Rapid Repair of Prestressed Concrete Bridge Beams

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Depending on local operating and environmental conditions, existing prestressed concrete bridges may experience deterioration from corrosion of the steel strands. Such bridges are often load posted or may require superstructure replacement after as little as 40 years of service. Load-posted or closed bridges are disruptive to commerce and local communities, and, especially in rural areas, they can result in lengthy detours with significant direct and indirect costs. Staffing levels and budget cycles dictate that state transportation agencies often need several years to design, bid, and install a replacement structure.

One such example was Bridge 810003 in Sampson County, N.C. This three-span, prestressed concrete C-channel bridge was built in 1955 and was closed following a biennial inspection in May 2020. **Figure 1** shows the Sampson County bridge, which exhibits deterioration typically experienced by C-channel beams, where corrosion of the steel strands leads to spalling of the thin concrete stems, further exposing the internal reinforcement. The North Carolina Department of Transportation (NCDOT) considered three options to deal with the closure. The first was an emergency replacement contract, as the bridge was already scheduled for replacement in fiscal year 2023. However, there were competing projects in the area and concerns regarding the time the bridge would need to remain closed to complete the design and construction, even on an emergency basis. The detour would be 6 miles long and would affect local commerce and agriculture. The second option was to replace the most deteriorated beams with spare beams recovered from prior bridge replacements. Several years earlier, NCDOT noticed reoccurring degradation in these C-channel beams and started saving channel beams in good condition in various regional maintenance yards. Downsides of replacing degraded beams with spare beams were that NCDOT would still need to hire a contractor, likely at high cost, and the time frame for this temporary repair would be comparable to that of an emergency replacement. The third option was to use the prestressed, mechanically fastened, fiber-reinforced-polymer (MF-FRP) rapid-repair system developed at North Carolina State University in previous research sponsored by NCDOT.

After discussing the installation procedure and observing the repair system on a demonstration installation on Bridge 340080 in Franklin County, NCDOT decided to use the rapid-repair option.

Figure 2 shows a schematic for the prestressed MF-FRP rapid-repair system. For convenience of installation, the system is installed on the inside faces of the C-channel stems. The fiber-reinforced-polymer (FRP) plate is mechanically connected to anchor plates, which are bolted through the concrete stems as close as possible to the ends of the beam. The FRP plate is commercially available in one cross section, which is ⅛ in. thick and 4 in. wide. The FRP plate is prestressed by tightening a turnbuckle attached to the "live end," which remains as a permanent element of the repair

Figure 1. The C-channel bridge in Sampson County, N.C., which was closed to traffic in May 2020, exhibits typical deterioration experienced by C-channel beams. All Figures: North Carolina State University.

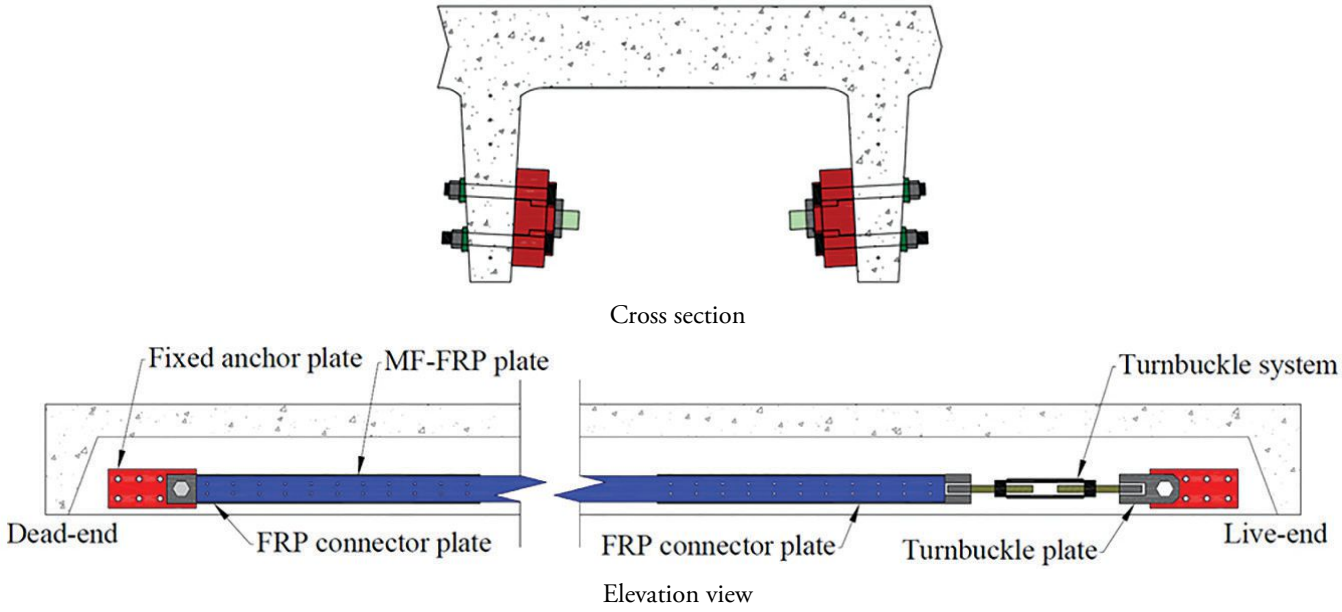

Figure 2. Schematic elevation and cross section of the prestressed, mechanically fastened, fiber-reinforced-polymer rapid-repair system installed on a C-channel beam.

system. Each FRP plate can restore the prestressing force equivalent to one lost steel prestressing strand, thereby restoring the load rating of a deteriorated beam. Lin et al.[1] provide detailed information on the American Association of State Highway and Transportation Officials' rating analysis of precast concrete beams repaired with the prestressed MF-FRP rapid-repair system, as well as the design and installation processes. The intended service life of the temporary repair is two to three years, which is sufficient to increase load postings or reopen bridges until a bridge replacement can be scheduled. The system does not require any adhesive bonding, and the FRP plates are prestressed on site by maintenance crews without any special equipment or expertise.

The repair is a cost-effective alternative that can be installed in hours by NCDOT maintenance crews, and the bridge may be reopened immediately after installation. **Figure 3** shows an NCDOT maintenance crew installing the system on the Sampson County bridge. **Figure 4** shows the system in place on the Sampson County bridge, which was reopened to traffic in November 2020.

Simple assessment and monitoring techniques are available to evaluate the integrity of the repair as part of routine bridge inspections. The Sampson County bridge repair was continuously monitored by strain gauges, and the North Carolina State University research team collected the data on a regular basis. During each data collection visit, research team members also performed a visual inspection of the bridge. The repair system remained in good condition throughout its 26-month service life until the bridge was demolished. A replacement bridge opened to traffic in April 2023.

As part of an ongoing NCDOT-funded research project, several MF-FRP repaired beams from the old Sampson County bridge were salvaged during demolition and delivered to North Carolina State University's Constructed Facilities Laboratory, where they were inspected and tested to failure to determine the condition of the system after more than two years in service. Experimental results showed that the repair system did not experience structural deterioration while in service, and the repaired beams performed as designed, delivering load capacities equivalent to original, undamaged beams.

The MF-FRP rapid-repair system was also installed on Bridge 910180 in Wake County, enabling a 5-ton load posting for all vehicles to be increased

Figure 3. A North Carolina Department of Transportation maintenance crew prestresses a fiber-reinforced-polymer plate by tightening a turnbuckle on the Sampson County bridge.

Figure 4. Completed installation of the repair system before the reopening of the Sampson County bridge in November 2020.

to 19 tons for a single vehicle and 25 tons for a truck-tractor semitrailer. The increased load rating was sufficient to enable school buses to resume use of the route. Here, too, the repair system remained in service for more than two years before the bridge was replaced with a new structure. At the time of writing, NCDOT was preparing to install the MF-FRP rapid-repair system on two recently identified C-channel bridges. Although the bridge examples presented herein are all prestressed concrete C-channel beams, the rapid-repair system was also successfully installed and tested in the Constructed Facilities Laboratory on previously used prestressed concrete cored slabs that were salvaged from bridge replacement projects. NCDOT anticipates continued use of the prestressed MF-FRP rapid-repair system to extend the service life of the remaining inventory of C-channel bridges until they are all replaced. To facilitate this process, the North Carolina State University research team developed a load-rating analysis spreadsheet and NCDOT produced a prestressed channel MF-FRP repair system standard drawing with installation notes.

Reference

1. Lin, S-H., B. C. McCoy, G. W. Lucier, R. Seracino, and N. A. Pierce. 2023. "Rapid Prestressed Concrete Retrofit with Prestressed Mechanically-Fastened Fiber-Reinforced Polymer: Field Performance and Observations for a Deteriorated Prestressed Concrete Bridge." *Transportation Research Record* 2678 (4): 804–818. https://doi.org/10.1177/03611981231186981.

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