

Corrosion-resistant Steel Plates



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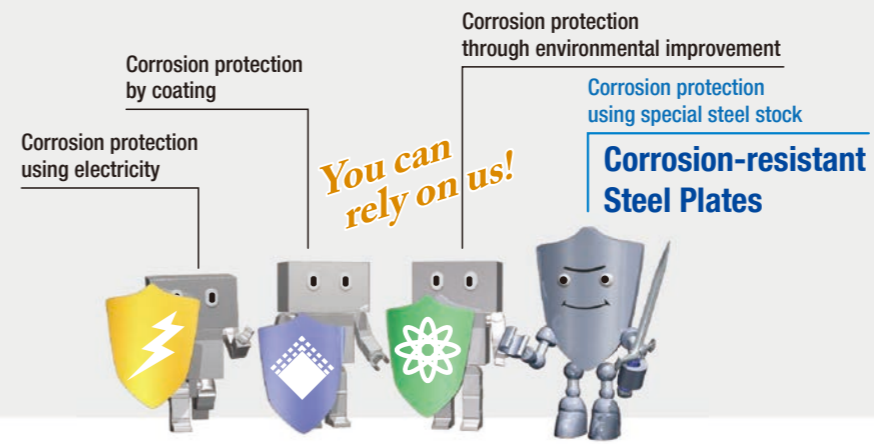
Corrosion (rusting)

We are surrounded every day by many steel objects in diverse shapes that are used for various purposes. A massive amount of steel is used in large structures (bridges, ships, vehicles, and buildings), oil well casings and pipelines, and automobiles and electric appliances. However, steel is intrinsically corrosive (rusty) if corrosion prevention measures are not employed.



Corrosion protection methods

There are roughly four corrosion protection methods: Coating, the use of special steel stock (with corrosion-resistant materials), the use of electricity, and environmental improvement. Each of them has its own characteristics such as the anti-corrosion effect, cost, workability, maintainability, etc., and is used on a case-by-case basis.



Corrosion-resistant Steel Plates

Corrosion-resistant Steel Plates are used as special steel stock for corrosion protection. They are steel materials with corrosion resistance improved by adding anti-corrosion elements (Cr, Cu, Ni, etc.) in an amount that most suits the environment in which the steel is used. Weather-proof steel, seawater-resistant steel, sulfate-resistant steel, etc., are available in accordance with the environment from which the object in need of an anti-corrosion measure is protected.

NIPPON STEEL Corrosion-resistant Steel Plate series

The Corrosion-resistant Steel Plates of NIPPON STEEL have been developed as a “shield” that protects the sustainability of steel structures from corrosion in both acid and neutral regions, atmospheric corrosion, dew-point corrosion, and seawater corrosion produced by various factors in diverse environments.

By selecting the Corrosion-resistant Steel Plate most suitable to the need that may vary according to the circumstances, the construction period and cost for maintenance can be reduced, effecting a significant life-cycle cost reduction.

- S-TEN™ P2
- NSGP™ P3
- NAW-TEN™ P4
- CORSPACE™ P5
- ARU-TEN™ P6
- MARILOY™ P7
- COR-TEN™ P8
- VINCOR™, CORQ™ P9

Corrosion Factors (environments) and NIPPON STEEL Corrosion-resistant Steel Plates

Acid region corrosion environments

Sulfuric acid/hydrochloric acid dew-point corrosion

- Exhaust gas treatment equipment at waste incineration facilities: >>> **S-TEN™ 1&2**
- Boiler air preheaters at thermal power generation facilities: >>> **S-TEN™ 1&2**

Acid corrosion

- Bottom plates and upper decks of crude oil tankers: >>> **NSGP™ 1&2**

Neutral region corrosion environments

Atmospheric/salt corrosion (coastal areas)

- Uncoated bridges and structures: >>> **NAW-TEN™ 12,15**
- Coated bridges and cranes: >>> **CORSPACE™**

Seawater corrosion

- Crude oil tankers, cargo oil pipes, ballast pipes, floodgates: >>> **MARILOY™**

Atmospheric/salt corrosion

- Building exteriors, bridges, towers in inland areas: >>> **COR-TEN™**
- Floors/walls designing: >>> **VINCOR™, CORQ™**
- Indoor environments/indoor vacuum containers/precision machines: >>> **ARU-TEN™**

Acidic
Neutral
Alkaline

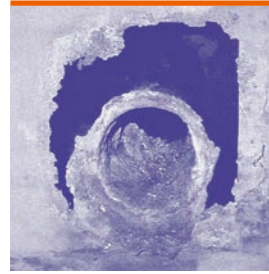
Sulfuric-acid/Hydrochloric-acid Dew-point Resistant Steel

S-TEN™

Applicable standard

NIPPON STEEL's hot-rolled steel plates comply with JIS G 3106.
S-TEN1 : SM400A
S-TEN2 : SM490A

Catalog QR code



Issues

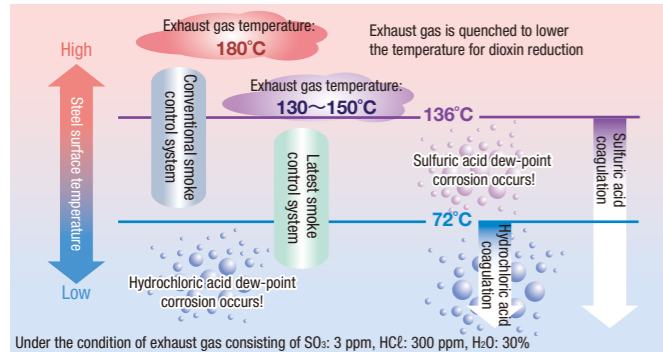
- Sulfuric acid dew-point corrosion due to fossil fuel-derived sulfur oxides.
- Hydrochloric acid dew-point corrosion derived from dioxins.

Effect of application

- Delivers superior performance against sulfuric acid/hydrochloric acid dew-point corrosion in smoke control systems of coal-fired boilers, waste incineration facilities, etc.

Hydrochloric acid dew-point corrosion of an inner cylinder of a chimney

Mechanism of sulfuric acid/hydrochloric acid dew-point corrosion taking place in the smoke control system of a waste incineration facility

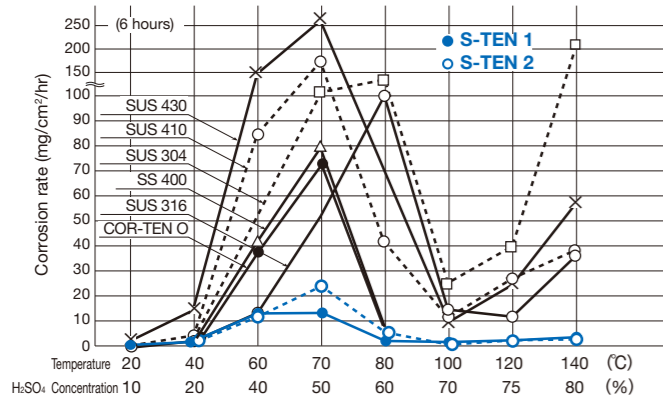


Under the condition of exhaust gas consisting of SO₂: 3 ppm, HCl: 300 ppm, H₂O: 30%

Has excellent corrosion resistance in a strong acid environment at low pH levels.

Sulfuric acid immersion test results in a vapor-liquid equilibrium state of sulfuric acid and the water system

- Under the conditions of 70°C and H₂SO₄ at 50%, S-TEN shows corrosion resistance of approx. five times that of conventional steel and approx. 10 times that of stainless steel.



Superior corrosion resistance is confirmed through a sulfuric acid immersion test.

Features

- S-TEN™ is NIPPON STEEL's original sulfuric/hydrochloric-acid dew-point resistant steel that has a long-term and excellent track record.
- More economical than stainless steel.
- It offers a wide variety of types including hot-rolled and cold-rolled steel plates, steel pipes, and weld materials.
- High accessibility is secured by steel product wholesalers that constantly have the product in stock.
- Comparable strength, workability, and weldability with those of conventional steel.
- Major prizes awarded
 - Ichimura Prize in Industry for Excellent Achievement (FY2006)
 - Award for excellence of Nikkei Excellent Products & Services Award (FY2003)

Has an excellent track record mainly in the area of smoke control systems.

Real machine test results

- The life extension effect of approx. five times that of conventional steel is confirmed in an air preheater of the steel pipe type for heavy oil-fired boilers.

Test subject		Air preheater of the steel pipe type for heavy oil-fired boilers at electric utility company K			
Test piece installation point		Used at the front of re-heater low-temperature tanks of the air preheater			
Test conditions	Exhaust gas temperature	124 ~ 130°C	Gas composition	SO _x	360ppm
	Sulfuric acid dew point	130°C		H ₂ O	Approx. 10%
	Metal temperature	70 ~ 80°C	Test time period	4,808 hours	
Test results	Steel type	Measurement value of reduced wall thickness due to corrosion (mm/4,808 hours)		Estimated annual corrosion amount (mm/year)	
		Maximum	Average	0.04 ~ 0.22	
	S-TEN 1	0.12	0.02	0.04 ~ 0.22	
	SS 400	0.62	0.25	0.46 ~ 1.13	

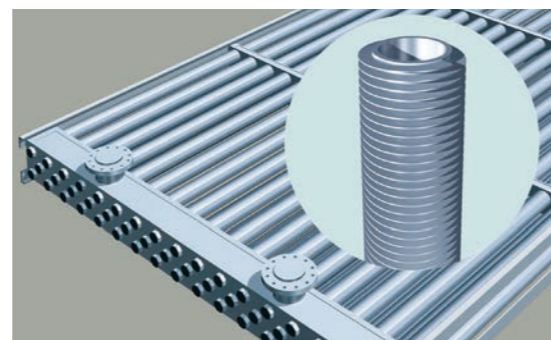
The effect is confirmed in a real machine exposure test as well.



Flue-gas desulfurization equipment in a coal-fired power station



City of Nagoya Environmental Affairs Bureau



Steel pipes for air fin coolers and fin tubes

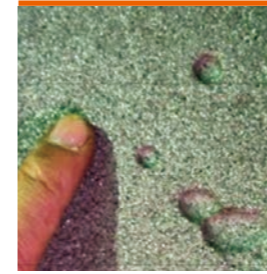
High Corrosion-resistant Steel for Crude Oil Tankers

NSGP™ -1&2

Applicable standard

Approved by classification societies as a corrosion-resistant steel product for cargo oil tanks.

Catalog QR code



Issues

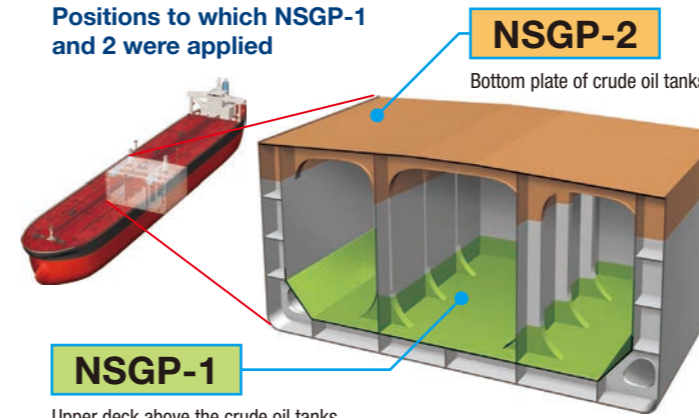
- Deep pits are formed in tank bottom plates.
- All surfaces of tanks under the upper deck corrode.
- Taking corrosion prevention measures for tanks was made obligatory in 2013.

Effect of application

- The frequency of pit forming in the bottom plate decreases to 1/15 of conventional steel.
- The corrosion amount under the upper deck decreases to approx. 60% of conventional steel.
- By eliminating the coating process, a reduction in construction cost and life-cycle cost can be achieved.

Pitting corrosion on the tank bottom plate of a crude oil tanker

Positions to which NSGP-1 and 2 were applied



NSGP-1

Upper deck above the crude oil tanks

NSGP-2

Bottom plate of crude oil tanks

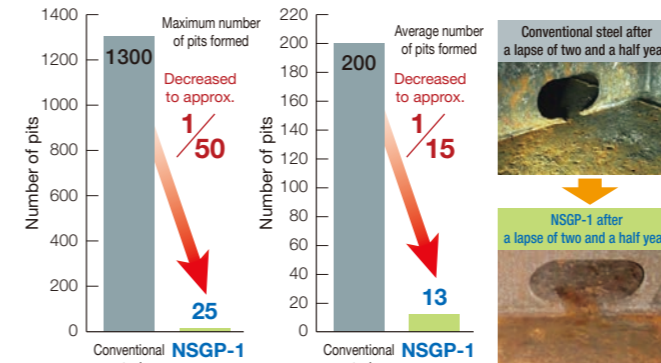
Produces corrosion reduction effect for COTs (cargo oil tank) of crude oil tankers.

Features

- NSGP-1 significantly delays the progress of pitting deep into bottom plates (pitting corrosion) attributable to salt water contained in crude oil.
- NSGP-2 significantly delays the corrosion expansion over all surfaces of tanks attributable to H₂S contained in crude oil, exhaust gas charged into tanks to prevent explosion, and dew condensation caused by the temperature gap between day and night.
- The corrosion resistance that is produced by the alloy components does not vary contrary to products with corrosion resistance provided by coating.
- Welding materials for exclusive use with enhanced corrosion resistance are also offered.
- Major prizes awarded
 - Ichimura Prize in Industry for Distinguished Achievement (FY2010)
 - Special Prize of Monozukuri Nippon Grand Award (FY2011)
 - Award for excellence of Nikkei Excellent Products & Services Award (FY2007)

Significantly suppresses the generation of pits and corrosion on all surfaces of crude oil tanks.

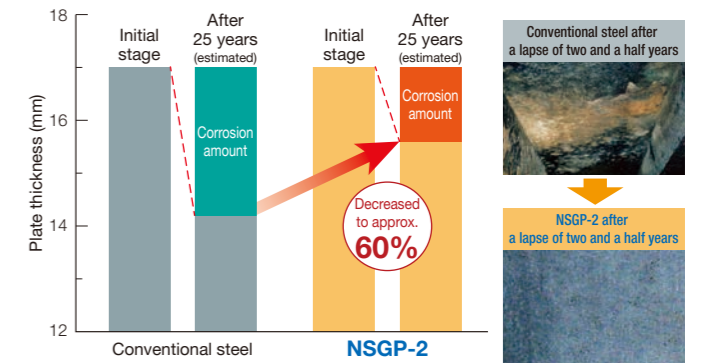
Comparison of pitting corrosion (4 mm deep or more) occurrence frequency after a lapse of five years (NSGP-1)



In ships that use conventional steel for tanks for five years, up to 1,300 pits of at least 4mm-deep per tank are formed from corrosion. In those that use NSGP-1 for tanks, the number of pits formed from corrosion has reduced to approx. 1/50 of those with conventional steel, or to approx. 1/15 on average.

The high performance of NSGP-1 and 2 has been confirmed in actual ships to which they have been applied.

Transition of the corrosion amount and comparison (NSGP-2)



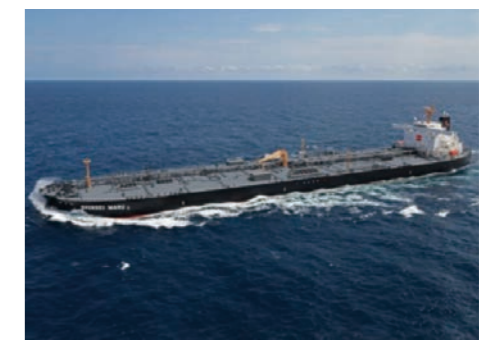
When the corrosion amount after 25 years is estimated from the results of the use of conventional steel and NSGP-2 in actual ships for eight years, it can be predicted that the corrosion amount of NSGP-2 can be reduced to approx. 60% of the corrosion amount of a ship with conventional steel in which the depth of a pit exceeded 2 mm.



VLCC/TAKAMINE (to which NSGP-1 was first applied)



VLCC/TSURUGA (to which NSGP-1 was applied)



Aframax tanker Shinsei Maru (to which NSGP-1 and 2 were applied at the same time)

Nickel-based High Weather-resistant Steel

NAW-TEN™

Applicable standard

NAW-TEN™ complies with JIS G 3114, with the chemical components excluded.



Issues

Although the use of weather-resistant steel compliant with JIS (JISG3114) is desired, the Specifications for Highway Bridges, the Design Standard of Railway Structures, etc. (hereafter referred to as the "regulations") do not apply to the installation environment.

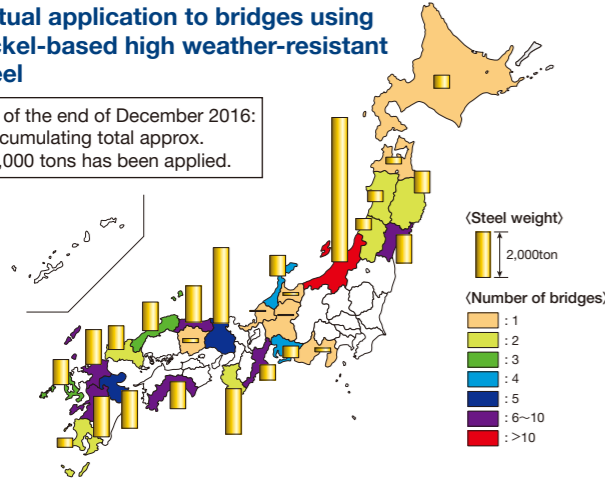
Corroding bridge (in an environment with severe salt injury)

Effect of application

- Displays superior weather resistance without coating even when installing the structure in an area not applicable to the regulations regarding weather-resistant steel compliant with JIS.
- The use with no coating is possible leading to LCC and VOC reductions.

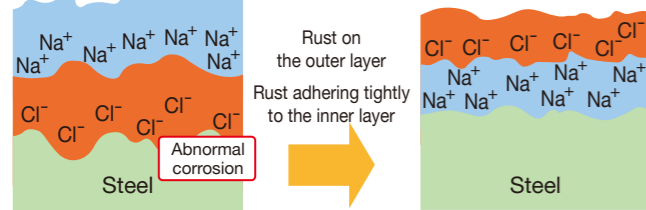
Actual application to bridges using nickel-based high weather-resistant steel

As of the end of December 2016: Accumulating total approx. 31,000 tons has been applied.



NAW-TEN™ has been applied to road bridges and railway bridges not applicable to the regulations of weather-resistant steel compliant with JIS.

Rusting mechanism control principle by alkalinizing the base steel interface



Hydrochloric acid interface (Conventional steel)

Becoming an alkaline interface (NAW-TEN)

Rust has a two-layer structure; If the inner layer rust is stable and solid, the progress of corrosion is inhibited.

Conventional steel: Cl⁻ becomes hydrochloric acid, causing abnormal corrosion. NAW-TEN: Na⁺ becomes sodium hydrate, which is alkaline.

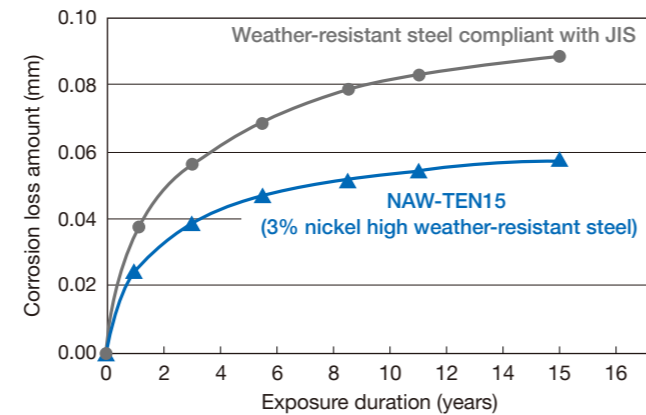
Cl⁻ detrimental to the formation of protective rust has concentrated in the outer layer rust.

Features

- Exhibits superior weather resistance without coating even in an environment not applicable to the regulation of weather-resistant steel compliant with JIS. (Applicable environment assessment is necessary.)
- Two types of steel that can be selected in accordance with the application environment and required performance are offered. (They comply with JIS with the components excluded.)
 - Lineup of products with tensile strength of 40-60 kg
 - Welding materials and high-tension bolts for exclusive use are also included in the lineup
 - Comparable workability with that of conventional steel
- There are abundant application cases for about 20 years.
- Prediction of the corrosion loss amount is possible using the YOSOKU™ software.
- Major prizes awarded
 - Ichimura Prize in Industry for Distinguished Achievement (FY1999)
 - Excellence Prize of Monozukuri Nippon Grand Award (FY2009)
 - Tanaka Award in Excellence in Research Paper of the Japan Society of Civil Engineers Award (FY2005)

We offer products necessary for applicability evaluation technology and construction of steel structures.

Small-scale exposure test results



The corrosion loss amount is reduced by over 30% of that when using weather-resistant steel compliant with JIS.



Hokuriku Shinkansen Hokurikudo Overbridge (Niigata Prefecture)



Ohama Grand Bridge (Oita Prefecture)



Shimane Museum of Ancient Izumo (Shimane Prefecture)

Coating Cycle Extension Steel

CORSPACE™

Applicable standard

CORSPACE™ complies with JIS G 3101, JIS G 3106 and JIS G 3140.



Issues

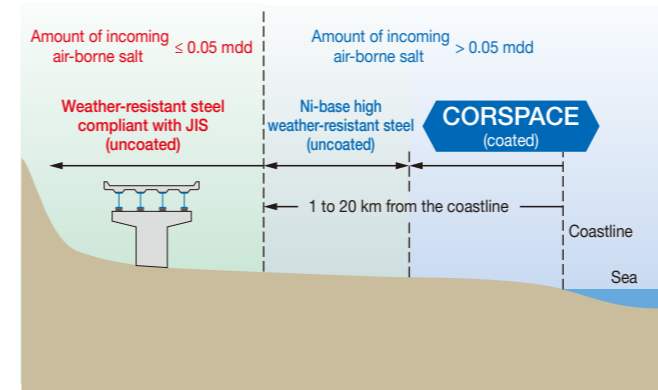
- Rusting from coating pinholes, deteriorated parts, etc.
- Rusting from the sharply angled part of a member

Peel-off of bridge coating (in an environment with severe salt injury)

Effect of application

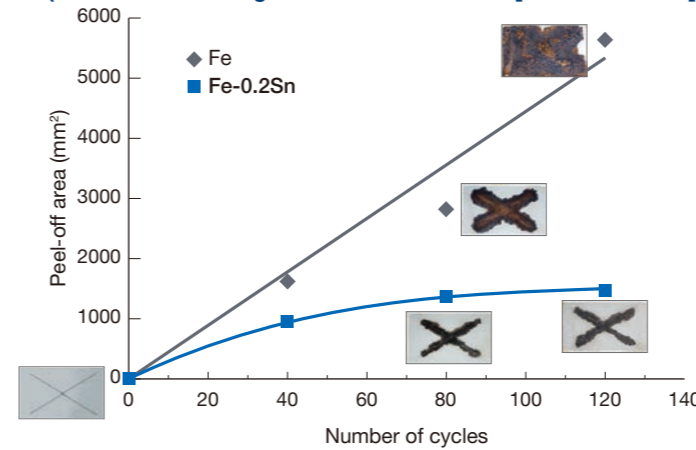
- In an environment in which salt damage is severe, extending the coating replacement period can lead to the reduction of maintenance cost and environmental load.

Concept of CORSPACE application to a bridge of Japan



Exhibits effect in coastal areas with severe salt injury.

Corrosion resistance properties (assessment through an acceleration test [SAE J2334 test])



The peel-off area of the flawed part is small; and corrosion is suppressed.

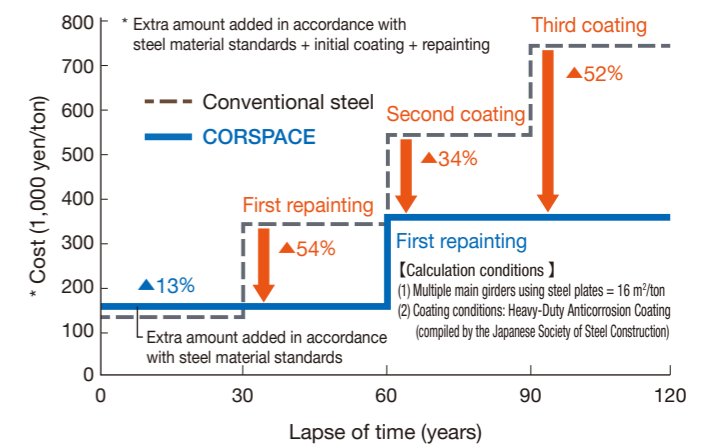
Advantages on order receipt, designing and manufacturing

- We can assist with the use of the NETIS registered technology (KK-150056-A, registered in February 2016) and in making technical proposals and construction performance rating.
- Cited as tin-added steel in Materials Used of the Bridge Structure Design/Construction Guidelines issued by the Metropolitan Expressway Company Limited in June 2015.
- Complies with all JIS regarding steel products that are mainly used for bridges. The steel plate manufacturable range is also equivalent to that of conventional steel.
- Workability in cutting, bending, welding, etc., is comparable with those of conventional steel.
- Welding materials and bolts for exclusive use are offered.



Provides point addition factors in assessment after completion when making proposals.

Concept of life-cycle cost reduction



Life-cycle cost can be reduced. Repainting frequency is reduced to once per 100 years.



Hanshin Expressway Sambo Junction



Higashiharima-Nanboku Road (Mizuashi Shintsuji No. 5 Elevated Bridge)



Unloader

Low-alloy Corrosion-resistant Steel Close to Stainless Steel

ARU-TEN™

Applicable standard

The mechanical properties are equivalent to JIS G 3106 SM490.



Issues

- There has been no corrosion-resistant steel that balances corrosion resistance and economic efficiency in a mild indoor environment.

Effect of application

- Exhibits red rust resistance close to that of stainless steel in a mild indoor environment.

Red rust caused by contamination from human hands indoors

Positions to which ARU-TEN was applied



Can be used in an indoor environment as an alternative to stainless steel.

Features

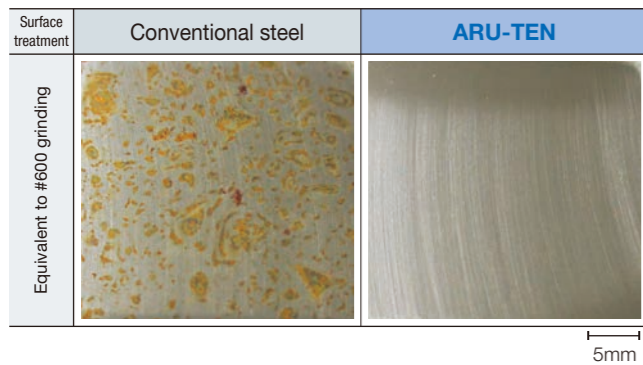
- Suppresses red rust without coating in an indoor environment. (The use in outdoor environments is enabled by applying a zinc-rich primer.)
- The total amount of alloy addition (Ni, Cr, etc.) is approx. 1/4 that of SUS304.
- Comparable yield strength with that of SM490.
- Machining properties close to that of SS400.
- Comparable magnetizability with that of conventional steel.
- Comparable weldability with that of conventional steel.

Has corrosion resistance close to that of stainless steel and workability close to that of conventional steel.

Appearances of test pieces after a dry-wet-cycle test

- Excellent corrosion resistance has been confirmed through a dry-wet-cycle test assuming a general indoor environment.

Test conditions: ① 25°C 50%RH for one hour → ② Transition for 0.5 hours → ③ 50°C 90%RH for one hour → ④ Transition for 0.5 hour
The process cycle ①-④ was repeated 1,120 times (for 140 days).



Excellent corrosion resistance has been confirmed through a dry-wet-cycle test.

Effects

- A promising new corrosion-resistant steel that balances corrosion resistance and economic efficiency without coating in a mild indoor environment.

Item		Steel type		
		SS400	SUS304	ARU-TEN
Corrosion resistance	Without coating indoors	×	◎	◎
	Economic efficiency	◎	△	○
Mechanical properties	Yield strength (MPa)	≥235	≥205	≥315
	Tensile strength (MPa)	400 - 510	≥520	490 - 700
Workability	Gas cutting properties	○	× (Plasma)	× (Plasma)
	Machinability	◎	×	○
	Weldability	◎	△	◎
Physical properties	Magnetic properties	Present	None	Present

A corrosion-resistant steel with similar properties to that of stainless steel designed considering the economic efficiency.



Vacuum container (uncoated)



Indoor nameplate (uncoated)



Pulverized fine coal injection equipment (with a zinc-rich primer)

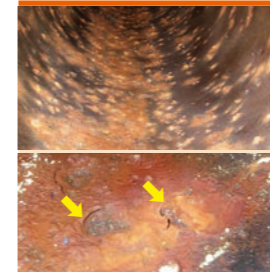
Seawater Corrosion Resistant (Undersea) Steel

MARILOY™

Applicable standard

The mechanical properties are equivalent to JIS G 3106 SM400 and SM490.

Catalog QR code



Issues

- Corrosion in a seawater immersion environment.

Effect of application

- Exhibits superior corrosion resistance to that of conventional steel in a seawater immersion environment.

Corrosion in a water ballast pipe

Positions to which MARILOY was applied



Suitable for steel structures used in seawater immersion environments.

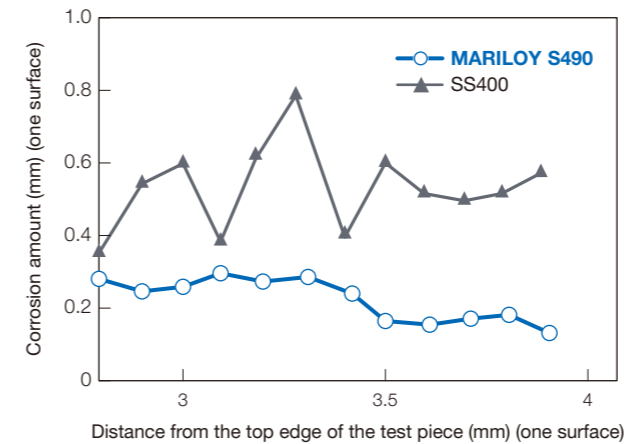
Features

- The corrosion rate in seawater is approx. one half that of conventional steel.
- The mechanical properties are comparable with those of 400-490 MPa carbon steels.
- The weldability is comparable with that of 400-490 MPa carbon steels.

Exhibits superior corrosion resistance in a seawater immersion environment.

Seawater immersion test result

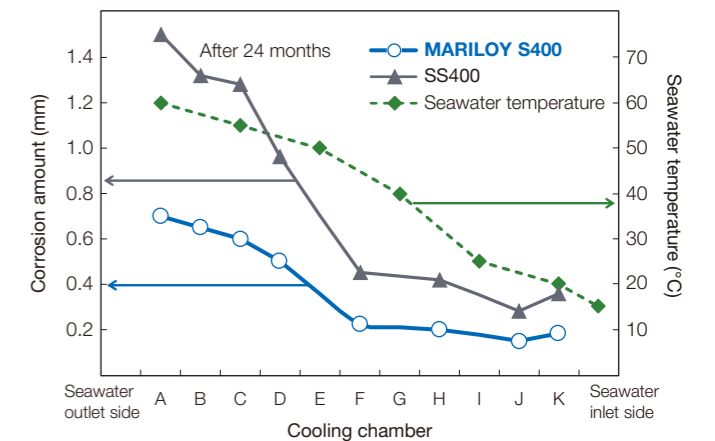
- Excellent corrosion resistance has been confirmed through a seawater immersion test conducted in an area of Setouchi for three years.



Excellent corrosion resistance has been confirmed through a seawater immersion test.

Corrosion amount measurement result for a seawater-gas cooler piping

- The results of application to the gas cooler tube of a heat exchanger have shown a corrosion rate of approx. one half that of conventional steel.



The effect has been confirmed with actual structures to which MARILOY was applied.



Cargo oil pipes of crude oil tankers



Cargo oil pipes



Floodgate

High Weather-resistant Steel

COR-TEN™

Applicable standard

COR-TEN™ is equivalent to SMA400W to 570W for JIS G 3114, and SPA-H for JIS G 3125.

Catalog QR code



Issues

- Conventional steel requires coating to prevent corrosion, leading to the heavy burden of repainting and other maintenance and management costs.
- The use of steel in harmony with nature is desired.

Effect of application

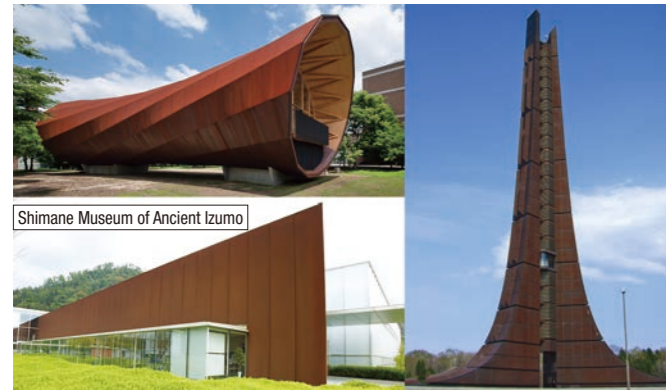
- The use without coating is allowed, which reduces repainting and other maintenance and management costs.
- The esthetic effect can be expected from the soft color of rust ("Beauty of Rust").



Daigo Fukuryu Maru Exhibition Hall

COR-TEN is a registered trademark owned by United States Steel Corp.

"Beauty of Rust" appearance change across the ages



Shimane Museum of Ancient Izumo

COR-TEN meets needs considering the scenery and for other aesthetic purposes.

Features

- COR-TEN is used without coating (including that of rust stabilization auxiliary treatment) to exhibit excellent weather resistance.
- The change of surface colors across the ages can be enjoyed.
- Coating is also possible in the same way as conventional steel. A repainting cost reduction can be expected by extending the cycle of repainting.
- The weldability and workability are comparable with those of conventional steel.
- Joining materials (welding materials and bolts) for exclusive use are also offered.
- Major prizes awarded
 - Otani Art Museum Prize (FY2011)

This weather-resistant steel has overcome rust as the biggest weakness of steel in a unique manner using rust to prevent rust.

Styling with uncoated COR-TEN

The soft color of the protective rust and the change across the ages provide the appearance with an excellent effect.



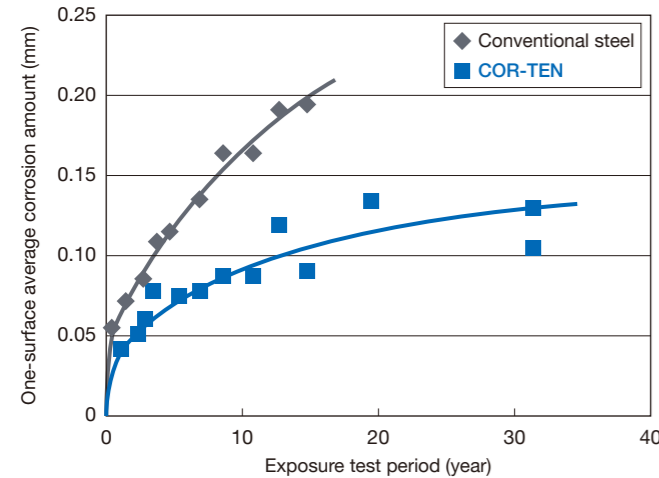
1969: At the time of completion

1973: After a lapse of four years

2010: After a lapse of 41 years

There are many socially important structures and buildings to which COR-TEN has been effectively applied.

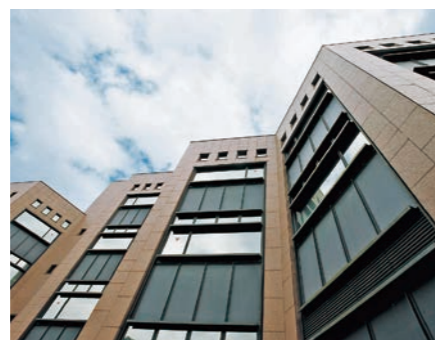
Corrosion amount



The corrosion amount can be reduced more than that of conventional steel.



Used without coating/treatment



Used with rust stabilization auxiliary treatment



Used with coating

Vintage COR-TEN

VINCOR™

A Casting of COR-TEN

CORQ™

Catalog QR code



Issues

- The use of COR-TEN is desired indoors.
- There is a concern about initial rust in the shape of a flow or stream.
- The use of COR-TEN for floor material, etc. is desired for styling purposes.

Effect of application

- COR-TEN in the aged state is provided.
- Castings are provided for floor materials, etc.



Discoloration due to rust in the shape of a flow or stream

CORQ is a registered trademark owned by Kyoji Takubo and NIPPON STEEL.

Features

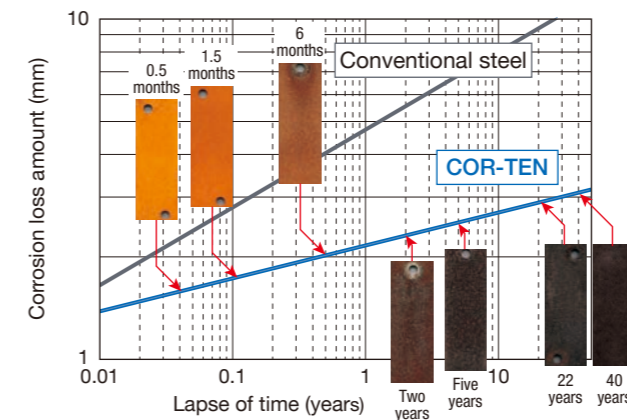
VINCOR

- VINCOR is prepared by rendering COR-TEN aged before shipping to give it a special initial color.
- VINCOR is sold by Chikumakozai Co., Ltd. (TEL: 81-47-354-5721).

CORQ

- CORQ is a casting with the features of COR-TEN.
- Mainly used as a floor material.
- CORQ is manufactured and sold by Okayama Casting Center Cooperative Association (TEL: 81-86-277-5588).

Example of corrosion loss amount and surface color change across the ages

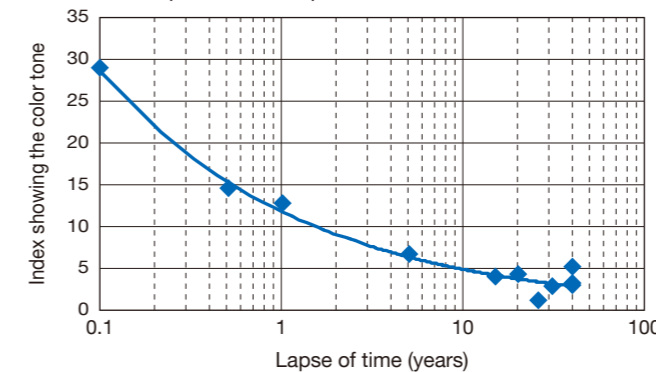


Needs considering the scenery and for other aesthetic purposes can be satisfied.

A new form of COR-TEN produced from customers' needs is proposed.

Concept of VINCOR

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



The quantification of colors enables customers to select the color tone of the product at shipping.

Positions to which CORQ is applied

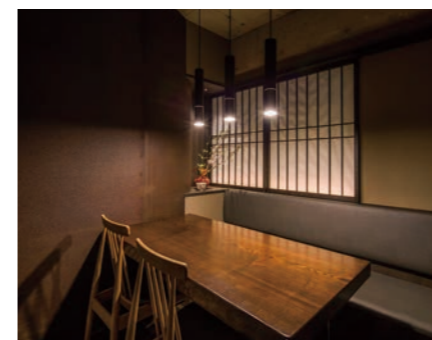
Example of a general floor material (granite flagstones)



Parts made of CORQ



Expands the possibilities as a floor material used for styling purposes.



Partition wall in restaurant



Exhibition in 2016 at the Tokyo Metropolitan Art Museum



Iiyama Church of the Resurrection