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IMPROVING CONCRETE DURABILITY

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SHRINKAGE COMPENSATION COMPONENTS OFFER MANY BENEFITS

Today's concrete marketplace provides many challenges to the production and placement of quality durable concrete. Cement production is being pushed to meet increasing concrete demands, resulting in the use of blended cements containing slag, fly ash, and silica fume as secondary cementitious materials. Concrete suppliers are using blended cement as a means to remain competitive while meeting performance specifications that usually are focused on strength and plasticity. In turn, owners and design professionals are increasingly placing specification limits on allowable shrinkage of the placed concrete mix to minimize shrinkage cracking. Unfortunately, the slag, fly ash, and silica fume used to make blended cements, as well as some of the aggregates used in a concrete mix, can all contribute to the plastic shrinkage of many concrete mixes. Fortunately, there is a class of cementitious components that produce a shrinkage-compensating concrete (SCC).

Shrinkage-compensating components can be used to everyone's benefit to atone for drying shrinkage by creating a temporary expansion in the curing concrete and a residual expansion in the hardened concrete. The standard to use for design, supply, and placement of shrinkage-compensating concrete is the American Concrete Institute's (ACI) publication 223, Standard Practice for the Use of Shrinkage-Compensating Concrete. There are multiple manufacturers producing shrinkage-compensating components or cement, creating a competitive market with the full support and protection offered by using ACI standards and guidelines, as well as ASTM test procedures.

History Shrinkage-compensating concretes have been used successfully in the United States and other parts of the world—particularly the Pacific Rim area—for more than 50 years. Until recently, use in the United States has been limited to shrinkage-compensating cements, while concrete and components have been used elsewhere. Recently, ACI Committee 223 Shrinkage-Compensating Concrete, has reviewed and accepted testing done on components and revised its standard practice document to include shrinkage compensating components in addition to shrinkage-compensating cements.

Approval of such components has made SSC much more competitive because of reduced shipping costs. The ready-mix producer realizes additional savings since the component becomes just another additive to a standard mix, while shrinkage-compensating cement requires storage and special handling that increases the cost of the concrete.

TYPES

Shrinkage-compensating concrete is achieved by an expansive mechanism that is formed during the curing of the concrete. Currently, Type G and Type K SCCs are produced and marketed domestically, but in its next edition, ACI 223 will recognize four types of shrinkage compensating concrete—G, K, M, and S. Type G is achieved by the formation of calcium hydroxide platelets in the curing concrete. Type K is achieved by the formation of ettringite crystals in the curing concrete. While these mechanisms form at a slightly different rate, the end results and benefits are comparable.

As the concrete begins to cure, the expansion mechanism is activated and the curing concrete starts to bond to the reinforcing. The expansion forces in the concrete try to stretch the reinforcing, but the resistance of the reinforcing is much greater, resulting in a compressive force being built up in the concrete. This restrained expansion is necessary and required since it provides the compressive stress in the concrete that is relieved as the expansion mechanism dissipates after the concrete hardens. Ideally, the concrete mix design is formulated and tested so that a residual compressive stress remains in the concrete, as indicated on the expansion curves. Since the concrete remains in this compressive mode, tension forces do not develop in the curing concrete and drying shrinkage cracking is eliminated. Manufacturers' recommendations should be followed to determine the correct dosage of each component or cement to use for trial-mix designs.

ASTM C878, Test Method for Restrained Expansion of Shrinkage-Compensating Concrete, should be performed to determine expansions at different component dosages to select the trial mix meeting specification requirements.

BENEFITS

A systems approach—in which the design engineer, concrete supplier, and placement contractor perform as a team with each member performing their function in accordance with ACI 223, will result in a concrete placement with greater durability, better performance, and often at a lower cost than the same project using conventional portland cement concrete.

Shrinkage cracking—Both micro and macro shrinkage cracking is reduced greatly and often eliminated when using SCC. While drying shrinkage compensation is the primary purpose for using SCC, secondary advantages provide the user with additional benefits.

Shrinkage control—Concrete made from blended cements containing slag, fly ash, or silica fume are subject to increased plastic shrinkage. Aggregates, such as those common in some parts of the western United States, also can contribute to increased plastic shrinking and cracking. Tests can be performed to predict the shrinkage in concrete mixes containing one or more of these ingredients.

A shrinkage-compensating component can be added to this mix in various trial amounts and ASTM C878 tests performed to provide data on which mix design to select that will keep shrinkage within desirable specified limits.

Contraction joints—Joints, particularly in large slabs-on-grade, can be greatly reduced or eliminated. Figure 1 depicts a typical warehouse or big box retail store floor slab constructed with conventional portland cement concrete.

Slab curling—The expansion process inherent in SCC greatly reduces the tension at or near the top surfaces, which can result in edge curling.

Reduction or elimination of this curling reduces or eliminates future joint maintenance.

Maintenance costs created by floor joint deterioration are greatly reduced also.

Reduced permeability—Elimination of plastic shrinkage cracking, both micro and macro, eliminates penetration paths for liquids to enter the concrete.

Elimination of bleed water also eliminates the pore holes through which excess mix water rises to the surface.

These pore holes in conventional concrete then become entrance paths for moisture to permeate the concrete.

Elimination of these two entrance paths greatly reduces the structures' susceptibility to freeze/thaw damage.

Permeability through the concrete matrix itself is reduced by the residual compressive force remaining in the concrete. While SCC increases impermeability, generally by a factor of four as compared with regular portland cement concrete, there are other components that are much more efficient at reducing permeability. The combination of these three factors—shrinkage cracking elimination, pore hole elimination, and residual compressive stress—make SCC an excellent material for bridge decks in areas where deicing materials are applied to the driving surface, or the structure is exposed to marine conditions.

There are examples of bridge decks constructed with SCC that have been in service for more than 20 years without signs of salt penetration or notable deterioration on the bottom side of the deck.

Performance—The ability to place large, concrete monolithic structures without contraction joints, construction seams, or shrinkage cracks makes SCC an ideal choice for primary and secondary containment structures. Elimination of these potential leak paths to the environment could prevent environmental contamination and the subsequent environmental cleanups. Environmental structures such as water treatment plants, sewage treatment facilities, and storage structures for hazardous materials are a growing market for SCC.

Treatment plants benefit from the increased abrasion resistance of SCC.

ACI 223-98, Section 2.5.7 Durability, cites a 30- to 49-percent increase in abrasion resistance, but actual abrasion resistance could be higher depending upon project and construction specifics.

Costs—Although costs can vary considerably depending upon project type, size, and location, adding a component to a standard mix design will increase concrete costs per cubic yard.

However, other factors—including elimination of contraction joints, fewer placements, and larger monolithic placements—will result in construction savings that usually are greater than the modest increase in concrete costs. Long term maintenance cost savings, such as decreased joint maintenance, are factors in life-cycle cost and do not impact construction cost. A longer structure life span results in the lowest per year lifecycle cost for the owner.

SPECIFICATIONS

Recommended dosages of the calcium hydroxide and ettringite components are different per cubic yard of concrete and should be verified by ASTM C878 tests to determine the proper mix design.

Follow component manufacturers' recommendations to ensure proper use of their products to achieve the desired result. Specifications for either the Type G or Type K component should start with the concrete supplier's standard mix design for the specified concrete strength. Then, add shrinkage-compensating component amounts based on a percentage of cementitious material in the standard mix and manufacturers' recommendations.

ASTM C878 tests should be specified and the test results used to select the proper mix design that meets specification requirements. Smaller amounts of component can usually be added directly to the concrete mix, since this amount is within the tolerance limits of many concrete batch plants. For larger dosages, or for exact cubic yard quantities, it is recommended that the component be substituted for equivalent sand, secondary cementitious materials, or portland cement, [as recommended by the Type G or Type K manufacturer]. Once the project mix design is selected, follow good concrete placement practices as recommended by ACI.

RECOMMENDED USE

Adding a shrinkage-compensating component to any concrete mix will improve the quality and characteristics of that concrete mix placement. There are, however, several types of projects where the intrinsic characteristics and benefits of SCC make it a desirable building material. These projects include the following:

- warehouse, big box store floors, and other floors where contraction joints may be objectionable or undesirable;
- bridge decks, truck aprons, and other pavements subject to deicing material exposure;
- bridge decks, docking facilities, and other structures subject to marine exposure;
- parking structures;
- primary and secondary containment structures for storage of hazardous materials;
- catch basins and containment areas where hazardous materials are processed or transferred;
- precast or cast-in—place components for ocean-front structures;
- water treatment plant facilities; and wastewater treatment plant structures

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