EVALUATION OF PORTLAND FLYASH CEMENT AS A PREVENTIVE AGAINST ALKALI-SILICA REACTION

S. Chatterji
Building Technology, The Technological Institute, Denmark
Dr.

P. Nepper-Christensen
Aalborg Portland, Denmark
Manager Cement and Concrete Laboratory

SYNOPSIS

In a recent paper /1/ to the Nordic Concrete Research it has been shown that the use of a Portland flyash cement delays the onset of alkali-silica expansion of a structure which is in contact with an external alkali source. However, due to an early termination of expansion measurement no definite conclusion could be drawn as to the effect of Portland flyash cement on the ultimate expansion capacity. This shortcoming has been amended in the investigation presented below.

In this investigation mortar bars, made with a highly reactive and a medium reactive sand and each of a Portland flyash cement and a low alkali sulphate resistant Portland cement, were tested by the saturated NaCl solution bath method. Expansion measurements were carried out up to 48 weeks. The results show that compared to the low alkali sulphate resistant Portland cement the use of Portland flyash cement significantly reduced alkali-silica expansion of mortar bars made with both high and medium reactive sand types.

Key-words: Alkali-silica reaction, Blended cement, Low alkali cement, Flyash, Deicing salts, Expansion

1. INTRODUCTION

As regards alkali-silica reaction Denmark is in a difficult situation as many of her aggregate sources are contaminated by reactive silica. In normal circumstances (closed system), the use of a Danish Portland cement, which has an alkali content less than 0.8 percent, in conjunction with a reactive aggregate does not give rise to any destructive alkali-silica reaction.

However, in an open system, where alkali salts from an outside source can migrate into a structure, destructive alkali-silica reaction can develop very quickly.

It is a common practice to use either a low alkali Portland or a pozzolanic cement as a precautionary measure against alkali-silica reaction. In a recent study /1/ Byggeteknik, Teknologisk Institut, has compared the alkali-silica expansion capacities of mortar bars made with Nymølle (Hedehusene) sand and each of an ordinary Portland cement, a low alkali Portland cement (alkali content less than 0.4 percent) and Portland flyash cement. The saturated NaCl bath method, which simulates an open system, was used in this investigation. Results of that investigation are shown in Fig. 1. From Fig. 1 it can be seen that in an open system the use of a low alkali Portland cement has not much advantage over an ordinary Portland cement; the use of the Portland flyash cement looks encouraging. Unfortunately, however, the investigation was discontinued due to a shortage of funds after 8 weeks storage in the salt bath. It will be of interest to investigate the long term expansion capacity of mortar bars made with one or two reactive sands and Portland flyash cement.

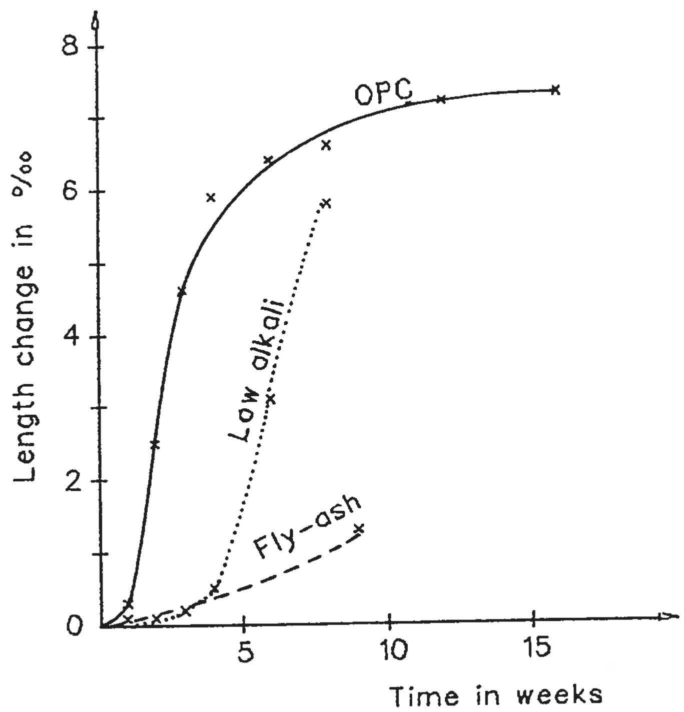

FIG. 1. Expansion characteristics of sand-cement mortar bars stored in a saturated NaCl bath at 50^0 C

In the normal testing by the saturated NaCl bath method, mortar bars are cured at room temperature (approx. 20^0C) for 28 days prior to their exposure to the salt bath. However, in practical concreting, a concrete structure often heats up to about 40^0C and remains at that temperature for a few days. It has been claimed that the latent pozzolanic activity of a flyash is accelerated by this temperature rise. This is expected to occur with Portland flyash cement also and may change its expansivity due to alkali-silica reaction. It will be of interest to investigate this aspect also.

The experiments and the results described below may be considered as complementary to Norwegian experiences, reported by Maage and Johansen /2/ in the present publication, since flyash of the same origin (i.e. from Danish power plants) was used in manufacturing both the Danish Portland flyash cement (Portland flyash cement) and the Norwegian Portland flyash cement (MP 30) dealt with in the two papers.

2. MATERIALS AND EXPERIMENTAL TECHNIQUE

One batch of low alkali sulphate resistant Portland cement and one batch of Portland flyash cement have been used in this investigation. Both the cements have been supplied by Aalborg Portland.

The low alkali sulphate resistant Portland cement is characterized by an alkali content less than 0.4 percent, and a C_3A content less than 2 percent. The Portland flyash cement is characterized by a flyash content of approximately 23 percent. Typical analysis of flyash used in manufacturing this type of cement is given in Table 1.

TABLE 1. Typical data (1986) for flyash used in manufacturing Portland flyash cement in Denmark

CaO	5.0 pct
SiO_2	54.7 -
Al_2O_3	29.0 -
Fe_2O_3	5.0 -
MgO	1.2 -
SO_3	0.4 -
K_2O	1.2 -
Na_2O	0.3 -
Loss on ignition	3.2 pct
45 micron sieve residue	24.1 -

Two sand types, one very reactive i.e. Nymølle (Hedehusene), and another medium reactive sand, Kallerup, have been used in this investigation. Two separate series of experiments were carried out.

Series A

Using both the sand types and low alkali cement and Portland flyash cement, mortar bars were made for each combination. These bars were cured at room temperature (approx. 20^0C) for 28 days, thereafter transferred to a saturated NaCl bath at 50^0C. Expansion of the bars have been measured up to 48 weeks.

Series B

Using both the sand types and low alkali cement and Portland flyash cement, mortar bars were made for each combination. These bars were cured at room temperature for first 24 hours and then at 40^0C for 27 days in water. The cured bars were then transferred to a saturated NaCl bath at 50^0C. Expansion measurements were carried out up to 48 weeks.

In the above experiments the mortar bars made with low alkali cement acted as controls as well as to show the effect of a low alkali cement on the alkali-silica reactivity of the two types of sand.

In each of the above series the mortar bars were made from 1:3 cement:sand mortars. The water/cement ratio of these mortars was 0.5. 40x40x160 mm mortar bars were cast following the Danish Standard specification DS 427 (corresponds to ISO R772).

3. RESULTS AND DISCUSSION

Results of both series are shown in Figs. 2 and 3. Fig. 2 shows the expansion characteristics of mortar bars made with the high reactive sand. From Figs. 1 and 2 it can be seen that in an open system, the use of a low alkali sulphate resistant cement can not prevent expansion due to alkali-silica reaction.

Fig. 3 shows the expansion characteristics of mortar bars made with the less reactive sand. A comparison of Figs. 2 and 3 shows that the use of Portland flyash cement has considerably reduced the expansion of mortar bars made with both sand types. In the case of Kallerup sand the expansion has nearly been eliminated by using the Portland flyash cement. This has, however, not excluded the formation of some popouts and consequent surface damages. The figures also show that curing of the prisms at 40^0C prior to their exposure to the saturated NaCl solution, has actually resulted in a slightly higher expansion compared to the mortar bars cured at 20^0C. The reason for this somewhat unexpected result is not clear.

Whether the reduced expansion, due to the use of a Portland flyash cement, is acceptable or not depends on the prevelant acceptance criterion. For example, the Kallerup sand/Portland flyash cement combination satisfies the Danish requirements for durable concrete (as set out in the socalled Basic Concrete Code), whereas the Kallerup sand/low alkali sulphate resistant cement combination does not.

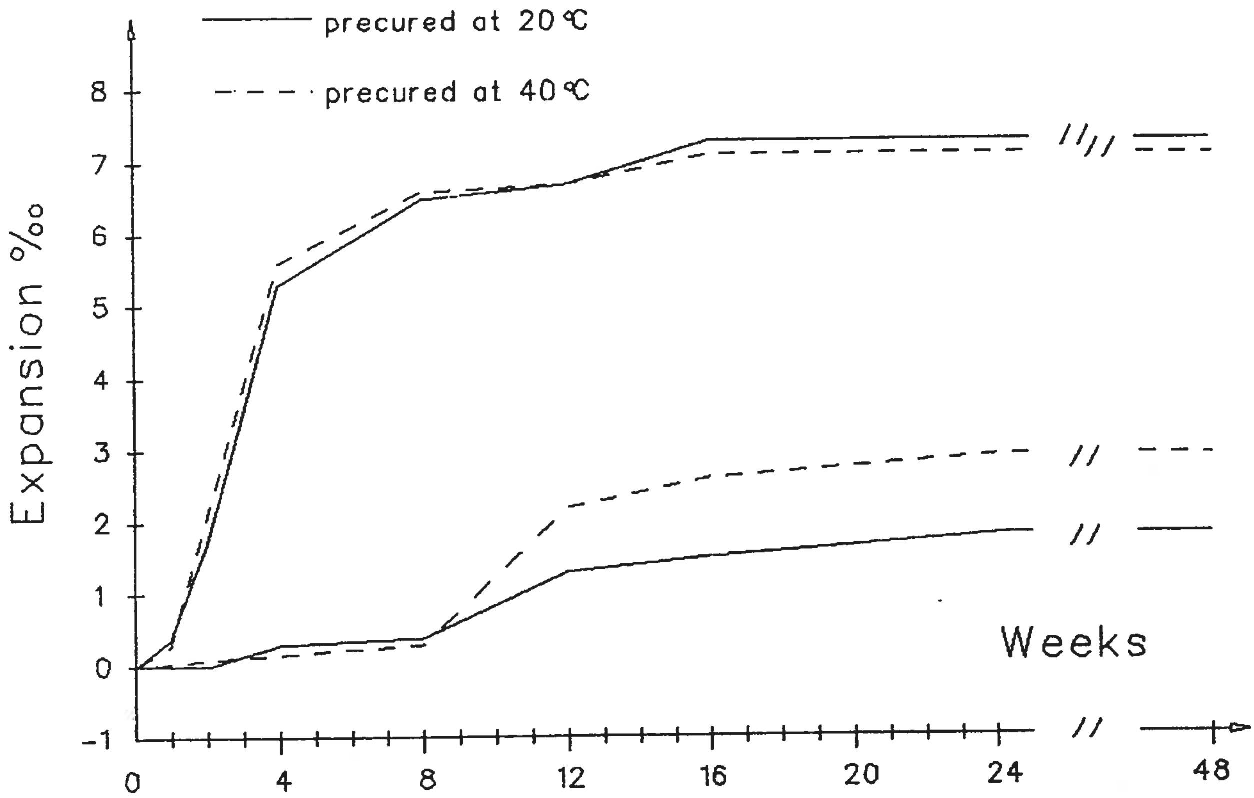

Fig. 2. ALKALI-SILICA TEST. Expansion characteristics of mortar bars of Nymølle sand together with low alkali cement and Portland flyash cement, respectively

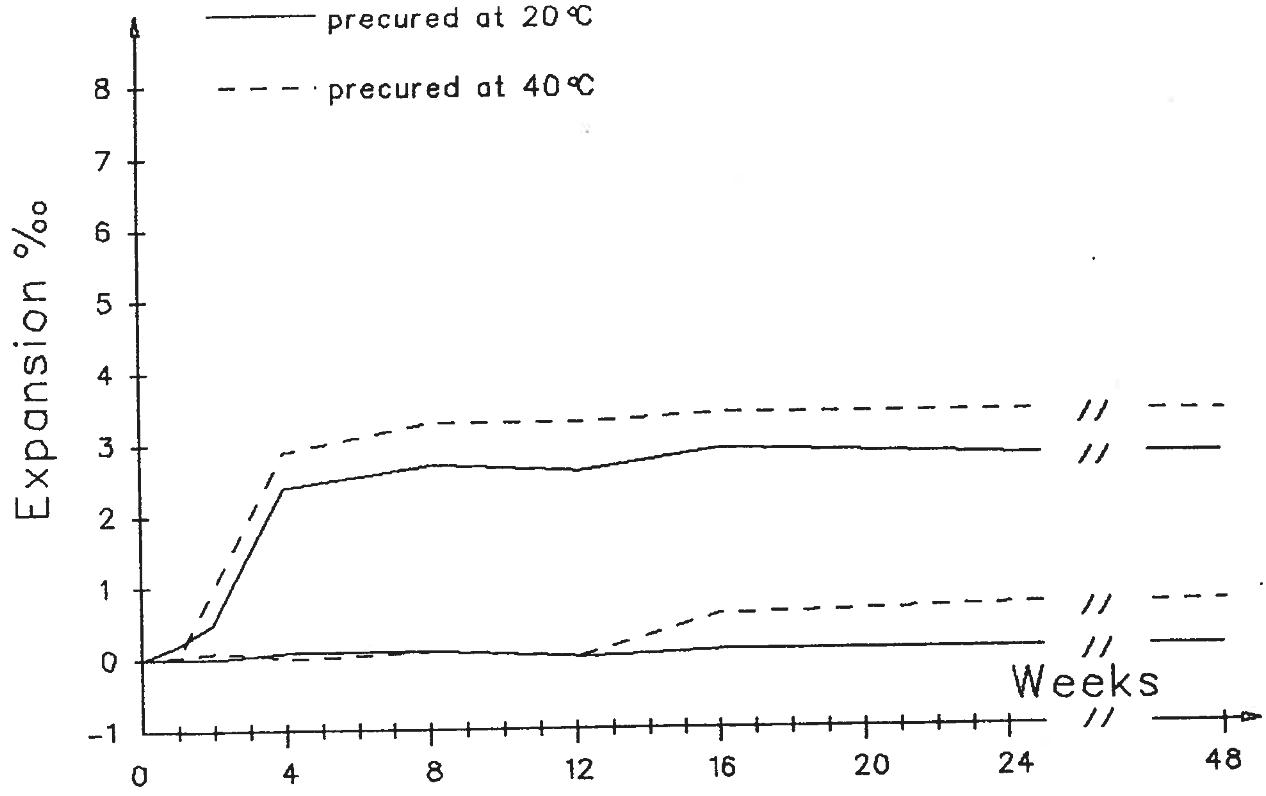

Fig. 3 ALKALI-SILICA TEST. Expansion characteristics of mortar bars of Kallerup sand together with low alkali cement and Portland flyash cement, respectively

4. CONCLUSIONS

From the results of this investigation the following conclusions could be drawn:

(i) The use of the Portland flyash cement reduces expansion due to alkali-silica reaction even in an open system where alkali-salts from an outside source may penetrate into a concrete structure

(ii) For the case of a moderately reactive sand, this reduction in expansion due to the use of the Portland flyash cement may make the sand acceptable for concrete making

(iii) In an open system the use of a low alkali sulphate resistant Portland cement has very little advantage over an Ordinary Portland cement.

5. REFERENCES

/1/ Chatterji, S and Fördös, Z.: "Effect of Flyash addition on alkali silica expansion". Nordic Concrete Research. Publikation No. 4, 1985.

/2/ Maage, M. and Johansen, R.: "Properties of Norwegian blended cements with and without silica fume". Nordic Concrete Research. Publication No. 6, 1987.