Steel Bridge System With Continuity for Live Load only and Utilizing 100 ksi High Performance Steel

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INTRODUCTION

The incorporation of several innovative ideas and concepts allowed addressing several limitations that had to be accommodated while producing an economical steel bridge system. Following is a brief description of the basic information related to the bridge.

Name:	N-2 over I-80 Bridge	
Owner:	Nebraska Department of Roads	
Industry Team:	Nebraska Department of Roads	Lyman Freemon, S.E. Bridge Engineer Fouad Jaber, P.E. Designer Sam Fallaha, P.E. Research
	National Bridge research Organization (NaBRO) at University of Nebraska-Lincoln	Atorod Azizinamini, Ph.D., P.E.
	Capital Steel Co., Lincoln	Fabricator
	Capital Contractors, Inc., Lincoln	Contractor
Constructed:	September 2003	

Like many states the steel bridges in Nebraska are constructed using the concept of having continuity for both dead and live loads. This traditional system usually requires installing many bolts for connecting segments of each girder. Bolted connections are expensive and consequently result in a loss of economy. Additionally, in Nebraska, like many states, the maximum bridge girder length is limited to approximately 120 ft. Closer examination indicates that this limitation is a reflection of crane capacity of the fabricators, rather than the shipping limitations. The maximum crane capacity for most fabricators in the region is limited to approximately 60,000 pounds (30 tons).

A Description of the Innovative Approach

The N-2 over I-80 Bridge is a two span steel box bridge with each span being 139 ft. long. The Bridge crosses over the I-80 highway so minimizing the interruption to traffic was a major design consideration.

Input from contractors and fabricators indicated use of simple for dead and continuous for live system developed at University of Nebraska-Lincoln was a suitable system. However each span of the bridge was 139 ft., which is more than 120 ft (30 ton weight) limitation imposed by local fabricators.

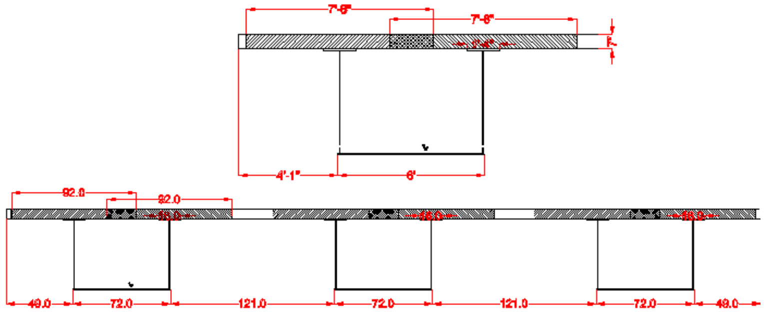

Figure 1- Bridge Cross Section Showing the Three Box Girders (Dimensions are in Inches)

Design of the box girders was based on the assumption that the girders will utilize a hybrid arrangement, with bottom flanges of the box sections using 70 ksi HPS and webs and top flanges utilizing conventional 50 ksi steel. After the design was completed, conservatively, the 100 ksi HPS was substituted for all webs and flanges. The intent was to demonstrate that there is nothing unusual about 100 ksi HPS and 100 ksi HPS can be fabricated and constructed similar to other steel types.

Use of HPS for each girder in hybrid arrangement kept the maximum weight below the 60,000 pound crane capacity of the local fabricators, but girder lengths were increased from the traditional 120 ft. to 139 ft. HPS plates allowed thinner material for bottom flanges and reduced the web depth, while meeting all design limitations.

As shown in figures 1 and 2 the webs of the girders are perpendicular to bottom flange and are not sloped. This significantly reduced the fabrication time and cost. This allowed the fabricator to use equipment and procedures commonly used for fabricating typical I-shapes. Figure 3 shows one of the completed girders in the shop being picked off the ground using the fabricator's 30 ton crane.

Figure 3- A Box Girder in the Shop

A unique feature of the bridge was to use a new steel bridge system developed at NaBRO. This system is referred to as simple for dead, continuous for live load. In this system each girder is placed on the supports; in this case, from abutments to the middle pier. Prior to hardening of the deck slab and continuity diaphragm, each girder behaves as a simple beam, with maximum moment being at the middle of the span. For any loads applied after the concrete deck and continuity diaphragm have hardened, the bridge behaves as continuous spans. This includes dead loads applied after concrete has hardened, such as weight of the barriers and overlays and live loads due to traffic. The continuity for super imposed dead loads and live loads is provided by placing additional reinforcement in the slab over the pier, similarly practiced in prestressed concrete bridges for years. In the simple for dead, continuous for live load bridge system, the need for bolted splices is eliminated, which significantly reduces the cost.

In the new system the girders are joined together, over the interior pier, by casting a concrete diaphragm. The challenge is to connect the girders over the pier in such a manner that allows the girders to act as simple beams during slab casting. Under live loads, the bottom flanges of the girders near the pier are subjected to relatively large compressive forces. These compressive forces have to be transferred to the concrete diaphragm joining the girders over the pier. If girders are simply embedded in the concrete diaphragm, there would be a possibility of crushing the concrete in the diaphragm near the bottom flanges of the girders. Full scale tests carried out at NaBRO confirmed that under service loads, crushing of the concrete diaphragm, near bottom flanges is possible if steel girders are directly embedded in the concrete diaphragm.

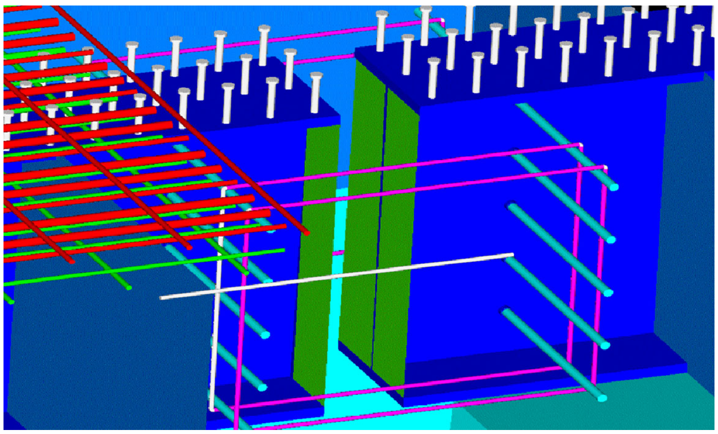

Figure 4 – Possible Detail to Join Girders over the Support

For the case of I-girders, preliminary research data obtained at NaBRO indicates that the detail shown in figure 4 is a possible solution. Test data indicates the detail shown in Figure 4 passes both fatigue and ultimate load tests.

The detail shown in figure 4, consists of welded plates at girder ends. This allows the compressive force from the girder bottom flanges to dissipate over a larger area for transfer to the concrete diaphragm, thus preventing concrete crushing near the girder bottom flanges.

In the case of the bridge under consideration (N-2 over I-80 Bridge) a more conservative approach was selected. Figure 5 shows the type of end detail used. It consists of solid diaphragm plates, which are set back approximately 6 inches from the girder ends and welded to the webs and bottom flanges. The concrete diaphragm is cast between the end plates of the two adjacent girders. As shown in Figure 5, small plates are welded to the top flanges. These plates prevent the pull out of the tension flanges from the concrete diaphragm. Detail shown in Figure 5 also includes a relatively thick plate welded to the end of the bottom flange of the box section. The girders placed along the same line at the interior pier, contact each other through these thick steel plates. The steel plate welded to bottom flange of the box transfers the compressive force from one girder to the other directly, eliminating the possibility of crushing the concrete diaphragm.

Figure 5- Girder End to be Embedded in Concrete Diaphragm

Use of this new steel bridge system, namely simple for dead and continuous for live load, significantly reduced the time required to place the girders from the abutment to the middle pier. The I-80 highway had to be closed for only 90 minutes for placing the three girders for each span. This significantly accelerated the construction time and reduced the interruption to traffic. Figure 6

Figure 6- One of the Girders During Placement over the

shows one of the girders being maneuvered for final placement.

As shown in Figure 2, there are no cross frames between the girders. This is esthetically pleasing and reduced costs. However, stability during erection is an issue requiring investigation.

The stability of the girders during construction was investigated by carrying out a detailed analysis. Designers need to be very cautious about global stability during construction. The AASHTO LRFD Bridge Design Specifications do not provide any check for global stability of I or box girders during construction. AASHTO code provides a check aginst local flange, web or lateral torsional buckling of single girders, however, it does not provide any checks against Global stability. Global stability is where one box as a whole or all the girders as one system may move in the lateral direction, causing catestrophic collapses. In recent years, there have been field problems and even bridge collapses due to designers neglecting the global stability issue.

Another unique feature of the bridge is the use of a concept that allowed keeping the thickness of the bottom flange constant over the entire span length, without using longitudinal stiffeners. The compressive force in the bottom flange near the pier demands adding a longitudinal stiffener to the bottom flange or increasing the thickness of the bottom flange plate in the vicinity of the pier. These options would have added to the total fabrication weight of the girder which was undesirable. The solution was to keep the thickness of the bottom flange constant over the entire girder length and increase the compressive capacity of the bottom flange by placing concrete inside the box near the pier after the girders were erected. Figure 7 shows the inside of the box, near the pier, after casting of concrete. This concrete is intended to prevent the buckling of the compression flange. The effect of this concrete in enhancing the strength of the cross section near the pier was conservatively ignored.

Figure 7– Inside the Box Girder near Pier

In the analysis however, the stiffening effect of this additional concrete was considered.

The construction of the bridge was completed and bridge was opened to traffic in October 2003, marking the opening of the first 100 ksi HPS Bridge in U.S to traffic. Figure 8 shows the view of the completed bridge, after opening to traffic.

Figure 8- Picture of Completed Bridge

Conclusions and Acknowledgement

The system described resulted in an economical system using advanced material (ASTM A708, Gr HPS100W) to produce an easthetically pleasing bridge and significantly reduced interruption time of traffic. The project was part of FHWA's IBRC program, which perhaps is one of the most important unertakings by FHWA. The IBRC program could be argued to be responsible for implementing so many new ideas in the field. The progressive attitute of the Nebraska Department of Roads Bridge Division, combined with extremely good communication between NDOR, FHWA and the University is among the reasons for the success of this project. Nebraska Department of Roads has funded an extensive instrumentation program for this bridge. Monitoring of the bridge was inititated before casting the slab and will continue for at least two years. Results are being used to rationalize the design assumptions to true behavior of the bridge. These results will be published in the near future. The bridge described in this paper is also a recipient of an NSBA Merit Award for 2005. An important lesson learned from this project is that design and construction of an innovative bridge is a multi-disciplinary problem requiring involvement of all interested parties from the very beginning. Such was the case for this project.