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Discussion

Reply to the discussion by E.F. Irassar of the paper "Durability of the hydrated limestone–silica fume Portland cement mortars under sulphate attack"☆

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The authors are thankful to Dr. Irassar for his interest in our paper and for the observations he has made.

The present work is a part of the comparative study on the effect of silica fume on the physical and the mechanical properties, the microstructure, chemical resistance and durability in the real cement systems with and without limestone addition.

The commercial blended Portland cement containing up to 30 mass % of the blast furnace slag, confirming to the European standard cement EN 197.1: type CE II-s (Portland-slag cement) was used in examination. The sulphate-resisting Portland cement, SRPC (there has been no attempt to standardise SRPC in EN 197 so far), roughly equivalent to type V in ASTM 150 C-89 was used as a control (referent) cement for monitoring the changes in the behaviour mortars exposed to sulphate environments.

The results of the study were reported in previous papers [1,2], and complete reports will be published later.

We would like to point out that the present article reviews global changes in the Portland cement–silica fume–limestone systems exposed to sulphate attack. Various methods were used to observe the changes and relate them to the behaviour of mortar samples during the cement hydration and during sulphate attack. Based on the experimental data (expansion of mortars, leaching of lime, change in dynamic modulus, X-ray analysis) compared for blended Portland cement only and for blended Portland cement–silica fume systems, it has been shown that simultaneous addition of finely ground limestone and silica fume contributes to higher corrosion resistance in mortars exposed to sulphate attack. Mortars showed lower expansion than the referent sulphate-resisting Portland cement mortar, regardless of the type of the sulphate solution.

The sulphate performance was examined using ASTM C 452-68 mortar bar expansion test. We agree with Dr. Irassar that this standard method applies only to the plain Portland cement. For this reason, we used only part of this test, as described, but not emphasised in Section 1.2. (Test methods) of our paper. The experimental procedure used corresponds to the ASTM C 1012-84 both for plain Portland cement and for blended cements or composite cements [3].

The literature contains a number of reports on sulphate resistance of different composite cement mixes. The types of disruption observed during sulphate attack on mortars or concrete and chemical processes involved with respect to the type of hydraulic binders (active, latent, and composite) have been reported by Lawrence [3]. The C_3A content of the Portland cement was an important factor determining the sulphate resistance of composite cements containing pozzolanas or blast furnace slag. Binders utilising high C_3A Portland cement clinker were more sensitive to the slag composition, fineness, and percentage replacement. The reason for the improvement in performance of silica fume composites is still a subject of speculation. The formation of finer pore structure, the reduction of $Ca(OH)_2$ content, and the removal of aluminate fraction of the cement by incorporation into extra silicate hydrate being formed have all been proposed as explanations [3].

Results from our studies show that the behaviour of mortars exposed to sulphate environments depends on microstructure of mortars before immersion in sulphate. The microstructure of mortars is a function of water to cement ratio (W/C), pore size distribution, hydration and pozzolanic reaction degree, and products formed. Under different condition, the binary systems such as the Portland cement–silica fume system, and the ternary systems, such as the Portland cement–silica fume–limestone system, show

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differences both in the hydration reaction and in the pozzolanic reaction. It has been confirmed that pozzolanic reaction is delayed in comparison to the hydration reaction [1].

Although not specified here, the quantity of limestone incorporated is affected by the silica fume contents. As both silica fume and limestone can act as either inert or active participants during cement hydration, the ratio of their effect changes depending on their individual content and on the hydration time. Details will be reported [4].

Based on monitoring changes in parameters related to stability and durability of cement stone, the completed study will make it possible to observe and envisage the sequence of events, and determine the circumstances under which a synergistic action is obtained in this ternary system. Further studies would be useful in confirming our observations and providing better insight into this complex phenomenon.

References

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