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THE ANTI-CORROSIVE REPAIR METHODS FOR DEGRADED WEATHERING STEEL BRIDGES

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The existing rust with heavy amounts of salinity or anti-freezing agents on the weathering steel bridge surface can lead to serious durability issues. In the event that the anticorrosion functions of weathering steel bridges do not perform satisfactorily, it is necessary to eliminate the cause or to consider the repair coating and the life extension process. In order to achieve the expected life of the repair coating, it is important to perform the correct surface treatment, appropriate surface preparation (near-white blast cleaning, ISO standard Sa2 1/2 equivalent), and the certain removal of rust containing salinity (50 mg/m^2 or below). This study provides state-of-the-art techniques on repair method, which is two repair coating methods and one simple repair method for weathering steel bridges. In 2015, some repair methods, with considerable effectiveness, were carried out to actual weathering steel bridges with undesired rust generation. The investigation of three years after repair coating shows that both repair coating film is confirmed to exhibit good corrosion resistance. The weathering steel surface repaired by simple repair method is also in a good state.

Keywords: Weathering steel bridge, Surface preparation, Water wash less method, Washing method, Life-prolonging treatment method.

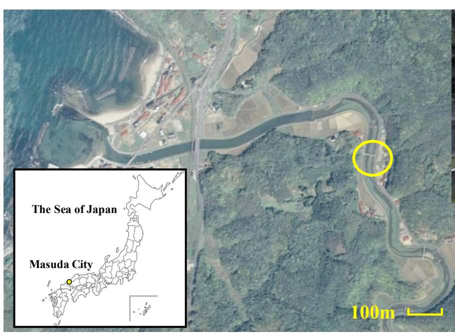
1 INTRODUCTION

In a suitable corrosion environment, many weathering steel bridges form a protective rust. By protective rust exhibits a sufficient anticorrosion function, the weathering steel bridge is generally good rust state. On the other hand, damage to weathering steel bridges has been confirmed due to chloride damage by a high level of airborne salt particles and water leakage from drainage or bridge expansion devices including anti-freezing agents. With such a severe corrosion environment, it has been reported that anticorrosion performance of weathering steel bridges is not necessarily exhibited as expected (Japan Society of Steel Construction 2006). However, there are few reports that weathering steel bridges with abnormal rust have been carried out what kind of repair (Imai *et al.* 2012, Ohya *et al.* 2016). Recently, it is hoped that this maintenance issue for weathering steel bridges will be more deeply discussed from prior corrosion environment survey, detailed investigation of corrosion, repair design, implementation of repair construction, and so on.

In this study, some repair methods were examined for actual weathering steel bridges with undesired rust generation in 2015. For the repair coating method, one is Rc-I repair coating method (Japan Society of Steel Construction 2006) for weathering steel bridges (washing method) having surface preparation process and water washing process for removing salinity, and the others (water wash less method) have a new alternative process that is not washed with water for removing salinity during repairs. This new repair coating method was implemented as a test construction. Furthermore, new simple repair method (life-prolonging treatment method) without painting was applied. This method makes it possible to take advantage of the characteristics of the weathering steels. The authors report the investigation results of these repair methods for weathering steel bridges of three years after repair.

2 OUTLINE OF REPAIR TARGET WEATHERING STEEL BRIDGES

Figure 1 shows the location and an outline of the target bridge. Figure 2 shows the airborne salt particle level by dry gaze method. The annual value is 0.84[mdd] below the girder and 0.60[mdd] within the girder. The value within the girder greatly exceeds the threshold of 0.05[mdd] for the unpainted use of weathering steel bridges. To measure the corrosion loss over one year, a short-term exposure test was carried out using the specimen (50mm x 50mm x 2mm/t). The corrosion loss quantities are shown in Figure 3. The corrosion loss of the inside web surface and the upper surface of the lower flange exceeds the threshold value of 0.03[mm], corresponding to the level I corrosion resistance performance. From the above results, the target bridge is in a severely corrosive environment, which is unfavorable for applying an unpainted weather-resistant steel bridge and is in a state requiring repair.



Construction Date	March 31, 1985
In-service Piriod	34 years
Bridge Type	HBBC
Bridge Span	35 m
Offshore distance	800 m

Figure 1. Location of study site and target bridge overview.

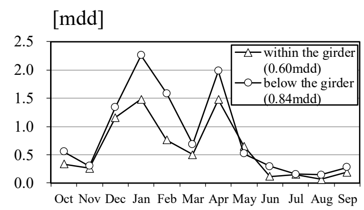


Figure 2. Airborne salt.

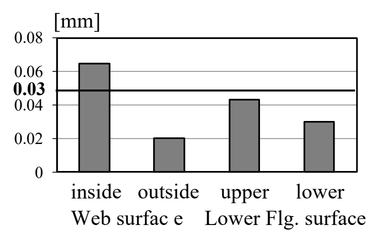


Figure 3. Corrosion loss.

3 DETAILED INVESTIGATION OF CORROSION STATUS AND REPAIR DESIGN

In the event that the anticorrosion functions of weathering steel bridges do not perform satisfactorily, it is necessary to eliminate the cause or to consider the repair coating and the life extension process. However, excessive repair coating on the region where the weathering steel exhibits a sufficient anticorrosion function should be avoided. Therefore, a detailed investigation was conducted to determine the appropriate repair painting area and repair method. The detailed investigation results and the outline of the repair painting design are shown below.

3.1 Detailed Investigation of Corrosion Status

Figure 4 shows the detailed investigation locations. In the detailed investigation, visual inspection, rust and/or coating thickness measurement, accumulated salt measurement, iron transfer resistance, core collection and cross section observation, and EPMA analysis were performed.

This paper presents some of the survey results. The existing rust status is judged by visual inspection and using I score by the ion transfer resistance method (Imai *et al.* 2013). Figure 5 shows the relations between the ion transfer resistance and the rust and/or coating thickness at each investigation site. The vertical axis of Figure 5 shows the measured value of ion transfer resistance (denseness of rust), and the horizontal axis shows the measured value of rust thickness (index corresponding to corrosion rate). This is a method of classifying the rust status (I score) from the relationship between the ion transfer resistance and the rust thickness. Figure 6 shows the corrosion mapping based on the results of I score.

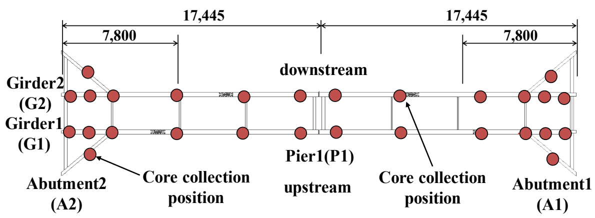


Figure 4. Detailed investigation locations.

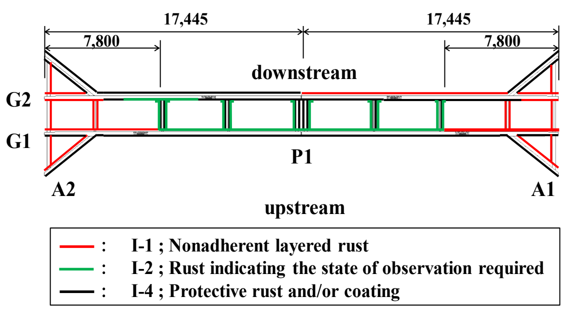


Figure 6. Corrosion mapping in I-score.

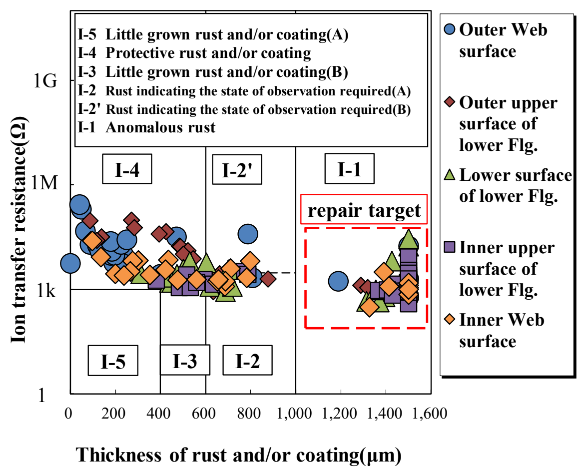
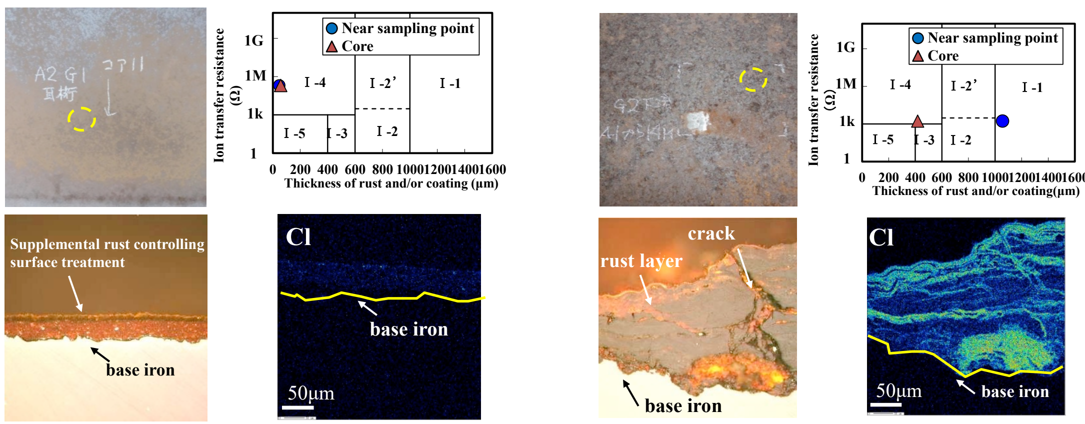


Figure 5. Relations between ion transfer resistance and rust and/or coating thickness at each investigation site.

In order to examine the surface preparation method for repair coating, it is confirmed whether Cl exists up to the surface of base iron. Cores were collected from two locations in the region of I-1 and the region of I-4. The collection position is shown in Figure 4. Figure 7 shows the cross-section observation results and the EPMA analysis results. As shown in Figure 7(a), the coating of the supplemental rust controlling surface treatment is continuously present in the core in the region I-4, and the presence of Cl is not confirmed by EPMA analysis. From Figure 7(b), the rust of the core in the I-1 region exceeded 1000[μm], and nonadherent layered rusts are confirmed. Cracks and pitting that are vertically and horizontally continuous are confirmed from the collected core. In addition, it is confirmed that Cl penetrated along the cracks and reached the base iron interface.

3.2 Repair Design for Weathering Steel Bridges

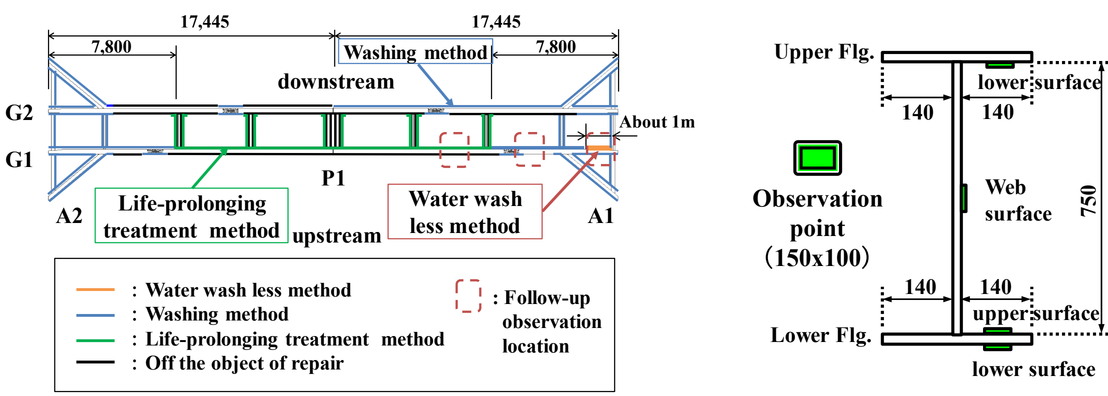
Figure 8 shows the repair region and repair method for the target bridge. In order to make the most of the properties of the weathering steel, the repair method and repair region were selected based on the corrosion map shown in Figure 6 on the premise of partial repair. From I score by the ion transfer resistance method, a washing method was applied using a repair coating with an environmental barrier function in the region of I-1 (nonadherent layered rust). A new repair coating method (Water wash less method) that does not use water washing was used as a test construction in the region of the A1G1 girder end where the corrosive environment was confirmed to be the most severe in preliminary investigations. New simple repair method (life-prolonging treatment method) without painting, with only the rust and salinity of the surface being removed, was applied in the region of I-2 (rust indicating the state of observation required).



(a) A2G1 outside girder outer web surface [I-4]

(b) A1G2 outer web surface [I-1]

Figure 7. Cross section observation results and EPMA analysis results.



(a) Repair region map and follow-up location.

(b) Follow-up point of each observation location.

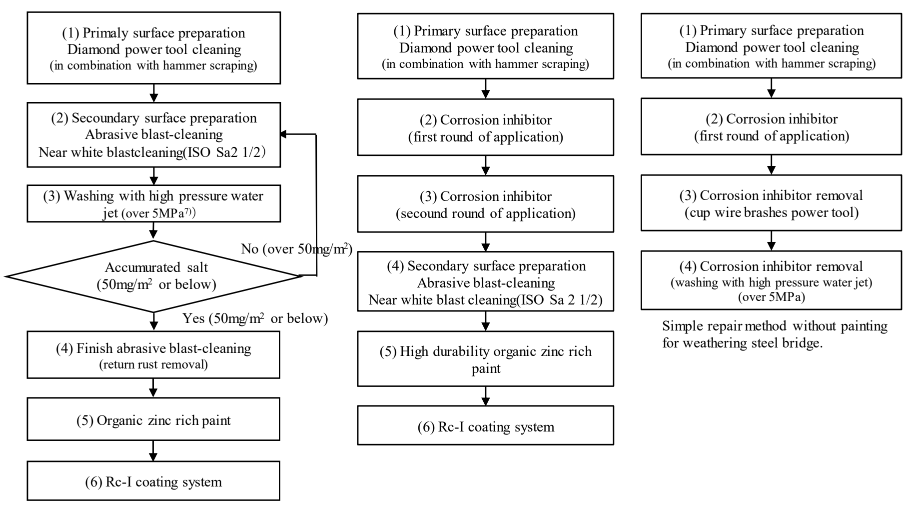
Figure 8. Repair region and repair method for the target bridge.

3.2.1 *Washing method*

Figure 9(a) shows the construction flow of the washing method. In the washing method for weathering steel bridges, the number of processes for secondary surface preparation is increasing compared to the repair process for painted bridges. To satisfy the conditions of the preparation grade (ISO Sa2 1/2) and the accumulated salt (50mg/m^2 or blow), the washing method must be repeated abrasive blast-cleaning and water washing in the secondary surface preparation. If proper surface preparation can be performed, it is considered that the corrosion resistance of the repair coating film of the weathering steel bridges is also good.

3.2.2 *Water wash less method*

A water wash less method has been developed as a new repair coating method that can be used as an alternative when water cleaning is not applicable. This method combines the primary surface preparation with a diamond power tool cleaning, the salt removal effect using a corrosion inhibitor, and the salt improvement using a high durability organic zinc-rich paint before the abrasive blast-cleaning. Figure 9(b) shows the construction flow of the water wash less method. In this method, a step of applying a corrosion inhibitor is interposed between the primary surface preparation and the abrasive blast-cleaning process. The corrosion inhibitor is intended to absorb Cl on the steel sheet surface and render it harmless. Furthermore, for Cl that cannot be completely removed even in the blast-cleaning process, a high durability organic zinc-rich paint, in which a corrosive ion fixing agent is blended with the conventional organic zinc-rich paint, is used. The organic zinc-rich paint performs ion exchange with corrosive ions (chloride, sulfate ions, etc.) and fixes corrosive ions as insoluble salts. Furthermore, the corrosive ion fixing agent, released at the time of ion exchange, can passivate the steel material.



(a) Washing method (b) Water wash less method (c) Life-prolonging treatment method

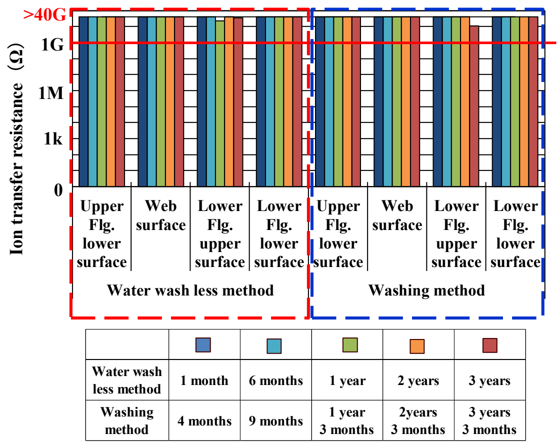
Figure 9. Construction flow of repair coating methods and simple repair method.

3.2.3 *Life-prolonging treatment method*

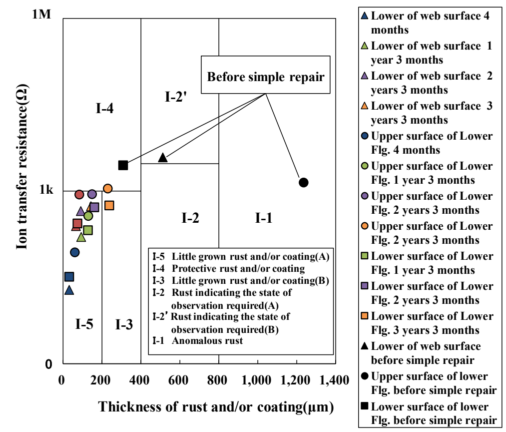
As a new simple repair method without painting, only rust and salinity of the surface is removed, life-prolonging treatment method has been developed. This method makes it possible to take advantage of the characteristics of weathering steels. Construction flow is shown in Figure 9(c).

4 FOLLOW-UP OBSERVATION RESULTS

The investigation results of two repair coating methods and simple repair method for weathering steel bridges of three years after repair are reported. The location of follow-up observation and the observation point of each location is shown in Figure 8(a) and Figure 8(b). Figure 10 shows the follow-up observation results of the ion transfer resistance for repaired part over. From the investigation of three years after the repair coating, the repair coating film is confirmed to exhibit good corrosion resistance when the surface preparation is appropriate. The weathering steel surface repaired by a simple repair method is also in a good state.



(a) Repair coating method.



(b) Simple repair method.

Figure 10. Follow-up observation results of ion transfer resistance for repaired part.

5 CONCLUDING REMARKS

This study provides state-of-the-art techniques on repair method, which is two repair coating methods and one simple repair method for weathering steel bridges. The detailed investigation method for the repair design and the concept of selection of the repair method are shown. In 2015, some repair methods with considerable effectiveness were carried out to actual weathering steel bridges with undesired rust generation. From the investigation of three years after the repair coating, the repair coating film is confirmed to exhibit good corrosion resistance when the surface preparation is appropriate. The water wash less method seems to be an effective repair coating method for weathering steel bridges. The weathering steel surface repaired by a simple repair method is also in a good state.

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