Accelerated Bridge Construction Keeps Tappan Zee Bridge Open

By Helena Tam, P.E., Mohammad Shams, Ph.D., and Kenneth Standig, P.E.

Aerial photo of Tappan Zee Bridge. Courtesy of New York State Thruway Authority.

Located 13 miles north of New York City, the 53-year old Tappan Zee Bridge is a 3-mile long Hudson River crossing connecting the New York State communities of Nyack and Tarrytown. The bridge is part of Interstates 87 and 287 and with an annual average daily traffic of 140,000 vehicles, reaching 170,000 vehicles a day during major holidays, is considered heavily travelled. This is significantly more than the 18,000 vehicles the bridge averaged daily when it went into service in 1955.

The aging bridge deck experienced more than 100 punch-throughs (holes) from 2002 to 2003. Without bridge deck replacement, the New York State Thruway Authority (NYSTA) estimated more than 900 punch-throughs would occur annually by 2020. The NYSTA held a Federal Highway Administration (FHWA)-sponsored Accelerated Construction Technology Transfer (ACTT) workshop in 2005 to affirm its approach to use prefabricated systems to quickly repair deteriorating bridge decks with minimum disruption to traffic. The FHWA selected this project for the following reasons: the immediate need for the repairs; the function of the bridge as a lifeline structure connecting New York City to points north and west; the limitations imposed by an unremitting traffic stream; and its traffic volume.

The entire bridge consists of four types of structural systems. The main span is a central 2,400-foot three-span through truss. There is a 3,100-foot-long deck truss to the east of the central truss and a 1,750-foot-long deck truss to the west. Finally, there is an 8,300-foot-long steel stringer-supported causeway at the western extent of the bridge. The bridge is seven lanes wide, with three lanes northbound (NB), three lanes southbound (SB), and a center lane that can be converted into either direction via a movable barrier system to accommodate rush hour traffic.

HDR was retained to work with NYSTA staff to implement the recommendations of the ACTT conference. HDR was responsible for designing the deck replacement for the outer two lanes for both the NB and SB directions of the main span over the navigation channel, as well as the West Deck Truss, while NYSTA staff designed the deck replacement for the outer two lanes in each direction on the causeway. The central three lanes, which exhibit less deck deterioration, are programmed for replacement at a later date.

Installation of exterior precast deck panel, including permanent steel barrier, at main span, ready for vehicles to ride on in the morning.

Project Description

The scope of work called for replacing the concrete deck plus its supporting stringers with a prefabricated superstructure system for the two-outer lanes for the Northbound and the Southbound lanes. The stringers were included as part of the prefabricated deck panels to enhance constructability by making handling and installation easier. This ensured that sections of the bridge deck could be removed, replaced and opened to traffic within a single night work shift. The innovative pre-engineered panels also included saw-cut grooving, permanent steel barriers, and pavement striping, making them ready for the immediate use of the roadway. Tolerances between existing/new and new/new panels were tight enough that a simple joint system could be employed, thus eliminating an additional construction stage.

Social, Economic, Sustainable Design Consideration

As a result of the stringent traffic criteria, the deck replacement scheme was developed with strict limitations on lane closures to minimize traffic delays. (The contractor was required to open all lanes at the end of each night shift, in time for the morning rush hour, and was subject to penalties of a minimum of $500 per minute for missing the deadline.) Three local contractors were contacted during preparation of the design to obtain feedback on the construction staging sequence and associated productivity rates. Based on these meetings, each prefabricated module was designed to be supported by two steel stringers with a concrete edge beam. They were sized to cover one lane of traffic, making it easy to lift and handle for installation during a single overnight shift. Also, since the deck of the main span and the West Deck Truss are at high elevations above the river, and because of the overhead members of the through truss, delivery from a barge was not practical. Therefore, the overall size of the deck module was determined based on roadway delivery constraints. Panels were transferred from flatbed trucks and set in place using on-roadway or barge-mounted cranes.

Deck panels are fabricated in this large precast plant in New Jersey.

The West Deck Truss

The West Deck Truss (WDT) consists of two longitudinal main trusses with a length of 250 feet per span. The transverse floorbeam trusses are spaced at 25 feet, connecting to the longitudinal main trusses. Fifteen steel stringers support the 6¾-inch thick concrete deck. The stringers are continuous over the 250-foot length of the main trusses. The stringers are connected to the top chord of the floorbeam trusses using steel bearing stools.

The location of cut lines in the deck were determined based on three considerations: a) pre-cutting of the existing deck can be performed during the daytime work shift, b) eliminating temporary and permanent support for the remaining three-inner lanes, and c) minimizing the temporary support for the existing outer lanes. A comprehensive work procedure was developed to ensure that the two adjacent outer lanes could be replaced during one night work shift.

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Barge-mounted crane is used to replace deck. Courtesy of New York State Thruway Authority.

Main Span

The main span consists of deep floorbeams which are connected to the bottom chord of the through truss at approximately 34-foot spacing. Fifteen steel stringers span between the two adjacent floorbeams. A 6¾-inch thick concrete deck is supported by the steel stringers.

The same design approach as the WDT was employed for the deck replacement in the main span portion of the bridge. Due to the complexity of the main span structural system, and to ensure that the deck replacement for two adjacent outer lanes can be accomplished during one nightly work shift, new seat brackets for the new stringers were placed between existing stringers. This operation was performed prior to the deck removal during daytime work shift. *Figure 1* shows a typical seat bracket installed for the new stringers. An expansion joint detail was developed to prevent out-of-plane bending of the floorbeams due to the thermal movement of stringers.

Steel Bearing Stools Rehabilitation

The project also provided an opportunity to address a long-standing problem of cracking in the fabricated steel bearing stools supporting the stringers in the West Deck Truss.

This involved the replacement of 500 steel stub columns, or stools, in the superstructure that are cracking. HDR utilized three-dimensional (3-D) Finite Element (FE) modeling for the analysis of these overstressed structural components. The stool components were modeled both globally as one span of the truss structure, and locally as the stringer with its stool connections to determine the overall solution to the problem (*Figure 2*). Over the years, engineers had stiffened the columns in an attempt to prevent further cracking; however, the computer analysis determined that an opposite approach was necessary. A connection detail was designed

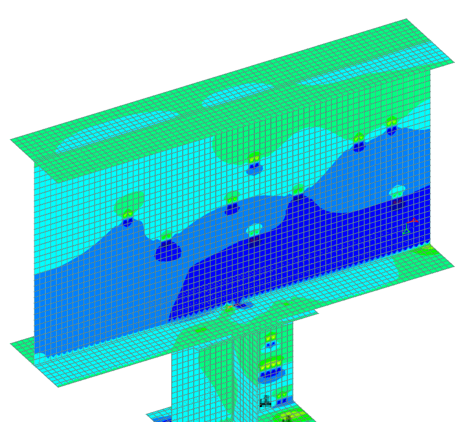

Figure 2: Finite Element model of existing bearing stool and stringer system.

Figure 1: Installed seat bracket at Main Span.

that includes elastomeric bearing pads and slotted bolt holes to increase the flexibility of the columns' connections. The new connection details enable the columns to continue to support the same vertical elements, but also allow them to flex with the bending movements that the bridge experiences.

A Successful Project

Exceptional team work between the bridge owner, designers, fabricators and the contractor was needed to complete this successful Accelerated Bridge Construction project. Up to 18 deck panels were replaced during one nightly work shift without incurring a single morning traffic delay.▪

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