Steel Bridge System, Simple for Dead Load and Continuous for Live Load

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Introduction

A detailed market analysis was carried out to investigate the trends in bridge construction in the mid-west region of the country. National Bridge Inspection Data (NBIS) compiled by the Federal Highway Administration (FHWA) for Wyoming, Iowa, Colorado, Kansas, Oklahoma, South Dakota, and Nebraska were analyzed. Study of the data resulted in following major conclusions.

1) The use of timber as a bridge construction material, although basically limited to lower span lengths, has significantly decreased.
2) In most states studied, reinforced concrete has remained a fairly consistent choice for span lengths of 50 ft or less.
3) Prestressed concrete construction captured a large market in the 60 – 100ft span range in the 1960's and 70's. The current trends indicate that prestressed concrete has extended its presence as a construction material choice across all span lengths. In the last two decades, steel bridge construction in all span lengths has remained steady or decreased in number whereas there has been an increase in the number of prestressed concrete bridges built in the longer span lengths.

One of the major conclusions was that in short span ranges (80 to 110 ft. span lengths), prestressed concrete girder bridges were the dominating bridge type.

An investigation sponsored by the Nebraska Department of Roads was carried out to develop a steel bridge system that would offer better economy in these span ranges.

Current State of Practice

Before developing a new steel bridge system, it was deemed necessary to evaluate the factors that add to the cost of constructing steel bridges and issues that could enhance steel bridge economy.

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In general, each girder in a two span continuous steel bridge consists of three pieces. Over the pier is a middle piece which is field spliced to the adjacent segments using bolted or welded type connections.

In a series of discussions held with designers, fabricators and contractors in the preliminary stages of the project, two factors were identified to be essential in developing a new system: a) elimination of field splices, and b) simplifying the type of details currently used over the pier, which in general consists of various combinations of anchor bolts, sole plate and often expensive bearing types.

Possible Alternatives

The decision was made to focus on developing a system that could be suitable for steel bridges with two spans. For such situations, one alternative could be to use two simple span girders and join them over the pier. The joining of the girders over the pier could be achieved in various ways.

The reason for joining the girders over the pier is to provide continuity for imposed gravity loads. Short and long term dead loads and traffic live loads are the main gravity loads applied to bridge structures.

Two feasible possibilities would be to attach the two adjacent girders such that a) the system would behave as simple for dead loads and continuous for live loads or b) the system would behave continuous for both dead and live loads. In both scenarios super-structure (girders) and sub-structure (pier) could be made continuous. This alternative was believed to be suited mainly for seismic areas and therefore was not considered in this study. Further study was carried out to assist in determining the type of continuity that would be most suitable.

Trial bridge designs were carried out. Three two span bridges were considered. For each bridge considered, each span length was 100, 120 or 150 ft. Two possibilities were investigated for each span length. The girders were assumed to act as simple spans for dead loads and continuous for live loads only or continuous for dead and live loads. Figure 1 provides results of these trial designs in terms of maximum positive moments. Figure 2 provides similar information in terms of maximum negative moments over the pier.

From Figs. 1 and 2 the following conclusion could be drawn. When girders act as simple spans for dead load and continuous for live load only, the maximum positive moment increases while the maximum negative moment decreases when compared to cases where girders are made continuous for both dead and live loads.

Making the girders continuous for live load only has several advantages. In such cases, the decrease in negative moment coupled with an increase in positive moment allows use of the same cross section for the entire length of the girder. This potentially could eliminate the need for full penetration welds. This behavior makes use of rolled sections an attractive alternative for short span bridges. Table 1 gives a summary of three designs for two span continuous steel bridges with each span being 95, 100 or 105 ft. The girder spacing for all three cases was 8 ft.-6 inches. Table 1 provides possible rolled shapes that could be used for each span length.

After evaluating the advantages and disadvantages of various alternatives, as evident from information presented in Figs. 1 and 2, Table 1 and discussions with fabricators and contractors, it was decided to make the system continuous for live loads only.

The details of the selected system

The selected system consists of placing simple span girders over the supports and makes them continuous for live loads only. This will require use of a detail over the pier that will allow the girders to act as simple spans for dead loads consisting of weight of girders, cross frames, wet concrete and formwork. The detail should then allow the girder to behave as continuous for superimposed dead loads (weight of railing system and overlays) and traffic live loads.

Based on the input from fabricators and contractors, the detail selected to connect the girders over the pier is as shown in Figures 3 and 4.

The bottom flange of the girders is made continuous over the pier and welded using partial penetration welds prior to placement of the wet concrete. The girders are placed over bearing pads. The detail over the pier also consists of a reinforced concrete diaphragm. A series of embedded small bars are used to connect the concrete diaphragms to pier cap beams. Embedded small bars prevent the longitudinal movement of the girders with respect to the pier, allowing the pier connection to be defined as a fixed point. Prior to casting the concrete diaphragms, a thin layer of foam is placed over the pier, separating the concrete diaphragms from the pier cap beam. This allows rotation of the girders over the pier when subjected to live loads.

Experimental Test

A full-scale specimen representing a portion of a two span continuous steel bridge system utilizing the system described above was constructed and a series of tests were conducted to evaluate its behavior. Figure 5 shows the dimensions of the beams and connection details used for testing. Figure 6 shows the test specimen prepared for fatigue test. The specimen was subjected to 2,000,000 cycles of cyclic loads simulating 75 years of heavy truck traffic loads. The specimen was then loaded to collapse to evaluate its ultimate capacity.

The test specimen survived the cyclic test without any deterioration in stiffness or strength. The ultimate capacity of the specimen was well above the predicted values using AASHTO provisions.

A report providing a complete summary of the project is in preparation and should be made available soon.

Acknowledgment:

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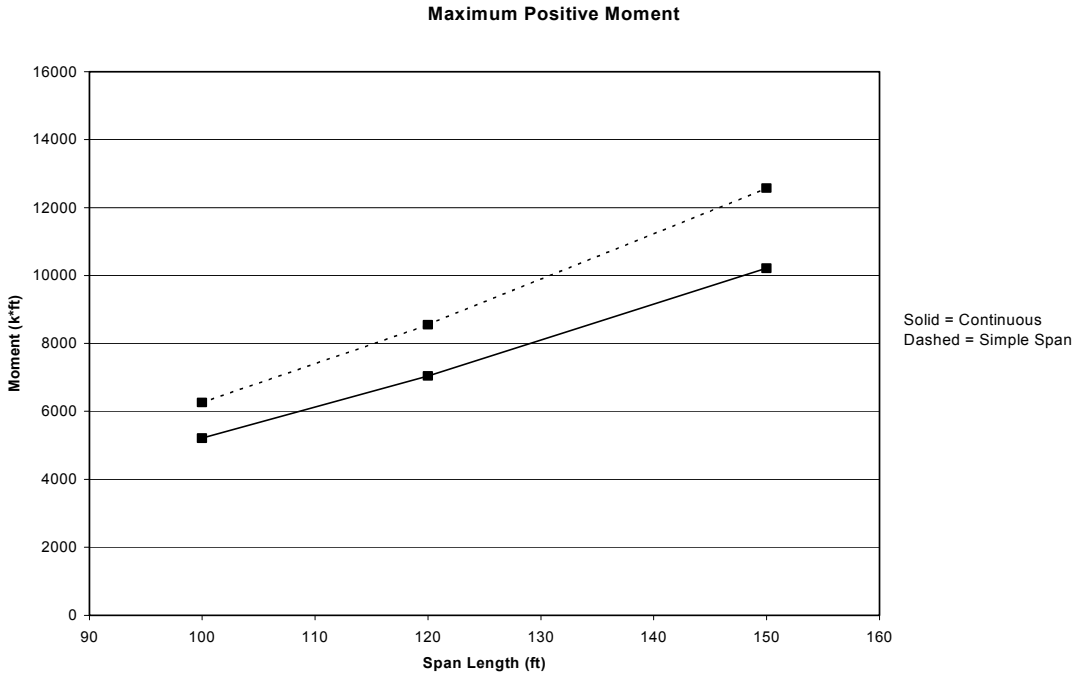

Figure 1. Maximum Positive Moment Comparison

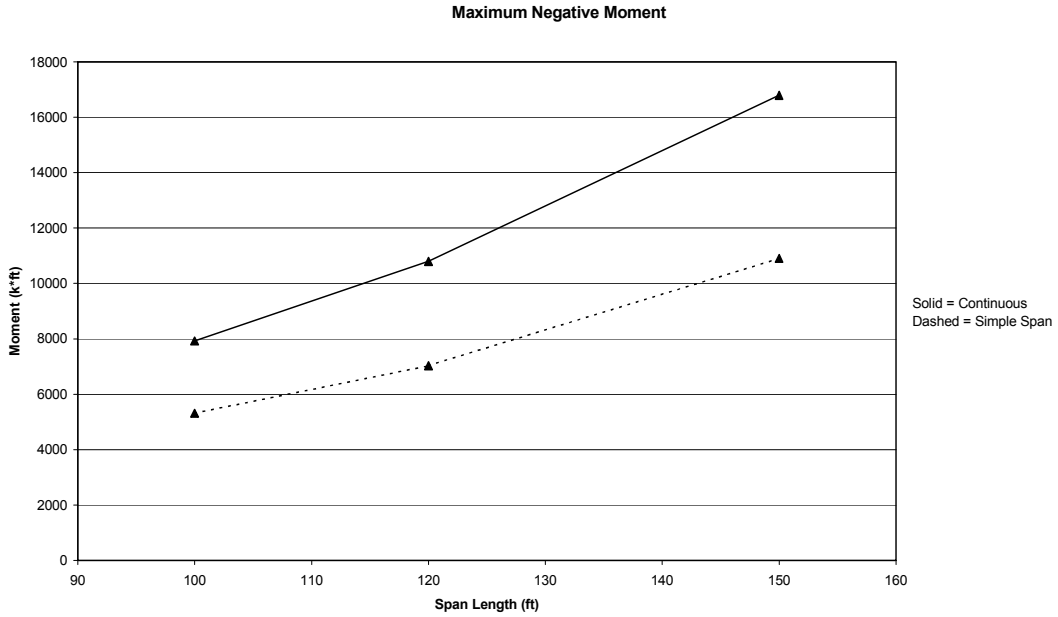

Figure 2. Maximum Negative Moment Comparison

Span Length	95'		100'		105'	
W - Section	40 X 215		40 X 249		40 X 277	
D. L. Defl. (int/ext)	4.4" / 4.2"		4.7" / 4.5"		5.3" / 5.1"	
L. L. Defl. (cal/all)	99.4		95.9		98.8	
Pos. Flex. (M_u / M_n)	92.6		88.8		88.5	
Neg. Flex. (M_u / M_n)	83		78.2		78.3	
Pos. Perm. Defl. (all = 47.5)	96.5	48.1	91.8	48.3	92.0	50.7
Neg. Perm. Defl. (all = 47.5)	62.6	80.9	60.5	75.7	82.5	75.2

Table 1. 95, 100, 105ft Design Summary

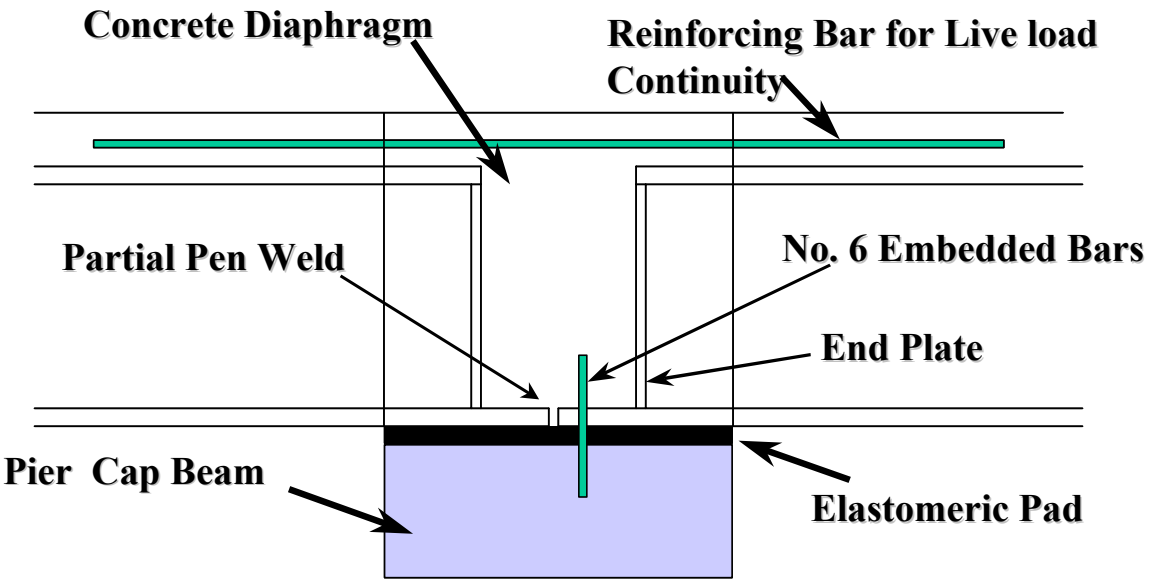

Figure 3. Connection Detail at Pier

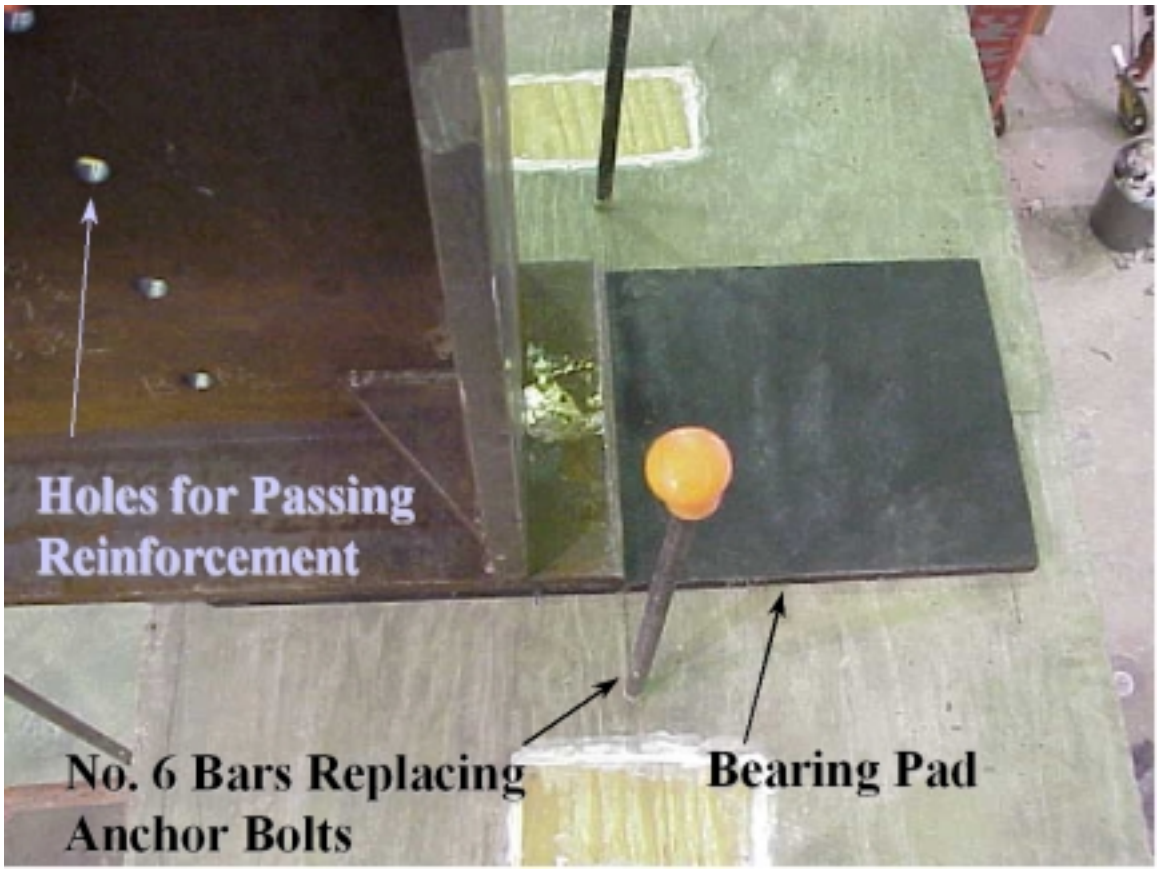

Figure 4. One Girder in Place Prior to Placement of Partial Penetration Weld

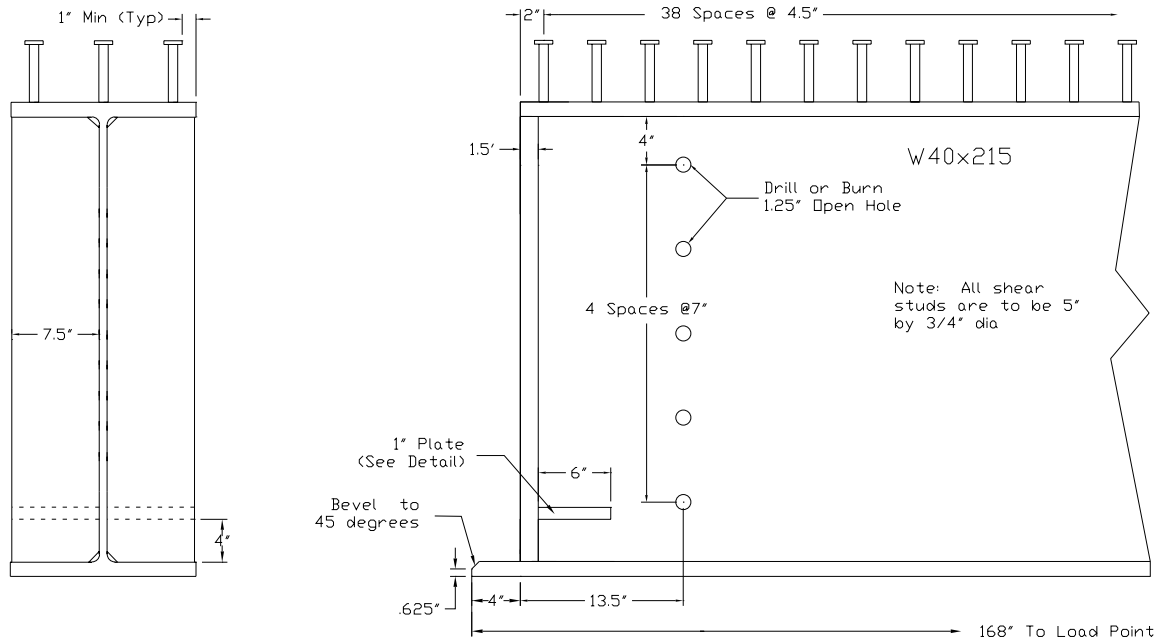

Figure 5. Dimensions of Test Specimen

Figure 6. Prior to Fatigue Loading