THE DEMONBREUN STREET VIADUCT REPLACEMENT

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ABSTRACT

The Demonbreun Street Viaduct Bridge replacement project is a classic study of how precast and cast-in-place concrete can be utilized to provide context sensitive needs while delivering a cost efficient solution in a minimum timeframe

This project was born in adversity in that the existing 70-year old viaduct, carrying 16,000 vehicles per day was suddenly ordered closed. The ramifications for businesses along the route as well as the motoring public seeking access to a metropolitan downtown center were grave.

In order to replace the viaduct, the Tennessee Department of Transportation had to maneuver through an obstacle course of environmental regulations concerning impacts to an historic district, local groups seeking a signature bridge in keeping with the historic nature of the surrounding area, the crossing of a railroad yard whose 47 trains per day could not be disrupted, as well as the press of time.

Keywords: Precast Prestressed Box Beams, Continuity, Integral Abutments, Construction, Drilled Shafts, Aesthetics.

INTRODUCTION

On July 6, 2004, bridge inspectors advised the Metropolitan Government of Nashville and Davidson County to close an aging 60-year old steel viaduct crossing the rail yard of the CSX Railroad, eliminating one of the three viaducts leading into the downtown business and tourist centers from the West. Age and lack of maintenance had taken its toll (Figure 1). Ten days later, a press conference was held on the veranda of the historic Union Station, overlooking the closed viaduct as Tennessee DOT and Metropolitan Government representatives pledged that within 3-years, a new viaduct would be open at an estimated cost of $8.3 Million, to be designed by TDOT Staff.

Figure 1 Condemned Viaduct

Thus began the development of a unique project that faced many procedural and physical obstacles that would have to be overcome. As the viaduct and the route, Demonbreun Street, is situated in an historic district, a rapidly growing urban renewal district and planned gateway to the County Music Hall of Fame and a $170 Million dollar Nashville Symphony Hall just beginning construction, it would be a highly visible project. The viaduct itself is adjacent to the Union Station, constructed in 1898 and the Frist Museum, the conversion of the former Art Deco Main Post Office, constructed in 1936 as well as touching the historic Cummins Station, a 1920’s constructed freight station, recently converted to offices. The viaduct crosses an active rail yard where 47 trains a day pass, many of which stop at the viaduct for crew changes.

The ramifications to the project development process were that NEPA 4f environmental regulations could be invoked; the project would require extensive coordination with the public, adjacent property owners, business interests, an Urban Design Center review and negotiations with the Railroad. Close coordination with all parties and developing a proposed bridge that could satisfy many interested groups was a must.

The TDOT design team was supplemented by an architect selected by Metro Nashville government to provide assistance in enhancing the viaduct, once TDOT selected the basic structure configuration.

Consultations with the Federal Highway Administration and the State Historic Preservation Office eliminated the need for a formal 4f review, as TDOT promised that the footprint of the replacement structure would be essentially that of the existing and that enhancements complementary to the historic rail facilities would be added, and no disturbance of the original viaduct abutments would occur.

DESIGN CONSIDERATIONS

The viaduct to be replaced was 773-ft. in length and 47-ft. in width, constructed with 13 spans of rolled beams supported on steel bents. The maximum spans over the railroad were two, 50-ft. spans. As the railroad prohibited any at grade crossing of the four tracks by construction equipment, it was decided that the replacement span over the
tracks would be 130-ft. This provided for piers set a clear distance of 25-ft. from the center line of the outside tracks.

Because of the existing tie-ins of the viaduct deck with existing buildings at two critical locations and the proximity of the ends of the viaduct to intersecting streets, as well as the need to provide 23-ft. 6-in. of vertical clearance over the tracks, the depth of the new bridge was critical.

Discussions with the Urban Design Center were held at the request of the Metropolitan government. These discussions focused on appearance and structural form and materials to be used for the superstructure and substructures. Some wished to see the viaduct replaced in kind, others wished to have haunched steel tub girders, while the designers at TDOT proposed a 7-span precast/prestressed concrete box beam bridge, continuous for composite loads. The Department argued successfully pointing out that the steel bridge alternatives would cost more and that delivery time for plate material would precipitate lengthening of the construction phase.

DESIGN IMPLEMENTATION

The final configuration chosen for design is a 7-span continuous bridge 773-ft. 7½ -in. in length, jointless from back to back of the full height abutments (Figure 2).


Figure 2 7-span Jointless Viaduct Replacement

The superstructure is composed of six (6) lines of 48-in. wide by 54-in. deep box beams with a 58-ft. wide, 8¼ -in. composite slab and is designed to be continuous for all composite loads.

The foundations for the integral abutment walls and the intermediate bents are composed of 42-in. diameter drilled shafts, set in two pair clusters for the bents and three shafts per abutment (Figure 3).

Figure 3 42-in. Diameter Drilled Shafts

The steel cages for the shafts extend into the bent columns functioning as hinge reinforcement. At the ground level, a pile cap is poured to form the base for the columns (Figure 4).

Figure 4 Shaft Reinforcement in the Hinge Zone

The restricted depth of the box beams and the length of the controlling 130-foot spans required a concrete strength of 10,000 psi and 46 - 0.6 in. diameter 270 ksi low relaxation strands with an initial jacking force of 2,021,200 pounds. The designers checked with several precasters to verify that the jacking force and beam lengths would not exceed their bed capabilities, so that competition could be maintained.

Because the bridge is designed to be continuous for composite dead and live loads, the hogging moment over the interior supports, combined with the effective prestressing force caused 21 of the 46 total strands to be wrapped, in order not to exceed the 0.6 f'_c limit on beam compression. This led to concerns that the number of wrapped strands might compromise the shear capacity at beam ends. Check of the shear capacity using the disturbed region analysis by strut and tie methods as well as the sectional method led to two decisions. To accommodate the tension in the strut, the prestressing strands are projected 30-in. outside the beam and bent up to be anchored in the cast-in-place 18-in. wide diaphragm that functions as the closure pour between beams at the support. No supplemental mild reinforcement is used in the strut. Additionally, the end diaphragm of the beams is increased from the normal 18-in. thickness to 48-in. and the shear reinforcement for the end region is designed as if the beam was not prestressed.

The abutments consists of a 42-in. thick stem, 16-ft. in height placed in front of the original abutments with a 4-in. thick Styrofoam layer glued to the original abutment walls, to accommodate thermal movements, as the abutments are made integral with the superstructure. The foundation for the abutment wall consists of three 42-in. diameter drilled shafts. A hinge is introduced between the pile cap and the base of the abutment wall to allow the rocking required to accommodate thermal movements.

AESTHETIC CONSIDERATIONS

The overall thematic approach to the bridge aesthetics was influenced by both the historic railroad station, constructed in 1898 and the historic art-deco inspired post office, constructed in 1936 and which now serves as an art museum. The over arching shapes of the bents and railings are art deco, down to the lighted sconces that conceal lighting behind them attached along the exterior of the rails (Figure 5). The bents are fashioned with fanciful custom form liners that depict steam locomotives of the type power used for trains through most of the active life of the station (Figure 5). The form liner for the railings and the specialized tube and cable hand rail (Figure 5) are a tribute to the previously demolished train shed that at one time was the largest clear span truss in the United States.

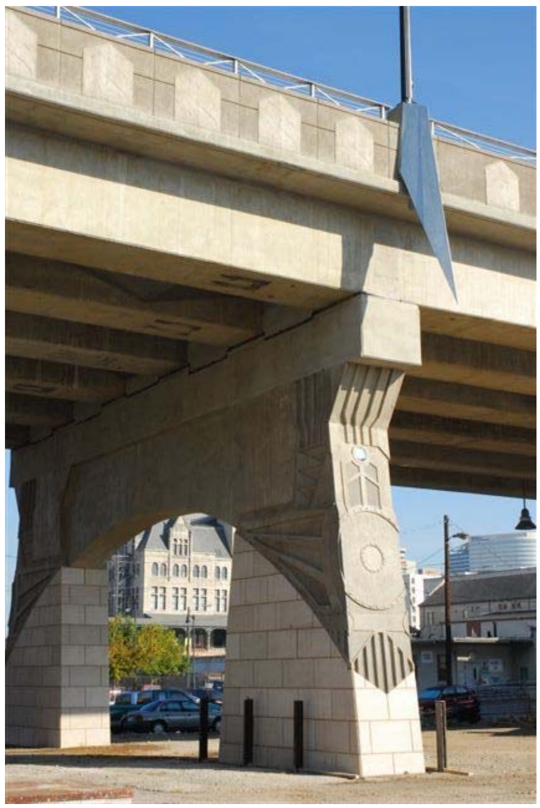

Figure 5 Architectural Bents and Sconces

One concern expressed by the property owners was that the bridge surface be designed to eliminate pigeon roosting that had plagued the old viaduct. This was accomplished by casting the bent diaphragms between adjacent beams full width of the bent caps (Figure 6). Bituminous fiberboard is used between the bent cap and the bottom of the diaphragm to prevent edge loading and spalls as the bents rotated out of plumb under thermal forces. Additionally, the sides and tops of the box beams ends are wrapped with ½ in. thick Styrofoam sheets so that beam deflections or bent rotations would not inhibit rotations and apply a torque to the beam ends. The beams at the bents sit on a common 1¾ -in. thick neoprene pad. Dowels embedded in the bent cap and diaphragm pass through the neoprene pads to form the pin connection. Similar details are used at the abutments.

The resulting configuration allows for the bridge to be jointless from the backs of both abutments.

Figure 6 Continuity Diaphragms

CONSTRUCTION

The major construction problem to be overcome was the erection of the 128-ft. long 158,000 lb. beams over the railroad tracks, as (previously mentioned) the railroad would not allow construction equipment or personnel to cross the four tracks. The designers consulted with contractors on this constructability issue. To accomplish the erection, a steel truss launching beam was used to push and pull the beams over the tracks. Two cranes were used to lift the beam and place the leading end onto a trolley that rode on rails atop the truss. Once in position, one crane pushed the beam forward until a crane on the far side could hook onto the beam and pull. Once over the supports on each end, the beams were shifted sideways by the cranes into their final position (Figure 7).

Figure 7 Launching of Beams

In order to speed the construction of the new viaduct, a separate contract was let earlier to demolish the existing viaduct. Additionally, the intricate form liners for the new bents were purchased as a part of the demolition contract, as was the provision to construct a mock-up of one end and column for the new bents.

CONCLUSION

Bids for the new viaduct were taken on October 14, 2005 and the bridge completed on October 14, 2006, 5 months ahead of the predicted date, and within the predicted budget (Figure 8). Costs for the bridge were $111.00 per sq. ft. for the superstructure and $31.00 per sq. ft. for the substructure. The ability to accomplish the rapid construction within the specified budget and satisfy context sensitive issues was the choice to construct the bridge from concrete components. The precast prestressed beams meet the critical clearance requirements and allowed for timely delivery schedules demanded. The infinite possibilities of cast-in-place concrete to be molded into intricate shapes made the aesthetics envisioned an achievable goal.

Figure 8 Finished Bridge