DURABILITY OF STEEL BRIDGE PAINT SYSTEMS CONSIDERING EDGE GEOMETRY OF STEEL PLATE

Yoshiyuki SHIMIZU[1], Naohiko Watanabe[2], and Yoshito ITOH[3]

[1]Nagoya city office, Aichi, Japan,
[2]Nagoya University, Aichi, Japan
[3]Nagoya University, Aichi, Japan

ABSTRACT
Paint and metallic coating systems have widely been used to prevent corrosion attacks and to keep good performance of steel bridges under corrosive environments. However, corrosion damages are often initiated from sharp free edges of bottom flanges and bolted connections, where securing a desired thickness of coating films is difficult. In this study, an accelerated exposure test was conducted for 600 days on steel plates with 21 different conditions: seven types of bridge coating systems and three types of edge geometries. The test results show that the edge geometry had a significant influence on durability of the paint coating systems whereas the similar influence was not found for the metallic coating systems. Durability of the coating systems is discussed in this paper in terms of initial coating thickness, rust initiation time, propagation rate at the edges, and residual thickness of the coating for each of edge geometry and each coating type.

KEYWORDS: steel bridge coating system, edge geometry, corrosion, accelerated exposure test

1. INTRODUCTION

To maintain good serviceability of steel bridges, paint and metallic coating systems are widely used to prevent corrosion damage. However the performance of anticorrosion system decreases from local area in bridge such as sharp free edge of bottom flange, bolts and nuts because it is difficult to secure desired thickness of coating films on such location. Corrosion occurred from these location is expanded and affects aesthetic and performance on steel bridges. So, it is said that sharp free edge should be produced as beveled edge or rounded edge in real steel bridges. To assess remaining life and design time for repaint, the information about corrosion initiation and expansion from these edges is important. But the effect of edge treatment has not been cleared. Therefore, the anticorrosive performance at edge is examined in this study. This information is also helpful for designing rational anticorrosive system.

This study performed accelerated corrosion test to examine corrosion characteristics at different types of edge geometry. The three types of edge geometry for specimen were prepared in 3 types, square edge without edge-treatment, beveled edge with 1 mm long and 45 degree, and rounded edge with a radius of 2mm. Then 4 types of painting systems, A-painting systems for a mild corrosion environment, B- and I-painting systems for a little severe corrosion environment and C-painting systems for a severe corrosion environment in Japan, and 2 types of metallic coating systems (zinc hot-dip galvanizing, zinc-aluminum alloy thermal sprayed coating) were applied. The combination of 3 types of edge geometry $\times 6$ types of anticorrosive system =18 group were observed. The specimens were made by4 pieces in each group; one of them was cut, and the thickness of coating of the sections was measured by a microscope with a magnification of $\times 100$. The others were exposed to an environment chamber controlled by S6-cycle corrosion condition, conforming to Japanese Standard Industrials (JIS) K 5621, for 200 days for metallic coating systems and 600 days for painting coating systems. These lengths correspond to about 10 years and 30 years in marine environment, respectively. Based on the occurred corrosion along the edge and the thickness of the coating, anticorrosive performance at the edge of the coating systems was discussed.

2. EXPERIMENTAL PROCEDURE

2.1 TEST SPECIMENS

Substrate steel plates of 150×32×12 mm were made of structural steels SM490A (JSA.1999). Edge prepared in 3 types of edge geometry, square edge without edge-treatment (C0), beveled edge with 1 mm long and 45 degree (C1), and rounded edge with a radius of 2mm (R2). Then specimens were coated with 4 types of painting systems, A-painting systems for a mild corrosion environment, B- and I-painting systems for a little severe corrosion environment and C-painting systems for a severe corrosion environment in Japan, and 2 types of metallic coating systems, zinc hot-dip galvanizing, zinc-aluminum alloy thermal sprayed coating. Coating details are shown in [5], and edge geometry is shown in Figures 1 and 2.

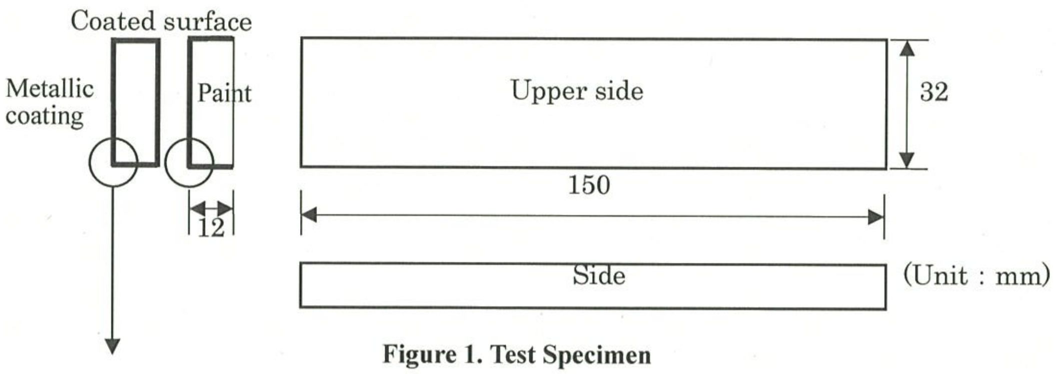


Figure 1. Test Specimen

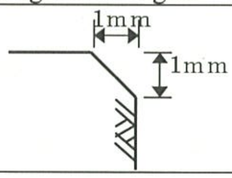
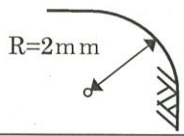
Type	C0	C1	R2
Processed geometry	no edge-treatment	beveled edge with 1 mm long and 45 degree	rounded edge with radius of 2mm
Section geometry			

Figure 2. Edge geometry

2.2 MEASUREMENT OF THICKNESS OF COATING FILMS

One specimen of each group was cut for measuring the thickness of the coating. Each specimen for measuring thickness of coating was cut into four to investigate the film thickness. Photographs of coating films were taken at regular intervals (1mm) using microscope. Then the thickness of coating films was measured by using the photographs, as shown in Figure 3. As the thickness of coating film on upper side, value where isn't influenced by edge is used while the thickness on edge indicates the minimum thickness on edge.

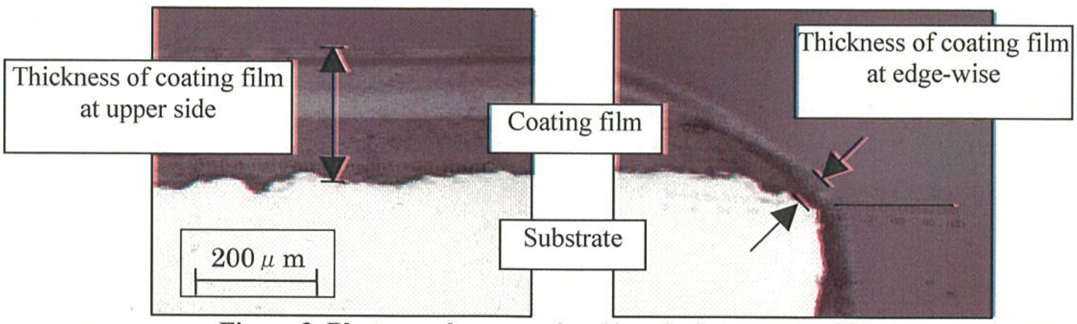


Figure 3. Photographs on section (A-painting system; C0)

2.3 MEASUREMENT PROGRESS OF CORROSION

The specimens of painting coating systems were taken pictures every 25 days. They were used to measure the appearance change with passage of testing time. As an indicator of corrosion progress, a proportion of corrosion length along the edge to the target center range (100mm), so called rust rate, was used. Metallic coating systems differ from painting coating systems in anticorrosive mechanics. Therefore to evaluate anticorrosive performance, thickness of residual coating film with cut specimen, after exposure corrosion test for 200 days were measured, as the other indicator from the case of paint system.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 MEASURED THICKNESS OF COATING FILMS

The proportion of the upper (under) side thickness of coating films to the edge one was used to evaluate the influence of the edgewise for thickness of coating films. As shown in Figure 4, the thickness of all painting coating films was C0<C1<R2 and C0, C1, and R2 were 21-43%, 41-77% and over 79%, respectively. Though Metallic coating systems seem to have similar tendency with painting systems, the differences in thickness of coating with edge geometry are smaller. So, it can be said that the edge geometry effect on thickness of metallic coating is smaller than painting coatings.

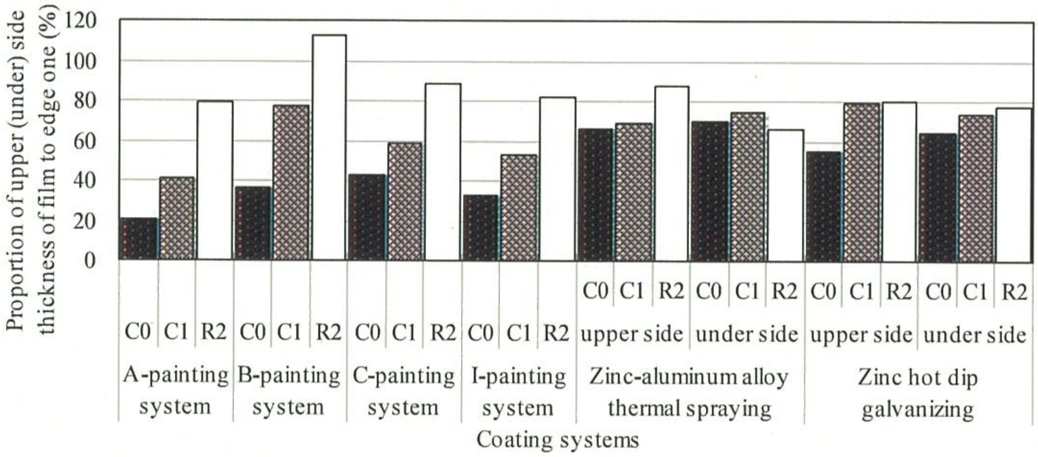


Figure 4. Thickness of coating films

3.2 ACCELERATED EXPOSURE TEST RESULTS

3.2.1 Paint coating systems

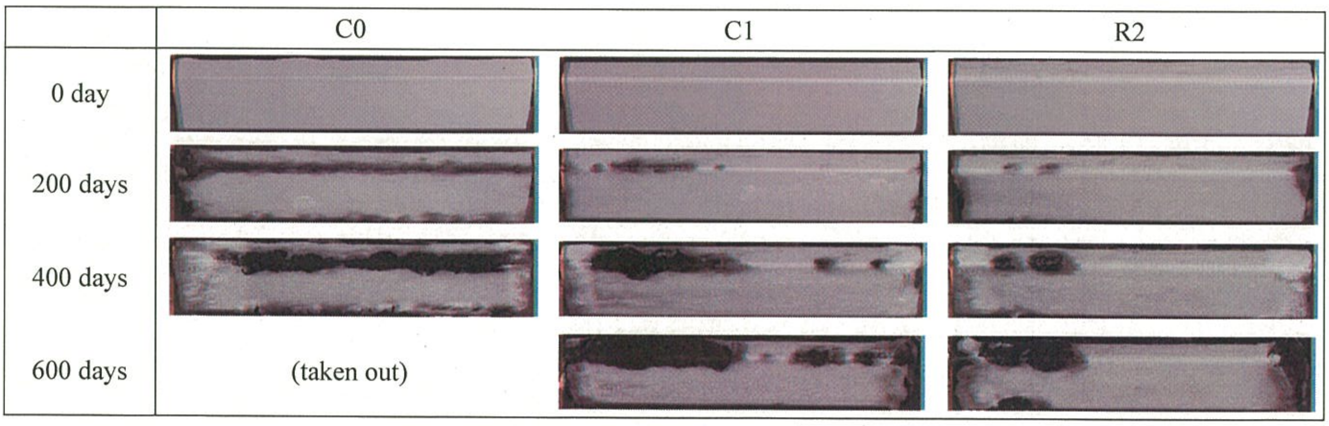


Figure 5. Corrosion progress (A-painting system)

(1) Visual observation

The test specimens exposed in S6-cycle corrosion test for 600 days. But corrosion from edge occurred so far on specimens with A-painting systems. In B and I-painting systems, because of defect in making specimens, corrosion sometimes occurred from the both ends or undersurface, while hardly occurred from the edge. On specimens with C-painting system, corrosion hasn't occurred. As shown in Figure 5, which shows corrosion

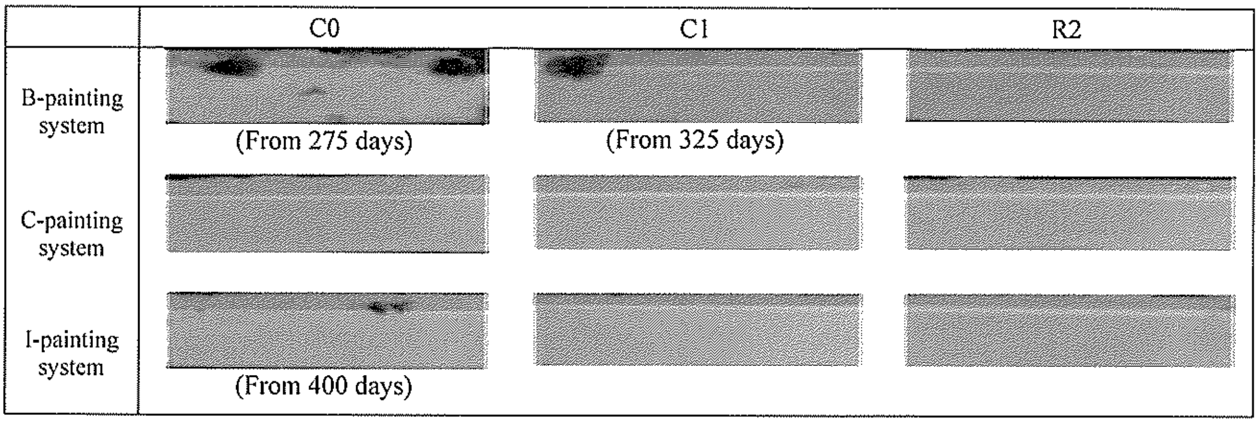


Figure 6. Most expanded corrosion in each specimen (at 600 days)

progress on A-painting system, corrosion occurred on some of the specimens of C0 for all length along the edge at the exposure time of 150 days. On some of C1 and R2 the same phenomenon occurred at the exposure time of 300 days. Figure 6 shows the case of B and I painting system. The specimens that corrosion expanded most largely at 600 days in each group were shown. The time each of corrosion initiated is noted in this table. On specimens on B-painting system, corrosion was shown larger than one on I-painting system. And on rounded edge, corrosion has not been shown. This result indicates that films coated with B, C and I paint system on rounded edge are too thick for corrosion to initiate.

(2) Progress of rust rate

A-painting system is taken as an object about progress of corrosion. The average rust rate and dispersion of each type of edgewise on specimen coated with A-painted system is plotted against the testing time in Figure 7. The error bars represent standard deviations. C0 increases linearly until the testing time reaches 200 days, and its increase speed decreases gradually. Around 300 days, growth of rust rate is almost zero. There is possibility that the area occurred no corrosion has thick coating compare with the area of corrosion occurred. On the other hand, corrosion on C1 and R2 occurred at 75 days and 125 days respectively. Thereafter increases linearly, and C1 and R2 reach about 40% and 10% while C0 reaches about 100% at exposure times of 600 days. It is clarified that preparing edge geometry like C1 and R2 can decrease the occurrence of corrosion greatly.

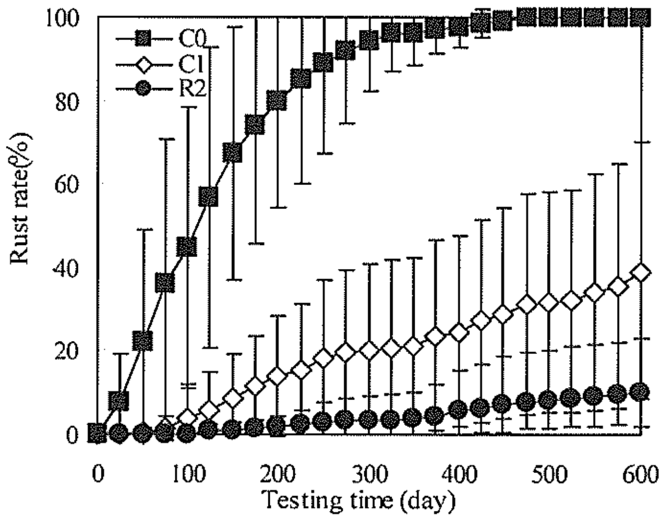


Figure 7. Rust rate

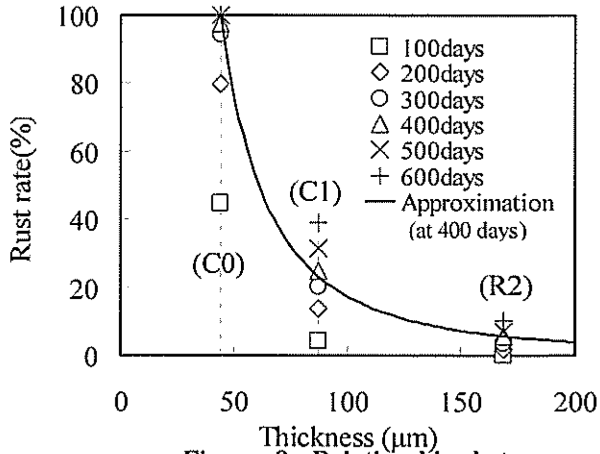


Figure 8. Relationship between thickness and rust rate

Figure 8 shows the relationship between rust rate and thickness of film. In this experiment, 3 points measured as thickness of film of A-coating, such as 44μm on C0, 87μm on C1, 169 μ m on R1, so these value is treated as typical on each edge type. This figure indicates that corrosion resistance is changed suddenly between 44μm and 87μm thickness. It can be observed on any type of edge that the growth of rust rate is remarkable when film is thin. And it can be predicted that corrosion hardly occurs when thickness is more than 200 μ m.

3.2.2 Metallic coating systems

Exterior of specimens that metallic coated after 200 days is shown in Figure 10. On specimens coated with Zinc-aluminum alloy, white rust occurs on almost whole surface, and film comes off. On specimens coated with Zinc hot galvanizing system, white rust and a few of red rust occurred. In specimens of both types, there is no difference depending on edge geometry.
The distribution of the initial and the remained thickness of metallic coating are shown in Figure 9. Referring the thickness of coating films, the edge geometry effect on the thickness of metallic coating was not clear. Edge geometry slightly affects anticorrosive performance. The thickness loss of the upper side for exposing salt spray directly is larger than under side which is not showed in here.

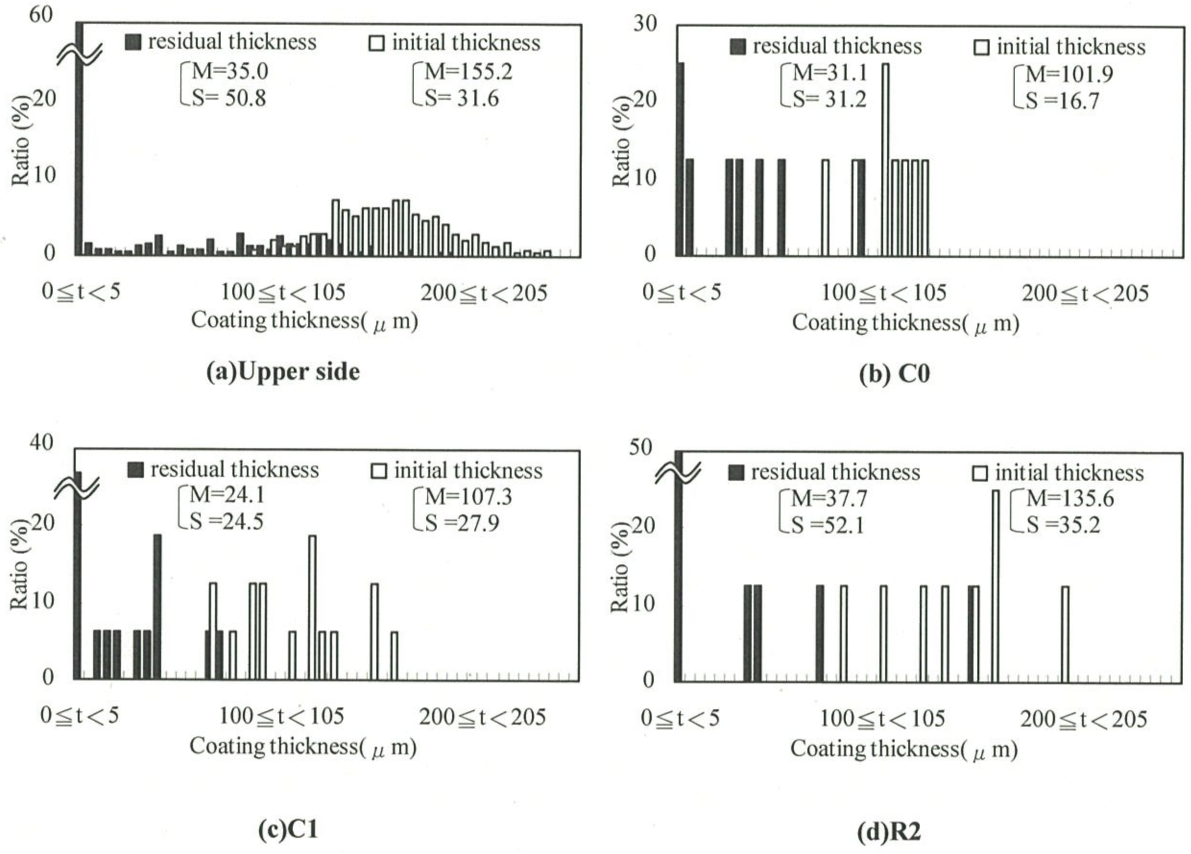


Figure 9. Distributions of coating thickness (zinc-aluminum alloy thermal sprayed coating)

	C0	C1	R2
Zn-Al alloy thermal spraying			
Zn hot dip galvanizing			

Figure 10. Metallic coating system (at 200 days)

Zinc-aluminum alloy thermal spraying and Zinc hot dip galvanizing were shown in similar result.

4. CONCLUSION

This study performed accelerated cyclic corrosion tests to examine the influence of the edge geometry on the anticorrosion performance at edge-wise. As edge geometry, 3 types such as square edge without edge-treatment (C0), beveled edge with 1 mm long and 45 degrees (C1), and rounded edge with radius of 2mm (R2), and as coating systems, 4 types of painting coating systems and 2 types of metallic coating systems were tested. Based on the test results of visual inspection and thickness measurement of coating films, anticorrosive performance of painting coating systems are affected by edge geometry, while metallic coating systems are slightly affected edge by geometry. The result of rust rate in A-painting system and the time of rust initiation in B,I-painting systems, show clearly that the relationship between thickness of film and resistance to corrosion. To discuss rational design for anticorrosion system, including various painting system besides A-painting system, further study is necessary.

5. REFERENCES

[1]Itoh, Y. and In-Tae, K., "Accelerated cyclic corrosion testing of structural steels and its application to assess steel bridge coatings, Anti-Corrosion Methods and Materials", 53/6, pp.374-381, 2006.

[2] Japan Road Association (JRA), *Painting Manual for Steel Brides*, 1990.

[3]Fujiwara, H. and Tahara, Y., "Research on the correlativity of outdoor exposure test of painting test piece with corrosion test for steel bridge painting", *Journal of Structural Mechanics and Earthquake Engineering,* No. 570/I-40, 129-140, 1997

[4]Itoh, Y. and Kainuma, S., "Accelerated exposure tests of environmental durability for steels and the estimation of acceleration coefficient", Journal of Structural Engineering, Vol. 48A, 1021-1029, 2002.

[5] Japanese Standards Association (JSA), *Japan Industrial Standard (JIS) Handbook*1-2, 42-51, 1999.

[6] Shimizu, Y., Itoh, Y., and In-Tae, K., "Influence of edge treatment of base steel plates on corrosion resistance of coated steel bridges", Journal of Structural Engineering, Vol. 53A, 825-833 , 2007.