Within the last few years, major U.S. admixture suppliers have introduced a new category of chemical admixtures—shrinkage-reducing admixtures (SRAs). These products are aimed at significantly reducing the amount of shrinkage that occurs over time in concrete. (See “New Admixture Combats Concrete Shrinkage,” Concrete Construction, July 1996, pp. 546-551.) If shrinkage is reduced, proponents argue that reductions in cracking must follow.

Although these new admixtures are not covered by ASTM C 494-98, “Standard Specification for Chemical Admixtures for Concrete,” this does not mean there are problems with the products. Like other admixtures that have been introduced in recent years, the technology is moving faster than the ASTM consensus process can accommodate. However, specifiers and users should assure themselves that the admixtures meet the minimum “harmlessness” provisions found in ASTM C 494.

Also, like other new admixture products such as corrosion inhibitors or alkali-silica reaction inhibitors, SRAs fall into a category of admixtures whose benefits are not immediately apparent. It may be years before the benefits of these products, such as reduced cracking or reduced curling, are seen. Therefore, a specifier or contractor must place a great deal of confidence in the technical capabilities and credibility of the suppliers.

Let’s take a look at various types of shrinkage and how SRAs have fared since their introduction. Perhaps these products can be of benefit on one of your upcoming projects.

**Types of shrinkage**

Shrinkage is a reduction in the volume of concrete caused by the loss of moisture as concrete hardens or dries. Shrinkage is a very complex phenomenon; it’s not simply the movement of free water from the large capillaries within concrete. There are several types of shrinkage, and SRAs are not designed to combat all of them.

Plastic shrinkage occurs as fresh concrete loses moisture after placement and before any strength development occurs. The amount of this shrinkage depends on air temperature, relative humidity, concrete temperature and wind speed. SRAs are not being marketed to address...
Fearing amounts of shrinkage. Autogenous shrinkage results from the chemical reactions that take place as portland cement hydrates. This shrinkage takes place without the actual loss of any water from the concrete and is difficult to measure because it starts before the standard shrinkage test begins (ASTM C 157-93, “Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete”). It’s also difficult to separate the effects of autogenous shrinkage from drying shrinkage. Fortunately, the effects of autogenous shrinkage are overshadowed by the effects of drying shrinkage, unless the water-to-cementitious materials ratio of the concrete is very low, say less than 0.30. While SRAs may play a role in reducing this type of shrinkage, it is not the primary target.

Drying shrinkage is what most of us think of as “true shrinkage.” This type of shrinkage involves the movement and loss of water within the extremely small pores of the hydrated cement paste and from within the structure of the hydration products, or gel. As the concrete dries in service, moisture is lost from these very small pores, and menisci form. The surface tension of the water associated with these menisci pulls the pores together, resulting in a loss of concrete volume. SRAs are designed to decrease drying shrinkage by reducing the surface tension of the water in these pores.

Additional drying shrinkage is caused by the loss of adsorbed water from the gel. But this shrinkage is probably not affected directly by the presence of SRAs because the spaces involved are too small for menisci to form. Since SRAs don’t address both mechanisms of drying shrinkage equally, they reduce rather than eliminate shrinkage.

Drying shrinkage is further complicated by the role of the concrete components. Different combinations of cementitious materials, aggregates, water and chemical admixtures can result in concretes with differing amounts of shrinkage. Therefore, be careful when interpreting the results of shrinkage testing, and be sure to test project-specific materials.

Also be aware that reducing cracking caused by drying shrinkage will not necessarily reduce all cracking that takes place. Often cracks caused by thermal shrinkage, or the reduction in the volume of concrete as it cools, are misidentified as cracks caused by drying shrinkage. SRAs are not intended to reduce thermal shrinkage.

Dealing with shrinkage conventionally

The conventional wisdom for dealing with shrinkage has three primary recommendations. First, use a concrete with a low total water content. It’s not enough to use a low water-to-cementitious materials ratio if the concrete contains a lot of cement. Second, use a lot of aggregate and as large an aggregate top size as is practical for the placement. Adding aggregate reduces paste content, and it’s the paste, not the aggregate, that ends up shrinking. Finally, wet cure the concrete for as long as practical. Though this step will probably delay and reduce shrinkage, it will not preclude all cracking.

Another more active approach to minimizing shrinkage has been to offset the anticipated volume loss by causing the concrete to expand initially through the use of a shrinkage-compensating (Type K) cement or a separate expansive agent. This approach is well established but requires careful attention to design and planning. (See “Using Type K Cement in Waste-Containment Structures,” Concrete Construction, October 1998, pp. 864-868.)

Before considering SRAs

The major advantage of using SRAs is simplicity. Just dose the concrete with the chemical, and don’t worry about cracks caused by drying shrinkage. The applications targeted by the admixture suppliers have been flatwork, parking structures, bridge decks and environmental structures such as tanks.

Testing of the products by the manufacturers certainly shows them to be effective in reducing drying shrinkage. But be careful interpreting the manufacturer’s data because, as noted earlier, each concrete is different, so the amount of reduction will depend upon the materials you use.

As effective as SRAs seem to be, you should pose the following questions before specifying or using one of these products:

What are the effects on fresh concrete properties? This and the effects on the hardened concrete properties make up the harmless testing mentioned earlier. Because there is no ASTM standard, you need assurance that the product doesn’t change the nature of the concrete. However, some changes may not be a problem if you are aware of their nature ahead of time.

What are the effects on hardened concrete properties other than shrinkage? For example, reductions in compressive strength up to 15% have been reported in concretes containing SRAs. It’s much better to find out this information before the first set of 28-day project cylinders is broken since this reduction is easy to overcome by adjusting the concrete mix proportions. Another approach is to consider specifying strength at later ages, such as 56 days. Strength loss caused by the SRA may be...
overcome at the later age.

- What is the effect on durability? One SRA supplier sent out a memo to specifiers cautioning them against using the product in concrete exposed to freezing and thawing. Another supplier recommends a high and tight air-tolerance requirement for the in-place concrete (7 ±1%). Apparently, failure to meet this air limit can have very serious consequences. Make sure you are comfortable with the restrictions that may be imposed by the product you select.

- What exactly does the shrinkage data from the relatively small test specimens required by ASTM C 157 mean in the real world? How do the results of shrinkage testing, with or without reductions in shrinkage, apply to actual structures? Very few structures have the same surface-area-to-volume ratios as the test specimens, and because of this, drying behavior differs from that of the small specimens. This is probably the most difficult question of all to answer, and the best way to address it is to relate how similar structures, where shrinkage data are available, have behaved in service. Applying engineering judgement will be necessary here.

- What is the impact on cost? These admixtures are relatively expensive, adding $25 or more (depending on the dosage) to the cost of a cubic yard of concrete. Can this additional expense be justified? Can it be offset by changes in design or construction? For example, can joints be eliminated or joint spacing extended? Can the number of prestressing strands be reduced if shrinkage is less? How much will SRAs reduce curling in critical floor slabs? SRA suppliers are studying all of these questions, but not enough hard data are yet available to help justify the additional costs.

**How are SRAs being used?**

Primarily, SRAs are being specified and used for projects where reducing shrinkage is seen as highly beneficial or necessary, even if it’s not immediately possible to calculate what the cost tradeoff will be. In essence, owners and specifiers are saying that, for these applications, any improvement is worth the cost, or that eliminating anticipated remedial actions may offset the cost of the SRA.

An example of such a project is the construction of concrete water tanks during a recent upgrade at the Burbank, Calif., water reclamation plant. An SRA was used at a dosage of 1/2 gallon per cubic yard of concrete. The tanks passed the required hydrostatic test on the first attempt, eliminating the expense of repair and retesting.

Another use of SRAs is to offset the effects of certain high-shrinkage aggregates. For this application, it’s important to compare the cost of the SRA required to get concrete containing high-shrinkage aggregate to within acceptable limits to the cost of using a better aggregate. Don’t forget that if you optimize such a mixture for shrinkage and then change cements, you may change the effects of the SRA.

Elimination of shrinkage cracking would be a tremendous boost to the use of concrete. By offering a reduction in drying shrinkage, SRAs appear to have the potential of being significant steps along the path to reduced concrete cracking. However, before using one of these products, ask the manufacturer how it will affect your specific project and materials. By following the progress of SRAs over the coming years, we may learn more about their effects and potential benefits.

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