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# DETERIORATION CHARACTERISTICS OF ANTI-CORROSIVE METALLIC COATINGS UNDER ACID RAIN AND APPLICATION OF PAINT REPAIR

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**Abstract**

For examining deterioration characteristics of several types of anti-corrosive metallic coatings under acid rain, an accelerated exposure test during 300 days was performed. The coating thickness after 300 days became 10% in the Zn hot-dip galvanizing, 20% in the Zn-Al alloys and around 30% in the Zn-Al pseudo-alloys and the Al compared with their virgin states. For evaluating repair effects of painting on deteriorated metallic coatings, the same accelerated exposure test was performed on the repaired specimens by painting after removing the rust on them. The residual metallic coatings largely affected the durability of the repair paints on them. Although the degree of the effect depended on the types of the metallic coatings, there was a risk that the durability of the repair paints became lower than that of the paint coatings on the virgin specimen due to the residual metallic coatings. The results indicated that the residual thickness of the deteriorated metallic coatings should be noted in repairing them by painting.

**Keywords**: Maintenance, Anti-corrosive metallic coating, Paint coating, Acid rain, Accelerated exposure test

## 1. INTRODUCTION

For preventing corrosion of steel bridges, paint coating systems have been used generally. A lot of researches about anti-corrosive performance of paint coating systems have been conducted [1]. Recently, metallic coatings such as galvanizing or thermal spray have been used also from the view point of minimum maintenance.

The deterioration characteristics of the anti-corrosive coatings are basically examined under the conditions assuming the salt water spray [2]. On the other hand, concerns to influences of acid rain also become larger in all over the world. However, it cannot be said that the deterioration characteristics of these metallic coatings under acid rain have been examined sufficiently.

By the way, repair of deteriorated coating due to corrosion is necessary for maintaining steel bridges. In the cases of the metallic anti-corrosive coatings such as galvanizing, it is difficult to repair the deteriorated part with the same metallic coating on site. Therefore, repair by paint coating on the deteriorated metallic coating is sometimes performed. However, the effect of the paint repair on the deteriorated metallic coatings under acid rain is unknown.

For examining the deterioration characteristics of several types of anti-corrosive metallic coatings (Zn hot-dip galvanizing and thermal sprays by Zn-Al alloys, Zn-Al pseudo-alloys and Al) under acid rain, an accelerated exposure test during 300 days is performed in this study. Furthermore, for evaluating repair effects of painting on deteriorated metallic coatings, the same accelerated exposure test is performed on the repaired specimens by painting after removing the rust on them.

## 2. DETERIORATION CHARACTERISTICS OF METALLIC COATINGS UNDER ACID RAIN

### 2.1 Test specimens

**Fig. 1** shows the geometry of the specimens.

The substrate steel plates of 70x150x9mm are made of JIS SM490A structural steel.

The steel plates are covered with four types of anti-corrosive metallic coatings; Zn hot-dip galvanizing and thermal sprays by Zn-Al alloys, Zn-Al pseudo-alloys and Al.

In order to simulate corrosion deterioration behavior from cut on the coatings, cross-scribe lines through the coatings are made on the coated specimens for exposing the underlying substrate steel. The width of the scribe lines is 1mm. The length is 40mm. The cross angle is 50 degrees.

Furthermore, 20x70 mm region at the lower part of a specimen is not coated for exposing the substrate steel. This is for simulating the corrosion deterioration behavior from discontinuous part of the coatings such as a boundary between two members in bolted joints.

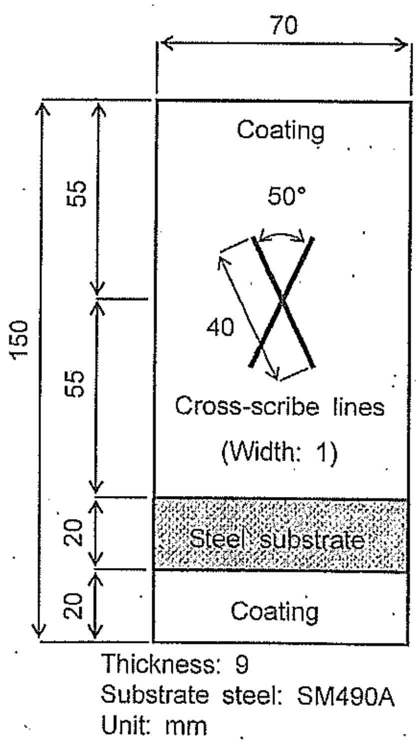



**Fig. 1** Geometry of specimen

### 2.2 Conditions of accelerated exposure test

It is actually impossible that the deterioration characteristics of the coating under acid rain are examined by a field weathering test because the long test term and the high cost are needed and the test conditions are limited.

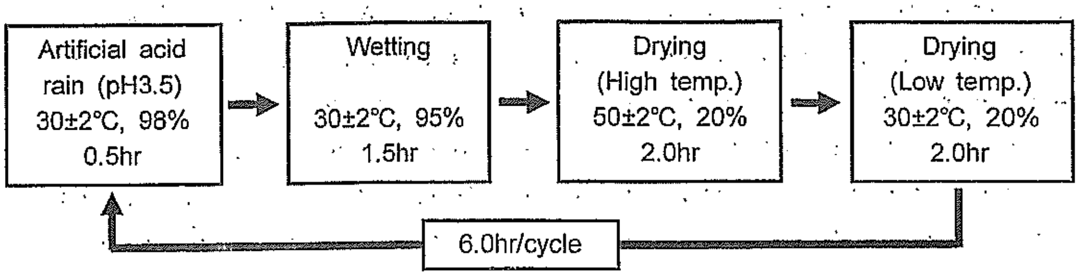



**Fig. 2** Accelerated exposure test condition

In this study, an accelerated exposure test with considering the acid rain conditions is carried out. This test can simulate various environmental conditions in short terms.

**Fig. 2** shows the test conditions. The S6 cycle specified in Japanese Industrial Standard (JIS) K 5621 is used [3]. Although the S6 cycle is the test condition by using salt water spraying, the salt splaying periods are replaced with the artificial acid rain periods. This is selected because the test standards for evaluating the deterioration characteristics of metallic coatings under acid rain have not been established.

The test period is 300 days (1200 cycles).

The number of the specimens in each kind of the metallic coating is basically twelve. Three specimens are kept as the virgin state. Three specimens are taken out from the test machine by every 400 cycles (400, 800 and 1200 cycles.) The appearances are observed and the coating thicknesses of the specimens are measured.

### 2.3 Test results

**Fig. 3** shows the appearances of the specimens.

It can be confirmed that the deteriorations in the upper side of the specimen are milder than those in other parts such as around the cross-scribe lines and the uncoated part in the lower side.

**Fig. 4** shows the coating thicknesses measured by 400 cycles (100 days).

The measured points are described in Fig. 4(a). The points 1, 2, 3 are defined as the coated region in which no cut on the coatings or no boundary of the coatings are. The points 4, 5, 6 are the cross scribe region on which the cross scribe lines may affect. The points 7, 8, 9 are the boundary region in which the deterioration may spread from the boundary between the coatings and the substrate steel. The average coating thickness and the standard variations at all 9 points or at 3points in each region is shown in Fig. 4 (b), (c), (d) and (e). In the case of the Zn hot-dip galvanizing (Fig. 4(b)), almost all of the coating is lost until 400 cycles. The difference of the deterioration behaviors between the measured regions cannot be confirmed. The difference is also small in the case of the Zn-Al alloys (Fig. 4 (c)). The coating hardly remains when 800 cycles. The results indicate that these metallic coatings themselves are

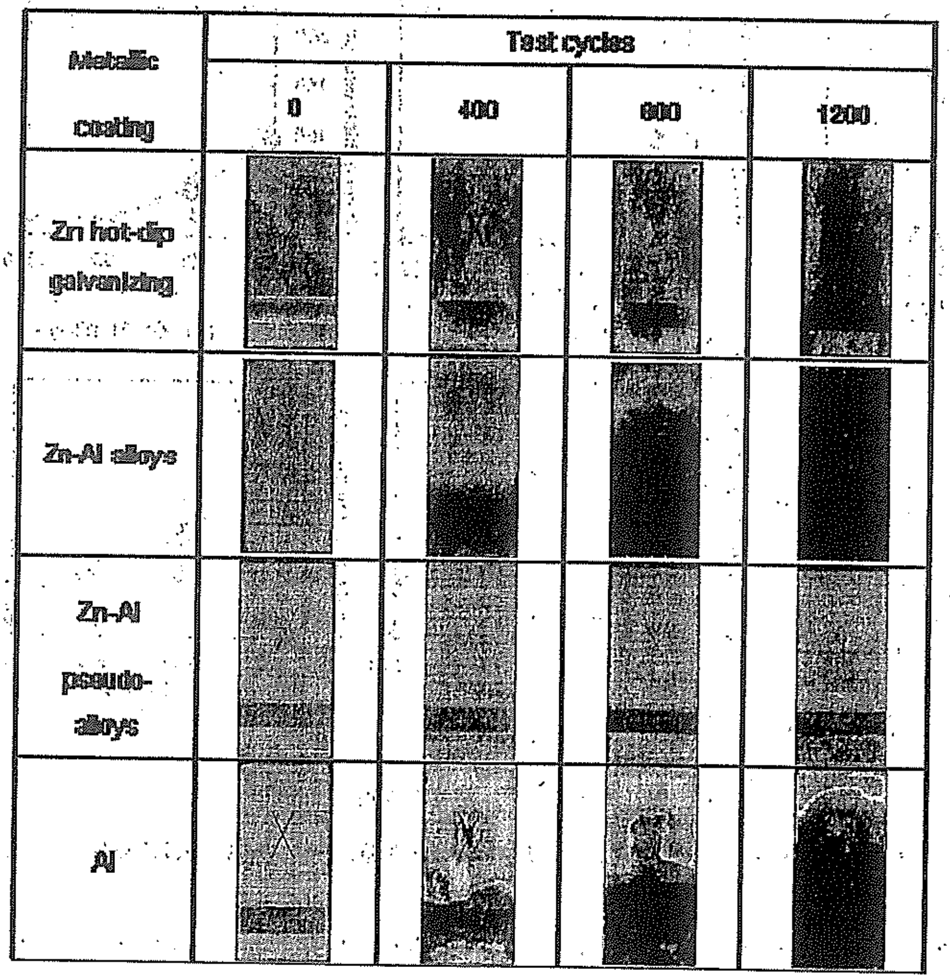
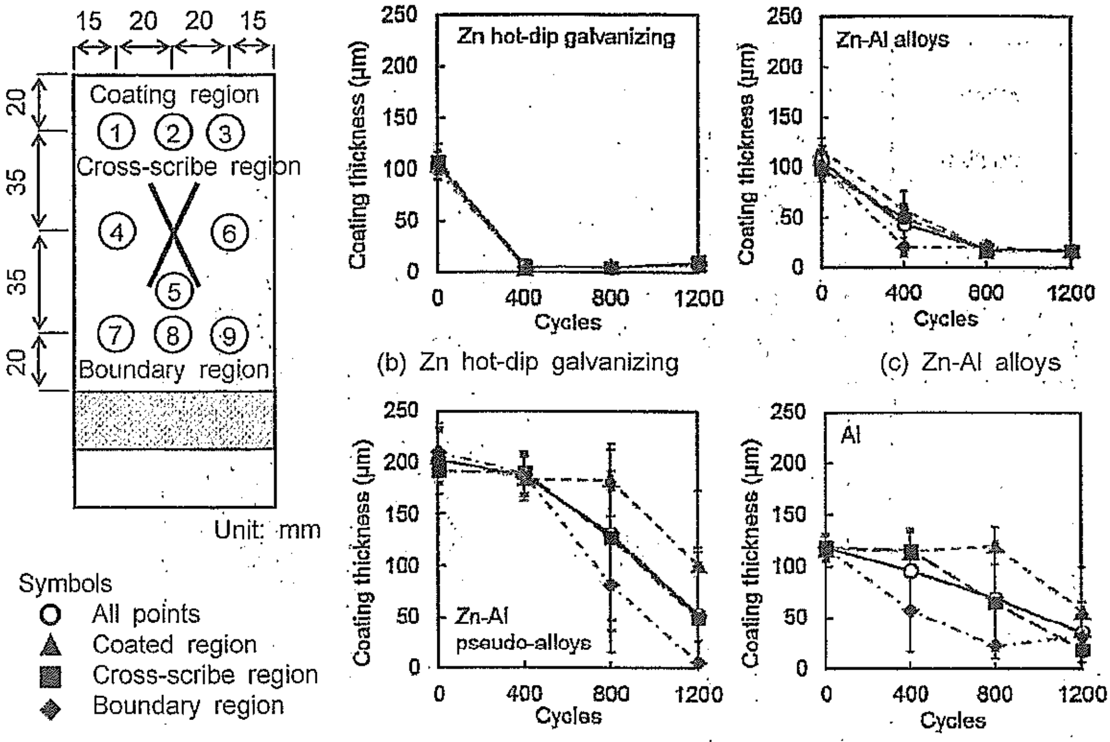



**Fig. 3** Appearances of specimens (after removing rust)

vulnerable to acid rain regardless of the existence of the cut on the coatings or the boundary of the coatings.

In the cases of the Zn-Al pseudo-alloys and the Al (Fig. 4 (d) and (e)), the deterioration behaviors differ from each region. The deterioration speed is the highest in the boundary region. That is the second highest in the cross-scribe region. Scarcely any deterioration occurs in the coated region until 800 cycles.

When noting the average coating thickness measured at all 9 points after finishing 1200 cycles, the thickness of each coating after the test become 10% in the Zn hot-dip galvanizing, 20% in the Zn-Al alloys and around 30% in the Zn-Al pseudo-alloys and the Al compared with their virgin states.




(a) Measured points (b) Zn hot-dip galvanizing (c) Zn-Al alloys (d) Zn-Al pseudo-alloys (e) Al

**Fig. 4** Deterioration of coating thickness

## 3. EFFECTS OF PAINT REPAIR ON DETERIORATED METALLIC COATINGS

Here, for evaluating effects of paint repair on the deteriorated metallic coatings, the same accelerated exposure test is performed on the repaired specimens by painting after removing the rust on them.

### 3.1 Paint repair conditions

The virgin and the deteriorated specimens by the accelerated exposure test in the above chapter (so called the pre-test) are repaired by painting.

After removing the rust generated during the pre-test by chemicals and blasting with alumina, organic zinc-rich paint is coated [4]. For examining the effect of the paint repair on the deteriorated metallic coatings, a series of specimens directly painted on the steel without any metallic coating are made.

### 3.2 Conditions of accelerated exposure test

The conditions of the accelerated exposure test are the same as those of the pre-test in the above chapter.

### 3.3 Test results

**Fig. 5** shows the appearances of the deterioration of the paint coatings on each metallic coating in the case that the pre-test cycle is zero.

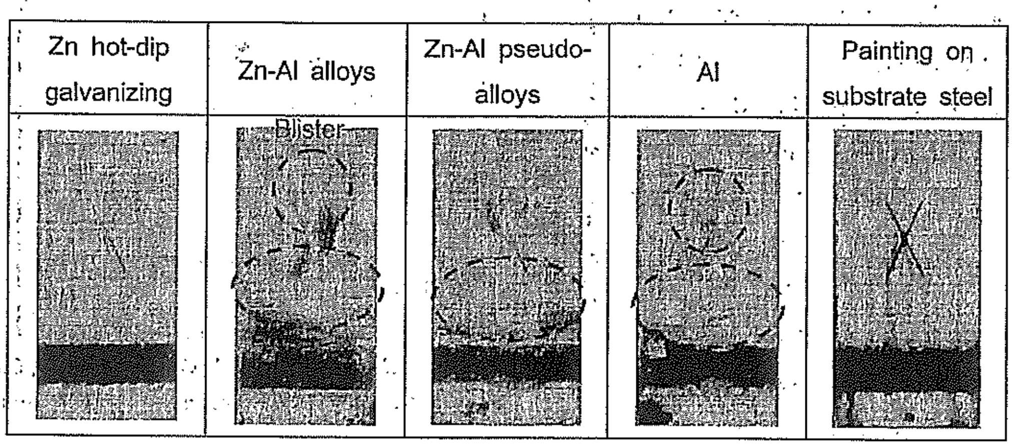
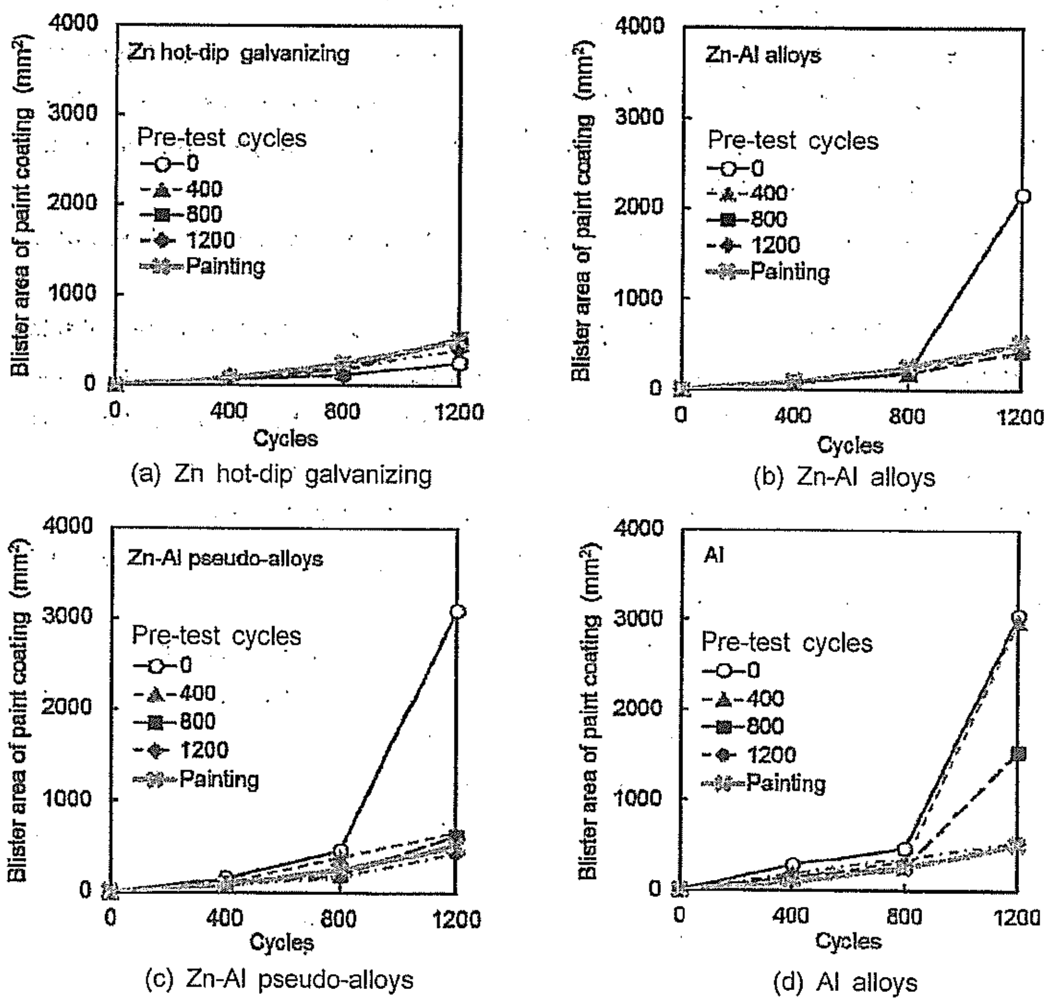



**Fig. 5** Appearances of deterioration of paint coatings (pre-test cycle: zero)




(a) Zn hot-dip galvanizing
(b) Zn-Al alloys
(c) Zn-Al pseudo-alloys
(d) Al alloys

**Fig. 6** Blister area

Blister of the paint coatings due to the rust of the steel is observed.

For evaluating the deterioration of the paints, the blister areas shown in **Fig. 6** are noted. The blister area is defined as the area in which the thickness of the paint coating becomes 150μm larger than that in the virgin state.

In the case of the Zn hot-dip galvanizing (Fig. 6(a)), the differences of the changes of the blister area are small regardless of the cycles of the pre-test for deteriorating the metallic coating. They are almost the same as the case that the specimens directly painted on the steel. This is because hardly any coating remained until 400 cycles in the pre-test. In the cases of the Zn-Al alloys and the Zn-Al pseudo-alloys (Fig. 6 (b) and (c)), the deteriorations of only the specimens painted on the virgin metallic coatings increase from 800 cycles.

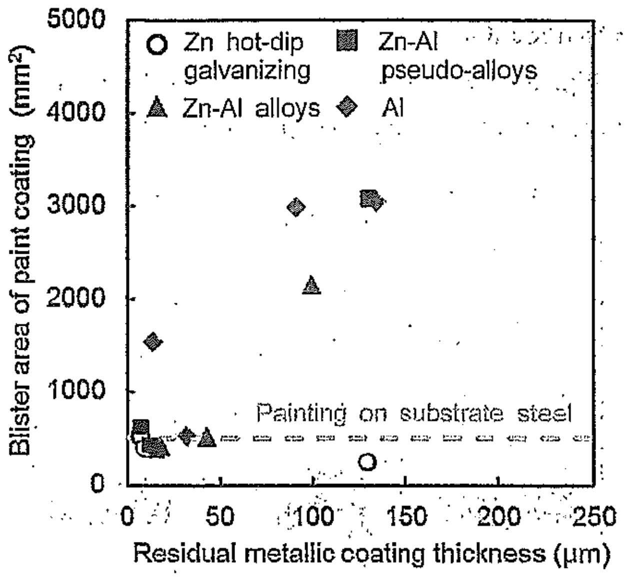



**Fig.7** Relationship between residual coating thickness

In the case of the Al (Fig. 6 (d)), longer the cycles in the pre-test are, larger the blister area become.

The results indicate that the degree of the residual metallic coating in the pre-test affects the deterioration of the repair paint coatings. For investigating this effect, the relationship between the residual metallic coating thickness by the pre-test and the blister area of the repair paint coatings after finishing the 1200 cycles accelerated exposure test is shown in **Fig. 7.**

The dotted line means the blister area of the specimen directly painted on the steel.

In the case of the Zn hot-dip galvanizing, the blister area of the repair paint coating is not affected by the residual metallic coating thickness.

In the cases of the Zn-Al alloys and the Zn-Al pseudo-alloys, the blister areas become larger when the residual metallic coating thickness is over 50μm. In the case of the Al, the blister area becomes large although the metallic coating thickness hardly remains.

The residual metallic coatings largely affect the durability of the repair paints on them. Although the degree of the effect depends on the types of the metallic coatings, there is a risk that the durability of the repair paints becomes low due to the residual metallic coatings.

The results indicate that the degree of the residual metallic coating thickness should be noted when repairing them by painting.

## 4. CONCLUSIONS

For examining the deterioration characteristics of several types of anti-corrosive metallic coatings under acid rain, an accelerated exposure test during 300 days was performed:

(1) The differences of the deterioration behaviors in the normally coated region, around the cross-scribe region and the boundary region in the specimens were not confirmed in the cases of the Zn hot-dip galvanizing or the Zn-Al alloys thermal splay. In the cases of the Zn-Al pseudo-alloys or the Al thermal spray, the metallic coatings around the boundary region and the cross-scribe region deteriorated earlier than the normally coated region.

(2) The thickness of the metallic coatings after the accelerated exposure test considering acid rain condition became 10% in the Zn hot-dip galvanizing, 20% in the Zn-Al alloys and around 30% in the Zn-Al pseudo-alloys and Al compared with their virgin states.

Furthermore, for evaluating repair effects of painting on deteriorated metallic coatings, the same accelerated exposure test was performed on the repaired specimens by painting after removing the rust on them:

(3) In the case of the Zn hot-dip galvanizing, the blister area of the repair paint coating was not affected by the residual metallic coating thickness.

(4) In the cases of the Zn-Al alloys and the Zn-Al pseudo-alloys, the blister areas became larger when the residual metallic coating thickness was over 50μm. In the case of the Al, the blister area became large although the metallic coating thickness hardly remained.

(5) The residual metallic coatings largely affected the durability of the repair paints on them. Although the degree of the effect depended on the types of the metallic coatings, there was a risk that the durability of the repair paints became low due to the residual metallic coatings. The results indicated that the degree of the residual metallic coating thickness should be noted when repairing them by painting.

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