Technical Topic

Introduction of the Analysis and Evaluation Technology from Nippon Steel Technology Co., Ltd. to the Building and Infrastructure Market

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Abstract

This paper introduces the advanced technology, proposed by Nippon Steel Technology Co., Ltd., relating to not only the on-site diagnosis technique to support maintenance needs, but also the performance evaluation technology to meet new construction requirements.

1. Introduction

With the aging deterioration of existing structures, such as roads, railroads, building structures, and energy-related infrastructure, demand for their maintenance and management is escalated, being further accelerated by decarbonization policies. On the other hand, falsified performance data and other problems with new structures have extended the time it takes to get new materials and new technologies approved and to have their performance evaluated. Under such circumstances, more rational and faster performance demonstrations are required. Due to these social trends, Nippon Steel Technology Co., Ltd. (hereafter abbreviated as NSTEC) is strengthening its maintenance and management technology for existing structures and its performance evaluation technology for new structures. In this report, we describe the advanced technologies that NSTEC can propose and provide for both areas.

2. Testing and Analysis Technologies to Meet Maintenance and Management Needs and New Construction Needs

Figure 1 shows how NSTEC's testing and analysis technologies meet social needs, and **Table 1** does specific technologies. For the maintenance and management requirements, we undertake the inspection and diagnosis stages of the maintenance cycle, measure the conditions of deterioration mainly due to corrosion and fatigue on site, and conduct more detailed evaluations in laboratories as required. For corrosion, by using drones to perform remote diagnosis, relatively plate thickness reduction, machine failure, and areas where temperature becomes relatively abnormal due to plate thickness reduction, etc. can be observed. Preparation of corrosion maps and diagnostics of paint film deterioration can be, additionally, conducted. For fatigue, it is enable to detest defects mainly in welds, measure residual stress, and predict the material strength of old structures.

Otherwise, for the new construction requirements, we can manage performance evaluation tests specified for obtaining approvals and carry out tests as conducted by the Architectural Welding Certification Association. In addition to the on-site deterioration diagnosis related to corrosion and fatigue described above, cracks and defects diagnoses in structures, corrosion tests in circulating natural seawater, and fatigue tests at high and low temperatures are available. One of our strong points of technologies is in visualization of surface strain distribution during structural test, and parametric evaluations linked to numerical simulations (CAE). We can also undertake relevant tests such as wear resistance and failure cause investigations. As described above, NSTEC has built a system that can consistently perform everything from measurement to analysis, structural testing, and numerical analysis. NSTEC's main feature is that it can provide customers with comprehensive solutions.

3. On-site Deterioration Diagnosis Technologies

3.1 Detection of thickness reduction and cracking due to corrosion

3.1.1 Investigation of plate thickness reduction, etc., with drone-mounted measuring instruments

To predict the remaining strength of existing structures, it is necessary to determine the thickness reduction due to corrosion. **Figure 2** shows on-site ultrasonic thickness measurement on a steel bridge.

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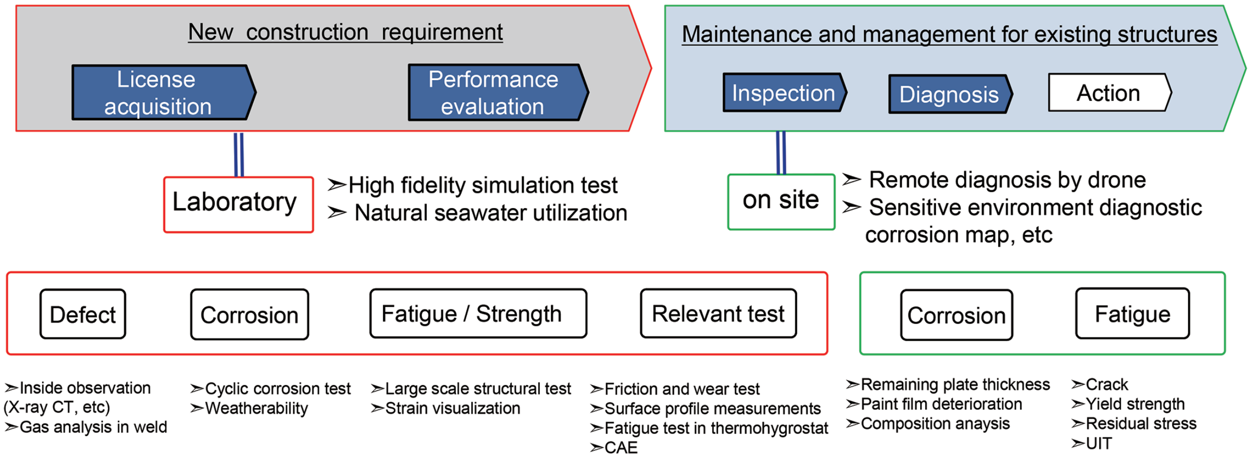


Fig. 1 Analysis and evaluation technology that meets the needs of society

Table 1 Analysis and evaluation technology related to the building and infrastructure at Nippon Steel Technology

		Objective	Evaluation method
Maintenance and management (existing structures) ↓ Inspection	Corrosion	Plate thickness reduction	Ultrasonic thickness gauge (Fig. 2), Thickness indicator mounted on a drone (Fig. 3)
		Abnormal temperature	Thermal video camera
		Corrosion map	Patch test (Fig. 6)
		Corrosion rate	Patch test, Atmospheric corrosion monitoring (ACM) sensor
		Paint film deterioration	Electrochemical impedance spectroscopy (EIS), Fig. 7
		Chemical composition	(Portable) X-ray fluorescence analysis
	Fatigue	Crack and defect	Ultrasonic testing (UT), Radiographic testing (RT), Penetrant testing (PT), Phased array UT, Time of flight diffraction (TOFD), Fig. 4
		Residual stress	X-ray residual stress measurement device
		Bolt looseness	Measurement of axial tension of bolt
		(Yield) Strength deterioration	Hardness, Instrumented indentation technique (IIT), Fig. 5
New construction ↓ Performance evaluation and certification exam	Defect	Crack and defect	UT, RT, PT, Phased array UT, TOFD, Microfocus X-Ray CT (Fig. 8), Gas analysis in blowhole
	Corrosion	Corrosion resistance	Salt spray test (SST), Combined cyclic corrosion test (CCT), Salt deposition cyclic corrosion test (Table 2), Corrosion test in circulating natural seawater tank, Microbial corrosion analysis via DNA examination
		Weatherability	Using artificial light sources weatherability test and light resistance test
	Fatigue Strength	Material certification (strength)	AW certification of welding competency, AW welding procedure specification evaluation, Tensile strength test according to JIS standard, Fatigue strength test, Charpy impact test, Crip tip opening displacement (CTOD) test, Drop weight tear test (DWTT), J_{IC} destructive test, Ultrasonic impact treatment (UIT), Fig. 13 & 14
		Strength characteristics of large-scale structures	Testing with modified methods and/or jigs
		Strain distribution measurement in plane during testing	Strain gauge method, Digital image correlation (DIC), Fig. 9
		Fatigue and under special environments and improvement	Torsion-axial force combination, Thermal fatigue, Corrosive environments (sea water, oil, etc.), Constant temperature and humidity environments (Fig. 10), Ultrasonic impact treatment (UIT), Fig. 12
		Numerical simulation	(Fig. 11) MARC, ABAQUS, LS-DYNA, Fluent
	Relevant tests	Cracking susceptibility of welds	Varestraint test, Y-groove weld cracking test
		Friction and wear characteristics	Rotary, Reciprocating, Block on ring, Abrasives, Slurries, Erosion wear
		Surface profile measurements	Three dimensional measurement of shapes of pillars using light section method, Laser microscope, White light interferometry (WLI)
		Analysis for fracture, replication	Surface and/or cross-sectional observation (Fig. 13, 14)

After removing the surface rust or paint film, the thickness can be measured by the ultrasonic instrument and then compared with the specified value to determine whether to repair or replace is necessary or not. Especially in the case of weathering steel structures, the stability of the structure is evaluated by collected rust from them. Scaffolding is required for measurements at high elevations, increasing measurement costs and construction time. The use of drones makes it possible to monitor the condition of structures without scaffolding.

NSTEC can not only take visual images from the air but also remotely measure the thickness reduction with an ultrasonic thickness gauge mounted on a drone (**Fig. 3**). The remote thickness reduction measurement, therefore, has been introduced to many plant facilities. One of the advantages of NSTEC is that it is able to improve the maintenance and management technologies by combining various measurement technologies with drones and deploying these combinations in iron and steel plant facilities.

3.1.2 Crack diagnosis with phased array UT and TOFD

The remaining strength of existing structures also depends on cracks and defects caused by fatigue and stress corrosion cracking (SCC). Conventional techniques for the on-site evaluation of these cracks and defects, such as ultrasonic testing (UT), radiographic testing (RT), and liquid penetrant testing (PT) are used.

Another of NSTEC's advantage is application of a phased array UT and time of flight diffraction (TOFD) units. **Figure 4** shows an example where a stress corrosion cracks in a weld were detected using TOFD. In the inspection area of a 30 mm thick steel plate, the diffracted waves from the top edge of the cracks (encircled with the yellow line) are detected near the surface, and the reflected waves from the bottom of steel plate are lost. It can be found that the crack propagated from the bottom surface to near the top surface. Since TOFD uses diffracted waves from the edge of a flaw, it is able to measure the crack height more accurately than conventional UT methodology.

Fig. 2 On-site thickness measurement of steel plate by ultrasonic equipment

Fig. 3 Drone equipped with ultrasonic thickness gauge

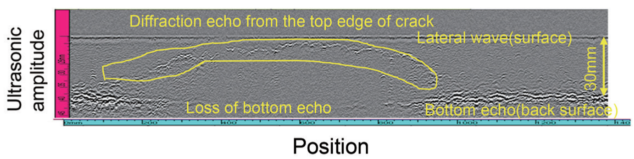


Fig. 4 Cross-sectional image of crack height detection in weld by TOFD

3.2 Nondestructive strength diagnosis

There are many requests for nondestructive investigation of the material strength (yield strength and tensile strength) of obsolete steel frames and steel frames after fires. NSTEC can measure the material strength on-site with the Advanced Indentation System (AIS, an instrumented indentation technique (IIT)) of FRONTICS. The Nano Indenter, one of the IITs, measures the hardness of the steel frame surface. The AIS cyclically loads and unloads the material with a spherical indenter having a tip radius of about 0.25 mm and calculates the stress-strain curve (ss curve) of the material. The yield strength measurement accuracy of the AIS for general construction steels is ±10% (**Fig. 5**). The normal yield strength is the yield strength measured by the tensile test. Also, the AIS is compact (φ90 mm × L320 mm) and lightweight (about 5 kg), and can be used for on-site measurement. NSTEC has expertise in fabricating AIS jigs that match the shape of the object to be evaluated and has achieved results through joint research with Kansai Electric Power Co., Inc. on the soundness evaluation of steel structures for hydroelectric power generation.[1] NSTEC is currently the only company in Japan that is able to evaluate material strength by using the AIS.

3.3 Evaluation of corrosion progress and corrosion environment

3.3.1 Preparation of corrosion map and measurement of corrosion rate

In a new construction project, preparation of a corrosion map showing where corrosion is likely to occur in the premises, and understanding of change with time due to corrosion and its rate are important to ascertain the progress of corrosion. In order to do these, measurement of the corrosion rate is performed using coupon specimens (patch test), atmospheric corrosion monitoring (ACM) sensors etc. Simultaneous measurement of the deposited airborne salt content and deposited deicing salt content helps to clarify the causes of corrosion.

Figure 6 shows the results of a patch test that measured the effect of the deposited salt content on the corrosion rate in a factory site.[2] The patch test verified that the corrosion rate tended to increase with the deposited salt content. However, there are variabilities. Factors other than the deposited salt content are also considered to affect the corrosion rate.

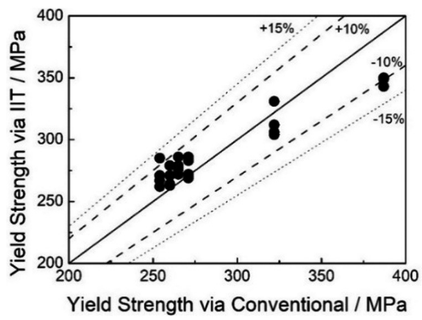


Fig. 5 Comparison of yield strength using IIT with conventional strength test

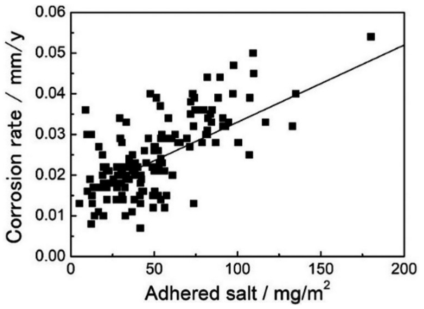


Fig. 6 Relationship between the corrosion rate and the amount of adhered salt on the test coupons

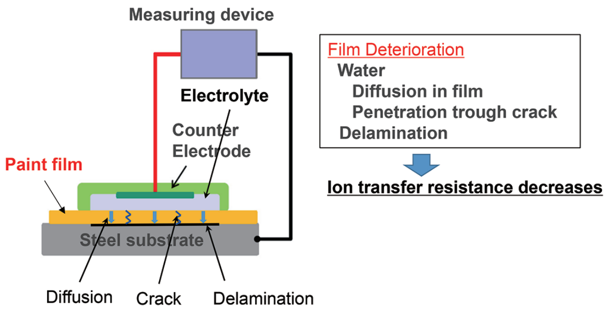


Fig. 7 Experimental setup of the coating deterioration diagnosis via electrochemical impedance spectroscopy measurement

3.3.2 Measurement of paint film deterioration and paint film peeling ratio

Corrosion resistance depends not only on the substrate material but also on the deterioration of the paint film applied to the surface and on the corrosion resistance after the paint film peels off. The quantification of these conditions is valuable in diagnosing the remaining lifespan. This quantitative evaluation can use the measurement of the electrical resistance of the paint film by electrochemical impedance spectroscopy. **Figure 7** shows the principle of this technique. The paint film peels off when water diffuses into the paint film and swells the paint film and when water enters through paint film defects or cracks and reaches the paint film-substrate interface. The electrical resistance of the paint film depends on the change in ion permeation resistance of the paint film with the intrusion of water. When the relationship between the paint film peeling ratio and the ion permeation resistance is prepared as a calibration curve, the deterioration of the paint film can be evaluated using the electrical resistance. The electrical resistance of the paint film can be used as an aid in determining when to repaint.

4. Laboratory Evaluation

4.1 Internal defect evaluation (internal defect evaluation by microfocus X-ray CT)

Demands are growing for a more accurate understanding of internal defects, aggregates, and voids in welded structures and reinforced concrete structures. Microfocus X-ray CT is available as a method for detecting internal defects with a resolution higher than the defect size (several 100 μm) that can be detected by UT. X-rays are irradiated on the test specimen to capture a transmission image. The captured transmission image is used as a CT image for the three-dimensional analysis of the position and size of internal voids and foreign matter. The microfocus X-ray CT unit owned by NSTEC has an X-ray transmission capability of 30 mm for iron and 150 mm for aluminum. The minimum detectable defect size is about 40 μm (subject to the influence of the specimen size). As this high resolution can accommodate large samples, the microfocus X-ray CT unit is, therefore, used in a wide variety of applications. For example, **Fig. 8** shows the extraction results of voids in a concrete sample with a diameter of about 45 mm and a height of about 70 mm. In this example, the position, volume, and number of voids are quantitatively evaluated.

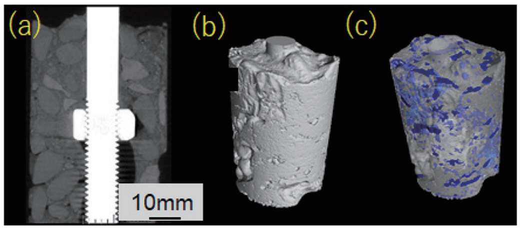
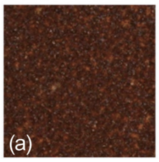
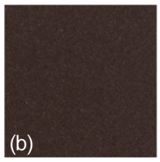
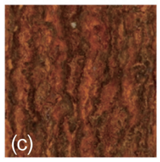
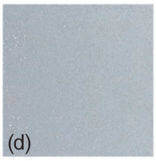
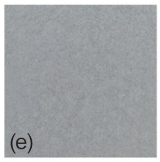
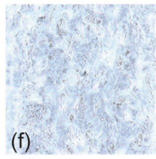


Fig. 8 Micro-focused X-Ray CT images of voids in concrete
(a) CT image, (b) 3D image, (c) image of voids less than 250 mm³ in volume

Table 2 Comparisons of the salt deposition cyclic corrosion test with other tests

	Exporsure Test (Okinawa, 1 year)	Salt deposition cyclic corrosion test (56days)	SST (7days)
Steel Plate	 (a)	 (b)	 (c)
Zinc Plate	 (d)	 (e)	 (f)
Rust	Dense and homogeneous	Dense and homogeneous	Porous and inhomogeneous

4.2 Corrosion resistance tests

4.2.1 Salt deposition cyclic corrosion test in an environment closer to the actual environment

The salt spray test (SST) and combined cyclic corrosion test (CCT) have been widely used for accelerated corrosion testing of steels. NSTEC can perform the corrosion test with specimens from 10 mm to 2 m in size and at temperatures of −20°C to 70°C, and up to 100°C for some specimen sizes. However, in recent years, there have been cases where the corrosion conditions simulated by these accelerated corrosion tests seem to deviate from the corrosion conditions of actual structures. The salt deposition cyclic corrosion test in an environment closer to an actual environment is standardized as Method D in JIS G 0594. This test method simulates an actual corrosive environment[3)] where airborne sea salt is deposited and the dry and wet conditions are repeated at a constant dew point. **Table 2** confirms that coarse and uneven rust (c) is formed in SST and that dense and uniform rust (b) is formed as observed in an actual exposure test (a). This tendency is also confirmed in the results for zinc plates (d), (e), and (f). It can be said that this is an effective test method for evaluating corrosion resistance as observed in construction site environments. NSTEC can provide corrosion data helpful in determining the life expectancy of structures by integrating the corrosion rates from the investigation results of environmental factors described in 3.3.1 and from these corrosion test results.

4.2.2 Test water tank with circulating natural seawater

Exposure tests in actual environments are more reliable than the accelerated corrosion tests described above but are difficult to carry out. One of NSTEC's strengths is that test equipment is installed in a test water tank in which natural seawater drawn from Tokyo Bay is circulated to perform exposure tests simply and, in an environment, closer to the actual environment. We can also conduct exposure tests by considering the effect of microbial deposition and evaluate corrosion resistance by electrochemical measurements.

4.3 Strength tests

4.3.1 Material approval tests and welding tests

There are fracture toughness tests, such as the tensile test, fatigue test, Charpy impact test, crack tip opening displacement (CTOD) test, drop weight tear test (DWTT) test, and J_{IC} test. These tests are all specified in the JIS standards. Especially in the construction sector, column-beam connections, etc., are evaluated in accordance with the certification of welding competence tests and welding procedure specification evaluation established by the Architectural Welding Certification Association. It is, also, perform strength and toughness tests under high-pressure hydrogen gas and liquid hydrogen environments related to carbon neutrality.

4.3.2 Strength tests of large structures

NSTEC evaluates non-standard and large-scale structures without clear test specifications and standards. In addition to our own testing machines, an appropriate selection of testing equipment[4)] owned by the Nippon Steel Group, and equipment from external testing institutes are available. We also design prototype jigs as required, determine measurement methods, develop test plans, and evaluate structural characteristics. Some of our achievements are described in Reference 4). Our strength of these large-scale experiments is the ability to combine strength tests and simulations (described later).

4.3.3 Visualization of strain distribution (DIC)

For strength tests, strain distribution is essential information for detailed analysis of structural properties, but it is difficult to measure the strain concentration initiating fracture in a wide area with a strain gauge. Therefore, NSTEC has focused on the strain distribution visualization technology using the digital image correlation (DIC) method. By optimized photographing of the specimen under loading, it is possible to measure the strain distribution at any point after the test. **Figure 9** shows the measurement of the equivalent strain distribution in a drop weight impact test as an example of a DIC application. The strain distribution on the side surface of the hat-shaped member is confirmed in the image where the hat-shaped member bends and deforms under the dynamic load. Positions where the strain is concentrated are visualized in red. Furthermore, by combining with a high-speed camera in this way, the DIC method continuously measures the change in the strain distribution during dynamic strength testing. We are, therefore, striving to expand the scope of DIC application by accumulating measurement expertise for materials other than steel.

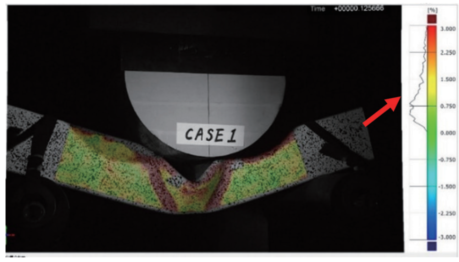


Fig. 9 Results of equivalent strain distribution in a drop weight impact test using DIC

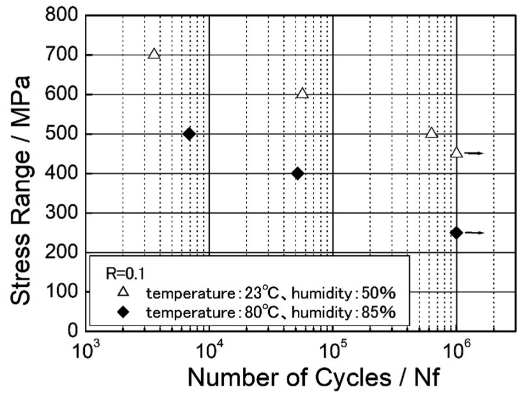


Fig. 10 Effect of testing temperature on the fatigue strength of a CFRP

4.3.4 Fatigue test under specific environment

In the fatigue test, it is important to assume and evaluate the actual force and/or environment. NSTEC is able to adapt to various test environments, such as torsion-axial force combination, thermal fatigue, corrosive environments (sea water, oil, etc.), and constant temperature and humidity environments. It is able to control our equipment with a temperature from −100°C to 250°C, and a humidity from 30% to 85%. In **Fig. 10**, the fatigue strength of CFRP is evaluated with humidity and temperature as variables. It is generally believed that the fatigue properties of adhesive bodies and resins such as CFRP are greatly affected by temperature and humidity. The test results of Fig. 10 indicate that the fatigue limit decreases by about 200 MPa under high temperature and high humidity conditions.

4.3.5 Evaluation of hot and cold cracking susceptibility of welds

With the increase in steel strength, it is necessary to evaluate high-temperature and low-temperature cracking of welds. In order to evaluate them, the Varestraint test for hot cracking susceptibility and the Y-groove weld cracking test for cold cracking susceptibility are applicable. Especially, the latter test can be carried out under a constant temperature and humidity environment. These tests clarifies the relationships of cracking with the steel grade, welding material type, and welding conditions, as well as the effect of improvement on the cracking generation.

4.3.6 Wear test (measurement of surface profile with white light interferometry (WLI))

In the friction and wear test, it is important to select the wear and sliding modes for each object. Our equipment can be applied to various types, such as the rotary or reciprocating test for point and area contact modes, block-on ring testers with line contact mode used for lubrication evaluation, and the abrasive or slurry test used for sediment wear evaluation. Characteristic of NSTEC is its ability to test under a wide range of conditions, or at speeds of 0.1 rpm to 5 000 rpm for rotation and 0.1 Hz to 80 Hz for reciprocation, temperatures of −40°C to 1 000°C, and loads of 0.1 N to 5 000 N.

The recent trend of wear assessment is to determine wear according to the three-dimensional surface profile change as well as conventional weight reduction. White light interferometry (WLI) can measure specimen surface waviness differences (up to 7 mm) and wide areas (up to 150 mm square) while maintaining a high vertical resolution of 0.1 nm to 1 nm. Although, it is impossible to achieve with a confocal microscope (laser microscope), WLI can be used to measure not only the amount of wear but also the surface profile of members and materials.

4.4 Numerical simulation (simulation of large deformation elastoplastic cyclic loading)

NSTEC can carry out elastic analysis, such as vibration eigenvalue analysis and buckling eigenvalue analysis, by using general-purpose numerical analysis software like MARC, and large deformation elastoplastic analysis by changing the stress-strain relationship of steel. We also have a track record of fluid analysis and heat conduction analysis and can widely apply these techniques in the civil engineering and construction sectors.

Figure 11[5] shows an example of simulating the energy absorption capacity of a seismic device in a cyclic loading test to derive the energy absorption capacity. The seismic device consists of a U-shaped steel plate and is installed as a seismic element in the load-bearing wall of a low-rise house. The energy absorption capacity simulated by the Hashiguchi model somewhat differs from the measured energy absorption capacity around the cumulative deformation of Δ=40 mm but agrees well with the measured energy absorption at the cumulative deformation of Δ=80 mm. The elastoplastic large deformation behavior accompanying this complex cyclic cumulative deformation can be precisely simulated by utilizing the analysis expertise accumulated in the Nippon Steel Group.

4.5 Proposal of solutions through fatigue improvement and failure/material investigation

4.5.1 Solutions for improving weld fatigue properties (UIT treatment)

One of NSTEC's strengths is that it has the exclusive right to use ultrasonic impact treatment (UIT) that are effective for improving weld fatigue characteristics. It is widely known that the fatigue life of steel structures is governed by welds, even though the strength of steel has increased. The UIT has been proposed as a peening treatment technology that uses ultrasonic vibration as a measure for improving fatigue life. The primary reasons for the improvement are possibly due to the reduction of the stress concentration by increasing the curvature of the bead toe, the reduction of the welding residual stress by application of the compressive stress, and the refinement of the microstructure.[6] It is certain that the quantification of the applied amount of the compressive residual stress by UIT is difficult, however, it is possible to measure the residual stress with X-rays on limitedly the surface.

In a joint research with Nippon Steel and the Metropolitan Expressway Co., Ltd., NSTEC has verified that the UIT can extend the remaining life of cracked weld toe regions and uncracked weld regions (preventive maintenance). The reason for this effect is thought to be the reduction of stress concentration and the application of compressive residual stress due to the closure of cracks (**Fig. 12**).[7]

4.5.2 Damage cause investigation and phenomenon simulation experiment

Investigation of the cause of damage to a structure is essential for devising corrective measures for the damaged structure. There are many requirements for not only identifying the causes of damage to structures but also proposing corrective measures for damaged structures. Based on the material pieces, welding methods, and environments (temperature, pH and other corrosion factors, stress field, etc.), by nondestructive inspection and fracture surface and/or cross-section observation, the failure mechanism is identified. In some cases, conduct simulation tests are conducted. **Figure 13** shows the SE photo of a fractured surface of a 1 400 MPa grade high-strength bolt. A corrosion pit and intergranular cracks were observed at the fracture origin. The cause of the fracture was determined to be the hydrogen embrittlement on grain boundary. To solve

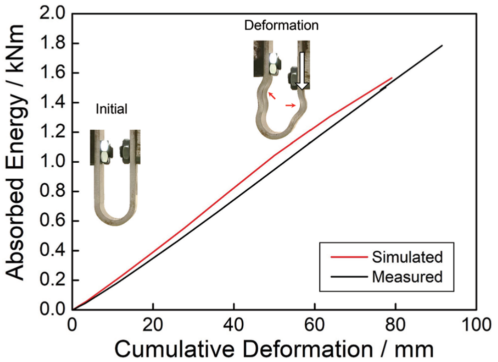


Fig. 11 Comparison of measured energy absorption with simulations

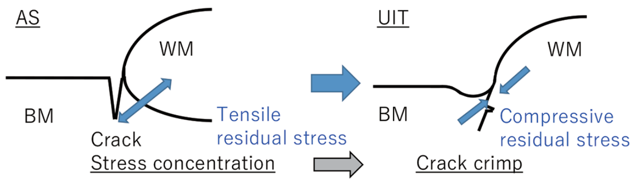


Fig. 12 Schematic diagram of enhancement of UIT for the remaining fatigue life of weld bead with crack

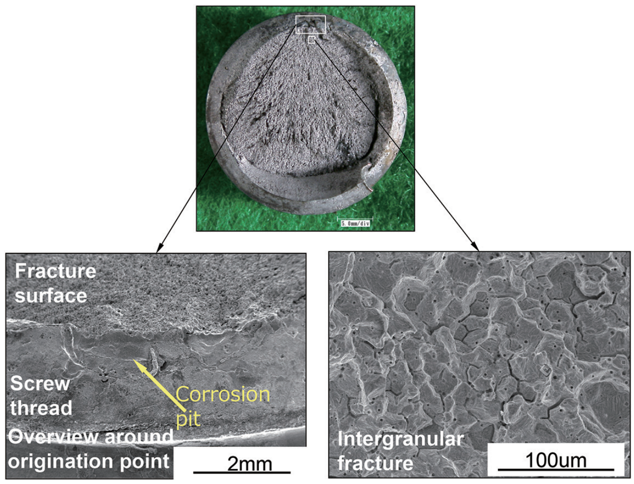


Fig. 13 SE photos of fractured high strength bolt

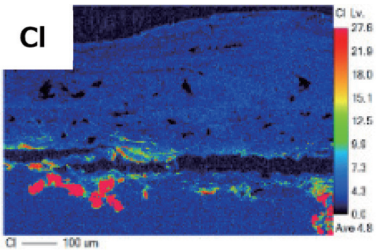


Fig. 14 Cl mapping of the corrosion product by EPMA

this problem, we investigated the hydrogen intrusion route and found that the route was pickling before plating in the production process. This result indicated the cause of crack inhibition.

To analyze the corrosion products via elements, the use of an electron probe microanalyzer (EPMA), utilizing the wavelength and intensity of characteristic X-rays, is an effective method (**Fig. 14**). Furthermore, in order to identify the corrosion products and clarify their formation mechanisms, Raman spectroscopy and x-ray diffraction (XRD) are also other very useful analysis techniques.

5. Conclusions

This report outlines the on-site deterioration diagnosis of structures, the mechanical and chemical evaluations in laboratories, and numerical analysis techniques. Nippon Steel Technology has specialists in a wide variety of fields as introduced in this report. We will contribute to the development of our customers by working in partnership with them in various situations, such as research, research and development and construction applications, to meet their needs.

We hope that this report will serve as an opportunity to receive further guidance from all of you.

References

1) Matsuoka, Y. et al.: Electric Power Civil Engineering. (416), 51 (2021)
2) Inoue, H. et al.: Zairyo-to-Kankyo. 69, 175 (2020)
3) Mutou, I. et al.: Zairyo-to-Kankyo. 47, 519 (1998)
4) Hanya, K. et al.: Nippon Seitetsu Giho. (420), 117 (2023)
5) Itou, I. et al.: Proc. Architectural Institute of Japan, Kinki Branch (2019)
6) Nose, T.: Shinnittetsu Giho. (391), 156 (2011)
7) Uesaka, K.: J. JSCE. 77 (1), 121 (2021)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