Pergamon

Cement and Concrete Research 32 (2002) 991

CEMENT AND CONCRETE RESEARCH

Discussion

Comment on the "Reply to the discussion by S. Chatterji of the paper 'Delayed ettringite formation in heat-cured Portland cement mortars' by Yang, Lawrence, Lynsdale and Sharp"

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Received 20 November 2000

Yang and coauthors discuss research showing that delayed ettringite formation (DEF) may occur at ambient temperatures [1]. My colleagues and I have discussed actual occurrences of this phenomenon in several publications [2–4]. The most discussed occurrence involved the "Friday railway tie" phenomenon that generated a great amount of negative press, much of it by experts for Portland cement producers and the Portland Cement Association.

Subsequent to our first paper, several researchers published their observations of non-heat-cured concrete undergoing DEF. It is reassuring that Yang and coauthors report their studies of late development of ettringite in mortars made at room temperature.

Our experience, including studies for Portland cement producers, has suggested that room temperature DEF can occur if the clinker component contains several percent sulfate. This conclusion is based on study of cements known to have caused DEF, and which have clinker sulfate levels of 3% to over 5%.

Arguments against this position and my criticism of them, include:

(1) "No commercial clinker can have such a high level of sulfate—the kiln couldn't handle it." This might be true if the sulfate was in the form of an alkali compound, but it need not be. For example, a kiln burning a high sulfur fuel produces SO_3, which does not react with the kiln feed to produce alkali sulfate.

(2) "High sulfate clinkers are readily soluble in water." Such arguments are usually based on experiments where gypsum is added to clinker and reburned at kiln temperatures. However, the kiln may be doing something entirely different. For instance, with high sulfur fuels, SO_3 is produced. For SO_3 to react with clinkers, it must "borrow" a cation. Even if the reaction is

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

the $CaSO_4$ may be well incorporated into the C_2S and not be "soluble" until substantial hydration has occurred.

Further, "solubility" of the sulfate compounds is usually measured by extracting with considerable quantities of water. But at water–cement ratios of 0.35–0.40, and considering reaction of much of the water to produce calcium hydroxide, ettringite and hydrated calcium silicates, surely there is not much water left to dissolve all the calcium sulfate in cements having 4–5% SO_3.

(3) "The presence of two-tone clinker relics proves high-temperature curing." This argument was used in the railway tie litigation. Diamond [5] has demonstrated that two-tone relics can occur at room temperature.

Obviously, more study is needed.

References

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[5] S. Diamond, J. Olek, Y. Wang, The occurrence of two-tone structures in room-temperature cured cement pastes, Cem. Conc. Res. 28 (1998) 1237–1243.

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PII: S0008-8846(02)00718-4