The preservation and upgrading of historic metal truss bridges and the load carrying capacity

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Abstract

With respect to historic metal truss bridges the most frequently asked questions are:

- How can we preserve our historically important bridges before they collapse from even just self-weight alone?
- How much longer can these bridges be preserved?
- How economically can these bridges be upgraded to carry modern traffic?
- How safely can these bridges be rehabilitated?

It is well recognized that conventional repair and rehabilitation procedures cannot preserve these bridges for an extended period of time, even for greatly reduced weight limits. Since these bridges were constructed for much lighter loads, they are not able to carry today's traffic loads, even with the total replacement of every member and connection. Thus, conventionally rehabilitated historic bridges are sometimes moved to remote locations such as parks. Of course, this is not the most desired option because of costs and practicality.

It would be ideal to preserve more historically important bridges by strengthening them so that they can carry modern traffic at their present locations for extended periods. One way would be to preserve the original architecture but with discrete elements added in such a manner that these historic bridges can continue to carry modern traffic for a duration equivalent to that of a new bridge. In this way, the original architecture would be readily recognizable for greater appreciation of our engineering and cultural heritage.
Keywords: bridge, metal truss, preservation, safety, load carrying capacity and upgrade.

1 Introduction

Most metal truss bridges are non-redundant fracture-critical structures, i.e., failure of one member or one joint (or connection) would theoretically cause a total collapse of the bridge. None of these conventional rehabilitation procedures applied to truss bridges eliminate the fracture-critical nature of these truss bridges. Therefore, nearly all of these conventional procedures are often considered as being “temporary”, “band-aid” repair methods.

A cost effective system for rehabilitation and reinforcing aged metal truss bridges has been developed. It superimposes steel arches on the existing trusses resulting in bridges that are redundant, non-fracture critical structures that can carry modern traffic loads.

2 Conventional rehabilitation methods [5]

Because of high degree of uncertainty with respect to forces in members and joints, it is not possible to determine the true magnitudes of these forces. Field tests have shown results that differ from the theoretical values by as much as 650 percent [1]. Accordingly, it is often not possible to accurately predict the true load-carrying capacities of old metal truss bridges. A study performed by a consultant for Baltimore County of Maryland for eight historic metal truss bridges [2, 3] is given below.

Table 1: Baltimore County, Maryland Historic Metal Truss Bridges. (Bridge spans ranged from 75 ft to 175 ft.)

	BRIDGE NAME	STRINGER RATING	FLOORBEAM RATING	TRUSS RATING	PIN RATING
1	SPARKS ROAD	31.8	42.2	42.6	3.6
2	GREEN ROAD	52.1	22.7	32.3	2.6
3	MASEMORE ROAD	63.7	24.8	29.0	14.8
4	CUBA ROAD	22.7	14.4	43.3	14.7
5	VINEGAR HILL ROAD	15.4	23.0	34.3	13.9
6	CARROLL ROAD	33.4	35.5	31.8	No Capacity
7	FALLS ROAD	19.5	29.7	26.4	4.4
8	BOTTOM ROAD	24.4	27.5	31.6	10.4

1989 OPERATING RATINGS FOR HS-20 TRUCK (IN TONS)

Although a failure would most likely occur at joints and connections, current inspection standards do not usually address methods for the evaluation of these joints and connections. Additionally, over the years these joints and members have undergone such changes as lengths and geometry shifts, which cause uneven and unintended stress distributions in truss members and joints.

Figure 1: Hairpin bars/Posttension bars looped around a pin – conventional rehabilitation.

Figure 2: Several posttension bars looped around one common pin – conventional rehabilitation.

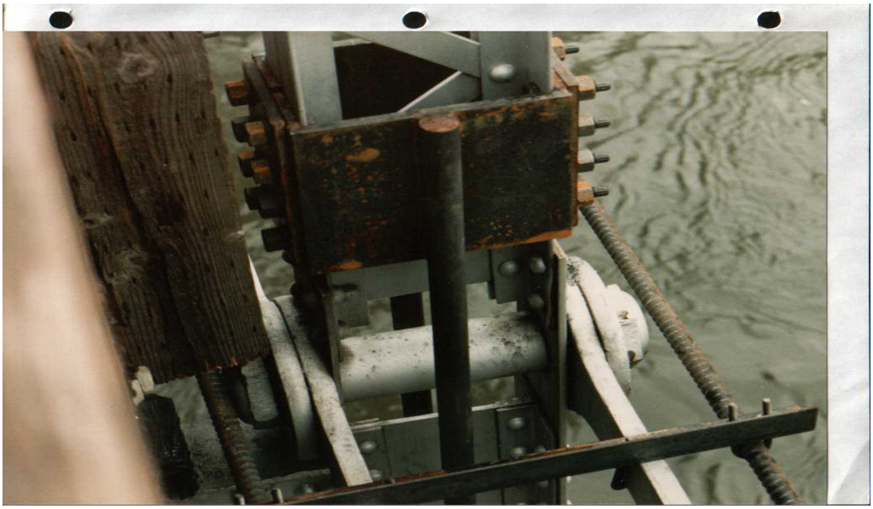

Figure 3: The truss pin is bypassed (direct load transfer from floor beam to vertical to the arch).

Figure 4: Historic Stuyvesant Falls Bridge over the Kinderhook Creek, New York (1889).

For pin connected truss bridges, pin analyses are often neglected, and the bridge's live load rating is based solely upon the live load capacity of its truss and floor members. The study by Shahin [2, 3] determined that this approach is invalid. It was found that the pins controlled the present load ratings. It was also found that the slightest geometric deviation of truss members' alignment relative to the pins width and length has a large effect on the pin's load capacity, i.e., shear and moment strength of the pin.

This study concluded that: 1. For pin-connected truss bridges which lack the redundancy, pin analyses are essential; 2. Slightest deviation of truss member alignment relative to the pins has a substantial effect on the pins load capacity (thus, further movement of truss member components must be prevented in order to prevent fluctuation in pin's load ratings); and 3. The strengthening of the existing bridges should be done only with due consideration to its effect on pin load capacity when the future strengthening work is performed.

Figure 5: Rehabilitated Stuyvesant Falls Bridge for HS-20 Loading.

Figure 6: Montana Rail Link Bridge, Paradise, Montana over the Clark Fork River.

There have been many rehabilitation techniques applied to metal truss bridges in the past. Some of these methods neglected the critical elements of the truss bridges. Also, none of these methods eliminated the fracture-critical characteristics of the trusses. Some conventional truss strengthening techniques consists of looping posttension cables or hairpin bars around truss members and joint pins. This strengthening provides a false sense of safety since it has not addressed the forces and fatigue progress of the truss joints. Further, as the truss bridge undergoes even the slightest deformations and the multi-jointed truss readjusts its geometry, as well as its creep under the posttension forces applied, the new forces introduced by posttensioning would be either lost or distributed in unknown load paths. Other conventional techniques also cannot eliminate the fracture-critical nature, i.e., failure at just one joint or connection will result in a total collapse of the truss. These techniques consistently ignore the fact that the truss joints are the weakest link.

Figure 7: Montanal Rail Link Bridge rehabilitated for the AREA Cooper E80 (1.472 million pounds live loading).

3 New arch reinforcement method for aged metal truss bridges

The method of superimposing steel arches on the existing trusses to rehabilitate the aged steel truss was developed at Bucknell University as a senior design project. Tests were performed on truss bridge models and subsequently on an existing truss bridge.

Some of the advantages of this method are: a) elimination of “non-redundant fracture critical” characteristics of typical pin-connected truss bridges with bypassing of the pins; b) assurance of public safety; c) cost-effectiveness; d) short rehabilitation time period; e) maintenance of traffic during rehabilitation; f) no encroachment on waterways and surrounding properties/environment; g) renewal of life expectancy to that of a new bridge; and h) preservation of the original structure while being used for modern traffic.

The rehabilitation method consists of superposition of steel arches connected to the existing trusses, additional and existing (or replacement) floor beams supported by arches above via suspension rods or existing truss verticals that bypass the pins, and additional stringers, and minor modifications of substructures to seat the arch bearings. The arch bearings are separated from the existing truss bearings. The final load carrying capacity of the arch superimposed truss bridges will depend on arch sizes and its connectors, and amount of posttensioning forces in the arches if the posttensioning is required for a large increase in the bridge load capacity.

Figure 8: Mumma Ford Road Bridge, Carroll County Maryland (over the Monacasy River).

Figure 9: Worthington Bridge, Douglas County, Oregon (over the Little Umqua River).

4 Examples of arch reinforcement

Some examples of arch reinforced aged and historic truss bridges are the Historic Stuyvesant Falls Bridge in New York, Sparks Road Bridge in Baltimore County [4], Limerick Bridge, Montana Rail Link Bridge in Montana, Carroll County Mumma Ford Road Bridge in Maryland, and a Douglas County highway bridge in Oregon.

The Preservation League of New York State chose the Stuyvesant Falls Bridge in New York for one of the 1997 Annual Awards.

References

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