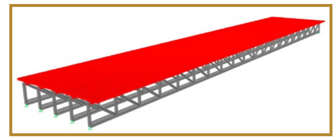
Montana Department of Transportation **December 2017**

R E S E A R C H   P R O G R A M S



Project Summary Report: 8226-001

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Investigation of Prefabricated Steel-Truss Bridge Deck Systems

http://www.mdt.mt.gov/research/projects/structures/prefab.shtml

Introduction

Steel truss bridges are an efficient and aesthetic option for highway crossings. Their relatively light weight compared with plate girder systems make them a desirable alternative for both material savings and constructability. A prototype of a welded steel truss constructed with an integral concrete deck has been proposed by a steel fabricator as a potential alternative for accelerated bridge construction (ABC) projects in Montana.

This system consists of a prefabricated welded steel truss topped with a concrete deck that can be cast at the fabrication facility (for ABC projects) or in the field after erection (for conventional projects). This specific bridge and prefabricated construction technique are not well represented in the literature, and thus there is a need to identify potential bridge spans and traffic volumes where the proposed system is viable and economical.

What We Did

The following four tasks were completed for this project:

1. A literature review identified the current state-of-practice related to the analysis, design, and construction of similar bridge systems constructed on an accelerated schedule. The review focused on four primary topics pertinent to the proposed bridge system and this project: 1) modular systems, 2) concrete decks, 3) welded connections subjected to fatigue, and 4) full-scale experimental studies.
2. An analytical evaluation was conducted to 1) identify any impacts on the projected service life of the prototype truss bridge configurations proposed by a steel fabricator based on fatigue of the welded member-to-member connections, 2) perform a cost analysis for the proposed systems and compare the results with the cost of plate girder alternatives and 3) identify revised connection details to improve fatigue performance.
3. A 205 ft. span steel truss with bolted and welded connections was investigated as an alternative to the proposed all-welded truss. The 205 ft. span was selected so that results could be readily compared with the Swan River plate girder project currently being designed by MDT.
4. A comparison was made of materials and fabrication costs for both the steel truss and plate girder bridge systems. Shipping, construction, and erection considerations for both accelerated and conventional construction methods were considered.

Based on findings from these four tasks, conclusions were made related to the analysis, design, and construction of a steel truss with bolted connections and compared with a plate girder alternative.

What We Found

No documentation was found during the literature review specifically addressing the proposed bridge structure, i.e., a prefabricated welded steel truss with a composite concrete deck, cast-in-place at the fabrication facility. The most common application for modular prefabricated steel truss systems has been for temporary bridge crossings in through-truss configurations. Some information was also found on prefabricated bridge elements consisting of a concrete deck precast on steel stringers (note that one such structure was built by MDT over Maxwell Coulee). This review of the available information confirmed the need for further analysis/investigation of the proposed system.

Subsequently, an analysis was conducted on a preliminary design of the proposed concrete deck/steel truss elements (with welded connections in the truss) under AASHTO's Fatigue I load combination for a 148 ft. span. This analysis, performed using a two-dimensional finite element model, found that load-induced fatigue stresses exceeded threshold values for an infinite life design by a factor of approximately 4.0. For a 75-year design life using Fatigue II load combinations, calculated fatigue stresses exceeded threshold values by approximately 18% in a design scenario typical of that in which MDT would use this bridge system (for this purpose, measured traffic on Hwy 200 East of Jordan, MT was used to determine fatigue demands). Material and fabrication cost estimates from three sources for the 148 ft. truss and a comparable plate girder suggested a welded steel truss would cost approximately 5% to 20% less than a comparable plate girder.

Based on discussions with steel fabricators and the projected fatigue performance of the welded connections, a new truss configuration was designed with more economical wide flange vertical members and bolted diagonal member connections. The steel truss used a welded connection between the vertical compression members and top and bottom chords. The new truss members and bolted connection configuration produced a system that satisfied the strength and fatigue requirements for an infinite-life design. The connections of the proposed truss for a 205 ft. span are shown in Figure 1. A 205 ft. span was used in this re-design, as MDT had available a plate girder design at this span length from a recent project (the Swan River project), allowing for cost comparisons to be readily prepared between the two systems. To further investigate the potential material and fabrication cost savings for the truss system, a three-dimensional finite element model (Figure 2) was created to more accurately estimate the distribution of multiple lane and axle loads to the trusses in the system and attendant individual truss members. Results of this analysis indicated that a distribution factor for use with a 2D model could be lower than previously calculated using the relatively simple and typically conservative lever rule (by approximately 25 percent), and in further analyses, this new distribution factor was used.

The 205 ft. steel truss bridge was re-analyzed and designed using a two-dimensional finite element model with the refined distribution factors. Conventional and accelerated construction

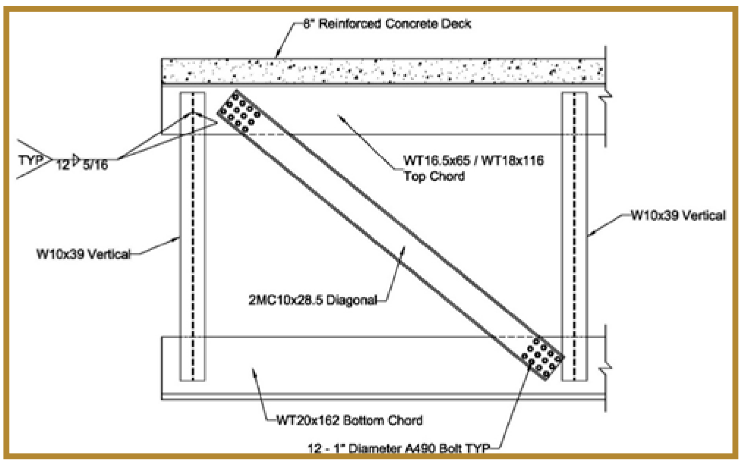

Figure 1: Proposed Steel Truss Panel

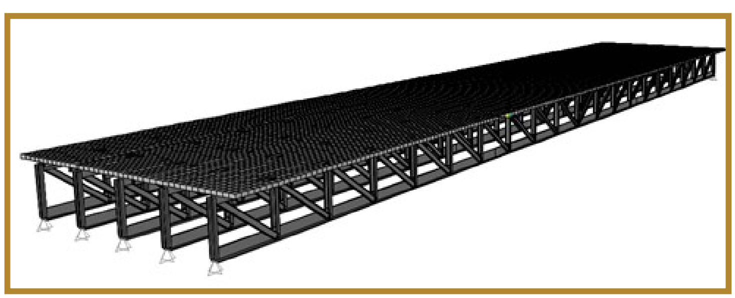

Figure 2: 3D Finite Element Model

scenarios were considered in the design of the truss members, connections, and splices. The conventional construction scenario assumed a single splice at mid-span with a concrete deck cast after the truss was erected. For the accelerated construction scenario, the assumption was made that the truss elements with integral concrete deck would bridge the span in three segments (resulting in two splices). The weights and spans of the two trusses are shown in Figure 3 with the splice locations and weight of the Swan River plate girders. Estimated prices for the two truss scenarios and the plate girder from three sources are shown in Table 1. Although the costs of the splice connections were not included in the estimates, one fabricator indicated additional cost savings could be realized by building camber into the truss through the bolted connections. Additional costs not included with the plate girder alternative are the required weld inspections for the full-penetration welds between shop splices in the flange and the web. The steel weight of the bolted and welded steel trusses assuming conventional and accelerated construction were 15% and 28% less than the steel weight of the Swan River plate girders. Using an average of the materials and fabrication estimates from various fabricators suggests a reduction in cost of 10% and 26% for the two construction alternatives, respectively.

	Plate Girder	Truss 1	Truss 2
Allied Steel	$135,000	$105,000	$94,000
AVEVA	$95,000	$103,000	$85,000
RTI Fabrication	$126,000	$112,000	$84,000
Average	$119,000	$107,000	$88,000

Table 1: Final Steel Price Estimates

Based on this investigation, a steel truss with integral concrete deck, either precast on the truss for accelerated bridge construction, or cast-in-place for conventional construction, are attractive alternatives for bridge projects in Montana. For the case considered in this study, using a combination of bolted and welded connections in the trusses, this system was found to offer good performance at a potentially lower cost than comparable plate girder construction.

What the Researchers Recommend

The following recommendations are made based on the results of the Prefabricated Steel Truss Bridge Deck Systems project:

- Discuss potential bridge crossing sites and geometries with steel fabricators and local contractors to receive more specific suggestions for successfully implementing a steel truss bridge system built using conventional or accelerated construction methods.
- Evaluate the joint and concrete deck performance of the Maxwell Coulee bridge that utilized a rolled wide-flange section with an integral concrete deck.
- Investigate alternative contracting methods for a steel truss bridge constructed with an integral concrete deck. The Construction Manager/General Contractor method could provide a more efficient and economical delivery.
- Complete a final design of a steel truss for a selected bridge crossing with input from an erector and fabricator, combined with Maxwell Coulee observations.
- Implement a monitoring and evaluation program, including instrumentation and remote data acquisition, for the constructed steel truss bridge.

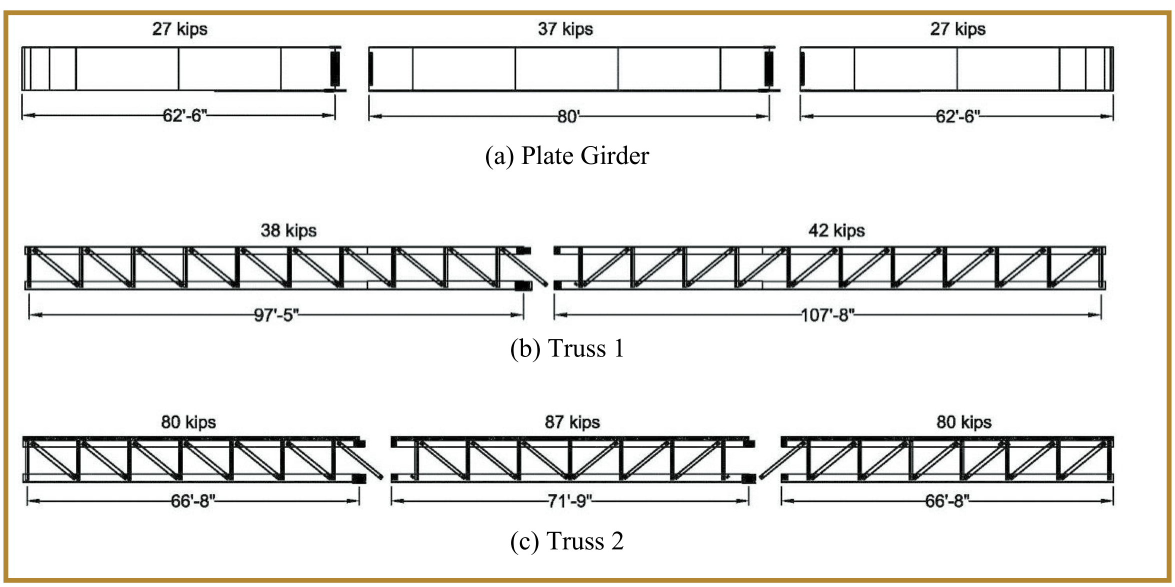

Figure 3: Weight of each Splice Section for the (a) Plate Girder, (b) Truss 1 and (c) Truss 2

For More Details . . .

The research is documented in Report FHWA/MT-17-009/8226-001, http://www.mdt.mt.gov/research/projects/structures/prefab.shtml.

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To obtain copies of this report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.

MDT Implementation Status: December 2017

The implementation recommendations documented above were made to MDT. These recommendations, along with MDT's response, are documented in the implementation report, which can be found at the above URL.