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Discussion

A state-of-the-art review of delayed ettringite attack on concrete by Mario Collepardi [Cement & Concrete Composites 25 (2003) 401–407] ☆

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Dr. Collepardi's excellent review of the "State of the Art" on DEF summarizes "what has been said." We would address that which has not been said.

First, the affect of curing temperature has been extensively investigated but inadequately explained. Do higher temperatures cause more dissociation of already formed ettringite (e.g. to lower hydrate forms), prevent some of the "potential ettringite" from forming, negatively affect porosity or permeability of the paste, or cause sulfate-bearing phases to migrate (such as into the CSH)?

On the same point, does the lowest temperature reported to cause DEF imply that DEF will not occur at lower temperatures, so simply mean that we'll have to wait longer for it to occur? Along that line, I note that in the early 1990s we received "Friday ties" cast in the mid 1980s that were not cracked. We left them outdoors. Two began to crack after the turn of the century, 15 years after casting.

Further, as sponsored by PCI and us, we have cast many prisms made with different cements and cured at various temperatures. All those cured at 90 °C have suffered DEF distress. One cured at 65 °C has expanded. Would one from the same mix, if cured at 50 °C, eventually crack? Have all or most of the investigators stopped their experiments after a few years?

Second, has the SO_3 content of the cement been adequately considered? If a portland cement having 4% SO_3 is used in concrete made at a w/c of 0.4, much of that water is required simply to make ettringite. Will all of the potential ettringite be formed at 1 day, 1 year, or 10 years? Interestingly, Gebhardt [1] found that in 1994, 31 portland cements produced in the United States had SO_3 contents of 4% or more (and one type 5 cement had an SO_3 content of 3.63%!).

Third, has the chemistry been well considered? For example, use of high-sulfur fuels provides a greatly different chemical reaction than considered by investigators who "duplicate" this situation by adding anhydrite to their experimental samples. SO_3 in fuel gases must change the chemistry of the kiln feed by "borrowing" a cationic group from it. For example, even when anhydrite is formed by the reaction:

$$SO_3 + 3CaO \cdot SiO_2 \rightarrow CaSO_4 + 2CaO \cdot SiO_2,$$

the anhydrite is now in the belite phase.

Fourth, are "holistic" conditions for occurrence required? In our experiments, non-alkali-reactive aggregates were used. Significant expansion occurred in the non-cracked concrete prisms, without even observable development of cracking during expansion. Certainly the "holistic" approach recommended by Collepardi must not be used to rule out DEF. ASR and microcracking may promote DEF, but neither are necessary. One of us (Hime) also believes that high temperature may not be required.

We must advance the State of the Art.

Reference

[1] Gebhardt RF. Survey of North American portland cements: 1994. Cement, Concrete and Aggregates 1995;17(2):145–89.

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