TENNESSEE STATE ROUTE 385 OVER THE WOLF RIVER WETLANDS: A PRECAST SOLUTION

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ABSTRACT

Environmental considerations necessitated a change in the bridge required on State Route 385 over the Wolf River in West Tennessee. During preliminary design a 5-span, 720-ft long structure was proposed for the crossing. This evolved into a 33-span, 3,250-ft long structure composed of 4 continuous units which bridged not only the Wolf River, but adjacent wetlands as well.

To optimize economies of the major structure, both prestressed concrete and steel rolled shape girders were included as alternates in the contract plans. Both girder systems were designed incorporating simple for dead load, continuous for live load (SDCL) details.

Thermal displacements at 3 out of the 31 pile-bent substructures were accommodated with strip seal expansion joints located between "double-bents". Pipe piles were designed for seismic loading and extended beyond liquefiable layers. Out-of-phase transverse seismic deformation of the "double-bents" was prevented with pipe restrainers to protect the expansion joints.

The bid cost of the bridge was $14,220,000 resulting in a unit price of $50 per square foot for the dual, 44-ft wide structures. All five bidders opted for the precast, prestressed girder alternate.

Keywords: Bridges, Wetlands, Pile-bent, Seismic, Thermal

INTRODUCTION

The Tennessee Department of Transportation completed plans to construct a new highway between existing State Routes 193 and 196 in Fayette and Shelby Counties. The north-south running State Route 385 (also known as Interstate 269) consisted of 9 bridges, including a 5-span, 720' structure (Bridge No. 3) over the Wolf River main channel with a 2-span, 177' structure (Bridge No. 4) over a Wolf River tributary. In the original design, both Wolf River structures included plans for prestressed concrete girders with cast-in-place columns on pile-supported footings at the substructures.

Environmental concerns which identified the surrounding area as wetlands necessitated a change in the plans for Bridge Nos. 3 and 4. It would not be possible to fill in the wetlands and the entire area had to be spanned. Bridge No. 4 was eliminated and Bridge No. 3 became dual 3,250 foot long structures, each composed of 33 spans in 4 continuous units with pile bent substructures. Approximately the first half of each structure is in a curve of radius 2,865 feet with the last half in a tangent section. Figure 1 is a partial cross section of the superstructure.

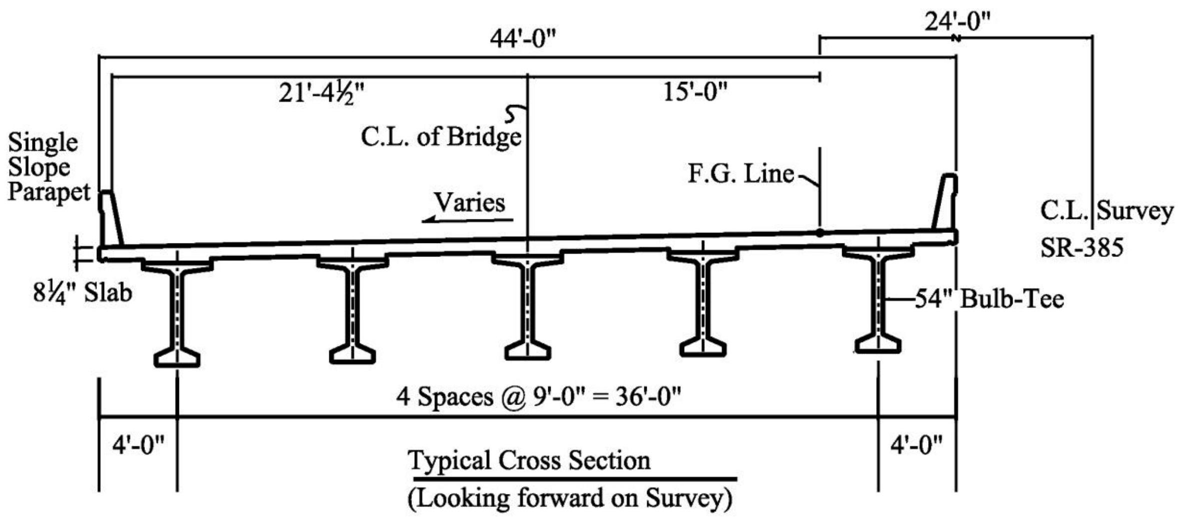

Figure 1. Cross-section of the Bridge

ALTERNATES

To foster competition, alternate superstructure designs were included in the contract plans. A 54" bulb-tee girder design along with a rolled steel girder (W40X149, Grade 50W weathering steel) design comprised the two options offered.

The steel girder required a 6" increase in girder spacing over the bulb-tee alternate to optimize deck reinforcing. More transverse deck reinforcing, and less longitudinal deck reinforcing, was required for the steel alternate. The net effect was a reinforcement total of 2,450,898 pounds for the concrete alternate and 2,117,119 pounds for the steel alternate, again a source of potential savings for the steel alternate.

Due to the lighter total weight for the steel alternate, thinner pipe piles (18”x3/8” versus 18”x 1/2” for the bulb-tee alternate) were required resulting in somewhat advantageous substructure costs for the steel alternate. This savings was not realized at the bents which span the main channel of the Wolf River (Bent Nos. 23 and 24). Due to a longer unsupported length, 24”x1/2” piles were required for both alternates at these substructures. The total estimated steel piling for the alternates was 3,015,910 pounds for the steel alternate and 4,721,580 pounds for the concrete alternate.

Both prestressed concrete and rolled steel girder alternates were designed and detailed to behave as simple spans for non-composite dead loads and continuous thereafter.

Double-bents – each bent having its own row of piles – were used to accommodate thermal expansion and contraction requirements at Bents 8, 16, 1nd 24. See the section on Seismic Design Features for a further discussion on the double-bents.

Precast, prestressed concrete deck panels (3 ½ inches thick) were selected by the Contractor for each of the eight (8) bridges on the project. Girder type, number of deck panels and deck panel nominal sizes are given in Table 1. In addition to the precast superstructure elements, 20,805 LF of 14-inch square precast concrete piling was installed on the project.

Figure 2 shows an aerial view of the completed dual structures.

Table 1. Precast Superstructure Component Summary

Structure	Girder Type	Girder Qty (LF)	PPC Panel Size	No. of Panels
SR-385 / Wolf R. Lateral	Type II	2,298	8’7” x 8’0”	256
SR-385 / Fletcher Rd	BT-72	2,278	5’8” x 8’0”	248
SR-385 / Wolf River	BT-54	31,941	5’10” x 8’0”	3,384
SR-385 / Wolf R. O.F.	Type II	1,710	8’7” x 8’0”	194
SR-385 / Wolf R. Trib.	BT-63	1,170	5’10” x 8’0”	256
Raleigh-Lagrange / SR-385	BT-63	1,075	8’1” x 8’0”	102
SR-385 / Johnson’s Creek	BT-63	1,166	5’10” x 8’0”	128
SR-385 / Monterey Road	Type IV	1,768	7’8” x 8’0”	200

Figure 2. Completed Dual Structures

END BLOCKS WITH POST-TENSIONING

For the prestressed bulb-tee alternate, end blocks and vertical post-tensioning ere incorporated. These two features were included to enhance the shear strength and bursting capacity of the discontinuous ends of the girders. End block and post-tensioning details are depicted in Figures 3 and 4. Note that these features appear only at abutment ends and at double-bent ends of the girders. Plain elastomeric pads were used at all bearing locations

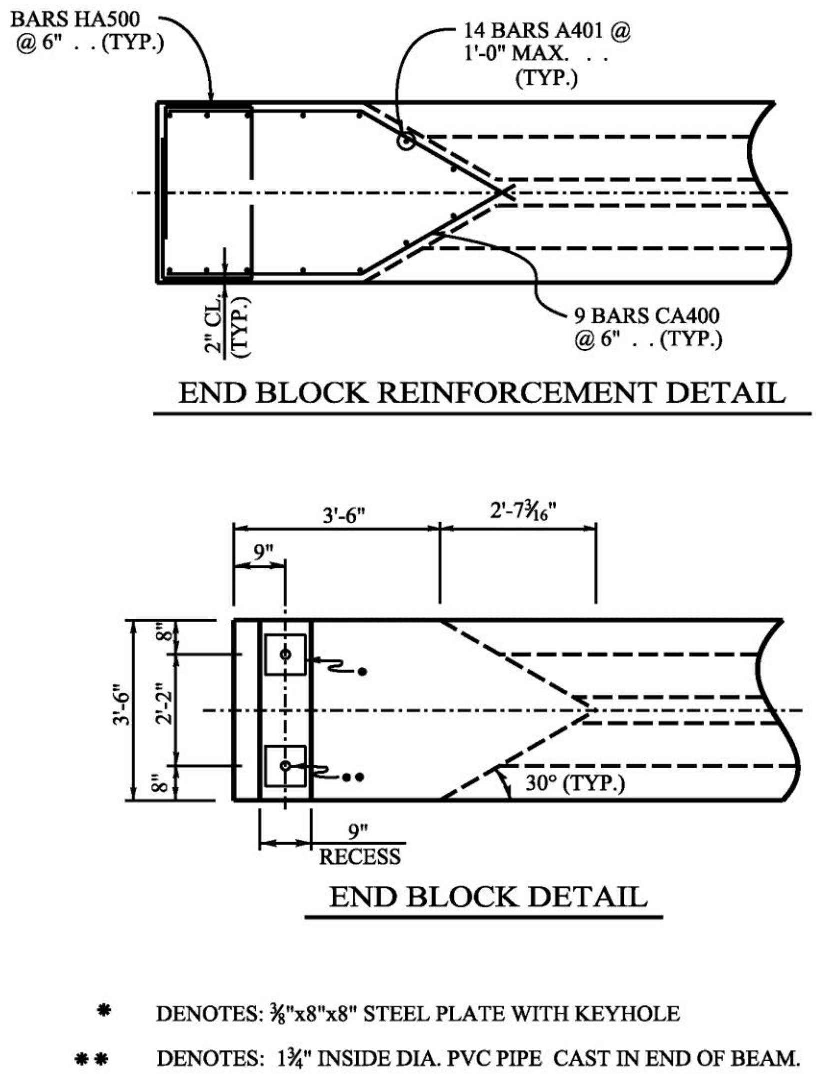

Figure 3. Plan View of End Block Details

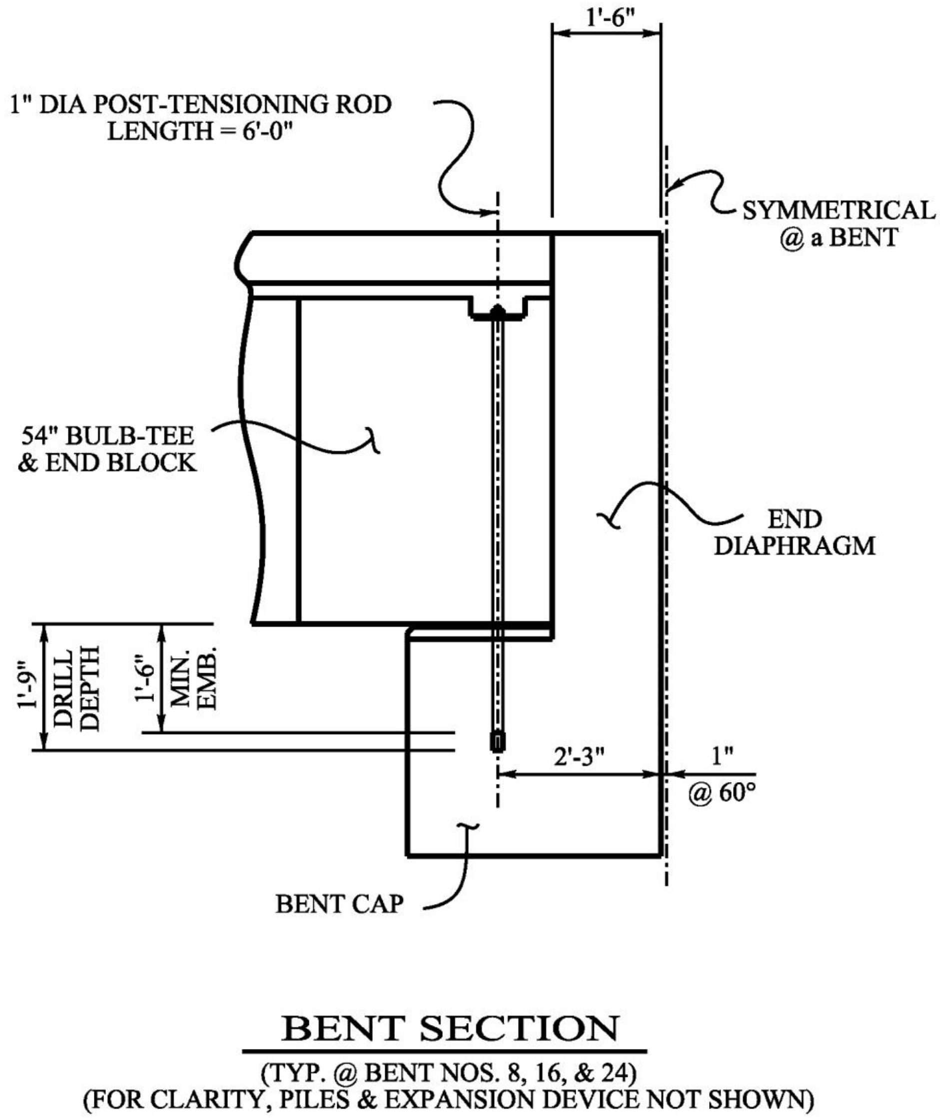

Figure 4. Post-tensioning System

SITE CHARACTERIZATION

Code-base site amplification, including that in AASHTO, is based on subsurface profile properties in the upper 100 feet (30 meters) at the site. The New Madrid Seismic Zone lies within an embayment of soils as deep as 3,000 feet or more in certain locations. Clearly, effects of embayment depth upon site amplification need further study in the NMSZ but, for now, at least, code-based site amplification is the option of choice for most engineers designing structure sin the region. The stretch of SR-385 lies in the Mississippi Embayment of the New Madrid Seismic Zone. From maps in the literature[1] (See Figure 5), the embayment depth was found to be approximately 2,000 feet (600 meters). Eighteen (18) 80' deep borings were made to investigate subsurface conditions.

Borings away from the main channel of the Wolf River indicated average blow counts computed in accordance with AASHTO[2] of about 19, while those nearest the main channel were in the 12-15 blows per foot range. These blow counts correspond to Site Class D conditions away from the main channel and Site Class E conditions at the main channel of the Wolf River. Using the site latitude and longitude, OpenSHA[3] software was used to establish an inferred shear wave velocity for comparison to the blow count correlations already reported. OpenSHA reported an inferred shear wave velocity of 785 fps (240 meters/second). The range for which Site Class D conditions are applicable is 180-360 meters per second. Thus, blow count data combined with an inferred shear wave velocity of 780 fps indicate Site Class D conditions.

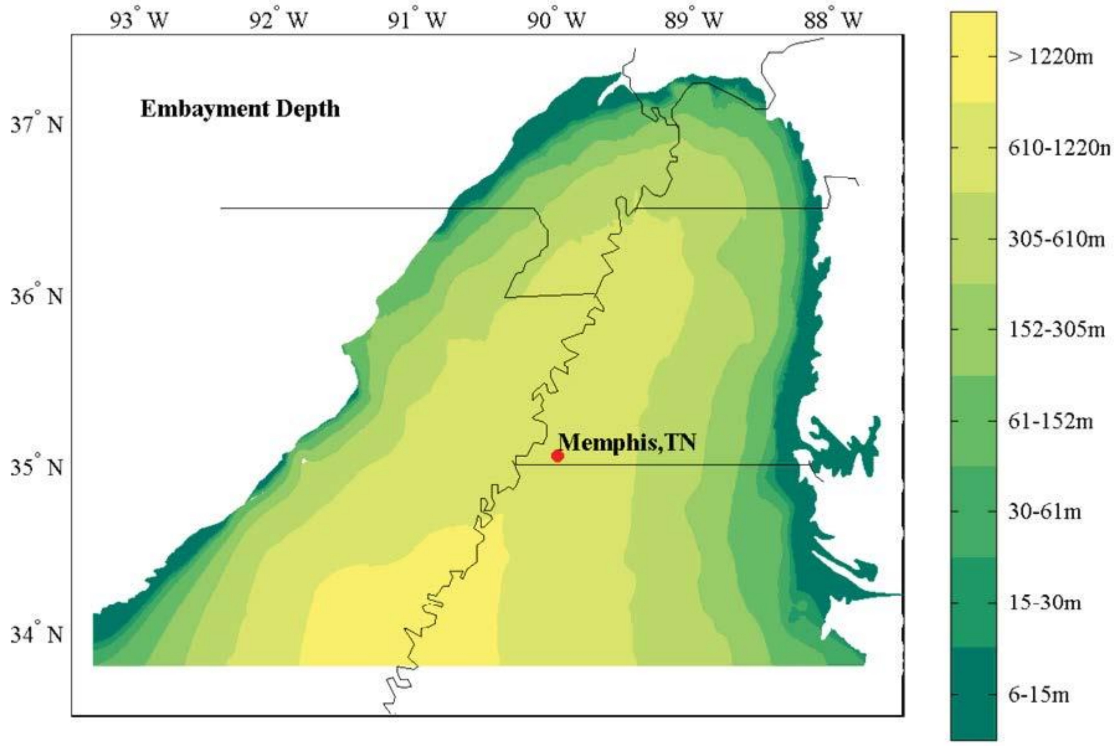

Figure 5. Mississippi Emabyment Depth (from Fernandez[1])

SEISMIC DESIGN FEATURES

The pipe piles in a pile bent substructure may be forced to behave in an inelastic fashion when subjected to earthquake loading. In addition to the potential inelastic behavior of the piles, the expansion joints present in the structure at intermediate supports are susceptible to large deformations which could potentially damage the joints.

Abutments were designed and detailed to behave integrally. No expansion bearings were used at the double bents. Rather, movements from thermal expansion and contraction were accommodated via flexure of the pipe piles at each double bent.

To simultaneously permit longitudinal thermal displacements and prevent transverse (out-of-phase) deformation at the expansion double bents, a series of 4 pipe restrainers per bent was installed. The details of the restrainers are given in Figure 6. To accommodate the transfer of seismic loads from the superstructure to the cap to the piles, a reinforced concrete 'plug' was designed at the interface between piles and bent caps as shown in Figure 7. Photographs of a completed expansion double-bent and installed pipe restrainers are included in Figures 8 and 9. The design load for restrainers in such an application may conservatively be taken as twice the transverse seismic shear acting on one of the bents. Implicit in this is the assumption that the pair of bents moves perfectly out of phase with one another in the transverse direction. The shear strength of the concrete filled pipe multiplied by the number of restrainers gives the estimated capacity.

The project lies in Seismic Design Category "B" in accordance with the AASHTO Bridge Design Specifications at the time of design work. Thus, no pushover analysis was required for the structural design.

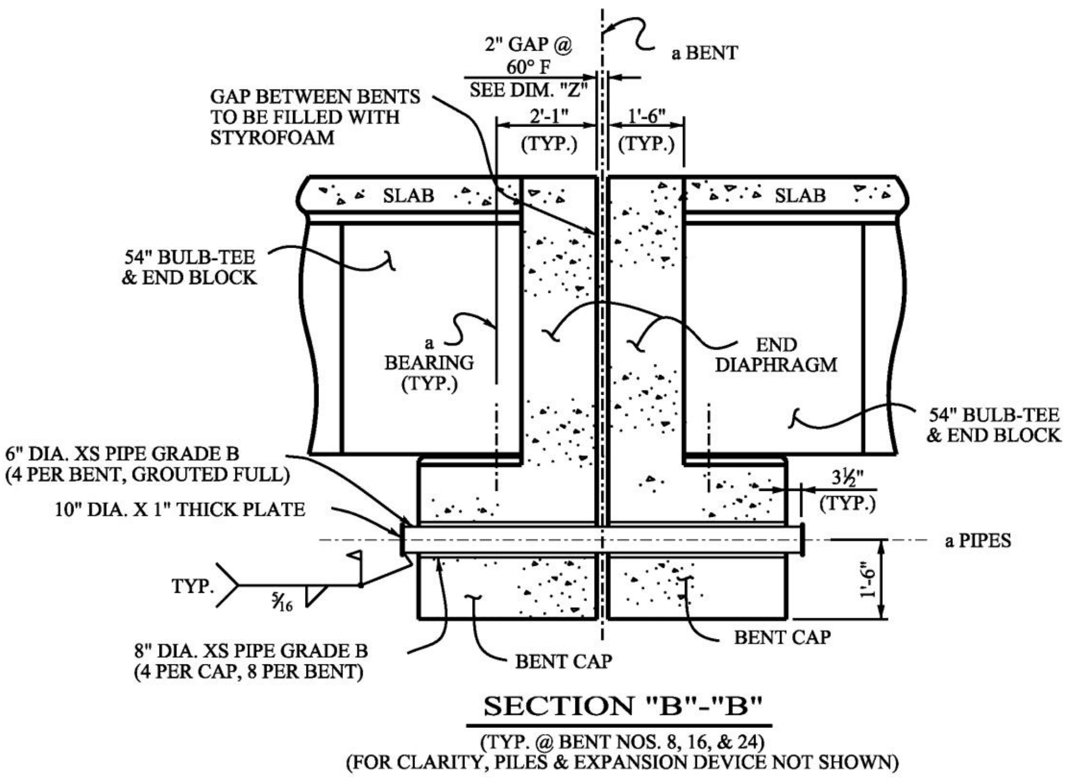

Figure 6. Double Bent with Pipe Restrainers

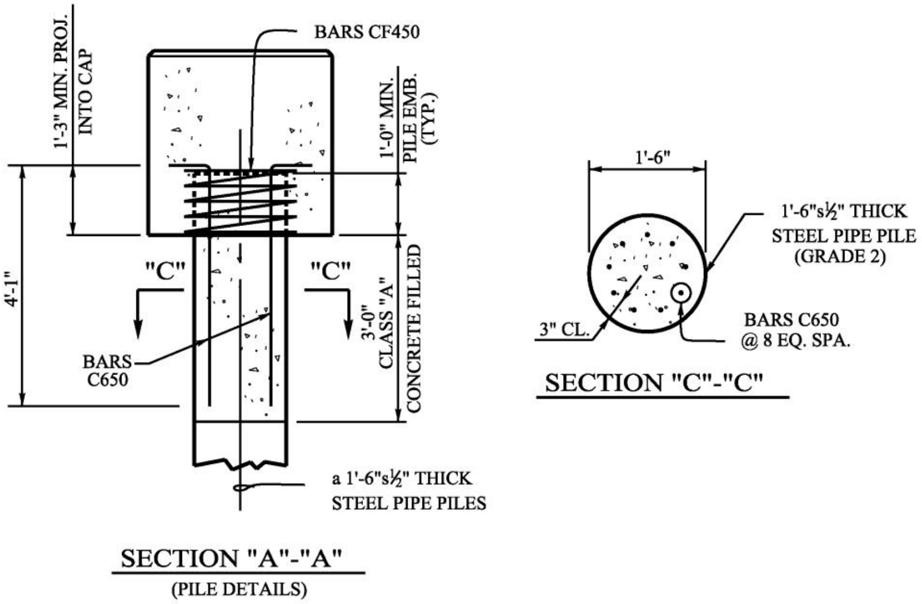

Figure 7. Pile to Cap Connection Detail

Figure 8. Double Bent

Figure 9. Installed Pipe Restrainers

COST CONSIDERATIONS

Five contractors provided a bid for the SR-385/I-269 project. Each bidder selected the 54" bulb-tee girder alternate over the W40X149 rolled steel girder alternate.

The total as-bid price for the project $53,473,493 compared to the State estimate of $55,433,176. The price consisted of $32,079,825 in roadway costs and $21,393,668 in bridge costs. Included in the bridge cost is $14,220,000 for the dual, 44-foot wide Wolf River bridges. This gives a unit cost for the Wolf River bridges equal to $50 per square foot.

For the eight bridges on the project, prestressed component bid prices were as follows:

- $85 per foot, Type II AASHTO I-beams
- $150 per foot, Type IV AASHTO I-beams
- $129 per foot, 54-inch Bulb-Tee girders
- $175 per foot, 63-inch Bulb-Tee girders
- $155 per foot, 72-inch Bulb-Tee girders
- $36 per foot, 14-inch square precast concrete piles

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