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A Reply to Discussion by B. Mather of the Paper "The Process of Sulfate Attack on Cement Mortars"*

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We thank Mr. Bryant Mather for his very useful discussion on our paper. We will address some points related to the discussion.

1. *The effects of formation of gypsum on expansion of cement mortar (related to points 1, 5, and 6 of the discussion).* The minerials of ettringite and gypsum are the major products in cement mortars that have been attacked by sulfate solution. In the circumstance of pore solution of cement mortar under sulfate attack, the formation of ettringigte is prior to the formation of gypsum, and causes the expansion of mortar. This is believed to be the major factor for the sulfate attack. However, the formation of gypsum needs to be considered for mortars that are made from cement composed less aluminate.

In our study of sulfate attack on cement mortar samples MQS (with aggregate of quartz sand) and MTQS (with aggregate of pretreated quartz sand), the relative amounts ($Xi/\Sigma Xi$) among minerals of ettringite, gypsum, and portlandite were tested in the samples that had been attacked by sulfate solution for 16 weeks. The testing method and major results published in reference [13]. Some data of the MQS sample, as well as the corresponding expansion, are shown in Figure 6.

Under the attack of sulfate solution, the expansions of samples are proportional to the aggregate contents (Φa). Although the expansion of the samples (Φa = 0.3~0.5) are much bigger than others, the relative amounts of ettringite do not increase largely. Because of the lower aluminate content of cement in this study, the amount of ettringite cannot be very high, even if most of the hydrated aluminate and hydrated sulfoaluminate were sulfated to ettringite. However, it is obvious in those samples that the amount of portlandite decreases and the amount of gypsum increases. It is meant that with the progress of portlandite sulfated to gypsum, samples expand continuously. Because the sulfate solution was renewed periodically, the contents of sulfate were maintained in a high level of the attack solution. It is possible that the formation of gypsum produces the pressure of crystallization in the samples.

The cement used in our study is a typical and widely used Portland cement in China. No high C_3A content cements can be found due to the technological conditions in China. Therefore, we quite agree with the opinion that if the experiments were remade with a cement of higher aluminate, more ettringite would be found in samples.

We believe that both ettringite and gypsum produced by sulfate attack causes the expansion of cement mortar if the contents of sulfate are maintained in a high level

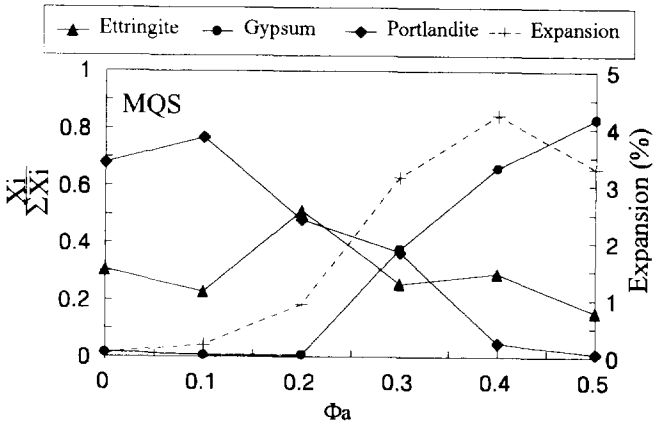

FIGURE 6. The relative amount ($Xi/\Sigma Xi$) in MQS samples and their expansion with aggregate content (Φa). Samples were attacked by 5% Na2SO4 solution for 16 weeks. $Xi/\Sigma Xi$: X is the amount of minerial; i is ettringite, gypsum or portlandite. Φa: Volume of aggregate over volume of sample.

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of solution. The relation between ettringite and gypsum should be that the formation of ettringite is earlier and causes the early expansion of cement mortar; after both the hydrated aluminate and hydrated sulfo-aluminate in situ are sulfated to ettringite, the formation of gypsum takes place and also causes the expansion.

2. *The formation of gypsum (related to points 2 and 4).* This is not the main subject of our paper. We agree with the author's view that the gypsum is produced through solution, but we believe the product of gypsum causes the expansion of cement mortar as mensioned above.

Reference

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