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Discussion

Reply to the discussion by J. Bensted and J. Munn of the paper "Thaumasite formation in Portland-limestone cement pastes"☆

S.A. Hartshorn, J.H. Sharp*, R.N. Swamy

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We should like to thank Prof. Bensted and Dr. Munn for their discussion of our paper on thaumasite formation in Portland-limestone cement pastes. They have correctly emphasised some of the major implications arising from our study. (Incidentally, there are two typographical errors in the first sentence of their discussion: 2°C should read as 5°C, and 30% limestone addition should read as 35%.)

The use of Portland-limestone cements will increase not only in Western Europe, but also across almost the whole world because of the pressures to enhance energy savings in cement production and to reduce carbon dioxide emissions. The fact that the presence of even 5% limestone filler can induce thaumasite formation tells us that, even though the amount found may be small, in exposure conditions, which are susceptible to sulfate attack, such as in foundations and sulfate-bearing soils, extreme care as to the amount of filler content needs to be exercised. Indeed, the French recommendations and practice, quite correctly, exclude the application of Portland-limestone cements not only in below ground structures, but also in marine exposure conditions. Existing research shows that deleterious effects on engineering properties can occur when Portland-limestone cements are exposed to sodium and magnesium chloride solutions as well [1]. Incorporation of 5% limestone filler in Portland cement is, however, much less threatening than when higher levels of replacement are used [2,3].

Prof. Bensted and Dr. Munn refer to the internal formation of thaumasite. No doubt such a possibility exists but, as pointed out in the discussion, such an occurrence also appears to be less widespread, at least for the time-being. However, more importantly, the internal formation of thaumasite could be much more complex because of the further interactions of carbonation with hydration products if chlorides are also additionally present.

It is true that the initial formation of thaumasite is gradual and time-dependent, but tests show that once the deterioration is initiated, its progress can be very rapid and catastrophic [2]. Often remedial measures may not be possible because of the lack of ready visibility and access to marine and below ground structures. This fact puts quite a different connotation to the use of Portland-limestone cements in environments where sulfates are abundant and/or accompanied by chloride or magnesium ions. The important role of the latter is highlighted in our original Discussion.

Bensted and Munn draw attention to the mineral, woodfordite, a solid solution between ettringite and thaumasite. We have had no experience of this mineral, but an interesting paper investigating the crystallography of solid solutions between ettringite and thaumasite has been published very recently [4]. This demonstrates that there is a probable discontinuity in the solid solution, characterised by a gap in the *a* dimensions between approximately 11.11 and 11.17 Å. This gap may indicate that there is a range of compositions in the solid solution series, which are unstable. It is likely that further solid solutions based on ideal thaumasite, such as sulfate- or carbonate-rich forms, will be identified, and their possible role in the durability of cementitious products can only be speculated upon.

References

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* Corresponding author. Department of Engineering Materials, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK. Tel.: +44-114-222-5504; fax: +44-114-222-5943.

E-mail address: j.h.sharp@sheffield.ac.uk (J.H. Sharp).

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