PLATTE RIVER EAST SETS PRECAST RECORD IN NEBRASKA

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ABSTRACT

Platte River East is a bridge project consisting of two structures about 10 miles West of Omaha, Nebraska, on N-92 over the Platte River. One of the bridge structures will set a record for the longest precast/prestressed concrete I-girder units ever fabricated in the State of Nebraska. In addition, the girders for both bridges will be spliced together over the piers using a unique method for creating superstructure continuity for deck weight.

The method, known as the "threaded rod continuity connection", consists of Grade 150 ksi high strength threaded rods embedded in the girder top flange and spliced together between girder ends to create girder continuity before the deck is cast.

Keywords: Precast/Prestressed concrete, Bridge, Continuity connection, Girder

INTRODUCTION

Historically, concrete girders have not been able to compete depth for depth and span for span with steel plate girder, except when the concrete girders are post-tensioned, (Ref. 1). In order to match structure depth, other variables had to be adjusted, such as reducing girder spacing or reducing span lengths. As a result, concrete structures have not been cost competitive with steel in spans longer than about 150 feet (45 m). A major advantage steel has had over concrete is its ability to act continuous before placement of the deck slab. In addition, Hybrid steel plate girders can use higher strength steel in the high moment regions. Grade 70 weathering steel is increasingly being used in Nebraska for flange plates over the piers. Designing the Platte River East concrete structure represents an attempt to incorporate advancements in precast/prestressed concrete prismatic beams that are not fully continuous at the piers, without having to resort to post-tensioning or to complicated precast concrete girder geometry.

Precast prestressed concrete I-girder bridges represent about one-third of the bridges built in the United States each year. They are generally constructed as simple span for their weight and the weight of the cast-in-place deck. Cast-in-place diaphragms and reinforcement in the deck render the superstructure continuous for superimposed dead loads and live loads. This system has served very well over the past three decades, especially in cold climate states where expansion joints over the piers create maintenance problems. However, the girders are made continuous for only about one-third of the total load and are thus not fully utilized in the negative moment zones. In addition, some of the bridges built using this type of continuity have experienced cracking due to positive time-dependent restraint moments at the piers, especially in highly prestressed girders. With a new continuity system developed by Dr. Maher K. Tadros at the University of Nebraska, the girders are coupled over the pier using four 1-3/8” diameter, Grade 150 ksi threaded rods before the deck weight is applied (Ref. 2). The threaded rod system resists the negative moments due to deck weight; therefore, the girders are made continuous for about two-thirds of the total loads. After the deck concrete has hardened, deck reinforcement, along with the high-strength threaded rods, resist the negative moments due to superimposed dead load and live load. Span capacities are improved by about 10 to 15 percent within a given girder size. More importantly, bridge performance is improved as the negative moments due to deck weight more than offset the positive restraint moments due to time-dependent effects. Reduction in positive restraint moments results in less cracking in the pier diaphragms.

ANALYSIS AND DESIGN

The Platte River East project consists of two structures, one main structure with a total length of 970’-0” (Fig. 1) from centerline to centerline of abutments. The second structure has a total length of 592'-0". Both structures are tangent with the bridge centerline (no skew) and have overall bridge widths of 46'-4" (Fig. 2). The roadway consists of a 44'-0" clear roadway and two 1'-2" wide rails. The bridge was designed using AASHTO LRFD Specifications, 2nd Edition (Ref. 3). Due to the size and cost of the two structures, the state requested that alternate steel and concrete superstructure designs be completed. Providing alternate concrete and steel superstructure designs has been successful in increasing competition and ultimately reducing prices.

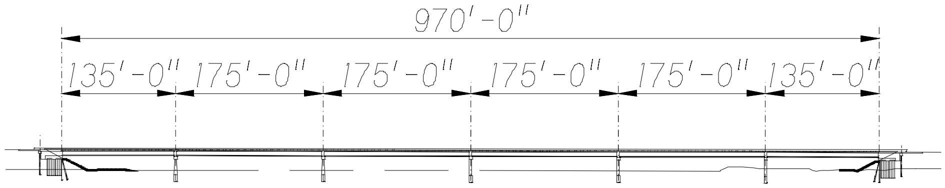

Fig. 1 View of the 970'-0" Bridge Showing Span Lengths

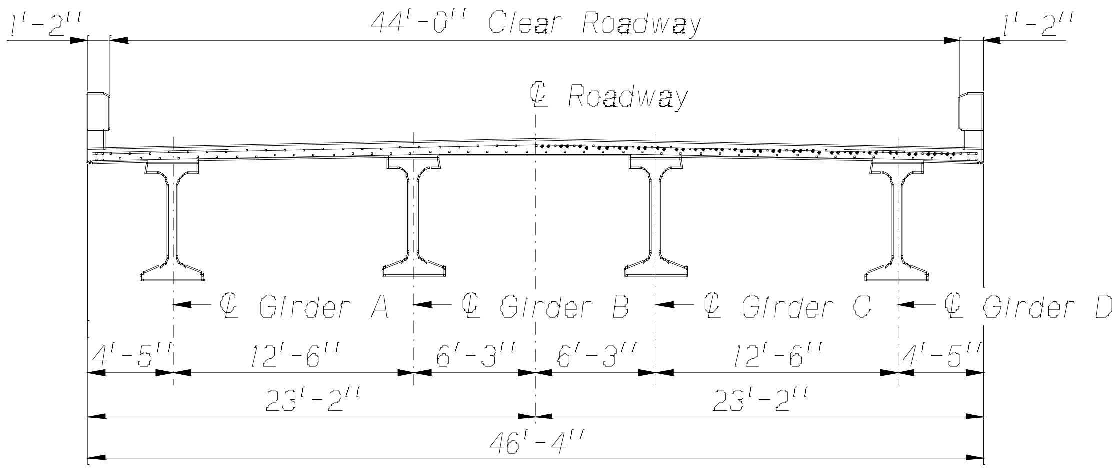

Fig. 2 Cross-Section of 970'-0" and 592'-0" Bridges

During the initial system selection, the steel plate girder alternate was analyzed first. The girder depth, spacing and span lengths were determined for both structures. The steel hybrid plate girder sections were optimized based on input from the National Steel Bridge Alliance, local steel fabricators, and the state bridge staff. The resulting steel hybrid plate girder system used four girder lines with beam spacings of 12'-6" (both structures) and spans of 135' - 4 @ 175' - 135' (970'-0" structure). The smaller structure used span lengths of 131' – 2 @ 165' – 131'. All structural steel for girder flanges, webs, and splice materials were Grade 50W, except for girder flanges over the piers, which used Grade 70W steel. Once the steel bridge system selection was complete, the process of selecting a competitive concrete section began.

The decision was made to match the steel hybrid plate girder structure span for span, depth for depth, and girder spacing for girder spacing. The only way to achieve these goals was to use the longest precast/prestressed concrete girders in the state's history. The girders also used high performance concrete. In addition, the concrete girders needed to be made continuous for deck weight, similar to the steel alternate. This was accomplished using the threaded rod continuity system developed by Dr. Maher Tadros and first used in the US-30/N-92 Clarks Viaduct in central Nebraska (Fig's 4 & 5), (Ref. 4).

The longest previous girder in the state was a 165'-0" NU 2000. The concrete girders used for Platte River East are modified NU 1800's with approximate 3 in. of depth added to the top flange of the standard NU 1800 girder. The top flange was narrowed from 4' to 2'-7.5" in width in order to save the beam self-weight (Fig. 3). The longest girders will have a length of 174'-0". The concrete used in the modified NU 1800 girders have a release strength of 5,500 psi and 56-day strengths of 9,500 psi and 9,000 psi for the 970' and 592' structures, respectively. The 3" of depth was added to accommodate the four 1-3/8" diameter Grade 150 high-strength threaded rods used for the threaded rod continuity connection.

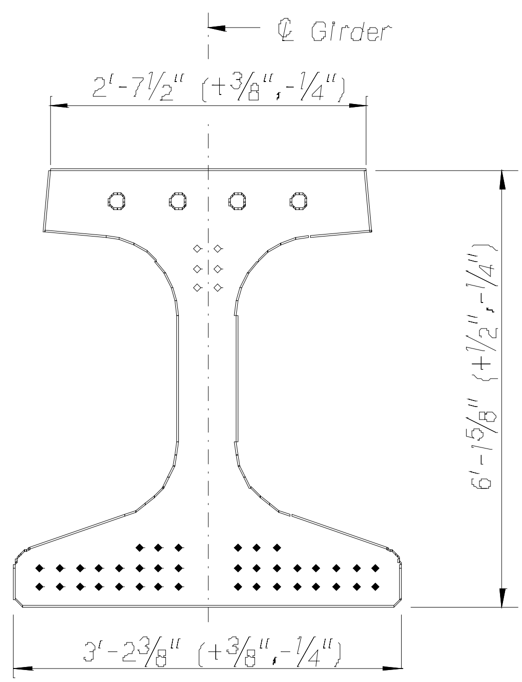

Fig. 3 Cross-Section of Modified NU 1800 Girder with four 1-3/8" threaded rods (Not to Scale)

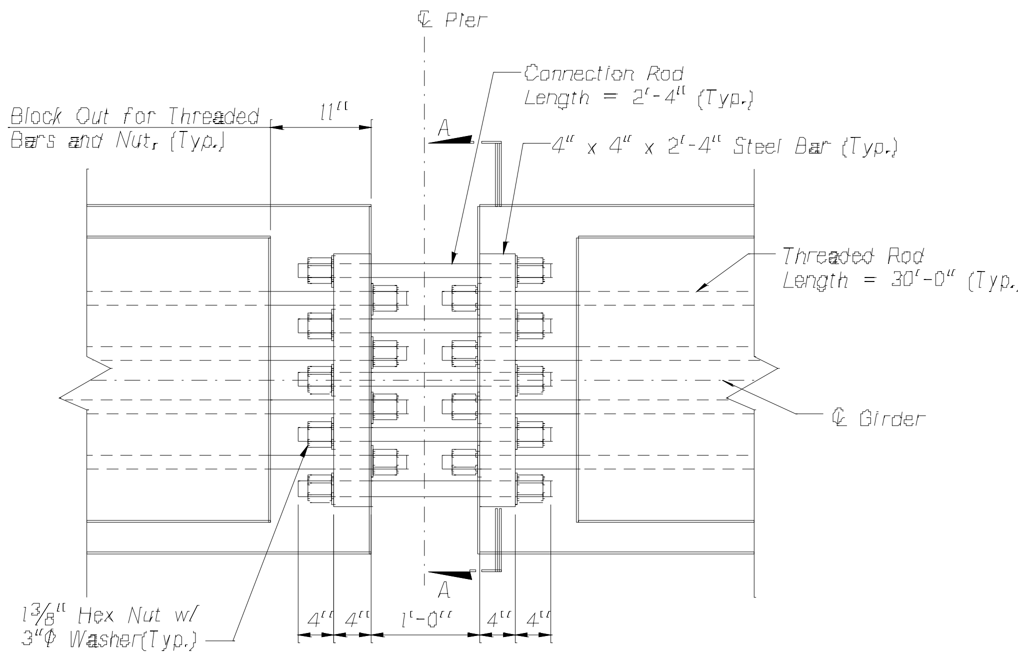

Fig. 4 Plan View of Threaded Rod Continuity Connection at the Piers

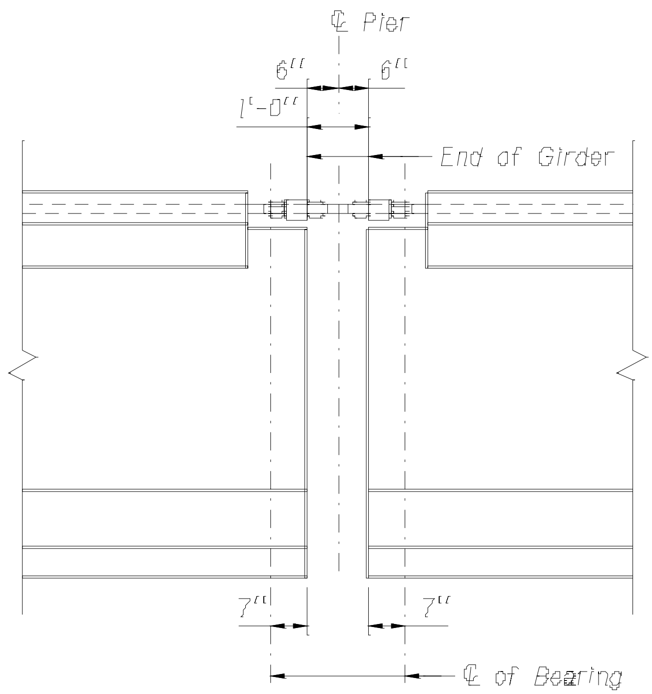

Fig. 5 Elevation View of Threaded Rod Continuity Connection at the Piers

Due to the complicated design and analysis, typical bridge design software could not be used. Instead, the analysis was performed using Excel spreadsheets and RISA-2d. LEAP Software's CONSPAN LA was used to obtain camber data. The first step in girder design was to determine the number of pretensioned strands required based on the allowable tension stress at final. A spreadsheet was written that allowed the designers to quickly change the number of strands and see how it affected the girder tension stress. The spreadsheet incorporated AASHTO LRFD lump sum prestressed losses and transformed section analysis for stress computations (Ref. 5). Once the number of strands was determined based on tension stresses, the concrete release strength was determined using strength design (Ref. 6). The State of Nebraska has recently eliminated the allowable compressive stress check and instead adopted a strength design approach that utilizes strain compatibility at prestress release.

Once the number of strands was set for each span and the concrete release stress determined, the ultimate flexural capacity was determined using Excel spreadsheets. The spreadsheets were used for both ultimate positive and negative moment capacities. The spreadsheets utilized strain compatibility and Mast's Unified Approach (Ref. 7). Strain compatibility was used in order to account for the high strength threaded rods in addition to the mild reinforcement in the deck slab. Strain compatibility also allows for inclusion of the compression steel. The analysis indicated that the compression stress limits at the pier sections were exceeded but that strength (using Mast's Unified Approach) was acceptable. The analysis and design resulted in 42 - 0.6" diameter, Grade 270, low relaxation strands for the longer bridge. Six of the strands were draped (2 strands in each of three rows).

Due to the large spans and girder spacing, shear design was critical. The section would not have worked if the AASHTO Standard Specifications limit of $8\sqrt{f_c^{'}}b_w d$ was used (Ref. 8). In order to develop the full shear capacity up to $0.25 f_c^{'} b_w d$ specified by the AASHTO LRFD Specifications, 18 strands (all of the strands in the bottom row, 3'-0" of extended length) were bent and extended into the abutment diaphragm. At the pier diaphragms, 8 strands were extended. The number of extended strands was reduced at the pier diaphragms because the tension tie for shear design in the negative moment regions is the longitudinal deck reinforcing.

Another unique feature of this bridge is the detailing of the pier diaphragms. Since the concrete girders are made continuous for deck weight, a partial height diaphragm must be in place prior to casting the deck slab in order to transfer the compression force from girder to girder. The tension force is transferred through the threaded rods in the top of the girder. The negative moments developed over the piers in the 970' bridge were very large (14,000 kip-ft / girder line). The girders are acceptable according to strength design but required a girder concrete strength is 9,500 psi. The pier diaphragm concrete strength is typically 4,000 psi (same as the deck slab). In order to avoid having a large difference in concrete strength, the concrete strength of the diaphragm was increased to 6,000 psi. In addition, three #5 rectangular ties were placed between the girder bottom flanges to confine the compression strut that develops between the two adjacent girder bottom flanges (Fig. 6 & 7).

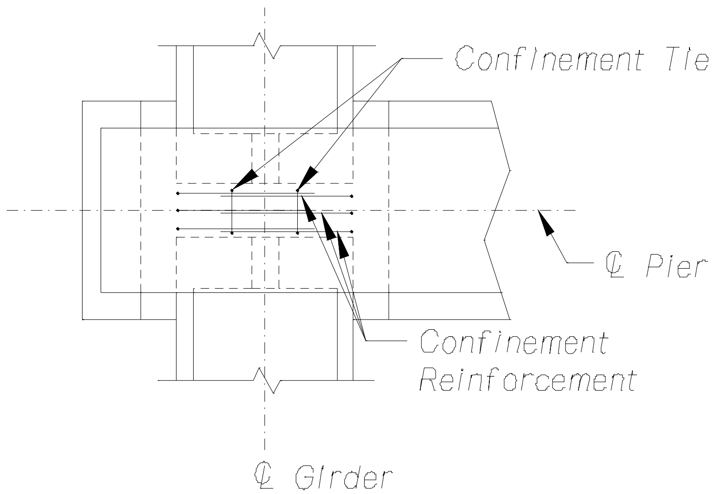

Fig. 6 Plan View Showing Confinement Reinforcement in Pier Diaphragms

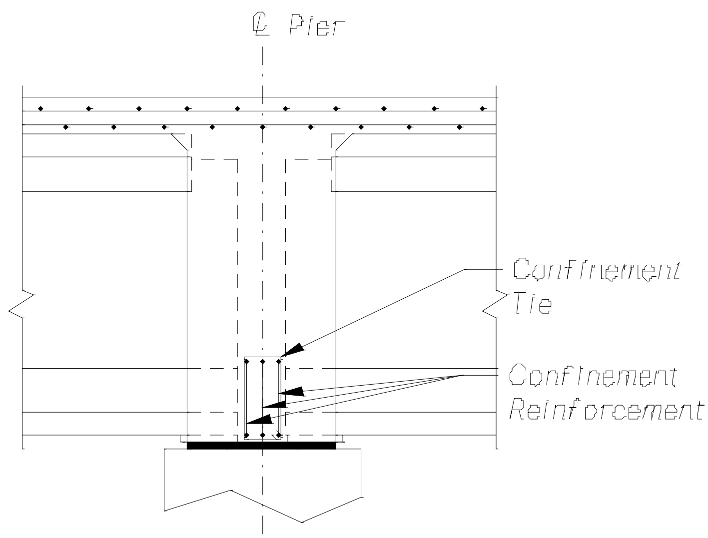

Fig. 7 Elevation View Showing Confinement Reinforcement in Pier Diaphragms

In addition to having alternate steel and concrete superstructures, the two bridges also have alternate substructures. Both structures were designed with encased wall piers, but the deep foundation elements are either driven steel piling or drilled shaft with rock sockets. For the 970' bridge, the original design consists of four 5'-6" diameter drilled shafts with 5'-0" rock sockets. The rock socket is drilled 34'-0" deep into the natural shale. The four shafts are spaced at 14'-0" on center. The alternate foundation consists of 15 - HP14x89 driven steel piling with centerline spacings of just over 3'-0" (Fig. 8). The piers do not include a pile or drilled shaft cap on the bottom of the wall section. The piling extends into the wall for the alternate and the wall sits on top of the drilled shafts for the original design.

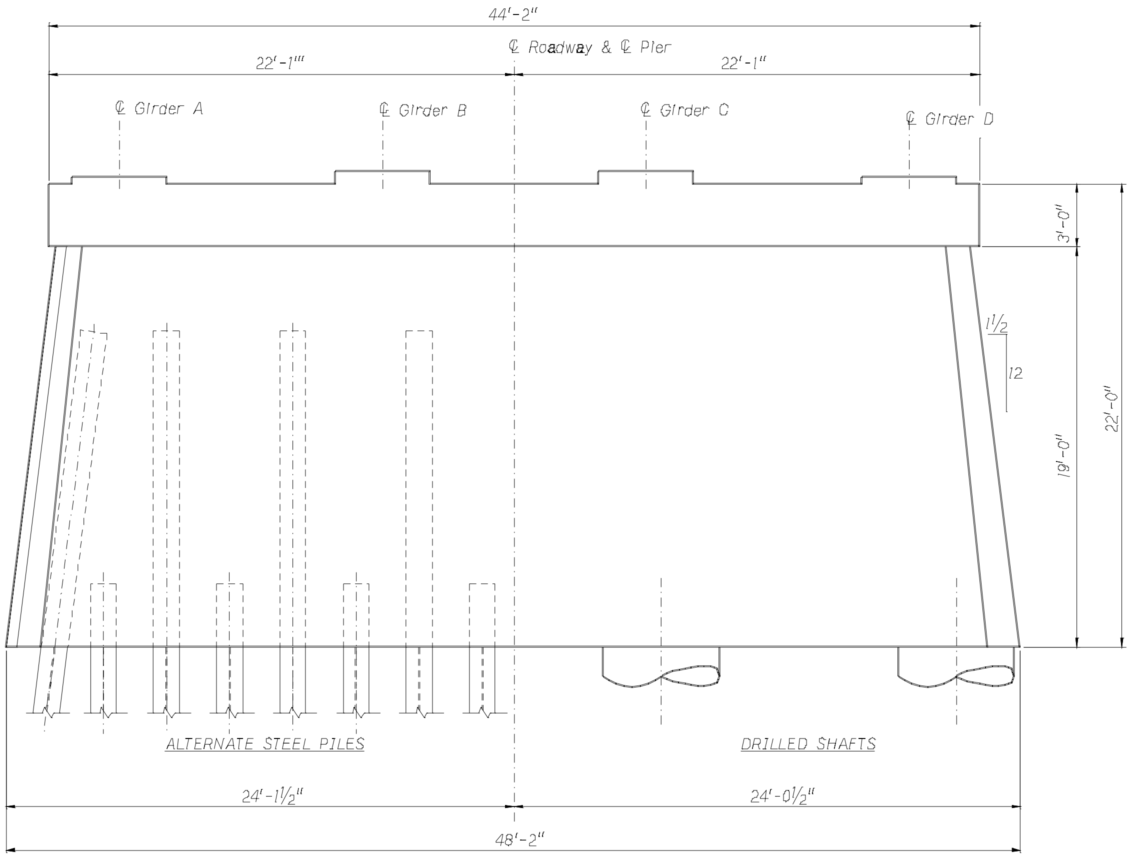

Fig. 8 Pier Elevation Showing Alternate Deep Foundation Elements

CONCLUSIONS

In designing the concrete alternate on Platte River East, Tadros Associates will set a record for the longest precast/prestressed concrete girders used in Nebraska to date. In the past, when alternate concrete and steel superstructure designs were performed on a structure, each system was optimized, with the steel alternate often having fewer spans or wider girder spacing than the concrete. With the concrete alternate design on this project, Tadros Associates has shown that designers can first optimize a steel design and then match spans, depth, and girder spacing with a concrete design.

Platte River East also uses the threaded rod continuity connection originally developed by Dr. Tadros and first used on the US-30/N-92 Clarks Viaduct. One of the main benefits of the threaded rod continuity connection is its simplicity. The connection creates an inexpensive and simple way to splice concrete girders together, making them continuous for deck weight.

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