BRIDGE DESIGN AND ECONOMICS

Karl Svaty, PE, SE

BIOGRAPHY

Karl Svaty, PE, SE is the bridge section manager for MKEC Engineering, Inc. in Wichita, Kansas. His experience includes complex structures, construction engineering, bridge repair and rehabilitation, load rating and bridge inspection. He is a past president of Kansas State University Civil Engineering Advisory Board.

SUMMARY

The replacement structure is located in Wichita, Kansas on a major thoroughfare. The bridge spans a double track main line of the Union Pacific Railroad.

The bridge construction presented many unique challenges; requiring two lanes of traffic continuously throughout construction. The Union Pacific traffic could not stop. The 479-foot three span structure was placed with all these constraints for a very economical cost.

BRIDGE DESIGN AND ECONOMICS

One of the comments that I hear often is “steel costs too much”. What does that mean? Where do we get these ideas? I believe that there are many qualitative assessments that we are able to use in our design that will result in much less expensive structures and simultaneously increasing the aesthetic value. This is a discussion of a number of ideas that may be incorporated in to a design will enhance the structure’s value and its incorporation into the community.

Some of these ideas were taken directly from the AISI document “Steel Bridge Construction: Myths & Realities”. I think that maybe the title should be changed to include the element so design. Usually when construction is at hand most of the decisions about structural elements have been completed and are part of the contract document, unable to be changed. My discussion is about how the design team can influence the total economic situation of a bridge construction project.

The structure I am presenting is a steel welded plate girder of three spans, 100’-276’-100’, which is a railroad grade separation (see Figure No. 1). It incorporates a number of ideas I am discussing here. The reason to use this structure as a presentation is that the construction cost is quite low.

Figure 1: Complete Bridge

Some details of the structure, it is essentially a M270 Gr50W steel bridge. There are ten (10) girder lines and the bridge is curved (see Figure No. 2). One of the important ideas that I will present is you don’t complete your design in the closet. There are many people out there with construction and design experience that will share with you. Talk to as many individuals from all disciplines of the completed structure as possible. First, I would ask, have you talked with a fabricator? Don’t just talk to one. Send some details to several. Get comments and suggestions. They are always interested to be included. There’s another group, the contractors. Contact several about your project, give them details, maybe some preliminary drawings. You never know where the comments you receive may lead. There is one final group that needs to be in the bridge discussion, the road group. In some cases, this does not happen. It needs to. During the design of the bridge, there were many discussions with our road team and to address the details and dimensions of the structure. With that said, let’s address some of the design and construction challenges.

Figure 2: Aerial View

One of the first elements of the project was an owner requirement. The road will be open to two way traffic at all times. There were detours available; however, there was a very significant group of constituents with the owner that required the road. This brought the bridge and road design teams together. There were many solutions; however, the one chosen was very innovative. Since we were replacing an existing structure crossing the railroad that was in place, the unique solution was to demolish about half of the existing bridge for construction of the new bridge. The remaining existing structure was used as a grade separation crossing for the duration of the project. A road berm was placed adjacent to the west of the remaining existing bridge with a short steel span to the existing structure. A GRS (Geosynthetic Reinforced Soil) abutment was constructed (see Figure No. 3). (FHWA for details of the type of structure) The abutment was about thirty (30) feet in height. It performed flawlessly for the year and half construction. The important aspect of this detour scheme was the cooperation between the road and bridge teams (see Figure No. 4). It could not have been accomplished without that interactivity. Although, there was a significant cost to this in place detour, it allowed the contractor to construct the bridge without any restrictions or special construction sequences.

Figure 3: GRS wall with steel span

Figure 4: Steel span at the detour bridge

One of the significant items to the design, was the discussion with our road team. In preliminary discussions of the structure there were various centerline grades used on the bridge. This variation of grades makes a very cumbersome detail for the vertical camber of the web plates. We had a number of discussions about what vertical curves were required. Many were tried. The final outcome was an equal vertical alignment on both the north and south approaches. We then placed the vertical point of intersection in the middle of the bridge. Very significant, it made the bridge now quarter symmetric. It was half symmetric by the bridge design team. However, now it is quarter symmetric. This just reduced the construction complexity by about half to 60%. This was a result of the road and bridge teams discussions. Talk to someone about your problem. They helped solve ours.

The team discussions continued. It was now the road's turn. They were experiencing some difficulty with right-of-way (R/W). The curves at the ends of the structure were taking a lot of R/W. They came to the bridge team with ideas to change the bridge. It was a discussion of the various elements. We came up with a unique solution. The bridge is curved. This means we have curved girders. NO! Look at the aerial photo. The framing is tangent. This did require some details and dimensions in the abutments and deck; however, very easily accomplished. Here to the fabricator, the bridge is tangent and without any associated detail problems. The result was the curves were accommodated only in the deck (see Figure No. 5). A variable overhang was provided at the north and south abutments. An unusual situation developed with this. How is the crown of the bridge placed on the curve? I asked that it remain on the bridge centerline for the entire length of the structure. This was done and a transition placed in the approach slabs. The result here was quite pleasing as it was a field detail we observed quite closely. The road and bridge teams worked to produce a unique solution, a curved bridge that saved a significant R/W cost.

One of the most significant cost savings of the structure was a jointless bridge. This was a challenge since the structure is 479 feet in length. Using the expected temperature differential, this produces a large longitudinal load at the abutments. Details here are placed to accommodate the longitudinal movement of the abutment. When detailing the elements that surround the abutment ensure that all are addressed for the movement. Any restraints will cause some distress in the diaphragm or the abutment wings. There restraints could be in the form of a concrete CIP riprap that is essentially rigid. The approach slab of the pavement needs to allow the movement. A part of this is the curbs and sidewalks. It's surprising how much restraint that can be developed by just the sidewalk without appropriate expansion in it. In this design, if it is employed in other structures, the angle of the abutment needs to be considered. This structure was 90 degrees to the road centerline. Hence, the expansion did not produce a lateral load in the bridge. If considering a skew structure, some provision should be included to deal with the lateral load that develops in a skew structure.

Figure 5: Extra length on needle beams

Another caution about of design, it needs to consider the bridge as a complete system. This is all of the bridge elements needed to be considered interacting when experiencing a loading. The bridge bearings for this structure were very simple. The pier bearings consisted of a simple steel masonry plate and a curved sole plate fixed to each welded plate girder (see Figure No. 6). As would be expected, this introduces a longitudinal load in the piers. The longitudinal pier stiffness needs to be considered for this design. The piers were proportioned to allow the expected displacement that occurs due to girder thermal response. Since the structure has been in service for four year, our design principles are well qualified.

Figure 6: Pier bearing and masonry plate

The abutment bearings were a simple elastomeric bearing pad. Since this essentially only supports the bridge dead load, they are more than adequate. From physical observations of the bearing in place, they are working well.

One of the points, I would like to make here is about the choice material and the type of design. To start with, we used plate steel extensively. If you look at the bare prices of materials, plate steel is one of the least cost materials that you can use, so use it. With the web design, longitudinal stiffeners were not used. First, they are very time consuming to install and the welds presents a significant fatigue detail. The webs were designed for the minimum vertical stiffeners possible and they were placed for cross frame connection only. This was a very good cost savings in the fabrication of the welded plate girders.

The summary of the structural steel for this bridge was about 1,250 tons of steel fabricated bridge for this structure. This did not include the temporary detour steel span. The unit employment of steel was about 77 pounds per square foot. This was reviewed from previous experience and a study of welded plate girder steel requirement. The best estimate we could arrive at was 75 pounds per square foot for the 276 foot main span. The steel cost was $1.06 per pound fabricated and erected. It’s an interesting sidelight that there were three bidders on the project and the other’s proposed cost of the structural steel was $1.00 per pound.

The major items of the presentation are:

- Communicate with other industry member, fabricators, contractors, suppliers and maybe other engineers
- Communicate with other teams - road
- Complexity was reduced by the use of quarter symmetry, if it’ easier to design it is easier to build
- The bridge was curved. The steel framing was tangent. The curve was introduced into the deck
- The bridge was jointless. Ensure the abutment environment accommodates the expansion
- Pier design was proportioned to allow a stiffness to for expansion

- Use simple bearing devices, ensure that all bridge systems will perform with the bearings
- Steel framing was simple, longitudinal stiffeners were not used, minimum transvers stiffeners
- Reduce complexity for the contractor as much as possible, GRS detour
- Parallel flange welded plate girders were chosen
- Use repetitive systems and the symmetry to reduce complexity

The last comment was demonstrated by the fact of the forty (40) field splices of about 250 bolts each. Not a single splice was misaligned or required some type of adjustment, they all fit (see Figure No. 7).

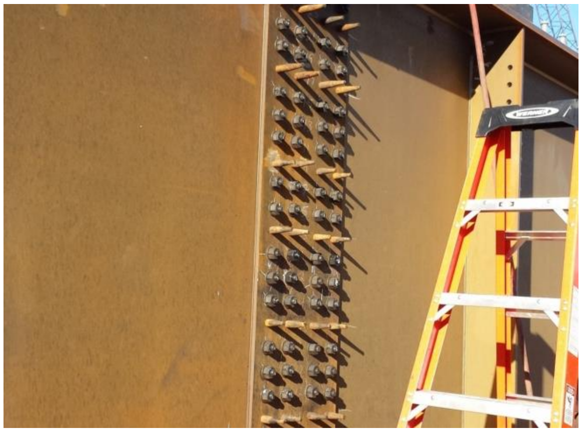

Figure 7: 1 of 40 field splices, ~250 bolts/splice

Steel bridges are able to be designed and constructed inexpensively if details, appurtenances are complete, very simply and allow the contractor tolerances.

OWNER

City of Wichita, Kansas

General Contractor

United Contractors Inc., Johnston, Iowa

Designer

MKEC Engineering, Inc., Wichita, Kansas

Fabricator

Capital Contractors, Inc., Lincoln, Nebraska