LOUISIANA'S FIRST 10,000 PSI PRECAST PRESTRESSED CONCRETE BOX GIRDER BRIDGE

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ABSTRACT

The new North Boulevard Bridge represents a first for the State of Louisiana by using precast prestressed concrete box shaped girders designed with high strength 10,000 psi (69 MPa) concrete. The new North Boulevard Bridge, which was opened to traffic in March 2006, is in an existing underdeveloped combination business area and urban community within the city limits of Baton Rouge. The City of Baton Rouge/Parish of East Baton Rouge Department of Public Works and the local community wanted a visually pleasing bridge with landscaping that improved the quality of the area for future cultural events and to preserve several historic buildings. The bridge was constructed in a reverse curve alignment that had to pass within a few feet of and between two existing historic buildings, and over the Kansas City Southern Railroad (KCSR) tracks in Baton Rouge, Louisiana. The solution was a horizontally S-curved, medium span bridge with smooth surfaces that was provided by the graceful, shallow depth, high strength, straight precast prestressed, concrete box girders and the uniquely sculptured arch shaped concrete piers. This article presents a review of the design, details, costs, construction challenges, and the successes in using the precast prestressed concrete box girders for the bridge superstructure.

Keywords: Bridge Aesthetics, Precast Prestressed Concrete Box Girders, Design, Construction, U Beam.

INTRODUCTION

In 1997, the City of Baton Rouge/Parish of East Baton Rouge voters approved the proposed North Boulevard improvements. The major benefit of the project was to improve the west to east flow of traffic to exit or enter the downtown area without the railroad train obstructing traffic.

Public meetings were held for the proposed North Boulevard improvement project. Discussions with the community initiated the desire to construct a bridge that was aesthetically pleasing. The local community initially resisted the proposed grade separation improvement versus an at grade improvement for several reasons. Many local residents felt that a bridge would destroy the core of their community. Others said that they were concerned the overpass will bring crime, vagrancy and litter to the area near two public recreation parks and the historic Prince Hall Masonic Temple, which are historic meeting places for the community. The City of Baton Rouge/Parish of East Baton Rouge Department of Public Works promised the community that a visually pleasing bridge would be built. The bridge would be surrounded by landscaping that improved the quality of the area for future cultural events. Also, the bridge would be built in an alignment which would preserve several historic buildings.

The solution became Louisiana's first 10,000 psi (69 MPa) precast prestressed concrete box girder bridge which was opened to highway traffic in March 2006. The new North Boulevard Bridge is a horizontally reverse curved (S-curved), medium span bridge with smooth surfaces that was provided by the graceful, shallow depth, high strength, straight precast prestressed, concrete box girders and the uniquely sculptured concrete arch shaped piers as shown in Figures 1 and 2.

Figure 1: Finished Bridge Elevation View of the West Spans

Figure 2: Finished Bridge Elevation View of the East Spans

CONCEPT DEVELOPMENT

The new North Boulevard Bridge needed to be a four (4) lane highway facility. The bridge had to provide a vertical clearance of 23.5 feet (7.16 meters) over the existing railroad top of rail. The bridge spans needed to be designed for the planned future railroad tracks, track and roadway realignments, and provisions for under bridge usage such as public gathering and parking areas. The need to provide for an aesthetically pleasing bridge and the under bridge usage was instrumental in the selection of a smooth under surface type bridge superstructure. The concrete box girder type superstructure with its smooth surfaces satisfied all the project requirements.

A nearby church with arch type architecture was instrumental for the selection of the uniquely sculptured arch shaped concrete piers.

DESIGN

The bridge is designed with a total of nine (9) spans in a horizontal reverse curve alignment. The horizontal curve radius is 1,146 feet (349.30 meters) for both the horizontal curves. Each span is 120.0 feet (36.58 meters) long measured along the project baseline. The total length of bridge is 1,080 feet (329.18 meters). There are three (3) continuous for live load units which have three (3) spans each. All the piers were set normal or radial to the baseline as shown in Figure 3.

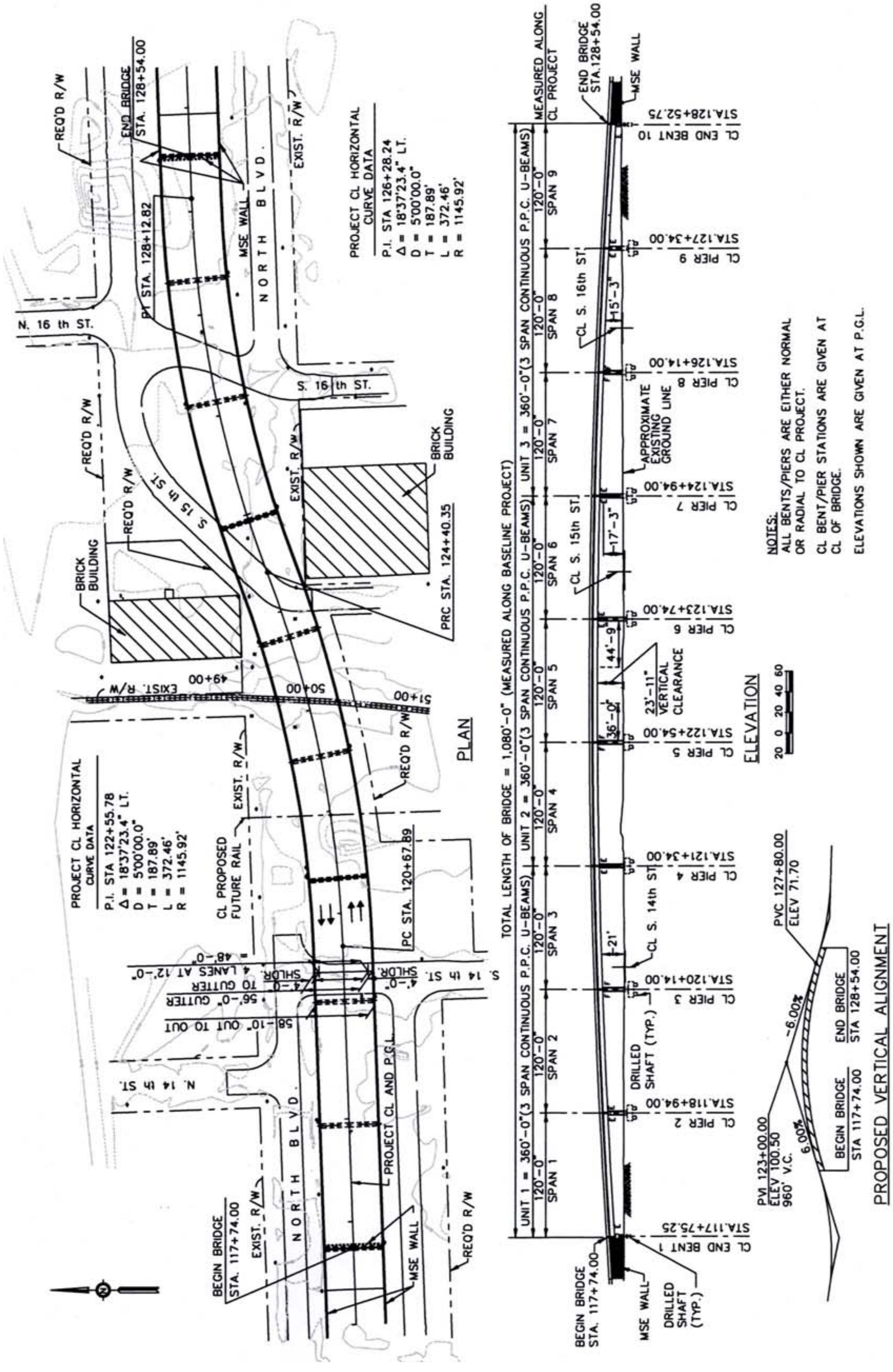

Figure 3: Plan and Elevation

The bridge superstructure is a single 58.83 feet (17.93 meters) wide horizontally S-curved structure. All spans contain a total of five (5) straight precast prestressed concrete box girder lines. The precast prestressed concrete box girders are integral with a 7.5 inch (191 mm) cast-in-place concrete deck. The box girder spacing varies between 11.33 feet (3.45 meters) and 11.71 feet (3.57 meters). Internal full depth concrete diaphragms, cast with the box girder, were provided at all box girder ends and 12.0 feet (3.66 meters) from the midspan. External full depth cast-in-place concrete diaphragms between the box girders were provided only at the pier locations. These diaphragms provided structural stability to the system during deck pouring and finishing operations. Galvanized stay-in-place metal forms were allowed within and between the box girders in order to minimize construction time and costs. The bridge typical section is shown in Figure 4.

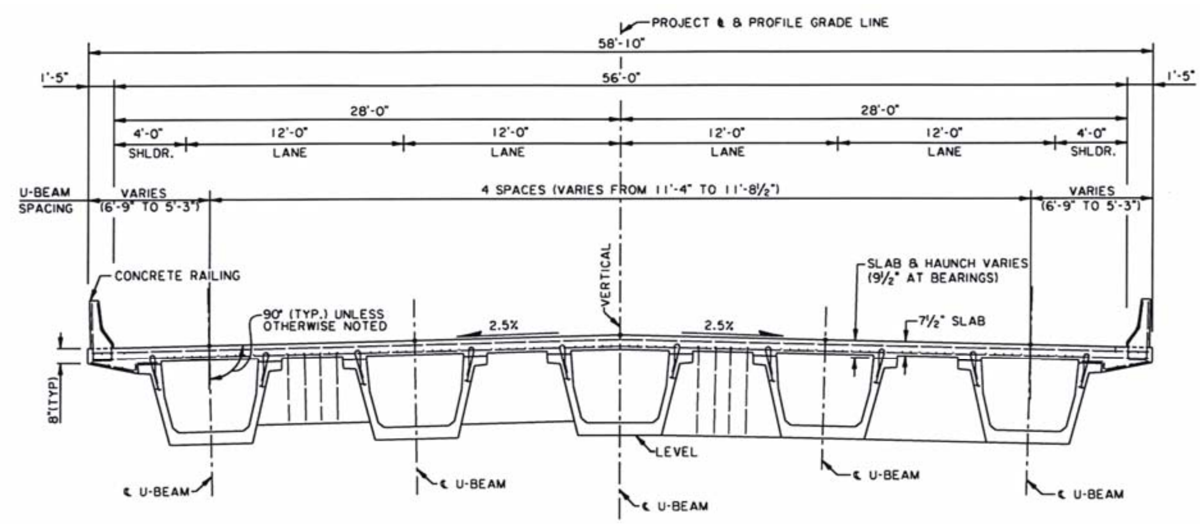

Figure 4: Typical Bridge Superstructure Section

The cast-in-place superstructure deck, diaphragm and barrier concrete were all designed with a 28 day strength of 4,200 psi (29 MPa). A thinner deck slab could have been provided based on the girder system strength requirements. However, a 7.5 inch (191 mm) minimum depth slab was used to satisfy durability and barrier impact resistance requirements.

The superstructure precast prestressed concrete (PPC) members are 54 inch deep U Beam shaped box girders. The U Beam shaped box girders contain top flanges and have the same dimensions as the recently developed standard Texas U54 Beams. The PPC box girders were designed for the release strength of 6,000 psi (41 MPa) and the 56 day strength of 10,000 psi (69 MPa). Ninety-two (92) straight 0.5 inch (13 mm) diameter prestressing strands with a minimum ultimate tensile strength of 270 ksi (1.86 GPa) were used. The total prestress force was 2.9 million pounds. There were twenty (20) strands debonded with different debond lengths in the box girder bottom flange. The precast prestressed concrete box girder section is shown in Figure 5.

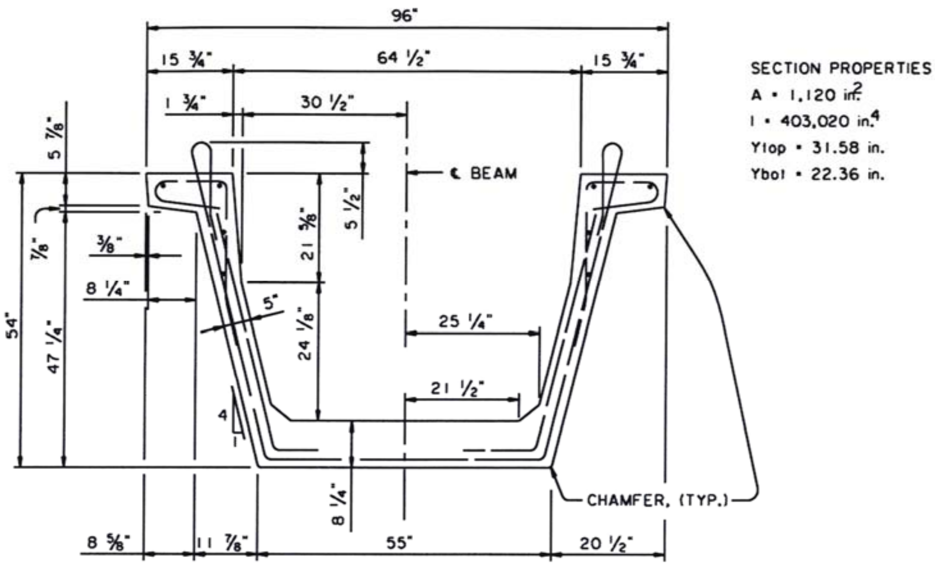

Figure 5: Precast Prestressed Concrete Box Girder Section (Texas U54 Beam)

All structural members are designed in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges 17th Edition.

An in-house proprietary computer program was used for the structural design of the three span continuous units. The computer program can simulate the erection procedure and all prestressed conditions. The computer program can also include non-composite and composite conditions for any type structure. Time related effects of concrete creep, shrinkage, prestressed losses and secondary moments due to restraint conditions and prestressing are included in accordance with AASHTO and the international CEB-FIP Model Code.

The bridge superstructure concrete box girder design using high strength concrete resulted in a much lighter and shallower overall superstructure which in turn required a smaller less costly substructure system and a shorter approach length. The shorter approach length saved project costs which included the reduced expensive right-of-way acquisitions.

CONSTRUCTION COSTS

Construction Bids were taken in June 2004. The total construction cost for the project was \$12.0 million. The total construction cost of the bridge items was \$5.1 million or about \$80 per square foot. The first use of the 10,000 psi (69 MPa) Texas U54 beam box girders in Louisiana, the complex geometry and the uniquely sculptured arch shaped concrete piers were the major reasons for the high costs. It was anticipated that the Contractor might use an experienced Precaster from the neighboring State of Texas. At the time of the construction bid for this project, the cost of the Texas U54 beam was in the range of about $200 per linear foot based on published bids. The construction bid for the North Boulevard Bridge box girders was $385 per linear foot. The Contractor indicated that he was unable to obtain a Texas Precaster that could produce the box girders within the time frame needed for the project. The high cost of the box girders was due primarily to the required complex geometry, the need to purchase box girder forms for the project and the first time start up costs for the Precaster.

BOX GIRDER FABRICATION

The 10,000 psi (69 MPa) design high strength precast prestressed concrete box girders were fabricated by Gulf Coast Pre-Stress, Inc. in Pass Christian, Mississippi. This Precaster had previous experience with the fabrication of the 10,000 psi (69 MPa) high strength precast prestressed concrete which proved to be vital.

The following was the project box girder concrete design requirements (Source Louisiana DOTD specifications):

56 Day Strength	Minimum 10,000 psi
Slump	Maximum 10 inch
Permeability	Maximum 2,000 coulombs in 56 Days
Silica Fume	Maximum 10.0% by weight*
Fly Ash	Maximum 35.0% by weight*

* by weight of the total combination of cement, fly ash and silica fume

The following was the approved box girder concrete mix design (Source Gulf Coast Pre-Stress, Inc.):

Component	**Quantity**	**Type**
Cement Quantity	691 lb/yd^3	Type III
Fly Ash Quantity	296 lb/yd^3	ASTM Class C
Fine Aggregate	1,091 lb/yd^3	Sand ASTM C-33
Coarse Aggregate	1,803 lb/yd^3	Limestone ASTM C-33 Size 78
Water	250 lb/yd^3	Potable
Retarder	60 fl oz/yd^3	HPS-R (Hunt Process Corp.-Southern)
Air Entrainment	1.0%	
High-Range Water Reducer	275 fl oz/yd^3	HP-HRWR-SP (Hunt Process Corp)
Water Cement Ratio	0.25 (by weight)	
Unit Weight	153 lb/ft^3	
Slump	7 inch maximum	

For the box girder, the concrete strengths based on test cylinders for 23 recorded pours were as follows:

Age in Days	Compressive Strengths in psi (MPa) Average	Range
1	6,800 (47)	3,990-8,680 (28-60)
2	9,900 (68)	9,140-10,970 (63-76)
3	9,300 (64)	3,890-10,790 (27-74)
28	13,600 (94)	9,790-15,840 (68-109)

For the box girder, some actual cylinder breaks were recorded as follows:

Age in Days	Compressive Strengths in psi (MPa) Pour No. 2	Pour No. 5
1	8,277 (57)	8,683 (60)
28	13,330 (92)	13,121 (90)
28	13,456 (93)	13,757 (95)
28	14,731 (102)	14,302 (99)
28	15,151 (104)	14,647 (101)

The fabrication of the high strength precast prestressed concrete box girders did not pose any significant problems that could not be overcome with minor adjustments. All of the box girder ends were fabricated with skews and batters in order to accommodate the bridge geometry and grade.

CONSTRUCTION

The North Boulevard Bridge was constructed prior to and during the huge surge in the Baton Rouge local traffic that resulted in the aftermath of the 2005 hurricanes Katrina and Rita. The bridge was constructed in a reverse curve alignment that had to pass within a few feet of and between two existing historic buildings, and over the Kansas City Southern Railroad (KCSR) tracks in Baton Rouge, Louisiana.

The project's high strength precast prestressed concrete box girder's inherent stability, its lighter weight (i.e. lighter than a similar box girder designed for similar span lengths using normal strength concrete) and its ease of erection proved to be the best solution for the construction within the limited right-of-way. The construction over the KCSR tracks and between the existing buildings went very fast because there were very few members to erect compared to the many multiple standard AASHTO type girders that would have been required. The fast erection minimized the interruption of the railroad train operations and the local traffic.

Each 120 foot (36.58 meters) long 10,000 psi (69 MPa) concrete box girder weighed an average of about 80 tons (72.6 metric tons). A precast prestressed concrete box girder on a previous project in Louisiana, with similar type and length box girders designed using 6,000 psi (41 MPa), weighed an average of about 120 tons (108.8 metric tons) each. The precast prestressed concrete box girders were trucked to the site and then erected with cranes as shown in Figures 6 and 7.

Figure 6: Precast Prestressed Concrete Box Girder Delivered by Trucks

Figure 7: Precast Prestressed Concrete Box Girders Erected

The box girders inherent torsional stability allowed the contractor to erect all the girders quickly without having to provide temporary or permanent intermediate diaphragms, bracing or special blocking between the erected 120 foot (36.58 meters) long box girders as shown in Figures 7 and 8.

Figure 8: Precast Prestressed Concrete Box Girders Erected

The cast-in-place concrete deck forming and pouring proceeded without any major problems. The erected box girder cambers prior to the deck pour varied widely. The estimated design camber was computed to be 4.6 inches (117 mm) at 35 days for 10,000 psi concrete. The actual box girder cambers varied from 2.5 inches (64 mm) to 4.1 inches (104 mm) prior to deck pour. The girder camber variance was normal and typically the result of many factors. The differing concrete strengths during release of strands, the actual 28 day concrete strengths between 9,790 to 15,840 psi (68 to 109 Mpa) and the age of member prior to deck pour affected the box girder camber the most. The actual number of days between the casting of box girders and pouring of the deck varied from about 180 to 330 days. Minor adjustments in the roadway grade were made to compensate for the differences in cambers.

CONCLUSION

The major aesthetic considerations required a bridge that the community could all agree on, it had to fit the challenging geometric and physical conditions, it had to preserve historic facilities, it had to be functional and economic, and be sculptured to reflect the local culture to integrate the bridge into its community's history. The final bridge turned out to be visually appealing, slender, elegant and one that compliments its surroundings. The slender and smooth surfaces of the PPC box girder in combination with the uniquely sculptured arch shaped concrete piers resulted in a visually pleasing structure that the community is proud of.