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Analysis of the time-dependent volume reduction of concrete containing silica fume

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Contribution by M. N. Haque

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I congratulate Dr Al-Sugair for providing very interesting data on the drying-shrinkage characteristics of normal and high strength concretes with and without additions of silica fume. The author concludes on the basis of his data, 'that the drying shrinkage strain increases as more SF is added to the concrete mixes'. This conclusion as it stands is true. I would, however, like to add the following:

First, the only difference in mixes NC2 and NC3 as compared to mix NC1 is that these contain additional quantity of 38 and 57 kg of SF, respectively. Put simply, NC1, NC2 and NC3 contain 380, 418 and 437 kg of total cementitious materials per 1 m³ of concrete, respectively. Other quantities (parameters) remaining the same, should not their drying shrinkage be in proportion to their total cementitious contents? Would you say that the increase in drying shrinkage of NC2 and NC3 as compared to NC1 is due to SF? While NC1 is 30 MPa concrete, NC2 and NC3 are 45 MPa concretes. Would not the shrinkage of these concretes be in somewhat similar order if the three concretes had plain cement contents of 380, 418 and

437 kg respectively? I would extend exactly the same argument in regard to HSC1 and HSC2. In fact, the difference between HSC1 and HSC2 is more stark; HSC2 contains 772 kg of total cementitious materials as compared to 643 kg for HSC1.

Now, I give you an example of our own data, which is yet to be published. These are two very high strength concretes (VHSC) of about 115 MPa 28-day compressive strength with water/cementitious material ratio of 0.23. Both contain 660 kg of total cementitious material. The first concrete contains 560 kg of Portland cement and 100 kg of SF; the second contains 395 kg of cement, 70 kg of SF and 195 kg of ground granulated blast furnace slag (GGBFS). The 56-day drying shrinkage strain of the first concrete is 400 while that of the second is 650 microstrain. In this instance, we may justifiably say that the presence of GGBFS has increased the drying shrinkage of the second concrete.

Second, without being too pedantic, the mix quantities of HSC2 as shown in Table 1 are not exactly correct. When one adds 129 kg of SF in the quantities

shown for mix HSC1, the yield HSC2 is certainly going to be more than 1 m^3 . Often, allowance for this is made by decreasing sand and/or coarse aggregate proportions to maintain the same yield.

Author's closure by F. H. Al-Sugair

I would like to start by thanking Professor Haque for his interesting discussion of the paper. I have a number of clarifications and comments to make in the following paragraphs.

First, in this author's opinion, the best way to objectively evaluate the effects of any additive on the properties of concrete is to prepare identical concrete mixes in all constituents with the only change being adding the material under investigation. This will result in comparing mixes with slightly different volumes. The key, however, is that the difference in yield is not large. So for example, in mix HSC2 in the paper, the addition of 128.6 kg of silica fume increases the volume of the mix by 5.8% only. To adjust the volume of the mix by decreasing the sand and/or coarse aggregates, as suggested by Professor Haque, would be worse than accepting the increase in the volume, since the mixture proportions will be

different; in addition, comparison with the data of other authors would become almost impossible.

Second, on reporting total cementitious materials (TCM) by adding the cement and the silica fume in this case, or the cement to other pozzolans in other cases. The water to TCM ratio could obviously be included; however, the extent of its use is questionable. The reason for this is that cement reacts in a primary manner in the concrete mix whereas pozzolans go through a secondary reaction. In other words, the reaction of silica fume or other pozzolans in a concrete mix depends on the extent of reaction which happens to the cement. Therefore, one could say that adding the weights of cement and the pozzolan used (in this case silica fume), results in mixing independent and dependent variables. A bigger problem exists when one attempts to correlate changes in concrete properties with TCM; for example, adding 50 kg of silica fume rather than the same amount of fly ash would yield the same TCM, but would certainly yield a concrete with different properties due to silica fume being a much richer pozzolan than fly ash.

In closing I would like to express my sincere thanks to Professor Haque for his stimulating comments and discussion.