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RECENT DIAGNOSIS AND REPAIR TECHNIQUES FOR DAMAGED CONCRETE STRUCTURE BY ASR —A GUIDELINE FOR PUBLIC WORKS STRUCTURE—

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ABSTRACT

A concrete structure damaged by the alkali silica reaction become less durable, because rain water and carbon dioxide in the air penetrate into the cracks which results in the neutralization of the surrounding concrete and erosion of reinforcing rods. For this reason, a study of development of repairing materials for concrete structures damaged by the alkali-silica reaction was conducted, and based on the results "Guideline for repairing concrete structure damaged by ASR(draft)" was prepared. The guideline (draft) includes diagnosis, repair design, repairing materials, and follow-up survey. The major contents of the repair guideline are described.

INTRODUCTION

Concrete structures damaged by the alkali-silica reaction spread widely in the country. Japan island were mainly formed from volcanic activities and upheaval from the sea bottom. Volcanic rocks and chert with characteristic properties distribute widely, which are knows as aggregates vulnerable to the alkali-silica reaction. Meteorologically Japan has high temperature and high humid summer over the country, and much snow and rainy winter along the Japanese Sea coast. As a result, in concrete structures which are always wet, the reaction proceeds rather quickly. Up to the present (as of 1988) , more than 40 concrete structures have been repaired. The details of the structures , the time of repair,and repair methods are summarized in Table 1.

Table 1 Repaired Concrete structures

TYPE OF STRUCTURE	number
bridge foot,abbut	36
concrete wall	7
guarder	2
pc beam (girder)	1
concrete box	2
REPAIR WORK	
1983	2
1984	5
1985	14
1986	9
1987	10
INJECTION(GROUT) METHOD	
epoxy	28
sealant	2
prepacked concrete	1
non	11
SURFACE COATING MATERIALS	
polyurethane	14
epoxy	6
polybutadien	6
acrylurethane	7
polymer cement	3
cement mortar	2
silan	1
silicone	2

REPAIR GUIDELINE

"Guideline for repairing concrete structure damaged by ASR(draft)" was prepared. These guidelines are applied to repair and reinforcement design/implementation of civil engineering concrete structures damaged by the alkali-silica reaction are composed of as in Figure 1. The essential parts are briefly described.

START
DIAGNOSIS AND CLASSIFICATION OF CRACK
  periodical inspection
    appearance inspection
  detailed inspection
    crack propagation
      concrete surface strength
    non destructive investigation
      infrared thermography
      steel corrosion
    concrete core sampling
      expansion test/ aggregate reactive test
      gel analysis
    load bearing test of concrete members
DESCISION FOR REPARING OR NOT
REPAIR DESIGN
  patching and injection
  coating
REPAIR WORK, WORK CONTROL AND INSPECTION
FOLLOW UP INSPECTION
END

Figure 1 Flow of diasgnosis and repair

DIAGNOSIS AND CLASSIFICATION OF CRACK

In a preliminary investigation(Table 2), the degree of advance of the cracking of structures was divided into two groups, cracking progress division A where cracking is in progress, and cracking progress division B where the progress of cracking has discontinued . In addition, in consideration of repair costs, 2 classes of 0.2-5.0mm crack width and more than 5.0m crack with set. In a general environment, when the width of a crack is less than 0.2mm the structure is not subjected to repair.

With respect to repair techniques, most cases are made by a combination of crack injection, water proofing by coating of the concrete surface. Depending on the purpose and the surrounding environment of a structure only coating may be applied.

REPAIR DESIGN

Based on past results and findings, the basic requirements for inhibiting aggregate reaction consist chiefly of : Drying the concrete, blocking off supply of moisture, a substance essential to reaction, and providing corrosion protection for the reinforcing bars.

The framework of the present repair work(Figure 3), consisted of removing all loose sections on the concrete surface and performing patching for the sections where concrete had spoiled off, injecting resin into the cracks, sealing off the supply

Table 2 ASR Judgment from Concrete Core

test		items
concrete core		gel observed. reaction rim observed.
core expansion test		expansion ratio > 0.05%/3months
aggregate test	chemical test	reactive or non reactive
accelerated test		gel observed
gel analysis		silica gel analysed

of moisture by coating the concrete.

Table 3 Crack Classification and Repair Design

	crack	crack width (mm)	crack sealing		surface coating
			injection		
A	crack progressed	0.2~0.5	epoxy grout		soft, high build type coat
		>0.5		sealant	soft type coat
B	crack stabled	0.2~0.5	epoxy grout		soft or hard type grout
		>0.5		sealant polymer cement	soft type coat hard type coat

PATCHING AND CRACK INJECTION

Patching has three objectives, one being, to eliminate the danger of concrete fragments falling off. this is achieved by removing those parts of the concrete surface which have come loose and turned brittle by chipping them off. The second objective is to obtain smooth surface. Through surface treatment performed with a disc grinder, or sand bluster, a firm concrete substrate for crack injection and to ensure that the coating applied to the concrete will not spoil off. The third objective is to obtain a level surface configuration in order to restore the overall appearance of the structure to the original one, by patching those irregular sections where concrete is missing.

There is a large variety of methods for injecting resin into cracks(Table 4). Resin materials used for crack injection include the standard hard type which is designed for integration with the concrete, and the soft (flexible) type designed to relax crack expansion to suppress crack generation in other parts of the concrete. In consideration of the fact that ASR was still in progress, the soft type which has an elongation capacity was used. In the present repair work, epoxy resin to have a rupture elongation rate of 100%, or more, was selected as the resin material for injection: injection for cracks measuring 0.3mm, or more.

COATING AND MATERIALS

A coat placed on a concrete surface can control as not to be intruded on surface from factors to progress the alkali-silica reaction such as water supplied from the outside, and thus it plays an important role in controlling the alkali-silica reaction.

Coats are required to be those which have permanent and satisfactory adhesiveness and the ability to prevent and water penetration from the outside(Table 5). When cracking is in a fairly advanced stage, coats have to be those which expands with the progress of cracking and prevent water penetration through cracks.

In coating, concrete which has been seriously deteriorated and resultantly raised to the surface has to be removed, because it hinders adhesion of the coating material. At this time, any corroded steel parts have to be subject to corrosion-proofing treatment, patching and coated.

Table 4 Specification of Injection Grout

	epoxy	soft type epoxy	high soft type epoxy	polymer cement	sealant
viscosity (cps)	1000	1000	1000	10000	
pot life time (hour)	16	16	24	16	24
crack adaptability (%)	−	50	100	−	800
harden shrinkess (%)	0.1	0.1	0.1	0.1	0.1
adhesiveness to concrete (kg/cm²)	60	60	60	60	60

Table 5 Specification of Coating Materials

	A	B		
	soft, high build type	soft type	hard type	
crack adaptability	100% or more	50% or more		tensile elongation
waterproofing	20mℓ/m²·day or less	30mℓ/m²·day or less	20mℓ/m²·day or less	imperme-ability
bond strength	10kg/cm² or more	10kg/cm² or more	10kg/cm² or more	bond with concrete
alkali resistant	30days	30days	30days	$Ca(OH)_2$
weathering	300hours	300hours	300hours	sun-shime accelerating weathering

Waterproofing coatings used for coating the concrete surface can be divided into three groups, coating systems that have adaptability to cracks, coating systems that perfectly seal off moisture and water vapor, and those that seal off water but permit water vapors to permeate.

In the present repair work such performances as, having excellent adaptability to cracks, and being capable of sealing off intrusion of water from the outside were set as significant assessment items, in consideration of the progressive state of ASR. Further, a coating system capable of causing the moisture contained inside the concrete to escape outside and disperse was also assessed, though it had only a small number of application results.

The following coating systems were selected for example. A thick-film type flexible epoxy resin paint of the full-seal-off type, which features adaptability to cracks, an elasticity-imparting type polymer cement-based paint, which, in addition to having adaptability to cracks, causes the moisture inside concrete to escape outside and disperse, was selected. The standard film thickness for both coating systems was set to 500-1,000(um).

Table 6 Examples of Coating Systems

coat	material	No. of coats	film thickness (μm)	volume (kg／m²)	appli-cation	interval (20℃)
pre treat-ment	surface preparation with power tool					
leveling	epoxy primer	1	－	0.15／coat	brush	16hr-7days
	epoxy putty	1	－	0.40／coat	spatula	16hr-7days
middle	high build type epoxy	2	500	0.40／coat	spatula	16hr-7days
top	polyurethane	2		0.12／coat	brush	8hr-3days

coat	material	No. of coats	film thickness (μm)	volume (kg／m²)	appli-cation	interval (20℃)
pre trea tment	surface preparation with powerfool					
leveling	putty	1	－	0.12／coat	brush	1hr-7days
top	polymer cement	3	1000	0.70／coat	spatula	16hr-7days

In order to obtain full repair effects, thorough control was effected for each process during repair work.

In conducting crack repair, thoroughgoing construction work was carried out for each process, working in conformity to the control items and control standards for crack injection. Following the completion of crack injection work, cores were sampled to confirm the state of injection and crack depth. In coating concrete, thorough on going work was carried out for each process, working in conformity to the control items and standards. On completion of coating work, the film thickness was measured to confirm the formation of a film thickness as specified in the coating specifications.

FOLLOW UP INSPECTION

The follow-up inspection consist of;easurement of the crack width and crack length conducted on an appearance investigation bases, follow-up measurements of the crack widths using such means as a contact gauge, external observation of the film (blistering, cracking, flaking), and investigation of the bonding strength of the film.

CONCLUSION

In the present repair work, the waterproofing measures taken to inhibit ASR for the concrete by supply of water from outside is most promisible system. however,the effect and control of the internal moisture on the reaction is not clarified. At present, there is no alternative but to rely on the effects gained by applying elasticity-imparting polymer cement based paint to the cement, thereby causing the internal moisture to escape and disperse.

In Japan, it has not been long since the ASR phenomenon has been discovered, and examples of repair works are still a few. Meanwhile, research on repair technology is still progressed day after day, and repair methods have not been established perfectly although we have new reccomendarion "guideline for repairing concrete structure damaged by ASR(draft). Therefore, we make it common practice to conduct a follow-up investigation after each repair work has been completed, not only to confirm the repair effects but also together practical data for use in developing repair methods of even higher efficiency.

REFERENCES

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Photograph Repaired Concrete Structure