EFFECT OF COATING TO INHIBIT AAR IN CONCRETE STRUCTURES

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The effective method for repair of concrete structures deteriorated by the AAR should be based on :(1) firstly to remove the contained water in the concrete, (2)then to prevent the penetration of water from the outside into the concrete,and (3)to use the flexible material for surface coating or for injection into the cracks in order to maintain the function after the further propagation of the cracks. This paper describes the results of comparative test carried on several kind of repairing materials, and the in-situ observation of the existing deteriorated structure repaired by several methods.

INTRODUCTION

In the Hanshin Expressway Public Corporation, a series of comparative tests have been carried out in order to establish the effective method for repair of deteriorated structures since the damage due to the alkali-aggregate-reaction(AAR) was discovered in 1982.

Some repairing works were also done in the actual deteriorated structures by the use of a few materials chosen from the above tests, and the effectiveness of repairing works was examined by the field observation.

LABORATORY TEST

Test Procedures

Typical repairing materials were used in the laboratory test as listed in Table 1. The dimension of the test specimens was of 10x10x40 and 15x15x25cm.

The mix proportion and mechanical properties of concrete are listed in Table 2. Normal portland cement of equivalent alkali content of 0.63%, non-reactive river sand for the fine aggregate and Bronzite Andesite for the coarse aggregate determined to be deleterious by the ASTM chemical method as Sc=775mmol/l and Rc=170mmol/l were used in the mix. The total alkali content of the concrete was adjusted to 8 kg/m^3 as the equivalent Na_2O by the additional use of NaCl.

TABLE 1 – Repairing Materials used in the Laboratory Test.

System	Materials	Standard Usage
Silane Monomer	Silane Monomer	0.3 ℓ/m²
Silane Monomer with Polymer Cement	Silane Monomer Polymer Cement	0.3 ℓ/m² Thickness of 600 microns
Silane Oligomer with Polymer Cement	Silane Oligomer Polymer Cement	0.3 ℓ/m² Thickness of 600 microns
Epoxy Resin	Epoxy Resin	Thickness of 420 microns

TABLE 2 – The Mix Proportion and Mechanical Properties of Concrete.

W/C %	Unit Weight (kg/m³) Water	Cement	Equiv. Alkali	Slump cm	Air content %	Compressive strength N/mm²	Static modulus of elasticity N/mm²
50	176	352	8.0	7.0	2.7	40.3*	2.97×10^4*

* standard curing—20deg.C in water

Surface coating and combination of surface coating and crack injection were used as the repairing method. The age of repair was 28 days and after cracking.

The repaired specimens were exposed under the natural environmental condition and under the drying and wetting repetition with temperature of 40deg.C.

The expansion and weight change ratio were measured according to JIS A 1129 "Test Method for Change in Length of Mortar and Concrete (Dial Gauge Method)".

Types of Repairing Materials and their Effects

The test results were shown in Figure 1. The specimen coated by epoxy resin exhibits a remarkable expansion under the drying and wetting condition, but it shows only a little expansion when tested under the natural environmental condition.

This suggests that the reaction proceeded gradually only by the internally contained water under suitable condition of high temperature of 40deg.C, but the reaction did not go on under low temperature of natural condition.

The reaction was reduced in the specimens coated by silane monomer or silane oligomer with polymer cement with some exceptions.

When compared silane monomer and silane oligomer, the specimens with silane monomer and polymer cement system had the superior effect as compared with those with silane oligomer and polymer cement system. It is because silane monomer is more effective in releasing internal water.

Effect of Combination of Coating and Crack Injection

Figure 2 illustrates the comparison of the effect in reducing expansion betweem the coated specimens with and without crack injection treatment. In this case epoxy resin of 4% was used as coating material with thickness of 60 microns.

There is a remarkable difference between the specimens with and without injecting material in the cracks under the condition of drying and wetting repetition.

The effect in reducing expansion by injection of resin into cracks was observed. Amount of expansion of 300×10^{-6} was shown in the specimen only with coating, but no expansion was observed in those with injection.

Therefore, the combination of resin injection and coating treatment is more effective. Flexible type of epoxy resin as a injecting material is more effective as compared with normal epoxy resin.

APPLICATION TO ACTUAL STRUCTURES

In some T-shaped reinforced concrete piers shown in Figure 3 constructed in 1976, cracks due to AAR were observed in 1979, and these piers were to be repaired by the use of five types of coating resin with epoxy resin injection into cracks. The repairing methods for these piers are listed in TABLE 3. After repair, the crack width, the transverse strain and the ultrasonic pulse velocity were measured.

Figure 3 shows the relationships between expansion and time after repair. Measured expansion of concrete surface reached about 1200×10^{-6} within 7 years after coating in the piers coated by the polyacrylurethane and by the epoxy resin, and new cracks were observed.

In the pier coated by polymer cement , strain is increasing gradually, but its value is still less than 500×10^{-6} .

And in the other piers coated by silane monomer and silane oligomer with polymer cement system, there is no increase of strain. In these three piers, no new cracks is not found after 7 years.

In this field test, repairing method using silane monomer with polymer cement system is recognized as the most effective method as well as in the laboratory test.

TABLE 3 – The Repairing Methods for Actual Structures.

Coating System	Silane Monomer	Polymer Cement	Acryl	Epoxy	Silane Oligomer
Structure	T-shaped reinforced concrete pier				
	(MP-44)	(MP-43)	(MP-42)	(MP-48)	(MP-38)
Construction	1976	1976	1976	1976	1976
Repair	1985	1985	1984	1984	1985
Expansion of core($\times 10^{-6}$)					
Total	122	1457	1115	12260	—
Release	17	319	1150	125	—
Residual	139	1138	-35	12135	—
Coating Material and Standard Usage					
Pre-treatment	Silane Monomer	Epoxy resin	Epoxy resin	Epoxy resin	Silane Oligomer
(kg/m^2)	0.20	0.10	0.10	0.10	0.20
Main Coat	Silane Monomer	Polymer Cement Mortar	Polyacryl -Urethane resin	Flexible type of Epoxy resin	Silane Oligomer
(kg/m^2)	0.20	0.50	0.25	0.26	0.20
Top Coat	Polymer Cement Mortar	Polymer Cement Mortar	Polyacryl -Urethane resin	Poly-urethane resin	Polymer Cement Mortar
(kg/m^2)	0.20	0.50	0.25	0.12	0.30
Crack Injection	Flexible type of Epoxy resin				

CONCLUDING REMARKS

From the laboratory and field tests, the silane monomer with polymer cement type of coating is expected to be one of the most effective method to inhibit aggregate silica reaction.

To combinate surface coating treatment with resin injection is more effective in repairing work.

The flexible type of epoxy resin has the more excellent properties than the normal type when used as injecting material.

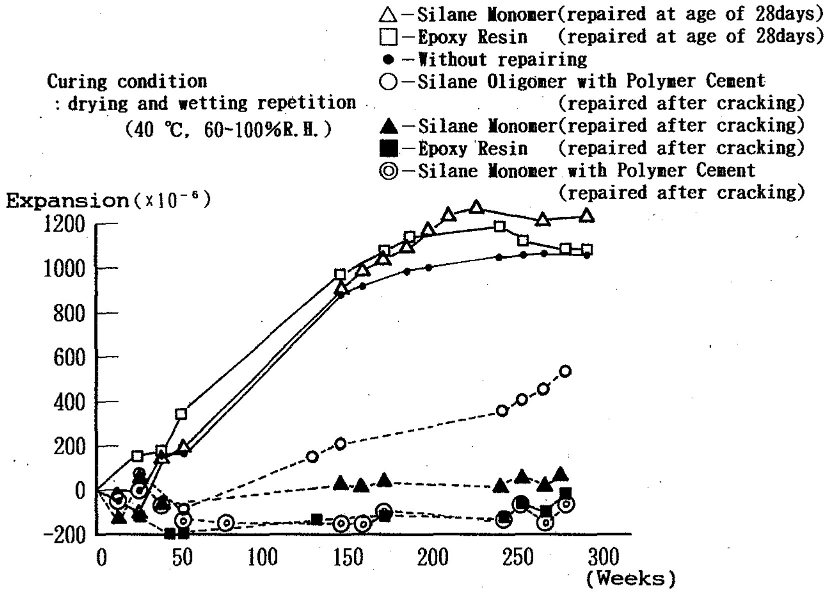

Figure 1 Relationship between Repairing Materials and Expansion

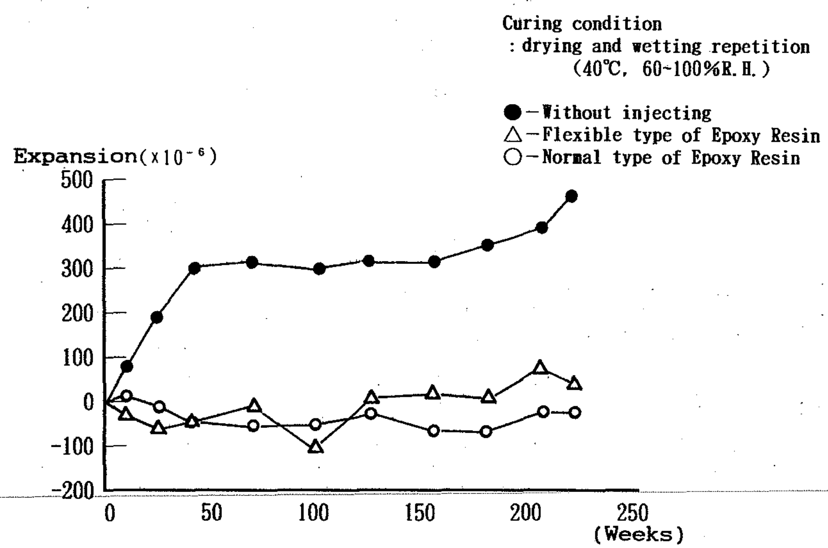

Figure 2 Relationship between Injecting Materials and Expansion

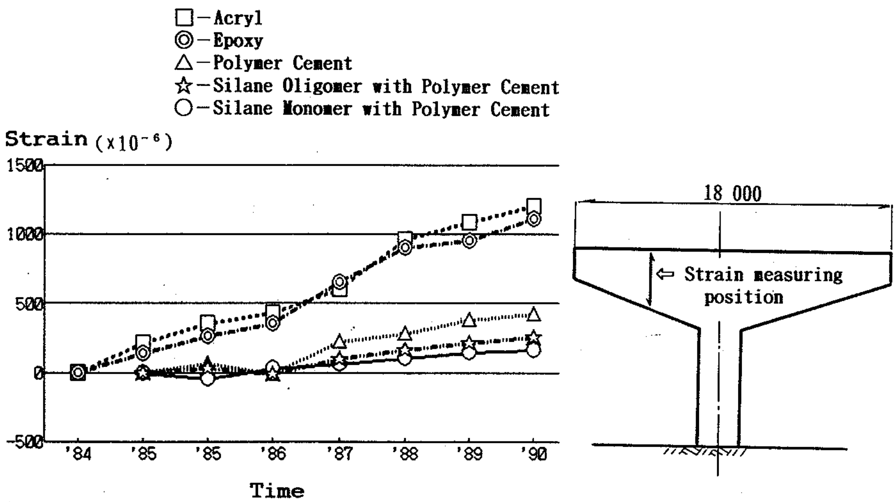

Figure 3 Relationship between Repairing Materials and Expansion in Actual Structures