

Dynamic Response of a Steel Ballasted Plate Girder Bridge to Wheel Impact Loads

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Summary

The AAR conducted a series of tests in the summer of 1994 to investigate the dynamic response of a ballasted through plate girder steel bridge to impact loads. The test results show that after considerable attenuation, the impact load is transmitted from the wheel/rail interface into the bridge stringers and floor beam through the ballast and deck beams. The stresses due to severe service induced wheel defects were more than twice as much as stresses recorded from a wheel without tread defects.

As a result of the impact forces, a wide range of track resonant frequencies were excited. Measured frequencies of the shear forces and moments in the stringers and floor beam under large flats ranged from 20-70 Hz. Such high frequency impact loads may be detrimental to the structural details and welds, and may reduce the fatigue life of these components.

Testing was conducted using a test train made up of a locomotive, six loaded 100-ton cars, and seven loaded 100-ton cars with service induced out-of-round wheels with large divots, flats, and machined flats. The test train was run over an instrumented ballasted through plate girder bridge belonging to a member railroad. The bridge response was measured by monitoring bending and shear strains in the stringers, floor beam, and plate girders. Wheel impact loads were measured by ten vertical wheel/rail load circuits on each rail.

These tests are part of an Association of American Railroads program to study behavior and structural integrity of railway bridges under current loads and operating conditions.



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INTRODUCTION AND CONCLUSIONS

Recently, the increased use of wheel impact load detectors revealed the existence of certain types of wheel defects which could generate very high impact loads on the rail.

As part of an overall program to determine the maximum allowable sizes of wheel tread defects, the AAR conducted a series of tests to determine the extent of the transmission of impact loads into the vehicle and track structures. The transmission of the high frequency dynamic forces from the wheel/rail interface to the truck and vehicle components was reported earlier in Technology Digest TD 92-001 and AAR Report R-810. In Technology Digest TD 93-001, the transmission of impact loads into the tie plates and ballast was reported. Researchers at the University of Queensland, Australia used artificial rail defects on a prestressed-concrete bridge. They reported that the impact was transmitted to the girders and that it generally increased as wheel or rail defects became more severe. They have also concluded that the wheel defects could lead to high frequency stress cycling over high stress ranges. Recently, Canadian Pacific (CP), in their efforts to study the effect of increased axle loads on bridges, instrumented a ballasted through plate girder and measured the bridge response under normal traffic. They reported measuring very high impact stresses at the bottom of welded stiffeners and similar locations on the girder without stiffener. The CP researchers also concluded that the wheel defects are very detrimental to the fatigue life of the structural details and contribute to crack development.

The study reported here deals with the effects and transmission of impact loads into the various components of a ballasted through plate girder bridge. This bridge was instrumented as part of the HAL revenue service monitoring project under AAR's bridge research program to study the behavior and structural integrity of railway bridges under current loads and operating conditions. The

following conclusions are drawn from these tests:

- After considerable attenuation, the impact loads are transmitted from the wheel/rail interface into the ballast and deck plate, then to the deck beams, stringers, and floor beams.
- Increases in bending stresses, due to service induced flat wheel defects were as high as 100% in the instrumented stringer at 50 mph.
- Dynamic augments of the shear stresses at the end of the stringers were as high as 110%.
- Dynamic augments of the moments at the center of the floor beam and shears at the end of the floor beam were around 55%.
- Frequencies associated with impact forces and moments measured in the stringers and floor beam under large wheel flats were in the range of 20-70 Hz.
- The high frequency impact loads may be detrimental to the structural details and welds and may reduce the fatigue life of these components.

Dynamic Response of a Ballasted Through Plate Girder Bridge to Wheel Impact Loads

As part of AAR bridge research program, a ballasted through plate girder bridge was instrumented to measure the bridge response under 100-ton car traffic and heavier axle loads.

The instrumented section of the bridge is in the 65' middle section of a 265' three-span bridge. The plate girders are 6' deep, and there are eight 15-ft floor beams. In each panel between floor beams, there are three stringers. Center-to-center spacing of stringers is 3.9'. The track is tangent with no vertical grade and consists of 133 RE CWR rail on wood ties.

The load path is from the wheel/rail interface to the

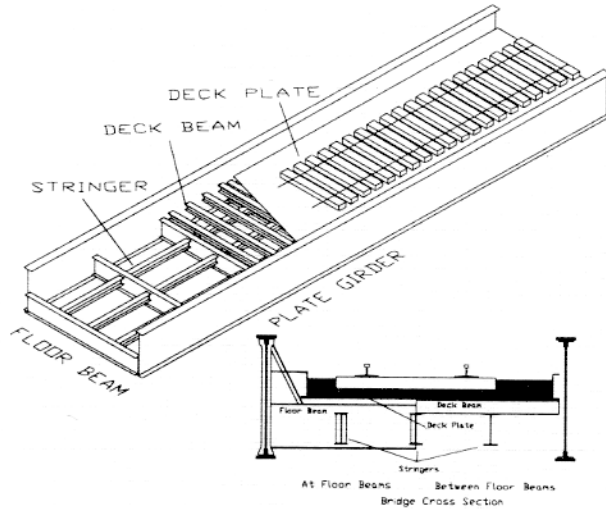


Exhibit 1. Schematic of the Bridge Section

tie-plates, ties, ballast, and then to the deck plate and deck beams. Loads are transmitted from the deck beams to the stringers, and then to the floor beams, and finally to the girders and the piers.

Exhibit 1 shows a schematic of the bridge section used in this test. The floor beams close to the center line of the bridge were instrumented to measure moments at the center and shears at the ends of each beam. Similarly, the stringers were instrumented to measure the moment at the center and the shear at the end connected to instrumented floor beams. Bending strains were measured at the top and bottom flanges of the girder at mid-span. In addition to the bridge instrumentations, 20 vertical load circuits (10 on each rail) were used to measure the wheel load and capture the wheel impacts.

A test consist was assembled with a locomotive and thirteen loaded 100-ton cars. Three cars were equipped with wheels with 3 and 4-inch machined flats, and 140 mils deep x 22" long service induced out-of-round wheel. Exhibit 2 shows the mean and standard deviations of impact loads produced by these wheels under 100-ton loaded cars from a previous test. In addition to the AAR wheelsets, four other wheelsets from the host railroad were installed under the trailing axle of the trailing truck of other test cars. The other six cars were used as buffer cars. The test consist was run over the

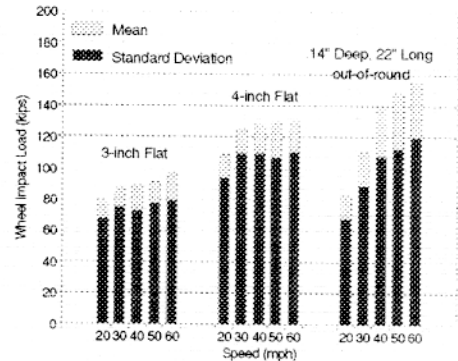


Exhibit 2. Wheel Impact Loads at 20 to 60 mph.

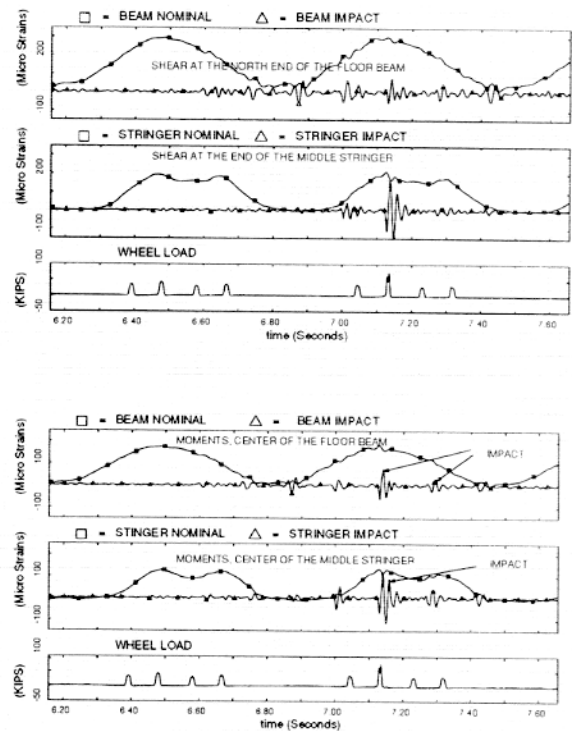


Exhibit 3. Effects of Wheel Impact on Bridge Members at 50 mph.

instrumented track section at 5, 10, 20, 30, 40 and 50 mph. Both the wheel/rail load and response data were collected at 1024 samples per second.

Exhibit 3 shows the moment strains at the center of the floor beam and the center of the middle stringer along with the wheel load. These readings were taken at 50 mph. This exhibit also shows the shear strains at the north end of the floor beam and east

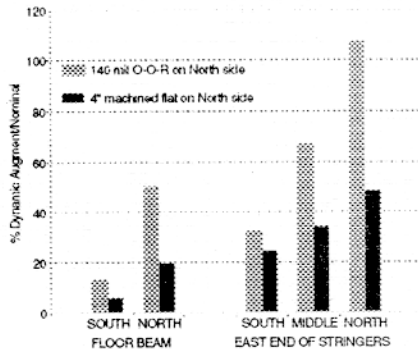


Exhibit 4. Percentage of increase in Shear Strains in the Floor Beam and Stringers Due to wheel Defects, 50 mph.

end of the north stringer. In this figure, the bridge response was high and low-pass filtered to separate the low and high frequency components of each response. The high frequency components show the response due to wheel defect and the low frequency components show the response for the wheel without the defect. It can be seen that at every wheel revolution when the defect hits the rail, impact is transmitted first to the stringer and then the floor beam. The amplitude of the impact is reduced going from the stringer to the floor beam. The highest measured impact occurred when the defect hit near the instrumented section on the bridge. From the traces in the second panel from the top, one can see that the shear strain at the end of the middle stringer due to impact is about 173 μ S, while response due to the passage of four wheelsets is about 178 μ S. This means that the response of the stringer due to this defect is almost as high as the response due to four good wheels. A similar trend is also observed for the moment

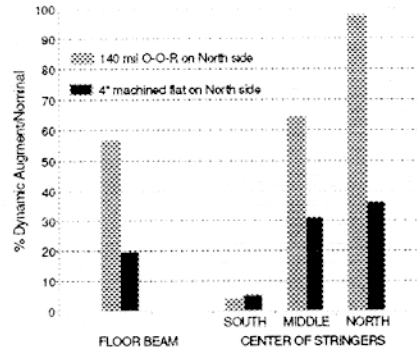


Exhibit 5. Percentage of the increase in Moment Strains at the Center of Stringers and Floor Beam Due to Wheel Defects at 50 mph.

strains at the center of the stringer. The vertical rail load measured under this defective wheelset was at least 118,000 pounds on the north rail and 116,000 pounds on the south rail.

Exhibits 4 and 5 show the percentage increase in shear and bending moment strains in the floor beam and stringers due to various wheel defects at 50 mph. It is clear that the impact was transmitted from the north rail to the south rail through the tie, ballast, floor deck, and floor beam. These exhibits also show that the increase in shear and moment strains in the north stringer due to a 140-mil defect are about 110% and 97%, respectively. The shear and moment strains in the south stringer increased by 25% and 5% due to the impact on the north rail. These exhibits also show that the long wavelength O-O-R wheel defect with lower impact frequencies such as the slid flat, can produce higher impacts on the bridge components than the slid flat.

Note: Contact Ali Tajaddini at (312) 808-5850 with questions or comments about this document.

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A more detailed report, which may contain revised information, will be available at a later date through the Association of American Railroads, Publication Order Processing, 50 F Street N.W., Washington, D.C. 20001. A report list is available upon request.