TECHNOLOGY DIGEST
Timely Technology Transfer

SUPERSTRUCTURE LOAD PATH TESTING OF TWO OPEN-DECK TIMBER BRIDGES

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Summary
As part of the Association of American Railroads' (AAR) Timber Bridge Life Extension program, two open-deck timber bridges were field tested on a Southern Pacific line located in southwestern Texas. This is AAR's first field investigation of timber railroad bridge performance under heavy axle load traffic. As such, the emphasis is on assessing factors that may contribute to faster degradation of timber bridges. Based on the initial results, the following conclusions can be made concerning the load path behavior and existing condition of the superstructures:

- Stringers within a chord acted independently to resist applied loading. The chord did not behave as a unit. In some cases, this may lead to overstressing of individual stringers.
- There was little continuity of deflection between chords of adjacent spans.
- The bearing condition between ties and stringers and between stringers and caps was not uniform, causing unequal load distribution on the stringers. This may lead to premature degradation of the structure.
- There is potential for significant improvement in timber bridge life and behavior as a result of changes in design and construction details, which will be developed from this research.

The primary objective was to evaluate the static and dynamic load paths in two bridges scheduled for strengthening in 1996. Data was obtained from revenue service trains as well as a test train These tests represent the first phase of a two-phase test in which load path information will be used to determine the effectiveness of two strengthening techniques: (1) replacing sawn timber stringers with glued laminated stringers and (2) using both new glued laminated stringers and, a ballasted-deck. Upon completion of SP strengthening operations in 1996, both bridges will be retested.

Testing was done in conjunction with Iowa State University and. the USDA Forest Service, Forest Products Laboratory.

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Suggested Distribution:
ž Maintenance Planning
ž Research & Development
ž Bridge Maintenance
ž Maintenance of Way

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INTRODUCTION AND CONCLUSIONS

In an effort to develop cost effective techniques for strengthening and/or extending the life of existing open-deck timber bridges, the AAR conducted a series of tests in the fall of 1995 on two opendeck bridges in southwestern Texas; one near Cline and another near Pinto. Both bridges, located along a main east-west route of the Southern Pacific (SP) line, are typical of other bridges slated for strengthening along the line. Both bridges are scheduled for strengthening in 1996. The bridges were selected based on heavy axle load traffic and Southern Pacific's aggressive inspection, rating, and strengthening program, which allowed for the selection of test bridges scheduled to be strengthened in 1996.

Results from these tests indicate that the stringers experienced uneven load distributions which caused differential deflections within the chord. Uneven load distribution can lead to increased degradation rates and shorter bridge life. Moreover, there is very little continuity of deflection between chords of adjacent spans, despite the fact that two of the four stringers in each chord are continuous over intermediate bents.

Test Procedures

In order to monitor bridge performance, both the Cline and Pinto bridges were instrumented prior to testing. Measurements of primary interest included bridge deflections and vertical rail forces. For both bridges, testing was conducted on two adjacent spans (one end span and one intermediate span).

Vertical wheel loads were measured using strain gages installed on the rails by AAR instrumentation specialists. Circuits were located near midspan and near the face of a bent (pile and cap assembly). These gages provided both wheel loads and train speeds. Vertical deflections were measured using displacement transducers referenced to ground. For the north chords of both bridges, displacement transducers were installed on all stringers at midspan and near the bent. Three displacement transducers were installed on the south chords of each bridge. In addition to measuring vertical deflections, two displacement transducers for each bridge were mounted horizontally to outside stringers in order to monitor the deflections across horizontal splits.

Testing was conducted with both revenue service trains and a test train provided by the SP. A test train, consisting of two four-axle EMD locomotives and seven loaded hopper cars, was used to evaluate the dynamic response of the Cline bridge. Prior to testing, hopper car geometry and weights were measured. Load tests with the test train were completed at crawl speed (approximately 2 mph) and at speeds of approximately 15, 30, and 40 mph. Readings from revenue service trains at speeds ranging from 13 to 66 mph were also recorded and analyzed.

Bridge Description

The Pinto and Cline bridges have very similar configurations (refer to Exhibit 1). Both bridges have substructures comprised of nominal 14-inch square caps supported by six pile bents at the intermediate supports and five pile bents at the abutments. Bent spacing is 15 feet center-to-center. The superstructure for each bridge consists of two longitudinal chords, each containing four nominal 8-inch wide by 16-inch deep sawn timber stringers. (Several stringes within the chords exhibited horizontal cracks.) The majority of the stringers were 30 feet in length and continuous over two spans. Individual stringers were bolted together with 3/4-inch diameter bolts at the bearings and at midspan. Both bridges were

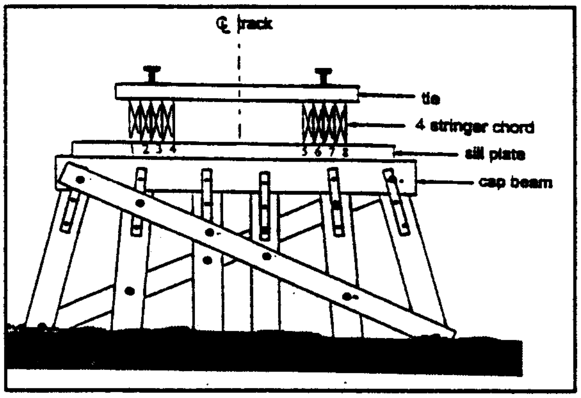

Exhibit 1. Cross Section View of Timber Bridge

constructed in 1937 using creosote treated Douglas Fir-Larch. There were also several notable differences between both bridges. For example, the Cline bridge has 119 lb/yd continuous welded rail, whereas the Pinto bridge has 136 lb/yd continuous welded rail. The Pinto bridge is scheduled to be strengthened in 1996 with new glued laminated stringers. The Cline bridge will receive a ballasted-deck in addition to glued laminated stringers, making it easier to maintain track surface, since a turnout is located just off the west end of the bridge. Changes in the load distribution due to ballasted deck will be evaluated in the second phase of testing, estimated to take place in the fall of 1996.

RESULTS AND ANALYSIS

Chord Deflections

Deflection measurements provide indications of stringer bending as well as movement at the ends where the stringers bear on the bents. Exhibit 2 shows the relative stringer midspan deflections for the end span of the north chord of the Cline bridge for a test tram of ballast cars at a speed of 40 mph. Relative deflection is defined as the absolute deflection (relative to the ground) minus deflections occurring at the bents. The exhibit shows that a maximum relative deflection of approximately 0.45 inch occurred at Stringer 8. Stringers 5 and 6 deflect approximately 0.3 inch less than the other two stringers. Stringer 8 also tends to deflect more than Stringer 7. Stringers 7 and 8 were replacement stringers, suggesting that these replacement stringers act independently and are carrying the majority of the load. This uneven load distribution may be due to nonuniform tie/stringer bearing or permanent deflections in the older stringers. Bearing conditions at the bents might also lead to uneven load distribution.

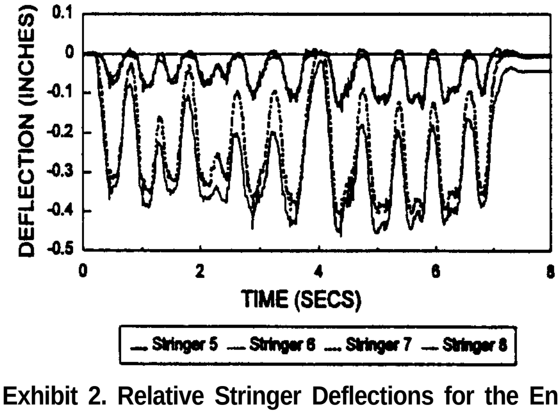

Exhibit 2. Relative Stringer Deflections for the End Span of the Cline Bridge (North Chord)

Exhibit 3 shows absolute end deflections of the north chord stringers at the Span 5 side of Bent 5 for a test tram speed of 40 mph. The exhibit shows that there are significant deflections at the bent and that there are differences in stringer bearing conditions and deflections within the same chords. There are a variety of reasons for the differences in deflection and bearing conditions at the bents, including notching of stringer ends, crushing of the cap, use of shims, and variations in tie/stringer bearing, as mentioned above.

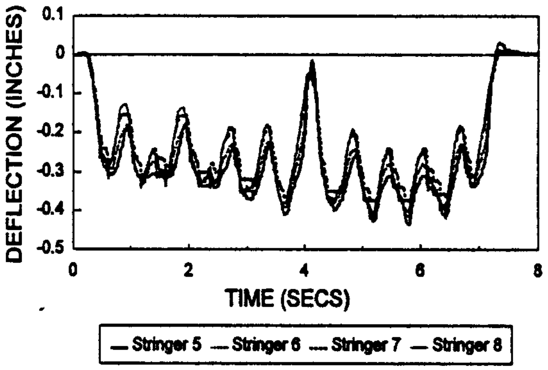

Exhibit 3. Absolute Stringer Deflections at the Bent for the Wine Bridge (North Chord)

For the bridge at Pinto, deflection data from revenue service trains showed similar behavior. In general, the magnitudes of deflection were similar to those of the Cline bridge, but deflection variance among stringers in a chord was not as large. For the north chord, a maximum deflection of approximately 0.50 inch occurred in the intermediate span at Stringer 6. The maximum deflection variance was 0.15 inch, approximately half the variance reported for the Cline bridge. This indicates that it is difficult to get an even load distribution when using replacement stringers. Deflections for Stringer 1 of the south chord reached a maximum value of 1.05 inch, but it appeared that one of the other interior stringers in the chord was cracked prior to testing.

As a check for continuity, relative deflections for all stringers within a chord at two adjacent spans were plotted for both bridges. Exhibit 4 illustrates the insignificant continuity of deflection of Spans 4 and 5 for the test train at Cline. The largest upward deflection for any of the stringers was 0.02 inch for Stringer 7, which occurred at Span 4 when the lead axle of the test train was near the midspan of the adjacent end span (5.8 seconds). Data collected under revenue service trains show that the Pinto bridge exhibited similar behavior.

‘These tests illustrate the importance of bearing conditions between the ties and stringers as well as between the stringers and caps. The nonuniform stringer load distribution within the chords of each bridge indicates that the chords are not behaving as designed. This nonuniform load distribution will most likely lead to faster degradation of the structure. From both a design and construction viewpoint, connection details need to be reviewed more closely to ensure optimum bridge performance. Better installation, bearing, and connection details could lead to more uniform load distributions and longer structural life. The tests indicate there is significant potential for improving timber structure performance through proper design, detailing, and construction practices.

Vertical Rail Forces

Dynamic locomotive and car wheel loads were measured at both bridges for a variety of revenue service trains. At the Cline bridge, the maximum locomotive and car dynamic wheel loads were 47.1 kips at a speed of 13.1 mph and 51.2 kips at a speed of 51.1 mph respectively. Likewise, for the Pinto bridge, these values were 40.0 kips and 39.2 kips at a speed of 22.4 mph.

Based on vertical force readings from the test train, the amount of impact was determine for the Cline bridge, for wheel loads measured at the bents and midspans for speeds of 15, 30, and 40 mph. Impact is the increase in load at a given speed, compared to the same load moving at crawl speed, typically expressed as a percentage. Vehicle dynamic action and vehicle-bridge interaction contribute to impact load. The maximum wheel load impact measured at midspan was 15 percent at a speed of 40 mph. At the bent, it was 4 percent at 15 mph. Timber bridges are typically designed assuming that the short-term strength increase in timber is greater than the total effect of impact loads.

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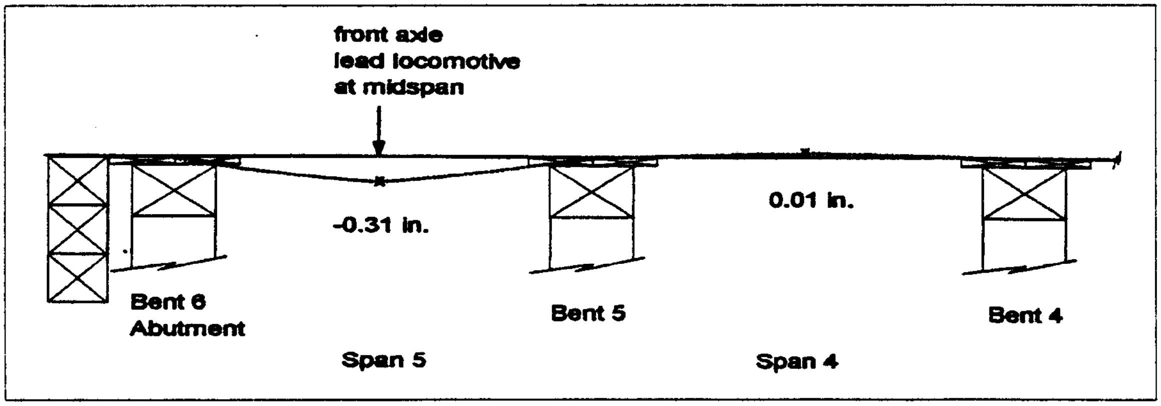

Exhibit 4. Deflection of Two Adjacent Continuous Spans (Cline Bridge)