Alkali-Aggregate Reaction: A Study on Causative Factors

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1. PREFACE

Recently the alkali-aggregate reaction has received a great deal of public attention in Japan. While a lot of studies are under way on this problem, details of the reaction system and the expansion mechanism still remain unclarified. In this study, tests were carried out to examine the effects of salt content of aggregate and proportion of reactive material in the aggregate on the alkali-silica reaction by using the expansion of mortar as a parameter. The effect of chemical admixtures for concrete on the reaction was also examined.

2. OUTLINE OF TESTS

(1) Materials Used

Ordinary Portland Cement with an alkali content of 0.72% equivalent Na_2O was used.

Bronzite andesite that is reported to cause the alkali-silica reaction in some part of Japan was used as a reactive aggregate. Hard sandstone and granitic sand were used as non-reactive aggregates (See Table-1).

7 kinds of admixtures for concrete as shown in Table-2 were used.

(2) Test Method

The expansion of mortar was measured in accordance with the mortar bar method (ASTM C 227) under the various combinations of test conditions indicated in Table-3.

The alkali content in the cement was adjusted by adding NaOH in order that equivalent Na_2O attained 1.0%.

[Test A]: The effects of the salt content and the proportion of reactive aggregate in the aggregate on the alkali-silica reaction were studied.

The salt content of aggregate was adjusted by adding sodium chloride in varied percentage to weight of aggregate. The proportion of reactive aggregate (bronzite andesite) was adjusted by weight ratio to the aggregate as shown in Table-3.

Rock	Chemical Method (ASTM C 289)		Deleterious Mineral (ASTM C 295)
	Sc/Rc (mmo *l*/*l*)	Judgement	
Bronzite andesite	539/198	Potentially Deleterious	Cristobalite Trydymite
Hard sandstone	1/125	Considered Innocuous	None
Granitic sand	12/ 96	〃	〃

Table-1 Characteristics of Aggregates Used

Classification	Type	Chemical Composition (%)					Amount Used (%)
		Na^+	K^+	Cl^-	OH^-	R_2O	
A.E. agent	Vinsol-resin	0.71	0.001	0.15	1.06	2.30	0.04
A.E. water reducing admixture retarder	Carboxylic acid	2.32	0.035	0.068	<0.10	3.16	0.25
A.E. water reducing admixture	Lignin-A	0.16	0.065	10.1	<0.10	0.27	0.25
	Lignin-B	0.15	0.056	0.22	0.31	0.24	0.25
	Lignin-C	5.88	0.036	7.90	<0.10	7.96	0.4
Super plasticizer	Melamine	2.26	0.002	0.093	<0.10	3.05	*10cc
	Naphthalene	3.60	0.002	0.21	<0.10	4.85	0.5

R_2O: Na_2O equivalent ($Na_2O + 0.658\ K_2O$%)
Amount Used: Standard quantity expressed in percentage to cement weight. But, *mark shows use of 10cc per cement 1 kg.

Table-2 Characteristics of Chemical Admixtures Used

	Aggregate Used		Reactive Aggregate Proportion (%)	Salt Content of Aggregate (%)	Alkali Content of Cement (%)	Chemical Admixture
	Reactive	Non-reactive				
Test A	Bronzite andesite	Hard sandstone	0, 20, 40, 60, 80, 100	0, 0.1, 0.3, 0.6	1.0	—
	—	Granitic sand	—	0.1, 0.3	1.0	—
Test B	Bronzite andesite	—	100	0.1	1.0	See Table-2

Table-3 Table of Test Conditions

[Test B]: The effects of 7 kinds of chemical admixtures as given in Table-2 on the expansion of mortar made of reactive aggregate were studied. The admixtures were used in the standard quantity specified by the manufacturers.

The salt content of aggregate was adjusted by adding sodium chloride to 0.1% of aggregate by weight.

3. RESULTS OF TESTS AND DISCUSSION

[Test A]: Fig.-1 shows the relationship between the proportion of reactive aggregate and the expansion of mortar at the age of 6 months, in the case where the salt content of aggregate was varied from 0 to 0.6%.

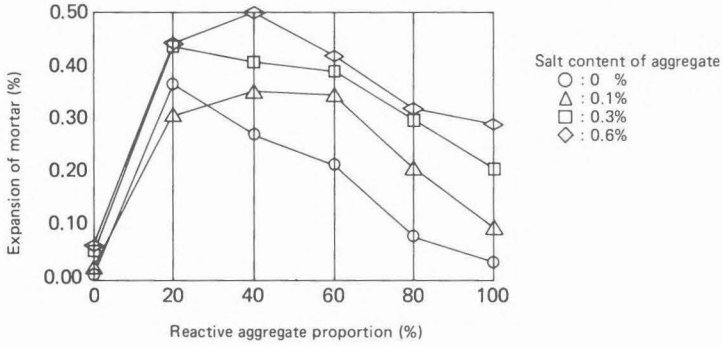

Fig.-1 Effect of Reactive Aggregate Proportion (at 6 months)

It is shown that increased salt content of the aggregate results in more expansion of mortar and that the expansion varies with the proportion of reactive aggregate.

The pessimum content for the reactive aggregate is about 40%, though the expansion of mortar varies, depending on both the salt content of aggregate and the age of mortar.

Fig.-2 shows the expansion of mortar made of the reactive or non-reactive aggregate containing various quantities of salt. When the reactive aggregate (bronzite andesite) didn't contain salt, the expansion of mortar was, even at the age of 12 months, less than 0.1% — the ASTM limit value at 6 months.

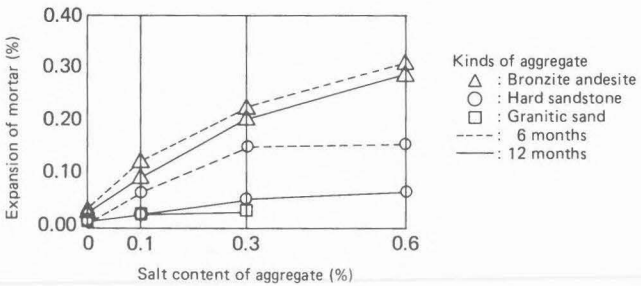

Fig.-2 Effect of Salt Content of Aggregate

On the other hand, each of the two kinds of non-reactive aggregates (hard sandstone and granitic sand) gave about 0.05% expansion of mortar at 6 months. The hard sandstone mortar showed after 6 months a sudden increase of expansion with the increase of salt content and the rate of expansion was faster especially in the case of more than 0.3% salt content. Though the non-reactive granitic sand was tested for two salt contents 0.1 and 0.3%, no appreciable amount of expansion was recognized as shown in Fig.-2.

Thus, it may be concluded that mortar made with some kinds of non-reactive aggregates containing salt promoted expansion. But it is unclear that such expansion is caused by either mineral composition of aggregate or some factors other than alkali-silica reaction.

[Test B]: Fig.-3 shows the relation between the age and the expansion of mortar with various admixtures in case where only the reactive aggregate containing 0.1% of salt was used. The mortars with admixtures showed a larger expansion at the earlier age (until 4 months) but they showed little expansion after 6 months. The expansion of mortars with admixtures at 9 months was less than that of the reference mortars.

The expansion of mortar at 6 months, made of reactive aggregate together with an admixture other than naphthalene type, was smaller than the ASTM limit value of 0.1%. The expansion of mortar with vinsol-resin or carboxylic admixture was reduced to about a half of that with naphthalene type or without admixture.

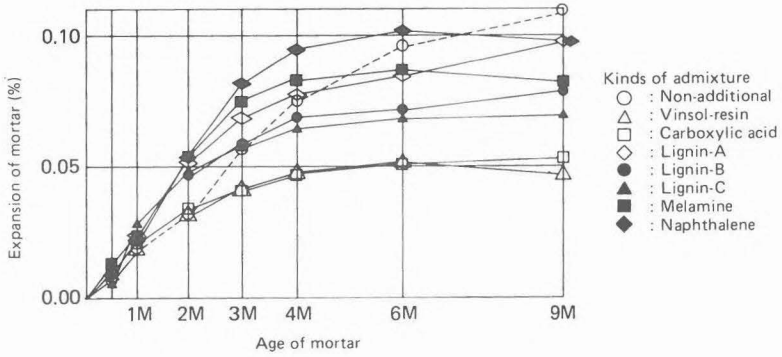

Fig.-3 Effect of Admixture
(Reactive aggregate 100%, Salt content 0.1%)

4. CONCLUSIONS

(1) Alkali-silica reaction is affected by the proportion of reactive aggregate as well as by salt content of aggregate.
(2) Expansion of mortar made with non-reactive aggregate may be increased by the presence of salt but this depends on the mineral composition of the aggregate used.
(3) Vinsol-resin is expected to have a constraining effect on the alkali-silica reaction.