

STRUCTURAL STRENGTH AND BEHAVIOR OF A PIN JOINTED "SPINDLY" TRUSS

by

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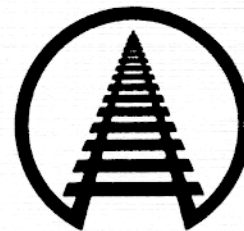
Summary

Recent AAR tests conducted on a pin-jointed "Spindly" truss bridge show that the structure performs very well for the loads and traffic density operating on it. However, if the traffic volume is increased or higher axle loads are introduced, the floor system and some truss members will need strengthening.

Impact factors are a measure of the dynamic interaction of the moving vehicle and the track structure and the induced response of the bridge structural members. The test bridge has a posted speed limit of 30 mph and is restricted to four axle locomotives and no more than 100-ton freight cars. The rail and track condition on the bridge and approaches was very good. Therefore, for test speeds of up to 40 mph, very low impacts were observed.

The tests were conducted on a 155 foot span truss bridge. Some members of the truss are built of eyebar construction with pins at joints. This type of truss construction, sometimes referred to as a "Spindly" truss is believed to be weaker and requires more maintenance. The load measurements of eyebars indicated that the two eyebars of one set may not share the load equally, and in the case where there are two sets of eyebars (for example in the lower chords), each set may carry substantially different loads. AAR tests found that one set of eyebars carried as much as four times the loading as the other set of the same member.

These tests are part of an ongoing AAR research program to evaluate the fatigue behavior and structural integrity of railway bridges in today's operating environment. Effective management of bridges requires accurate evaluation of remaining life of bridges so that cost-effective repair and effective replacement strategies can be formulated.



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TECHNOLOGY DIGEST
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INTRODUCTION AND CONCLUSIONS

The majority of railroad bridges are more than 50 years old and have continued to serve the industry very well. In the last 50 years, there has been no major failure of a railroad bridge. These older bridges were designed for excess capacity and have some redundancy built into them. In many cases, the design loads were established for steam locomotives which were heavier than today's diesel locomotives.

However, the bridges are aging, freight car axle loads are increasing, and the cost of maintaining and replacing bridges is high. Thus, in 1988 the AAR began a research program to evaluate the fatigue behavior and structural integrity of railway bridges in today's operating environment. Effective management of bridges requires accurate evaluation of remaining life of bridges so that cost-effective repair and effective replacement strategies can be formulated.

Findings from the tests conducted on a 155 foot span truss bridge shown in Exhibit 1 are presented here. Some members of the truss (lower chords and diagonals) were built of eyebar construction with pins at joints. This type of truss construction, sometimes referred to as a "Spindly" truss is believed to be weaker and requires more maintenance.



Exhibit 1. Test Bridge

The maximum test speed was 35 mph with a few tests at 40 mph. Higher speeds may alter the vibration behavior of certain eyebar members of such a structure. Also, considerable variations in the size of eyebars, especially for diagonal members, are common from structure to structure. Therefore, the findings should be applied to other structures with engineering judgement, taking into consideration the design differences, operation speeds, and general condition of the track and structure. Behavior of pins may also differ in other applications. These types of trusses have generally 4, 5 or 6 inch pins. The bearing area provided to the eyebars and the pins depends on the pin diameter and the relative match of the curvature of the eye and the pin surface.

The load measurements of eyebars indicated that the two eyebars of one set may not share the load equally, and in the case where there are two sets of eyebars (for example in the lower chords), each set may carry substantially different loads. AAR tests found that one set of eyebars carried as much as four times the loading as the other set of the same member. This obviously leads to considerably higher bearing forces on overloaded portions of the pins, while other portions of the same pin may be carrying minimal bearing forces. It is thought that this inequality of load sharing induced bearing forces may be a leading cause of excessive wear or grooving of pins. Since, inspection of the pins is difficult because the pins are not visible, the grooves may continue to increase in depth over a period of time. It is felt that the presence of deep grooves will cause excessive vibration and deflection of the pin joint. This excessive vibration and/or deflection may be an indication of deteriorating condition of the pin.

If the eyebars (or pairs) of a truss member are equally tight, they will share the loading equally and the pins will perform as intended. It was found that some eyebars experienced axial stresses in the range of 10 to 12 ksi. These stresses are not high for a solid eyebar member and should not be of major concern. However, if the bars have been welded (after cutting during repair), the 10-12 ksi stress seen by the transverse welds may be sufficient to cause fatigue cracks. Such repairs should be made at locations which can be inspected so that cracks, if any, can be discovered in their early stage.

The built-up members (such as the hangers) of the truss behave similar to a conventional truss of built-up construction. In-plane and out-of-plane bending effects are in the order of 20 to 30 percent. The built-up



part of the lower chord had total bending strains of approximately 20 percent of the axial strains. Since the stress levels due to axial loads were fairly low, 4 to 5 ksi, 20% additional stress due to out-of-plane bending makes the overall maximum response about 6 ksi. This is fairly low from a fatigue standpoint and significantly lower than design stresses. These members have excess capacity built into them. For the hanger U1L1, which is a built-up member, the effect of bending was approximately 30 percent. Maximum axial stress was measured in the 5.5 to 6.0 ksi range. A 30 percent addition to this value would make it 7.5 to 8.0 ksi. At these stress levels, there will be fatigue implications dependent upon the volume and nature of the trains crossing such a bridge. Heavier axle loads are expected to cause even higher stresses and a faster fatigue life consumption.

The diagonal members of eyebar construction behaved as expected. Lower levels of stresses (less than 4 ksi) were measured and loads were shared equally by the two eyebars. Again, bending contributes approximately 25% of the axial stresses. Eyebar members vibrated during train passage, but the amplitude of the vibrations were found to be low and not of any consequence in so far as fatigue is concerned.

The floor system was slightly weak for this truss bridge, but more than adequate for the light density and loads carried by this line. The maximum stress in the stringers was approximately 9.0 ksi and in the floor beam about 8.7 ksi. These values are much lower than the design stresses, but higher than the fatigue limit for such members. If this bridge was to carry heavier axle loads, with stresses increasing to 10 to 11 ksi, the fatigue life would be reduced considerably.

TRUSS CONSTRUCTION

The 155 foot truss span consists of six panels, each 25 feet 10 inches long. A line sketch of the truss is shown in Exhibit 2. The truss height is 28 feet 6 inches from center to center of the chords and the two trusses on one span are 16 feet 5 inches apart. The middle third of the lower chord is composed of four eyebars (two pairs of two eyebars). These eyebars are 6 inches deep and 1 1/16 or 1 3/8 inches thick. The diagonal U1L1 has two eyebars, each 6 by 1 1/2 inches. The diagonal L2U3 also has two eyebars, each 4 inches by 1 inch. This truss also has counters U2L3 and U4L3. These counters have two bars, each 5 by 1 1/16 inches. Presence of the counters makes the truss indeterminate for theoretical analysis. Also, the end posts have collision struts as shown in Exhibit 2. Other than the eyebar members described above, all the members are of the conventional built-up construction. All the truss joints are of pin construction.

IMPACTS

Impact values are generally expressed as a percentage in bridge design. For example, an impact value of 20% at 40 mph indicates that the response (maximum stress) of the member at an operating speed of 40 mph is 20% larger than its response at a crawl speed of approximately 2 to 5 mph. The AREA Manual for Railway Engineering (Chapter 15) has guidelines for calculating impact on steel structures. Actual impact factors also depend upon the condition of the track and rail and on the freight vehicle characteristics such as wheel and suspension condition.

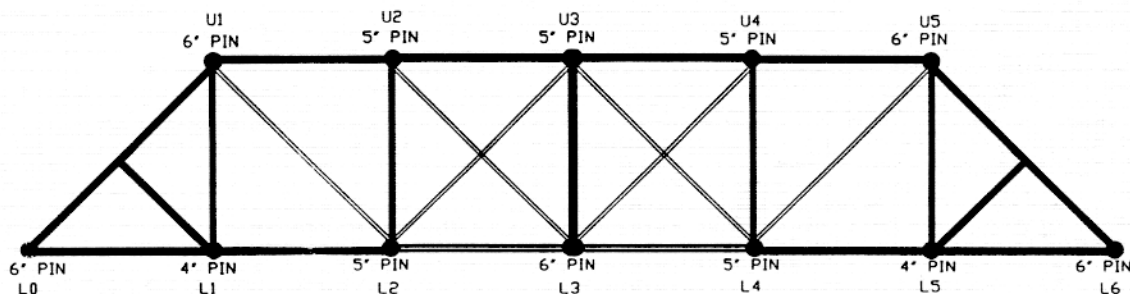


Exhibit 2. Line Sketch of the "Spindly" Truss



In general, previous AAR bridge tests showed that the actual impacts were much lower than the calculated values. This is because the test vehicles and the track conditions have been very good. This bridge is restricted to 4 axle locomotives and no more than 100-ton freight cars (263,000 lb gross load). Also, the track condition on the bridge and approaches was very good. Therefore, for test speeds up to 40 mph (posted speed limit is 30 mph) low impacts were expected. This was confirmed by the test.

Each test series was run at speeds of 2, 5, 10, 15, 20, 25, 30 and 35 mph. A total of four test series, two tests with the work train heading north and two tests with the work train heading south, were conducted at each speed. Two of the four tests series were run at speeds of 40 mph.

Floor Beams

The three floor beams L1L1', L2L2' and L3L3' were instrumented for measuring bending moment at their mid-span. In all cases the impacts were less than 10 percent.

Stringers

Six stringers (3 on the east and 3 on the west side) were instrumented at their mid-spans to measure top flange

and bottom flange strains. In all cases it was found that for speeds up to 40 mph the maximum measured impact was less than 10 percent.

Hangers and Diagonals

The impact factor for the hanger U1L1 was found to be 10 percent or less. A plot of the impact factor versus speed for one test series is shown in Exhibit 3. The impact factor for axial load in the diagonal members was less than 15 percent.

Lower Chords

The lower chord from L0 to L2 is built-up section. L2 to L4 portion of the lower chord is eyebars, two sets of two eyebars. The maximum impact factor for axial loads for all test series was 12 percent for the chord portion L0 to L2.

For the eyebar portion (L2 to L4) of the lower chord the maximum impact for axial loads was 25 percent. A typical plot of the impact factor versus speed is shown in Exhibit 4.

In general, for all the truss and floor system members, the impact values were lower than those given by theoretical calculations based on AREA guidelines. This was because the track quality (roughness and general condition) was very good.

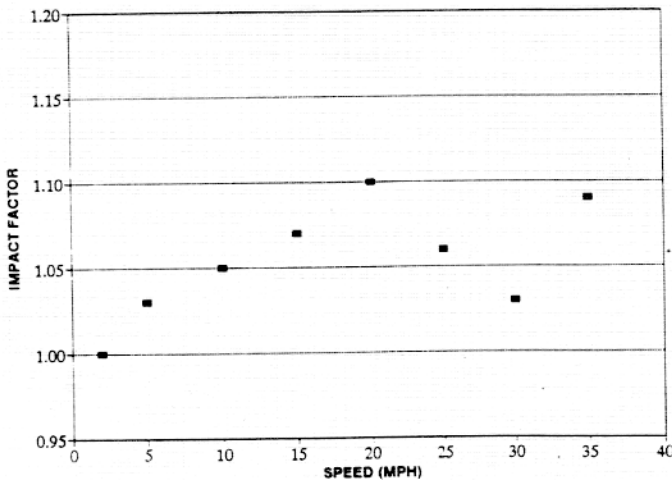


Exhibit 3. Impact Factor Versus Speed for Hanger U1L1 - Test Series N1

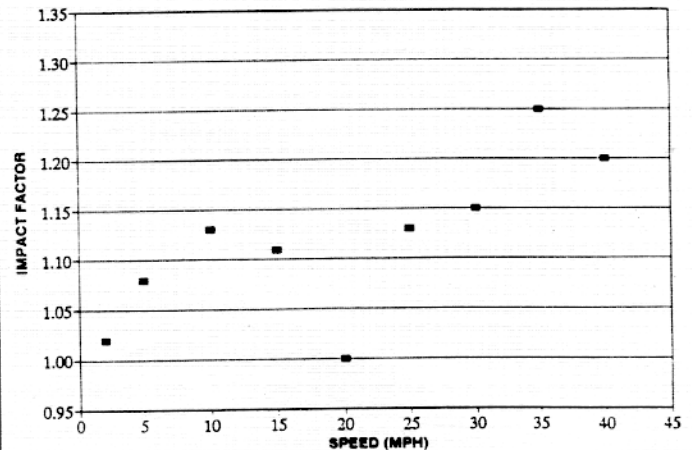


Exhibit 4. Impact Factor Versus Speed for Lower Chord L314 West Truss - Test Series N2

Note: Contact Vinaya Sharma at (312) 808-5843 with questions or comments about this document.

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