Mineral Additions for the Inhibition of Delayed Ettringite Formation in Concrete: The Role of Limestone Filler

[1]Santos Silva A.[*], [1]Soares D., [1]Matos L., [1]Salta M., [1]Gonçalves A., [1]Bettencourt Ribeiro A.
[1] *National Laboratory for Civil Engineering (LNEC), Materials Department, Lisbon, Portugal*
[2]Pavoine A., [2]Divet L.
[2] *Laboratoire Central des Ponts et Chaussées (LCPC), Materials Department, Paris, France*

Abstract
One of the most popular preventive measures to minimize the occurrence of chemical expansive reactions, namely the internal sulphate reaction (ISR), in hardened concrete is the use of mineral additions. This pathology is due to the formation of expansive ettringite (delayed ettringite formation - DEF) inside the material and is very difficult to deal with, because presently there is no efficient method to repair concrete structures affected by DEF. Hence, there is an urgent need to find preventive methods that may enable the inhibition of DEF in new constructions. Nowadays, it's recommended the use of mineral additions to sustain this type of degradation. Moreover, their effect depends on the chemical and mineralogical composition and also the cement replacement.
The research work presented in this paper deals with the influence of limestone filler, a type I mineral addition, in the inhibition of DEF (Santos Silva et al., 2010a, 2010b), and is part of an extensive study to elucidate the role that the mineral additions have in the mechanism of inhibition of DEF in concrete. For this purpose different concrete mixes were produced by using the same cement type (CEM I 42.5Ra with 3.11% SO_3 and 6.4% C_3A) and water/cement ratio (0.45), incorporating different amounts of mineral additions, like fly ash, metakaolin, blast-furnace slag, silica fume and limestone filler. The filler influence was followed by expansion and microstructure evaluation of concrete mix at several ages. These studies showed an interesting behaviour of limestone filler, which motivated new concrete formulations with different cement types (CEM I 42.5Rb and CEM I 52.5) that differ in SO_3 and C_3A contents, in order to investigate its influence in development of DEF. This research includes also a concrete composition with a cement type II (CEM II A-L 42.5R). The results obtained were compared and the conclusions were extracted.
It was found that the concrete mixes with limestone filler showing higher expansions than the control composition. According to these results it seems that the limestone filler does not inhibit rather it promotes the expansion due to DEF. Thus, for concretes subjected to high temperatures in early ages, the limestone filler is not adequate to sustain DEF development rather it may even increase the expansion behaviour in concrete mixes. According to these findings, it was proposed that the ISR recommendations must prohibit this kind of mineral addition.

Originality
The degradation of concrete structures due to delayed ettringite formation (DEF) is a problem that affects nowadays growing number of concrete structures (mainly dams and bridges), where the concrete is subjected to high temperatures during its cure. When this pathology occurs, its effects are particularly dangerous because DEF is extremely expansive causing cracking of the concrete, thus contributing to the reduction of life-time due to early degradation of concrete structures and in extreme cases can lead to its demolition. This reaction is also difficult to detect early, requiring expensive diagnostic tools and highly specialization, and when detected in a concrete the repair is not guaranteed. In this context, it is urgent to find preventive methods that allow the inhibition of DEF in the new concrete structures. It is already known that some mineral additions could be used as partial replacement of cement in concrete to mitigate the effects of these reactions. However, the behaviour of each mineral addition depends on its mineralogical composition and cement replacement content. The present work shows that limestone filler additions do not mitigate the DEF as expected instead they promote the deleterious expansion due to this reaction.

Chief contributions
Nowadays, one of the biggest challenges is to reduce the environmental impact of Portland cement, which is the most consumed material manufactured in the world. Some cements, like CEM II that have already a reduction in the portland clinker content are normally recommended for concretes that could be subjected to internal expansive reactions.

∗ Corresponding author: Email ssilva@lnec.pt Tel +351218443674, Fax +351218443023

Besides the use of cements with less Portland clinker, the employment of mineral additions is a well known mitigation measure to inhibit the expansion due to internal expansive reactions in concrete. However, the chemical, mineralogical and replacement content of a certain type of mineral addition are important factors to take into account at this respect.

The study presented in this paper is part of an extensive work developed in LNEC, Portugal, aiming to study expansion rate and microstructure of heat-cured concretes with different amounts of mineral additions, like fly ash, metakaolin, blast-furnace slag, silica fume and limestone filler. The results obtained show that only type II mineral additions are effective in DEF suppression. According to these findings the recommendations for DEF inhibition must prohibit the use of additions or cements with limestone filler, like CEM II A-L, in concrete.

Keywords: *ISR, DEF, limestone filler, mineral additions, microstructure*