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Feature Story

COR-TEN®: Marking Its 50th Anniversary on the Market

The Task Ahead: Pursuit of New Possibilities as a Weathering Construction Material

Head Office Building of Nippon Steel in Tokyo
- Completed in 1970; photographed in 2009
- 40 years after completion

La Chapelle des Pommiers (apple tree chapel) in Normandy, France
- Completed in 1999; photographed at the time of completion

Susa Bridge in Yamaguchi
- Completed in 1990; photographed in 1992
- 3 years after completion in Yamaguchi

The year 2009 marked the 50th anniversary of the manufacture and marketing by Nippon Steel of COR-TEN®, a weathering steel, in 1959. The superb weather resistance (corrosion resistance) of COR-TEN® permits minimum maintenance and an ultra-long service life for buildings, bridges, and other applications, thereby contributing to reduced lifecycle costs and environmental stress. More recently, the reevaluation of special COR-TEN® characteristics, such as a distinctive color and decorative effect that only increase over time, has led to the growing use of COR-TEN® in construction projects.

The 50th anniversary provided an opportunity for Nippon Steel to emphasize the pursuit of new possibilities for COR-TEN® as a construction material that is not only in tune with Japan's climate and landscape, but is also environmentally sound.

COR-TEN: Registered trade name of United States Steel Corporation

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Compatibility with Japan's hot and humid climate

Nurturing COR-TEN® as a worldwide brand

Paint-free Weather Resistance

Steel tends to rust and is usually painted before use to prevent rust from occurring. COR-TEN® defies this common conception of steel because it offers four to eight times more atmospheric corrosion resistance than ordinary steel. Soon after application, COR-TEN® begins to rust in the same way as ordinary steel. But later, due to the action of special alloying elements, it develops a fine-textured protective rust film on the surface. This film prevents rust from reaching the base metal (Fig. 1). This "rust cures rust" property allows COR-TEN® to be used without painting. Furthermore, over the course of time, the protective film begins to create a distinctively beautiful shade of color that blends harmoniously with Japan's climate and landscape (Photo 1).

Fig. 1
Comparison of Corrosion Process between COR-TEN and Ordinary Steel

Appearance of test specimens subjected to long-term exposure

Ordinary steel

COR-TEN®

While a thick, rough layer of corrosion is generated on the exposure test specimen of ordinary steel, a thin yet dense corrosion layer is generated on the exposure test specimen of COR-TEN®.

Photo 1
Secular Changes of Appearance of the Hokkaido Centennial Memorial Tower Employing COR-TEN®

October 1969:
Under construction

April 1973:
4 years after completion

May 1991:
22 years after completion

May 2007:
38 years after completion

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Active Introduction of New Technology and Quality Improvement

R&D into atmospheric corrosion resistance—the most notable feature of COR-TEN®—has a long history that dates back to U.S. efforts early in the 20th century. In order to realize bridges of increasing span length and railway vehicles and ships of increasingly lighter weight, a major theme at that time was the development of steel with excellent strength and toughness. In 1916 and later, an array of steel products that were newly developed to meet these needs underwent full-scale atmospheric exposure testing by the American Society for Testing and Materials (ASTM), the British Standards Institution (BSI), and other internationally noted institutes. This led to the manufacture and marketing by US Steel in 1933 of a new type of atmospheric corrosion-resistant steel under the trade name of COR-TEN.

In Japan, since 1959 when Fuji Steel (forerunner of Nippon Steel) introduced related technology from US Steel, constant innovation has solidified the position of COR-TEN® as a preeminent high-strength steel offering excellent atmospheric corrosion resistance. Subsequent to being used early on as rolling stock for the Shinkansen superexpress railway between Tokyo and Osaka, applications for it gradually expanded to include railway vehicles, marine containers, and industrial machinery. Later, it began to find use in large-scale steel structures—with increasingly extensive service in bridge applications.

Reviewing the 50-year history of the manufacture and marketing of COR-TEN®, Manager Mutsu Tanaka of the Plate Technical Dept. of the Plate Division says: “When COR-TEN® technology was introduced, Japan’s distinctive climatic and geological conditions presented a particular challenge: large amounts of precipitation, high temperatures and high humidity, and the exposure of many coastal areas to stiff briny winds. It seemed unlikely that the “rust cures rust” property of COR-TEN® could be given full play in such a severe environment. As a measure to cope with this, Nippon Steel strove to elucidate a mechanism by which the protective rust could be stabilized and to improve the quality of COR-TEN® to suit Japan’s climate. By doing so, we have maintained a commitment to nurturing this worldwide brand in Japan.”

Mutsu Tanaka
Manager, Plate Technical Dept., Plate Division

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A Challenge for Nippon Steel
Providing Improved Salt-corrosion Resistance

Mechanism of Inherent Properties Clarified by Highly Accurate Testing and Analysis

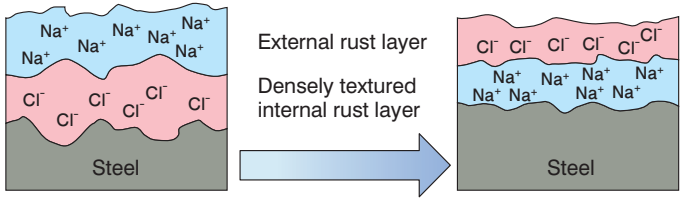
COR-TEN® reduces the maintenance load of steel structures due to its "rust cures rust" property. Particularly in bridge applications, COR-TEN® attracted attention as an infallible measure to reduce repainting costs. This was especially true following the 1983 revision of related JIS standards to cover specifications for COR-TEN® when it saw a sudden growth in demand. However, when untreated COR-TEN® was used in coastal bridges exposed to a high amount of airborne sea salt, it was not always able to fully demonstrate the expected rust-prevention performance. In order to realize safe and reliable minimum-maintenance bridges, Nippon Steel remained committed to clarifying a mechanism for improving seaside corrosion resistance.

Chief Researcher Hiro Kihira of Steel Research Laboratories, who has long been engaged in R&D regarding atmospheric corrosion resistance in steel, comments as follows: "The protective rust film of COR-TEN® differs from that of ordinary steel in that it consists of a two-layer structure. Distinctive is the internal layer, which, due to the way that the alloying elements function, develops densely textured protective rust that inhibits progressive corrosion.

"The addition of phosphorous, copper, chromium, or nickel is deemed useful for corrosion protection in general atmospheric environments, but we found that nickel was particularly effective in improving corrosion resistance in seaside environments. According to our tests, when nickel is concentrated in the internal rust layer, it absorbs sodium ions contained in airborne sea salt, and these sodium ions alkalify the boundary surface of the matrix, thus retarding corrosion (Fig. 2). Chromium, on the other hand, causes deterioration in the atmospheric corrosion resistance of

Hiro Kihira
Chief Researcher,
Steel Research Laboratories

Fig. 2
Mechanism of Corrosion Control by Means of Alkalifying the Boundary Face of the Matrix (NAW-TEN®)



Acidic boundary surface (conventional steel)
Alkaline boundary surface (NAW-TEN®)

The rust layer is composed of two structures, and when the internal rust layer is stable and solid, corrosion ceases to develop.

Conventional steel: Chloride ions (Cl^-) transform into hydrochloric acid, causing abnormal corrosion.
NAW-TEN®: Sodium ions (Na^+) transform into alkaline sodium hydroxides, retarding the further development of corrosion.

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steel located in corrosive seaside environments. This is because chloride ions gather around inner layers of rust that contain concentrations of chromium and then react with condensed water to form hydrochloric acid. The acid makes the boundary surface of the matrix acidic that eventually leads to enhanced corrosion."

Corrosion-control Solutions in Support of Customer Trust

Nippon Steel was the first steelmaker in the world to successfully clarify the mechanism of protective rust formation for the purpose of improving the seaside corrosion resistance of steel. Based on this acquired knowledge, Nippon Steel developed "NAW-TEN®," a nickel-added advanced weathering high-tensile steel—an advanced version of COR-TEN® that is highly compatible with Japan's environment. With conventional COR-TEN® as its base, NAW-TEN® is produced by increasing the amount of nickel added to the steel and by eliminating chromium. Within the NAW-TEN® series, 3%-nickel advanced weathering steel showed excellent performance in atmospheric exposure tests conducted over several years following its development and has already found wide application in bridges and construction projects.

"With a major emphasis on semi-permanent corrosion protection for unpainted steel structures, we have endeavored to provide practical corrosion protection systems that enhance the reliability and value of COR-TEN® and to bring about ongoing advances." (Chief Researcher Hiro Kihira)

In light of these achievements in R&D by Steel Research Laboratories, Joe Nakai of the Plate Sales Div. describes his goals for the future: "We will focus on the integration of our research and marketing departments, and also on collaboration between Nippon Steel Group companies in order to provide COR-TEN®-based solutions that are responsive to customer needs."

Joe Nakai
Plate Sales Div.,
Plate Division

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Structural Aesthetics of COR-TEN® Adopted as Building Materials
High Decorative Quality Brought About by Fine Rusting

Shimane Museum of Ancient Izumo

Design: Fumihiko Maki, architect, representative of Maki and Associate

Harmonization of image scale and high toughness with surrounding landscape

- Completed in 2006; photographed in 2009
- 3 years after completion

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IRONHOUSE

Design: Ryozo Umezawa, structural designer, representative of Umezawa Structural Engineers

Strength and architectural design to support housing with a 200-year service life

- Completed in 2007; photographed in 2009
- 2 years after completion

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Operating Roundup

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"Kamitsubaki" (café & restaurant) at Konpira Shrine

Design: Kyoji Takubo, artist, cultural advisor of Konpira Shrine

Fusion of the proof of existence and architectural aesthetics with contemporary art

- Completed in 2007; photographed in 2009
- 2 years after completion

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