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

ALKALI-SILICA REACTION IN TILECOVERED CONCRETE

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1. SYNOPSIS

Alkali-silica reaction has sometimes been observed where concrete and mortar have been used together with ceramic building materials, like ceramic tiles.

In this work possible reactivity in ceramic materials has been investigated in the alkaline surroundings of cement pastes. Pastes of ordinary Portland Cements, low-alkali cement, fly ash cement, and silicafume-blended cements have been used.

Ceramic building materials show reactivity. Low-alkali cement and fly ash cement reduce the reactivity compared with OPC. A limited effect of using silicafume-blended cements in reducing alkalireactivity has been shown and is discussed in terms of Na^+, K^+ and OH^- concentrations in the pore water.

2. INTRODUCTION

Concrete deterioration due to alkalireactive aggregates has not represented any serious problems in Norway. About 10-15 years ago, however, damages caused by alkali-silica reactions were observed in swimmingpools and shower cabinets. Gel was detected on the surface of ceramic tiles. When this gel is allowed to dry, the hardened reaction products are impossible to remove from the surfaces. The gel may also cause a loosening of the tiles from the underlying concrete followed by a leakage of water through the concrete. Owing to the fact that alkali-silica reactions in Norway mainly are reported from constructions where tilecovered concrete is involved, it was of interest to investigate if the reactive silica might be originated from ceramic tiles. The aims of this investigation therefore were

to examine if ceramic tiles may contain reactive silica which reacts with the alkaline water in cementpaste.

to examine if the testing methods ASTM C 289-81 "Potential Reactivity of Aggregates (Chemical Method)" /1/
and ASTM C 227-81 "Potential Alkali Reactivity of
Cement Aggregate Combinations (Motar-Bar Method)" /2/, might be suitable methods for testing ceramic tiles regarding alkalireactivity.

to examine if the reactivity could be reduced by useing blended cements in mortars for the fixing of tiles.

3. EXPERIMENTAL WORKS

METHODS

Following methods were used to investigate alkalireactivity in tiles

ASTM C 289-81 /1/ and
ASTM C 227-81 /2/ using crushed tiles as aggregates.

After about 18 months of exposure according to ASTM C 227-81 the specimens were examined by use of microscopical methods like thin section analysis and scanning electron microscopy (SEM).

4. MATERIALS

3 types of ceramic tiles have been investigated. X-ray diffractograms of the ceramic materials showed that α-quarts, and mullite or plagioclas were the main crystalline phases. The tiles are throughout this paper designated, 1, 5 and 6.

The examinations include 6 types of cement

2 ordinary Portland Cements (OPC)
1 Fly ash cement (20 % fly ash)
1 Low-alkali cement
2 Silicafume-substituted cements (10 % silica fume)

The chemical composition of the cements and silica fume are given in Table 1.

Table 1 Chemical composition of cements and silicafume.

	OPC (1)	Fly ash cement	OPC (2)	Low-alkali cement	Silica fume
Silica (SiO_2)	20,2	27,0	19,7	21	96,0
Calciumoxide (CaO)	62,9	50,9	63,0	64	0,06
Magnesiumoxide (MgO)	2,3	2,2	3,2	0,7	0,23
Ferricoxide (Fe_2O_3)	3,2	3,8	2,3	4,6	0,06
Aluminina (Al_2O_3)	5,0	9,5	4,6	3,5	0,12
Sulphurtrioxide (SO_3)	3,3	3,0	3,1	2,2	-
Tot. alkali (K_2O)	1,7	1,7	1,7	0,73	0,40
Insoluble materials	0,4	-	0,2	-	0,81
Loss on ignition	1.4	0,6	2,2	-	1.7

5. RESULTS AND DISCUSSION

Watersorption of the ceramic tiles and their contents of soluble silica determined according to ASTM C 289-81 (Chemical method) /1/ are given in Table 2.

Table 2. Watersorption and soluble silica in ceramic tiles. (ASTM C 289-81).

Tile	1	5	6
Water sorption % (W/W)	3,6	15,4	5,8
Soluble silica mmol/l	139	86	501
NaOH-reduction mmol/l	49	21	35

Table 3 shows the changes in length of the mortar prisms tested according to ASTM C 227-81 (Morter - Bar Method) /2/. The time of exposure has been extended to 18 months. The results are given in % $\cdot 10^{-2}$ of original length and shown on fig 1, and fig 2 as function of time.

Table 2 Changes in length of mortarprisms % · 10^{-2} of original length (ASTM C 227-81) /2/

		Time of exposure in months								
Type of cement	Tile	14 days	1	2	3	4	6	9	12	18
OPC (1)	1 5 6	1,4 2,4 2,2	2,3 3,4 3,6	2,5 3,9 4,8	3,7 4,5 5,5	4,0 4,5 5,5	4,1 4,7 6,1	- -	5,1 5,8 8,3	5,6 5,8 8,3
Fly ash cement	1 5 6	1,0 1,6 2,2	- 2,0 3,3	2,3 2,2 4,4	2,7 2,3 4,8	3,1 2,4 4,5	3,4 2,7 5,8	- -	4,4 3,4 6,3	4,5 3,4 6,3
OPC (2)	1 6	0,8 1,2	1,5 2,8	3,2 4,3	3,7 5,1	- -	4,7 6,0	4,8 6,7	5,7 -	6,0 -
Low alkali OPC	1 6	0,7 1,6	0,9 2,0	1,4 2,2	1,9 4,0	- -	3,4 4,9	3,8 5,3	4,5 -	5,3 -
90 % OPC (1) 10 % silica-fume	1 6	0,9 1,6	1,6 2,0	1,9 3,1	2,3 3,5	2,7 3,4	3,7 4,4	- -	6,6 7,3	6,6 7,3
90 % Fly Ash Cement 10 % silica-fume	1	0,8	-	1,5	2,0	2,3	2,7	-	4,3	5,0

As can be seen from fig 1 the mortar prisms made from tile 6 show the largest expansion compared with tile 1 and 5. This was to be expected because of the rather great content of soluble silica in this ceramic material.

Together with OPC the prisms made with tile 5 as aggregate have expanded more than the corresponding tile-1 prisms in spite of less content of soluble silica in tile 5.

This is most likely due to the large watersorption of tile 5 which means a great inner surface available for exposure to the alkaline solution of cementpaste. As can be seen from fig 1, use of fly ash cement in the prisms reduces the reactivity of the ceramic materials, and so did the low-alkali cement.

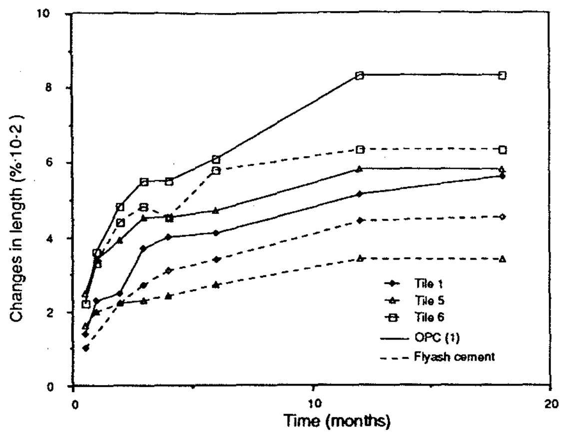

Fig 1 Changes in length of mortar prisms containing ceramic tiles as aggregate (ASTM C 227-81)

The measurements of length-changes in the prisms made from 10 % silica-fume substituted OPC and FA-cement are shown on fig 2. These results indicate that silica fume reduces the alkali-silica reaction in these prisms for a shorter period of time and then giving an increased reactivity compared with OPC and fly ash cement.

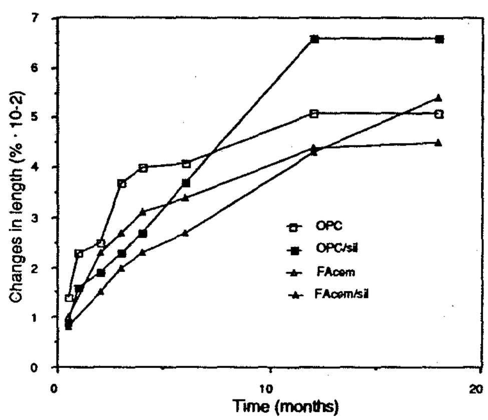

Fig 2 Changes in length of mortar prisms. Different types of cement with tile 1 as aggregate. (ASTM C 227-81)

This is difficult to explain. It may, however, be due to an increase of alkali concentration in pore water. In his study of the pozzolanic reactions of silica fume, H. Justnes, et al. /3/ suggest that the pozzolanic reaction between $Ca(OH)_2$ and silica fume goes through a dissolution of the silica fume in NaOH/KOH-solution. This solution in turn reacts with $Ca(OH)_2$ giving C-S-H and free Na^+ and K^+-ions. A steadily dimishing content of pore water and silica fume in the hydrating pastes brings about an increase of the alkali-ion concentration and thereby a high OH^- concentration, which according to Thaulow and Andersen /4/ is the ion determining the progress of the alkali-silica reaction. This may be the cause of the greater expansion of the silica fume bearing prisms.

The fact that the microstructures of the ceramic materials and the cement paste were very much alike, complicated the microscopical examinations of the specimens. Thin section analysis of the of exposed mortar prisms showed gels in pores whilst the SEM examinations revealed growth of large crystals in the prisms as shown on fig 3. The magnitude of gel and growth of crystals in the specimens showed good agreement with the degree of expansions of the prisms in question.

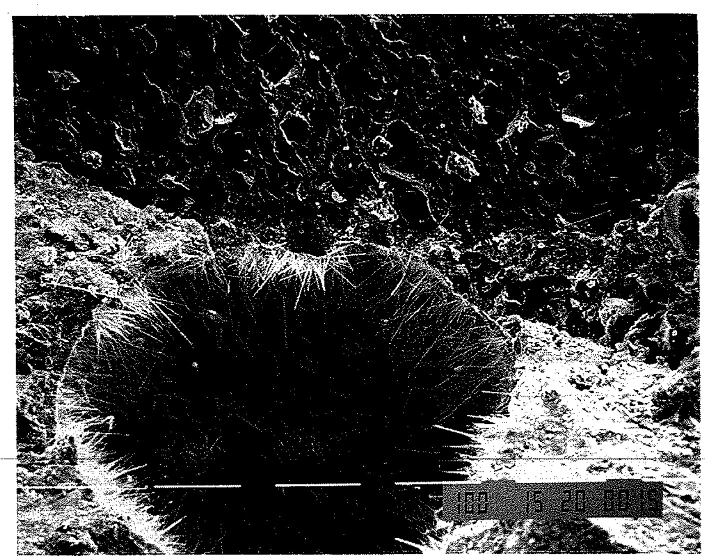

Fig 3 Crystal growth in mortar prisms

6. CONCLUSIONS

The questions asked in the very start of the project may be answered

- Ceramic building materials may cause alkali-silica reaction when they are in contact with cement paste

- ASTM C 289-81 (Chemical Method) /1/ and

- ASTM C 227-81 (Mortar-Bar Method) /2/
seem to be suitable methods for testing ceramic building materials with respect to alkaline reactivity

- Use of fly ash cement and low-alkali cement in mortars for fixing ceramic tiles will most likely reduce a possible alkali-silica reaction in ceramic building materials

- Only a limited benefit of using silica fume-blended cements to reduce alkali reactivity has been obtained.

7. ACKNOWLEDGEMENT

The author wish to thank

The Royal Norwegian Counsil for Scientific and Industrial Research

Norcem A/S, Norway

Cementa AB, Sweden

Hogenas Byggkeramik AB, Sweden

Laboratory for Building Materials and Structures NTH

for their support to the project.

8. REFERENCES

/1/ ASTM C 289-81 "Potential Reactivity of Aggregates (Chemical Method); Annual Book of ASTM Standards, Section 4, Vol 04.02, 1983.

/2/ ASTM C 227-81 "Potential Alkali Reactivity of Cement Aggregate Combinations (Mortar-Bar Method), Annual Book of ASTM Standards, Section 4 Vol 04.02, 1983.

/3/ H. Justnes, I. Meland, J.O. Bjørgum, J. Krane "The Mechanism of Silica Fume Action in Concrete studied by Solid State ^{29}Si MAS NMR". To be published.

/4/ Niels Thaulow, Kim Thordal Andersen, "Ny viden om alkalireaksjoner", Dansk Beton nr 1 1988, (In Danish).