance of Various High-strength Bolts (1st year)



Secular Changes



(Test piece: Heat-treated to prescribed strength level)

Delayed Fracture Strength

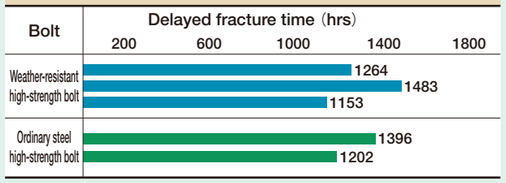
High-humidity atmospheric delayed fracture tests and tightening exposure delayed fracture tests were conducted to survey the delayed fracture strength.

High-humidity Atmospheric Delayed Fracture Tests

Main points in the test

- ●Test method…Round bar notch tension test (stress concentration coefficient 4.5)
- ●Load stress……0.9N.T.S
- ●Atmosphere…Saturated vapor atmosphere(humidity:36～37°C)

Test results



Tightening Exposure Delayed Fracture Tests

Main points of the test

- ●Bolt size……M22×85
- ●Tightening plate……WT60R
- ●Tightening outline…Nut rotation angle method(0.9N max.); Plastic range tightening
- ●Exposure site……Minoshima Coast

Fracture condition (as of December 31, 1992)

Bolt	Date to start exposure	Number of test piece	Fracture number
Weather-resistant high-strength bolt	November 28, 1978	10	0