Development of Beams for Sections Susceptible to Salt Damage

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Beams that support overhead contact lines in sections susceptible to salt damage corrode fast and need to be replaced before reaching their expected service life. We have thus developed beams with high anticorrosion properties for those sections. First, aiming to improve corrosion prevention performance, we carried out salt water spray tests for three types of materials on which double rust prevention was applied. The tested materials were zinc hot dip galvanized steel + saturated polyester powder coating, zinc hot dip galvanized steel + ceramic coating and weather-resistant steel + epoxy resin coating + polyurethane resin coating. Test results demonstrated that saturated polyester powder coating was superior. Then, we made prototype beams of steel pipe coated with saturated polyester powder. Those prototype beams are now undergoing long-term durability testing in Omigawa Station on the Shin-etsu Line. Since the average decrease of coating thickness is as small as 19 μm/year, we expect that this type of beam will not require replacement for 60 years, the standard replacement interval for sections without salt damage.

●Keywords: Salt damage, Beam, Corrosion, Double rust prevention, Saturated polyester powder coating

1 Introduction

Hot-dip galvanized steel is mainly used for beams that support overhead contact lines. However, with beams installed in sections susceptible to salt damage in the JR East operation area, steel corrodes before reaching its expected life as shown in Fig. 1, creating worries in terms of maintenance. We have therefore developed for sections susceptible to salt damage a beam that we expect will not need replacement for 60 years. Our report on the development is as follows.

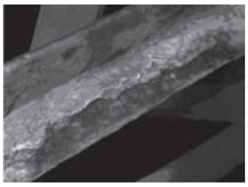

Fig. 1 Corroded Beam

2 Current Status and Issues for Beams with JR East

JR East uses steel made from iron (SS400, SS490, STK400 and STK490) for the beams that support overhead contact lines. While conventional beams are of equal-angle steel, use of beams made of steel pipe is increasing. For corrosion prevention, zinc hot dip galvanizing is applied. The main types of the zinc galvanization are HDZ50 for general sections and HDZ55 for coastal sections. The explanation for JIS H 8641 “Hot dip galvanized coatings” states that the durability of zinc galvanizing is around 53 years for urban areas and around 45 years for coastal areas. Considering the corrosion speed of zinc hot dip galvanization and steel, we have specified the life of beams to be around 60 years. However, beams installed in sections susceptible to salt damage often reach the corrosion limit at 35 to 40 years and are replaced.

3 Corrosion Prevention Performance

Measures to improve corrosion prevention performance include replacing beams with those of material having higher corrosion prevention performance. Those materials include weather-resistant steel, stainless steel and aluminum alloy. Rust can also be prevented by coating or plating. Recently, coating double rust prevention[1)] is being introduced to weather-resistant steel since structures of weather-resistant steel in coastal areas are found to be corroding more than expected. We have thus studied the possibility of applying double rust prevention by coating zinc hot dip galvanized steel and weather-resistant steel. Stainless steel and aluminum alloy have been excluded from the scope of examination because they are much more expensive than zinc hot dip galvanized steel and will increase costs.

4 Selection of Coating

We have decided to apply saturated polyester powder coating and ceramic coating for double rust prevention of zinc hot dip galvanized steel and epoxy resin and polyurethane resin coating for that of weather-resistant steel. The epoxy resin and polyurethane resin coating is the same as that used for ordinary bridges.

4.1 Saturated Polyester Powder Coating

Saturated polyester powder coating is powder coating made of saturated polyester resin that is transformed and given strong self-adhesiveness. Its features are as follows.

①Excellent adhesiveness to metal, with adhesive strength of more than 150 kg/cm^2
②Remarkable weather resistance (the weak point of usual resin coating) and anticorrosion properties in seawater, saline environments and other corrosive conditions
③High surface strength and high flexibility
④Need for heat treatment at processing, requiring a large processing furnace and making on-site processing difficult
⑤Inability to be used for double coating on already-coated steel
⑥Ease of scratching at impact due to high surface hardness

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4.2 Ceramic Coating

Ceramic coating uses more than 30 types of mineral materials. Its features are as follows.

①Little effect by UV light that is harmful for usual coating as it is inorganic

②Applicable to concrete, painted surface, tiles and vinyl chloride material as well as zinc galvanized material

③Environmental-friendly, not containing volatile organic compounds included in conventional organic coating

4.3 Epoxy Resin and Polyurethane Resin

Epoxy resin is excellent for preventing corroding factors but not good in terms of weather resistance, so it is not suitable for coating of material for outdoor use. We thus decided to overcoat with polyurethane resin that has high weather resistance. This coating method has been applied to bridges in coastal sections.

5 Accelerated Deterioration Test (Salt Water Spray Test)

To confirm corrosion prevention performance of the selected coating, we carried out accelerated deterioration tests (salt water spray tests) and compared the performance of each coating. As instructed in JIS A 2371 “Methods of salt spray testing”, we set the salinity at 5% ± 0.5% and the spray volume at 1 - 2 ml/80cm^2/h and conducted tests with eight hours cycles consisting of spraying salt water for two hours, drying for four hours, then moistening for two hours.

5.1 Determining the Age Equivalent to the Salt Water Spray Test Cycle

In order to determine the age in the field equivalent to an eight-hour cycle (spraying salt water for two hours, drying for four hours, then moistening for two hours), we carried out salt water spray tests using untreated steel pieces shown in Fig. 2. We calculated ages equivalent to each cycle based on the amount of corrosion of the pieces.

Fig. 2 Test Pieces for Age Calculation

5.1.1 Testing Method

To find the amount of corrosion per 50 cycles, we used 11 test pieces in total and evaluated the amount of corrosion after salt water spray tests. To evaluate corrosion, the corroded pieces were cut with a grinder and the thickness compared with steel pieces where the corroded parts were removed.

Thickness of the steel pieces was determined as follows. The length of each piece was specified to be 100 mm. As shown in Fig. 3, ten measurement points were marked in advance at 10 mm intervals from the L-shaped part of the equal-angle steel. The thickness of the steel pieces was measured at those ten points each with an electron microscope and the amount of corrosion calculated using the average of the measured values.

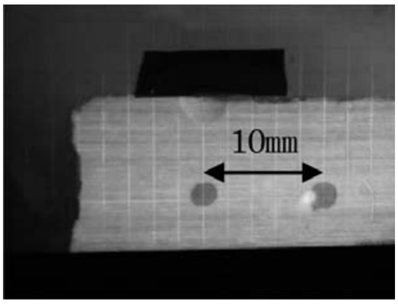

Fig. 3 Measuring Using Electron Microscope

5.1.2 Test Results

Fig. 4 shows the electron microscope image of a steel piece before the test and Fig. 5 shows its corrosion after having been tested for 500 cycles. The white part is the cross section of the steel. Those images clarified that the normal white part was diminished.

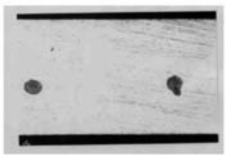

Fig. 4 Test Piece Before Test

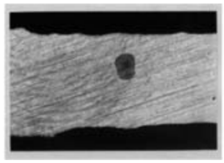

Fig. 5 Test Piece After Test

Fig. 6 shows a graph of the relationship between the number of test cycles and the amount of steel corrosion according to the measurement results of the remaining thickness. The data indicates that the amount of steel corrosion was for the most part proportional to the number of test cycles. Approximating the results revealed that the corrosion progressed by approx. 0.3 mm at every 100 cycles.

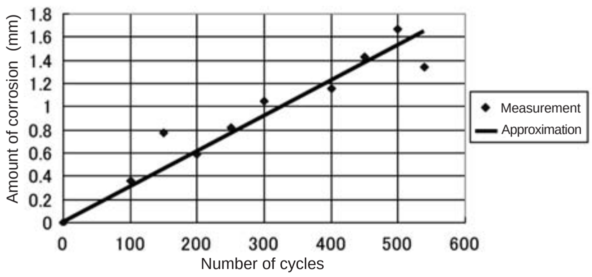

Fig. 6 Salt Water Spray Cycle and Amount of Steel Corrosion

5.1.3 Method of Estimating Age from Amount of Corrosion

The amount of corrosion of steel material used in coastal areas depends on the amount of airborne salt (in mdd). For steel material, annual amount of corrosion is generally converted from amount of airborne salt according to formula 1 below.[2) 3)]

Formula 1

1 mm/year ≒ 1 A/m^2 ≒ 250 mdd *

* mdd: mg/1dm^2/day

The amount of airborne salt varies by area and distance from the coast. We planned to use developed beam in sections susceptible to salt damage in the JR East operation area within 100m from the Sea of Japan coast in Niigata and Yamagata prefectures. Therefore, we calculated annual amount of corrosion based on data of airborne salt shown in Table 1[4)] and the above-mentioned formula 1. Airborne salt data had been surveyed by the Public Works Research Institute. The calculation results are shown in Table 2.

As the general annual amount of corrosion in coastal areas is assumed to be approx. 0.03 mm/year, we consider that our calculation method was reasonable.

Table 1 Data on Airborne Salt Surveyed by Public Works Research Institute[4)]

Prefecture	Survey location	Distance from coast (m)	Airborne salt (mdd)
Niigata	Shinanogawa River downstream	100	6.227
Yamagata	Atsumi	0	28

Table 2 Annual Steel Corrosion Calculated from Airborne Salt

Prefecture	Survey location	Airborne salt (mdd)	Annual corrosion (mm/year)
Niigata	Shinanogawa River downstream	6.227	0.0289
Yamagata	Atsumi	28	0.1299

5.1.4 Results of Age Estimation in Test Cycles

We calculated ages equivalent to test cycles based on annual amount of corrosion obtained in 5.1.3. Table 3 shows the results.

Table 3 Age Calculation Results

Number of test cycles (cycles)	Approximate corrosion (mm)	Shinanogawa river downstream: 100m from coast (years)	Atsumi: 0m from coast (years)
0	—	—	—
100	0.360	10.67	2.37
150	0.463	16.00	3.56
200	0.617	21.34	4.75
250	0.771	26.67	5.93
300	0.925	32.01	7.12
400	1.223	42.68	9.49
450	1.388	48.01	10.68
500	1.542	53.34	11.87
540	1.665	57.61	12.82

Based on the results, we can predict that corrosion after 540 cycles of this test is equivalent to corrosion for approx. 60 years at the presumed area around 100m from the coast.

5.2 Salt Water Spray Test Using Test Pieces

Using test pieces on which the three types of corrosion prevention shown in Table 4 were applied, we evaluated corrosion prevention performance in salt water spray tests. The test pieces were 60.5 mm diameter steel pipes modeling steel beams. In the test, we observed the pieces at every 50 cycles to check rust development according to appearance. The test pieces were given the cross cut recommended in JIS Z 2371 in advance, and we observed the corrosion at the cut.

Table 4 Test Pieces

	Corrosion prevention measure
Test piece 1	Zinc galvanized steel
Test piece 2	Zinc galvanized steel + Saturated polyester powder coating
Test piece 3	Zinc galvanized steel + Ceramic coating
Test piece 4	Weather resistant steel + Epoxy resin coating + Polyurethane resin coating

5.2.1 Test Results

We used the thickness of coatings recommended by their manufacturers. Table 5 shows the thickness of coatings of the test pieces before salt water spray tests and the number of test cycles at which rusting was found. Fig. 7 to 10 show the test pieces after 540 cycles.

Table 5 Coating Measurement Results and Number of Cycles when Rust Found

		Test piece 1	Test piece 2	Test piece 3	Test piece 4
Thickness of coating before test	Ave.	82 μ m	516 μ m	199 μ m	122 μ m
	Max.	94 μ m	612 μ m	240 μ m	141 μ m
Number of cycles when rust found		50	No rust other than at bolts	250	100

Fig. 7 Test Piece 1 after Test

Fig. 8 Test Piece 2 after Test

Fig. 9 Test Piece 3 after Test

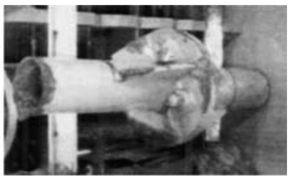

Fig. 10 Test Piece 4 after Test

We found rusting at 250 cycles on the zinc hot dip galvanized steel + ceramic coating, at 100 cycles on the weather resistant steel + epoxy resin coating + polyurethane resin coating and at 50 cycles on the zinc hot dip galvanized steel. On the zinc hot dip galvanized steel + saturated polyester powder coating, no rust was generated on the steel body even after 540 cycles. While no rust was generated at the cross cut as shown in Fig. 11, some rust was found at the bolt fastening area as shown in Fig. 12. This could be because bolts stripped the coating when fastening. Based on these results, we confirmed that saturated polyester powder coating has an advantage over other tested coatings.

Fig. 11 Cross Cut

Fig. 12 Bolt Fastening

6 Field Tests

As we confirmed that double rust prevention by zinc hot dip galvanized steel + saturated polyester powder coating to be effective in corrosion prevention, we made prototype beams and installed them on-site. The test site selected is Omigawa Station on the Shin-etsu Line, which is in a section near the coast susceptible to salt damage. Fig. 13 shows the installed prototypes. Installation could be done in the same time amount of time as with existing zinc galvanized steel pipes.

Fig. 13 Installed Beams for Sections Susceptible to Salt Damage

7 Durability Tests

In order to check the durability of the installed prototypes, we have been checking condition by appearance and measuring coating thickness once a year since 2007 when the prototypes were installed. Fig. 14 shows a prototype beam three years after installation and Fig. 15 shows the changes in thickness of coating. Corrosion progressed at scratches made in installation work at some parts, but coating shows favorable progress with no stripped coating. The decrease of coating is around 19 μm/year on average, and coating shows a tendency to have almost no decrease in the last one year. We thus consider that no major repairs will be needed until the target replacement standard.

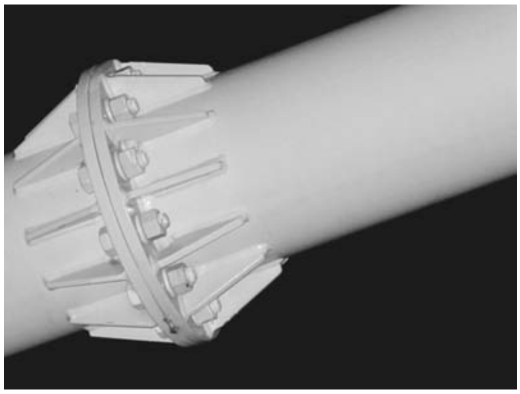

Fig. 14 Beam Three Years after Installation

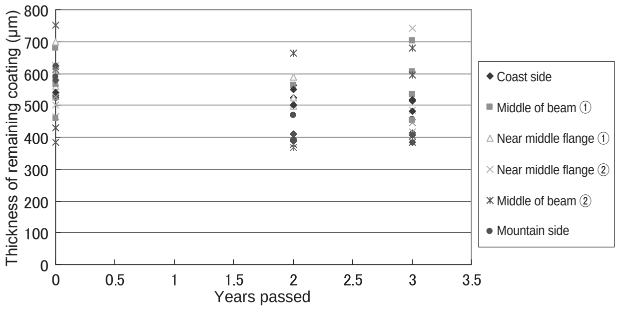

Fig. 15 Changes of Thickness of Coating up to Three Years from Installation

8 Conclusion

We have developed beams for sections susceptible to salt damage using double rust prevention by zinc hot dip galvanized steel + saturated polyester powder coating. The developed beams are now undergoing durability checking by being installed in Omigawa Station on the Shin-etsu Line, with favorable results seen whereby the coating did not decrease much after three years. We expect that using the developed beams will eliminate the need for replacement in the standard replacement interval of 60 years.

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