TECHNOLOGY DIGEST
TD-16-032
©AUGUST 2016
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

High Impact Wheel Effect on Rail Failure, Part I: Test at FAST

Harry M. Tournay, Xinggao Shu, Przemyslaw Rakoczy, and Duane Otter

Summary

Transportation Technology Center, Inc. (TTCI) has conducted a series of static and dynamic load tests on rail installed at the Facility for Accelerated Service Testing (FAST) to investigate load and track structure effect on rail stress and its distributions, and to optimize instrumentation for subsequent tests at a wheel impact load detector (WILD) site near Calrin, Manitoba, Canada.

The following conclusions are from the tests conducted on rail installed at FAST:

- High and localized tensile stress can form under the rail head under direct loading.
- Maximum rail reverse bending was observed approximately three ties from the direct load.
- Track stiffness is almost bilinear (soft for the approach and hard directly under the wheel).
- Under normal train dynamic load conditions (without flat wheels), timber tie track rail deflections doubled compared to that of concrete tie track due to soft rail support from timber ties; the rail reverse bending strains under indirect loading in these two types of track were similar; however, the maximum rail base bending strains under direct loading in timber tie track increased by 20 percent over that of concrete tie track; running speeds have little effect on rail strains and deflections for such load conditions.
- Under high impact (drop hammer) load conditions, rail base strains under direct loading increased significantly due to high impacts. Compared to concrete tie track, timber tie track rail deflections were almost doubled, but its rail base strains were less than half. The resulting stresses were 68 percent lower than the yield strength of rail.
- Using test results at FAST, optimal instrumentation was determined for the Calrin WILD test site (Calrin test results will be published separately).

This research was conducted under the Association of American Railroads' Strategic Research Initiatives Program to determine the relationship between the magnitude of wheel impact loads and the probability of rail failure.

Please contact **Harry Tournay (719) 584-0704** with questions or concerns regarding this *Technology Digest.* E-mail: Harry_Tournay@ttci.aar.com.
©2016 Transportation Technology Center, Inc. Unauthorized duplication or distribution prohibited.

INTRODUCTION

TTCI conducted a series of static and dynamic tests at FAST prior to revenue service WILD site tests to investigate load and track structure effect on rail strains and distributions, and to optimize the instrumentation design for tests at a WILD site near Calrin, Manitoba, Canada.

TEST CASES AND INSTRUMENTATION

The load tests were conducted at two locations on the track at FAST: one with concrete ties, and the other with timber ties. Three different types of loads were applied to rail:

- Static load: two vertical loads were applied on rails slowly but continuously from 0 to 40,000 pounds and kept constant for 1 second.
- Train dynamic load: a six-axle locomotive and two loaded cars ran over the instrumented cribs at 10, 20, and 30 mph.
- Impact load (drop hammer): a 3,300-pound steel block was suspended 5 inches over the test rail and dropped to the rail through a quick disconnect.

Four cross sections (A, B, C, E) along a rail were instrumented on a track with concrete ties, as Figure 1 shows. The static load was applied on the rail top at nine locations along the track. Vertical displacement sensors were installed on Cross Section A, C and E; strain gages were installed on rail (Figure 2) on Cross Section A, B, and C; all strain gages were oriented longitudinally along the rail to measure rail bending stress.

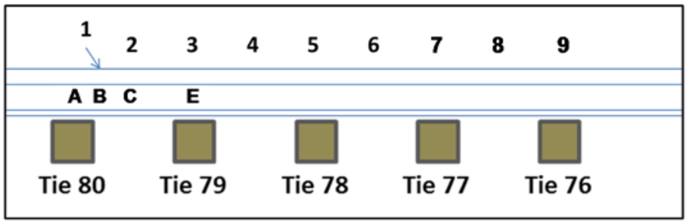

Figure1. Static Load Application Locations (1–9) and Instrumentation Cross Sections (A, B, C, E)

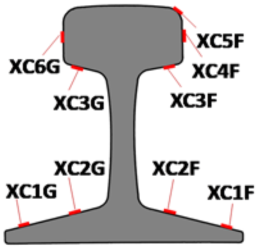

Figure 2. Strain Gages on Cross Section C

STATIC LOAD TEST RESULTS

The first static load test was conducted on track at FAST with concrete ties; the second test was conducted on track at FAST with timber ties. Figure 3 depicts rail deflections under a vertical load. The rail uplift, also refered to as rail reverse bending, is an important characteristic of track structures. Figure 4 shows measured strains on the rail head at Cross Section A under loads at different locations. The rail head on Cross Section A was in compression status (negative strain) when the load was applied within one tie distance (24 inches) under a single vertical load condition. The rail head on Section A underwent reverse bending when the load was one tie distance away, and reached maximum reverse bending when the load was two and a half tie distances away.

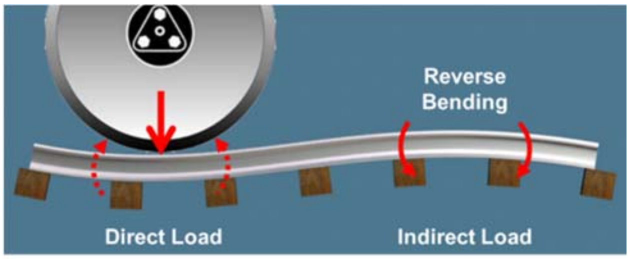

Figure 3. Rail Deformation under Static Loads

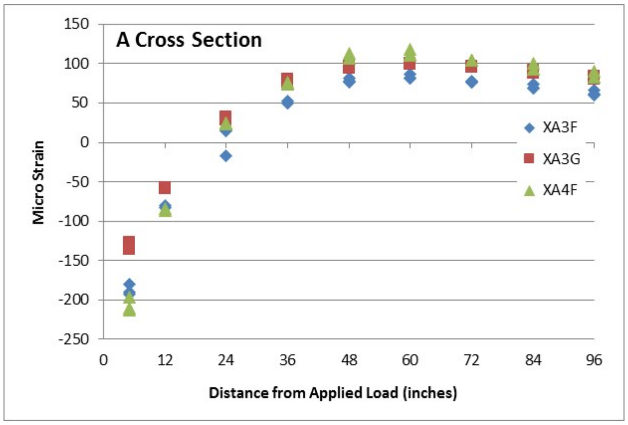

Figure 4. Cross Section A Strain Gage Outputs

Figure 5 shows measured strains on rail head and base at Cross Section B under loads at different locations. Clearly, the status of rail head on Section B is similar to that of Section A from load positions 2 to 9, except load position 1, which is aligned in the same cross section of B. The strain on the underside of rail head XB3G and F was in less compression or even a little tension status when the load was applied on rail head directly, compared to that when the load was applied with a half tie distance at position 2.

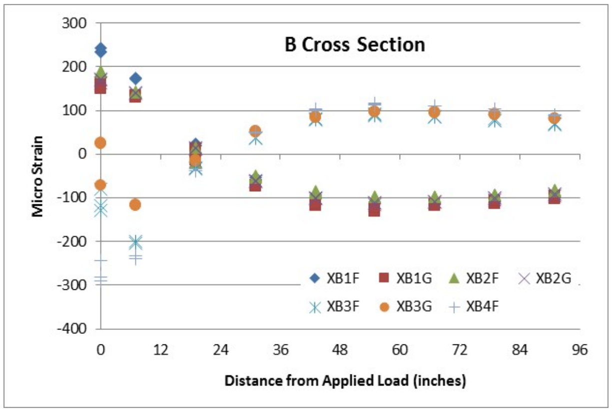

Figure 5. Cross Section B Strain Gage Outputs

Figure 6 shows measured strains on rail head and base at Cross Section C under loads applied at different locations. The strain on the underside of rail head (XC3G) at Section C showed significant changes (from compression to tension) when the load was applied to the rail above the strain gages. The other strains on rail head and base changed from positive bending to reverse bending as the vertical load moved away along the track.

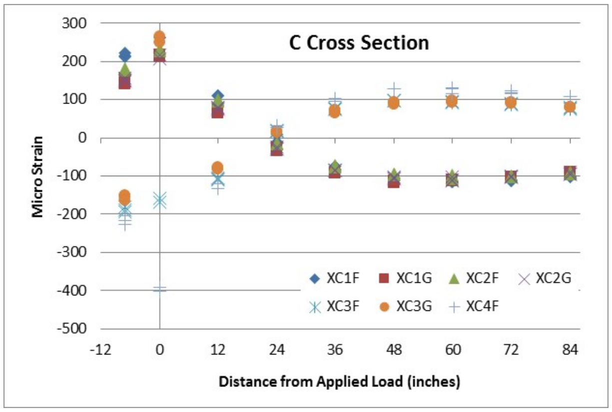

Figure 6. Cross Section C Strain Gage Outputs

TRAIN DYNAMIC LOAD TEST RESULTS

A six-axle locomotive and two loaded hopper cars were used to apply dynamic axle loads in the test zone at speeds from 10 to 30 mph. The strain time histories in Figure 7 show the strains on the underside of rail head (such as XC3G and XC3F channels) change from compression to tension in a very short time period under a wheel pass. The strains on rail base never showed this localized short-duration stress reversal. This phenomenon occurred on both static and dynamic load cases, as discussed above. The short-duration stress reversal was caused by rail head local deformations under direct loading.

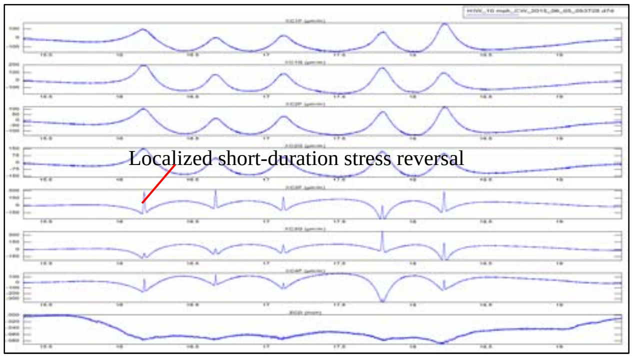

Figure 7. Strain & Vertical Displacement Time Histories (under Two Loaded Trucks) at Cross Section C

Figure 8 shows the maximum and minimum strains measured on Cross Section A when the train passed. All maximum strains occurred during the short-duration stress reversal. The underside of rail head short-duration reversal strains were even higher than those during reverse bending.

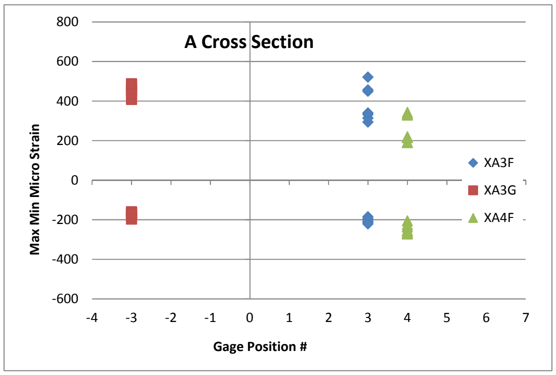

Figure 8. Maximum & Minimum Strains at Cross Section A (10, 20, 30 mph; Positive Strain Gages Were on Field Side, Negative Gages Were on Gage Side, Position # see Fig. 2)

Figure 9 shows the rail responses under static and dynamic loads are different: the rail dynamic stiffness under train load was higher than that under a single static load; the dynamic track stiffness is almost bilinear (soft for approach and hard directly under the wheel) probably due to the nonlinear characteristic of the track foundation.

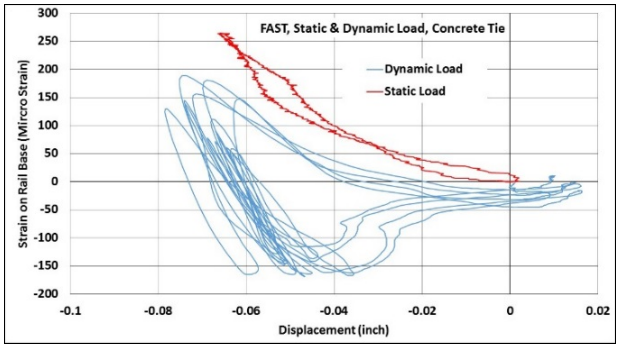

Figure 9. Rail Response Comparison between a Quasi-Static & a Dynamic Train Load (30 mph)

IMPACT LOAD TEST RESULTS

The drop hammer generated about 105 kips impact on rail measured from the shear force channel on the rail web.

Figure 10 shows the maximum and minimum strains measured at Sections C under impacts applied from locations 1 to 9 (shown in Figure 1). The rail head compression and rail base tension strains increased significantly due to high impacts. The impact effect was mostly local and diminished quickly in less than one tie distance (19 inches).

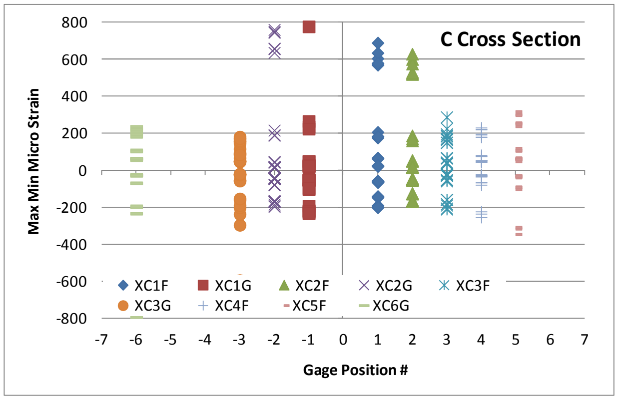

Figure 10. Maximum & Minimum Strains at Cross Section C (Drop Hammer from Position 1 to 6)

The rail vertical deflection and uplift rebound also increased significantly due to high impacts

To investigate track stiffness and its effect on rail responses, two cross sections along a rail were instrumented between two ties on a track with wood ties. Under normal train dynamic load conditions (without flat wheels), timber tie track rail deflections doubled compared to that of concrete tie track due to soft rail support from the timber ties; the rail reverse bending strains under indirect loading in these two types of track were similar; however, the maximum rail bending strains under direct loading in timber tie track increased by 20 percent over that of concrete tie track, as Figure 11 shows.

For normal train load environment (without flat wheels), running speeds had little effect on rail strains and deflections. Under high impact (drop hammer) load conditions, timber tie track rail deflections almost doubled compared to that of concrete tie track; but, the peak rail strains were less than half those on concrete tie track, as Figure 12 shows.

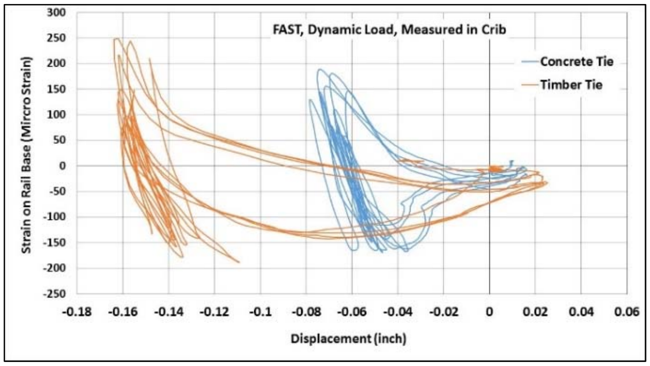

Figure 11. Comparisons of Rail Strain & Deflection between Concrete & Timber Tie Track

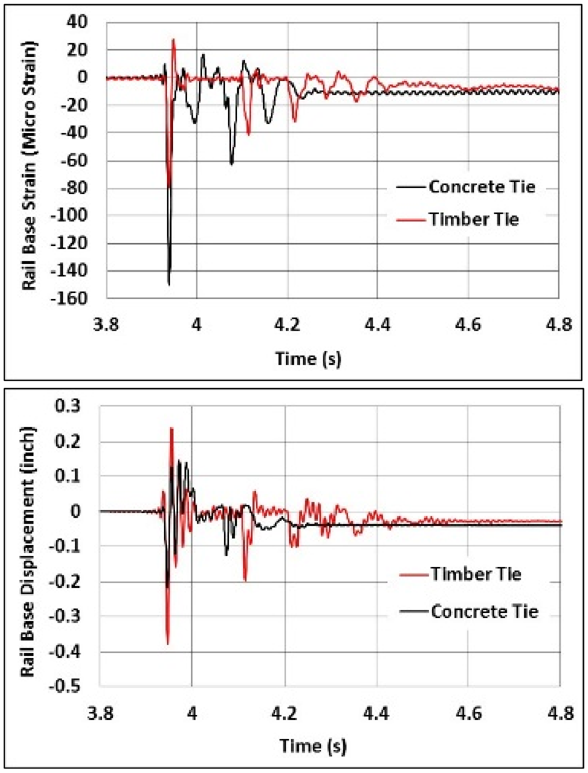

Figure 12. Comparison of Rail Strain & Deflection (Cross Section C) under High Impacts (Load Location #5 in Fig 3)

CONCLUSIONS

The static, train dynamic, and high impact track load conditions were tested on rail installed at FAST to investigate load conditions and track stiffness effects on rail responses. The tests provided important findings for better understanding high impact wheel effect on rail failures. Based on the test results at FAST, optimal strain gage positions were determined for Calrin WILD site tests.

Disclaimer: Preliminary results in this document are disseminated by the AAR/TTCI for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR/TTCI makes no representations or warranties, either expressed or implied, with respect to this document or its contents. The AAR/TTCI assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.