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HP concrete flexes its muscles

High-performance concrete is being used on bridges throughout the U.S., but to reap its benefits care must be taken when batching and mixing

by Tony Kojundic

As the use of high-performance (HP) concrete with microsilica increases on bridge decks, engineers and contractors need to understand that the material requires a keener eye to the batching sequence, better mixing, and equipment capable of meeting ASTM C 94 uniformity standards. If basic, good concrete practices are followed with no shortcuts taken, the resulting concrete will live up to its high-performance name.

While there have been a few isolated problems with HP concretes, these can be traced back to improper batching, mixing or equipment problems. As DOTs loosen bidding guidelines for approved ready-mix contractors, the burden falls on the engineers and contractors to ensure that the concrete producer uses the most up-to-date procedures and equipment to avoid such problems.

To properly batch HP concrete, first simultaneously add the course aggregate, fine aggregate, a minimum of 75% of the batch water, water reducers and air-entraining admixture. Photo courtesy of Elkem Materials. Photo by John Wee

The microsilica advantage

Microsilica first started being used in concrete bridge decking in 1984 to help extend the life of the decks, which through the years have faced increased traffic volumes and heavier truck weights. Some states, such as New York, now require all bridge decks to be constructed with HP concrete. This forward thinking is supported by a recent 10-year study on an Illinois bridge that showed the microsilica concrete used in the replacement bridge deck overlay is expected to last more than 50 years compared to 13 years for the first full-depth conventional concrete deck.

One reason for the longer life is that microsilica acts as a pozzolan, which reacts with water and cement to form compounds with cementitious properties. Without microsilica, cement/water hydration produces 75% to 80% strength-generating calcium silicate hydrate (CSH) products. The remaining is a weak by-product called calcium hydroxide. Microsilica reacts with the calcium hydroxide by-product, converting it into good strength-producing products such as CSH.

Another benefit of microsilica concrete is that it helps prevent chloride-induced corrosion of reinforcing steel. It does this by reducing chloride permeability and increasing the electrical resistivity of the surrounding concrete.

Microsilica has an extremely small average particle size of less than 0.50 micron. This is up to 100 times finer than cement grains and 50 times finer than fly ash. This fine size allows microsilica to fill in the gaps between cement particles, like marbles would fill in the gaps between a volume of bowling balls. This particle packing reduces the ability of deicing chemicals to penetrate the bridge deck concrete.

But chloride permeability is only half of the electrochemical corrosion process. The "electro" part concerns the transport of electrical currents, which determine the rate of corrosion. If corrosion has initiated in a bridge deck, corrosion currents will flow from one steel rebar to another. The rate of corrosion is proportional to the current flow. Corrosion of the reinforcing steel will cause swelling to about four times its regular size. The resulting tensile forces will cause cracks in the concrete.

Microsilica increases the concrete's electrical resistance and thus limits this damaging electrical flow. Conventional concrete has an electrical resistivity of about 4,000 ohms-cm. Microsilica concrete has demonstrated more than seven-fold increases in resistance, beyond 30,000 ohms-cm. By reducing the electrical current flow with high-

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resistive microsilica concrete, the potential for macro cell corrosion is reduced. The result is a bridge deck that can last many times longer than conventional concrete decks.

Proper batching critical

A main factor in how long a HP-concrete bridge deck will last is how the concrete materials were batched. Before HP concrete, concrete producers had mix designs that were routine. Most of the designs had water-to-cementitious material (w/cm) ratios that were above 0.40. HP concretes have mix designs that consistently are below the 0.40 w/cm ratio, making the batching and mixing steps much more critical. Any shortcuts in this area of batching and mixing will result in significantly magnified problems.

The challenge the industry is facing is that the material technology is ahead of the experience of some ready-mix contractors and material suppliers, many of which have not recognized that HP concrete is not as forgiving as conventional, higher w/cm-ratio concretes. When the industry first started making HP concrete, there were many people babysitting the process to make sure there were no problems. Now that HP concrete is being used extensively throughout the world, some producers may forget to use proper HP concrete batching and mixing procedures.

When making HP concrete, the material batching sequence must be controlled. The materials, especially the fine cementitious powders, need to be fed into the mixer at a slower rate for better mixing efficiency with the aggregate materials.

In powder form, microsilica should always be treated and batched as any other cementitious material. It should be accurately weighed and slowly fed into the mixing vessel at the same time as the cement. You should never feed dry or slurry microsilica products into the mixing vessel without aggregate and water already in it. If you do, the microsilica may ball and not disperse throughout the concrete, just as cement would if batched first.

One batching sequence that has successfully been used with dry bulk microsilica is concurrently adding the course aggregate, fine aggregate, a minimum of 75% of the batch water, water reducers and air-entraining admixture. Next add the cement with microsilica batched on top. Follow this with high-range water reduction chemicals as needed and then the remaining batch water.

In slurry form, microsilica should be added concurrently with the water and aggregate. If using microsilica in repulpable bags, add them first followed immediately by the coarse and fine aggregates and a minimum of 75% of the batch water. These special bags need the mixing energy provided by the aggregate and water combination to help in their disintegration. Keep in mind that repulpable bags may not be appropriate for some HP concrete mixes. The typically smaller diameter course aggregate and low water contents of some HP concretes may not fully repulp the bags.

Mixing it up

According to the ASTM C 94 Standard Specification for Ready-mix Concrete, conventional concrete should be truck mixed a minimum of 100 revolutions. Some international standards currently being written for HP concrete often require 200 revolutions or more.

Rather than counting revolutions, mixing speed should be the key mixing criteria for HP concrete. If the mixing speed is in the 16- to 20-rpm range, the mixing blades effectively pull the mix ingredients into the truck and throw them back on themselves. If the mixing speed is less, even by 1 rpm, the mixing energy and action are off and the concrete mixture may not be optimized.

HP concrete also does not combine or mix as well at high slumps since it needs to collide against itself to thoroughly mix the constituents with the microsilica and cement. The recommendation is to mix the concrete at a 2- to 4-in. slump for a minimum of 100 revolutions. High-range water reducers can then be added and mixed to produce whatever slump is desired or specified. This chemically induced slump helps the concrete maintain its high strength while making it easier to pump and place.

It is important to note that slump can no longer be used to monitor the water-to-cement ratio of HP concrete because of the inherent water-reducing additives needed. The only fresh concrete properties now determined by HP concrete slump is, at best, how easy the concrete will be to pump, work and finish.

The longer mixing time on top of the slower batching process will increase the time needed to make HP concrete. Keep in mind that HP concrete is routinely more expensive than conventional concrete. As such, most concrete producers should have no problem slowing down the batching and mixing processes and keeping a closer watch on both.

Advance work

There are numerous steps that engineers and contractors can take to ensure proper batching and mixing of HP concrete.

All HP-concrete jobs should have a pre-placement test pour. This is an absolutely critical step for an engineer to ensure that the ready-mix producer demonstrates the ability to make the HP concrete.

Your bridge deck pour should not be the first HP concrete that the ready-mix contractor does. Keep scheduling test pours until the concrete producer has proven its ability to produce and control your HP concrete. You may even consider having more than one successful pour to further test and evaluate the consistency of the delivered and placed HP concrete.

Keep in mind that the microsilica and chemical admixture company representatives can be your best friends. Ask for their involvement early on to help the ready-mix contractor with proper batching and mixing. Also require the admix representative to be on-site during the test pours and first placements on the job.

An overlooked step

A simple yet often overlooked upfront step is to ask the concrete producer to provide a written batching sequence to be followed on the job. This should list the steps, material ratios and mixing parameters. It's an easy way to catch a big problem.

When experiencing problems producing uniform HP concrete that are not caused by improper batching, usually the problem can be traced back to one or two trucks on the project that do not have updated equipment.

Make sure to ask the ready-mix contractor to use only those trucks that can meet ASTM C 94 concrete uniformity requirements. This uniformity standard covers five components that

The second step in batching HP concrete is to slowly add the cement with microsilica batched on top. Finish up with high-range water reduction chemicals and the remainder of the batch water. Photo courtesy of Elkem Materials. Photo by John Wee

indicate good, uniform concrete: air content, slump variances, unit weight, aggregate proportions and compressive strengths. With this requirement enforced, ready-mix contractors will pick their best trucks—not necessarily their newest trucks—for your HP-concrete jobs.

Finally, schedule a pre-job conference at least four weeks before the start of the job. At this conference, you can review the batching sequence, put in your request for trucks that meet uniform testing, determine how many trucks will be needed to do the job and request the presence of the admix representative during the critical test pours and job start-up. Schedule the test pour for no less than three weeks before the first job pour. This gives time to adjust the mix design, batching sequence and mixing parameters to meet everyone's expectations.

Once all of the up-front bugs are worked out through the pre-job conference and test pours, the project can commence on time with the learning curve already completed.

The future of bridge decking

HP concrete for bridge decking has become synonymous with microsilica concrete. Other materials commonly used in addition to microsilica to produce HP concretes are fly ash and ground granulated blast furnace (GGBF) slag. Combinations of two or three of these materials with portland cement often make good material sense.