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Reducing the Stress State of the Railroad through Testing at FAST

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Summary

There have been significant changes and additions at the Facility for Accelerated Service Testing (FAST) program in the past year. The railroad industry has again demonstrated its commitment to FAST by providing materials and support. This *Technology Digest* (TD) will provide an overview of the changes and an update on test results. Subsequent TDs will provide details on tests and experiments.

A different train is now operating at FAST. The Union Pacific (UP) Railroad provided 110 current generation aluminum coal cars for use at FAST. The new cars allowed the retirement of the 40-year-old steel cars that had been used at FAST since 1988. The new train should enhance safety, increase productivity, and reduce maintenance costs. Norfolk Southern, UP, and CSX have provided the use of modern, high-horsepower, fuel-efficient EMD SD 70M and SD 70 MAC locomotives. These locomotives replace older, less efficient locomotives. Fuel consumption has been reduced by about 20 percent, and the new locomotives facilitate unmanned train operations.

New track and structures experiments have been added. A new test of rail steels, referred to as the “super premium rails” developed to provide better wear and rolling contact fatigue resistance, was begun. The test includes high-hardness, wear and fatigue resistant rails provided by manufacturers from around the world, as well as an experimental rail developed in a collaborative effort between Transportation Technology Center, Inc. and the University of Pittsburgh. As a cost-effective alternative to premium rails, intermediate-hardness rails are also being tested.

A riveted steel bridge span built in 1912 replaced a 40-year-old welded steel span. The effects of heavy axle loads on the older span will be studied. Plans are underway to install a new generation advanced bridge design referred to as the hybrid composite bridge. Efforts are proceeding to reduce the stress state of the track and structures using innovative materials and designs. New design heavy-duty concrete ties and conventional concrete ties (with and without rubber pads and innovative foundation designs) were installed as part of tests to improve the strength and lower the impact forces exerted on track. Individual components that could become parts of a continuous (mainline) surface switch were installed. The components will provide information to further the development of a switch that would result in a smoother running surface for the mainline side of the turnout (which carries most of the traffic).

Long-term experiments at FAST continue. Head-repair thermite welds, track substructure tests, concrete bridges, wood and concrete ties and their fastening systems, rail joints, and turnouts are being evaluated. Implementation of computer-controlled, unmanned train operations, as well as machine-vision based vehicle inspection systems are progressing.

INTRODUCTION

North American railroads have experienced significant traffic growth over the past 20 years. Some studies have projected that rail freight traffic will double in the next 20 years. Railroads are continuing to develop cost-effective ways to safely increase capacity. One strategy that North American railroads have used is to raise the allowable axle loads for freight cars. Research funded by the Association of American Railroads (AAR) and the industry has been helping minimize the adverse effects of increased axle loads. Achieving lower unit costs per ton mile of freight carried continues to be one of the efficiency goals of the industry.

Since 1988, testing at FAST has been a mainstay in the AAR heavy axle load research program, and it continually evolves to meet the changing needs of the industry. There have been significant changes and additions to FAST in the past year.

The primary goal of FAST is to develop a quantitative understanding of the impact of heavy axle loads on the safety and economics of track and structures. The FAST facility provides full-scale proof testing of materials and designs that are intended to counteract the effects of increased axle loads before their introduction into revenue service. This TD will provide an overview of recent changes, new tests, and an update of test results. Subsequent TDs will provide details on tests and experiments.

A different train (Figure 1) is now operating at FAST. The UP provided 110 current generation 315,000-pound gross rail load aluminum coal cars for use at FAST. The new cars allowed the retirement of the 40-year-old steel cars that had been used at FAST since 1988. Component failures and maintenance costs for the old cars were increasing, and the cars were not representative of the current coal fleet.

Figure 1. Train at FAST

The new train should enhance safety, increase productivity, and reduce maintenance costs. Norfolk Southern, UP, and CSX have provided the use of modern, high-horsepower, fuel-efficient EMD SD 70M or SD 70 MAC locomotives. These locomotives replaced older, less efficient GP-39 and GP-40 locomotives. Fuel consumption has been reduced by about 20 percent since the introduction of the new locomotives. The modern control systems on the locomotives also facilitate the unmanned train operations that are now standard practice at FAST.

The experiments and tests at FAST have evolved to meet the needs of the industry. Though the types of components being tested may be similar to those being tested several years ago, the actual components being tested reflect current industry needs as railroads continue to improve the safety and efficiency of their businesses. The next sections describe current tests and provide summaries of recent results.

1912 Riveted Steel Bridge Span

Extending the service life of bridges is one of the primary goals of FAST. One of the newest tests is an evaluation of one of the oldest components ever tested at FAST. A riveted steel bridge span built in 1912 (Figure 2) was installed early this year, replacing a 40-year-old welded steel span. The riveted span is typical of hundreds of spans currently in service. Better understanding of how these spans react to heavy axle loads will be valuable as railroads make decisions on upgrading or replacing them to accommodate heavier cars.

Figure 2. 1912 Riveted Steel Span being installed at FAST

Preliminary strain data collected at FAST indicates that there is more fatigue activity in the 1912 span than there was in the welded span it replaced and more than it experienced when it was in revenue service. This information can be used in fatigue models to estimate remaining bridge life.

The top lateral braces in the riveted span were heavily corroded in places. Girder deflections were measured with the bridge in the as-arrived condition and after repairs were made.

As expected, deflections decreased after the bracing was repaired (though it was not excessive in either case). Several of the braces that were partially corroded have cracked in the 90 million gross tons (MGT) since installation. They were repaired with bolted splices; none of the splices have failed.

New Rail Tests

Rails are the single most valuable track asset to the railroads. The most frequently replaced rail is curved rail. In 2008, more than $3 billion was spent by the U.S. railroads to renew and maintain rail. Thus, increasing the service life and decreasing the life-cycle costs of modern rail steels is of great importance to the railroads. In 2010, nearly 2,000 track feet of new state-of-the art rail was installed in two 5-degree curves at FAST for performance evaluation under heavy axle loads. Testing in the controlled and well-maintained environment of FAST allows accelerated testing while minimizing test variables in a safe environment.

The latest test at FAST includes eight high-hardness (413 HB average) premium rails developed to provide better wear and rolling contact fatigue (RCF) resistance from manufacturers in North America, Europe, and Asia. In addition to commercially developed rail, an experimental rail developed in a collaborative effort between Transportation Technology Center, Inc. and the University of Pittsburgh and produced by Voestalpine will soon be added to the test. The super premium rails were installed in a 5-degree nonlubricated curve.

As a result of heavy axle loads, all rail types are showing shallow RCF after 90 MGT. There are minor differences in rail wear, but it is too early in the test to make meaningful comparisons.

Intermediate-hardness (340 HB average) rails from several manufacturers were installed in a lubricated 5-degree curve, and are being tested. These rails are intended to provide satisfactory performance under moderately demanding conditions, at a lower cost than premium rail. All of the intermediate-hardness rails are showing shallow RCF. There is less wear on the intermediate-hardness rails in the lubricated curve than on the premium rails in the nonlubricated curve, again demonstrating the effectiveness of gage face lubrication in reducing rail wear.

Improved Strength Track

More and more is being demanded of the track structure. The trend is toward heavier, faster, longer trains. Maintenance windows will get even shorter as traffic increases. Innovative types of track structures are needed to meet the increased demand. New design heavy-duty concrete ties and state-of-the practice conventional concrete ties were installed at FAST as part of a test to evaluate improved strength track. The heavy-duty ties (Figure 3) have larger vertical and lateral footprints than conventional ties and have integral under-tie pads. These features should reduce surfacing requirements and increase resistance to track buckling.

Figure 3. Improved Strength Track with Heavy-Duty Ties

Some of the more conventional concrete ties being tested also have pads attached to the bottoms of the ties, which are intended to reduce the need for track maintenance. The first 140 MGT of testing shows that the heavy-duty concrete tie track is indeed very stable, but some of the ties have developed minor cracks. Modifications are being considered. Also, there are obvious differences in ballast movement and churning between tie types. The ballast in the heavy-duty tie zone has been shown little movement, while the ballast in one of the conventional tie zones has gradually moved to the inside of the curve during train operations. The zone had to be regulated to move the ballast back to the outside of the curve after about 80 MGT, and the ballast movement continues. The composition and stiffness of the under-tie pads appears to be the major factor. The zone with the stiffest pads has shown the most ballast movement.

Special Trackwork

Stronger track is one way to accommodate heavier cars. Another way is to reduce the dynamic loads those cars produce. Removing or lessening the rail discontinuities associated with special trackwork is one example. Carrying a car on its wheel flanges over a smooth surface instead of on its wheel treads over a gap in the rail can dramatically reduce load impacts. Some of the preliminary work on flange bearing crossing diamonds was done at FAST. More recently, flange bearing turnout frogs have been tested. The tests showed that dynamic forces on the mainline side of the turnout were reduced by about 70 percent compared to conventional turnout frogs, and cars can be safely operated over the diverging route on flange bearing turnout frogs at speeds up to 15 miles per hour.[1]

The next step is to test continuous (mainline) running surface switch points. The concept being considered is based on earlier vertical switch designs. Cars traversing the mainline side of a turnout would not have to transition from switch point to stock rail, or vice versa. An example of the intended use is a set-out track where diverging traffic is extremely limited. Individual components that could become parts of a continuous running surface switch are being tested at FAST. Testing the components will provide information that will further the development of a prototype switch.

Rail Welding

Second generation thermite, head-repair welds (improvements based on earlier tests at FAST) have accumulated up to 100 MGT. Weld performance has been good so far with no weld removals. For comparison, approximately 40 percent of the earlier head-repair welds had been removed by 100 MGT. Repair welds were recently installed over electric flash butt welds, and welds will be installed in rail directly over concrete ties in summer 2010.

Another change at FAST has been in maintenance rail welding. Previously, thermite welds were used for all day-to-day rail welding. Thermite welds are relatively easy and inexpensive to install, but typically have lives substantially shorter than rail. UP donated an in-track electric flash butt welder for use at FAST. The welder will reduce the number of thermite welds in track and should reduce the number of service failures.

Concrete Bridges

A new type of concrete bridge is being tested at FAST. The hybrid composite concrete (HCB) bridge is a tied-arch design that reduces the weight of a span. The first one tested at FAST was a 30-foot bridge span. Preliminary testing showed that its design was capable of supporting 315,000-pound cars, but the original deck was insufficient for heavy axle loads. The deck was replaced, and the span has accumulated 240 MGT since then. It remains in track and has performed as expected, with deflections similar to reinforced concrete. The 30-foot span will be removed in fall 2010 concurrent with the installation of a new, 42-foot HCB span. The original 30-foot box-girder span will be reinstalled, while the 42-foot high-strength concrete span currently in track will be replaced with the new HCB span.

Other concrete bridge spans being tested at FAST are performing well through 885 MGT. In summer 2010, the track and ballast will be removed from one of the bridges and ballast depth reduced from 12 to 8 inches for the first of a series of tests on the effects of ballast depth. Earlier tests showed that using tie materials and ballast mats to modify track modulus is an effective method of lowering the stress state and reducing track maintenance requirements.[2]

Wood and Concrete Ties and Fastening Systems

In 2008, over 1,000 hardwood, softwood, and concrete ties were installed. The softwood ties with cut-spike plates have shown the least gage restraint and the most gage widening in the wood tie test after 255 MGT. Gage restraint provided by hardwood ties with elastic fasteners has been similar to that provided by concrete ties. Component failures have also been documented. Approximately 12 percent of the screw spikes in one of the test zones had cracked 2-3 inches below the spike head through 230 MGT; those spikes have been replaced with high-strength screw spikes. About one-third of the insulators in one of the concrete tie zones had cracked through 210 MGT. The insulators have been replaced.

Computer-Controlled, Unmanned Train Operations

The computer control system was moved to one of the new locomotives, and most train operations are now without anyone in the cab. The test controller activates the automated system, which then controls throttle position and can stop the train in an emergency. The test controller can also stop the train remotely.

CONCLUSION

FAST continues to provide the industry with a valuable facility for the evaluation of innovative track components and designs. It provides a facility for proof testing of components with the potential to provide improved performance, but are considered too risky to test directly in revenue service. Tests are regularly updated at the direction of railroad committees to assure that the program meets the changing needs of the industry.

In addition to the cars and locomotives noted earlier, track components and other equipment are regularly donated by railroads and suppliers, demonstrating the railroad industry's commitment to FAST.

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