

Durability evaluation of newly developed fluoropolymer emulsion paints

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Abstract

A new type of water-based emulsion paints by using fluoropolymer have been on the market recently in Japan. These water-based paints are expected to decrease air pollution and also to keep such high durability as organic solvent type of paints.

This paper outlines the results of a series of performance evaluation tests for the new paints and other standardized paints such as solvent type of fluoropolymer paints, solvent type of polyurethane paints, and acrylic emulsion paints for comparison. A sunshine carbon arc type of irradiation test, outdoor exposure tests and corrosion tests for steel protective coating systems were carried out in the study. Moreover, repainting works with the new water-based paints and with other paints for exterior finishing systems were performed.

Through the sunshine carbon irradiation test and the corrosion tests, it was confirmed that the water-based fluoropolymer paints possessed competitive durability with solvent type of fluoropolymer paints which are more durable than solvent type of polyurethane paints. The outdoor exposure tests and periodical inspection for repainted exterior finishing have been continued for a few years. The fluoropolymer emulsion paints have shown good durability in the both tests. Finally, the draft of standard specifications of coating work with the fluoropolymer emulsion paints was obtained for both new painting works and repair painting works through this study.

Keywords: Air pollution, durability, fluoropolymer, paint, repaint, standard specification, water-based emulsion.

1 Introduction

According to the report [1] of Environment Protection Agency in Japan, about 30% of the total amount of organic carbons which were emitted into the air due to human activities has been considered to come from painting works. Different from coating in controlled manufacturing factories, it is difficult to collect organic solvents evaporated in the air, because painting works in construction are usually carried out in outdoor conditions.

For this reason, use of water-based paints has been recommended from the viewpoint of environment protection. This demand is becoming very strong recently. Paint manufacturers are intensively developing safer and more durable paints. Figure 1 shows fundamental methodologies for developing safer paints.

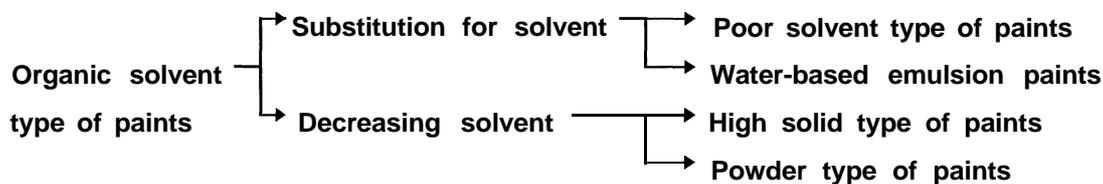


Figure 1 Basic methodology for developing environmentally safer paints.

Among the paints shown in Figure 1, poor solvent (mineral spirits, solvent with higher boiling point) type of paints, water-based paints and high solid type of paints have been on the market aiming at substituting for existing solvent type of paints used in construction works. Especially, water-based paints are considered to be suitable from the viewpoint of environment protection. However, water-based paints are generally less durable than organic solvent type of paints. Therefore, it is not so easy to replace water-based emulsion paints for existing solvent type of paints especially where high durability is required.

In this background, new type of emulsion paints by using fluoropolymer have been recently developed in Japan. As reported before[2][3], solvent type of fluoropolymer paints were already developed and have been prevailing in Japan. The durability level of these paints has been classified at the one of the highest ranks among the all types of paints on the market. The solvent type of fluoropolymer paints were already standardized in JIS K 5658[4] and JIS K 5659[5] for their materials qualities and the painting work specifications were also standardized in JASS18[6].

The newly developed emulsions consist of polymers whose molecular structures are similar with solvent type of fluoropolymer. One of the key points for imparting high durability to fluoropolymer emulsions is not to use usual emulsifiers. It is reported by the

manufacturer that the durable fluoropolymer emulsion paints can be obtained by using macro-monomers compatible with both fluoropolymer and water as emulsifiers.

In this study, a series of tests including sunshine carbon arc irradiation test, outdoor exposure tests and corrosion tests have been conducted for the newly developed emulsion paints in order to evaluate their durability and applicability to construction work.

2 Experiment

2.1 Tested materials

The coating specifications listed in Table 1 and Table 2 were applied for cementitious substrate specimens and steel sheet specimens, respectively.

Table 1 Coating specification for cementitious substrates.

Coating system	Under coat	Top coat (dry film 40 μ m in thick)
System A	acrylic emulsion	water-based fluoropolymer emulsion
System B	epoxy primer	solvent type of fluoropolymer paint
System C	acrylic emulsion	water-based acrylic emulsion
System D	epoxy primer	solvent type of polyurethane paint

Substrate : fiber reinforced cement sheet (70mmx150mmx4mm).

Table 2 Coating specification for steel sheets.

Coating system	Under coat	Middle coat	Top coat (dry film 40 μ m in thick)
System E	anti-corrosive emulsion	none	water-based fluoropolymer emulsion
System F	anti-corrosive emulsion	acrylic emulsion	water-based fluoropolymer emulsion
System G	solvent type of anti-corrosive paint	none	water-based fluoropolymer emulsion
System H	solvent type of anti-corrosive paint	none	solvent type of polyurethane paint
System I	solvent type of anti-corrosive paint	none	solvent type of fluoropolymer paint

Substrate : cold rolled carbon steel sheet, ss400 (70mmx150mmx0.8mm)

2.2 Sunshine carbon arc irradiation

Sunshine carbon arc irradiation was performed according to ISO 4892-4[7]. The water spray cycle used was 18 min spraying with 102 min dry interval. The test was carried out until 5,000 hours for the cementitious board specimens and until 2,000 hours for the coated steel specimens.

2.3 Salt spray test and cyclic corrosion test

A neutral salt spray test was performed based on ISO 9227[8]. 28 cycles of treatment shown in Figure 2 was also done in the cyclic corrosion test after 60 hours of sunshine carbon arc irradiation. The both corrosion tests were performed for the coated steel specimens with intentional scratched marks.

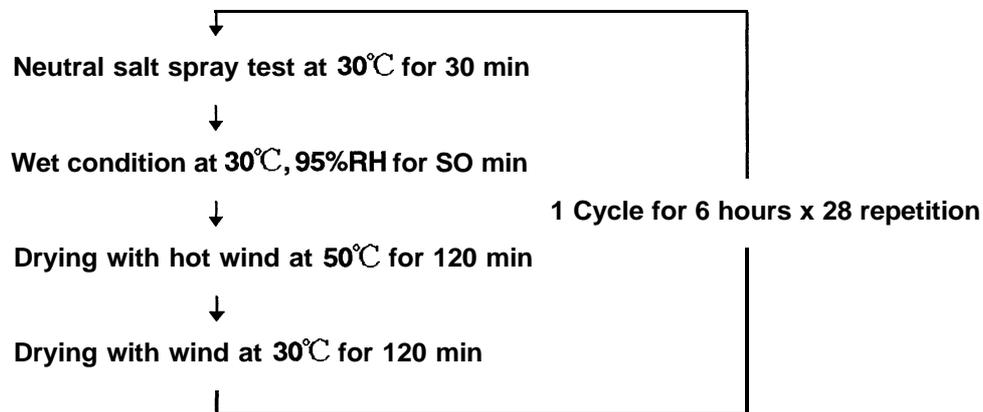


Figure 2 1 cycle of treatment for the cyclic corrosion test.

2.4 Outdoor exposure tests

Outdoor exposure tests have been conducted in the 4 locations (Sapporo, Tsukuba, Kawasaki and Okinawa) for the coated cementitious specimens and in the 2 locations (Tsukuba and Kawasaki) for the coated steel specimens. The specimens were mounted on the exposure racks facing the south at an angle of 30 degrees. The tests have been continued for a few years until now.

2.5 Test painting work for repairing

Repair painting was carried out for deteriorated textured coating on fiber reinforced cementitious boards. The deteriorated textured coating specimens (sized 180 cm x 90 cm) listed in Table 3 had been exposed for 14 years in Tsukuba. Extensive chalking and partial peeling and checking could be observed on the exposed specimens, however, bonding strength of the old layers to the substrate was not so low as initial bonding strength. The new coating systems in Table 3 were applied on these old coating layers

after cleaning with water at the pressure of 15 MPa. The top coating layers in all the old textured coating systems were partially removed after such treatment and repainting work was conducted on the old coating layers including the partial old top coating layers.

Table 3 Repair coating specification for exposed textured coatings on the cementitious boards.

Coating system	Top coat of the old coating systems	New coating system	
		Under coat	Top coat
System J	solvent type polyurethane	water-based sealer	water-based fluoropolymer
System K	solvent type polyurethane	solvent type sealer	solvent type fluoropolymer
System L	water-based acrylic paint	water-based sealer	water-based fluoropolymer
System M	water-based acrylic paint	water-based sealer	water-based acrylic paint
System N	solvent type of acrylic paint	water-based sealer	water-based fluoropolymer
System O	solvent type of acrylic paint	solvent type sealer	solvent type polyurethane

Preparation of old coatings: water cleaning with pressure at 15MPa

3 Results and Discussion

3.1 Acceleration test

Figure 3 shows the changes in gloss values at 60 degrees' reflection with carbon arc irradiation time for the coated cementitious boards. The results for the coated steel specimens showed similar behavior with Figure 3. As shown in the figure, it was confirmed that the water-based fluoropolymer paints kept about 90 % of their initial gloss up to 5,000 hours' irradiation and their resistance against ultraviolet light is competitive with that of the solvent type of fluoropolymer paints reported previously[2],[3]. This high durability is considered to be primarily due to strong bonding energy between C-F bonds. On the other hand, the controlled polyurethane paints and the acrylic paints lost their initial gloss remarkably with the irradiation time.

Table 4 shows the results of visual inspection after the salt spray test and the cyclic corrosion test. One of the important results was that System E did not possess enough corrosion protective performance. In System E, bonding performance to the substrate is considered to be insufficient due to insufficient performance of under coat.

To improve System E, addition of a process of middle coating with a water-based paint (System F) or use of a solvent type of paint as under coat (System G) is necessary.

System H and System I are rather popular as anti-corrosive coating specifications for heavy duty protection. Although the slight blistering could be observed in the cyclic corrosion test, the both systems showed good performance in total.

As to the anti-corrosive coating systems using water-based fluoropolymer paints, it can be said that such systems are as good as the coating systems using the polyurethane paints or solvent type of fluoropolymer paints if the under coating systems are sufficient. To improve the performance of under coats, addition of a middle coating process with a water-based paint or use of a solvent type paint for under coating is necessary.

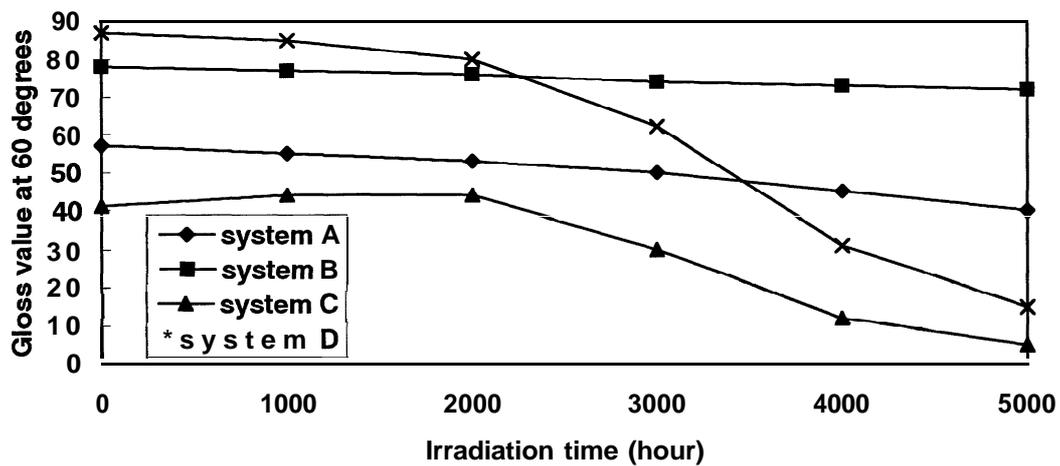


Figure 3 The changes in gloss values for the coated cementitious board specimens.

Table 4 Results of the salt spray test and the cyclic corrosion test.

Coating system	Cross-cut test before corrosion tests	Visual inspection after salt spray test	Visual inspection after cyclic corrosion test
System E	poor (1 0/25)	rusting within 120 hours	color change
System F	good (25/25)	no change more than 500 hours	no change
System G	good (25/25)	no change more than 500 hours	no change
System H	good (25/25)	no change more than 500 hours	slight blistering
System I	good (25/25)	no change more than 500 hours	slight blistering

3.2 Outdoor exposure test

Measurement of color difference and gloss has been performed periodically in the outdoor exposure tests. Figure 4 shows the changes in gloss retention after washing with water for the coated cementitious specimens exposed in Okinawa located in southern part of Japan. As shown in the figure, the specimens coated with the water-based fluoropolymer paints and the solvent type of fluoropolymer paints keep high gloss retention percentages. On the other hand, the specimens coated with the water-based acrylic emulsion paints and the solvent type of polyurethane paints are significantly losing their initial gloss. The outdoor exposure tests in other places showed similar results with the results obtained in Okinawa.

The results obtained in the outdoor exposure tests are consistent with the results obtained in the sunshine carbon arc irradiation test. The outdoor exposure tests are to be continued until the data after 10 years will be obtained.

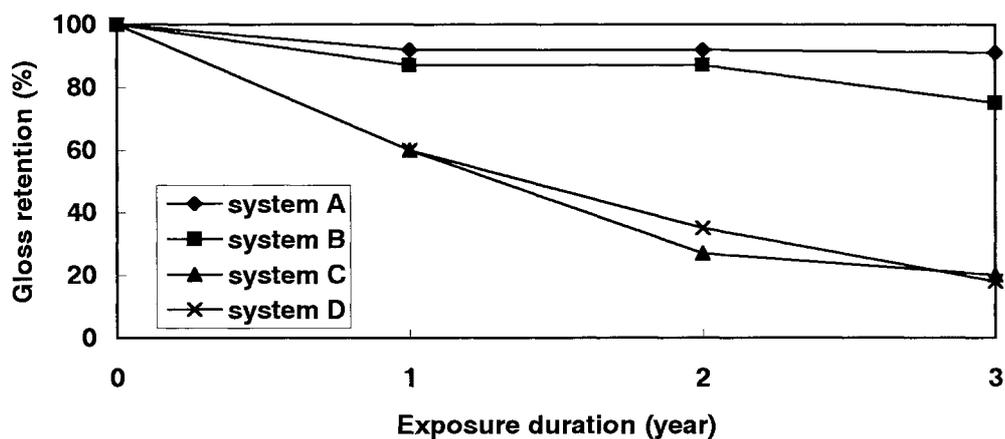


Figure 4 The changes in gloss retention after washing with water for the coated cementitious board specimens exposed in Okinawa area.

3.3 Applicability for repair coating

The repaired coating with the specifications listed in Table 3 was successfully conducted in every specification. The failures due to incompatibility with the existing coated layers such as delamination and swelling of the old coated layers could not be observed in and after repainting. The repainted specimens have shown no deterioration phenomena except for natural loss of the gloss until now. Moreover, adhesive strength to the old coated layers was confirmed to be sufficient by a pull-off test and a cross-cut test.

Generally speaking, water-based emulsion paints are preferable for repair coating to avoid swelling the old layers. On the other hand, adhesive performance to old coated

layers are generally not so good as that of solvent type of paints. For this reason, the adhesive strength of the specimens are planned to be checked periodically in future.

4. Conclusion

A series of performance evaluation tests for newly developed fluoropolymer emulsion paints were conducted. It is considered that the durability of the water-based fluoropolymer paints is as high as that of organic solvent type of fluoropolymer paints.

Through these tests, a draft of useful coating specifications with water-based fluoropolymer paints could be obtained both for new construction and for repair works. The obtained draft of the specifications is helpful for application of the water-based fluoropolymer paints, although it will need to be reviewed based on the further data.

5. References

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