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Slab Track Long-Term Performance and Behavior at FAST

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Summary

Transportation Technology Center, Inc. recently examined the slab track at the Facility for Accelerated Service Testing (FAST) to assess long-term performance. Slab track has been used in North American freight operations for tunnels and other special applications. It has been proposed for use on bridges and other areas where minimal maintenance time is available. It has also been proposed for tracks that carry heavy freight traffic that must also be maintained to track geometry standards for higher speed passenger operations.

For the first 10 years, the slab track was nearly maintenance free as intended. But after nearly 500 million gross tons of testing under heavy axle load (HAL) traffic, some degradation in the independent dual block track (IDBT) section of the slab sections has required maintenance. The direct fixation slab track (DFST) section has required less maintenance. Results from periodic measurements, FAST maintenance records, and recent inspections of the slab track are as follows:

- IDBT section of slab track is showing wear of rubber boots/pads between tie blocks and main portion of slab. Wear is causing increase in dynamic gage widening under traffic, as measured by the Track Loading Vehicle.
- IDBT section has required replacement of field side rail insulators and a few fasteners. As these are not a common standard design, special order components are required.
- IDBT section is showing several cracks in the primary slab; however, they are not a structural concern at this point.
- DFST section is showing only slight cracking of the primary slab.
- DFST section has some broken insert bolts. These are difficult to remove in order to install replacements.
- DFST section has needed some replacement of fasteners. Because these are a common standard, replacement is straightforward.
- Instrumented wheelsets have quantified that vertical and lateral wheel/rail forces are typical of HAL cars operating at FAST.

This research has been conducted as part of the Association of American Railroads' Strategic Research Initiatives Program to investigate improved track structure for use in bridge and tunnel applications. Portland Cement Association and Federal Railroad Administration originally designed and built the slab track at FAST in 2003.

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INTRODUCTION

Slab track has been used in North American freight operations for tunnels and other special applications. It has been proposed for use on bridges and other areas where minimal maintenance time is available. It has also been proposed for tracks that carry heavy freight traffic that must also be maintained to track geometry standards for higher speed passenger operations.

Use of slab track is prevalent on high-speed passenger lines internationally. The Shinkansen high-speed lines in Japan are almost entirely slab track. European and Chinese high-speed lines have also constructed large sections of slab track, and it is also in use on some freight lines in Europe.

Slab track offers the following potential benefits:

- Lower routine maintenance costs
- Higher availability for train operations due to reduced routine maintenance
- Higher lateral track stability
- Improved load distribution
- Reduced under-clearance in bridge applications

Potential drawbacks are:

- Higher initial construction cost
- Higher repair cost and time outage when damaged
- Not enough operation experience for heavy freight or commuter/passenger rail bridge decks

Two types of slab track construction were installed at FAST in 2003. The Portland Cement Association (PCA) and the FRA originally installed the slab track to explore the possibility that it could carry heavy haul freight traffic while maintaining the strict track geometry requirements for higher speed passenger traffic. More recently, some freight railroads have expressed interest in the long-term performance of slab track, for both existing applications such as tunnels, as well as for potential applications such as bridges.

A pure slab with the rail fasteners attached directly to the slab is known as direct fixation slab track. For DFST, the construction is generally “top down,” with all of the track material attached and the track alignment set. When casting the slab, care is taken to ensure that the rail and hardware are not disturbed because this would affect the alignment.

The other construction at FAST is known as independent dual block track, which consists of using dual block ties holding the rail placed on a strong subgrade foundation. The concrete slab is cast around the tie blocks, locking them into place.

Slab Track at FAST

Both types of slabs were installed at FAST on the High Tonnage Loop (HTL) to determine their ability to maintain track geometry for high-speed track class while supporting HAL.[1] Total length of both sections of the slab track (Figure 1) is 550 feet and is on a 5-degree curve with 4 inches of superelevation. Results of the long-term performance evaluation are presented in this digest showing long-term component behavior and load environment of the slab track. (References 1, 2, and 3 contain results from the PCA and FRA experiments on this slab track.)

Figure 2 shows a portion of the IDBT section. Note the deterioration of the rubber material between the tie blocks and the main portion of the slab. In some areas, the wear has been sufficient to allow increased dynamic gage widening under traffic. Also note some cracks in the concrete slab. Many of the cracks originate from the corners of the tie block recesses. These cracks do not appear to be working or widening and do not seem to pose any structural concerns at this point.

This portion of the IDBT slab track has also required some maintenance of fasteners and insulators. The insulators on the field side have all been replaced, and a few of the fasteners were replaced.

Figure 1. DFST Slab Track at FAST

Figure 2. Independent Dual Block Tie Slab Track showing Deterioration of Rubber Boots around Rail Seat Blocks

In the DFST portion of the slab track, a few of the elastic fasteners have been replaced, and a few of the anchor bolts have broken. This is not prevalent. Figure 3 shows a broken anchor bolt in the DFST portion of the slab track. To install a new anchor bolt, the lower portion of the broken bolt must first be removed from the embedded insert. Removal must normally be accomplished by reverse tapping the remaining portion of the bolt.

In a few locations, commonly used elastic fastener clips were replaced because they were loose or broken. Figure 4 shows a portion of the DFST at FAST.

Figure 3. Direct Fixation Slab Track showing Broken Anchor Bolt

Figure 4. Direct Fixation Slab Track

Wheel Load Environment

Testing performed with instrumented wheelsets (IWS) provides information concerning variation in wheel load as the wheel travels across a segment of track. One advantage of IWS data is that the data is continually being acquired, providing a complete picture of the dynamic variation in load as a vehicle travels over the track. However, IWS will not provide specific data concerning the load variations from car-to-car. This must be done with rail-based instrumentation. The IWS data provides the dynamic spectrum of load being input into the track structure by a typical car, which is extremely useful information and is not available when using rail-based instrumentation.

Available IWS data across the HTL concrete slab track has been acquired from testing in years from 2003 to 2005 and during 2011 and 2012. Results have been consistent from testing with IWS on different 315,000-pound coal cars during these years (see Figures 5 through 8 in the next section). Testing with IWS-equipped cars occurs with a range of speeds so that data is available for that range of speeds. This has occurred over the years of the testing. The results are presented for all speeds for the operations of the test trains, with the data for 40 mph chosen for additional examination. Note that 40 mph is the typical operating speed for the HAL train at FAST. IWS data was collected per standard operating practice at FAST with a minimum sample rate of 500 Hz and low-pass filter of 100 Hz.

Cumulative Tonnage on Slab Track by Year

The total tonnage (million gross tons) accumulated on the slab section by year where IWS are available is:

- 2003 – 2.0 MGT
- 2004 – 61.9 MGT
- 2005 – 137.8 MGT
- 2011 – 393.8 MGT
- 2012 – 470.1 MGT

Data for All Speeds

Figure 5 displays the data for average vertical wheel loads of the IWS test runs for all test speeds and several years that the concrete slab test section has been in service.

Average wheel loads show the effects of superelevation and train speed. Nominal superelevation is 4 inches. Balanced speed for this curve is about 34 mph.

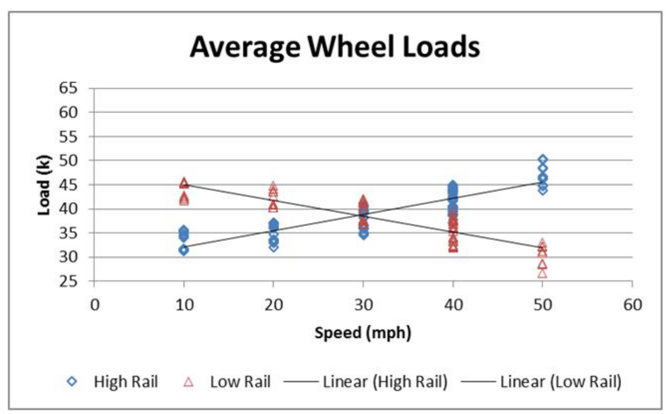

Figure 5. Average Wheel Loads (High Rail and Low Rail) for All Test Runs

Design guidelines for slab track in North America are provided in Chapter 8, Part 27, of the AREMA *Manual for Railway Engineering*.[4] These guidelines recommend using the same impact load used for concrete ties in Chapter 30. Concrete ties perform a similar function with the same materials, and there is a comparative wealth of experience with them.

Figure 6 shows maximum vertical wheel loads based on the speeds of the test train.The maximum wheel loads display a slightly different behavior than the average wheel loads. The maximum wheel loads increase as speed increases, which is in line with most of the design recommendations. IWS data can also be used to show how the concrete slab track is performing on a long-term basis. Examination for the average and maximum wheel loads does not provide a complete picture. The examination of the available data by year provides a better perspective of the long-term performance of the concrete slab track.

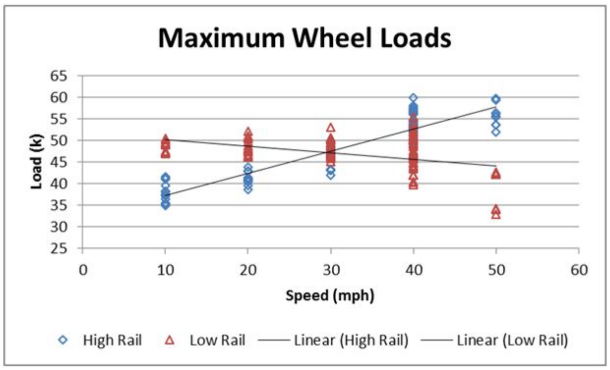

Figure 6. Maximum Wheel Loads for All Test Runs

Data at 40 mph by Year

The available IWS data runs were examined to see which data would be most available to provide a comprehensive picture for the years the concrete slab track has been in operation. From the data, the speed of 40 mph was chosen since more data was available at that speed for all of the years, and 40 mph represents the typical operating speed of the test train at FAST, which best represents actual loads experienced over the years. The data for 40 mph was analyzed in a similar fashion as the other data, but was kept separate by years to see if any trends were noticeable in the performance of the concrete slabs.

Figure 7 shows that since the concrete slab track has been in place, the average load (Figure 7) at 40 mph has remained very consistent. On the other hand, Figure 8 shows that the maximum wheel loads have increased slightly. Over the years, the approaches to the slab track have required more geometry maintenance than the adjacent open track. The maximum wheel loads tend to increase because of the track irregularities and result in higher forces due to vehicle dynamics. The ratios of the maximum wheel load to the average wheel load were calculated from the instrumented wheelset data for each run. The ratio for several years of testing increased from 1.26 in 2003 to 1.38 in 2012.

Note that this ratio is only part of the total impact load that should be considered in design and evaluation of slab track. Additional factors include the effects of wheel defects, rail surface anomalies (e.g., bolted rail joints and corrugated rail), and load variations from car-to-car due to overloads and imbalanced loads.

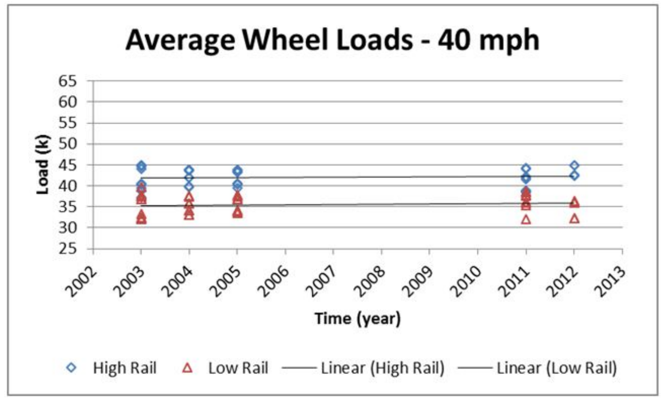

Figure 7. Average Wheel Loads by Year for 40 mph

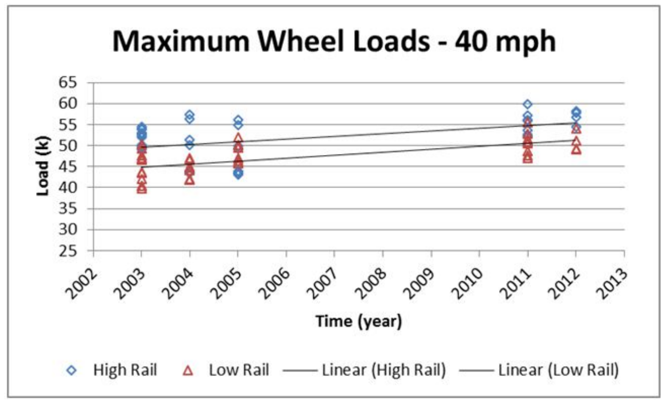

Figure 8. Maximum Wheel Loads by Year for 40 mph

CONCLUSION AND FUTURE WORK

After 10 years and nearly 500 MGT of testing under HAL traffic at FAST, the slab track has been nearly maintenance free. Recently some component replacement has been performed on one of the two slab track sections.

Proposed future work includes re-characterizing track stiffness, lab tests of rubber boots, pads, and clips, and measuring dynamic responses.

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