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CWR/Bridge Interaction under Train Operations: Testing at Eastern Mega Site

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Summary

Transportation Technology Center, Inc. (TTCI) is conducting tests on an open-deck steel bridge that crosses the Roanoke River at milepost 257.5 on the Norfolk Southern Railway at the Eastern Mega Site. Testing consists of a long-term test and a short-term dynamic test. Results from the short-term dynamic test conducted in November 2010 are reported here. Results from the long-term test will be reported in another *Technology Digest.*

The short-term dynamic test was completed in conjunction with installation of instrumentation for the long-term test. While the use of dynamic braking was minimal and most trains were in traction over the bridge, the following test results from the dynamic test were observed:

- Total tractive efforts and dynamic brake efforts from the locomotives recorded at this location are well below AREMA design requirements for traction and braking.[1]
- Test results have shown that the recorded longitudinal rail force and displacements of rail, tie, and girder under these operating conditions are unlikely to cause continuous welded rail (CWR) stability problems in the bridge approach.
- Track displacements on portions of the bridge that have a smooth interface between bridge and deck are 4 to 5 times greater than those on portions of the bridge that have rivet heads protruding from the upper surface of the steel girders.
- Rail to tie displacements are relatively small compared to tie-to-girder displacement. This indicates that the new elastic fasteners are effective for the range of train operations at this location.

The long-term test is being performed to characterize the longitudinal resistance between CWR and steel girders with a high-resistance surface; i.e., investigate whether bridge neutral temperature shifts on a seasonal basis and verify TTCI's CWR/bridge interaction model. The short-term test is being performed to address concerns about rail forces accumulating on bridge approaches due to traffic that could increase force at the approach and increase the potential of track buckling.

Rail longitudinal forces, relative displacements between the track and bridge, and span displacements at the west approach were monitored under traffic during the dynamic test. Applied tractive effort and braking forces were estimated based on locomotive cab readouts from trains crossing the test zone. Track behavior at the west approach is of particular interest because of eastbound loaded trains approaching the bridge on a downhill grade of 0.66 percent.

The work is jointly sponsored by the Association of American Railroads and the Federal Railroad Administration under the mega site testing program.

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INTRODUCTION

On open track, rail longitudinal forces are caused by thermal expansion of rail that is restrained by the resistance of the ballast and by longitudinal resistance provided by rail anchors or elastic fasteners. In addition, longitudinal forces are applied by train traffic. On open deck steel bridges, additional force is introduced. As these bridges expand and contract because of thermal effects, relative displacements are introduced between the bridge and the track. Depending on the longitudinal stiffness of the track-to-bridge attachment, undesirable forces may be introduced into the bridge and rail.

TTCI is conducting tests on an open-deck steel bridge that crosses the Roanoke River at milepost 257.5 on the Norfolk Southern Railway at the Eastern Mega Site. This test is intended to further characterize the interaction between CWR and open deck steel bridges. A long-term test is being conducted to measure thermal performance, and a short-term dynamic test is being conducted to measure CWR/bridge interaction under train traffic. The work is jointly sponsored by the Association of American Railroads and the Federal Railroad Administration under the mega site testing program.

This *Technology Digest* reports results from the short-term dynamic test, which was performed to evaluate the effects of traffic, particularly eastbound loaded coal trains, as it moves down grade toward the bridge, and addresses concerns about rail forces accumulating on bridge approaches due to traffic on downhill grades that could increase forces at the approach and increase the potential of track buckling.

SITE DESCRIPTION

Figure 1 shows the test bridge looking from west to east. It is 525 feet long, on a 6-degree curve, and is on a 0.66 percent grade, downhill from west to east.

Figure 1. Test Bridge over the Roanoke River at Milepost 257.5 on the Eastern Mega Site

The dynamic test focused on the first three spans at the west end of the bridge and the west approach. Figure 2 depicts the spans of concern in the test zone.

The test highlights the difference in behavior between tie-to-structure interfaces that are smooth and those that have more resistance to sliding (e.g., protruding rivet heads). Span 1 and Span 3 have an interface with protruding rivet heads, and Span 2 has a smooth interface.

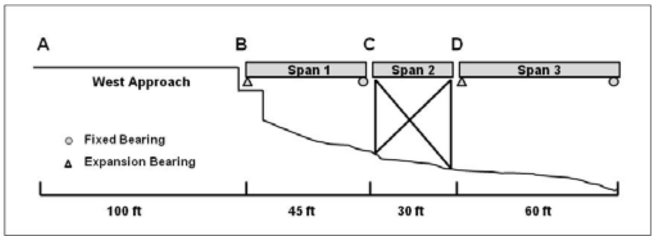

Figure 2. Test Zone

MEASUREMENTS

Locomotive tractive effort and dynamic braking effort applied over the test zone was estimated from locomotive instrument readings as the train passed through the test zone.

Instrumentation installed at locations A, B, C, and D (Figure 2) on the bridge recorded the bridge response as the train passed. Measurements included:

- Span expansion and contraction at bridge expansion bearings
- Relative displacements between the span and rail, broken down between rail-to-tie and tie-to-span measurements
- Changes in longitudinal rail force

TRAFFIC

Ten eastbound trains passed over the bridge during the dynamic test: seven coal trains and three mixed freight trains. The traffic on this track is primarily eastbound. No westbound trains passed through the test zone during the data collection periods. Table 1 summarizes the traffic. Note that negative values indicate dynamic braking effort.

Table 1. Train Summary

Leading Locomotive	Tractive Effort (kips)	Train Type
NS 9259	0	Coal
NS 7711	-19	Mixed Freight
NS 7545	-11	Coal
NS 7623	0	Coal
NS 9107	73	Mixed Freight
NS 8986	0	Mixed Freight
NS 8908	36	Coal
NS 9806	96	Coal
NS 9366	42	Coal
NS 6630	68	Coal

Applied tractive effort was calculated for each of these trains as they moved down grade toward the west end of the bridge based throttle/dynamic brake settings that were applied over the test zone.[1] A positive value represents tractive effort; a negative value represents dynamic braking effort. The maximum dynamic braking effort was 19,000 pounds, and the maximum tractive effort was 96,000 pounds.

These are comparatively low values. Compared to the results shown in Figure 3, which shows distribution of tractive efforts recorded over 350 miles of a mountainous western coal route in 1999,[2] the maximum tractive effort recorded was 435,000 pounds, and the maximum dynamic braking was 240,000 pounds. Median values were about 200,000 pounds for tractive effort and 100,000 pounds for dynamic braking.

In fact, the results indicate that most of the downhill trains passing this location were actually in throttle mode rather than dynamic braking. Only dynamic braking by downhill trains would contribute to bunching of rail on the uphill bridge approach.

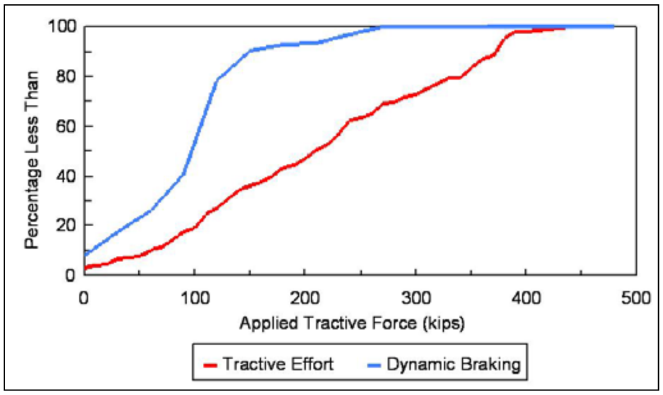

Figure 3. Distribution of Tractive Effort and Dynamic Braking from 1999 Analysis

DISPLACEMENTS

Three different longitudinal displacements were measured at locations B, C, and D: rail-tie displacement, tie-girder displacement, and girder-girder displacement.

Maximum peak to peak displacement was calculated for rail-tie and tie-girder displacements. Figures 4 and 5 show that tie-girder displacement accounts for most of the movement of the span with the smooth top. Figure 4 also shows that the riveted-top span has significantly less displacement than the smooth-top span shown in Figure 5. In fact, track displacements on portions of the bridge that have a smooth interface between bridge and deck are 4 to 5 times greater than those on portions of the bridge that have rivet heads protruding from the upper surface of the steel girders. These results are supported by previous tests.[3] The displacements were sorted by tractive effort. However, for the small tractive efforts recorded, the results do not show a correlation between applied tractive effort and track displacement for the range of train operations at this location. This may be because the longitudinal effects are overshadowed by deflection caused by bending of the span due to traffic.

Figure 6 shows span displacements. The span displacements are small across locations B, C, and D. This was expected because of low forces applied to the spans.

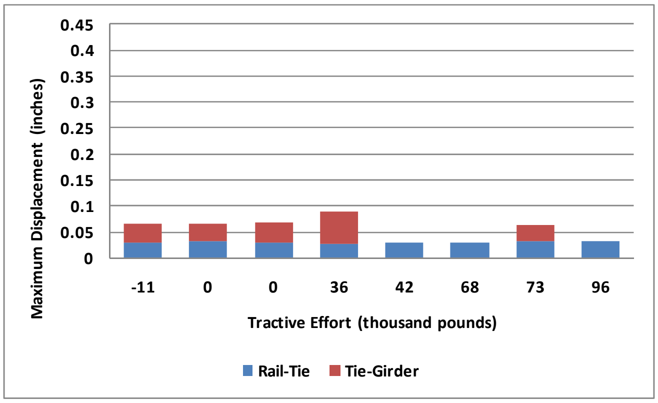

Figure 4. Rail-tie and Tie-girder Displacements on Riveted Top Span (Location C)

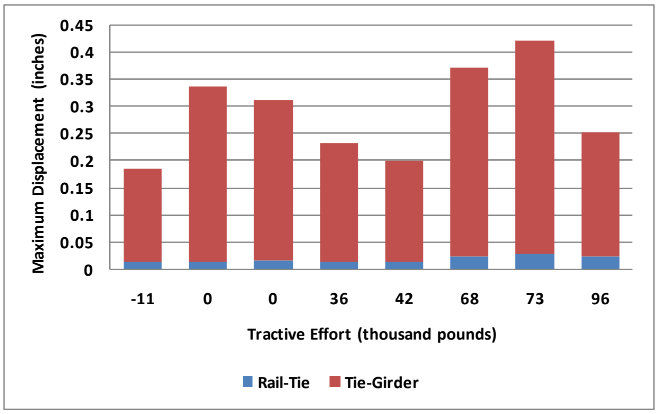

Figure 5. Rail-tie and Tie-girder Displacements on Smooth Top Span (Location C)

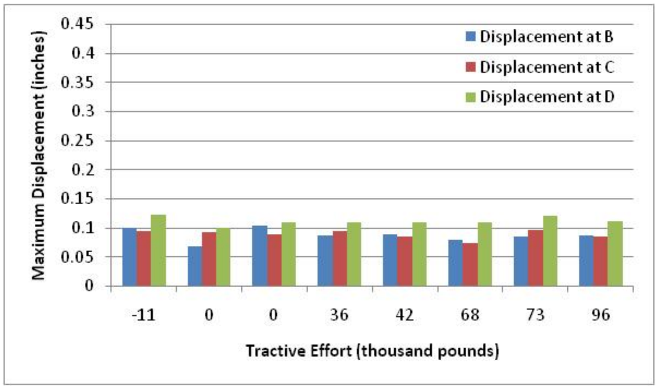

Figure 6. Span Displacement at Locations B, C, and D

LONGITUDINAL FORCES

Forces in the rail were measured at locations A, B, C, and D. Figures 7 and 8 show forces measured at locations A and C as a function of train pass (tractive effort).

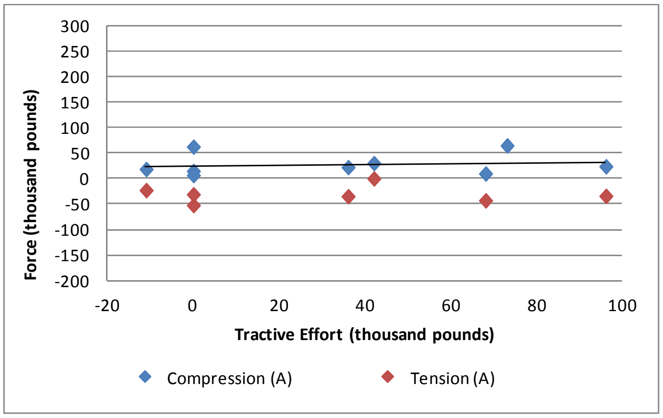

Figure 7. Force versus Tractive Effort at Location A

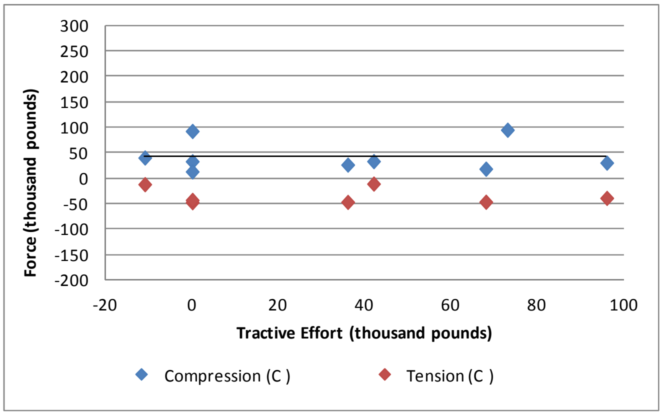

Figure 8. Force versus Tractive Effort at Location C

At both locations, longitudinal force in the rail did not change much as a function of tractive effort. This, however, might be due to the low tractive efforts recorded at this location. In other words, longitudinal rail force is essentially dominated by its thermal component because of temperature change from its rail neutral temperature.

These results indicate that at this location, train operations would not cause additional longitudinal rail force that might increase the risk of bridge approach track buckling,

Figures 9 and 10 show the correlation between maximum rail force (compression and tension) and displacement for locations C and D. As expected, greater force caused larger deflection. This trend was more obvious for location D than for location C because D represents the displacement for the span that has the smooth top. There are less data points in tension since some forces stayed in compression during data collection.

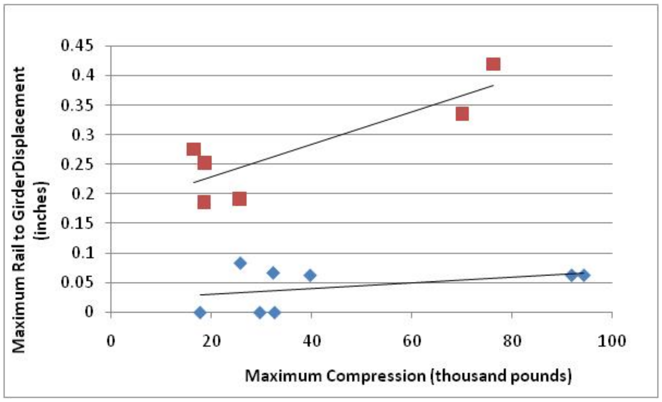

Figure 9. Compression Force versus Displacement at Locations C and D

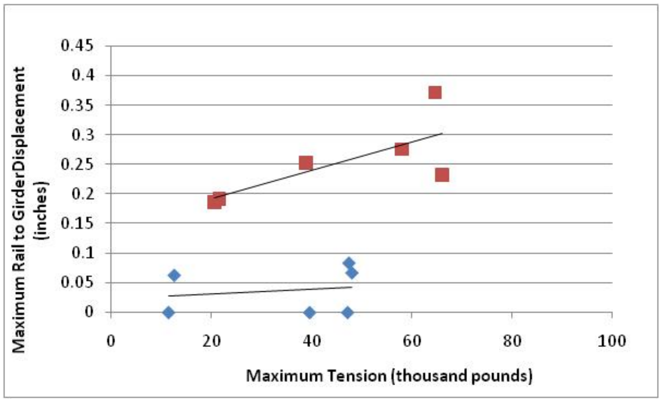

Figure 10. Tension Force versus Displacement at Locations C and D

FUTURE WORK

Results of long-term monitoring of thermal interaction between track and bridge will be used to characterize the longitudinal resistance between CWR and steel girders with a riveted top surface, investigate whether bridge neutral temperature (setting temperature) shifts on a seasonal basis, and validate TTCI's CWR/bridge interaction model.

ACKNOWLEDGEMENTS

Steve Lakata, Ronnie Doss, and Brad Kerchof of the Norfolk Southern provided valuable assistance during this test.

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2. Uppal, A. S., D. E. Otter, and R. B. Joy. July 2001. "Longitudinal Forces in Bridges Due to Revenue Service Traffic." Research Report R-950, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.
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