# Influence of Fly Ash in Alkali-Aggregate Reaction

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## ABSTRACT

A systematic study of the long term hydration PFA + cements and PFA + $Ca(OH)_2$ systems has permitted us to draw some conclusions concerning the behavior of alkalis. Alkalis are not released from Belgian fly ash particles. Some well cristallized hydrates in the hexagonal system are observed in the investigated hydrated mixtures. The potassium content of this crystalline compound is significant. The authors suggest that the beneficial role of PFA particles in the reduction or the inhibition of the expansion due to alkali-aggregate reaction could be attributed to the formation of this stable compound.

## INTRODUCTION

The use of fly ash in the production of concrete can provide considerable advantages. It saves raw material, energy and makes possible to avoid problems with alkali-aggregate reaction (Nixon et al 1983).

One of the most important parameters which governs the alkali-aggregate reactivity is the available alkali content of the concrete matrix (Mehta 1983).
Generally, fly ash contains higher alkalis than OPC. So the replacement of cement by fly ash leads to an increase in the total alkali content of the blended cement.
The solubility of alkalis from fly ash has to be investigated after various periods of hydration, to determine the amount of soluble alkalis that could participate to the alkali-aggregate reaction.

## MATERIALS AND METHOD

The cement used in this work is an ASTM type I low alkali cement. The two ashes used are representative of ashes commonly produced by Belgian thermal power stations. The alkali content is relatively higher than in cement : 0,92 % $Na_2O$, 2,56 % $K_2O$ and 0,71 % $Na_2O$ 2,21 % $K_2O$ for PFA A and PFA 4 respectively.

Microscopical investigation coupled with EDAX was performed on the 2 to 3 years hydrated fly ash + OPC systems and fly ash + $Ca(OH)_2$ systems at room temperature.

## RESULTS AND DISCUSSION

Some previous work (Tenoutasse 1984 - 1986) was devoted to the study of the solubility behavior of alkalis from Belgian fly ashes. It has been demonstrated that 25 % cement replacement by fly ash does not influence significantly the level of alkali hydroxides in the pore solution during the early hydration period.

In order to better understand the "alkalis development" in long term hydrated fly ash cements, the hydration of cement containing 10 to 80 % fly ash was investigated after 2 and 3 years hydration, by SEM coupled with EDAX.

The microstructure of the samples demonstrates well the participation of fly ash particles in the pozzolanic reaction with $Ca(OH)_2$ generated by cement hydration.

Furthermore, well crystallized hexagonal compounds are observed in PFA blended cements (Fig. 1-2). The chemical composition of these hexagonal plates revealed by EDAX shows, concomitantly with an appreciable potassium content, large amounts of aluminum and silicon, which prevent confusion with $Ca(OH)_2$ or monosulfoaluminate.


Fig. 1 OPC + 30 % PFA 2 years


Fig. 2 OPC + 20 % PFA 2 years

In the two ashes tested, the number of hexagonal plates becomes significant in the 40 % PFA cement, and is further increased in the 80 % PFA cement (Fig. 3).


Fig. 3 OPC + 80 % PFA 2 years

The microscopical investigation was also conducted on the 3 years hydrated 80 % PFA + 20 % $Ca(OH)_2$ system.

The presence of such hexagonal plates with the same chemical composition confirms these are resulting from the pozzolanic reaction between $Ca(OH)_2$ and the vitrous phase of fly ash particles (Fig. 4-5).

X-ray diffraction performed on 3 year hydrated 80 % PFA + OPC and 80 % PFA + $Ca(OH)_2$ systems, both reveal the presence of $C_2ASH_8$ which crystallizes well in the hexagonal system (Fig. 6).

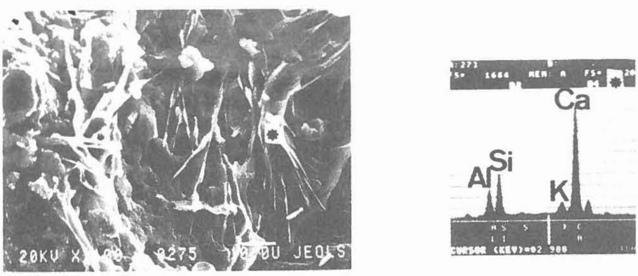


Fig. 4 20 % $Ca(OH)_2$ + 80 % PFA 3 years


Fig. 5 20 % $Ca(OH)_2$ + 80% PFA 3 years

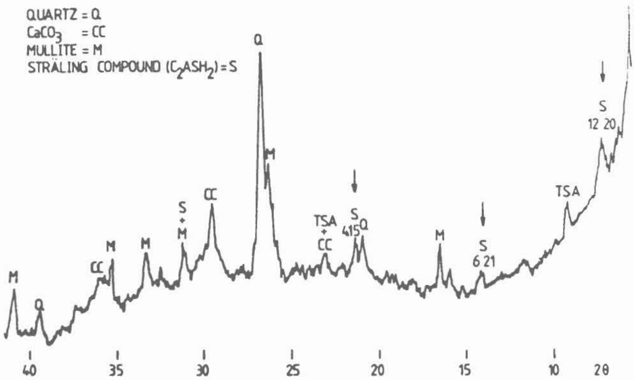


Fig. 6 X-ray diffraction on the 3 years hydrated 80 % PFA cement.

The most exciting observation is related to the significant amount of potassium in this crystalline pozzolanic compound. The microscopical data suggest that alkalis from Belgian fly ashes are not released. They seem to be kept in a hydrated product resulting from the pozzolanic reaction.

Probably the alumino-silicate vitrous phase of fly ash particles reacts with $Ca(OH)_2$ without any potassium release.

However, the participation of alkalis from cement in this chemical process has to be considered. Indeed, fly ash particles could have some sorptive capacity for alkalis, especially for potassium (Glasser 1983).

These observations improve to some extent our understanding of the beneficial effect of fly ash particles in reducing expansion due to alkali-aggregate reaction. They participate in the pozzolanic reaction resulting in the formation of a stable crystallized compound.

Apparently, this latter is non expansive, probably because of its high calcium content. Closely related to that hypothesis, it is well known that the reaction between $Ca(OH)_2$ and the expansive alkali-silica gel leads to the formation of the white opaque non swelling calcium-alkali silica complex (Vivian 1983). These data suggest that the replacement of cement by fly ash promotes indirectly a decrease in available alkalis (alkali content in the pore fluid).

This conclusion is very important as it is the soluble alkalis and not the total alkali content of the concrete matrix which plays the predominating role in alkali-aggregate reaction.

## CONCLUSIONS

Alkalis from Belgian fly ashes are not released even after long hydration periods. They are kept in stable pozzolanic reaction products.

The beneficial influence of the substitution of OPC by PFA in reducing expansion due to alkali-aggregate reaction could be attributed to a decrease in available alkalis.

## ACKNOWLEDGMENTS

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