Chinese Experience in the Use of ASTM Method

Z.-Y. Cai and W. Qin

Research Institute of Highway
The Ministry of Communications
The People's Republic of China

ABSTRACT

This article briefly describes the experiences gained with selected cements in preventing excessive expansion of concrete due to the alkali-aggregate reaction in a large hydraulic construction in China. The accelerated test method, ASTM C 441, used to evaluate the ability of individual cements to control alkal-aggregate reaction plays an important role in insuring that satisfactory concrete is used in construction. The main conclusions drawn from the experiments are the following:

(1) A maximum expansion of 0.020 percent specified for the average of mortar bars at age of 14 days in ASTM is quite strict.

(2) The method of evaluating the relative effectiveness of a number of different blended cements is more effective for controlling expansion compared to controlling the alkali-content in cement.

(3) Portland blast-furnace slag cements, or other blended cements are readily available in China, and also are safer than using low alkali-cements.

INTRODUCTION

At the commencement of a large hydraulic project on the Luan River in China, a considerable amount of reactive siliceous aggregates such as chert, tuff, andesite and rhyolite were found in local pits. Initial chemical tests indicated that some of these aggregates were reactive. To prevent concrete deterioration in this project it was necessary to specify the use of low alkali cement or blended cements with the potentially reactive aggregates. The effectiveness of the proposed preventative measures must of course be evaluated before being used in concrete. It is however, difficult to determine if local gravels will cause concrete deterioration; the reasons for this are as follows:

(a) It is difficult to determine the content of reactive aggregate in a pit and furthermore the distribution is not uniform.

(b) The amount of expansion observed is related to a number of factors such as the size of the reactive particles and the type of reactive silica present. It is difficult to allow for these factors in the laboratory tests.

(c) There is no sure test method for evaluating the reactivity of aggregates, the results of different tests are sometimes conflicting. Most tests also take more time to complete than is frequently available.

All aggregates should be tested regardless of whether they are thought to be reactive or not as this is the only way to insure that the concrete will behave satisfactorily in the structure.

MATERIALS AND TESTING

The testing was carried on basically according to ASTM C441. The alkali contents of cement and fly ash used is shown in Table 1. The composition of fly ash used is given in Table 2.

Table 1: Alkali Content of Cements and Fly Ash

	C 1	C 2	C 3	C 4	C 5	Fly Ash
Na_2O	0.05	0.21	0.16	0.15	0.11	0.10
K_2O	0.40	0.54	0.39	1.04	1.08	0.60
$Na_2O+0.658K_2O$	0.31	0.57	0.42	0.83	0.82	0.49
% Additive in Cement	/	7	47	15	38	/
Type of additive	/	slag	slag	shale	shale	/

*Most cements in China are manufactured as blended cement with various kinds and contents of mineral admixtures.

Table 2: Composition of Fly Ash Used

Composition	SiO	Al O	Fe O	TiO	CaO	MgO	I.L
Content (%)	51.04	37.47	3.27	1.30	3.05	1.48	1.32

RESULTS AND DISCUSSION

a. Effect of alkali additive on expansion value with low-alkali cement.

The test data in Table 3 indicate that the expansion of mortar bars made with glass as reactive aggregate are very sensitive to alkali additive. When the alkali additive is 0.2% (total alkali is less than 0.6%), compared with control bar, its expansion is more than triple that of the control bar.

Table 3: Effect of Alkali Additive on Expansion of Mortar Bars

Alkali Additive %	Total Alkali Content %	Expansion % 14 d	56 d	90 d	120 d
0	0.31	0.028	0.029	0.033	0.033
0.2	0.51	0.097	0.107	0.119	0.122
0.4	0.71	0.180	0.248	0.294	0.284
0.6	0.91	0.209	0.242	0.289	0.300

b. Comparison of expansion using various cements:

The test data in Table 4 show that cement 1 is a low-alkali portland cement, with an expansion in mortar of less than the limit (0.05%), cements 2 and 4 can't be used because they cause expansions greater than the limit. Expansion with cements 3 and 5 are lower because of a large amount of mineral admixture in them.

Table 4 Comparison of Expansions with Various Cements

Cements	Total Alkali Content %	Expansion % 14 d	56 d	90 d	120 d
C 1	0.31	0.020	0.024	0.026	0.032
C 2	0.57	0.085	0.135	0.151	0.160
C 3	0.42	0.015	0.012	0.012	0.013
C 4	0.83	0.083	0.082	0.084	0.086
C 5	0.82	0.009	0.002	0.006	0.007

It is worth noting that alkali content in cement 2 (in Table 4) is less than 0.6% which is considered to be safe, but it causes the greatest expansion. So controlling the alkali level without testing for expansion in mortar bars is not suitable for some cements. Not only the quality and content of admixtures should be considered but also state of free alkali in the cement and admixture.

c. Effectiveness of fly ash on controlling alkali-aggregate reactivity.

The test data in Table 5 show that when 0.2% alkali additive is added to cement without fly ash, the expansion at 14 and 56 days is increased as much as 6 times; the more mineral admixture in the cement, the less expansion it causes at 14 and 56 days. As the alkali content of the fly ash is higher than that of low-alkali cement, the total alkali content in cementitious materials, is increased as the percent fly ash admixture in the cement goes up.

d. What should the limiting expansion be?

This question is worth exploring. Formerly, according to ASTM C595 for Blended Hydraulic Cement, it was 0.02% for 14 days and 0.06% for 56 days and the limiting alkali content in China and in most countries is 0.6%. In our testing, cement 1 is a type of low alkali portland cement (0.31%), but its average 14 day-expansion value is 0.019% (an average repeated 7 times within 5 months). The limiting expansion value in ASTM C441 was considered quite strict.

Table 5: Test of Effectiveness of Fly Ash on Controlling Alkali Aggregate Reactivity

Cement + Fly Ash	Total Alkali Content %	Expansion % 14 d	56 d
C1 + 0	0.31	0.008	0.017
C1 + 0	0.51	0.050	0.071
C1 + 6%	0.53	0.026	0.036
C1 + 17%	0.56	0.012	0.022
C1 + 22%	0.58	0.006	0.016
C1 + 36%	0.63	0.005	0.012

SUMMARY

1. Mortar bars with glass as reactive aggregate are very sensitive to alkali additive; the more additive the cementitious materials have, the greater the expansion they cause. Evaluating alkali-aggregate reactivity of cementitious materials by this method is satisfactory.

2. Expansion of cementitious materials depends on various factors. Some cements with low-alkali content cause big expansions, but some blended cements with a large amount of mineral admixtures cause only low expansions. So evaluating expansion potential through testing is more effective than controlling the alkali content in cement.

3. The effect of fly ash admixture on controlling alkali-aggregate reactivity was proved through tests, but its effectiveness with high-alkali cement needs further evaluation.

4. The average expansion of portland cement with an alkali content of 0.31% just meets the requirement in ASTM, which explains why this standard is quite strict.