Innovative Approach for Restoration of Historic Bridge

By Sarah Cruickshank

The Woodland Viaduct Bridge in Westchester County, New York, is a 75-year-old concrete open-spandrel arch bridge carrying the Bronx River Parkway over the Bronx River and the Metro North Railroad. Located within the Bronx River Parkway Reservation, the roadway is on the National Register of Historic Places as "an early example of a limited access parkway." Completed in 1922, the parkway is located within a beautiful setting, but was not designed to meet modern-day traffic requirements. By 1994, the Woodland Viaduct Bridge showed serious deterioration, with two of the four lanes closed to traffic. A decision needed to be made on whether to restore or replace this historic bridge.

Access to the arches was provided by hanging scaffolding. Application of the composites was performed in 6-ft sections

Access to the arches was restricted by a commuter railroad and river

Design Assessment

The Westchester County Department of Public Works retained a New York City consulting engineer to complete a design/environmental assessment that would examine alternatives for this structure. This assessment included an in-depth structural analysis along with public hearings to evaluate the historic character of the bridge. Based upon the findings, Westchester County decided to rehabilitate the structure instead of replacing it.

The main span of the Woodland Viaduct Bridge consists of four large arch ribs with spandrel columns projecting up to the floor beams that support the deck structures. Due to the severe deterioration of the superstructure, the original plan was to rehabilitate the arches and most of the columns and to replace the deck, floor beams, and some of the columns. Subsequent analysis, however, indicated that the arches and columns did not meet current seismic code requirements. After a full seismic analysis, a decision was made to replace all of the columns, redesigning them with pin connections at the base. Fiber-reinforced polymer (FRP) composites were chosen as an innovative method of rehabilitating the arches. This type of retrofit strengthens the arches while maintaining the appearance of the members.

FRP composites consist of high-strength fibers in an epoxy matrix. Glass, carbon, or aramid fibers are typically used. These materials were applied using a wet layup process. In this process, the dry fibers are saturated with the epoxy at the job site. The saturated fibers are then bonded to the structural member. Once cured, the composite provides the design strength. The advantages of these materials are their high strength-to-weight ratio, environmental durability, and minimal effect on the appearance of the structure. These materials can be finished with a variety of coatings that can match the appearance of the existing structure.

A seismic analysis of the Woodland Viaduct Bridge revealed that the four arches lacked adequate confinement steel to meet current seismic code requirements. The FRP needed to provide this missing confinement. The final FRP design consisted of three layers of a unidirectional glass composite system. The installed thickness of these layers was 0.15 in. Glass was chosen over other types of composites because of its high ductility and lower comparative cost. Extensive structural and environmental durability test reports were required to verify the performance characteristics of the glass FRP.

Project Challenges

There were several challenges that had to be addressed during the application process. The arches are not uniform in cross section, preventing multiple layers from being applied in one continuous application. At the column locations, it was not possible to completely encase the arch. In addition, access to the arches involved working around a commuter railroad schedule and over a river.

To address the first problem, the glass composite material was applied in two half-sections around the arches and overlapped in the center. Testing has demonstrated that 3 in. is an adequate bond length to transfer the full tensile capacity of this FRP. A minimum length of 6 in. was used for this application.

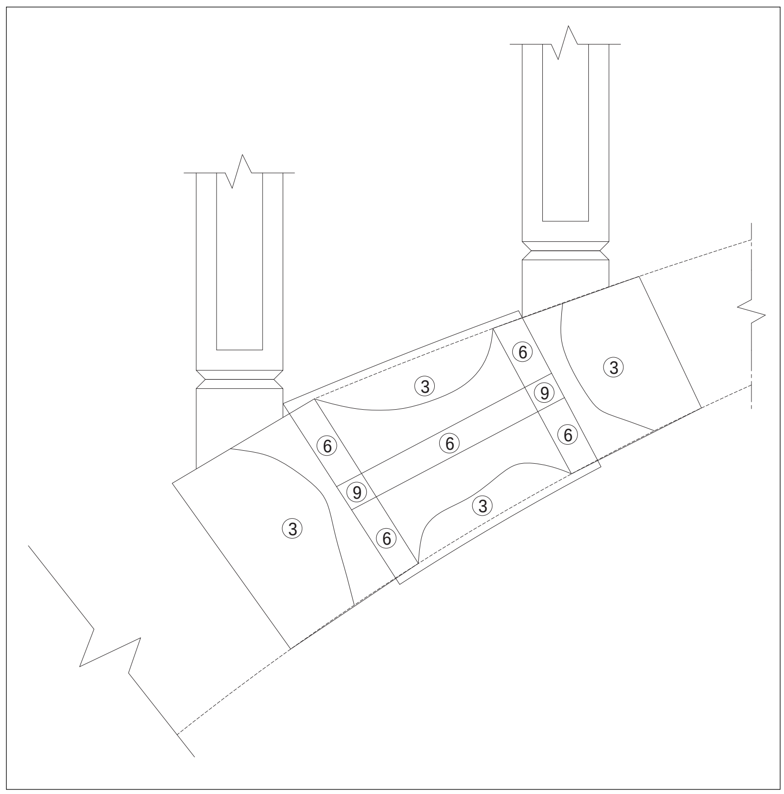
At locations where the columns prevented continuous wrapping, an innovative layup sequence was designed such that the required design thickness would be achieved. This design included using additional continuous wraps to anchor the discontinuous layers. This resulted in nine layers of composite being applied at some locations (see diagram).

Scaffolding

To supply access to the columns, a unique scaffolding system was designed that allowed access to the arches without disruption to the Metro North Railroad. The scaffolding was designed to attach and hang from the existing deck, thereby avoiding the need for supports on the ground. The hanging platform allowed access to the arches in 6-ft increments. After the application to one 6-ft section, the rigging was moved to allow access to the next 6-ft section of the arch. This system did not interfere with the railroad schedule, which decreased the impact of the construction on surrounding areas.

Overall, FRP composites provided a state-of-the-art rehabilitation design for the arches of the historic Woodland Viaduct Bridge. This solution maintained the appearance of the bridge and had a minimal impact on the community. This retrofit solution offered a significant cost savings over replacement of the entire structure. Overall, FRPs offer a unique solution for rehabilitation of historic structures.

Completed application



Elevation: The exterior arch rib is shown—the interior is similar (not to scale)

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