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Evaluation of Maintenance Coating Materials for Steel Bridges

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Coating performance of various coating systems including chlorinated rubber and epoxy/urethane used most for steel structures of highway in Korea, was evaluated by exposing test specimen to complex deterioration factors such as ultraviolet ray, moisture, freeze-thaw cycle and salt. Deteriorated specimens were evaluated by chalking and rust grades according to ASTM, and measurement of color differences and adhesion. In overall coating performances such as corrosion resistance, photochemical stability, and adhesion, ceramic/ urethane, moisture-curable urethane/ urethane, etc. were superior. As for other coating materials tested in this study, superior materials against certain deterioration factors may be inferior against other factors. Accordingly, in order to select suitable maintenance coating materials for the use, it is thought that investigation of suitability through experiment should precede selection of materials, especially for unusual coatings or paints.

Keywords *: coating performance, complex deterioration factors, corrosion resistance, photochemical stability, adhesion*

1. Introduction

Protection of steel used as constituent of structure is essential in order to prevent it from being corroded by oxygen and moisture in atmosphere. Protective coating is one of the most convenient and effective methods for protection of steel. However, life of coating is much shorter than that of structure, and therefore maintenance coating is very important. In addition, importance of maintenance coating will be more emphasized in the future, since use of chloride-containing deicer such as calcium chloride, and construction of structure under marine environment are increasing.

2. Experimental

2.1 Materials

Coating materials used for test were 13 coating systems containing moisture-curable urethane/urethane, epoxy mastic/urethane, ceramic coating, acrylic silicone, etc. as well as chlorinated rubber that most applied for steel bridges in Korean highway. All of coating systems used for test are showed in Table 1. The size of steel plates used for test specimens was $70 \times 150 \times 3$ mm.

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2.2 Deterioration and evaluation of specimens

Test specimens were exposed in complex deterioration cycles considering various deterioration factors in the nature such as sunlight, rain, freeze-thaw and salt. In the first step, UV-condensation, test specimens were repeatedly exposed in ultraviolet ray at 60 ℃ for 8h and condensation at 40 ℃ for 4h, in turn for 7 days. In the second step, test specimens were exposed in -20 ℃ chamber for 1 day. In the third step, test specimens were immersed in 5% NaCl solution at 35 ℃ for 6 days. From the first to the third step was 1 cycle of test, and total 10 cycles were carried out over again. The schematic test procedure is shown in Fig. 1.

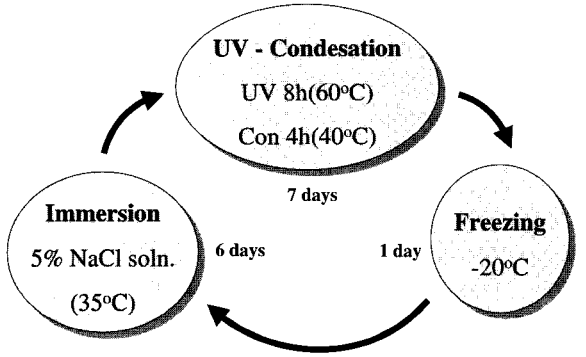

Fig. 1. Method for deterioration of specimens

Table 1. Coating systems used for test

Abbreviation	Coating system	Primer	Intermediate coat	Topcoat	No. of coat
C/U	Ceramic/urethane	Ceramic		Ceramic urethane	2
MCU/U1	Moisture-curable urethane/urethane1	Moisture-curable urethane		Urethane	2
MCU/U2-1	Moisture-curable urethane/urethane2-1	Moisture-curable urethane		Urethane	2
MCU/U2-2	Moisture-curable urethane/urethane2-2	Moisture-curable urethane		Urethane	2
Al/E/U	Al-epoxy mastic/ epoxy mastic/urethane	Al-epoxy mastic	Epoxy mastic	Urethane	3
Sil	Acrylic silicone	Acrylic silicone			1
CR	Chlorinated rubber	Chlorinated rubber MIO	Chlorinated rubber	Chlorinated rubber	3
IOZ	Waterborne inorganic zinc	Waterborne inorganic zinc			1
ZEU	Waterborne inorganic zinc/epoxy/urethane	Waterborne inorganic zinc	Epoxy	Urethane	3
Zn/E	Zn metalizing/epoxy	Zn metalizing		Epoxy	2
Al/E	Al metalizing/epoxy	Al metalizing		Epoxy	2
Gal/E	Galvalume metalizing/epoxy	Galvalume(Al 55%/Zn 45%) metalizing		Epoxy	2

For the deteriorated specimens, chalking and rust grades according to ASTM D 4214[1] and D 610[2] were evaluated. In addition, measurements of color differences using X-Rite SP88 Spectrophotometer according to ASTM D 2244,[3] E 805[4] and E 1347,[5] and adhesion using Elcometer Adhesion Tester according to ASTM D 4541[6] were carried out.

3. Results and discussion

3.1 Deterioration by UV

Chalking is the most preferable type of coating failure. The mechanism of chalking is essentially one where the coating binder tends to gradually disintegrate by UV, leaving the surface covered with the pigments that have been held on the surface by binder. This process continues until the surface coating is worn through, at which time the primer is visible or corrosion begins to occur on the substrate.[7] Chalking grade can be criterion of stability against photochemical reaction by UV.

Chalking grades of test specimens in this study are shown in Fig. 2. From the result that chalking grades of acrylic silicone, ceramic/urethane and one kind of moisture-curable urethane/urethane did not decrease under grade 8, it is thought that the 3 coating systems were most superior in stability against photochemical reaction by UV. On the other hand, chalking occurred most rapidly for 3 kinds

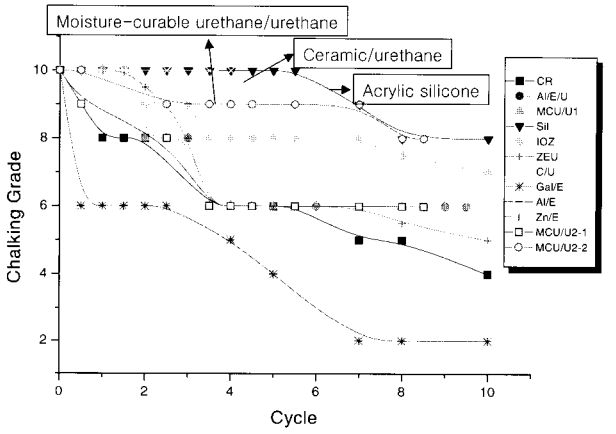

Fig. 2. Chalking grades by ASTM D 4214

of metalizing (galvalume, zinc and aluminum) with epoxy topcoat. Generally, epoxy coating is vulnerable to UV-induced breakdown due to carbon to carbon double bond (-C=C-) in aromatic ring, where one carbon atom excited by UV forms highly reactive free radical that results in the occurrence of many complex intrapolymeric reactions. These reactions may include chain splitting, depolymerization, and even the evaporation of smaller polymeric fragments.[8] Accordingly, it is thought that topcoat should be substituted with other material such as urethane, or not be applied.

In order to confirm above results, color differences

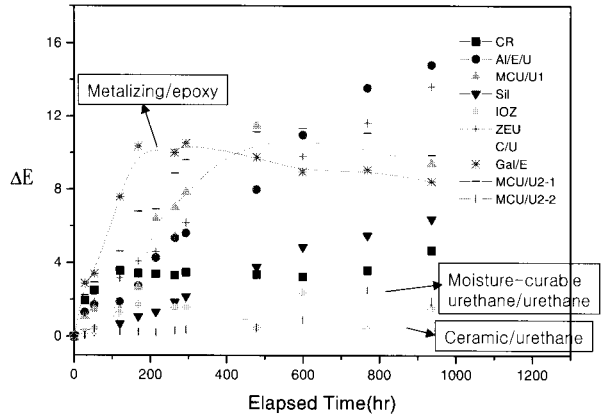

Fig. 3. Color differences measured by spectrophotometer

measured by spectrophotometer are shown in Fig. 3. Test results showed similar trend to the chalking grade. The fastest decolorized coating in the first stage was epoxy topcoat used in metalizing, the second one was moisture-curable urethane/urethane2-1, and the third one was chlorinated rubber, while the slowest decolorized coating systems were ceramic/ urethane and moisture-curable urethane/urethane2-2.

3.2 Corrosion resistance

Rust grades with exposure time are shown in Fig. 4. The most superior coating systems in corrosion resistance were ceramic/urethane, 2 kinds of moisture-curable urethane/urethane, and 3 kind of metalizing that maintain grade 10 until the end of test. Chlorinated rubber coating maintained similar corrosion rate to most of other coating systems, though it corroded fast in the first stage. While, rust grade of acrylic silicone was lowest at the end of test, though it was high in the early stage of test. From the result, it is thought that acrylic silicone single coat

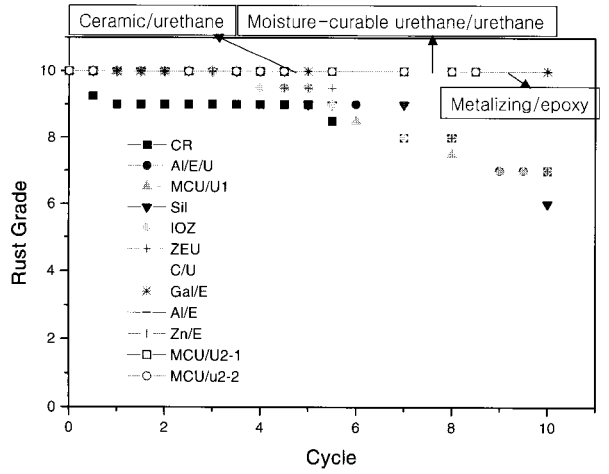

Fig. 4. Rust grades by ASTM D 610

is not suitable for protective coating. However, acrylic silicone coating, in spite of its inferiority in corrosion resistance, is expected to be substituted for urethane topcoat to make coating performance be enhanced, since it was more stable than most of urethane photochemically in the evaluation of chalking grade and color difference measurement.

3.3 Adhesion test

Measured results of adhesion are shown in Table 2. It is thought that adhesion between coat and substrate was higher than that between coats, from the result that all the breakdown sections were coat to coat except acrylic silicone applied as single coat. The most superior coating systems in adhesion were Al-epoxy mastic/epoxy mastic/ urethane, moisture-curable urethane/urethane2-1, and ceramic/urethane. Three kinds of metalizing also showed high adhesion values more than 4Mpa, but those were adhesion between metalizing and epoxy. It is expected that adhesion of the metalizing itself will be much higher than the values measured in this test.

Table 2. Adhesion test results

Coating system	Breakdown Section	Adhesion (MPa)
Chlorinated rubber	P - I	4.05
Ceramic/urethane	-	4.80<
Al-epoxy/epoxy/urethane	P - I	5.25
Waterborne inorganic zinc	-	3.70<
Waterborne inorganic zinc/epoxy/urethane	P - I	0.97
Acrylic silicone	Substrate - Coat	2.07
Galvalume metalizing/epoxy	P - T	4.20
Al metalizing/epoxy	P - T	4.40
Zn metalizing/epoxy	P - T	4.80
Moisture-curable urethane/urethane1	P - T	3.08
Moisture-curable urethane/urethane2-1	P - T	5.63
Moisture-curable urethane/urethane2-2	P - T	4.83

4. Conclusions

From the evaluation of various coating materials for steel bridges through accelerated test exposing test specimens to complex deterioration factors, we concluded that:

(1) Ceramic/urethane, moisture-curable urethane/urethane, etc. were superior in overall coating performances such

as corrosion resistance, photochemical stability, and adhesion.

(2) It is thought that topcoat used in metalizing/epoxy should be substituted with other material such as urethane, or not be applied.

(3) Acrylic silicone single coat is not suitable for protective coating. However, it is expected to be substituted for urethane topcoat to make coating performance be enhanced, since it was more stable than most of urethane photochemically.

(4) In order to select suitable maintenance coating materials for the use, it is thought that investigation of suitability through experiment should precede selection of materials, especially for unusual coatings or paints.

References

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