ULTRA-HIGH PERFORMANCE CONCRETE (UHPC) FOR STEEL BRIDGE REPAIR

Zhanfei "Tom" Fan, PhD, PE
Texas Department of Transportation
Houston, Texas.

Abstract

Ultra-High Performance Concrete, or UHPC, is an advanced class of cementitious composite that has superior mechanical and durability properties. With high percentage steel fibers in the mix, UHPC is a powerful material with high strength, high flowability, high ductility, and low porosity. It has been championed by FHWA and used in hundreds of bridge projects in North America. For bridge applications, UHPC has been mostly used in joints and closure pours between the prefabricated members. In this presentation I'll discuss an application in which UHPC is used for steel bridge repair.

The Sidney Sherman Bridge in IH 610 East Loop over Houston Ship Channel is a major thoroughfare in east side of Houston with an ADT of 165,000 VPD in 2019. The 154' wide bridge deck is supported by only six deep steel plate girders spaced at 27.5'. The total length of the steel unit is 1230.0' and is divided into five spans.

Severe corrosion occurred at the ends of the steel girders. The corrosions attacked mostly the steel plates immediately above the rocker bearings where the connection details between the diaphragms and girders are complex. Water and debris leaked through the finger joints were trapped in these details. The corroded steel plates are also in the main load paths of the girders. The combination of corrosion and high stresses resulted in failures of these plates, including buckling of webs and stiffeners as well as fracture of a steel girder flange. Corrosion also occurred in the rocker bearing assemblies with serious damages such as loss of anchor bolts. Large base plates movements and large rocker shoe rotations have resulted, endangering the stability of girders at the locations.

Emergency temporary repairs were performed using shim plates to stop further girder settlements and bearing movements. However, a permanent repair must be performed to stop the continuous deterioration of the steel girders and ensure a sustained serviceability of the bridge. The scope of the permanent repair consists of three tasks: (1) Repair the corroded and damaged plates at the girder ends to restore their load carrying capacity. (2) Provide safe load paths to jack the girders, and then repair several rocker bearings and replace the deteriorated bearing base plates. (3) Improve the connection details to eliminate the small spaces that trap water and debris.

If the traditional cut-and-weld steel repair methods are used to perform these repairs, the steel girders must be jacked. However, jacking/lifting of the steel girders will be difficult due to the location and current condition of the bridge. The girders are more than 110 feet from the ground at the repair locations. Any ground based temporary supports would require use of very high shore towers, complicated by the fact that the ground surface at one girder end is occupied by railroad tracks. In addition, the severely corroded

connections between the girders and the diaphragms preclude direct jacking without being repaired first.

After extensive investigations and feasibility studies, an innovative solution was proposed and developed to address the multiple challenges of the job. The proposed repair plan consists of two major steps. First, use UHPC to encase the girder ends and small segments of the diaphragms, including the shim plates installed in the temporary repair. Second, jack the diaphragms and steel girders under the hardened UHPC encasements from the concrete caps and then perform the bearing and base plate repair.

Using UHPC to repair steel girders was pioneered by Connecticut DOT in partnership with the University of Connecticut. The goal of repairing an IH 91 bridge in New Haven, CT is to restore the beam capacity by encasing the severely corroded steel girders. Our IH 610 Houston Ship Channel Bridge repair is the second reported project of using UHPC for steel bridge repair, however we are encasing not only the steel girder ends but also parts of the truss diaphragms for jacking purpose.

UHPC was chosen mainly because of the following attractive properties. (1) High fluidity, which enables flow and fill into the small spaces in the corroded and damaged areas, further divided by the shim plates added during the temporary repair. (2) High strength and ductility, which prevent or minimize damages when it experiences stress variations and reversals during jacking. (3) Dependable tensile strength, which enables continuous encasements of the corroded steel plates without large cracking even when the latter experience slightly further corrosion and volume expansion.

The UHPC encasement method offers many benefits for this difficult repair job. It avoids intensive cutting and welding on existing girders, and the use of high shore towers or other temporary supports. The encasements create solid load paths to transfer DL and LL from girders to bearings, and seal the corroded areas to stop or significantly slow down future corrosion. The encasements permanently eliminate the water and debris trapping details, and significantly strengthen the connections between diaphragms and girders to enable jacking for current and future bearing repairs. Most of the preparation work can be performed under the bridge deck while the bridge is still in service and therefore bridge closure time will be minimized.

The innovative idea has been developed and finalized in a detailed design. A special specification was developed to define the mix design, testing procedure, and construction method. Currently TxDOT is working closely with contractors and UHPC suppliers to implement the plan. The construction is expected to be complete by summer 2020.