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

EFFECTS OF ADMIXTURES ON EXPANSION CHARACTERISTICS OF CONCRETE CONTAINING REACTIVE AGGREGATE

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1. ABSTRACT

The authors produced 10x10x40cm concrete specimens using alkali reactive aggregate, which were judged potentially deleterious and deleterious based on the ASTM C 289 testing, and examined the expansion influence of various admixtures on the specimens under accelerating curing conditions. The admixtures used in the experiment included an air entraining agent (AE) and 4 AE water reducing agents (AEWR).

This report details the characteristic of expansion of each type of concrete specimen after 1 year curing at 40°C, and 95% or more relative humidity.

2. INTRODUCTION

Presently, many studies are being conducted on alkali aggregate reactions (AAR). However, test methods to determine the expansion caused with AAR are mainly mortar bar methods based on the ASTM C 227 or Attachment 8 of the JIS A 5308. These mortar bar methods are useful only for evaluating whether aggregate is deleterious or not. If the test results of the effect of factors to the AAR by the mortar bar method are amplified as is to the concrete level, problems appear in the evaluation of the reaction. They are due to the differences in the actual concrete mix proportion: water/cement ratio, unit cement content, the air content, etc.

In this study, the type of reactive aggregate, concrete mix proportion conditions, and the type of admixture were the main factors in the production of specimens for testing the effect of admixtures on the concrete expansion due to alkali aggregate reactions.

3. TEST PROGRAM AND CONDITIONS

3.1 Experiment plan

The main studied items were the effect of air content and the type of admixture. The experiment was conducted according to the test plan shown in Table 1.

Table 1 - Experiment plan

Items	Factors
Coarse aggregate type	S, T, N
Coarse aggregate proportions(%)	S:N=50:50, T:N=50:50, S=100, T=100
Unit cement content (kg/m^3)	350, 450, 550 (Plain, AE) 315, 405, 495 (AEWR)
Alkali type	NaOH, NaCl
Total alkali content (Na_2O eq.% in cement)	0.5, 1.0, 1.5, 2.0
Air content (%)	Air-free, 4.5, 6.0
Admixture type	None, AE-1, AEWR 1-4,

3.2 Materials

Normal portland cement containing 0.41% equivalent $Na_2O(R_2O)$ was used with the aggregates shown in Table 2. The main components of the admixtures used in the experiment are shown in Table 3.

Table 2 - Aggregate properties

Type	ASTM C 289 (mmol/liter)		Evaluation	ASTM C 227 Expansion(%)	
	SC	RC		3M	6M
Fine aggregate (Quartz)	29	36	Innocuous	0.03	0.06
Coarse aggregate (S) (Bronzite Andesite)	732	177	Potentially deleterious	0.01	0.02
Coarse aggregate (T) (Pyroxene Andesite)	252	65	Deleterious	0.19	0.28
Coarse aggregate (N) (Sandstone)	42	48	Innocuous	0.01	0.01

Table 3 - Admixture characteristics

Admixture		Main component	Alkali content (Na_2O eq.%)
Type	Symbol		
AE agent	AE-1	Alkylaryl sulfonate	2.00
AE water reducing agent	AEWR-1	Calcium lignosulfonate	0.46
	AEWR-2	Calcium lignosulfonate	1.04
	AEWR-3	Calcium lignosulfonate and thiocyanate	3.94
	AEWR-4	Polycarboxylate derivative	4.30

3.3 Concrete mix proportion

The basic mix proportion was as follows: Target slump, 15cm; target air content, air-free, 4.5%, and 6.0%; unit cement content, 450kg/m^3; R_2O=1.5%. The basic unit cement content of the AEWR concrete was set at 10% less than the plain and AE concretes, to 405kg/m^3, in consideration of the practical usage of AEWR.

3.4 Experiment for alkali aggregate reactions

Concrete specimens were prepared (10x10x40cm) and set in a constant temperature chamber (20°C, 80% or more relative humidity) for 24 hours. The standard lengths were measured, whereupon they were cured at 40°C in a 95% or more relative humidity curing room. Measurements were conducted at the ages of 14 days, 28 days, and thereafter every month until the age of 1 year.

4. RESULTS AND DISCUSSION

4.1 Type of aggregate

Figure 1 shows the effect of the type of alkali reactive aggregate and the mixing percentage. T aggregate showed no difference in the expansion whether used alone or as 50% of the aggregate. S aggregate showed little expansion when used alone; but used at 50%, it showed noticeable expansion, 0.35% at the age of 1 year.

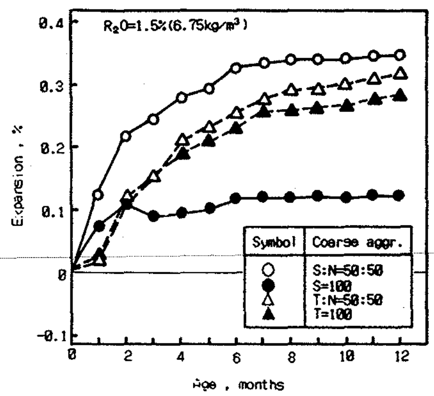

Fig. 1 - Effect of the coarse aggregate type and the mixing percentage

4.2 Air content

Figure 2 shows the relationship between the air content and expansion, at the age of 1 year. At R_2O=0.5%, no expansion was seen. At R_2O=1.5%, increases in air content were recognized to reduce the expansion. With S 50% aggregate , expansion was reduced by 40% at 4.5% air content, and by 75% at 6% air content, compared to plain concrete.

At R_2O=2.0%, hardly any reduction in expansion was recognized with increases in the air content. The air-void system in hardened concrete is considered a factor in this.

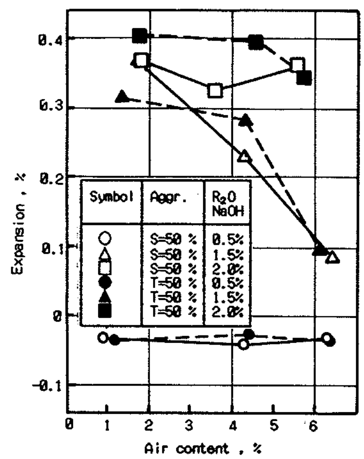

Fig. 2 - Relationship between air content and expansion

4.3 Cement content

Figure 3 shows the relationship between the cement content and expansion in concrete using AEWR-1. With the cement content at 315 kg/m^3 (R_2O=4.72 kg/m^3), expansion was almost nil.

At 405 kg/m^3 (R_2O=6.08 kg/m^3), signs of expansion were obvious, with the expansion increasing with increases in the cement content. NaCl showed a grater expansion than did NaOH at a cement content of 405kg/m^3.

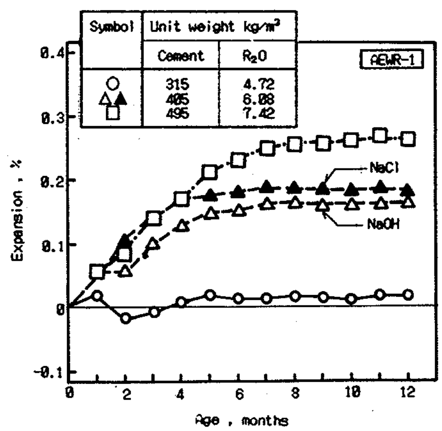

Fig. 3 - Effect of the unit cement content and the alkali type

4.4 Total alkali content

Figure 4 shows the effect of the total alkali content to the expansion of the concrete used with AE-1 agent and AEWR-1 agent. With the air content at the same level, the expansion due to the AEWR-1 agent and to the AE-1 agent showed to be about the same. With 6% air content, less early age expansion was seen than at 4.5% air content, but over time the expansion increased, such that at the age of 1 year the expansion was the same of or both.

4.5 Type of Admixture

Figure 5 shows the effect of 4 different types of AEWR agents. The expansion caused by AEWR-3 was slightly larger than the others, but the difference was very small.

The alkali contents per 1 m^3 of concrete for AEWR-1, 2, and 4 were 13-35g, and that of AEWR-3 was 170g, with the unit cement content at 405kg/m^3 and the total alkali content at 6.08kg/m^3.

Therefore, some expansion is possible with the use of certain alkali reactive aggregates, due to alkali from the admixture, but the expansion should be very small.

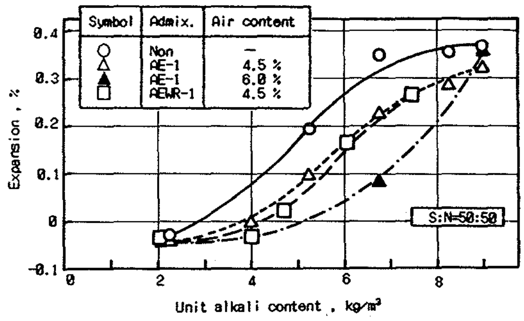

Fig. 4 - Relationship between the unit alkali content and expansion

5. CONCLUSION

In order to study the effects of admixtures on alkali aggregate reactions, several concrete specimens were produced, with the major factors being the type of reactive aggregate, the concrete mix proportion conditions, and the type of admixture. The relationships between these factors and the resulting expansion was studied under accelerated curing conditions. From the experiment results, the following can be said:

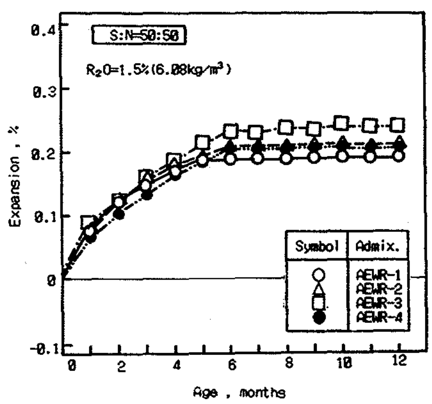

Fig. 5 - Effect of the type of admixture

(1) When an AE or AEWR admixture was used, concrete expansion due to alkali aggregate reaction was lower than that of plain concrete.

(2) The relationship between the unit cement content and expansion in concrete shows the same tendency for AEWR admixtures as for AE admixture. In actual use, however, the unit cement content was lower in the AEWR containing concrete, and so the expansion was lower.