Shrinkage Compensating Concrete: New Innovations

By W.B. King

While the benefits to concrete applications are numerous, there are draw backs. The process of curing wet concrete includes the loss of moisture which normally leads to concrete contracting, for example. This effect is also referred to as "drying shrinkage" which creates stresses that cause the concrete to crack. In short, concrete's shrinkage factor is like its kryptonite.

And from a manufacturing perspective, concrete that cracks means unsatisfied customers. Since the 1960s, scientists have been hard at work in hopes of developing formulas that would produce the same strength as traditional concrete applications but reduce the shrinkage factor. No easy task. The outcome has been a number of applications that fall under the category of shrinkage-compensating concrete (SCC).

Type K

The most well-known SCC is Type K Concrete also known Expansive Concrete. Over the last forty plus years, Type K Concrete has been used in the United States for thousands of slabs totaling hundreds of millions of square feet. In the early 1960s, however, it was called "self post-tensioning concrete." The rather long name emerged because as the concrete attempted to expand it would try to stretch the rebars forcing tension and itself into compression. This process is ideal since that is the preferred stress to have on each of those materials. As a result, Type K slowly became known within the industry, although many remained cynical. This cynicism has lessened over time due to success rates.

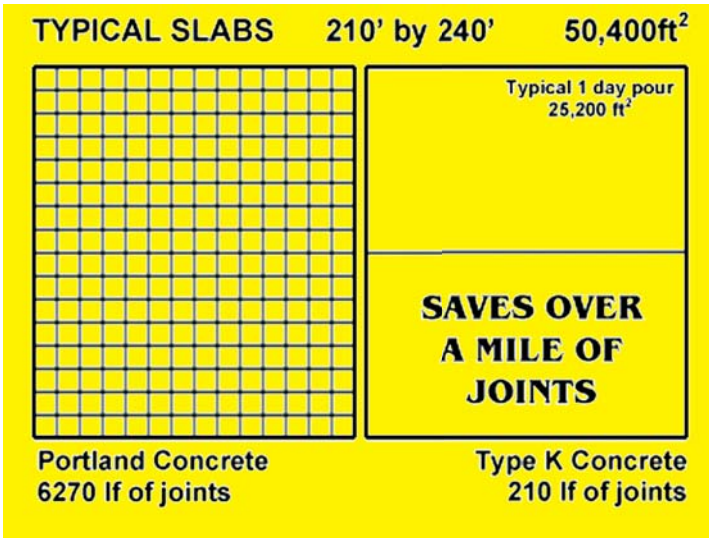
Type K cement contains a sulfoaluminate (C4A3S) compound which differentiates it from other cements. During the hydration process the sulfoaluminate forms ettringite, an expansive material. This ettringite formation creates an initial expansion in the concrete during the first few days of curing. After maximum expansion is reached, the Type K cement concrete shrinks at approximately the same rate as Portland cement concrete, and the eventual net volume change is near zero.

How Type K Concrete Works

David Flax, General Sales Manager for Cypress, CA-based CTS Cement Manufacturing Corp., explained that for the first seven days after placement, concrete expands slightly. Most of the potential expansion is restrained by the reinforcement, he noted. "This restraint puts the reinforcement into tension and the concrete into compression, which is where these two materials work best. After seven days as the concrete dries, it merely shrinks the little bit that it had expanded and relieves the stresses in the reinforcement and concrete," he continued. "The concrete ends up the same size as when it was poured and in a neutral stress condition."

Besides the expansion, the other major factor that makes Type K Concrete work is that much more water is tied up in the hydration process. Flax explained that concrete is typically placed with a .45 to .50 water/cement ratio (w/c). Portland cement only needs about a .25 w/c for full hydration. "The rest of the water, known as water of convenience, is just there to help the contractor place the concrete and all that excess water has to come back out of the concrete," said Flax. One cubic yard of a typical 3,000 psi Portland concrete mix with a .50 w/c has an extra two cubic feet of water. There are only 27 cubic feet in a cubic yard and two of them must come back out. Type K concrete requires a .38 w/c for full hydration, so there is much less excess water. "Eliminating that huge volume change is a large factor in eliminating shrinkage," noted Flax.

Very large placements of 20,000 to 50,000 square feet without control joints are common with Type K Concrete. Flax offered the following example. Take a 50,000 square foot slab, which is about the size of an average grocery store. Assuming 15' joint spacing in the Portland concrete slab means that there would be 28 joints. If the joint spacing were only 12', there would be even more joints. [Note that there is only one joint in the Type K Concrete slab and the only reason that there is even one construction joint is that many contractors don't want to place 50,000 square feet in one day.] The end result is that there are only 210 lf of joints with Type K Concrete instead of the 6,270 lf of joints that are required for a Portland concrete slab, which means that over a mile of joints are eliminated on this relatively small slab by using Type K Concrete. [See image: Typical Slabs].



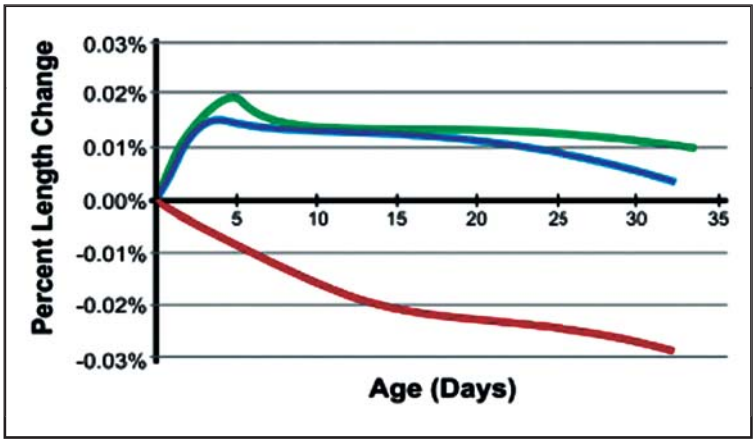
Type K: The Next Generation

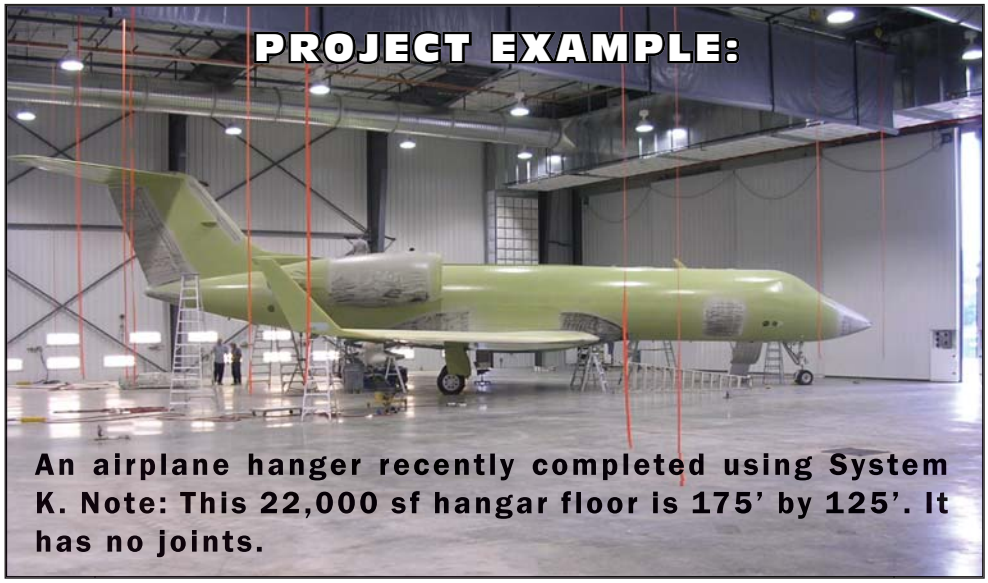
Type K Concrete has been designed to expand but the major problem is that expansion is restrained by the reinforcement. And while this formula is necessary, testing to find new applications began a few years ago to see what other materials might be used instead of steel. "We have shown that the same restraint can be accomplished using synthetic micro-fibers," said Flax.

To this end, extensive testing was done under the auspices of the UCLA Department of Materials Science and Engineering to determine if small synthetic micro-fibers could restrain the expansion of the Type K Concrete as well as the steel had been used to restrain that expansion for over forty years.

Nearly a year was spent testing many dozens of different synthetic fiber materials, configurations, lengths, diameters, and dosages, explained Flax. Hundreds of ASTM C-878 and ASTM C-806 beams were cast and measured for expansion and shrinkage over time. The ASTM C-806 bars are 2" by 2" by 10" mortar bars, while the ASTM C-878 bars are 3" by 3" by 10" concrete bars including coarse aggregate. Once stripped the bars were immersed in water for seven days and then allowed to air dry. They were measured daily with a length change comparator for the first seven days and then weekly thereafter.

All this testing resulted in the creation of a new fiber called K-Fiber, which works just like rebars to restrain most of the potential expansion of the Type K Concrete. "When the concrete dries it shrinks the little bit that it had expanded and relieves the tension in the fibers and the compression in the concrete to end up the same size that it started in a neutral stress condition," said Flax. [See: Percentage Length Chart]





An airplane hanger recently completed using System K. Note: This 22,000 sf hangar floor is 175' by 125'. It has no joints.

Eric P. Bescher, Ph.D, Adjunct Assistant Professor at UCLA oversaw the project. "Results show that out of the many systems we tested CTS's K-Fiber provided suitable restraint when mixed with CTS's shrinkage-compensating cement," he noted.

The new K-Fiber has a patent pending and, because the fibers are only ¼" long and monofilament, they do not create finishing problems and they are invisible on the surface. Flax explained that System K [15 percent expansive component] is a mixed with 85 percent Portland cement. For small jobs, the mix is available in 90 pound bags but truck [25 tons] load and rail car [100 tons] loads are shipped weekly. For each yard of pour, one water soluble bag of resin is required. "We encourage customers to acquire the Portland cement locally so as to cut down on the amount of product we need to ship," he said.

Field Test

One of the initial field test of System-K was a 50' by 6' by 6". This testing was designed to demonstrate that the System-K with K-Fiber instead of steel is dramatically better than Portland with rebar and slightly better than Type K with rebar, noted Flax. After a few months the Portland Concrete section had the usual drying shrinkage cracks every 6' to 8', but after three years there are still no cracks in the Type K Concrete or System-K Concrete. "This is amazing in light of the fact that the length to width ratio for the sections was over 8:1, which far exceeds the ACI recommendation of 2:1 maximum," he said.

Flax says there are adjustments to be made when using System K. "One draw back is that it requires a seven day wet cure which some contractors have a hard time with but you can make the time in other ways by concentrating on other aspects of the job that would be otherwise spent if not using System K such as the time you save cutting rebar," said Flax. He recommends Hyrdro Cure to ensure a proper "pond" effect during the all-important seven day wet cycle. .

System-K at the Job Site Can Save Time and Money

With System K you do not need:

- Rusty rolls of welded wire fabric
- Chair up the steel reinforcement
- Ready mix trucks and laser screeds driving on the steel
- Keep steel properly positioned in the concrete
- Workers' with the hooks
- Block the pump lines
- Dowel baskets

And there is no:

- Sawcutting
- Plastic cracks

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- Crazing cracks
- Drying shrinkage cracks

System K Cost Saving Potential:

- Rebar: eliminating temperature steel saves a tremendous amount of money in steel cost
- Rebar installation and job-day labor for hooking are eliminated.
- Without rebar the project can often be tail-gated eliminating the cost of pumping.
- Without sawcut joints the costs of dowel baskets and sawcutting are eliminated.
- Without sawcuts the costs for material and labor to fill the sawcut joints are eliminated.
- With 90 percent fewer joints the costs for spall repairs are significantly reduced.
- Without curling the cost for grinding is eliminated.
- Without joints and curl the cost to repair tilt-up panels is minimal.

Without joints and curl the on-going maintenance costs are reduced. Per a recently published survey, ninety-two percent of facilities managers said that joints were their number one repair concern.

While the benefits of using System K have been reported and implemented, skeptics, not unlike the early days of Type K, say that the technology is its infancy. To this point, Flax concedes that product testing only dates back roughly four years. To the skeptics, who he points out are also some of his customers, he says time will tell. "Some people are conservative in their thinking and I respect that," he continues. "But we're not going anywhere and we have time. They'll see." And while research is gathered, companies are lining up for System K to the point that CTS Cement is currently building a new manufacturing plant in Missouri.

About the Author

W.B. King is an award-winning journalist with over ten years experience writing for national and international business, technology, lifestyle, and healthcare publications. He has ghostwritten two feature length corporate history books, and operates www.enewsletterinsights.com, an all encompassing business writing service specializing in e-newsletters. He lives outside New York City with his wife Rita, and their dog, Riley. He can be reached at: brad@enewsletterinsights.com.