TECHNOLOGY DIGEST
Timely Technology Transfer

FIELD TEST AND ANALYSIS OF A THROUGH PLATE GIRDER RAILWAY BRIDGE

by
John Choros and Scott Schiff

TD95-013

Summary

Field testing of a through plate girder railway bridge has shown that very low strains, and hence low stresses, are experienced in the instrumented knee brace on this bridge. The knee brace increases the floor beam connection stiffness and provides buckling restraint for the plate girders. In addition, measured stress levels are less than design level stresses in those members instrumented. From analytical modeling, the captured data was closely matched, except for moments near stringer to floor beam connections. A finite element analysis indicated non-linear stress patterns near the connections. Knowledge of how to accurately model railway bridges can greatly reduce the time, effort, and cost of bridge design and rehabilitation projects.

A model was developed to analyze the bridge structure. It was validated using field data, such as measured wheel loads and connection fixities. Using the model, an analysis was performed to determine the excess capacity of the structure. Results indicate an excess capacity of as much as 8,000 pound static wheel load can be achieved for the stringer, taking into account load distribution and connection fixity. Limiting stresses were based on the AREA fatigue limit of 7,000 pounds per square inch (ksi) for category D detail.

The test bridge is a 72-foot, through plate girder railway bridge. The loading spectra and response for this bridge were developed from the passages of a special work train consist. Measurements were taken on the knee brace, primary, and secondary bridge members for a total of 32 channels of data.

This research is intended to provide a better understanding of track, structure, and member interactions to assist in determining bridge rehabilitation needs and modifications to existing design techniques. Recent proposed increases in axle loads and train speeds have caused concern due to their possible impact on railway bridge fatigue life as well as future design procedures.

Suggested Distribution:
Operating/Engineering:
- ❑ Bridges and Roadway
- ❑ Maintenance Planning

Research and Development

Association of American Railroads
Research and Test Department

April 1995

INTRODUCTION AND CONCLUSIONS

The primary causes for concern with the present condition of railway bridges are the increasing axle loads carried by today's rail traffic and potential problems with the aging inventory of bridge structures. These increased wheel loads may mean a significant increase in stress levels for bridge members found on older bridges, many of which predate 1940. The railway industry could be faced with substantial expenses to retrofit or replace these bridges.

The research project discussed in this digest will lead to a better understanding of loading spectra and response of a through plate girder railroad bridge. Field experiments were performed on a bridge to determine moments, shears, and strains in bridge members at selected sections. This data was used for comparison with computer models of the bridge. During field testing, a work train consist of a single diesel locomotive followed by two fully loaded coal cars and two fully loaded wood cars was used. The work train crossed the bridge at speeds of 5, 10, 20, 30, 40, and 50 mph, and the locomotive was used for a static test as well as crossings at 50 mph in each direction. Strain gages were placed at selected locations on bridge members and connected to a data acquisition system.

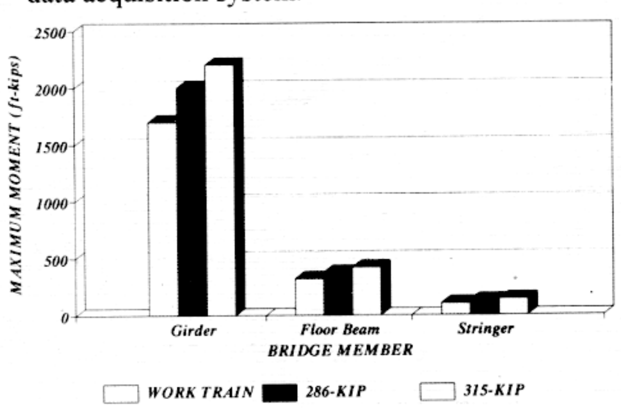

Exhibit 1. Maximum Moment Comparison - Experimental and Analytical Results.

A computer model was developed of the complete bridge using member properties of the bridge. Response of the model was investigated at locations corresponding to the location of gages during field instrumentation. The model was validated using field data such as measured wheel loads and connection fixities. Using the model, the structure was analyzed for 286,000 and 315,000 pound coal cars.

Maximum moments for the three primary members analyzed are shown in Exhibit 1. Moments are shown for the three loading conditions used in the analysis; the work train with two 263,000 pound coal cars, the work train with two 286,000, and with two 315,000 pound coal cars. Maximum moments were developed on the main girders at 2200 ft-kip by the 315,000 pound coal cars, leading to an increase of 29% from the work train. Increases of 32% and 34% were noted for the floor beam and the stringers respectively.

From the moments and section properties the maximum member stresses were determined (Exhibit 2). Added to this Exhibit is a fatigue limit of 7 ksi for category D detail listed in the AREA manual. As seen from Exhibit 2, the maximum stressed member is the floor beam. Girders and the stringers exhibit less stress than the fatigue limit for all the loadings analyzed. The floor beam exceeds this limit for the 315,000 pound coal cars by 11%. Strengthening the floor beam can substantially increase the capacity and the ability of this bridge to carry 315,000 pound traffic.

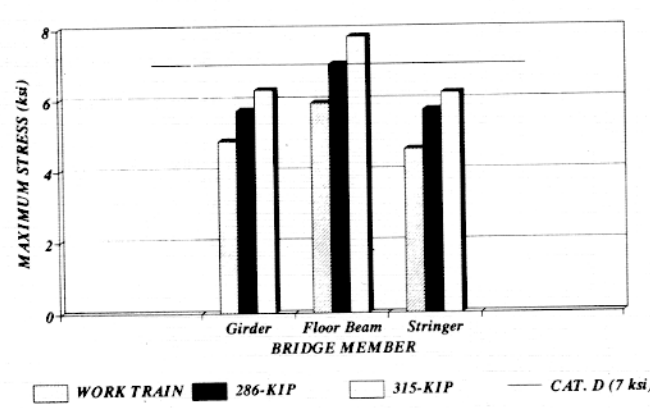

Exhibit 2. Maximum Stress Comparison - Experimental and Analytical Results.

Preliminary conclusions of this study are:

- Strains in the instrumented knee brace were very small and relatively insignificant when compared to those in the floor beam. For this reason, they were eliminated from the computer modeling with no apparent adverse effects.

- Full fixity of the connections between the floor beams and the plate girders gave a very good approximation of the moments at critical floor beam locations in the computer model. Assuming fixity between stringers and floor beams of somewhat less than 100 percent gave comparable results to experimental data at stringer mid spans. The moments do not agree at the stringer ends however.

- Distribution of concentrated wheel loads along the length of the rail at approximately 5% / 15% / 60% / 15% / 5%, with a spacing between each subloading of 4.5", provided good results using the computer model. This load distribution accounts for the absence of the track structure from the model.

- There is continuity of the floor system of the bridge. Loads applied to the stringers can cause significant shear and moment values in adjacent stringers. This is shown in Exhibit 3 by the reversal of moment at the stringer end when the work train wheel loads are on adjacent stringers.

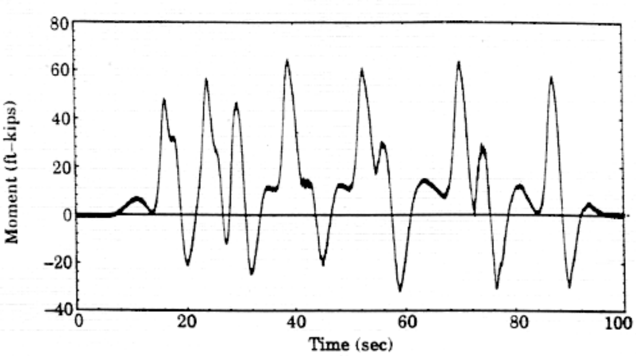

Exhibit 3. Bending Moment in the SS3 South Stringer near East End for 5 mph Work Train.

- Experimental results closely matched the fixed-distributed computer model. These results were as much as 20% lower than the simple pinned-concentrated load analysis commonly used. Taking advantage of the track structure and the fixity of the connection can increase the capacity of the structure.

TEST PROGRAM

The test bridge is a steel through plate girder railway bridge of riveted construction, built in 1917. It has a single span of 70'-0" from bearing to bearing and an overall plate girder length of 72'-6". The bridge is owned and operated by the Norfolk Southern Railway Company and is located at mile post S106.0 on the line between Asheville and Salisbury, North Carolina. A schematic of the bridge is shown in Exhibit 4. The bridge consists of the two plate girders, with floor beams at 14'-0" on center, spanning 16'-0" between the girders. Stringers span between the floor beams to carry the track structure and loading into the floor beams. Connections are made with angles riveted to each member coming into the connection. The floor beam upper flanges are connected to the plate girders via the knee braces, however the stringer

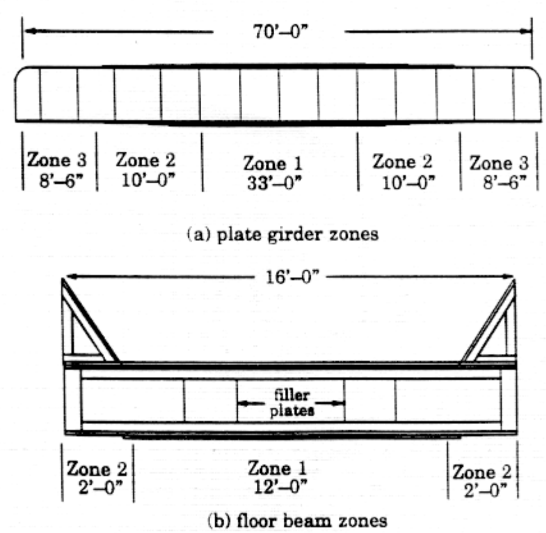

Exhibit 4. Schematic of Member Property Zones (not to scale).

flanges are not attached to the floor beams at connections. The plate girder depth at mid-span is 6'-10". The floor beam depths are 32" at mid-span, and the stringers have a depth of 23".

The instrumentation of the bridge included 16 shear and moment channels. Moment channels were located near mid-span of two stringers, on two stringers near connections to floor beams, at mid-span of a floor beam mid-span of the bridge, and on the floor beam just beyond the knee brace toe. Shear channels were located on stringers near their connections with a floor beam and on a floor beam just beyond the knee brace toe. Strains were also taken in the knee brace web and in the floor beam web directly beneath the knee brace.

The computer model developed using STAAD-III utilized line elements with specified member cross-sectional properties. The element center-lines were offset with respect to the plate girder center-lines to model actual connection locations.

Member property specifications were made simple by averaging them over minor cross-sectional geometry changes. A static load case was developed using measured wheel loads from the work train. This set of loads was incrementally moved across the structure to simulate a train passing.

The computer model gave very good predictions of moments throughout the structure except near stringer to floor beam connections. Moment predictions near these connections were too low. Since the flanges of the stringers are not attached to the floor beam, stresses in stringers go to zero in the flanges as they approach the floor beam and cross into the web to be carried into the connection by the connecting angles. This concentration of strains and stresses over less depth increases the moment in stringers at the stringer to floor beam connections. This does not appear to effect the results of the structural analysis model since the effects of the stress concentration damp out before the stringer gage locations are reached.

Note: Contact John Choros at (312) 808-5847 with questions or comments about this document.