COST EFFECTIVE DETAILING OF A DEAD LOAD SIMPLE LIVE LOAD CONTINUOUS WEATHERING STEEL GIRDER BRIDGE IN NEW MEXICO

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BIOGRAPHY

Ted Barber is a bridge design unit supervisor with the New Mexico Department of Transportation (NMDOT) in the Bridge Design Section. Mr. Barber is a graduate of New Mexico State University in 1990 with a BSCE. He has worked in the Bridge Design Section of NMDOT for five years.

SUMMARY

The concept of design of a multi-span steel plate girder bridges as simple span for dead loads and continuous for live load is not new to the New Mexico Department of Transportation (NMDOT), but was improved on this bridge replacement project.

Every consideration for ease of fabrication and erection should be given to a steel bridge to keep them competitive in the present economic climate.

Application of this simple span for dead load continuous for live load design of steel girders allows for simplicity in fabrication through repetition, full length girder erections, simplified connections, and flexibility of deck pour sequencing.

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INTRODUCTION

The bridge that is the subject of this paper is located on NM 187, near Array, NM, spanning the Rio Grande River. This 2 lane, 4-girder structure, designed by the New Mexico Department of Transportation (NMDOT) Bridge Design Section has 5-105ft spans, for a total deck length of 526.5ft, and a total width of 34.5ft. The subject bridge's substructure consists of driven filled steel pipe piles with concrete curtain walls around piles to 5ft below grade. The construction phase started in the fall of 2004 and will be completed in the summer of 2005. Figure 1 above is a photo of bridge art work showing the state bird (road runner), on a studded steel plate, with powder coating, that is cast flush with the concrete bridge barrier rail.

Figure 1

The design concept of a multi-span weathering steel plate girder bridge as simple span for dead loads and continuous for live load is not new to the NMDOT, but was improved with this bridge replacement project on NM 187. Previously, this concept was used in a dual design alternative (steel and prestressed concrete bridges) for a limited access project in southern New Mexico on US 70. Design consultant for the US 70 project bridge alternates was Parsons Brinckerhoff Inc. Bids for the US 70 project differed by only 0.2% in cost for the total project construction cost between alternatives on a $21M bid. This small differential cost made the decision to look at this new concept steel bridge in this similar geographic location feasible. Improvements in design and construction details are incorporated in the NM 187 project.

Economic analyses done using various configurations of steel girders and prestressed concrete beams, while limiting the total new depth of the new superstructure, proved decisive for selection of superstructure type. This limited the earthwork required to build the approaches to the new bridge and the amount of right-of-way needed for this new parallel offset alignment. Limiting the depth of the new bridge also had an effect on the aesthetics of the bridge in the river area. Other bridges built along the same river have vertical curves that seem out of place for this river valley. In performing these preliminary design scenarios it was determined that five girder lines were necessary for prestressed concrete where four girder lines were required for steel plate girders at comparable superstructure depths.

This economical bridge design incorporated an easily fabricated and constructible bridge superstructure with no traditional bolted splices, requiring no shoring towers for ease of erection, and implemented constant plate thicknesses and dimensions with no flange transitions. Diaphragms featured easy erection and were positioned on wide spacing. Girder cross sectional dimension measured 54" total depth, 0.866"x13.78" top flange, 0.472" web, and 0.866"x17.32" bottom flange, all steel being grade 50W. Girders could be erected at full fabricated length as simple spans between piers or abutment supports.

SUPERSTRUCTURE DETAILING

In the design of the simple field connections at the centerline of piers, new detailing insured that the top plate connection would slip properly under DC1 construction loadings allowing beam end rotation.

The US 70 project did not include this feature. On that project, the contractor placed the deck and pier diaphragm in one continuous pour. To do this, all top continuity plate connection bolts had to be tightened before slab pour because of their location inside the concrete pier diaphragm. This induced some level of stress throughout the beam. Neoprene bearing devices shear resistance induces these forces due to beam end rotation under deck pour loadings.

The design of the connection was improved by placing the connection bolts outside the poured concrete diaphragm at the piers. See figure 2 below. Bolts placed head up and nuts exposed down facilitated tightening of the connection after the deck and diaphragms were poured completely. After deck pours, heads of bolts were locked into the concrete deck so tightening was accomplished by turning nuts with direct tension indicators from below. Final tightening came after all concrete had been poured for the deck and pier and abutment diaphragms, prior to opening for traffic.

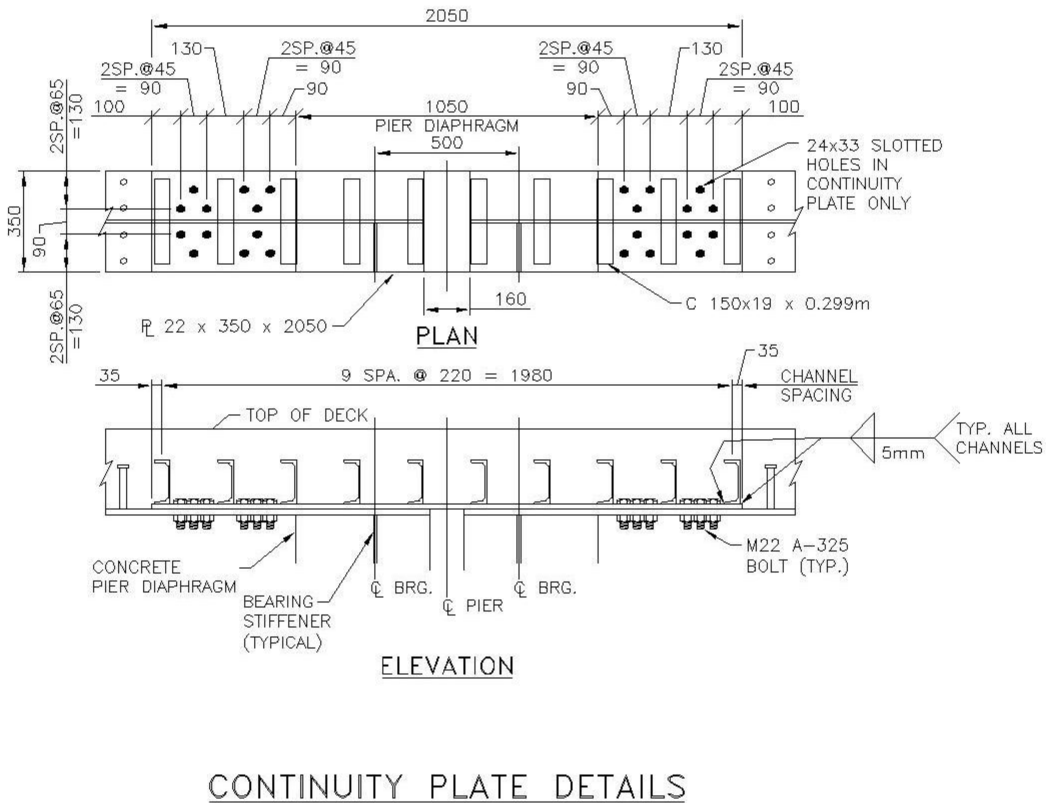

Figure 2

Additional reinforcing bars were added to normal deck reinforcement patterns longitudinally over the piers to achieve required negative moment capacity in the bridges continuous live load function. The positioning of these bars near the top of the deck allowed the continuity connection plate to be lightly stressed under live load. The continuity plate connection also serves as redundancy in the future where deck deterioration may reduce the effectiveness of the deck reinforcement for negative moment capacity. The bearing stiffener plate on each beam end at the piers served to develop compression for this moment connection. The bearing plate was braced in the compression zone by a simple plate perpendicular to the web and bearing stiffener.

This type of connection also gave more flexibility to the bridge contractor on pour sequences. There is a desire in the state for builders to pour entire bridges in one pour day. This was not possible on this bridge because of the 500+ cu.yd. deck volume, but with this type of design it is possible to pour across spans and pier concrete diaphragms and bulkhead 6.5ft from a pier cap.

In shop drawing review a correction was also noted to bend the connection continuity plates to conform to beam dead load camber at each beam end. This also allowed the connection plate to fit up with loose bolting during dead load application. The top plate slippage also ensures that there are no unintended shear deflections in the steel reinforced neoprene bearing pads during the slab pour and no induced moment in the girders. Upon final review of the shop drawings a small increase was made in the length of the slotted hole in the continuity plates to aid in erection tolerances. Beams were erected and continuity plates were lifted into place with bolts in place and slipped in without any alignment problem. The erection of this bridge was very straightforward and simple.

Girders for this bridge were detailed at the same exact length, plate thickness, dimensioning, and camber for ease of fabrication. Slight adjustment of end span length facilitated this.

The US70 design counted solely on embedment of the bottom flange in the concrete diaphragm to prevent buckling of the girder compression flange over the piers. On this project, simple horizontal steel channel diaphragms were added the bottom flange in the negative moment region over the piers, providing additional buckling resistance.

DESIGN

Intentionally designing the bridge's vertical alignment to be centered at the crest of a vertical curve allowed for the uniformity of all girders. Initially NMDOT had placed bridge in a vertical curve but not centered at the crest. This minor modification went a long way to simplifying the bridge in design and detailing for construction.

This is the first in-house design of a steel bridge with this detailing and the first project to implement AASHTO LRFD Bridge Design Specifications. STAAD Pro structural analysis software and Mathcad was used to perform the two-stage analysis and design calculations for the beam lines because no commercial software packages are available for this design concept. STAAD Pro's ability to handle staged loadings, the first being all spans simple and then second stage changing joints at piers to moment connections, allowed for girder line analysis of the bridge. STAAD Pro also allows for factoring of loads and graphical presentation of the location of axle loads and their position at maxima. Many of the software programs used today seem to lack presentation of positions of the loading on the structure. Mathcad was used to perform the calculations for the steel design using the LRFD code.

FABRICATION AND ERECTION

The start of fabrication of the girders for the project was delayed due to global steel market conditions. The contractor asked for suspension of work on the contract for 3 months over the winter to allow for delivery of the raw plate to the fabricator. The nationwide supply of steel decreased between the time of bidding and notice to proceed. This bridge was planned for construction during the low flow stage of the river and it was essential to complete the two river spans before the river was at high, spring irrigation levels. In spite of suspension of work, the two river spans for the bridge were delivered and erected. Due to the flexibility of this dead load simple/live load continuous girder system, the contractor was able to pour spans 4 and 5, stopping 6.5ft from pier 3, while beams had not been erected on spans 1, 2, and 3. This completed the work required to cross the main part of the river channel in time as required by the contract. Repetition in the girder design throughout the structure was paramount to economical fabrication. Like size flanges, webs and girder lengths enabled the most advantageous price and delivery of steel plate from the mill. Detailing was greatly minimized. Drafting of only one girder was required and all others were nearly alike. Cutting flanges and webs only required one drawing. During shop fabrication, only one jig was required for each function of tacking and welding. The continuity plates were all identical and could be processed full size using CNC equipment. Continuity plates did not have to be match-marked with individual girders. Repetition in shop fabrication increased production by at least 25%.

The simple span to continuous concept greatly reduced fabrication time and cost. The girders did not require full layout and assembly in runs. Assembly drilling was not required as it is for conventional bolted girder splices.

With all like parts, erection efforts in the field were much more efficient as well. Taking bolted splices out of the equation saved a tremendous amount of money.

Not requiring the girders to be sandblasted saved a lot of money and time on the end of a very aggressive schedule for this bridge. If a bridge is in an area not exposed to view, there is no need for blasting. The weathering steel girders will color and form the protective layer in time. Blasting girders should be considered if aesthetics are necessary to the project's success.

Beams were easily erected by two relatively small cranes that were readily available in the state. Prestressed concrete beam bridges require much larger cranes that require large mobilization costs, difficult lift configurations, and more erection time. The State of New Mexico is in the middle of a $1.5B road and bridge improvement bond program over six years and one of the goals of the program is to facilitate smaller bonding requirements so that more construction firms are able to bid projects. Using resources found within the state are essential for this program.

ECONOMICS

The design phase of this project started before steel price levels increased over the past few years. Despite this fact, per square foot costs for this bridge came in lower than some other concrete bridges recently bid in the State. Steel price per pound for the girders on this project were comparable to steel bridges bid two to three years ago.

The cost per square foot of this bridge as reported to the Federal Highway Administration in the yearly report was $75 per sq.ft., at a total deck area of 18,170 sq.ft. In this same report, other prestressed concrete girder bridges of comparable square footage were $68 and $88 per sq.ft. If the economics of steel market were different at the time of bid this project, it would really indicate how economical the bridge really is.

SUMMARY

This bridge structure was a success from many perspectives. Neatly constructed concrete work interfacing with steel girders has a well finished effect (see Figure 3). This project also showed that steel bridges can compete with prestressed concrete, in a predominantly concrete bridge state. This concept will work well in

Figure 3

other similar river and dry streambed crossings of significant length, requiring at least two spans. This type of design is limited to maximum girder lengths that can be hauled to the bridge location; otherwise expensive traditional field splices are necessary.

Keys to Economical Design:

1. Position the bridge properly to take advantage of road geometry if possible for repetition of superstructure framing components.
2. Design all girders to the equal length spanning between supports, apply constant plate dimensions throughout, and use equal beam camber throughout.
3. Implement the simple for dead load, continuous for live load concept to eliminate traditional flange and web bolted field splices. Splice top flanges over piers and add additional reinforcing steel to deck for negative moment capacity.
4. Use easily erected one piece diaphragms at wide spacing.

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