Pergamon

Cement and Concrete Research 33 (2003) 457–458

CEMENT AND CONCRETE RESEARCH

Discussion

Reply to the discussion by Duncan Herfort, Michael D.A. Thomas, Karen Scrivener of the review paper “Role of delayed release of sulphates from clinker in DEF”☆

Wiesław Kurdowski*

University of Mining and Metallurgy, Mickiewicz Avenue 30, 30-059 Cracow, Poland

Received 28 August 2002

I very much thank the authors for their interesting discussion. I agree with them that the idea to study two cements of identical chemical composition with different sources of SO_3: in one anhydrite from clinker and in another interground gypsum, is very interesting. I will try to make such experiment in the near future.

However, I must discuss with their opinion that my conclusions are not supported by the experiments presented in my paper. At the end of my reply, I will return to the problem that these conclusions are inconsistent with the data presented in literature.

It is important to underline that my first conclusion was that anhydrite in belite-rich and high-sulphate clinkers can form inclusions in belite and that such anhydrite can be the source of DEF expansion after heat treatment of the mortar at 90 °C. My conclusion is therefore different from that given by the authors of the discussion.

The tested cement 1 was composed only of ground clinker 1, which contained not only anhydrite, but also numerous inclusions of anhydrite in belites' grains. This cement gave the expansion of the mortar after heat treatment at 90 °C.

I wish to draw attention to three facts concerning this cement:

(1) This cement is sulphate-resisting and, according to Kelham [1], does not give expanding mortar after heat treatment.
(2) This cement contains a very low concentration of alkalis, namely, Na_2O_e is equal to 0.32% and, according to Kelham [2], the threshold value for cements giving expanding mortars is approx. 0.7%. In my experiments, I found a very similar value, slightly above 0.7% [3].
(3) In cases when anhydrite in the paste is quickly dissolved, the liquid phase of this cement would be rich in sulphates and poor in alkalis. In these conditions, ettringite will be stable during heat treatment [4].

Therefore there will be no expansion of the mortar.

For me, it is evident that in case of inclusions of anhydrite in belite, the sulphates will be released slowly and reacting with C_3A and C_4AF will give ettringite with expansion. This ettringite was found in expanding mortar in my experiments and the expansion reached 2.6 mm/m after 1200 days of water curing, i.e. till now. The reason for the different behaviour of this cement in comparison with the literature data is that the mortar expansion is caused not by the instability of ettringite during the heat treatment but by the slow release of sulphate from anhydrite inclusion in belite.

When cement contains interground gypsum (about 4% of SO_3), it will give expanding mortar after heat treatment if the content of alkalis is high (over 0.7%) and, consequently, ettringite is unstable during heat treatment [5]. In such a condition, the expansion will increase with alkali and C_3A content in cement [6]. I tested such cement similar to cement 1 of the following mineralogical composition [3]: alite 55%, belite 21%, C_3A 8% and C_4AF 9%, Na_2O_e 0.66, SO_3 1.2%. This cement with different SO_3 content from interground gypsum (2%, 4% and 6% SO_3) gives mortars with no expansion after heat treatment at 90 °C. However, with additional 2% of Na_2SO_4 or NaOH in this cement, the mortar expanded. Thus, this cement behaves consistently with the literature's data, but it does not contain any inclusions of anhydrite in belite, nor anhydrite at all.

I found the discussion to be very useful and I am sure that further study of belite-rich cements will give more information on their behaviour. At the same time, I support the opinion that the conclusions presented in my paper are proved with the results of the experiments.

☆ Cem. Concr. Res. 32 (2002) 401–408.

* Tel.: +48-12-617-20-29; fax: +48-12-633-15-93.
E-mail address: kurdowsk@uci.agh.edu.pl (W. Kurdowski).

PII: S0008-8846(02)00979-1

References

[1] S. Kelham, Effects of cement composition and fineness on expansion associated with delayed ettringite formation, Cem. Concr. Compos. 18 (1996) 171–179.

[2] S. Kelham, How to Avoid DEF, (Book of abstracts). Conf. Cement and Concrete Science, 2–3 September 1999, Keele University, IOM Communications, London.

[3] W. Kurdowski, Delayed Ettringite Formation in Case of Some Untypical Cements, in: W. Kurdowski, M. Gawlicki (Eds.), Proc. Int. Symp., Kraków, Poland, June 20–21, 2001, pp. 139–157.

[4] F.P. Glasser, D. Damidot, M. Atkins, Phase development in cement in relation to the secondary ettringite problem, Adv. Cem. Res. 7 (1995) 57–68.

[5] W. Wieker, R. Herr, H. Schubert, On the mechanism of secondary ettringite formation in "Corrosion of Cement Paste", in: W. Kurdowski (Ed.), Proc. Int. Coll., Mogilany, Kraków, Poland, 16–17 November 1994, pp. 3–12 (Kraków).

[6] S. Kelham, Effects of cement composition and hydration temperature on volume stability of mortar, 10th ICCC, Goeteborg, vol. IV, 1997 (paper ivo6o).