Improving Bridge Deck Service Life

Use of crack-resistant, high-performance concrete bridge decks at the Illinois Tollway

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The Interstate 90 bridge over the Fox River is an eight-span structure with an overall length of just over 1300 ft. Photo: Joe Pitlik.

Early age bridge deck cracking is a major concern for transportation agencies, including the Illinois Tollway, which maintains 440 bridge decks ranging in thickness from 7.5 to 8 in. Early age cracking can lead to a reduction in the initiation time of steel reinforcement corrosion and a decrease in service life of the bridge deck. The negative effects of corrosion can be further compounded by freezing and thawing cycles and the use of chloride deicing chemicals. Given the location of the 286-mile Illinois Tollway system in Northern Illinois, bridge decks experience many freezing and thawing cycles each year with deicing chemicals applied for at least 5 months out of the year. These environmental conditions, along with high traffic levels, require durable, crack-resistant concrete in order to maximize the service life of the epoxy-coated steel reinforced concrete bridge decks.

Crack-resistant, high-performance concrete and stainless steel reinforcement were used for the Interstate 90 bridge over the Fox River. Photo: Joe Pitlik.

Prior to 2013, the Illinois Tollway used a prescriptive concrete mixture proportioning approach and had standard superstructure mixtures for bridge decks with a cement content of 605 to 705 pounds of cement per cubic yard. The standard mixtures typically contained either no supplementary cementitious materials or only small amounts of fly ash, and would consist of only one coarse aggregate gradation. This required a concrete with excessive cement paste and, as a result, the mixture was susceptible to shrinkage cracking. Early age cracking was seen on many bridge decks built on the Illinois Tollway since the initial roadways were built and opened to traffic in 1958.

In August 2011, the Illinois Tollway's Board of Directors adopted the 15-year, $12 billion capital program called *Move Illinois: The Illinois Tollway Driving the Future*. The Move Illinois program will improve mobility, relieve congestion, reduce pollution, and link economies across Northern Illinois. It includes rebuilding and widening the Jane Addams Memorial Tollway (Interstate 90); constructing the all-electronic Elgin O'Hare Western Access Project; constructing a new interchange to connect the Tri-State Tollway (Interstate 294) to Interstate 57; and many other system-wide projects to keep the existing tollway system in good repair. These projects will require the reconstruction or construction of more than 100 bridges. Tollway bridge decks built before 2013 have been shown to have a typical service life of only 20 to 35 years before the need for repeated deck or joint repairs begin. They also have a total life of only 35 to 50 years before a complete deck replacement is needed.

Initial research was conducted by CTLGroup and the University of Illinois at Urbana-Champaign in 2012 and 2013 with the objective of extending the service life of Illinois Tollway bridge decks. That research developed mixture-proportioning specifications that would produce a deck concrete with minimal shrinkage cracking potential and with moderate resistance to chloride penetration. The Illinois Tollway elected to take a performance approach for high-performance concrete (HPC) bridge deck mixture proportions compared to the prescriptive approach that was used in the past, and is

Table 1. Mixture designs developed as part of Illinois Tollway research

Mixture ID	Bridge Superstructure	Concrete Mixture with Optimized Aggregate Gradation	SLF	SRA	Ternary Optimized Gradation with SLF and SRA
Material	lb/yd³ (saturated surface dry)				
Cement	515	375	409	403	313
Fly Ash	0	125	0	134	111
Slag	110	0	136	0	154
Coarse Aggregate (CM-11)	1875	1501	1714	1840	1245
Coarse Aggregate (CM-16)	0	391	0	0	325
Saturated Light-weight Fines	0	0	364	0	236
Fine Aggregate	1160	1370	986	1323	1039
Water	263	210	237	226	220
Total Cementitious Content	625	500	545	536	578
w/cm (including water in admixtures)	0.43	0.43	0.44	0.43	0.39

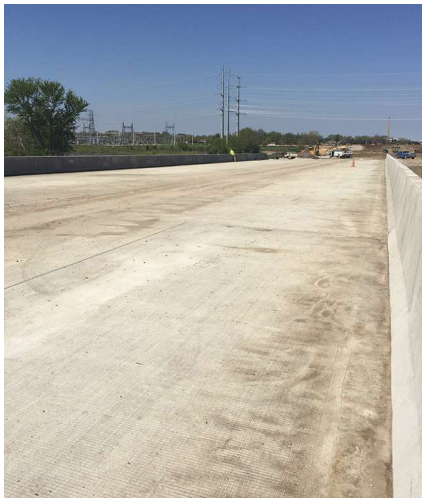
Note: CM-11 is an Illinois Department of Transportation (IDOT) coarse aggregate gradation number corresponding to a nominal maximum aggregate size of ¾ in.
CM-16 is an IDOT coarse aggregate gradation number corresponding to a nominal maximum aggregate size of ⅜ in.
SLF = saturated lightweight fines; SRA = shrinkage-reducing admixture; *w/cm* = water-cementitious materials ratio.

still used by most transportation agencies today. In addition to using approved materials, limits were set for compressive strength, slump, linear shrinkage, restrained ring shrinkage, freezing and thawing cycles, alkali-silica reactivity, and chloride ion penetration. Minimum cement contents and maximum water-cementitious materials ratios (*w/cm*) were not specified. Testing was required on laboratory-prepared and field-trial batch produced samples to ensure performance and verify that the proposed mixture could be produced at the concrete plant. Table 1 summarizes the mixture designs tested as part of the research. The top-three performing mixture proportions for shrinkage resistance contained saturated lightweight fines (SLF), shrinkage-reducing admixture (SRA), or ternary optimized gradation with SLF and SRA (ULT). Based on these results, all HPC mixtures were required to contain SLF or SRA to mitigate shrinkage cracking.

Since 2013, 77 bridges have been built with the Illinois Tollway's crack-resistant HPC special provision. Isolated cracking, most of it caused by restraint cracking due to temperature differentials between the deck and steel beams, has been identified on 24 of the bridges. Shrinkage cracking due to insufficient curing for a given concrete mixture has only been identified on seven of the 42 bridges.

There have been no verifiable constructability issues with these crack-resistant HPC mixtures. The mixtures are commonly placed using a pump or belt conveyor. The SLA and SRA materials used on the Illinois Tollway have had little effect on the fresh properties or finishing. For the major Illinois Tollway bridges over waterways or at interstate-to-interstate interchanges, stainless steel reinforcement is being used within the decks along with the shrinkage crack-resistant HPC to provide a deck service life that will exceed 75 years.

The Illinois Tollway is currently in the process of further improving the service life of crack-resistant HPC for use with epoxy-coated reinforcement. This will be achieved while maintaining the crack resistance and constructability of the mixture. At this point, two options are being considered. This includes lowering the threshold for the chloride ion penetration test, thus requiring a denser, less permeable ternary mixture and/or requiring the use of a corrosion inhibiting admixture. This work is being done as a joint effort between the Illinois Tollway, CTLGroup, and Tourney Consulting Group LLC. It will be using recently developed computer software to most accurately predict the service life of Illinois Tollway HPC bridge decks for the structural design, mixture properties, and climatic conditions that exist. The objective of this work is to ultimately develop specifications for crack-resistant HPC mixture proportions that—when combined with efficient preservation work—will provide epoxy-coated steel reinforced concrete bridge decks with service lives of at least 50 years before any repairs are needed, and total service lives that match the life of adjacent new pavements of around 75 years. By taking a holistic systems approach to materials selection, the Illinois Tollway plans to attain durable, cost-effective structures with service lives of 75 years.



Crack-resistant high-performance concrete was used for the IL 390 decks over Salt Creek. Photo: Supraja Reddy.

The Illinois Tollway has achieved consistent success since adopting crack-resistant HPC for bridge decks in 2013. With the help of consultants, researchers, and the concrete industry, the Illinois Tollway plans to continue improving the service life of bridge decks.

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