Protecting Against FIRE

by Craig A. Shutt

Concrete can help bridges resist a blaze's high heat and return quickly to service

On June 20, 2007, a fuel tanker truck rear-ended a loaded dump truck on State Route 386 under the Stop Thirty Road Bridge north of Nashville, Tennessee. The tanker erupted into flames beneath the 233-ft-long structure, a two-span, two-cell, hollow box-beam bridge. Fearing damage that would interrupt traffic for many months, both on and below the bridge, inspectors, and maintenance crews rushed to the site to conduct studies on the concrete once the fire cooled. After analyzing the bridge and finding no problems, traffic was restored under the bridge to the busy state route as soon as pavement repairs were completed. Traffic returned to service on Stop Thirty Road after core samples were evaluated.

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"The analysis showed that the bridge endured much heat but sustained very little damage," says Wayne Seger of the Office of Bridge Inspection and Repair at the Tennessee Department of Transportation. The affected span was 120-ft long. The bottom slabs of the hollow box-beams are 7.25-in. thick, and the sides of the box sections along with the common wall between the cells are 1-ft thick with two mats of reinforcement. Class A, 3000 psi concrete and epoxy-coated

Photo: U.S. Fish & Wildlife Service

Following a fire on the Bill Williams River Bridge in Arizona, it was determined that the girders could be repaired. Photo: Arizona Department of Transportation.

reinforcement had been used to construct the bridge in 1981.

After the bridge cooled, potential spalls were chipped off and concrete cores were cut to allow engineers at CTLGroup in Skokie, Illinois, to perform petrographic analysis. "The evaluation showed that the concrete was in good shape, so we removed the restricted load posting signs and returned the bridge to service," he says.

Keeping Cool

Engineers are well aware of the strength and durability that concrete can offer for bridge designs, allowing longer spans and long-term life cycles with minimal maintenance requirements. But the material offers considerable resistance to fires that could otherwise render other bridge types unusable.

The key problem is that bridge fires tend to be exceptionally hot, as they're caused by an external source of intense heat, such as fuel from an overturned truck or tankers carrying chemicals, says Richard B. Stoddard, Bridge Design Engineer with the Washington Department of Transportation, who inspected a fire-damaged bridge in his region (for more on this project, see the following article).

"Tanker fires caused by highway fuel-trucks or railway tanker cars are explosive in nature and greatly exceed the temperatures and rate of heating prescribed in the ASTM fire-resistance test," he said in his report. "Additionally, the heat-transfer mechanism in tanker fires is dominated by radiant energy as opposed to hot-air and heat convection." Concrete, with its high specific heat, can better endure these relatively short-duration, high-temperature fires.

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The heat from the Puyallup River Bridge fire was intense enough to cause damage to all 15 lines of girders.

Bridges Survive Fires

A variety of bridges around the country have suffered spectacular bridge fires yet have been able to return to service quickly due in part to the use of concrete. For instance, on July 28, 2006, a fuel truck crossing the Bill Williams River Bridge on Route 95 in Parker, Arizona, crashed about halfway across the structure. Built in 1967, the bridge spans the Bill Williams Wildlife Refuge, which receives about 70,000 visitors per year.

The tanker spilled approximately 7600 gallons of diesel fuel onto and under the bridge, which then ignited and burned on the bridge's AASHTO Type III precast, prestressed concrete girders and composite reinforced concrete deck. The fire-damaged girders did not show visible signs of loss of prestress but experienced varying degrees of spalling. A reduced girder section was rated for flexure and shear and compared to a prefire condition. It was determined that the fire resulted in a 6 percent reduction in the bridge load rating for the short term and a 12 percent reduction for the long term. Based on these results, and following a study of multiple alternatives, it was determined that the girders could be repaired. Both lanes on the bridge have remained open to traffic since the accident.

"The damage wasn't as bad as we initially feared," says Martha Davis, Structural Engineer for HDR Engineering Inc. in Tucson, Arizona. The firm worked with CTLGroup to identify the depth of the fire damage in structural elements, determine the extent to which spans were damaged, and note any reductions in section properties and material strengths.

Their assessment found that the overhang and shoulder in three spans, especially the ninth span, needed to be replaced. "The fuel spilled through the deck drains and expansion joints, spreading the fire under the bridge, and the wind whipped the fire along

Although flame temperatures at this methanol-fueled tanker fire under the Puyallup River Bridge, Wash., reached 3000 °F, the precast concrete bridge was reopened to traffic the next day.

The prestressing steel did return to its full strength without causing any deformation in the bridge girders following the fire.

The blackened beams of the Bell Isle Bridge, Oklahoma City, Okla., were cleaned and the bridge was reopened. Photo: Oklahoma DOT.

the bridge's barrier and overhang," Davis explains. But the girders in those spans, and in all of the others, retained their structural integrity. Transportation officials closed the shoulder on the affected span to keep vehicles off the overhang and to protect the barrier until repairs could be completed.

Those repairs are still to be scheduled, she notes. The plan is to save as much of the existing reinforcement as possible and rebuild the overhang, repair damage to the girders where reinforcement was exposed and concrete spalled, and add a protective coating to the deck to inhibit corrosion. The bridge also is being monitored to ensure no signs of additional damage arise.

An even faster return to service took place for a ramp to the Northwest Expressway in Oklahoma City, Oklahoma, when a truck crashed on the nearby Belle Isle Bridge on January 28, 2006. A portion of the truck became airborne and crashed to the ground near the ramp, where the resulting fire blackened the ramp's AASHTO Type II prestressed concrete beams. But after evaluation, the blackened beams were cleaned and the bridge was reopened.

"There was superficial damage that we repaired," explains Walter Peters, Assistant Bridge Engineer for Operations in the Bridge Division of the Oklahoma Department of Transportation. "It was mostly smoke damage and minor spalls."

A similar result occurred at a precast concrete bridge in Washington County, Oregon, in November 2004. A derelict car was abandoned in an area beneath the bridge and set on fire, causing charred concrete on the bridge above and disruption to traffic. The damage occurred at about midspan on a 37.5-ft-long span using 18-in.-deep voided slabs. "The fire was hot enough to melt aluminum and leave it puddled on the ground nearby," reports Greg Clemmons, Operations Engineer for the Washington County Land Use and Transportation Department.

An inspection of the bridge showed that spalling occurred in an approximate area of 2 sq ft and was 1/2- to 3/4-in. deep. In several areas, the concrete also turned pink, indicating it had been exposed to heat of at least 500 ˚F. Following pressure washing to remove soot, a detailed inspection took place, including hammer tests at various locations.

Following the inspection, the bridge was reopened to traffic. "The prestressing steel did return to its full strength without causing any deformation in the bridge girders following the fire," Clemmons reports. Debonding of the strand possibly took place at the center of the component, he notes, but central debonding would not produce any significant concern if the ends remain intact. "There was localized damage, but it did not impact the bridge's operation."

Although the department considered cleaning and repairing the spalled areas immediately, the damage was determined to be so minor that the bridge instead was put onto the county's accelerated inspection list.

Fast Replacement is Option

Another approach to maintaining traffic on a precast concrete bridge was used by the Connecticut Department of Transportation. A tanker truck carrying 8000 gallons of gasoline jack-knifed during an accident, spilling its contents over and under the 80-ft-long bridge over the Norwalk River near Ridgefield, Connecticut. The resulting fire exposed the precast concrete bridge to severe heat and fire damage.

A blazing car fire caused damage to a bridge in Washington County, Ore., but the affects were minimal and the bridge was reopened to traffic after an inspection.

Some spalling and exposed aggregate were noted during the inspection of the Washington County, Ore., fire, but it was not sufficient to require repairs.

After a tanker truck overturned, caught fire, and burned out on a bridge spanning the Norwalk River near Ridgefield, Conn., engineers decided to resupport the 50-year-old precast concrete bridge with intermediate supports. The bridge reopened to traffic in four days.

Gasoline that spilled from the tanker-truck accident on the bridge over the Norwalk River caused spalling on the precast concrete but left it in "reasonably good shape," engineers reported.

The 50-year-old bridge, one of the first precast concrete bridges built in the United States, suffered significant amounts of spalled concrete on its beams, reports Arthur Gruhn, Chief Engineer. Reinforcement was exposed in a number of locations. "We really had no idea how strong the bridge still was," he says. Despite its age, the bridge had been in good condition, and there had been no plans to replace it.

The design team moved into action quickly, setting up a detour and providing an initial inspection on the day of the accident. On day two, a contractor and remediation crew examined the bridge to determine its status. The team decided that the bridge was still structurally sound but needed some temporary intermediate support to ensure its stability.

Two heavy steel support beams were added, one under either edge for the length of the span, and three additional, shorter beams were inserted perpendicular to these at the one-quarter and one-half points. In addition, a Jersey barrier was placed along the damaged bridge railings.

"We really couldn't gauge how much damage the fire had done, but we could see the bridge still was in reasonably good shape," he says. "We were confident that if we shortened the spans of the precast concrete beams, enough strength remained to support the loads until a replacement could be built."

Installing the support beams took two more days, and the bridge reopened to traffic only four days after the fire occurred. A temporary bridge was created adjacent to the bridge, and once it opened, work on replacing the original bridge with another precast concrete version began. That work was completed a few months later, producing a brand new bridge to replace the fire damaged one in only four months.

In fact, a later evaluation of the beams performed at the FHWA Turner-Fairbank Highway Research Center showed that concerns over the short-term structural integrity of the beams were groundless. "The investigation found that the flexural capacity of the beams had not been degraded significantly as compared to their anticipated capacity," wrote Gary L. Henderson, Director of the Office of Infrastructure at the Federal Highway Administration in his report dated February 2007. However, their long-term durability may have been degraded by the fire, he noted, so replacement would have been needed eventually. See *Concrete Connections* on page 52 for the website address with the full report.

Avoiding such replacements can ensure budget and time are spent on projects where they are needed. HDR's Davis knows the balance that must be obtained. "If there was a close detour for the Bill Williams River Bridge, and money was no object, we might do more to improve the bridge, just to be on the safe side," she says. "But the closest detour is 100 miles away."

Even to do the work that will be needed on the overhang will require closing one lane and operating alternating-direction access during construction. "Work like this totally impacts traffic, especially in an environmentally sensitive area," she says. But that disruption is nothing compared to what would be required had the bridge been unusable and users had to drive 100 miles out of their way until a new bridge was completed.

Two major fires on highway structures in California last year demonstrated the disruption that they produce. The first in April was caused by a gasoline tanker truck that crashed and exploded into flames at the MacArthur Maze—one of California's heavily traveled freeway interchanges in the San Francisco Bay area. Although the steel superstructure of one connector collapsed, only 4 ft of concrete at the top of two columns supporting one outrigger bent were replaced. The original steel bent cap was replaced with a concrete one because it could be manufactured more quickly.

The second event in California occurred in October when a truck exiting a 550-ft-long truck-bypass tunnel on I-5 near Santa Clarita lost control resulting in a multi-vehicular collision and massive fire in the tunnel. Although the collision occurred at the exit from the tunnel, the winds drove the flames so that most fire damage occurred at the tunnel entrance. The tunnel structure consisted of concrete box girders supported on top of concrete strutted abutments. Repairs consisted of building a new wall in front of portions of the wall that were damaged and replacing approximately one-sixth of the total superstructure with precast girders and a cast-in-place concrete deck. This solution was adopted as the most conservative approach and allowed the tunnel to open 15 days ahead of the deadline.

For more information on this or other projects, visit www.aspirebridge.org.


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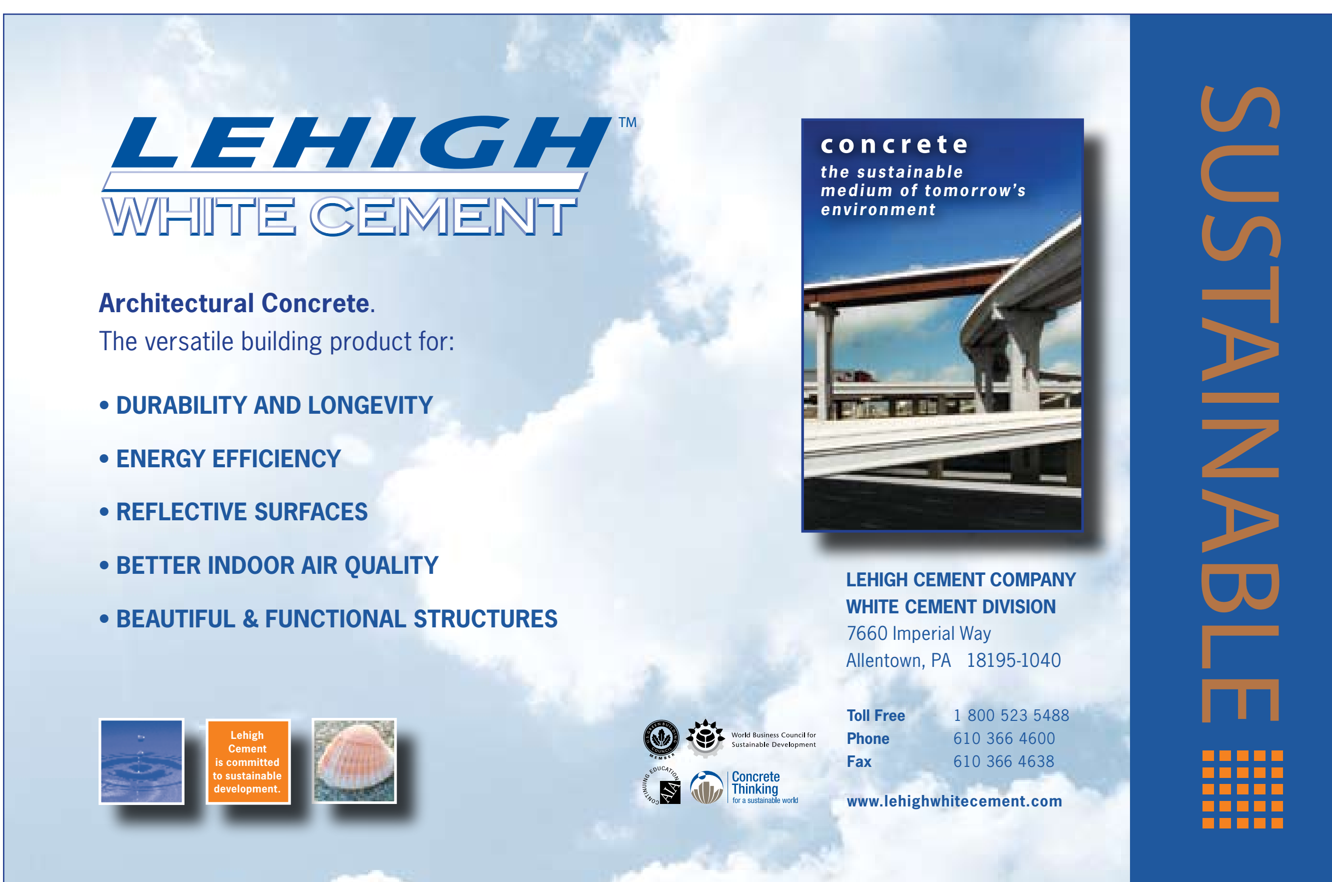
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