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Heavy Axle Load Revenue Service Mega Site Testing (2005–2012)

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Summary

Since 2005, the Association of American Railroads and the Federal Railroad Administration have jointly funded a heavy axle load (HAL) revenue service testing program with the following major objectives: (1) determine the effects of HAL traffic on track infrastructure by supplementing test activities performed at the Facility for Accelerated Service Testing with a wider range of track, operation, and climatic conditions; (2) identify potential issues that negatively affect HAL operations, determine their root causes, and develop methods and best practices to address those issues; and (3) test and monitor new technologies, new and alternative track designs and materials, and improved track maintenance procedures intended to mitigate adverse effects of HAL traffic on track degradation.

Transportation Technology Center, Inc. has conducted a number of experiments under this program. Results and findings have been reported to stakeholders and published in more than 50 reports including *Technology Digests* and industry conference proceedings. More importantly, many of the findings and guidelines developed from experiment results have been implemented by North American railroads. Some of the findings include:

Premium rails have shown excellent performance resisting wear and internal flaw growth, but still have a rolling contact fatigue (RCF) issue. Friction control and grinding are both effective to control RCF, but their applications can be optimized. Wide gap weld is a viable rail joining practice, with the benefit of reducing rail plugs while repairing rail defects. Improved designs of insulated joints have extended their life at least three times since 2005, with a minimum life of 1000 MGT achievable with many of these improved designs. For an 8-degree curve, the wood-tie track fitted with elastic fastening systems and screw spikes provided 3 times higher gage strength and 3 times higher lateral rail restraint than the track fitted with the cut spike system. Although not as good as wood ties in terms of measured performance, plastic composite ties have proven to be capable of supporting HAL operations. For concrete tie track, three days of traffic reduced rail neutral temperature (RNT) by 10 degrees from as-installed, and a broken rail and subsequent maintenance activities caused large variation of RNT within at least 250 feet. Plastic covered rail anchors did not provide any benefits in reducing short- and long-term changes in RNT for concrete tie track, nor did they prevent large drop in RNT due to broken joint bars.

Two revenue service mega sites were established for this research: one in the east of the United States on the Norfolk Southern mainline track near Bluefield, West Virginia, and the other in the west of the United States on the Union Pacific mainline track near Ogallala, Nebraska. Both sites are on coal routes with predominately loaded 286,000-pound per car traffic. In comparison, the eastern mega site typically has sharp curves (up to 12 degrees) and steep grades (up to 1.4 percent), wood ties, open deck steel bridges, 20 to 40 mph operating speeds, and 55 MGT per year tonnage, whereas the western mega site typically has shallow curves (1 to 2 degrees), concrete ties, ballast deck bridges, 40 to 60 mph operating speeds, and tonnage of 250 MGT per year.



INTRODUCTION

In 2003 and 2004, the HAL Technical Advisory Group, which consisted of representatives from the railroads in North America, the Federal Railroad Administration, and the Transportation Technology Center, Inc. (TTCI), proposed a “mega” site concept to consolidate field tests at two specific revenue service sites. Consolidation of field tests was intended to improve experiment design and capabilities, foster cost-efficiency, and simplify the coordination and communication between the host railroads and TTCI research team.

In 2004, two mega test sites were established: one in the eastern part of the United States on the Norfolk Southern (NS) mainline near Bluefield, West Virginia, and the other in the western half of the United States on the Union Pacific mainline, near Ogallala, Nebraska. Both sites are in coal routes with predominately HAL traffic. The eastern site typically has higher lateral wheel loads, while the western site typically has higher vertical wheel loads. Additionally, the eastern mega site receives more precipitation than the western mega site.

From 2005 through 2012, TTCI, with help from the host railroads, has conducted and completed a number of experiments at these two mega sites. Some experiments were designed to address safety items associated with HAL operations, such as the derailment potential related to broken rails, weld defects, large wheel/rail forces due to adverse track geometry, and track buckling related to longitudinal stress in continuous welded rail (CWR). Experiments were also designed to examine the effects of HAL on track component degradation, and the effectiveness of new and alternative materials, designs, and techniques developed to minimize negative HAL effects. This digest presents a summary of most experiments completed or in progress.

PREMIUM RAIL PERFORMANCE

A total of 10 premium rail types from six manufacturers around the world were installed at both the mega sites in 2005. The eastern mega site has four test curves from 6.8 to 11 degrees, whereas the western mega site has three test curves of 1 and 2 degrees. Most test rails had hardness values measured just below 400 BHN as installed, but were all work hardened above 400 BHN from traffic.

To date, 365 MGT has accumulated in the test curves at the eastern mega site, and 1,650 MGT has accumulated in the test curves at the western mega site. All test rails have shown excellent wear performance; i.e., natural wear from traffic was not projected as the main reason for future rail replacement, even for the sharp curves. The average natural wear rate from traffic was only 0.02, 0.04, 0.1 in² per 100 MGT, for the 2-, 6.8-, and 10.5-degree test curves, respectively. In addition, no internal flaws have been identified for all test rails.

RCF was found to be the main issue for the premium rail, especially on the low rail running surface. Occurrence of RCF also depended on track curvature. At the eastern mega site, with top of rail (TOR) friction control implemented from the beginning of the experiment, RCF occurred after 250 MGT for the 10.5-degree curves, but was not observed for the 6.8-degree curves until after 350 MGT.

At the western mega site, without TOR friction control, RCF occurred after 300 MGT for the 2-degree curves, but was not observed until after 1,000 MGT for the 1-degree curve.

RAIL LIFE EXTENSION

Two maintenance strategies were found to be effective to address RCF: TOR friction control and preventive grinding. At the eastern mega site, gage face lubrication and TOR friction control have been implemented in all premium rail test curves. With grinding not allowed for the sake of testing, it took 250 MGT for the low rails of 10.5-degree curves to develop RCF (a corrective grinding was done at 275 MGT), and it took 350 MGT for the 6.8-degree curves to develop RCF (a corrective grinding was done at 365 MGT).

Monitoring was also conducted for non premium rails in two groups of curves at the eastern mega site. One group has implemented both gage face lubrication and TOR friction control, whereas the other group has only implemented gage face lubrication. Measurements showed that implementation of TOR friction control reduced vertical wear by approximately 30 percent. In addition, TOR friction control reduced loss of rail metal from grinding operations, suggesting that TOR friction control reduced the occurrence of RCF.

At the western mega site, corrective grinding was used to remove RCF. From 690 MGT following a corrective grinding, however, a 2-degree curve has implemented TOR friction control, while the other 2-degree curve has implemented preventive grinding at an interval of 70 to 110 MGT. Subsequent monitoring showed that as a result of TOR friction control, RCF did not appear until additional 960 MGT was accumulated, compared to 300 MGT without TOR friction control. Preventive grinding was also found to be more effective compared to corrective grinding, reducing the amount of metal removed due to grinding by 3.5 times on a 100 MGT basis.

WIDE-GAP WELDS

Thermite wide-gap welds (WGW) were developed to join two rails with a nominal gap of 2.75 inches. Because of their extra width, WGWs can be used to directly replace most field weld defects and some rail defects without plug rails. This could lead to several major benefits, including fewer welds being performed in the field (a plug rail uses two welds) and less track time for replacing such defects, thus improving train operating safety and reducing track maintenance costs.

In 2005 and 2006, 32 WGWs were installed at the eastern mega site. A 6-year testing effort has shown that WGW is a viable rail joining practice for HAL operating environments. Even without the benefits of preventive grinding (for testing purposes), these welds had a minimum fatigue life of 265 MGT, with the average life projected to be 490 MGT. Spalling and plastic flow were the early signs of surface degradation. When not ground, these surface issues grew into shelling problems that required replacement. The life expectancy of a WGW is expected to be increased when preventive grinding is implemented to remove minor spalling and plastic flow in a timely fashion.

INSULATED RAIL JOINTS

Monitoring of improved insulated joint designs (IJs) has been one of the major experiments at the western mega site. The early experiment (2005 to 2009) compared 48-inch (8-hole) bonded bars with the end post of the joint supported on the tie versus 36-inch (6-hole) bonded bars with the end post of the joint suspended in the crib. Testing efforts showed that the suspended design failed at 330 MGT because of a broken bar (fatigue crack), whereas the supported IJ design had a minimum life of 1,000 MGT (fatigue crack was also the failure mode). Note that average service life of IJs before 2005 was 280 MGT.

In 2011, another 28 next generation IJs were installed at the western mega site to monitor long-term performance of various designs, including IJs with ceramic end posts, hi-modulus bars, fiberglass or improved epoxy, as well as centerline and tapered IJs. Testing and monitoring of their performance is currently in progress.

RAIL NEUTRAL TEMPERATURE

At the western mega site, a test curve was established in 2005 with two types of rail neutral temperature (RNT) devices installed to monitor changes in RNT as a result of traffic, seasonal changes, and track maintenance activities. In addition, this curve has been used as a test bed for evaluating new technologies developed for measuring RNT.

Test results showed that 72 hours of traffic reduced RNT by approximately 10°F from the as installed RNT, and its daily variation was measured to be approximately 5°F at this site. In addition, a broken rail and subsequent bolting, welding, and traffic caused large variation of RNT within 250 feet. For example, at a measurement location 92 feet from the rail break, an immediate drop of RNT due to this rail break was recorded, from 115°F to 56°F, and the daily variation of RNT after bolting, but before welding, was more than 10 degrees.

RAIL ANCHOR (CONCRETE TIES)

In 2007, a test was conducted to monitor the performance of rail anchors designed for concrete ties at three locations with IJs at the western mega site. These anchors are essentially regular rail anchors for wood ties, but with plastic cover to provide insulation between rail and concrete and also to prevent damage to concrete by the anchor.

Test results showed that these anchors did not provide added benefits in reducing short- and long-term changes in RNT, nor did they prevent a large drop in RNT when the joint bars cracked at one of the test locations; i.e., the anchors installed on the concrete ties at IJ locations did not provide additional longitudinal resistance when no apparent longitudinal rail movement was observed. In addition, measurement of fastener toe load indicated little difference in the magnitude of toe load or its change over time between the rail with anchors and the rail without anchors.

CWR/BRIDGE INTERACTION

In 2010, an experiment was started to characterize the interaction between CWR and an open deck steel bridge at the

eastern mega site. The test has a short-term objective to measure CWR/bridge interaction under train traffic and a longer-term objective to measure CWR-bridge interaction due to temperature change.

Under an operating condition with total tractive or dynamic brake efforts less than 100,000 pounds, the dynamic test has shown that the longitudinal rail force and movement of rail, tie, and girder due to traffic are unlikely to cause CWR stability issues in the bridge approach. Rail-to-tie displacement was relatively small (note that elastic rail fastening was used) compared to tie-to-girder displacement. In addition, tie-to-girder displacements on a smooth girder surface were found to be 4 to 5 times greater than that on the girder with rivet heads.

ELASTIC FASTENING SYSTEMS (WOOD TIES)

A test of elastic rail fastening systems was conducted on an 8-degree curve at the eastern mega site. From 2005 to 2010, two types of elastic fasteners were subjected to 260 MGT. Their performance was compared to the standard cut spike system.

Test results showed that the wood tie track fitted with the elastic fastening systems and screw spikes provided 3 times higher gage strength and 3 times higher lateral rail restraint than the track fitted with the cut spike system. Although gage rods were installed in the cut spike zone, they were not required in the elastic fastener test zones. In addition, the lateral deflection of the low rail measured under train operations throughout the cut spike zone was almost twice that measured on the same rail in the elastic fastening system zones. Cut spike uplift of more than 1 inch occurred in almost 4 percent of the spikes in the cut spike zone (five spikes per tie plate). In the elastic fastener zones (four screw spikes per tie plate), none of the screw spikes uplifted much nor fractured during the test.

Eleven out of the 360 rail clips from one type of elastic fastening system fractured during the test period. Results of the laboratory test on the rail clip samples showed that these fractures were incidental.

EFFECT OF MISSING FASTENING ON GAGE RESTRAINT (CONCRETE TIES)

In 2009 and 2010, an experiment was conducted to measure gage restraint of concrete tie track affected by missing/broken fasteners at the Facility for Accelerated Service Testing as well as at the western mega site. A rail fastener provides gage restraint through toe load (holddown force) of its clips on the base of rail as well as through lateral resistance from its insulators against the base of the rail. Missing/broken fasteners reduce gage strength, thus increasing risk of derailment.

The experiment showed that missing/broken field-side clips have less effect on gage restraint than missing/broken gage-side clips, whereas missing field-side insulators had greater effect than missing gage-side insulators. As would be expected, gage-side clips play a much bigger role than field-side clips in preventing gage widening due to rail roll, but field side insulators have a much bigger role than gage-side insulators in resisting gage widening due to rail translation.

In the case where only clips or insulators were missing, it took eight consecutive ties to reduce gage restraint below the allowable limit. When both clips and insulators were missing, however, it took only three consecutive ties to reduce gage restraint below the allowable limit.

COMPOSITE PLASTIC TIES

From 2004 to 2010, two types of plastic ties were tested on a 6.8-degree curve at the eastern mega site. The test ties were subjected to a total of 282 MGT before the test was concluded at the request of NS. The plastic ties tested were capable of supporting HAL traffic with acceptable performance. There were no problems related to track geometry, gage strength, tie plate cutting, cut spike uplift, or fastening system component failure in the test zone. Although gage strength degradation and gage widening were slightly higher in the plastic ties than in the wood ties, the trends were similar. Pilot holes for cut spikes reduced the occurrence of cracks and plastic composite material buildup between the plate and the top of the plastic ties during spike insertion.

Test results have shown that plastic ties tend to have lower bending stiffness and lower toughness, when compared to wood ties. Different material formulations and manufacturing processes may affect tie toughness, because plastic ties from only one manufacturer broke. After 212 MGT, one tie fractured near its center at a void in the plastic composite material. Near the end of the test, four more ties cracked along the cut spike plane as a result of a wedging force created as the spikes were inserted into hard synthetic tie plugging material.

BRIDGE APPROACHES

Bridge approaches often require frequent track maintenance, especially under HAL traffic. As a major part of the HAL mega site testing program, TTCI has conducted extensive research regarding root causes of problems and remediation methods. Testing has been performed in revenue service at both mega sites.

At the eastern mega site, the root causes of typical bridge approach problems were determined to be cross level differential support over approximately 5 to 10 ties at the ends of bridges, because of skewed abutments and large changes in lateral track stiffness/restraint from bridges to their approaches. A remedy proven effective is to change from open deck to ballasted deck to address the root causes of problems. In 2007-2008, this method was implemented on two bridges located in sharp curves. To date, these bridges and their approaches have performed well under HAL traffic, and they have not experienced any of the past problems.

At the western mega site, the root causes of bridge approach problems were determined to be high stiffness and low damping for tracks on bridges. With standard concrete ties and ballasted deck concrete bridge spans, track modulus on the bridge was often measured more than twice as high as that in the approaches. An effective remedy is to reduce stiffness and increase damping, thus reducing impact forces exerted on the track. Two methods have been implemented for two different bridges: (1) replacing standard concrete ties on a bridge with

concrete ties fitted with rubber pads on the bottom of ties and (2) using ballast mats between the bridge deck and the ballast. Since their separate installations in 2007 and 2009, track performance was much improved for these two bridges and their approaches, and both methods brought significant economic benefits for HAL and high tonnage lines.

BALLAST DEGRADATION

In 2010, a test was initiated in conjunction with another project "HAL Track Substructure" to investigate ballast degradation under HAL coal traffic at the western mega site as a result of ballast breakdown and coal fine accumulation. The test was started with new ballast materials from four separate quarries. Testing included monitoring ballast particle breakdown with tonnage and correlating the particle size distribution to the strength and deformation properties of the various materials. Measuring the relationship between gradation and strength allows a better understanding of the behavior and life cycles of different ballast types.

Preliminary results indicated that the as installed gradations for all ballast types were all within the recommended limits. The data also showed that after 234 MGT, one ballast type has degraded at a significantly higher rate. Nevertheless, testing is ongoing in order to achieve the objectives described above.

CROSSING DIAMOND

From 2006 to 2009, TTCI monitored the performance of a diamond crossing at the western mega site. Component breakage and rapid rail running surface degradation required frequent maintenance. The diamond was replaced approximately every 300 MGT on the track carrying higher tonnage (i.e., 420 MGT of total traffic).

Investigation has shown that the root causes of the problems are high impact forces resulting from running surface discontinuities and degradation, high contact stresses between castings and plates, inadequate resilience and damping to attenuate high impact forces, and irregular deformation due to abrupt changes in track stiffness caused by the large castings and multi-tie plates. At 25 mph, test results showed vibration of the diamond crossing was at least 3 times as high as that of the adjacent open track.

Several methods have been implemented to improve the performance of the diamond, including installing expansion joints and ramped up running surface profiles, installing rubber pads under tie plates, and placing ties longitudinally in higher tonnage track. However, these methods have not led to improvements to significantly reduce extensive maintenance requirements, because they have not addressed flangeway gaps and joints, which are the primary reason for high impact forces at crossing diamonds.

FUTURE

Research and testing activities under the HAL mega site testing program will continue. Furthermore, in 2013, a northern mega site will be established to address cold weather HAL track infrastructure issues.

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