A CASE STUDY

Evaluating FIRE DAMAGE

by Richard B. Stoddard, Washington State Department of Transportation

In December 2002, a railroad tanker collision caused a fire under a prestressed concrete girder bridge crossing the Puyallup River in Tacoma, Washington. The bridge, constructed in 1997, had span lengths of 146 ft with W74 girders spaced at 5-ft 0-in. centers. Specified 28-day concrete strengths were 7000 psi in the girders and 5000 psi in the columns and bridge deck.

The fire consumed 30,000 gallons of methanol, engulfed Span 8, and maintained a high flame temperature for approximately 1 hour. The bridge was closed immediately pending further inspections. The bridge displayed no unusual deflections or misalignments and was reopened to commuter traffic and legal weight trucks on the morning after the fire.

Visual Inspection and Mapping

Visual inspection of both columns at Pier 9 approximately 60 ft from the source of the fire, showed 2-in.-deep spalls that exposed spiral reinforcement for the full height of the column. The concrete inside the spiral sounded like delaminated concrete. Further investigation revealed delaminations

within the concrete just inside the spiral cage and vertical reinforcement. The crossbeam above the columns had several areas of spalling but no reinforcement was exposed.

All 15 lines of girders in Span 8 were damaged and the corners of the bottom flanges could easily be removed to expose the outermost strands. The soffit of the concrete deck displayed no evidence of spalling.

Visual inspection of the damage in Span 8 included recording the concrete color variations on the soffit of the bottom flanges that corresponded to changes in concrete condition. The color regions were described as extreme-white, ash-white, white-gray, and soot. The different colors corresponded with different exposures to the fire with the extreme-white region representing the most intense exposure directly over the fire source.

Concrete Hardness Mapping

In accordance with the recommendations for Post Fire Examination of the PCI *Design for Fire Resistance of Precast, Prestressed Concrete*, hardness testing was performed on the bottom flanges and webs of the girders using a Schmidt hammer. The purpose of the tests was to map relative changes in concrete hardness along the length of each girder. The rebound hammer readings for the soffit of the bottom flanges in Span 8 ranged from 42 to 61 compared to 61 in girder concrete not affected by the fire. The minimum hardness occurred directly over the heat source and in general, hardness increased with distance away from the heat source.

The web hardness readings did not follow a pattern of regular change because shadowing by the bottom flange affected the distribution of web damage. The bottom flange protected some parts of the webs from severe fire damage.

Prestressing Strand

The prestressing steel in the girders consisted of 1/2-in.-diameter 270 ksi strands. Concrete surrounding the straight strands in the bottom flange was easy to remove with a light rock hammer. Because of the high temperatures, there was concern that the strands could have lost strength and that relaxation of the prestress force could have occurred.

Prior to removing samples of prestressing strands for material testing, simple deflection tests were performed to calculate the prestressing force. The tests were conducted before the strands were cut and after the strand replacement splices were tensioned. The strand deflections were induced by hanging a 173 lb weight on the strand. Deflections were measured multiple times by two inspectors using a dial caliper with a measurement accuracy of 0.001 in. This method was estimated to have a probable accuracy of 5 percent and was certainly accurate to within 10 percent of the actual tensile force. Based on this approach, the strands in the hottest zones appeared to have retained 100 percent of their design force.

Three samples of strand were removed and tested for yield strength, tensile strength, and modulus of elasticity. The strand samples met the requirements for 1/2-in.-diameter uncoated seven-wire prestressing strands per ASTM A 416-96 indicating that no metallurigical changes occured.

The fire engulfed Span 8 and maintained a high flame temperature for approximately 1 hour.

Spalling of concrete cover on the columns resulted in areas of exposed spiral reinforcement.

The pink color shown in this girder from the Puyallup bridge fire indicates that the concrete was exposed to temperatures higher than 500 ˚F.

Concrete Core Samples

Eight vertical concrete cores from the hot zone, two vertical cores from the coolest zone, and eight horizontal cores from the hot zone were removed from the prestressed concrete beams. Seven cores were examined petrographically in general accordance with ASTM C 856. The extent and severity of fire damage was based on observed changes in aggregate and cement paste color, mineralogy, and microstructure. Based on the petrographers' evaluation, which also included some informal heating tests, the state was convinced that surface temperatures on the bottom flange soffits exceeded 1500 °F during the fire.

Compression tests performed on core samples indicated that much of the undamaged concrete had a compressive strength exceeding 9000 psi. Significant portions of core samples from the hottest zone, however, were fractured and untestable.

Eight concrete cores were taken from the two columns at Pier 9. These confirmed the existence of delaminations in the interior core of the column. The maximum depth of fracture was found to be 5 in. from the original surface and more than 1 in. inside the vertical column reinforcement. Aside from the delaminations, the concrete remaining in the column appeared to have very good strength.

A core sample from the crossbeam at Pier 9 did not show any abnormalities and indicated that the crossbeam sustained only superficial damage from the fire.

Summary

The railroad tanker fire subjected all 15 girders in Span 8 to intense heat in a short period of time. Flame temperatures were estimated to be approximately 3000 °F and surface temperatures on the soffit of the prestressed concrete girders may have reached 1700 °F. Internal temperatures in the bottom flange and webs were estimated to range from 500 to 1100 °F. The prestressing steel survived the fire without noticeable loss of prestress.

Rapid identification of concrete damage zones can be made by observing the variation in concrete color immediately following a fire. The visual color mapping correlated very well with variations in concrete hardness. The rebound hammer test validated the visual observations and provided an objective description of the damaged areas. With this information, rational discussions could be made about repair or replacement.

All 15 lines of girders in Span 8 were damaged by the fire but the bridge was opened on the next morning.

Reference

Design for Fire Resistance of Precast, Prestressed Concrete, Second Edition, MNL-124-89, Precast/Prestressed Concrete Institute, Chicago, IL, 1989, 96 pp.

Acknowledgement

This article is based on a full-length paper titled "Inspections and Repair of a Fire Damaged Prestressed Girder Bridge," presented at the International Bridge Conference, Pittsburgh, June 2004, Paper No. IBC-04-17 which is available at www.aspirebridge.org/resources.

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Some surface damage occurred in the top flanges.

Damage concrete surrounding the straight prestressing strands was easy to remove.

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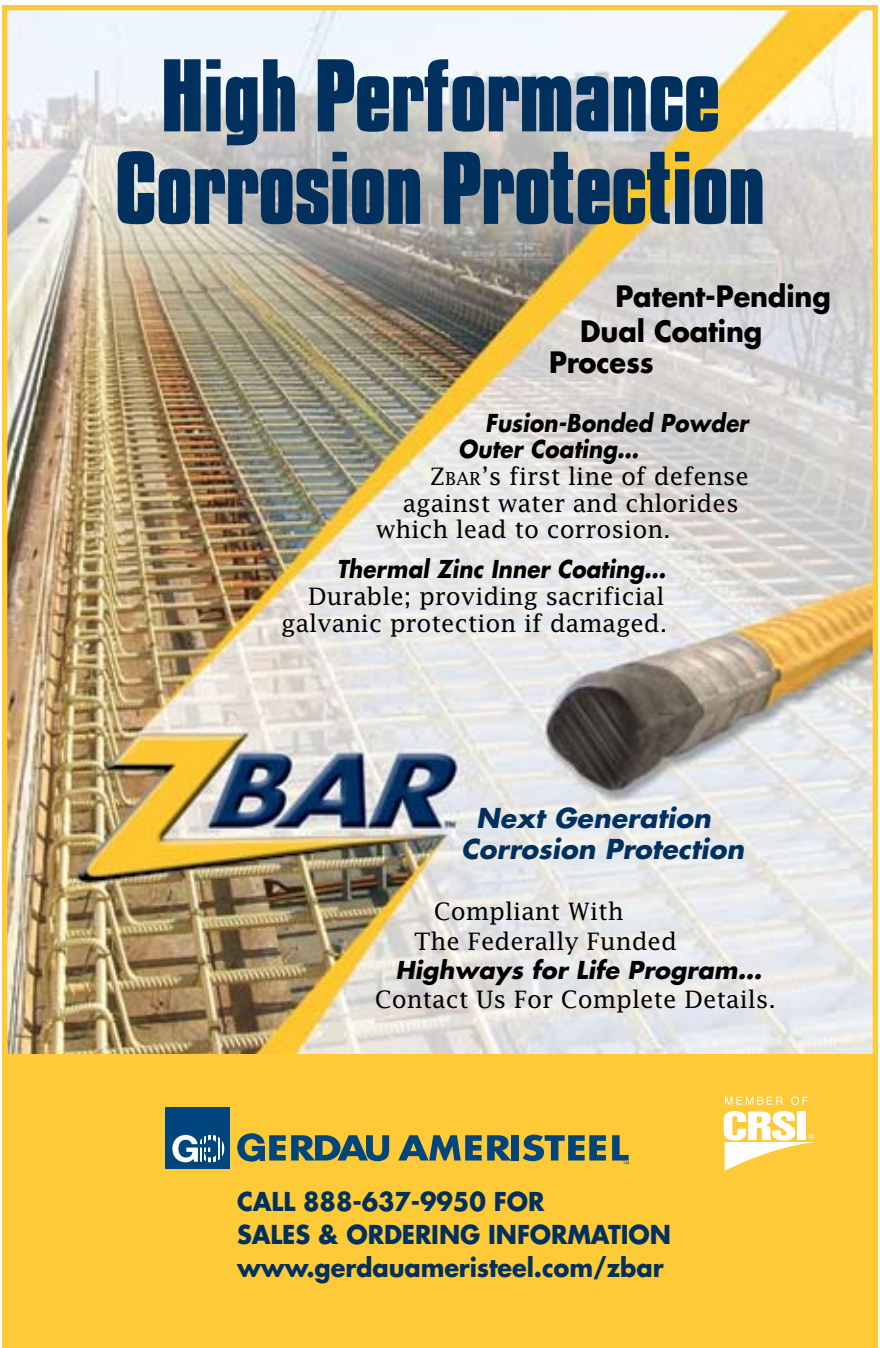

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