

### FLAT WHEEL IMPACTS AND TLV TESTS ON A PRESTRESSED CONCRETE BRIDGE

by

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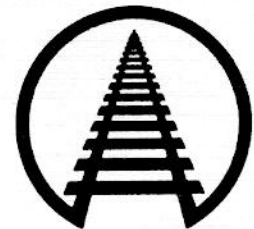
#### Summary

*The AAR recently conducted tests to measure impacts due to flat wheels on concrete bridges. Results show that the maximum tensile stresses (due to flat wheel impacts) measured on the bottom face of a concrete slab bridge are in the range of 400-600 pounds per square inch (psi). These values are much lower than the prestressing values of approximately 1200-1400 psi. This indicates that the prestressing values are more than adequate, and that the passage of a few flat wheels over a bridge does not pose any threat of introducing net tensile stresses (and thus cracking) of the concrete slab. The design prestressing values also provide an adequate safety margin for any anticipated higher axle loads.*

*A work train consist of a locomotive and loaded hopper cars was used for testing at controlled speeds up to 50 mph. Three of the original axles of the hopper cars were replaced by axles having condemnable wheel flats. One had an out-of-round wheel and the other two had flats of 4 inches and 3 inches respectively.*

*Additional tests were conducted using the AAR's Track Loading Vehicle (TLV). Since the span of the test bridge was only 18 feet, it was possible to have the TLV straddle the bridge and apply controlled cyclic loading up to 39,000 lbs (heavy axle loading) at the mid-span of the bridge. Thus, it was possible to study the load paths as well as forced vibration behavior of the concrete bridge. This test showed that the TLV can apply cyclic vertical loading at various frequencies of interest. Response behavior of the structure near resonant frequencies can be used to determine damping characteristics of a bridge.*

*The test bridge, work train test consist, and assistance with instrumentation and testing were provided by the AT&SF Railway.*



Association of American Railroads  
Research and Test Department



## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads is currently conducting a research program to evaluate the behavior and structural integrity of railway bridges under today's operating environment. Many of the existing steel railway bridges were built before 1950 and therefore range in age from 40 to 100 years. These older bridges were designed for steam locomotive power and comparatively lighter freight car loads of 50 tons or less. Most of the prestressed concrete railway bridges are not older than 30 years, and were designed for diesel locomotives and 70- or 100-ton freight cars.

The modern freight environment consists of unit bulk commodity trains with heavier load capacity freight cars, e.g. 100-ton capacity cars with wheel loads of 33,000 pounds and double-stack service unit trains utilizing 125-ton capacity trucks with wheel loads up to 39,000 pounds. All the trains are powered by diesel locomotives.

The main objectives of the tests described in this digest were:

- to measure maximum values of impacts from good, non-condemnable wheels as well as condemnable flat wheels,
- to measure response of the concrete bridge on the tensile (bottom) face to ensure the adequacy of precompression for impacts from higher axle loads, and
- to conduct forced vibration studies under controlled cyclic loading using the AAR's Track Loading Vehicle (TLV).

The 18-foot span bridge is shown in Exhibit 1. It was selected for this study as it was found from theoretical calculations as well as measurements during previous tests that the impact factors, in cases where flat wheels are the cause of impacts, are higher for bridges having smaller spans. This is due to the fact that a bridge with a smaller span is loaded by one or two trucks at the most in any instance. The presence of one flat wheel can increase the total bridge loading by a substantial amount depending on

the severity of the flat wheel impact load produced under wheels with tread irregularities. However, for a bridge having a larger span, more trucks are present on the bridge (depending on the length of vehicles and the bridge span) in any given instance. And the presence of one flat wheel does not constitute a substantial increase of the total loading.

A work train consist of a locomotive and loaded hopper cars was used for testing at controlled speeds up to 50 mph. Three of the original axles of the hopper cars were replaced by axles having condemnable wheel flats. One had an out-of-round wheel and the other two had flats of 4 inches and 3 inches respectively. Preliminary findings indicate that:

- For condemnable out-of-round wheels and wheels with 4-inch and 3-inch flats, the maximum impact factor was approximately 50 percent. Impact factor is the percentage increase in response of the structure at a higher speed, as compared to its response at crawl speed. Even for these impacts, the structure was subjected to live load tensile stresses of approximately 400-600 psi. These are much lower than the design stresses of approximately 1400 psi, thus ensuring a substantial reserve capacity. It must be pointed out that in revenue service trains, only a few wheels (1 or 2 per thousand) are condemnable, and they are removed when discovered.
- The condition of the bridge approaches and the quality of track on the bridge (track roughness and perturbations) are important factors affecting impact behavior. For continuous welded rail (CWR) on track maintained to FRA Class 5 standards or better, impact factors were quite low. Maximum values recorded were in the 10-15% range, provided that there were no wheel defects. However, the presence of non-condemnable, out-of-round or flat wheels can significantly increase the impact factor.
- Not all locations on the bridge span are equally affected. The bridge cross section at and near the point of impact of the flat wheel



Exhibit 1. AAR's TLV Loading the Concrete Bridge.

is affected the most. The impact values reported here were the maximum measured anywhere on the bridge.

- AAR's Track Loading Vehicle (TLV) was used to subject the bridge to controlled loading. Since the span of the test bridge was only 18 feet, it was possible for the TLV to straddle the bridge and apply controlled cyclic loading of up to 39,000 lbs (heavy axle loading) at the mid-span of the bridge. Thus, it was possible to study the load paths as well as forced vibration behavior of the concrete bridge. It was established that the TLV can apply cyclic vertical loading at various frequencies of interest. Response behavior of the structure near resonant frequencies can be used to determine damping characteristics of a bridge. Results of these tests will be reported at a later date.

### TEST METHODOLOGY AND RESULTS

Three axle sets, each having one condemnable wheel, were chosen for this test. These axle sets were used in earlier AAR tests (AAR Report R-829) to determine maximum rail loads caused by flat wheel impacts. Careful measurements of the wheel profile were done before testing. One of the condemnable

wheels was out-of-round and the other two had 4-inch and 3-inch flats respectively. The test work train consisted of a locomotive and five loaded 100-ton hopper cars. Three of the original twenty axles on the hoppers were replaced by the three axles with condemnable wheels. The test consist was operated at speeds of 5, 10, 20, 30, 35, 40, 45 and 50 mph. The bridge response was measured along the length of the bridge. Exhibit 2 shows the measured impact factors at the mid-span due to the out-of-round wheel for various test speeds.

To ensure that the flat wheel impact response is captured during train passage across the bridge, a 10 foot segment of the bridge was strain gaged at 6 inch intervals (21 gages). Since the circumference of the 36 inch wheels is approximately 9 feet 4 inches, this strain gage scheme designed to capture the maximum flat wheel impacts was more than adequate. A sketch of this scheme is shown in Exhibit 3. The impact factor at all the strain gage locations was determined by comparing the gages' maximum response at any speed to its response at a crawl speed of 5 mph. After having determined the impact factors at all gage locations, the absolute maximum value of the impact factor can be obtained. Exhibit 3 also shows the maximum impact factor (%) measured at various locations on the bridge due to the out-of-round wheel.

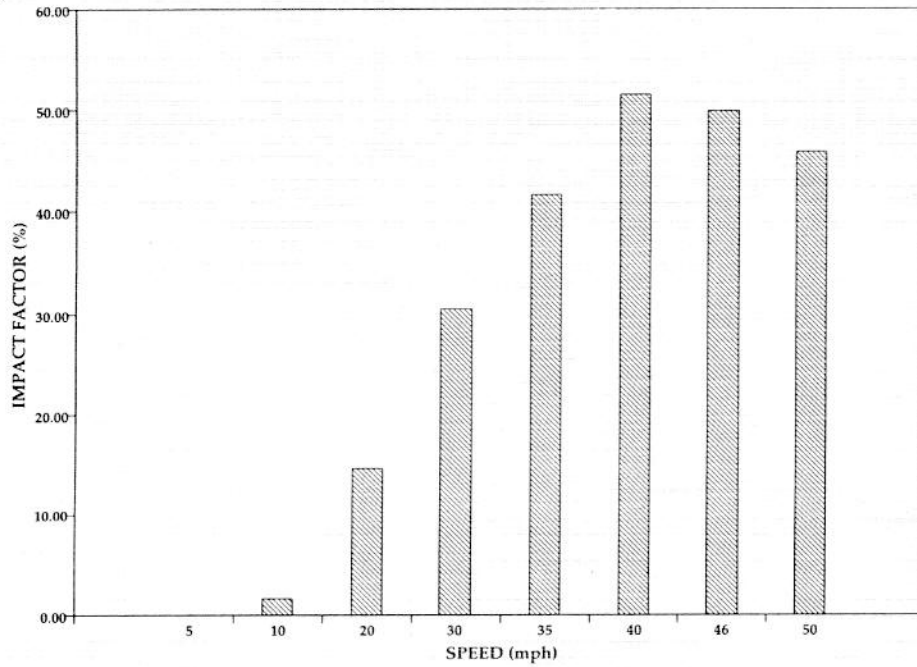


Exhibit 2. Impact Factors at Mid-Span due to the Out-of-Round Wheel.

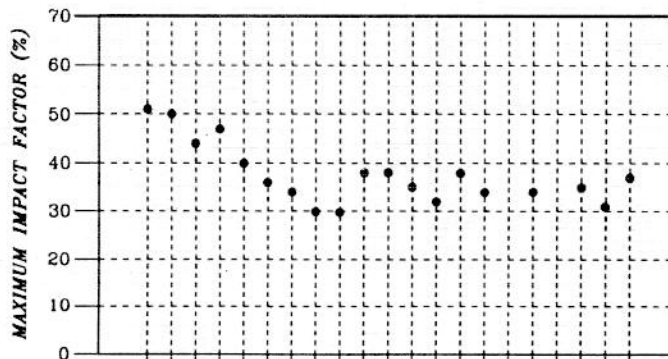
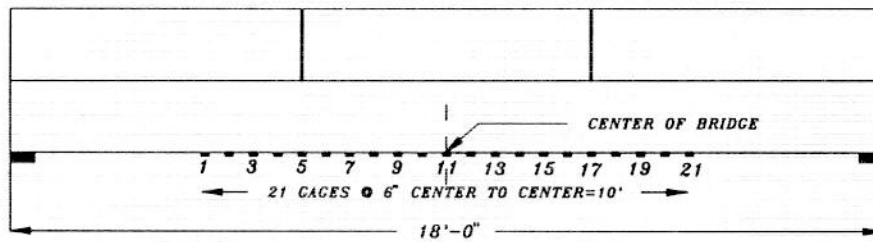


Exhibit 3. Maximum Impact Factor at Various Locations along the Span Length for the Out-of-Round Wheel.

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