SEGMENTAL CONTRUCTION IN THE INNER CITY: THE BQE CONNECTOR RAMP TO WILLIAMSBURG BRIDGE

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Abstract
The recently completed BQE Connector Ramp is the first segmental highway bridge built in New York City. The objective of the project was to replace an aging 400-meter long four-lane steel viaduct located in a dense urban area. The challenge was to minimize disruption to motorists and neighborhood residents during construction. Segmental construction was chosen, in spite of the fact that the number of segments (288) is less than the generally accepted economic minimum, due to its inherent speed and geometrical versatility, as well as its ability to minimize encroachment of equipment at grade.

The solution was to maintain two lanes of traffic at all times during construction and to keep the duration of lane closures to an absolute minimum. Precast segmental technology made possible the use of a twin box design that satisfied the traffic requirements during construction, and allowed erection to proceed at a maximum rate of one complete span per week. The primary design challenge was to accommodate severe constraints on pier locations imposed by the existing network of streets below the bridge, which could not be permanently modified. At five locations, the two box girders were linked together by massive post-tensioned transverse diaphragms, which allowed shear in the box girders to be transferred to a pair of columns located far inboard of the centerlines of the boxes.

1. Introduction

The BQE Connector Ramp to Williamsburg Bridge is located in Brooklyn, New York and links the Brookly-Queens Expressway, one of New York's major urban freeways, to the eastern approaches of the Williamsburg Bridge, a suspension bridge crossing the

East River into Manhattan. The Ramp carries high volumes of traffic every day between the boroughs of Manhattan and Brooklyn, and is a crucial component in New York City's highway network.

The original structure, built in the early 1950s, was a 398-meter long, four-lane steel viaduct, laid out in a roughly east-west direction. The eastern half of the structure is built above a vacant infield area between two branches of the Brooklyn Queens Expressway. The western half runs down the median of Borinquen Place, a four-lane boulevard in a dense residential and commercial neighborhood. The buildings on both sides of the boulevard define a narrow corridor for this portion of the bridge (Figure 1).

Figure 1 View of original bridge looking east along Borinquen Place

The owner of the bridge, the New York State Department of Transportation, had originally intended to rehabilitate the existing bridge. Given the advanced and extensive state of disrepair of the structure, however, preliminary estimates revealed that such an undertaking was likely to be similar in cost to a complete replacement of the bridge. The Department therefore began a process of detailed engineering studies on alternatives for demolition of the existing structure and construction of a new one. It was clear from the outset that the existing bridge would have to be replaced without acquisition of additional right of way, without demolition of buildings, without permanent change to existing highways and streets below the bridge, and with minimum disruption to vehicular traffic and to residents of the surrounding neighborhood.

Because no additional right of way could be acquired and no existing buildings could be demolished, it was necessary to locate the new Ramp along the same horizontal alignment as the original structure. It thus followed that demolition and construction would involve traffic closures on the Ramp. A primary challenge faced by the project team, therefore, was to keep the disruption to motorists and to neighborhood residents due to traffic closures on the ramp to an absolute minimum. This challenge was successfully addressed through a multidisciplinary project approach that involved close cooperation between two different Departments of Transportation (State and City of New York). The approach is based on the following three measures:

1. *Integrate the construction schedules of the BQE Connector Ramp and City DOT Rehabilitation Contract 7 on the Williamsburg Bridge.* As stated previously, the Ramp links the Brooklyn Queens Expressway to the eastern approaches of the Williamsburg Bridge. This bridge has been undergoing a series of major rehabilitation projects, one of which, Contract 7, would require closure of two lanes of traffic on the bridge for approximately one year. Given that practically all traffic using the BQE Connector Ramp has as its origin or destination the Williamsburg Bridge, it was conjectured that, by scheduling work on the Ramp to coincide with lane closures on Williamsburg Bridge, the increase in disruption to traffic would be negligible. Because the BQE Connector Ramp was a State DOT project and the Williamsburg Bridge rehabilitation was a City DOT project, close collaboration between the two agencies and their consultants was required to implement this measure successfully. Implementation of this measure also required a significant acceleration to the design schedule of the replacement structure for the Ramp.

2. *Accelerate construction of the foundations and piers of the BQE Connector Ramp*. Having defined the window of time available for lane closures, (November 2000 to December 2001, approximately) it was of critical importance to ensure that demolition of the original bridge and construction of the new bridge could be accomplished within these time limits. Given that the subsurface work had a relatively high potential for delays due to unforeseen subsurface conditions, and given that most of the foundation and pier construction could actually be accomplished without the need for traffic closures on the Ramp, it was recommended that construction of the foundations and piers be scheduled a comfortable length of time before the lane closures were to occur. In this way, any unforeseen difficulties due to subsurface conditions could be dealt with without impact to the lane closure schedule. This recommendation was implemented in the following way:

(a) Fast-track the design and preparation of construction documents for the foundations and piers,
(b) Split the foundations and piers off from the superstructure as a separate construction contract, and
(c) Negotiate a price for construction of foundations and piers with the contractor already mobilized on the Williamsburg Bridge rehabilitation contract.

Although the negotiated contract price was possibly higher than what might have been obtained had the project been bid competitively, the time saved by eliminating many steps in the State's contracting process was significant, and was judged to be worth any possible increase in cost. Since the Williamsburg Bridge rehabilitation contract was under the jurisdiction of the City Department of Transportation, Step (c) also involved an agreement between State and City which covered transfers of funding and assignment of specific responsibilities during construction. This could only have been accomplished through close cooperation between City and State.

3. *Use precast segmental technology for the BQE Connector Ramp superstructure.* Precast segmental construction has an excellent track record of rapid erection under conditions similar to those to be found at the BQE Connector Ramp site. As stated previously, only fourteen months were available for the entire demolition and construction effort. Following an in-depth study of alternatives, precast segmental construction was identified as the best means of completing the superstructure within the time available for lane closures, and also the best means of satisfying the other project requirements, which included:

(a) Maximize long-term durability
(b) Provide a high standard of aesthetics, and
(c) Maintain the existing arrangement of curbs on the streets and highway below the ramp

The total number of segments on the project is 288. Given the relatively high fixed costs associated with casting and erection equipment, the minimum limit for economy is generally considered to be higher than this value. On the BQE Connector Ramp project, however, minimizing disruption to motorists and neighborhood residents given the tight time and space constraints for erection of the superstructure was as least as important a project requirement as minimizing cost. Under these circumstances, 288 segments was considered to provide a reasonable balance between higher relative fixed costs and greater speed of construction.

2. Features of Design

The new superstructure consists of twin parallel box girders, each carrying two lanes of traffic. The depth of the box girders is a constant 2.26 meters. Each girder is 398 meters long and is divided into ten spans. The typical span length is 41 meters; the longest span length is 47.9 meters.

It was determined that formwork for an AASHTO-PCI-ASBI 2400-1 standard segment could be modified without undue difficulty to accommodate the required depth of 2.26 meters. The dimensions of the proposed cross-section differ from the 2400-1 standard only in the depth of the webs and width of the bottom slab; all other dimensions from the standard are maintained. The deck slab is transversely post-tensioned.

In the eastern half of the bridge, i.e. over the vacant infield area, the box girders are unconnected and are supported on conventional piers. In the western half of the bridge, i.e., down the middle of Borinquen Place, the piers are located on the median separating the two halves of the boulevard below the bridge. Since it was not possible to change the existing locations of the curbs, the columns for these piers needed to be shifted inward, away from the centerline of the box girders. Post-tensioned concrete diaphragms are provided at these piers to link the box girders and hence to transfer load from the webs of the box girders back to the columns. Design of the arrangement of transverse tendons in the diaphragms was integrated with design of the longitudinal tendons in the box girders to guarantee that the tendons could be laid out without conflict. Temporary steel piers were required at these locations to support the girders concentrically until closure pours linking the two pier segments were cast and post-tensioned.

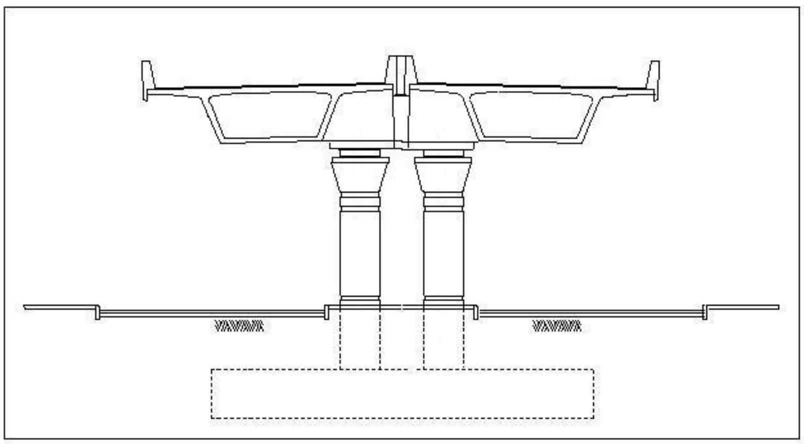

Figure 2 Typical cross-section at narrow median

The bridge was designed to be built by the span-by-span method, and is post-tensioned longitudinally using external, unbonded tendons. Flared trumpets ("diabolos") are used at all pier and deviation segments to allow maximum repetition of details in spite of constantly changing geometry.

The bridge is founded on spread footings at all pier and abutment locations. The locations of new piers were carefully chosen to clear foundations for the original bridge and known critical utilities. The original abutments and retaining walls are incorporated into the new structure, including reuse of existing ornamental granite veneer. Because the vertical profile of the new bridge was raised slightly relative to the original profile, it was necessary to extend the height of the original retaining walls for most of their length.

Pier cross-section is round for Piers 1 through 5 (along the boulevard) and elliptical for Piers 6 through 10. To ensure that the superstructure contractor had control over all critical geometrical issues, construction of the flared capitals at the tops of the piers was included as part of the superstructure contract.

Figure 3 Adjacent box girders are connected via a post-tensioned diaphragm during the final stages of construction

The BQE Connector Ramp is the first new bridge to be designed in accordance with seismic design criteria recently developed for bridges in New York City. The entire superstructure is seismically isolated from the piers by means of laminated elastomeric bearings. In accordance with the seismic design requirements for the project, behavior of the bridge was investigated under combined horizontal and vertical seismic action. This investigation showed that external tendons alone were sufficient to ensure adequate behavior under this load condition.

3. Construction

Construction of foundations and piers was begun in December 1999 and completed in November 2000. The negotiated price for this work was approximately US$13 million. At two locations, foundations for the original bridge required extensive underpinning.

The bid price for superstructure construction contract was US$34 million. This price included superstructure, maintenance of traffic, and modifications to the existing abutments and approaches. The superstructure portion of this contract was estimated at US $20 million. Segment precasting began in November 2000 and was completed in October 2001. The Contractor chose to erect segments onto conventional falsework using a crawler crane mounted on the previously completed span.

The milestone dates achieved for the superstructure construction are as follows:

Begin westbound lane closures:	January 2001

Begin demolition of first half of original superstructure:	January 2001
Begin erection of segments of north box girder:	April 2001
Finish erection of segments of north box girder:	July 2001
Shift traffic over to north box girder:	August 2001
Begin demolition of remainder of existing superstructure:	August 2001
Begin erection of segments of south box girder:	September 2001
Finish erection of segments of south box girder:	November 2001
Open entire bridge to traffic:	December 2001
Stress tendons at transverse diaphragms:	January 2002

Figure 4 View of precast superstructure near completion

4. Credits

Owner:	New York State Department of Transportation
Prime consultant:	Daniel Frankfurt, P.C.
Bridge design consultant:	J. Muller International
Pier and foundation contractor:	Yonkers Contracting Company
Superstructure contractor:	Perini Corp.
Precaster:	The Fort Miller Company