Influence of Aggregate Size on Concrete Strength and Shrinkage

Q. *I'm the resident project representative responsible for administering the construction of a reinforced concrete building with two-way slabs and perimeter beams. The concrete mixture specification called for a 3/4 in. (19.0 mm) maximum aggregate size, but the contractor wants to use a mixture with 3/8 in. (9.5 mm) nominal maximum aggregate size. As long as the water-cement ratio* (w/c) *is maintained, would there be any significant changes in the strength of the concrete or drying shrinkage?*

A. In general, a decrease in the maximum coarse aggregate size may have advantages when it comes to concrete compressive strength: "internal weak planes may be less likely to exist, and the smaller particles reduce stress concentration effects at paste-aggregate interfaces."[1] Also, smaller-sized aggregate having a higher surface area would be expected to provide stronger bond between the cement paste and aggregate particles. However, a decrease in the aggregate size will increase the shrinkage.[2] A decrease in the nominal maximum aggregate size from 1-1/2 in. (38 mm) to 3/4 in. (19 mm), for example, will increase concrete shrinkage by about 25%.[3] Smaller aggregate has a larger surface area that must be coated with paste for workability.[4] The paste volume as a percentage of the total must therefore increase, and the aggregate content must decrease. In effect, the constituent responsible for shrinkage is increased while the constituent that restrains shrinkage is decreased. Figure 1 shows the effect of cement and water content on drying shrinkage, while Fig. 2 (Fig. 3.7 in ACI 224R-01[4]) illustrates the influence of *w/c* and aggregate content (volume) on drying shrinkage. Even if the *w/c* is held constant, shrinkage is likely to increase.

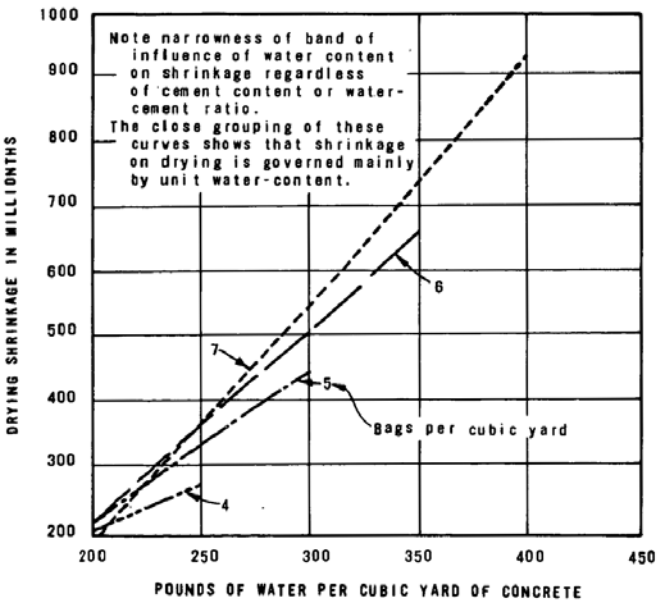

Fig. 1: Drying shrinkage of hardened concrete in relation to cement and water content in concrete mixture (based on Fig. 8 in Reference 5) (Note: 1 bag = 94 lb of cement; 1 lb = 0.45 kg)

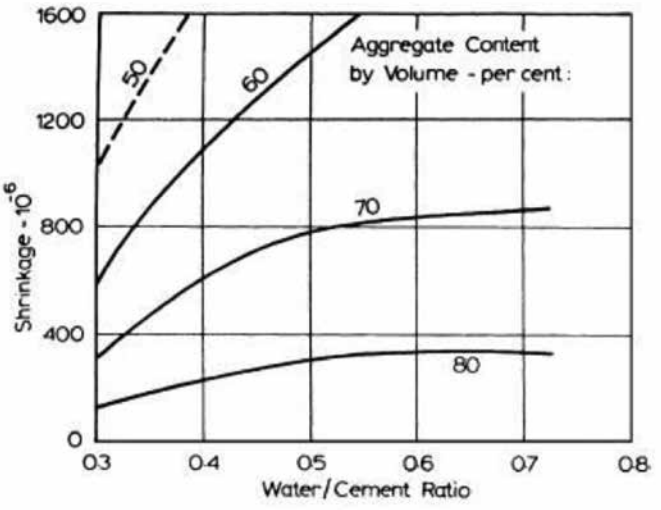

Fig. 2: Influence of *w/c* and aggregate content on shrinkage[6]

Questions in this column were asked by users of ACI documents and have been answered by ACI staff or by a member or members of ACI technical committees. The answers do not represent the official position of an ACI committee. Only a published committee document represents the formal consensus of the committee and the Institute.

We invite comment on any of the questions and answers published in this column. Write to the Editor, *Concrete International*, 38800 Country Club Drive, Farmington Hills, MI 48331; contact us by fax at +1.248.848.3701; or e-mail Rex.Donahey@concrete.org.

Additional information on shrinkage of mixtures in relation to water-cementitious materials ratios (*w*/*cm*), and shrinkage and cracking of concrete floor slabs can be found in References 7 and 8, respectively. Reference 9 also provides an extensive discussion of the causes of shrinkage cracking as well as mitigation measures such as shrinkage-reducing chemical admixtures and internal curing. Based on your question, the contractor is asking for change in the work (product substitution). If the contractor, owner, and you (as the architect's representative) agree to the change in the concrete mixture, the resulting change order should include the agreed tests to determine the mitigation measures.

References

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2. ACI Committee 209, "Report on Factors Affecting Shrinkage and Creep of Hardened Concrete (ACI 209.1R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 12 pp.

3. ACI Committee 360, "Guide to Design of Slabs-on-Ground (ACI 360R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 72 pp.

4. ACI Committee 224, "Control of Cracking of Concrete Structures (ACI 224R-01)," American Concrete Institute, Farmington Hills, MI, 2001, 45 pp.

5. *Concrete Manual*, eighth edition - revised, U.S. Bureau of Reclamation, Washington, DC, 1988, 627 pp.

6. Odman, S.T.A., "Effects of Variations in Volume, Surface Area Exposed to Drying, and Composition of Concrete on Shrinkage," *Proceedings of RILEM/CEMBUREAU International Colloquium on the Shrinkage of Hydraulic Concretes*, Madrid, Spain, 1968, 20 pp.

7. "Concrete Q&A: Shrinkage and *w*/*cm*," *Concrete International*, V. 35, No. 7, July 2013, p. 64.

8. Walker, W.W., and Holland, J.A., "The First Commandment for Floor Slabs: Thou Shalt Not Curl Nor Crack…(Hopefully)," *Concrete International*, V. 21, No. 1, Jan. 1999, pp. 47-53.

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