Low Shrinkage and Shrinkage Compensating Concrete Benefits

By William S. Phelan

Low shrinkage concrete is of great interest to owners, designers, contractors and concrete producers. High shrinkage is of concern since it increases the cracking potential when coupled with restraint. Many specifications today require a maximum of 0.04% shrinkage at 28 days as tested in accordance with ASTM C 157 Modified *Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete*. The test involves moist curing for seven days followed by shrinkage measurements at 7, 14, and 28 days. These tests are easily run and establish the fact that a low shrinkage mix is being used. Shrinkage tests from field specimens are rarely done. The verification of the mix is made by use of the Microwave Test, which confirms the water content as being the same as that in the tested mix. Concrete is a product manufactured on the job, and cement and aggregates change daily. The assumption is that, if the water content is verified, the change in shrinkage will not be significant.

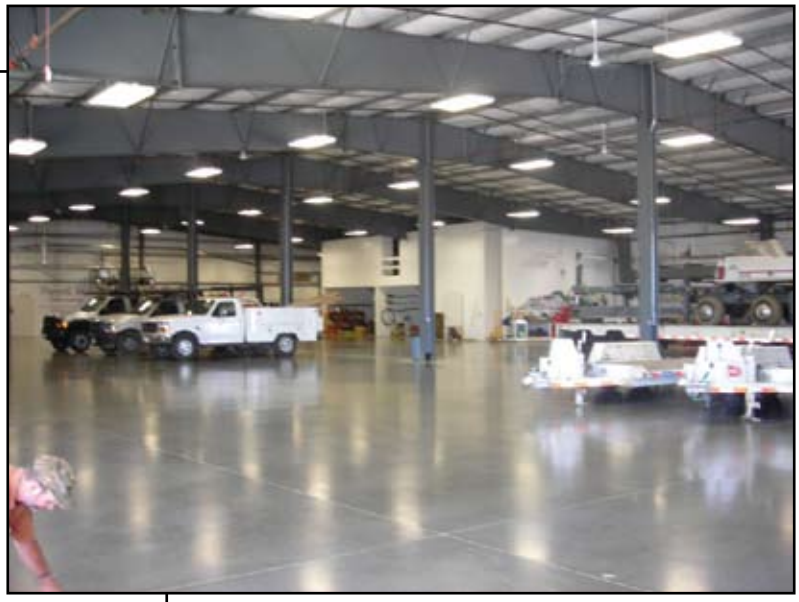

Figure 1.

If the shrinkage target of 0.04% at 28 days cannot be achieved in a given area, there are several choices to achieve it. A shrinkage-reducing admixture or a shrinkage-compensating admixture (Expansive Component) may be added to the mix. Samples of both mixes are listed in *Table 1*.

Messrs. A. Borsoi, M. Collepardi, J.J. Ogoumah Olagot, R. Troli, and E. Strazzer, in their paper titled *Combined Use of Chemical Admixtures and Polymer Macro-Fibers in Crack-Free Industrial Concrete Floors Without Wire-Mesh*, (Eighth CANMET/ACI International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Supplementary Papers, Sorrento, Italy, October 29 – November 1, 2006), stated their goal was to achieve a crack-free slab and eliminate wire-mesh. They did long term shrinkage testing on four mixes.

They used a shrinkage reducing admixture, superplasticized, structural macro fiber mix with a shrinkage of 0.025% at 6 months. They were able to build a crack-free slab, with no curing and with joint spacing at 8 meters (26.2 feet).

A similar approach was reported in *Concrete International* in January 2008 in an article titled "Standing on a Success Story". The concrete contractor, Poppoff Inc., installed a six inch thick slab with joint spacing of 25 feet x 20 feet, 10 inches, and used a high range water reducing admixture and macro synthetic fibers to achieve a crack-free floor at the 14-month walkthrough. (*See Figure 1*) The shrinkage of this mix design was 0.038% at 28 days.

The target shrinkage must be selected and shrinkage tests run. Shrinkage can be reduced by using a shrinkage-reducing admixture, or using a shrinkage-compensating component

Table 1.

	Distribution Center Rialto, CA	Structural Services Inc. Project
Cement	450 lbs.	520 lbs.
Fly Ash/Slag	80 lbs (Fly Ash)	
Fine Aggregate	1248 lbs.	1220 lbs.
Coarse Aggregate	1653 lbs. (#467 Stone) 325 lbs. ⅜" Stone)	630 lbs. (1½") 630 lbs. (¾") 630 lbs. (⅜")
Water Content	275 lbs.	310 lbs.
Air Content (Entrapped)	1.0%	2.0%
Shrinkage Reducing Admixture (SRA) or Expansive Component	64 oz.	100 lbs.
Water Reducter (Type A) or HRWR (Type F)	35 oz., Type F	18.6 oz., Type A
W/cm	0.52	0.50
Initial Slump (Water)	2" - 3"	
Final Slump	5" - 7"	4"
Shrinkage	0.035% with shrinkage reducing admixture*	Slight Expansion

** This mix, without the shrinkage-reducing admixture, had a shrinkage of 0.055% at 28 days.*

to offset shrinkage by causing sufficient expansion to result in the slab being slightly in compression for the long term. Even high strength concrete, 10,000 to 16,000 psi at 56 days, can achieve shrinkage of less than 0.04% at 28 days. The high cementitious content seems to be counterbalanced by a w/cm of 0.27 to 0.33. It is essential to run shrinkage tests to determine the shrinkage base line with the particular constituents to be used on a project. Crack reduction is the goal of many structural owners and designers. A low shrinkage mix or expansive concrete mix requires proper placement, consolidation, and curing to maximize the concrete potential and to minimize cracking. The initial curing procedure must start immediately after the strike off of floors, slabs, and toppings. The final curing procedure must begin immediately after final finishing. An irregular base under slabs-on-grade and existing slabs below toppings provide tremendous restraint, and can cause significant cracking.

In analyzing shrinkage reduction or expansive concrete, it is quite revealing to compare the cost of a standard low shrinkage mix of 0.04% at 28 days versus a shrinkage reduction offered by the use of a shrinkage reducing admixture. For example, if the original mix has shrinkage of 0.04% at 28 days, it has a shrinkage of 0.24 inches in 50 feet (one bay ±). A shrinkage reducing admixture could reduce that shrinkage 50% or to 0.12 inches in 50 feet. How much is the owner willing to pay for that reduction?

A shrinkage compensating concrete will have square placements with a 100-foot ± width. That cost should be compared to a typical bay, with 9 panels, versus joints only at the perimeter of a 10,000 square feet area. What is the cost reduction for the elimination of the interior contraction joints with semi-rigid joint fillers and the requirements for periodic maintenance and potential curling problems?

Many engineers use the following guidelines:

- Run shrinkage tests on locally available aggregates and cement proportioned on the basis of "Admixtures and Aggregates: Key Elements in 'Athletic Concrete' Revisited", *Concrete International*, September 2004.
- Review the benefits of reduced contraction joints, with respect to curling, breakdowns, and maintenance, on a long-term basis.
- Would the use of a shrinkage reducing admixture or expansive concrete significantly benefit the project? What are the relative costs?

Millions of square feet of floors, slabs, and toppings have used these approaches successfully. Success is based on placing, consolidating, finishing and curing (promptly) floors, slabs, and toppings using low shrinkage or expansive concrete mixes.▪

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Mr. Phelan has been published in both Concrete Construction Magazine and Concrete International Magazine. His latest articles include:

"Admixtures and Aggregates: Key Elements in "Athletic Concrete" – Revisited," *Concrete International*, September 2004
"Slaying the Curling Dragon," *Concrete Construction*, January 2002
"Admixtures and Aggregates: Key Elements of Athletic Concrete," *Concrete International*, April 2000
"Planning leads to high-performance floor," *Concrete Construction*, December 1999
"Admixtures and HPC: A Happy Marriage," *Concrete International*, April 1998
"High-Performance Concrete for Wear Resistant Floors," *Concrete Construction*, October 1997
"The Pre-Slab Conference – Essential for a Successful Floor," *Concrete International*, October 1994