# ACCELERATED SHORT SPAN BRIDGE REPLACEMENT USING PRECAST ELEMENTS

Lisa Carter Powell, P.E., President, P.E. Structural Consultants, Inc.
8436 Spicewood Springs Road, Austin, Texas 78759

## ABSTRACT

This paper describes a recent off-system bridge replacement project in Texas that exemplifies a quick, economical, constructible and durable solution for the replacement of short-span bridges. By using precast, prestressed concrete slab beams, precast abutment caps and other measures, the total time for road closure was abbreviated to 6 weeks. Good speed was achieved without compromising durability offered by the cast-in-place deck.

## INTRODUCTION – WHAT'S SO SPECIAL ABOUT THIS BRIDGE?

In a word – nothing. And that is precisely why it is important. In the realm of Accelerated Bridge Construction, marvelous advances have been made, making it possible to reduce construction time from years and months down to weeks, days or even hours, given the right site conditions, a unique and pressing need, and (typically) special equipment and sophisticated contractors. The project described herein is typical in many ways with regard to design constraints common to the ever growing inventory of aging short span bridges needing replacement. While the reduction in construction time represented by this project is not record-breaking, it is significant enough to make a real difference to owners and users. The precast elements described are easy to fabricate and erect using commonly available techniques and equipment. Details are simple, so that any reputable contractor experienced in basic bridge construction can successfully build similar structures within this reasonably short time frame, at around the same cost as a more conventional project. The end result is functional, attractive, durable, and virtually maintenance free – just a nice little bridge.

## THE PROJECT – TYPICAL IN MANY WAYS

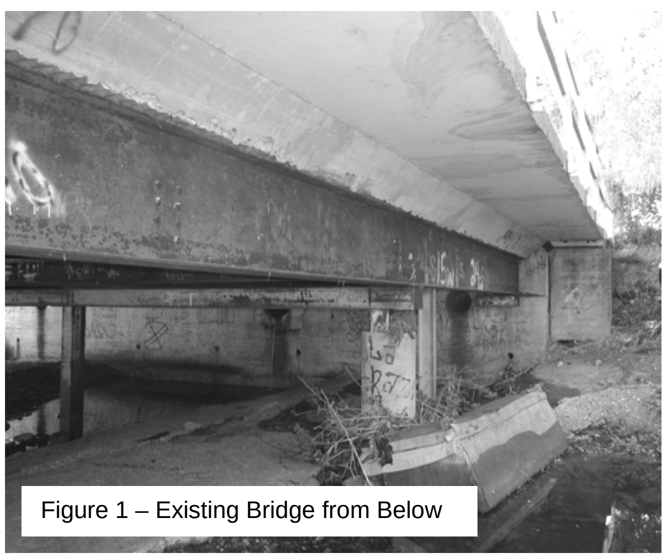


Figure 1 – Existing Bridge from Below

A recent off-system bridge replacement project for the Texas Department of Transportation (TxDOT) involves a structure within a FEMA controlled waterway in Travis County, Texas - West North Loop Bridge over Hancock Branch in Austin. The existing functionally deficient structure (originally constructed in 1939; modified and widened several times over the years) had a 40 foot long steel superstructure that had deteriorated due to age (see Figure 1). In its original configuration, the 24" deep steel I-beams carrying wood deck spanned to vertical concrete retaining wall abutments on spread footing foundations. An interim modification some 20 years later added approximately 10 inches of concrete deck and cantilevered sidewalks, requiring an extension to each side of the original abutment support wall and the addition of a midspan support. Several large storm sewer pipes had also been retrofit into the abutment retaining walls to divert runoff into the creek. The level of deterioration in the steel stringers and cross beams, the questionable nature of the substructure elements that had been added to the original structure and the presence of lead based paint effectively precluded phased replacement. This bridge had been inundated many times during its design life, but the profile could not be raised significantly due to the proximity of driveways for several businesses lining the roadway. Although detouring vehicular traffic during construction was not a problem, because West North Loop is an urban street that serves as a critical pedestrian route, the City wished to reduce the time the road would be closed. It was also desirable to minimize disruption of the creek channel. The new structure needed to add width for four standard lanes and ADA compliant sidewalks, and improve flow characteristics of the creek through the structure.

Many of these conditions – hydraulic constraints, inability to raise the profile, questionable existing structures, lack of pedestrian or vehicular detours - are fairly common challenges to the problem of replacing the aging population of both rural and urban short span bridges. Generally these structures have relatively simple geometry - either tangent or with minor skew, some vertical curve, no horizontal curves or flares - making them good candidates for the system described herein.

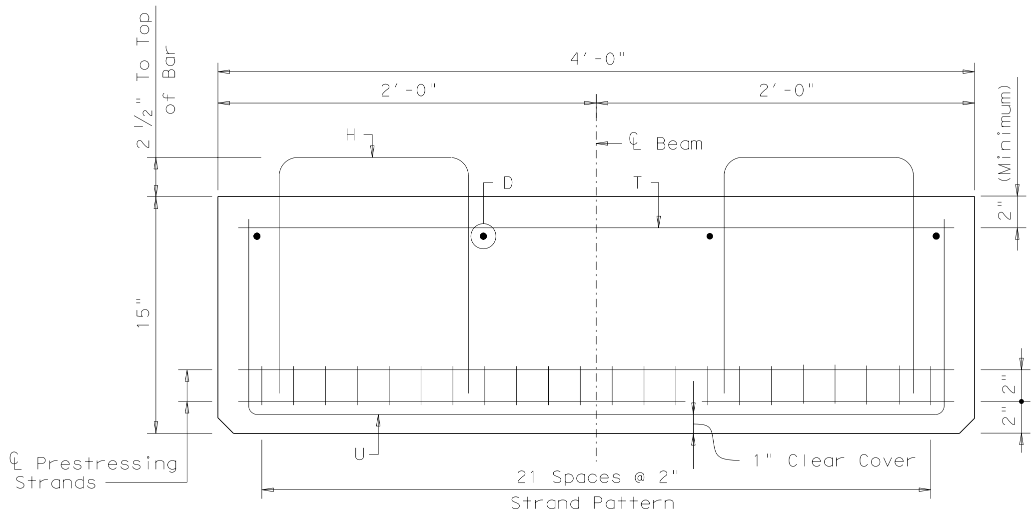
## DESIGN SOLUTIONS - TO GET IN, GET OUT, STAY OUT

Precast, prestressed concrete slab beams with 5 inch composite concrete topping provides an optimal structural system for the superstructure. This system offers minimal depth - 20 to 22 inches compared to the 34-inch deep existing section - as well as several other advantages. Reducing the depth increased the available hydraulic area under the bridge – a plus for this restricted site. The substructure system devised uses new abutment caps and wingwalls founded on concrete drilled shafts located approximately 5 feet beyond each existing retaining wall abutment. This placement enabled salvaging the majority of the existing retaining wall, thereby minimizing the disruption to the channel and preserving the existing channel profile as much as possible. To further speed construction, precast, conventionally reinforced abutment caps with grouted connections to the drilled shafts were designed. Traffic phasing and construction sequence guidelines included in the plans permitted drilling and casting of the shafts prior to road closure, removing this step from the critical path during road closure.

### Precast Prestressed Concrete Slab Beams

Figure 2 –Precast Slab Beam Placement

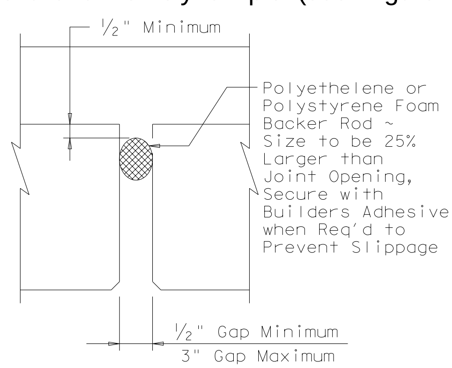
AASHTO/PCI standard shapes for rectangular slab beams using round voids have been available for over 40 years, but TxDOT has never constructed these (1). In the early 80's, the Houston District began experimenting w/ solid beam sections that could be cast on the same beds as standard box beams, but avoided problematic void forms. Design for this project began in 2002 and relied heavily on the working drawings for these beams available at the time from the Houston District. The TxDOT Bridge Division has since developed statewide standards (issued June 2003) for construction using prestressed slab beams. The standards are designed in accordance with the AASHTO LRFD Specifications (2), and accommodate 3 roadway widths, 3 standard skews and spans ranging from 35 to 50 feet.




4SB15 BEAM SECTION

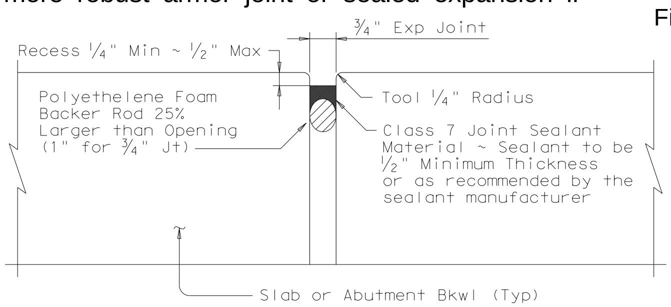
Figure 3 – Prestressed Slab Beam Detail

The 12" or 15" deep beam (see Figure 3) is nominally 4' or 5' wide; combining the different widths and adjusting joint spacing between beams enables the designer to achieve any desired deck width. The longitudinal joints between beams are extremely simple (see Figure 4), requiring just a backer rod (oversized to the joint width) "stuffed" into the joint and secured with builder's adhesive (eg., Liquid Nails) only if necessary to prevent slippage. This joint detail also lends itself well to phased construction; the topping slab is just headered off at the desired location over the outside beam in one phase, with the reinforcing extending a lap length into the next phase. The transverse expansion joints can be equally simple; rounded concrete edges with backer rod and sealant in the gap have proven to perform well under low to moderate traffic (see Figure 5.) The standards also accommodate a more robust armor joint or sealed expansion if desired. Closed reinforcement loops extending from the top surface of the beam provide composite action with the C-I-P topping slab. The 5" minimum slab depth is thickened as required to account for beam camber, deflection and roadway profile, and reinforced with a single mat of steel for shrinkage and temperature effects and to distribute loads transversely between beams. Keeping the deck as a cast-in-place element enhances the durability of the system; but simple reinforcement and forming details help to expedite this work. The edge of the deck is flush with the face of the outside beams so no overhang forms are required, however contractors customarily use the ready made overhang brackets from I-beam construction as a convenient way to provide a safe working platform. A simple 3-point bearing provided by laminated




GAP FORMING DETAIL

Figure 4 – Longitudinal Joint Detail




EXPANSION JOINT DETAIL

Figure 5 –Transverse Expansion Joint Detail

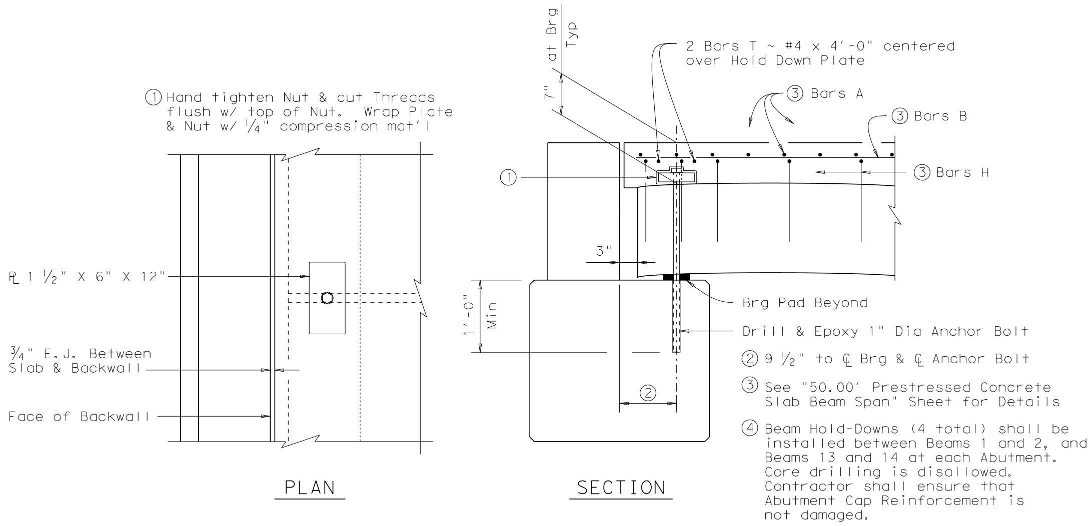



Figure 6 – Hold-Down Detail

elastomeric pads prevents rocking of the beam prior to casting the topping and accommodates thermal movement in the finished structure. Easy-to-fabricate beam hold-downs (see Figure 6) can be provided where overtopping under flood conditions is unavoidable (for this project, the best that could be done was to get the deck level at about the 10-year high water elevation.) The smooth bottom soffit formed by the flat beams laid side to side (no surfaces to impede the flow of water or debris) and the low buoyancy of the solid beams are also inherent benefits in this instance. Limitations of the system, such as inability to accommodate horizontal curves and some restrictions on vertical curvature and cross-slope, are not generally a hindrance for common cases.

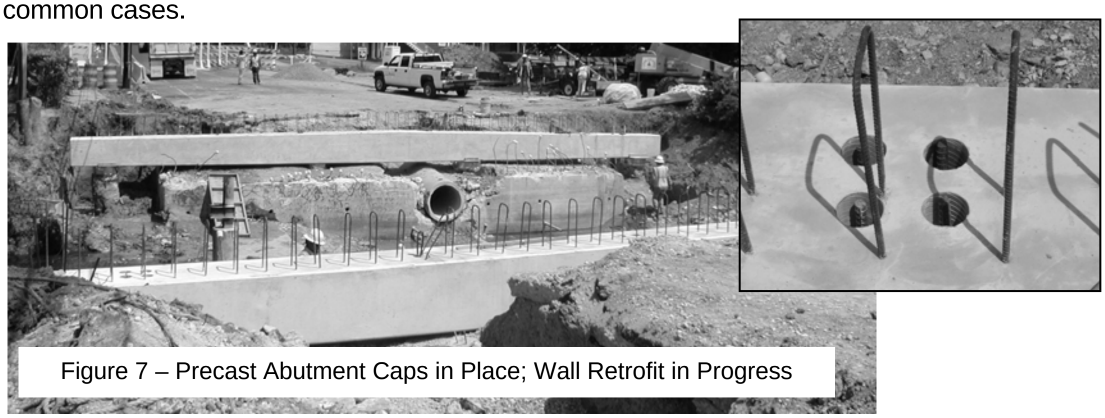


Figure 7 – Precast Abutment Caps in Place; Wall Retrofit in Progress

## Precast Abutment Caps

Another time saving measure involves precasting the two identical abutment caps, allowing fabrication of the caps to proceed simultaneously with the partial demolition and retrofit of the existing retaining wall and other utility relocation work around the abutments. The top of the cap slopes to follow the crown of the roadway, while the bottom of the cap is level, simplifying placement on, and connection to, the supporting drilled shafts. An excellent research report by Masumoto, et al from the University of Texas (3), provides

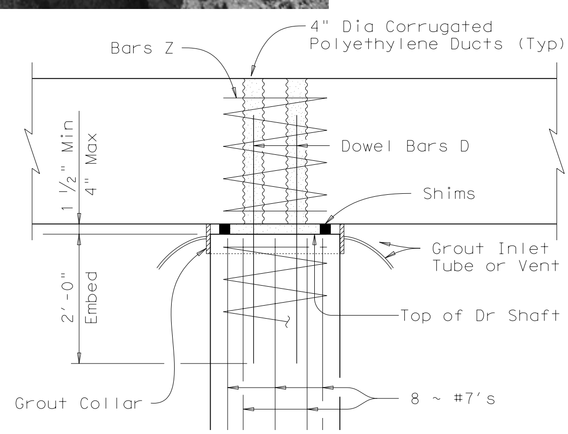



Figure 8 – Precast Cap to Drilled Shaft Connection

guidance for the detailing of the grouted doweled connection (see Figure 8). Only the cap itself was precast; the backwall and wingwalls were cast-in-place so that these elements could be more easily matched to adjacent approach pavement and extended retaining wall construction.

### Salvaged Abutment walls

While the steel superstructure had suffered significant deterioration, the original 55 year-old retaining wall abutments were in relatively good shape; the concrete was sound with no significant evidence of distress. Only some minor patching was needed to repair spalling and corrosion resulting from a previous retrofit installation of duct banks through the existing walls. Tearing out this construction completely would have slowed the demolition and reconstruction of the embankment considerably. It was mandatory to specify demolition of concrete "extensions" to the walls that were made in 1959 when the concrete deck had been added. This work was not tied to the original wall and was literally falling into the creek; when demolished it was discovered that old plow blades had been driven into the embankment with basically unreinforced, poor quality concrete cast around them. The top of the existing wall was sawcut to the level required to install the new abutment and riprap. Some of the large storm sewer penetrations were replaced and relocated at that stage. New walls, tied into the old footing and wall with drilled and epoxied dowels, extended the vertical face to the new limits of the bridge, wrapping back around the sides and under the new wingwalls. Where possible, existing fill behind the old wall was left undisturbed; cementitious flowable fill was easy to place and reduced pressure behind the new wall extensions. It is always advisable to creatively evaluate existing site elements, and to salvage those that still provide function or aren't in the way of new construction. "If it ain't broke, don't fix it!"

## POST-CONSTRUCTION EVALUATION – A WIN-WIN SITUATION

This project was very successful for all concerned parties. The TxDOT Project Manager on the job proclaimed this "a fun bridge to build" (4), and reports that the contractor also seemed to be pleased with the end result and the level of effort required on his part (which implies that it did not cost him more than he had estimated). According to the TxDOT PM, all of the bridge components went together well, without a hitch, and in retrospect, he wouldn't have changed any aspects of the design. He confirmed that the slab beams were easy to work with, that the installation of the precast abutment caps and associated grouted dowel connections was straightforward, and that it is beneficial to salvage the embankment elements whenever possible.

Figure 9 – Completed structure from Below

### Meeting Time Constraints

The contract specified both the total number of days and the maximum number of days the road could be closed to traffic. There was no early completion incentive in the contract but there were liquidated damages should the specified time have been exceeded. The road was closed on June 1, 2004 and the new structure was opened to traffic six weeks later on July 17th. Although provisions in the plans allowed drilled shafts to be placed prior to road closure, the contractor elected not to take advantage of this, believing (and rightly so) that he would not need to count on the extra time. On any construction project, it is wise to expect the unexpected, like hitting a natural gas line during drilling of shafts, delays in beam delivery, and rain (lots of rain) in a typically dry season. Even with these setbacks, the contractor easily met the contract goals (there were no additional days granted on account of weather). In fact, the TxDOT Project Manager estimated that if the second bridge superintendent, who was a good and efficient manager, had been on the job from the start (the first one had to be replaced), the bridge could have been finished in less than half the time.

### Cost Comparisons

The total project bid came in at 9% below estimate and there were no change orders associated with the bridge component of the project. From the bid tabulations for the March 2004 letting, the cost per square foot of deck for bridge items, including all of the substructure elements, amounted to approximately $71/sf. The total cost of bridge items was %52 of the total project cost, with mobilization and removal of the old structure each at roughly %10 of the total project cost. At first glance, the $71/sf figure may seem high compared to the most recent published cost data (5) for the work-horse of Texas on and off-system bridge types, the prestressed I-beam bridge. According to the 2004 data, the statewide average cost for I-beam type construction is approximately $35/sf for on-system bridges and $49/sf for off-system bridges. However, this data may not be entirely representative of costs for short single span structures, where economy of scale cannot be realized. Comparing bid tab data for four single span standard I-beam bridges of similar length that were bid during that summer in a nearby district, the bridge costs varied from $59 to $84/sf exclusive of embankments, and $74 to $136/sf including embankment cost. The $71/sf is right in line with the published data for prestressed slab beams, at $61/sf for on-system, and $75/sf for off-system bridges of that type. In any case, there appears to be no premium associated with the accelerated construction. Based on an educated guess, it makes sense that accelerated schedules may actually reduce costs, as resources seem to be used more efficiently in the shorter time frame.

## CONCLUSION

Precast, prestressed slab beam bridges can meet many of the typical challenges associated with the replacement of short-span bridges. The reader is encouraged to review the TxDOT standards that are accessible on-line (6); available at the same site is an accompanying guide that provides very helpful information for design. Using precast substructure elements, salvaging existing embankments, and creative construction sequencing can help to further speed construction.

## ACKNOWLEDGMENT

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