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

A SIMPLE CONCRETE BAR TEST WITH DOUBLE LAYERED CYLINDRICAL SPECIMENS

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SYNOPSIS

The chemical method and the mortar bar method have been widely adopted to judge the alkali reactivity of aggregate[1]. These methods have some short-comings such as difficulties in testing, necessity of special equipments, and long testing periods.

The authors have examined a simpler method in which expansion due to alkali aggregate reaction (ASR) is identified easily and visually[2].

The specimens for the double-cylinder method referred to as "DC", is the double layered cylindrical specimen which is made of mortar or comcrete using the aggregate to be tested and covered with mortar with inert fine aggregate. The determination of the reactivity is made by the occurrence of cracking on the outer mortar caused by expansion of the inner cylinder. Adaptability of the DC method as a simple testing method was examined for mortar and concrete samples and the results showed that there was a significant correlation between the DC method with mortar and the mortar bar method, and the DC method can yield results more quickly[3].

1. INTRODUCTION

The authors have developed the DC method which provides for easier determination of expansion of mortar or concrete due to ASR with simple visual observation, and studied its characteristics. The experimental study was conducted for the following 4 series.

Series 1: for studying the basic nature of the DC method using mortar specimens.

Series 2: for studying the basic nature of the DC method using concrete specimens with reactive coarse aggregate.

Series 3: for studying the adaptability for mortar and concrete of 70 kinds of aggregate.

Series 4: for examining the possibility of shortening the testing time by adding high alkali reagent.

2. TESTING METHOD AND CONDITIONS

2.1 Testing Method

The specimens for the DC method shown in Figure 1 were made with the following procedure.

(1) ø10×20 cm mortar or concrete specimens using aggregate to be tested were cast. (2) After hardening, the specimens were placed in the center of ø15×30 cm forms and mortar(c:w:s = 1:0.5:2.25) made of inert aggregate was placed around it. (3) After remolding, the test specimens were put into plastic bags, which were then filled with water to a 5 cm height and sealed for curing. (4) The specimens were stored for a specific period in a high temperature condition. At the specific age, we observed in the appearance and measured the expansion quantity by using the π tape at a constant temperature of 20°C.

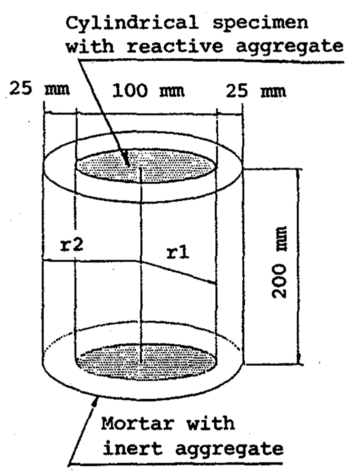

Figure 1 Shape of Double Layered Cylindrical Specimen

2.2 Testing Conditions and Materials

Testing conditions are summarized in Tables 1 through 3. The properties of aggregates used for series 1, 2, and 4 are shown in Table 4.

Table 1 Testing Condition (Series 1)

Material of Specimen	Mortar
Aggregate	A1,A2,A3(Fine Aggregate)
Mix Proportion	Cement:Mixing Water:Fine Aggregate =1:0.5:2.25(Weight retio)
kind of Alkali	NaOH
Alkali Quantity	Cement Weight×0.8,1.2,1.6(%)
Curing Condition	38℃,60℃ in Moisture

Table 2 Testing Condition (Series 2)

Material of Specimen	Concrete	Concrete	
Aggregate	A1,A2,A3 Coarse Aggregate(Gmax=20mm)	A4,A5(Inert) Coarse Aggregate (Gmax=20mm)	
Mix Proportion	C=300(kg/m³) W/C=55(%) S/a=45(%)	C=300(kg/m³) W/C=55(%) S/a=45(%)	C=400(kg/m³) W/c=55(%) S/a=42(%)
Kind of Alkali	NaOH	NaOH,NaCl	NaCl
Alkaki Quantity	Total 3,4,5,6 (Kg/m³)	Total(kg/m³) 4.95,5.95,6.95	Total(kg/m³) 5.60,6.60,7.60
Curing Condition	38℃,60℃,80℃ in Moistuer	60℃ in Moistuer	

Table 3 Testing Condition (Series 3 and 4)

Material of Specimen	Mortar	Concrete
Aggregate	Fine Aggregate	Coarse Aggregate (Gmax=20mm)
Mix Proportion	Cement:Mixing Water:Fine Aggregate=1:0.5:2.25	C=320(kg/m³) W/C=55(%) S/a=45(%)
Kind of Alkali	NaCl	NaCl
Alkaki Quantity	Cement Weight×1.2(%) Series 4:C×1.6(%)	Total 7.2 (kg/m³) Series4: 8~12 (kg/m³)
Curing Condition	60℃ in Moisture	

Materials: Cement: Normal Portland Cement (R_2O=0.65%),
Inert fine aggregate: Fujigawa, Mixing water: Ion change water.

3. TEST RESULT

Series 1: As shown in Figure 2, the occurrence of cracking in mortar specimens required more than 1.2%wt of alkali content of cement at both 38°C

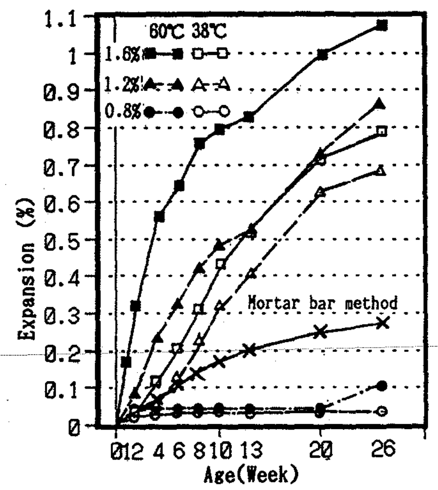

Figure 2 Expansion and Age

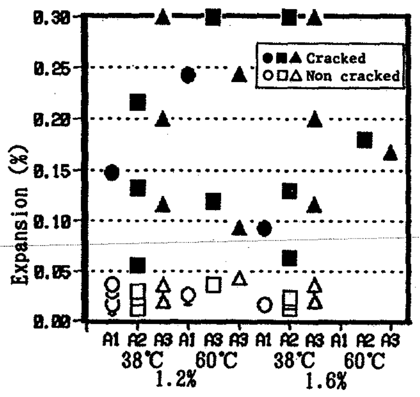

Figure 3 Expansion and Appearance of Crack

and 60°C of curing temperature. The early expansion was greater at 60°C than at 38°C. The expansion became greater for specimens with higher alkali content. The expansion after cracking was more marked in the DC method than that in the mortar bar method. The occurrence of cracking was found when the expansion quantity exceeded more than approximately 0.05% in the DC method regardless of the amount of alkali and curing condition (Figure 3).

Series 2: Concrete specimens made of reactive coarse aggregates cracked at total alkali content in concrete of 6(kg/m^3). Expansion started most quickly at curing temperature of 60°C in moisture condition, which was the most appropriate temperature of acceleration (Figure 4). With respect to the effect of different kinds of alkali reagents, cracking took place at the total alkali content of more than 6.5(kg/m^3) for NaOH and at total alkali content of more than 7(kg/m^3) for NaCl after 4 weeks (Figure 5). Specimens made with A5 aggregate (inert aggregate) did not crack at all. Expansion of concrete specimens were slower than that of mortar at the same total alkali level.

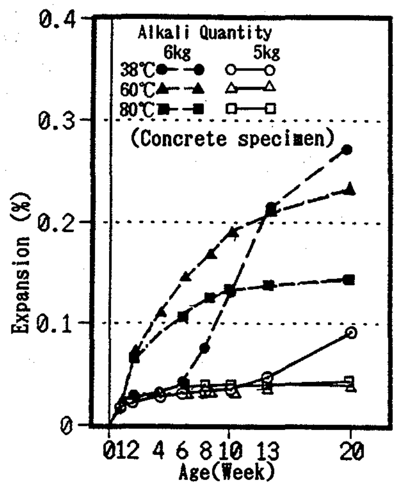

Figure 4 Expansion and Age

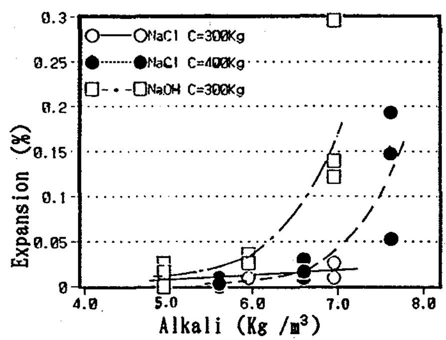

Figure 5 Expansion and Alkali Level at 4 weeks

Series 3: Based on the results from series 1 and 2, the total alkali content was set at 7.2(kg/m^3), and NaCl was used as an alkali reagent because of its easy availability.

In the case of the DC method for mortar specimens, 64 of the 70 kinds of aggregate showed the same results at 13 weeks, as did the mortar bar method at 26 weeks. Those which were different to the result of the mortar bar method were chert aggregates of $Sc<100$ (mmol/l) and $Rc<30$(mmol/l) (Figure 6). DC concrete specimens of 40 aggregates out of 59 showed the consistency in judgement at 26 weeks with that for the mortar bar method at 26 weeks. The aggregates which took a long time until cracking in the case of concrete specimens also took a long time in the case of mortar specimens.

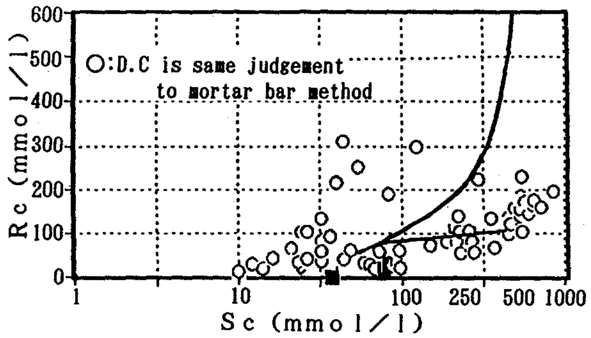

Figure 6 Judgement of the DC Method and Chemical Method

Series 4: Table 4 shows that when 9 kg/m³ or more of NaCl was added, expansion occurred even in specimens with inert aggregates (A5). The period up to the start of cracking of the DC specimens which were made with reactive aggregates were shorter than those with inert aggregates at the same alkali level.

Thus, the authors examined the period of the curing time and tolerable quantity of alkali to be added in concrete, in order to distinguish inert aggregates from reactive aggregates, before which period inert aggregates would not expand.

In the 60°C in moisture condition, DC specimens of concrete containing 9.6 kg/m³ of NaCl and being cured for 4 weeks showed the same result as the mortar bar method at 26 weeks, and the DC specimens with mortar which contained 1.6%wt of NaCl in cement (9.6 kg/m³ in mortar) being cured for 2 weeks showed the same result as the mortar bar method at 26 weeks.

Table 4 Type of Aggregate and the Period until Cracking in DC-Method Specimens

Aggregates			A1	A2	A3	A4	A5	A7	A8	A9	A10	A0
D.C Method Alkali	MortarC:1.6%		1W	1W	1W	1W	----	1W	2W	2W	NO	NO
	Concrete kg/m³	8	○	○	○	○	NO	----	----	----	NO	----
		9	○	○	○	○	8W	○	5W	NO	NO	----
		9.6	○	○	○	○	6W	○	○	○	NO	----
		10	○	○	○	○	○	○	○	○	NO	----
		12	○	○	----	○	○	----	----	----	○	----
Mortar bar Method		3M	0.2419	0.0962	0.2052	0.3805	0.0340	0.1349	0.0631		0.0150	0.0041
		6M	0.5314	0.1395	0.2640	0.4638	0.0343	0.2561	0.0767		0.0240	0.0301
Result*1			R	R	R	R	I	R	R		I	I
Chemical Method		Sc	845	98	209	267	24	87	115	163	9	83
		Rc	96	22	112	81	15	27	79	76	249	190
Result*2			P	D	P	D	I	D	D	D	I	I
Type of Rock			Bronzeite Andesite	Chert	Pyroxen Andesite	Pyroxen Andesite	Sand Stone	Slate	Chert	Chert	Lime stone	Fujigawa

○; Cracked specimen at the 4weeks Curing NO;Non Cracked specimen. No,W;The age of cracks were found.*1 R:Reactive I:Inert *2 D:dereterious P:Potentially dereterious I:Innocious

SUMMARY

1) It was found that in case of the DC method cracking occurs on the outer mortar when the inner cylindrical specimen expands approximately 0.05% (which unconfined), and expansion could be determined visually.

2) The test speed is accelerated for temperatures of up to 60°C and the amount of alkali also accerelates the test speed. However, if the amount of alkali exceeds 10 kg/m³, even inert aggregate expands in 4 weeks.

3) Cracking for concrete specimens starts later than for mortar specimens at the same alkali level.

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