# ACCELERATED BRIDGE CONSTRUCTION IN TEXAS

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## ABSTRACT

*The Texas Department of Transportation (TxDOT) is implementing a number of accelerated bridge construction techniques to reduce traffic disruption and construction duration while enhancing safety for the motoring public and constructability for the contractor. TxDOT is implementing traditional and innovative prefabricated bridge elements such as precast bent caps, precast columns, precast full-depth deck panels, and new precast beam types.*

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## INTRODUCTION

Transportation system owners are under increasing pressure to deliver projects more rapidly. Accelerated bridge construction is a method to meet this goal. To accelerate bridge construction, the Texas Department of Transportation (TxDOT) is implementing innovative bridge design and construction techniques to reduce construction project duration which translates into reduced traffic disruption, enhancing safety for the motoring public and constructability for the contractor.

In its accelerated bridge construction projects, TxDOT is implementing a number of new and traditional prefabricated bridge substructure and superstructure elements such as precast bent caps, precast columns, precast full-depth prefabricated deck panels, and new precast beam types. Prefabrication and other accelerated construction techniques can reduce construction time, increase work zone safety, mitigate environmental impact, improve quality, and sometimes lower costs.

## PREFABRICATED SUBSTRUCTURES

TxDOT has used a variety prefabricated substructures for bridge projects, including piling for trestle bents, precast columns, and precast bent or pier caps.

### Trestle Pile Bents

Trestle pile bents use prefabricated steel or prestressed concrete piles extending from their embedment in the ground to the bent cap that supports the superstructure. Such construction is common for low-lying short span structures over streams or bays. Structural demand limits the height of such bents to approximately 10- to 20-feet (3 m to 6 m) above the ground line. While trestle pile bents are typically used for waterway crossings, larger square piles have been used for grade separations. The replacement of NASA Road 1 over Interstate 45 southeast of Houston used 24-inch (610 mm) square prestressed concrete piles to help achieve bridge replacement in 9 days.  Piling, when coupled with precast caps, is the fastest way to construct a bent.

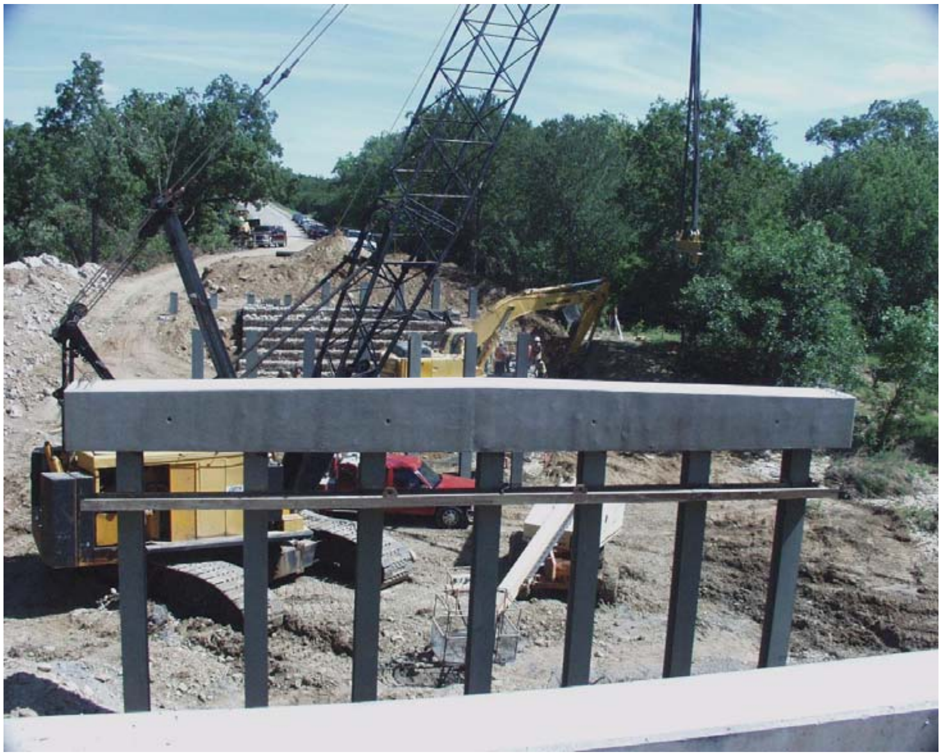

Figure 1, Trestle bent with precast cap on steel H piles

**Precast Columns**

Precast columns have not been used extensively in Texas due to the low cost of cast-in-place column construction. However, precast column shells were used for the Loop 340 overpasses over Interstate 35 south of Waco, Texas. Each column directly supports a line of the longitudinal girders of the superstructure, avoiding the need for a bent cap. These hollow column shells were precast their full height with a unique large limestone block form liner and large chamfers on their outer surfaces. Precasting the column shells allowed better control of the surface appearance. The column shells were erected over reinforced concrete drilled shafts with projecting reinforcing steel. After placing the concrete shells at the proper location and elevation with the aid of a leveling pad, the contractor placed in-fill concrete inside the hollow section. For this project, precast columns did not reduce construction time appreciably and required more complex formwork processes with the hollow section. However, precast columns could be a time-savings solution for large scale projects with simpler column cross-sections.

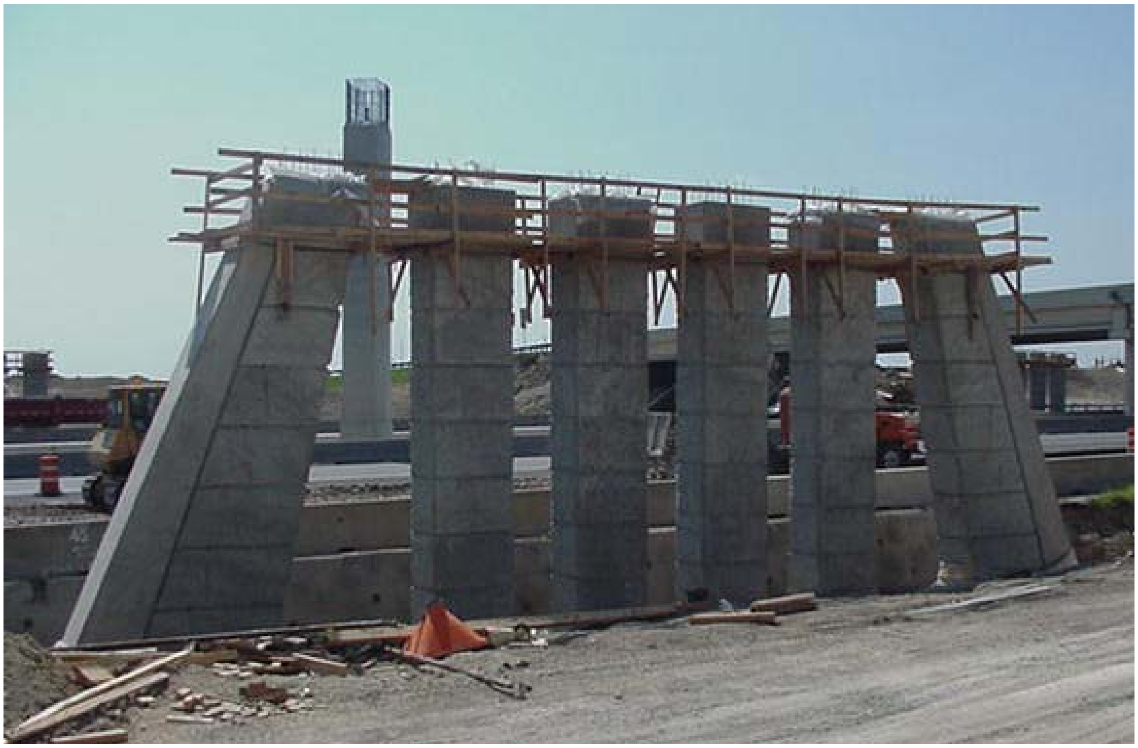

Figure 2, Precast column shells, Loop 340 Overpasses

**Precast Bent and Pier Caps**

Precast bent caps have gained popularity in Texas over the last 15 years and have successfully been implemented on several projects. The first significant use of precast bent caps in Texas was for the bridge over Redfish Bay. These trestle pile bents had U-shaped reinforcing bars projecting from the top of the prestressed concrete piles, which fit into mating slots in the precast bent caps. The slots were subsequently grouted to complete the connection. This connection method has not varied much over the years.

TxDOT-sponsored research (Matsumoto, et al, 2001) developed a number of details for connecting precast caps to columns or piles with low-to-moderate moment demand. This research also covered an associated design methodology and specifications for material properties, placement of caps, and grouting procedures. Incorporating these research findings, the bent caps for the Lake Ray Hubbard Bridge used a simplified connection and column analysis to determine the worst case of a pinned or rigid connection at the top of the column, with loads factored to improve ductility. Confining reinforcement around each connection zone in the cap was provided to enhance ductility and increase section strength. The Lake Belton Bridge employed precast hammerhead pier caps with relatively high moment demands. The caps were designed using an extrapolation of research results.

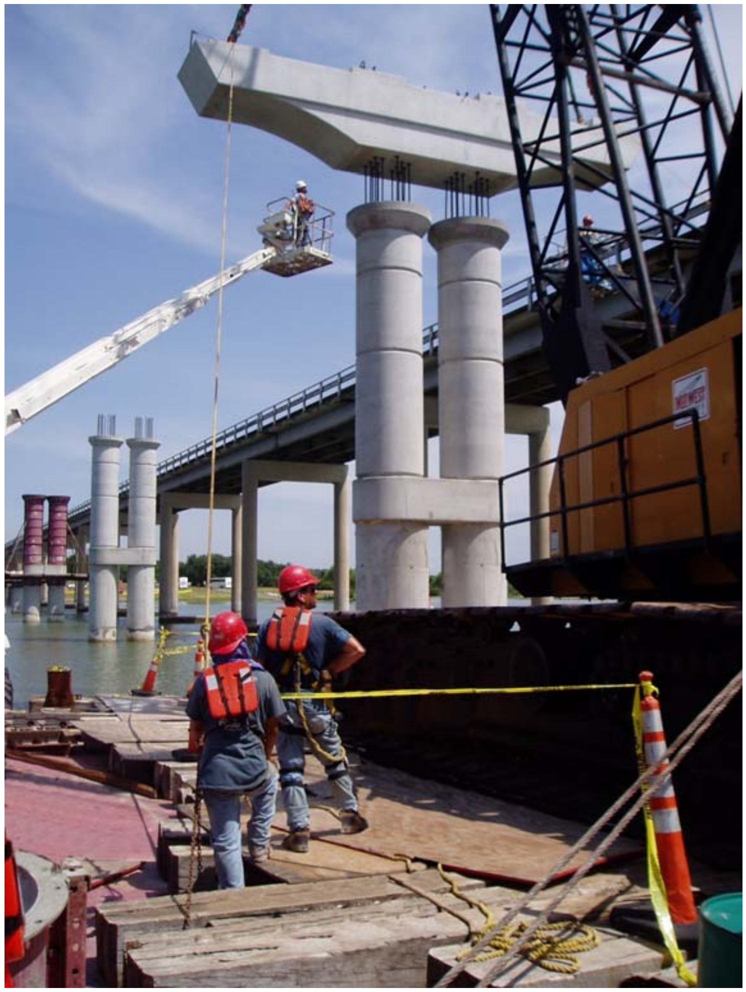

Figure 3, Precast cap installation, Lake Belton Bridge

## PREFABRICATED SUPERSTRUCTURES

A variety of prefabricated superstructure concepts, including prefabricated beams side-by-side, prefabricated decks, and prefabricated spans have been used in Texas to accelerate bridge construction.

### Prefabricated Beams Erected Side-by-Side

One of the more common forms of superstructure prefabrication is a series of precast prestressed beams—slab, box, single-T, or double-T sections—placed side-by-side. The AASHTO LRFD Bridge Specifications (AASHTO, 2010) refers to these as precast deck bridges or as multibeam decks. Among these sections, solid/voided slab beams and box beams have the best span-to-depth ratio.

TxDOT box beams feature cross-sections of 20-inches to 40-inches (508 mm to 1016 mm) in depth and come in two widths—4- and 5-feet (1.22 m and 1.52 m). The shear keys of TxDOT box beams are much larger when compared to their standard AASHTO/PCI box beam counterparts, since they use the side form of the AASHTO

Type I—known in Texas as the Type A—prestressed I-beam shape for most depths. The beams are placed side-by-side, the shear keys and diaphragms filled with a conventional concrete mix, and the bridge is post-tensioned transversely. This post-tensioning uses a single 0.5-inch (12.7 mm) diameter Grade 270 monostrand or 0.625-inch (15.9 mm) diameter Grade 150 threaded bar at a 10-feet (3.05 m) maximum spacing. The roadway surface applied to the top of these beams originally consisted of a sealing two-course asphalt surface treatment followed up with approximately 1.5-inches (40 mm) of hot mix asphaltic concrete pavement. Similar to other states, TxDOT has experienced reflective cracking and durability issues in these types of bridge span/pavement systems. To alleviate these problems, TxDOT has more recently used a nominal 5-inch (127 mm) thick composite concrete slab as a beam topping, though the option of direct topping with asphaltic overlay is still exercised on low volume roads and when accelerated bridge construction is favored. Transverse post-tensioning is omitted when the composite concrete slab is used.

TxDOT standard slab beams feature non-voided cross-sections of 12- and 15-inches (305 mm and 380 mm) in depth and come in the same widths as box beams. No shear keys are provided and the beams are topped with a 5-inch (127 mm) thick composite cast-in-place slab.

On select projects, standard box and slab beam details have been modified to maximize construction speed and avoid use of site cast concrete. Such modified details were implemented on the Commission Creek Bridge replacement in the Texas panhandle region. Completed in November 2005, the Commission Creek Bridge replacement involved a 2 week complete road closure in a remote region where delivery of concrete is difficult. The four-span 160-foot (48.8 m) long bridge was completely prefabricated. The substructure consisted of steel H-piles and precast bent caps and the superstructure consisted of precast prestressed slab beams modified to use grouted shear keys, transverse post-tensioning, and topped with a hot mix asphaltic concrete roadway surface.

Another instance of modifying standard beams for construction speed, this time with box beams, the Tanglewood Estates Bridge replacement, completed in 2006, involved a totally prefabricated bridge with limited on-site construction operations such as pile driving, precast member erection, connection grouting, and post-tensioning. The 60-feet (18.3 m) long by 35-feet (10.7 m) wide bridge structure was completed in a period of 10 days. The bridge included two precast concrete abutments supported by precast concrete piling and a single span of special 20-inch (508 mm) deep prestressed concrete box beams. The beams differed from the standard section by using a smaller shear key—intended to reduce grout volume.

Completed in 10 days, the Dry Creek Bridge, a replacement project on FM 774 near Refugio, Texas, used precast prestressed trestle pile substructure with precast abutment and bent caps and precast prestressed concrete double tee beams. This three-span 150-feet (45.7 m) long bridge had its roadway surface finished with hot mix asphaltic concrete overlay. The double tee superstructure incorporated TxDOT-sponsored research

(Jones, 2001) on lateral connections for double tee bridges, which developed simplified connection methods.

TxDOT also developed a new beam section for rapid bridge replacement. Called the decked slab beam, this section includes an 8-inch (200 mm) deep top flange integrally included with a voided 12- or 15-inch (305 mm or 380 mm) deep slab beam. This prestressed beam can span 65-feet (19.8 m) with a superstructure depth of 23-inches (584 mm), representing a span to depth ratio of 34. The flange allows beams wider than conventional slab beams in an easily transportable width up to 8-feet (2.44 m), while employing a simple welded and grouted beam to beam connection, similar to that used for double tee beams. Maximizing beam width minimizes the number of longitudinal joints and beam sections to be erected. This beam was first used, successfully, for two bridges northeast of Austin—Battleground Creek and Cottonwood Creek Bridges—which took 43 and 33 days to complete, respectively. Decked slab beams were successfully combined with precast caps and steel H-piling on a subsequent accelerated bridge construction project—Salt Creek Bridge in Wise County.

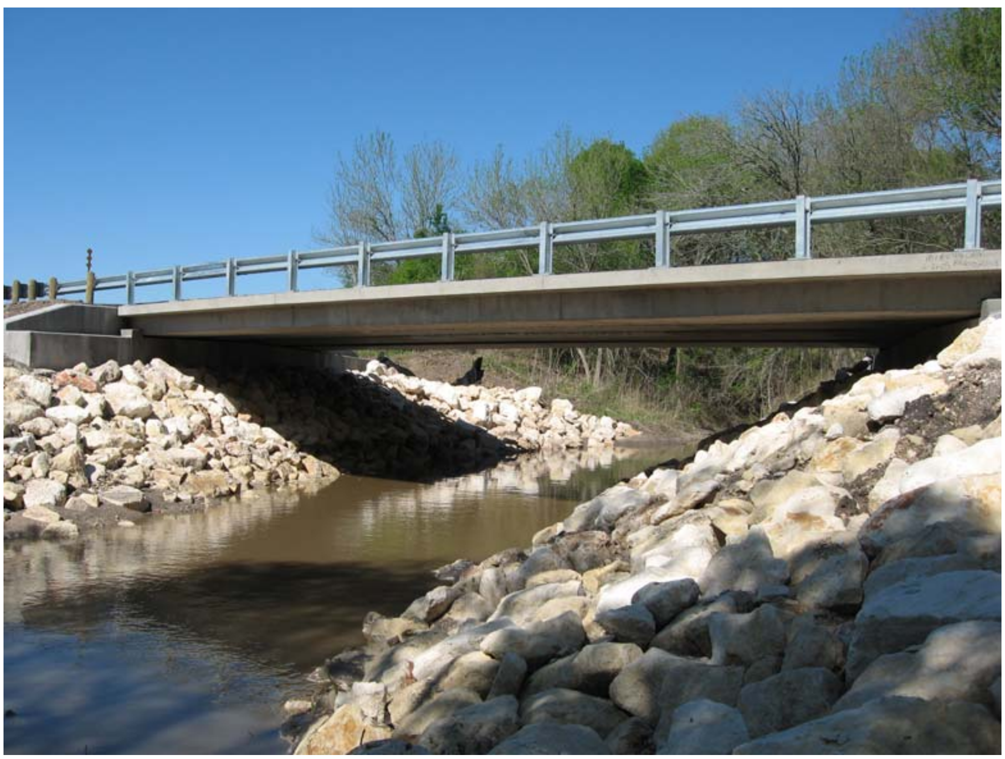

Figure 4, Decked slab beams, Battleground Creek Bridge

Figure 5, Decked slab beam erection, Salt Creek Bridge

TxDOT has begun the long process of replacing numerous bridges on the Interstate 35 corridor in central Texas. Replacement of bridges with minimal impact to traffic is critical since it is the busiest segment of the Interstate Highway System and a key portion of the NAFTA trade corridor. One of the early projects in this effort was the replacement of four overpass structures carrying Loop 340 over Interstate 35, south of Waco. The project used a totally prefabricated bridge construction system. The superstructure was designed with competing steel and precast concrete alternatives, with the concrete alternative being selected. The steel alternative featured trapezoidal steel box girders with a full depth, full length, and partial width precast bridge deck cast on each beam prior to erection. The concrete alternative featured trapezoidal precast prestressed girders with a similar deck that is cast prior to erection. In both cases, the girders are placed side-by-side and small cast-in-place closure pours form the longitudinal connection. The bridges were designed for a shallow superstructure depth of 40-inches (1016 mm) to carry the 115-feet (35.1 m) spans—a span to depth ratio approaching 35. The design also featured precast substructure in the form of hollow precast column sections that directly support each beam line for the interior bent.

These bridges used an intermediate placement of concrete in a fabrication yard to achieve the final profile in the span. The only cast-in-place concrete after beam erection were narrow closure pours, formed and placed from above without impacting traffic below. Beam erection was the only operation requiring closure of the Interstate 35 mainlanes, and an entire span could be erected in a single night. Subsequent inspections of the decks have found them to be performing as well as conventional cast-in-place bridge decks.

**Prefabricated Decks**

When constructing a traditional multi-beam bridge with concrete deck, construction of the cast-in-place concrete deck is a time intensive process that can easily take a month for a typical bridge. Full-depth prefabricated decks can greatly minimize the time associated with superstructure construction.

In the late 1980s, TxDOT first used full-depth prefabricated deck panels on the Spur 326 Bridge over the AT&SF Railroad in Lubbock as part of a research project (Osegueda and Noel, 1988) to demonstrate the feasibility of the concept. The full depth panels were used on a single span of the southbound structure, with the remainder of the twin structures built with conventional cast-in-place decks. A total of eight 45-feet (13.72 m) wide by 8-inch (200 mm) deep panels were fabricated for the 50-feet (15.24 m) long simple span. The connection between the panels and the rolled steel beams used full height pockets formed in the panels that accepted headed shear studs welded to the beams in groups of three and spaced at just over 2-feet (0.61 m) for the length of all 6 beams in the bridge cross-section. The panels were supported at the proper elevation by a combination of steel shims and elastomeric pads. The haunch varied in height from 0.50- to 2-inches (12 to 50 mm) and was grouted along with the shear stud pockets. Panel-to-panel connections were a female-female shear key arrangement with 0.25-inch (6 mm) panel separation and with no reinforcement across these connections. These panel-to-panel connections were filled with a flowable epoxy grout extended with sand.

Full depth precast concrete deck panels have been increasingly used nationally, but mostly on projects involving steel beams as opposed to prestressed concrete beams, which are much more cost effective in Texas. One of the challenges to using full depth panels with prestressed concrete beams is accommodating the camber caused by prestressing and its variability. TxDOT used full depth precast concrete deck panels on the Live Oak Creek Bridge replacement near Ozona, Texas. The 700-feet (213.35 m) long bridge is located in a remote region of west Texas where access to batch plants is limited and cast-in-place deck construction is problematic due to the arid climate. The bridge consists of Type IV prestressed I-beam spans measuring 32-feet (9.75 m) wide and either 65- or 114-feet (19.81 m or 34.75 m) in length. The panels were full bridge width and were 8-feet (2.44 m) long by 8-inches (200 mm) deep. The connection between the panels and the beams used partial height formed pockets in the panels that accepted headed threaded rods acting as horizontal shear connectors for the beam/deck interface. The threaded rods are assembled in groups of three spaced at 4-feet (1.22 m) for the length of each span. After adjusting the panels to proper elevation with leveling bolts, the gap between the bottom of the panels and the top of the beams varied from 0.50- to 4-inches (12 mm to 100 mm). This variable haunch was grouted along with the blockouts for the horizontal shear connectors. The panel-to-panel connections are a female-female shear key arrangement with 1-inch (25 mm) panel separation and reinforced with mild reinforcing steel connections. These panel-to-panel connections are also filled with a flowable non-shrink cementitious grout.

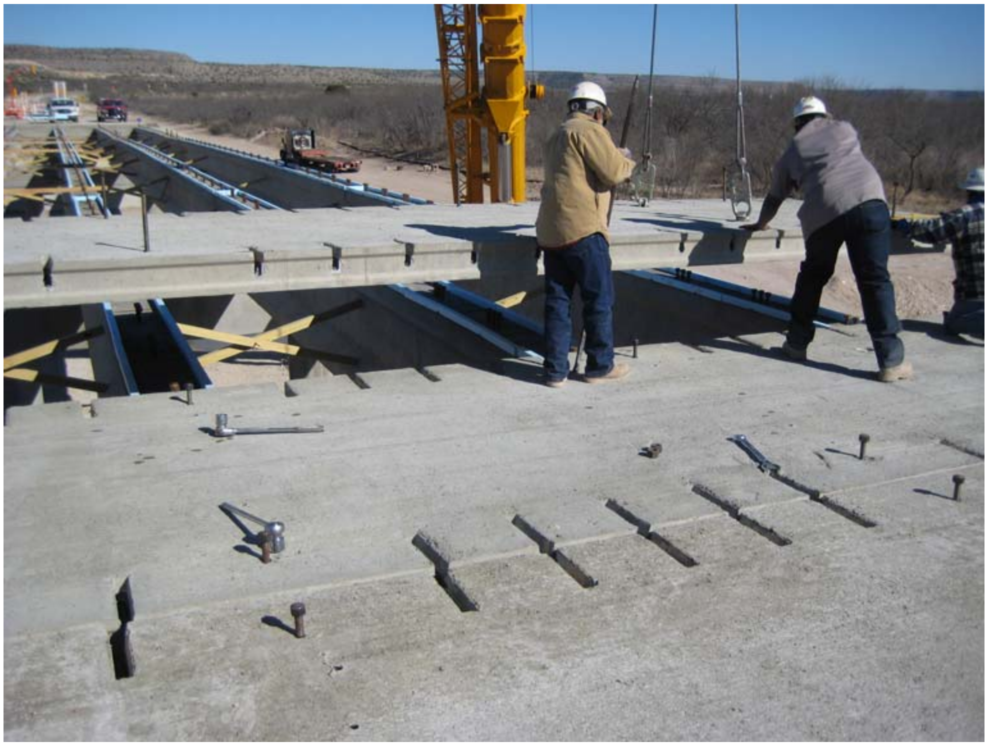

Figure 6, Erection of Full depth deck panels, Live Oak Creek Bridge

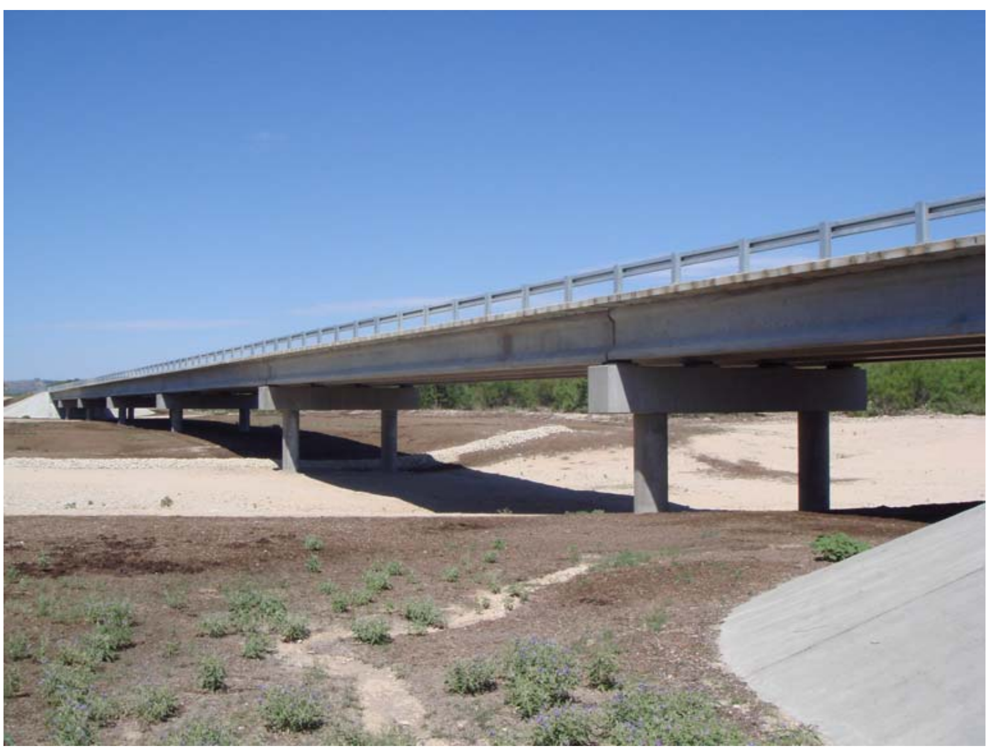

Figure 7, Completed Live Oak Creek Bridge

**Prefabricated Spans**

A bridge in north Texas, Martin Branch Bridge, was built with prefabricated spans which utilized a Sandwich Plate System (SPS) bridge deck. This proprietary bridge material is comprised of two outer steel plates sandwiching a polymer core which is bonded to the outer steel plates, forming a rigid, light panel. In this instance the SPS panel used two 0.3125-inch (7.9 mm) thick outer steel plates and a 1-inch (25 mm) thick polymer core, which weighed approximately one-third of a conventional concrete deck. This panel was welded to steel I-beams at the fabrication shop for one-half the bridge width of each of the bridge's three 50-feet (15.24 m) long spans, leaving only six span sections to be hauled to the site and erected. The steel deck's riding surface was topped with a waterproof membrane and thin polymer overlay.

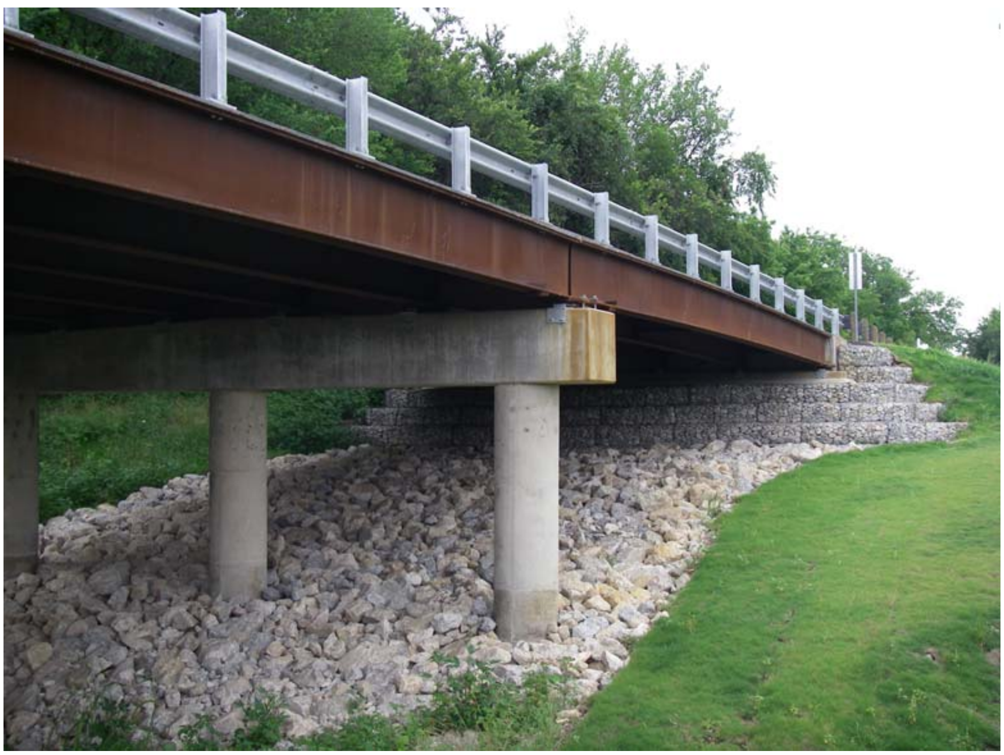

Figure 8, Completed Martin Branch Bridge

## CONCLUSIONS

A variety of prefabricated bridge elements are or have been successfully implemented by TxDOT to accomplish accelerated bridge construction. Both substructure and superstructure elements have been precast or otherwise prefabricated to reduce time of field construction, increase work zone safety, and improve quality.

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