8th ICAAR 1989 KYOTO 8th Internationl Conference on Alkali-Aggregate Reaction

STUDY ON THE REDUCING REACTIVITY RATE OF CONCRETE USED WITH REPAIRING MATERIALS IN LABORATORY AND FIELD

Susumu MORIYA, Hiroshi OBATA, Kiyoshi KATAWAKI
Public Works Research Institute, Ministry of Construction
1 Asahi Tsukuba-shi,Ibaraki,305,Japan
Masahiro KOIKE
Hanshin Expressway Public Corporation
1st Construction Dept.,Hanshin Expressway Public Corporation
Suminoe-ku,Osaka,559,Japan

ABSTRACT

The lack of established repairing techniques for deteriorated concrete structures due to ASR urgently requires the establishment of such techniques. For this purpose, Public Works Research Institute, Ministry of Construction, and Hanshin Expressway Public Corporation conducted a joint research for development of injection materials and coating materials.

This paper reports results of promotion testing in laboratory and exposure testing in the field for repairing materials selected by a performance test of various materials, for the purpose of elucidation of their repair effect.

INTRODUCTION

When a concrete structure deteriorated due to alkali-silica reaction (ASR) is left as it is, then rain water and carbon dioxide penetrating into cracks neutralize the surrounding concrete, resulting in corrosion of the reinforcing bar. Therefore, development of repairing techniques of concrete structures deteriorated due to ASR is urgently requested. The authors performed testing of various injection materials and coating materials as repairing materials, and promotion testing in laboratory and field exposure testing using concrete specimens,in order to identify the effect of these repairing materials.

For repairing materials selected through performance testing of various materials, their repair effect is identified through promotion testing in laboratory and field exposure testing.

ACCELERATED TEST METHOD IN LABORATORY

Coating materials selected through sealing test, crack adaptability test and crack control test were applied to concrete specimens as coating materials for the promotion testing in laboratory.

Sixty 150 x 150 x 500 mm specimens of reinforced concrete with W/C=50% were tested, and 2 types of andesites and 1 type of chart which are reactive to coarse aggregates were adopted. Alkali was adjusted by sodium hydroxide to the alkali level of 8kg/m^3 in R_2O conversion. The specimens were subjected to promotion curing at 40^{o}C and approximately 100% humidity for 6 months for cracking, and then coated in the specification shown in Table 1 for the promoted deterioration testing in the same condition with that of the promoted curing.

Table 1 Coating specifications

coating materials	thickness (μm)
① epoxy resin (flexible type)	200
② polyurethane (flexible type)	200
③ epoxy resin	500
④ rubber (flexible type)	500
⑤ cloth mixed epoxy resin (flexible type)	1,200
⑥ cloth mixed rubber (flexible type)	1,200
⑦ glass flake mixed epoxy resin	500
⑧ glass flake mixed vinylester resin	500
⑨ polymer cement (flexible type)	500
⑩ polymer cement mortar	15,000
⑪ silane-polyurethane	30
⑫ acryl resin	100

Result of observation of appearance of the cost 240 days after the promotion testing was :epoxy resin (flexible type) coated specimens (200um) and acryl resin coated specimens (100um) of coat thickness was set to be thin because the comparison got swollen, while specimens coated with polyurethane as silane (30um) yielded gel. However, all other specimens which were coated rather thickly didnot have any defects such as swelling.

ACCELERATED TEST METHOD OF THE LARGE SPECIMENS

Large reinforced concrete specimens repaired by either injection or coating were subjected to promoted deterioration, and the change in deformation of reinforcing bar with time was measured.

Eleven specimens being 50 x 50 x 140 cm beams were made at 0.5% tension reinforement ratio and 0.2% stirrup in accordance with the placement of bars shown in Figure 1. specified concrete strength was set at 210kgf/cm^2 and mix proportion shown in Table 2 was set. At that time, andesite which is reactive to coarse aggregate was mixed at the rate of 50%. In addition, alkali was adjusted with sodium hydroxide to 8kg/m^3 in R_2O conversion unit.

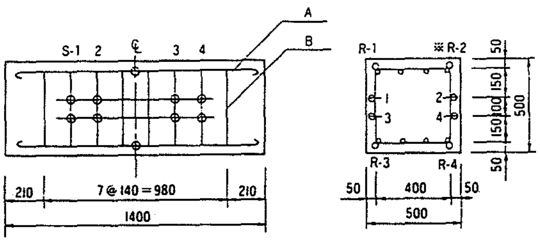

Fig.1 Drawing for re-bar arrangement

Table 2 Table of mix proportion

maximum size of coarse aggregate (mm)	slump (cm)	air content (%)	water cement ratio (%)	sand-coarse aggregate ratio, sand percentage (%)	quantity of material per unit volume of concrete (kg/m³)				
					water	cement	fine aggregate	coarse aggregate	sodium hydroxide
20	10	2.0	60	48	180	300	877	947	7.81

These specimens were subjected to ASR promotion curing a condition of 40°C and approximately 100% humidity for about 5 months, and then repair works were carried out in accordance with the specification shown in Table 3. After that, the specimens were placed again in the same environment with one before repaired to identify the repair effect by measuring the elongation of the specimens with contact gauge. The injection was conducted only for those with crack of more than 0.2mm width. The deformation of the reinforcing bar of specimen at the time of repair was approximately 1,000um for the main

Table 3 Repair specifications

injection materials	coating materials
① epoxy resin (hard type)	polyurethane (100μm)
② epoxy resin (flexible type)	polyurethane (100μm)
③ polyurethane resin	polyurethane (100μm)
④ polymer cement (acryl resin)	polyurethane (100μm)
⑤ slag (colloidal type)	polyurethane (100μm)
⑥ —	rubber (flexible type)
⑦ —	cloth mixed epoxy resin (flexible type)
⑧ —	epoxy resin (flexible type)
⑨ —	glass flake mixed vinylester resin
⑩ —	polymer cement (flexible type)
⑪ —	—

reinforcing bar, and approximately 1,200 - 1,700um for the stirrup, as shown in Figure 2.

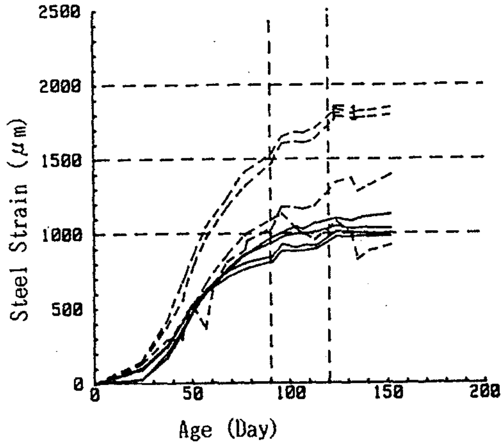

Fig.2 Steel strain before the repair

The elongation of specimens after being repaired was determined by using a contact gauge with the measuring precision of 1/1,000nm. Figure 3 shows the position where the elongation of specimens was measured. The elongation values are those at the front towards the longitudinal direction for sections from 1 to 4 of specimen (1,400 x 500mm), those at the front towards the transverse direction for 5 and 6, and those at the side for 7. A comparison of elongations of specimens at different positions indicate that the elongation is greater in the longitudinal direction where more reinforcing bars are placed on the whole than in the lateral direction where the volume of reinforcing bars is smaller. A tendency is recognized that the elongation gets greater at the end of the beam (section 5) and at the side face (section 7) than at the center of the beam (section 6) in the lateral direction. This is assumed because the restrict due to concrete as

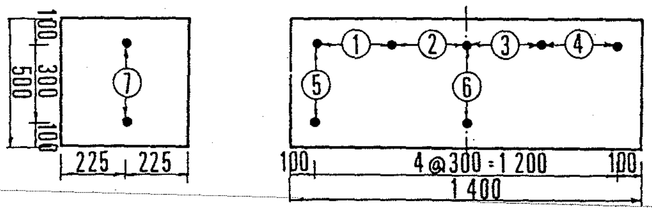

Fig.3 Elongation measuring point

well as restriction due to the elongated reinforcing bar function is more effective at the center of the beam than at the beam ends.

The elongation restriction effect at the time of 250 days is compared for each repairing materials with respect to the elongation between section 5 and section 7 where the restriction due to reinforcing bar is less; as to injection materials specimens into which epoxy resin (hard type) (NO.1) and epoxy resin (flexible type) (NO.2) were injected has less elongation. On the other hand, as to coating materials, relatively hard materials such as cloth mixed epoxy resin (flexible type) (NO.7), vinyl ester resin (NO.9) and polymer cement (NO.10) showed the restriction effect.

FIELD EXPOSURE TEST METHOD FOR REPAIR EFFECT

In order to know the long-term repair effect of injection materials and coating materials, concrete specimens were manufactured for field exposure testing.

The concrete specimens are 25cm x 25cm x 100cm reinforced concrete square pillars with W/C=50%, in which the alkali quantity was set at 3 levels of 1.5, 2.0, and 2.3% (8kg/m^3)in R_2O conversion unit with sodium hydroxide. Coarse aggregates are mixtures of two kinds of andesite and; a 3 kinds of reactive aggregates at 50%. The specimens were subjected to promotion curing at 40°C and approximately 100% humidity for about 6 months. The top 70cm section excluding the bottom 30cm of the above mentioned cracked reference specimens

Table 4 Field exposure test

aggligate		A								B			C		
alkali(R_2O) (%)		1.5			2.0		2.3			2.3			2.3		
injection materials															
① epoxy resin (hard type)		○	○		○		○			○			○		
② epoxy resin (flexible type1)		○	○		○		○			○			○		
③ epoxy resin (flexible type2)		○	○		○		○			○			○		
④ epoxy resin (flexible type3)		○	○		○		○			○			○		
⑤ polyurethane		○	○		○		○			○			○		
⑥ polymer cement (acryl resin)		○	○		○		○			○			○		
⑦ polymer cement (epoxy resin)		○	○		○					○			○		
⑧ slag(colloidal type)		○	○		○		○			○			○		
⑨ polisulfide		○	○		○					○			○		
coating materials	(μm)														
① epoxy resin (flexible type)	200							○			○			○	
② polyurethane (flexible type)	200										○			○	
③ epoxy resin	500	○					○	○		○	○		○	○	
④ rubber (flexible type)	500							○			○			○	
⑤ cloth mixed epoxy resin (flexible type)	1200							○			○			○	
⑥ cloth mixed rubber (flexible type)	1200							○			○			○	
⑦ glass flake mixed epoxy resin	500							○							
⑧ glass flake mixed vinylester resin	500							○			○			○	
⑨ polymer cement (flexible type)	500							○			○			○	
⑩ fluorine resin	200										○			○	
⑪ silane	30							○							
⑫ acryl resin	100							○			○			○	
no repair				○		○			○			○			○

was repaired in accordance with the specification shown in Table 4. The specimens were buried perpendicularly under the ground surface at the depth of 30cm in consideration of uncoated bridge piers, and the exposure was initiated in Oct. 1987.

Summarizes results of appearance observation of the specimens after 1 year exposure. Cracks developed and a part of the coat of the silane-polyurethane showed cracks, just other specifications had no change.

SEASHORE EXPOSURE TEST FOR ASR PREVENTION

Concrete specimens were manufactured for exposure at the seaside for the purpose of understanding the effect of sodium from the outside (sea breeze and; splash of sea water) on ASR and the ASR prevention effect of coating materials.

The concrete specimens are 15cm x 15cm x 100cm reinforced concrete square pillars, and they were adjusted to W/C=50%, slump of 8cm, air volume of 1.5%, and the alkali quantity of a $3kg/m^3$ and $5kg/m^3$ in R_2O conversion unit with sodium hydroxide. Coarse aggregate was made by mixing reactive andesite at 50%. Cement was low alkali portland cement and portland blast-furnace slag cement(B type).

As to ASR preventive measure, 4 specimens of silane-poly urethane,high density mortar(8mm), epoxy resin and acryl resin were applied. The details of the specimens are shown in Table 5.

Table 5 Seashore exposure test

	surface treatment				
	no-coating	silane-polyurethane	hight density mortar	epoxy resin coating	acryl resin coating
low alkali portland cement	2	2	2	2	2
portland blast-furnace slag cement (B type)	2	2	2	2	2
alkali gross weight 3 kg/m³	2	2	2	2	2
alkali gross weight 5 kg/m³	22	2	2	2	2

Exposure of the specimens was commenced along the shoreline in Noto Peninsulas in Ishikawa Prefecture in Nov. 1986.

Observation of the appearance of the specimens 2 years after the start of exposure suggests that no macroscopic cracking wasseen even for the specimens without the preventive measure of coating. Of the specimens coated with organic compounds such as epoxy resin and acryl resin did not develop cracking, and their coat layer was very sound. However, the coat exposed to violent splash of sand was partly exhausted.Silane-polyurethane developed fine cracks in the edge parts.

SUMMARY

Various material tests in laboratory, promotion tests in the laboratory and exposure tests in the field for injection materials and coating materials for repair, indicate the following.

To cut supply of water into the inner part of concrete is a key for ASR repair works. For this purpose, appropriate materials are injected or filled depending on the width of existing cracks, and then the outside of the structure is coated with materials with excellent water insulation. However, when aggregate in the structure is in progress of the reaction, the effect of cutting water supply from the outside does not manifest itself so quickly. As a result, the water left in the inner concrete may slowly promote the reaction. Therefore, materials for repair require elongation for the remaining expansive power, and strong adhesiveness of concrete. On the other hand, for a structure in which the reaction is almost over, it is important to prevent corrosion of reinforcing rods due to neutralization of concrete caused by water entering cracks and carbon dioxide in the air. For this reason,materials for repair do not necessarily require elongation, but strong adhesiveness to concrete is called for.

Results of the bearing test for reinforced concrete already cracked due to ASR show that cracking does not result in a decrease in durability and so reinforcement is practically unnecessary at this stage. When reinforcement is made, implementation in accordance with that for general reinforced concrete structures is good enough.

AFTERWARD

As a measure to prevent the ASR reaction, injection and coating are very effective in repairing structures already cracked due to ASR. Thus, the authors have proposed Repair/Reinforcement Guidelines (draft) based on the results from various material performance tests, promotion tests, and field exposure tests for injection materials for repair and coating materials which are for concrete structures already cracked due to ASR.

Since the effect of these repairing materials is that only for less than 2 years, the long-term repair effect is not yet known. Therefore, follow-up study will be conducted for a long time with respect to the field exposure tests to elucidate their repair effect.

ACKNOWLEDGMENT

This study was conducted as a part of the General Research Project for Improving Durability of Concrete.The authors appreciate the good advise from members of the research committee for The Concrete Durability.The authors also wish to thank Mr.Y.Mori(Public Work Research Center), Mr.K.Domon,Mr.Y.Masuda,Mr.K.Shirai,Mr.M.Hukusima,Mr.H.Tanabe and many colleagues for their assistance.

REFERENCES

1)Koike,M.,Katawaki,K.,Moriya,S.,Development of Injection Materials and the Standard for Repairing Damage to Structures Caused by AAR,In 8th ICAA,Kyoto,Japan,1989

2)Ministry of Construction,Development of Technology for Improving Durability of Concrete Structure,1988