Type of cement	Type of Pyrex glass	Expansions %		
		14-day	28-day	56-day
High strength and Rapid Hardening Portland	Italian	0,296	0,385	0,409
	American	0,310	0,400	0,425
High strength Portland	Italian	0,337	0,469	0,495
	American	0,360	0,460	0,490
Portland - Pozzolana	Italian	0,028	0,030	0,032
	American	0,035	0,036	0,039

Table II - Comparison between the expansions of mortar bars made with Italian and American Pyrex glass

Type of cement	Expansions %		
	14-day	28-day	56-day
High strength and Rapid Hardening Portland	0,296	0,385	0,409
High strength Portland	0,337	0,469	0,495
Portland - Pozzolana (fly ash)	0,028	0,030	0,032
Portland - blast furnace	0,018	0,022	0,040
Sulphate Resisting like Type V	0,011	0,018	0,041
Sulphate Resisting "Ferrico Pozzolanico"	0,021	0,036	0,040

Table III - Expansions of mortar bars made with the Italian Pyrex glass and the above mentioned cements

RAPID METHOD FOR DETERMINING THE PREVENTIVE EFFECT OF MINERAL ADMIXTURES ON ALKALI-SILICA REACTION

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ABSTRACT

A rapid method was worked out by us for the identification of alkali reactivity of aggregates, for which only two days are needed. In this paper, this method was used to examine the effectiveness of various mineral admixtures in preventing alkali-silica reaction. The examined admixtures included tuff, fly ash, blast furnace slag, finely ground quartz sand, limestone and dolomite, with different amounts of admixtures to replace the cement in the mortar bars made. The results are well in agreement with that obtained by ordinary methods, but the time needed is much shorter. Moreover, we also proved that it is more effectiv when the amount of admixture is increased. Thus the examination of the effectiveness of an admixture can be completed in two days.

KEY WORDS: Rapid method, Preventiveness, Admixture

1. INTRODUCTION

In the same way as the mortar bar test(ASTM C227-71)(1), the standard test for effectiveness of mineral admixtures in preventing excessive expansion of concrete due to alkali-aggregate reaction(ASTM C441-69)(2) also requires a long time to obtain a result, because mortar bars are [illegible]ged at a temperature of 38°C, at which the reaction proceeds slowly. A rapid method for identification of alkali reactivity of aggregate was suggested by us with mortar bars autoclave-treated in a 10% KOH solution(3). Now this method was used to compare the preventive effect of some mineral admixtures on alkali-silica reaction.

2. EXPERIMENTAL METHOD

The admixtures used were tuff, fly ash, slag, quartz sand, limestone and dolomite. The chemical compositions of clinker, tuff, fly ash and slag were similar to that described in reference(4). The fineness of these adxtures expressed by sieve test was:

	R_{70} %
Tuff	8.40
Fly Ash	0.50
Slag	0.72
Quartz Sand	2.28
Limestone	2.88
Dolomite	3.60

Mortar bars of 1x1x4cm of cement:aggregate(opal)=10:1, w/c=0.3 and sizes of aggregate=0.15-0.75mm were made and demolded after a one-day curing.

They were subsequently subjected to 100°C steam curing for 4 hours, after which they were immersed in a 10% KOH solution and autoclave-treated at 150°C for 6 hours. For comparison, other mortar bars were made in the same way, but with pure portland cement.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results, obtained by the rapid method, of the preventive effect of some active mineral admixtures(tuff, fly ash and slag) are shown in Table I.

Table I

Expansion of Mortar Bars Made from Cement with Active Mineral Admixtures

Contents of Admixtures in Cement%	Tuff			Fly Ash			Slag		
	eqv. Na_2O %*								
	0.43	1.0	1.5	0.43	1.0	1.5	0.43	1.0	1.5
	Expansion %								
0	0.245	1.364	1.454	0.245	1.364	1.454	0.245	1.364	1.454
10	0.171	0.172	1.672	0.174	0.339	1.501	0.072	0.610	1.371
30	0.067	0.044	0.073	0.055	0.039	0.073	0.065	0.252	1.212
50	0.025	-0.005	0.033	0.056	0.034	0.033	0.041	0.047	0.070
70		0.004	0.016	0.012	0.015	0.016	0.043	0.019	0.037

*Alkali content of cement(not including admixtures)

Table I shows that all these admixtures can considerably reduce the expansion of mortar bars caused by alkali-silica reaction. In general, the expansion of mortar bars made from blended cement is much less than that of the control sample. The reduced values continue to decrease as the amount of admixture in cement is increased. The preventive effect of tuff and fly ash is better than that of slag, when they are in the same proportion with cement. The results also proved that the amount of tuff and fly ash in cement must exceeds 30% and even more for slag, in order to prevent the expansion efficiently. All these regularities are very similar to the results obtained from the mortar bars cured at 20°C(see Table II).

Table II*

% Expansion of Mortar Bars

No.	Cement Mix				% Expansion(Months)			
	Cement	Tuff	Fly Ash	Slag	1	6	12	24
1	100				0.233	0.450	0.601	0.704
2	90	10			0.021	0.042	0.048	0.179
3	70	30			0.011	0.026	0.021	0.022
4	50	50			0.014	0.022	0.017	0.013
5	30	70			-0.043	-0.001	-0.004	-0.002
6	70		30		0.011	0.033	0.043	0.038
7	70			30	-0.013	0.014	0.064	0.112

*Taken from reference(4).

From Table I we see that mortar bars made from cement with 10% amount of tuff and fly ash sometimes have expansion even larger than that of control sample. This may be due to the alkalies in tuff(K_2O 2.35%, Na_2O 0.80%) or fly ash(K_2O 0.90%, Na_2O 0.50%) released in pore solution of the cement paste. Under this condition, the amount of $Ca(OH)_2$ in cement paste is still large enough to react with the high alkali pozzolanas, and to make ion-exchange with them to release alkalies into pore solution and thus to intensify the alkali-silica reaction.

We have proved by experiments carried out at room temperature that the finely ground inert filler admixtures such as limestone, dolomite and quartz sand also could reduce somewhat the excessive expansion caused by alkali-silica reaction(5), which was not due to the dilution effect of alkali content, as we added extra alkali in mixing water for the purpose to make the total content of alkali in cement(cement+filler admixtures) constant.

By the rapid method which we suggested, and using the same condition to keep the alkali content constant, we determined the effectiveness of some filler admixtures in preventing the alkali-silica reaction. The results are shown in Table III.

Table III

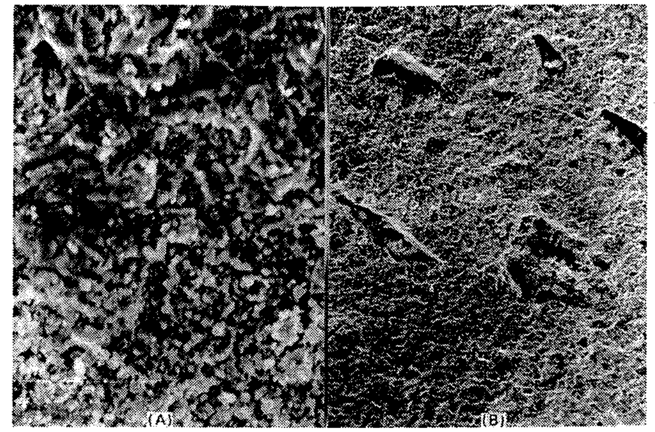
Expansion % of Mortar Bars Made From Cement With Inert Mineral Admixtures

Contents of Admixtures in Cement %	Quartz Sand			Dolomite			Limestone		
	eqv. Na_2O %								
	0.43	1.0	1.5	0.43	1.0	1.5	0.43	1.0	1.5
	Expansion %								
0	0.245	1.364	1.454	0.245	1.364	1.454	0.245	1.364	1.454
10	0.063	0.530	1.082	0.087	0.544	0.985	0.067	0.638	1.219
30	0.063	0.281	0.763	0.106	0.304	0.873	0.107	0.987	1.449
50	0.028	0.017	0.279	0.204	0.065	0.284	0.197	0.418	0.714
70	0.047	0.011	0.037	0.063	0.056	0.181	0.153	0.165	0.526

The results are also in agreement with those obtained at room temperature, and show that the filler admixtures can also reduce the expansion caused by alkali-silica reaction but they are much less effective than the active mineral admixtures. Perhaps the finely ground quartz sand and dolomite can react with alkali so that their preventive effect are much better than that of limestone .

Observation under SEM proved that the intensity of alkali-silica reaction was weakened by the action of active mineral admixtures so that the expansion of mortar bars with them were correspondingly reduced. For example, Fig.I(A) shows that the palticle of opal contained in mortar bar made from cement with 30% tuff is almost perfect(opal, left-corner above; cement paste, right-corner below). On the contrary, the particles of opal contained in mortar bar made from cement with 70% finely ground quartz sand were attacked seriously(see Fig.I(B)), even though the expansion of mortar bar was very small. So we come to conclusion that the mechanism of preventive effect of mineral admixtures on alkali-silica reaction is not only chemica but also mechanical, and a large amount of fine particles of admixtures might obstruct the development of cracks in mortar bars.

In general, this rapid method being able to evalute the effectiveness of mineral admixtures in preventing alkali-silica reaction, so can be used to make a primary selection of mineral admixtures.



(A) SEMx1000 (B) SEMx50

Fig.I The characteristics of particles of opal in (A) mortar bar made from cement with 30% tuff, (B) mortar bar made from cement with 70% finely ground quartz sand

4. CONCLUSION

The rapid method which was suggested by us for determining the preventive effect of mineral admixtures on alkali-silica reaction in two days, can be used for the primary selection and comparison of the effectveness of admixmitures.

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CHAIRMAN´S REPORT, Session 4

Udo Ludwig

There are in general enough standard and additional methods for the testing of the reactivity of aggregates and the reactivity of cement aggregate combinations.

With respect to ASTM C 289 - 81 some practical alterations should be made in the determination of the dissolved silica (Sc) and of the alkalinity (Rc). On the other hand the criteria for the non reactive, potentially reactive and reactive aggregates must be adjusted to the special deposits.

The German test methods discribed in the directive "Vorbeugende Maßnahmen gegen schädigende Alkalireaktionen im Beton" 1973 is valid.

D. Stark is developing an osmotic cell test for the testing of the reactivity of aggregates and gave first promising results.

With respect to the ASTM - mortar bar method (C 227 - 81) the long time needed for a statement was partly complained. Thaulow and Olafson found good correspondence with the accelerated Danish mortar test in saturated NaCl-solution at 50°C.

Nixon and Bollinghaus concluded from their results that the ASTM mortar bar test does not predict reactivity of aggregate from the UK known to have reacted in the field. They get better results with an increased alkali content of 2.4 % (m/m) Na_2O-equiv. already after 3 month storage.

In the Aachen testing method prisms in size and composition according to DIN 1164 are used. Changes in mass, expansion and resonance frequency are measured and give a better view on destruction than the measure of the expansion only. Lenzner found differences to ASTM in the course and in the intensity of the reaction.

In the Canadian concrete prisms test developed for the testing of reactive dolomitic limestone (CSA A 23.2 - 141) deleterious expansions of reactive silica are > 0.03 %. Nixon found an acceleration by curing at 38 instead of 23°C and raising the cement content from 560 to 740 kp/m^3 of concrete. Cracking was watched at > 0.05 % expansion. - In the German concrete cube test cracking is the criterion. The test is accelerated by storage in a fog room at 40°C.