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EFFECT OF COATING TO INHIBIT ALKALI–AGGREGATE REACTION OF CONCRETE STRUCTURES

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1. INTRODUCTION

An efficient method to inhibit alkali-aggregate reaction (AAR) has not been established yet. Since AAR is required water for the reaction, it is inferred that waterproof might be effective to inhibit AAR. Various types of coating materials have been tested in laboratory and some of the materials have been applied to bridge sub-structures damaged by alkali-silica reaction (ASR). This paper introduces the field test.

2. FIELD TEST

2. 1 Coating materials

Table 1 shows 5 different coating materials and the specifications selected for the test. Polyurethane, epoxy and polybutadiene resin are waterproof type of coating and silane and the polymer cement are aeration type of coating.

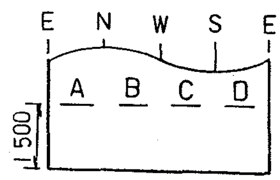
Table. 1 Coating materials

No	System	Process	Material	Standard usage (kg/m²)	Thikness (um)
1	Polyurethane	Pretreatment	Epoxy resin primer	0.15	60
			Epoxy resin putty	0.20	
		Main coat	Polyurethane resin	0.30	
2	Epoxy	Pretreatment	Epoxy resin primer	0.10	90
		Main coat	Flexible epoxy resin	0.26	
		Top coat	Polyurethane resin	0.12	
3	Polybutadiene	Pretreatment	Epoxy resin primer	0.16	1000
			Epoxy resin putty	0.20	
		Main coat	Polybutadiene resin	1.59	
		Top coat	Polyurethane resin	0.32	
4	Silane	Main coat	Silane resin	0.40	60
		Top coat	Polymer cement mortar	0.30	
5	Polymer cement	Primer	Aeration type of polymer cement mortar	0.15	400
		Putty		0.40	
		Main coat		0.90	

2. 2 Test methods

Piers and an abutment of highway bridges are selected as the test model. Before repair by coating, crack width and depth, corrosion of steel, reactive aggregate used and expansion of core drilled from the structure were investigated. After coating, strain measurement and crack observation were carried out periodically. The strain measurement was carried out by contact strain gauge. Figure 1 shows the test structures for each coating materials and position of strain measurement.

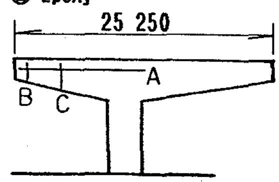
① Polyurethane



diameter ϕ 2000

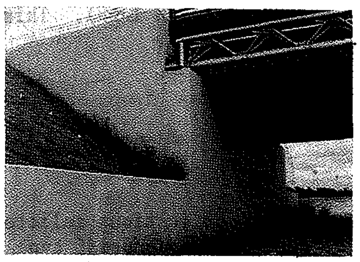
Strain measuring position	Gauge length	Number of gauges
A, B, C, D	10cm	8

② Epoxy



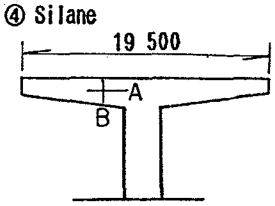
Strain measuring position	Gauge length	Number of gauges
A	30cm	38
B	10cm	16
C	10cm	20

③ Polybutadiene



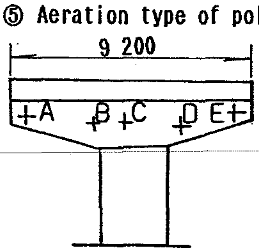
(No strain measurement)

④ Silane



Strain measuring position	Gauge length	Number of gauges
A	30cm	10
B	30cm	7

⑤ Aeration type of polymer cement



Strain measuring position		Gauge length	Number of gauges
A, B, C, D, E	Vertical	10cm	4
	Horizontal	10cm	4

Figure 1 Test structures

3 . RESULTS

3. 1 Polyurethane coating

Table 2 shows the results of investigation carried out for the column in 1984. The column was repaired by polyurethane coating in January 1985. Injection of the cracks was not done for this column. Since the repair, expansion and crack opening of the repaired column have been measured once a month. Expansion of the equivalent but undamaged column has been measured for the comparison. Figure 2 and 3 are these results. These measured values include strain by temperature change, drying shrinkage and ASR expansion. According to these results, this coating could not stop the ASR expansion. About 300×10^{-6}/year of ASR expansion and 0.1mm/year of crack opening have been occurring after coating. Figure 4 shows recracking occurred about 6 months after the coating.

Table 2 Results of investigation

Structure		Column of pier
Construction		1977
Investigation		1983
Repair		1985
Crack	width	1.5mm
	depth	12cm
Corrosion of steel		Nil
Reactive Aggregate		Bronzite Andesite
Expansion of core ($\times10^{-6}$)	total	1000
	release	350
	residual	650
Ambient condition		partially sheltered
Crack injection		Nil

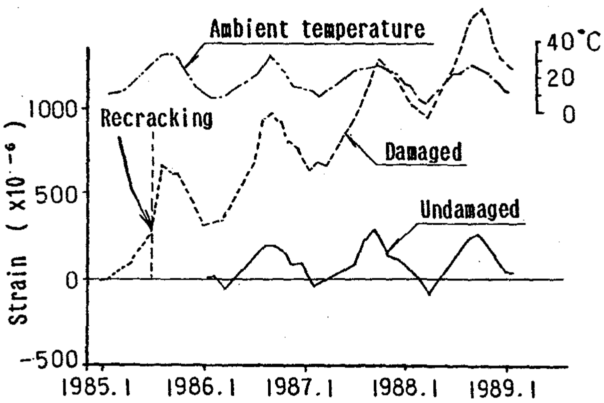


Figure 2 Expansion after coating (Polyurethane)

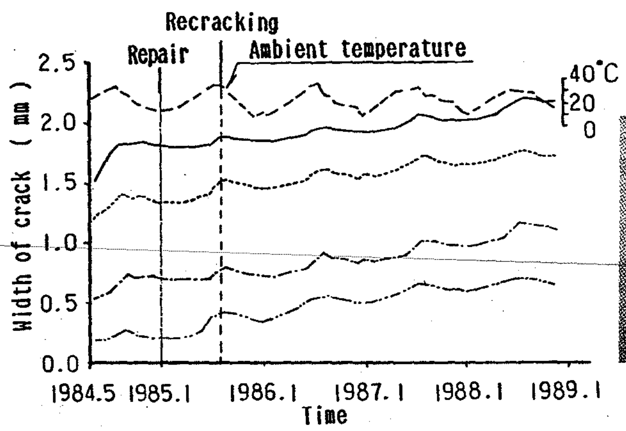


Figure 3 Increase of crack width

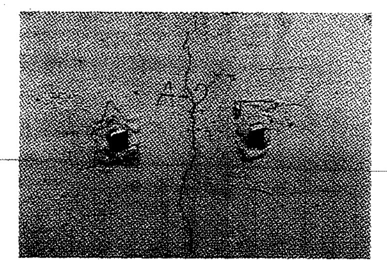


Figure 4 Recracking

3. 2 Epoxy coating

Table 3 shows the results of investigation carried out for the beam in 1984. This beam had plenty of typical ASR cracks in the horizontal direction before the repair. This beam was repaired by epoxy coating with crack injection by a flexible epoxy resin in March 1985. Figure 5 and 6 show the expansion and crack opening, respectively. This beam cracked again about 6 months after the repair and the cracks developed as seen in Figure 7. According to the results shown in Figure 6, opening of the injected crack ceased after the repair although expansion of the beam continued. This indicates that cracks appeared in Figure 7 were probably newly developed ones.

Table 3 Results of investigation

Structure		Beam of pier
Construction		1978
Investigation		1984
Repair		1985
Crack	width	1mm
	depth	13cm
Corrosion of steel		Not investigated
Reactive Aggregate		Bronzite Andesite
Expansion of core ($\times 10^{-6}$)	total	800
	release	500
	residual	300
Ambient condition		Partially sheltered
Crack injection		Flexible epoxy resin

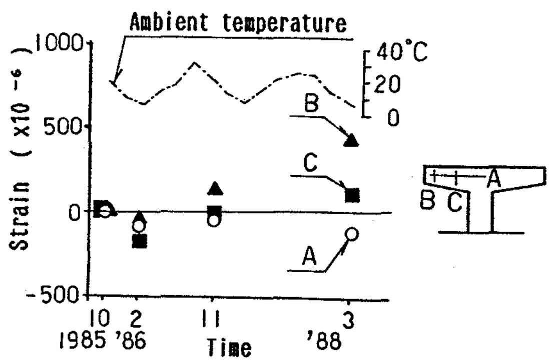


Figure 5 Expansion after coating (Epoxy)

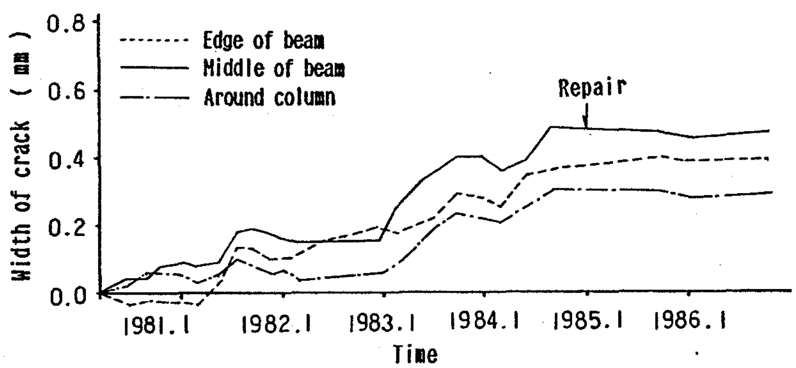


Figure 6 Increase of crack width

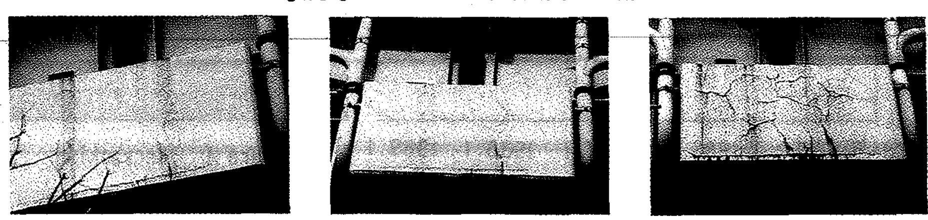


Figure 7 Development of cracks

3. 3 Polybutadiene coating

Table 4 shows the results of investigation carried out for the abutment in 1984. The abutment was repaired in 1986 by polybutadiene coating with crack injection by flexible epoxy resin. Strain measurement was not done for the abutment since the expansion estimated by the drilled core was small. However, 2 years after the repair, cracking appeared again partly and gel was exuded as seen in Figure 8.

Table 4 Results of investigation

Structure		Beam of pier
Construction		1969
Investigation		1984
Repair		1986
Crack	width	4mm
	depth	15cm
Corrosion of steel		partially
Reactive Aggregate		Bronzite Andesite
Expansion of core $(\times 10^{-6})$	total	350
	release	250
	residual	100
Ambient condition		partially sheltered at the seaside, once repaired
Crack injection		Flexible epoxy resin

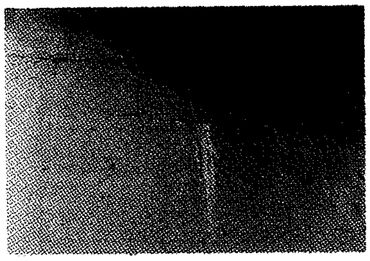


Figure 8 Appeared crack and exuded gel

3. 4 Silane coating

Table 5 shows the results of investigation done for the beam in 1983. The beam was repaired in March 1985 by silane coating with crack injection by flexible epoxy resin. This repair had been effective for 3 years as shown in Figure 9. However, micro cracking started to appear on the surface of the coating. Therefore, successive observation is required.

Table 5 Results of investigation

Structure		Beam of pier
Construction		1969
Investigation		1983
Repair		1985
Crack	width	4mm
	depth	13cm
Corrosion of steel		Nil
Reactive Aggregate		Bronzite Andesite
Expansion of core $(\times 10^{-6})$	total	1000
	release	50
	residual	950
Ambient condition		partially sheltered
Crack injection		Flexible epoxy resin

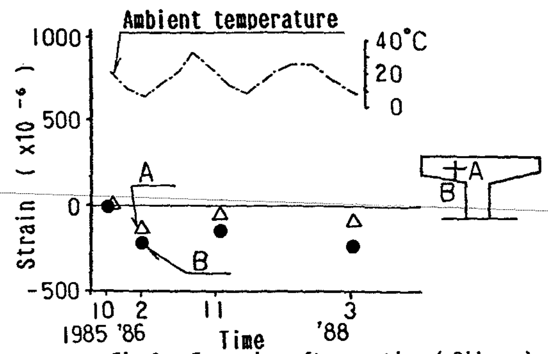


Fig.9 Expansion after coating (Silane)

3. 5 Polymer cement coating

Table 6 shows the results of investigation done for the beam in 1985. The beam was repaired in October 1986 by aeration type of polymer cement after injection of the cracks by flexible epoxy resin. Figure 10 shows that expansion of the beam after the repair is stable in spite of the high potential of the residual expansion. This result indicates that the repair by the polymer cement might stop the ASR expansion. Figure 11 shows the repaired beam in which no cracking has been observed since repaired. However, successive observation is required to confirm the effect.

Table 6 Results of investigation

Structure		Beam of pier
Construction		1971
Investigation		1985
Repair		1986
Crack	width	2mm
	depth	16cm
Corrosion of steel		partially
Reactive Aggregate		Bronzite Andsite
Expansion of core ($\times 10^{-6}$)	total	2000
	release	600
	residual	1400
Ambient condition		partially sheltered, once repaired
Crack injection		Flexible epoxy resin

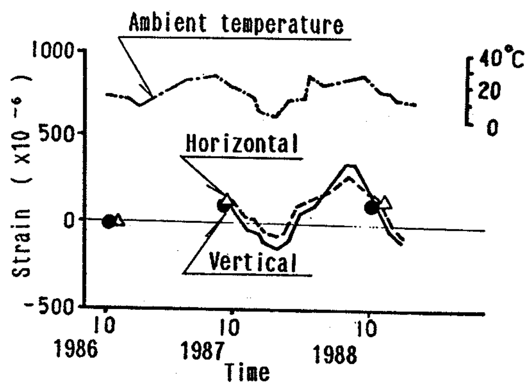


Fig. 10 Expansion after coating (Aeration Polymer)

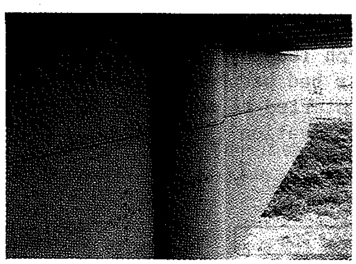


Figure 11 Repaired beam

4 . CONCLUDING REMARKS

From the field test, it was found that coating by polyurethane, epoxy and polybutadiene was not effective to inhibit ASR and that coating by silane and polymer cement was effective. However, successive observation and wide range of testing are required to confirm their effect.