Simple-Made-Continuous Bridge Cuts Costs

Cost-effective detailing was only one of the advantages of a simple-made-continuous weathering steel girder bridge in New Mexico.

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THE NEW MEXICO DOT HAS GREATLY IMPROVED MULTI-SPAN, PLATE-GIRDER STEEL BRIDGES DESIGNED AS SIMPLE-SPAN FOR DEAD LOADS AND CONTINUOUS FOR LIVE LOADS. These designs ease fabrication and erection, helping to keep steel bridges competitive with concrete. The simple-made-continuous concept cuts costs through repetitive fabrication, full-length girder erections, simplified connections, and flexible deck-pour sequencing.

Bridge Overview

The bridge discussed here crosses the Rio Grande River on NM 187, near Array. This two-lane, four-girder structure, designed by the NMDOT, has five 105-ft spans and a width of 34.5 ft. The substructure consists of driven, filled, steel pipe piles. Concrete curtain walls surround the piles to five feet below grade. The construction phase started in the fall of 2004, completing in the summer of 2005.

On an earlier project, the simple-made-continuous concept served in a dual-design analysis (steel vs. pre-stressed concrete bridges) for a bridge on US 70 in southern New Mexico. Design consultant for the US 70 bridge alternates was Parsons Brinckerhoff, Inc. Bids by construction contractors for these bridge alternates differed by only 0.2 percent out of a total project construction cost of $21 million. This small differential cost tipped the decision to look at applying the simple-made-continuous concept to steel bridges located in similar geographies.

The NM 187 steel bridge project incorporated further improvements in design and construction details. Selection of the superstructure type depended heavily on economic analyses of various configurations of steel girders and pre-stressed concrete beams, while limiting the depth of the new superstructure. The preliminary design scenarios determined that pre-stressed concrete required five girder lines, but steel plate girders required only four girder lines.

A shallower depth decreased the earthwork required to build the bridge approaches, as well as the amount of right-of-way needed for a new parallel offset alignment. It also improved the bridge aesthetics in the river area. Other bridges built along the same river have vertical curves that seem somewhat out of place for this river valley.

The economical steel bridge design incorporated an easily fabricated and constructible bridge superstructure with no traditional bolted splices between piers. Eliminating these bolted splices avoided the shoring towers required for erection. The design implemented constant plate thicknesses and dimensions with no flange transitions. One-piece diaphragms, positioned on wide spacing, also facilitated easy erection. The steel girders, all grade 50W, have a total depth of 54 in. The web is 0.472 in., and the cross sections of the top and bottom flanges are 0.866 in. by 13.78 in. and 0.866 in. by 17.32 in., respectively.

Superstructure Detailing

New detailing ensured that the top plate connecting in-line girders at the piers would slip properly under DC1 construction loadings, allowing beam-end rotation. By contrast, on the US 70 project the contractor placed the deck and pier diaphragm in one continuous pour. Construction workers had to tighten all top continuity plate connection bolts before slab pour because of their location inside the concrete pier diaphragm. This induced some level of stress throughout the beam. The shear resistance of neoprene bearing devices induced these forces, which are caused by beam-end rotation under deck pour loadings.

Figure 1. Dual-design analysis indicated that steel required only four girders, while concrete pre-stressed beams required five (for the same depth).

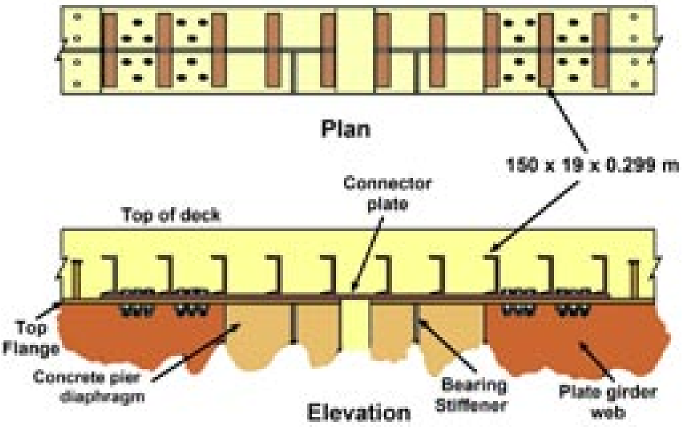

Figure 2. Connection plate bolts outside the pier permit tightening after the deck pour, minimizing induced stresses.

NMDOT improved the girder connection for the NM 187 bridge design by placing the bolts outside the poured concrete diaphragm at the piers (Figure 2). Bolts placed heads-up and nuts-exposed-down permitted tightening of the connection after pouring of the deck and pier diaphragms. After deck pours, the bolt heads were locked into the concrete deck. Workers tightened bolts 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.

The design required adding reinforcing bars to normal deck reinforcement patterns longitudinally over the piers. The additional reinforcement achieved the required negative moment capacity for the bridge's continuous live-load function. Under live loads the continuity connection plate will be lightly stressed. The continuity plate connection also added redundancy in the event that future deck deterioration reduces 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. A simple plate perpendicular to the web and bearing stiffener braced the bearing plate in the compression zone.

This type of connection also gave more flexibility to the bridge contractor on pour sequences. Contractors in the state want to pour entire bridges in one day. The 500+ cubic-yard volume of concrete on this bridge deck prevented a one-day pour. But with this design, contractors can pour across spans, pier concrete diaphragms, and bulkhead 6.5 ft from a pier cap.

Reviewers of shop drawings made a change requesting that the fabricator bend the connection continuity plates to conform to beam dead-load camber at each beam end. This allowed the connection plate to fit up with loose bolting during dead-load application. The top-plate slippage also avoided unintended shear deflections in the steel-reinforced neoprene bearing pads during the slab pour, as well as any induced moment in the girders.

Additionally, the reviewers requested a small increase in the length of the slotted hole in the continuity plates to aid erection tolerances. As a result, the contractor was able to erect beams and lift continuity plates (with bolts) into place without any alignment problem. Bridge erection was simple and straightforward.

The design intentionally centers the bridge's vertical alignment at the crest of a vertical curve, allowing for the uniformity of all girders and greatly simplifying the bridge in design and detailing for construction. Steel girders for this bridge were detailed for the same exact length, plate thickness, dimensioning, and camber, facilitated by a slight adjustment to the length of end spans. Simple horizontal steel channel diaphragms added to the bottom flange in the negative moment region over the piers provide additional buckling resistance.

Design Firsts

The bridge represents the first in-house design of a steel bridge with this detailing and the first project to implement *AASHTO LRFD Bridge Design Specifications*. No commercial software packages are available for the simple-made-continuous steel design concept. Instead, STAAD Pro structural analysis software and Mathcad performed a two-stage analysis and design calculation for the beam lines. For the first stage, all spans were simple. The second stage transformed joints at piers to moment connections for girder-line analysis. STAAD Pro also allowed factoring of loads and graphical presentation of the location of axle loads and their position at maxima. Many of today's software programs seem to lack presentation of positions for the loading on the structure. Mathcad performed the calculations for the steel design using the LRFD code.

Fabrication and Erection

Global steel market conditions delayed the start of fabrication of the girders for the project. The nationwide supply of steel decreased between the time of bidding and notice to proceed. The contractor asked for suspension of work on the contract for three months over the winter to allow for delivery of the raw plate to the fabricator.

NMDOT planned this bridge for construction during the low-flow stage of the river. It was essential to complete spans 4 and 5, the two spans over the river, before the water reached spring irrigation levels. In spite of the three-month suspension of work, fabricated steel delivery and erection took place to complete the two river spans on time. The flexibility of the simple-made-continuous girder system permitted the contractor to pour spans 4 and 5 while beams had not yet been erected on spans 1, 2, and 3. Thus, the contractor was able to fulfill this contact requirement.

Economical and fast fabrication resulted primarily from the repetition of girder design throughout the structure. Repetition in shop fabrication increased productivity by at least 25 percent. Like-size flanges, webs, and girder lengths provided the most advantageous price and delivery of steel plate from the mill. Additional advantages included:

Figure 3. A connection plate bolts the top flanges of the two girders that meet at a pier, making the girders continuous for live loads.

- Detailers could develop shop drawings for one girder; all others were nearly alike.
- The fabricator cut flanges and webs using only one drawing.
- Shop fabrication necessitated only one jig for tacking and welding.
- The continuity plates that spliced the girders together at the piers were all identical and could be processed full-size using CNC equipment.
- The girders did not require full layout and assembly in runs.
- Assembly drilling, required for conventional bolted girder splices, was unnecessary.

With all parts alike, erection efforts in the field were much more efficient as well. Big savings resulted from:

- Eliminating bolted field splices between piers.
- Eliminating sandblasting of girders (the bridge is not in an area exposed to view).
- Specifying weathering steel, which will develop a rich color and form a protective patina in time.

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

The design phase of this project started before steel price levels increased over the past few years. Despite these increases, cost per square foot for this bridge came in lower than some other concrete bridges recently bid in the state. With a total deck area of 18,170 sq. ft, the cost of this bridge as reported to the Federal Highway Administration was $75 per sq. ft. Prestressed concrete girder bridges of comparable square footage were $68 and $88 per sq. ft. each.

This simple-made-continuous project showed that steel bridges can compete with pre-stressed concrete in a predominantly concrete bridge state. This concept will work well in other similar river and dry stream-bed crossings of significant length and 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. MSC

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Owner and Designer
New Mexico Department of Transportation

Contractor
Reiman Corp., Cheyenne, Wyoming

Fabricator
Roscoe Steel & Culvert Co., Billings, Montana (AISC member)