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UIUC Concrete Tie and Fastener Field Testing at TTC

SUMMARY

In July 2012, the University of Illinois at Urbana-Champaign (UIUC) began an extensive experimental program at the Transportation Technology Center (TTC) in Pueblo, CO. The field experimentation program was part of a larger research program funded by the Federal Railroad Administration (FRA) to improve the design and performance of concrete crossties and fastening systems. The UIUC program recorded loads, strains, and displacements of the track components under passenger consists traveling at speeds of 2–102 mph, freight consists with car weights ranging from 263,000 to 315,000 pounds, and static responses from a track loading vehicle (TLV). The results of the experiment have yielded insight into the transfer of forces between the train wheels and the rail/fastener/crosstie system and provided a means to validate a comprehensive finite element model (FEM).

Figure 1. UIUC team at the test site in Pueblo, Colorado

BACKGROUND

As part of a 3-year research program funded by FRA, UIUC has begun work to improve the design methodology and performance of concrete crossties and elastic fastening systems in the United States. Program objectives include the development of an FEM, as well as laboratory and field experimentation to fill voids in the current understanding of concrete crosstie and fastening system behavior, which will allow us to improve mechanistic design procedures for these systems. Such an improvement will lead to the decreased life cycle costs of track components, as well as increased robustness and improved safety of critical infrastructure components.

OBJECTIVES

The primary objective of the field experimentation is to characterize the behavior and quantify the demands placed on each component of the crosstie and fastening system under varying field conditions. Additionally, these experiments will provide a means to validate the FEM being developed by UIUC. Finally, the program will provide the industry and future researchers with insight into industry-accepted and novel instrumentation strategies.

METHODS

The test program involved extensive instrumentation of two 15-crosstie test sections (tangent and curved track) to synchronously measure force and displacement at various interfaces.

Of the 15 crossties, 4 rail seats were fully instrumented with each methodology mentioned in this report, and 10 additional rail seats were instrumented with vertical rail web strains on each side of the rail (see **Figure 2**).

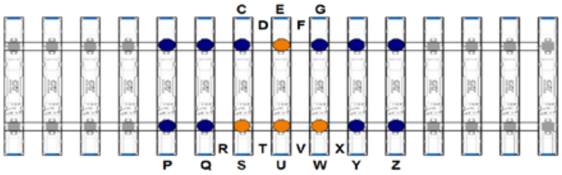

Figure 2. Locations of fully (orange) and partially (blue) instrumented rail seats

As shown in **Figure 3**, strain gages were positioned in the crib on the rail neutral axis (for vertical circuits) and rail base (for lateral circuits) to measure wheel-rail loads. For each configuration, there were two planes of shear strain being measured. (When the wheel is between these planes, the load is proportional to the difference between the two shears.) Strain gages were also placed on the rail seat to measure these forces.

Three strain gages were oriented vertically on each side of the rail web over the tie, as shown in **Figure 3.** These strains measure the compressive forces in the rail and the relative load distribution of adjacent crossties. Strain gages placed perpendicularly to the rail base were used to measure rail base bending stresses. Strains were also measured (1) on the surface of the fastening clips to estimate clamping forces and fastener demands and (2) on the insulator post to estimate lateral loads on the insulator.

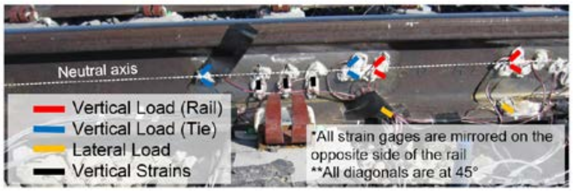

Figure 3. Configuration of strain gages for attaining vertical and lateral loads

Linear potentiometers were used to capture displacements of the rail and crosstie, as shown in **Figure 4**. For rail displacements, potentiometers were screwed into brackets on aluminum fixtures which were epoxied to the crosstie. Rail displacements included lateral measurements of the web and base and vertical displacements of the rail base on the gauge-side. Vertical crosstie displacements were measured using linear potentiometers clamped to a 6-foot rod driven into the subgrade.

Figure 4. Detailed instrumentation

Of the 15 newly installed crossties, 3 were internally and externally instrumented with strain gages (see **Figure 5**). During the manufacturing process, embedment gages were positioned below the rail seat surface in a 2x2 matrix to measure stress distributions and rail seat forces.

After curing, surface strain gages were placed parallel with the length of the crossties at each rail seat and crosstie center in order to determine bending moments at critical locations.

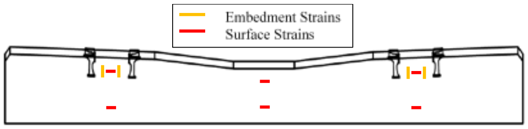

Figure 5. Locations of crosstie strain gages

The Association of American Railroads' (AAR) TLV was used to calibrate the vertical and lateral load circuits. This calibration consisted of vertical loads up to 40 kips being applied statically at various locations along the track (crib centers and rail seats) with the TLV. Additionally, lateral loads up to 20 kips were applied. Further tests were conducted with the TLV, including a dynamic test with a constant 10-kip lateral load.

Next, 10-car passenger and freight consists were driven over the 2 test sections: from 2 to 102 mph on the tangent and 2–45 mph on the curve. Additional tests using these two consists included pneumatic braking and accelerating from a stopped position over each test section.

RESULTS

From the vertical and lateral load circuits, adjacent cribs had agreeable axle loads and the range of input loads compared well with existing wheel impact load detector data. Results of the rail seat load circuits at low speeds agreed with expected values (e.g., 50 percent of load transfer for well-supported crossties).

Vertical rail strain data was used to identify the effect of lateral load on the vertical load path. The vertical rail strains, averaged from the field and gauge side of the rail, are shown in **Figure 6** for seven crossties. A 40-kip static vertical load was applied to the center crosstie while increasing the lateral load from 0 to 20-kips. The strain due to bending has been removed through the process of averaging the strains. Therefore, the distribution of the rail strains are equivalent to the distribution of vertical rail seat loads. Through the comparison of the three loading cases shown in **Figure 6**, which are 40-kip vertical load with 0-kip, 10-kip, and 20-kip lateral load, one can see the vertical rail strain (i.e. vertical load) distributions are very similar. The difference that is evident can be attributed to the change in wheel-rail contact patch location that occurred as a result of the increasing lateral load applied (e.g. the contact patch location shifted at approximately a 12-kip lateral load). Therefore, a lateral wheel load, in and of itself, does not affect the longitudinal distribution of the vertical load path.

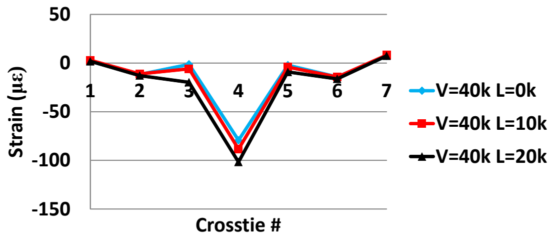

Figure 6. Average vertical rail strains (field and gauge)

Beyond understanding the vertical load path, these vertical rail strains were also used as part of the comprehensive FEM development and calibration process.

The displacement instrumentation strategy showed varied success. The vertical displacements were measured with mini-potentiometers, which proved to be problematic and provided noisy data in the field environment.

The lateral web and base displacements of the rail showed mixed results. Slightly more than half of the potentiometers had clean displacement waveforms with distinct peaks, whereas the others had excessive noise.

The measurements of clip strains were clean and, together with the UIUC FEM, successfully estimated expected clamping forces. Signals of transverse rail base strains were also clear and are being used as validation for the FEM. Most strain gages on the insulator post failed during installation, so different procedures for acquiring these lateral loads are being explored.

The embedment gages showed promising results. Vertical rail seat loads were obtained from the strain data and most embedment gages successfully output clean signals and are fully qualified for further analysis. The surface strain gages showed promise as well. Bending moments at rail seats and tie center can be obtained from the strain data.

FUTURE WORK

Following the July 2012 instrumentation program, UIUC carried out an additional field study in May 2013. This second study consisted of a similar instrumentation program,

In June 2013, UIUC published a YouTube video about the field experimentation program. This video is available at: the following URL: http://www.youtube.com/watch?v=1GGS5lwy2pA&feature=youtu.be

ACKNOWLEDGEMENTS

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KEYWORDS

Concrete crossties, elastic fastening systems, field instrumentation, concrete sleepers, loading conditions, displacements