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**Federal Railroad
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Research
Results

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Bridge Approaches and Track Stiffness

SUMMARY

Over time, it is not uncommon for a dip in the track to develop off the end of a bridge—on the bridge approach, as seen in Figure 1. This dip, or bump at the end of the bridge, is often a rough-riding spot and one that requires resurfacing at more frequent intervals than does the rest of the track. A commonly held belief is that this dip in the track is caused by dynamic wheel forces resulting from wheel loads crossing an abrupt change in stiffness between the track on the bridge and the track off the bridge. Figure 2 shows one case of the measured difference in track stiffness (or track modulus) between the track on a ballast deck bridge and the track off the bridge.

Numerous attempts have been made to eliminate the bridge approach track dip by reducing the track stiffness difference or by creating a more gradual stiffness transition; yet none of these have worked to any great degree. This inability to eliminate the bridge approach problem prompted a study to examine the track stiffness difference concept to determine why its past application had been unsuccessful.

Five different methods were employed to evaluate the effect of track stiffness difference in causing bridge approach track settlement and adversely affecting ride quality, ranging from the most technically sophisticated to the most basic. The results from all five pointed to the same conclusion—that changes in track stiffness at a bridge end have no practical effect on track settlement or ride quality at a bridge approach.

Figure 1. Track settlement at a bridge approach

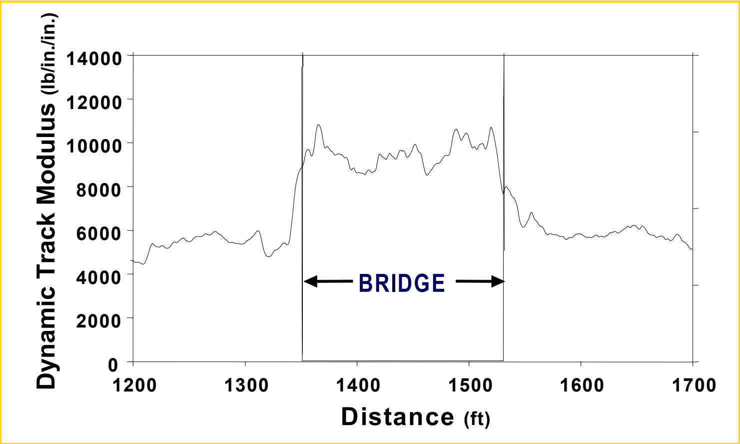

Figure 2. Track stiffness change at a bridge approach. Measurements are averaged over a 30-foot moving window.

BACKGROUND

Bridge approaches (the approximately 50 feet of track adjacent to a bridge) are a common source of poor ride quality and often require frequent resurfacing. The source of the problem is often said to be the difference in stiffness between the stiffer track on the bridge and the less stiff track off the bridge.

Many attempts have been made to remedy the bridge approach problem by trying to reduce abrupt stiffness change. These attempts have included increasing track stiffness on the approach by using gradually longer ties or by installing a concrete or asphalt pad below the ballast. Attempts to reduce the track stiffness on the bridge include installing rail seat pads. None of these methods have produced much success.

The Federal Railroad Administration (FRA) has initiated a study to find effective and affordable methods for remedying ride quality and track settlement problems at bridge approaches and other track transitions—locations where track construction changes, such as at bridges, turnouts, road crossings, and track crossings. This Research Results presents the first product from the study.

THE TRACK STIFFNESS DIFFERENCE THEORY

As normally built, track on a bridge is relatively stiff, being supported by a rigid bridge structure. Track off a bridge is supported by an earth subgrade, which permits more deflection when subjected to the same load. As a loaded wheel rolls over the end of a bridge and passes from the stiffer track on the bridge to the less stiff track off the bridge, an abrupt difference in vertical deflection occurs, which creates a bump in the track—a track surface deviation.

As is well known and documented, track surface deviations cause dynamic loads or impacts when trains pass over them, and those higher loads increase track settlement.

The validity of the track stiffness difference theory is apparent, but the magnitude of its effect needs to be explored, and that is what was done using the five methods described below.

COMPUTER MODELING

Figure 3 shows results of modeling the vertical dynamic forces below the ties when 286,000-pound freight cars cross a 10,000 to 2,000 (pounds/in/in) stiffness change (between tie 192 and 193) at 50 mph. The graph shows a force increase on the bridge end, with a following decrease adjacent to the bridge abutment, leveling off to a value somewhat below that on the bridge by the third tie (no. 195) from the bridge end. In the approximately 13 feet past the bridge end shown in the graph, no forces are higher than nominal (or near static) level.

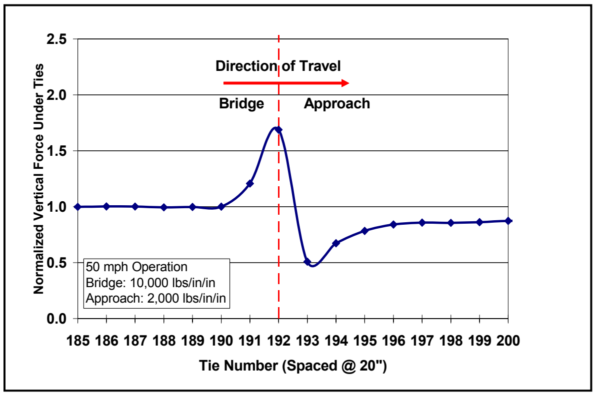

Figure 3. Calculated vertical tie forces from crossing a 10,000 to 2,000 (pounds/in/in) stiffness change. 1.0 on the vertical scale equals the static wheel load on the bridge.

WHEEL FORCE MEASUREMENTS

Data were examined from vertical force measurements made with instrumented wheelsets on the Northeast Corridor between Washington and New York. Figures 4 and 5 are representative examples of data at bridges. Each shows forces, filtered at 50 Hz, over a 400-foot section of track, with the bridge locations marked below the graph. The static wheel load is about 17,000 pounds. The train is running from left to right, in Figure 4 at 108 mph and in Figure 5 at 88 mph.

In both cases, the forces before the bridges, over the bridges, and past the bridges remain nearly steady, generally oscillating within +/-15 percent of static wheel load (up to about 20,000 pounds), which would be considered the nominal dynamic force range when traveling at these speeds. In other words, the forces generally remain within what could be called the noise level (marked by the red horizontal line).

The figure shows that if the bridge locations were not marked, there would be no indication from the force measurements that a deviation or change of any kind was present in the track.

According to the railroad, no alterations were made to the track to change stiffness on the approaches or on the bridges. Similar results were found at other bridge locations.

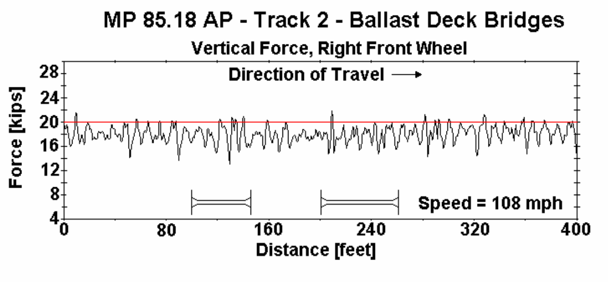

Figure 4. Vertical wheel-rail forces at two ballast deck bridges north of Baltimore, MD. The bridges are marked between the 100 to 145 and 200 to 280-foot points.

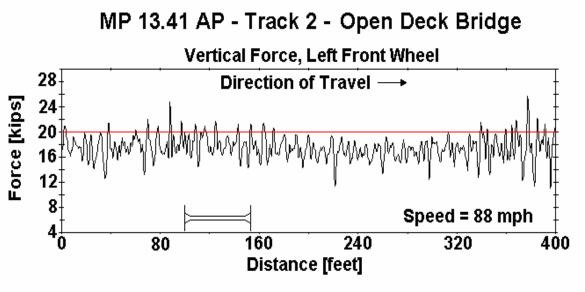

Figure 5. Vertical wheel-rail forces at an open deck bridge at Chester, PA. The bridge is marked between the 100 and 150-foot points.

EXAMINATION OF BRIDGE APPROACH SETTLEMENT

A limited examination of bridge approach settlement showed variation in the approach profile patterns. Profiles similar to that shown in Figure 6 were common, in which top-of-rail elevation near the bridge was sometimes lower than in track farther away, but often not. While not conclusive, these observations indicate that bridge approaches often do not settle at a much greater rate than the rest of the track does, which suggests that vertical forces on bridge approaches are often not significantly greater than typical. (The increased settlement shown on the bridge ends is consistent with the higher forces shown in Figure 3 at the last two ties on the bridge.)

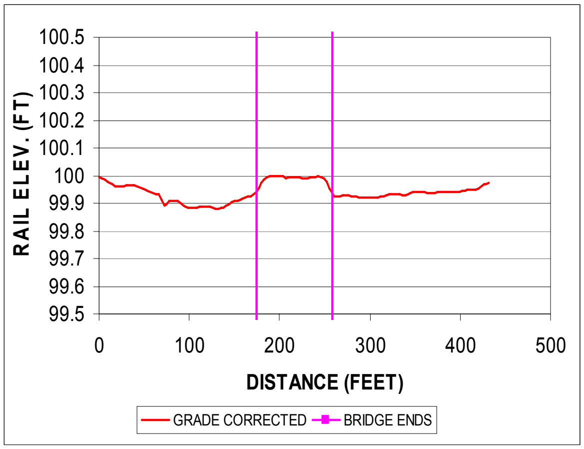

Figure 6. Top of rail profile at the ballast deck bridge with stiffness data shown in Figure 2. Vertical lines near the 170 and 260-foot points indicate bridge ends.

SIMPLIFIED ANALYSIS

The track stiffness difference theory can also be examined using readily available track and beam deflection equations, along with some basic railroad maintenance guidelines.

Figure 7(a) shows the change in deflection from a 286,000-pound freight car crossing a 2,000 to 10,000 (pounds/in/in) change in track stiffness. As shown, the elevation difference is 0.15 inches (calculated from the beam-on-elastic-foundation track deflection equation). However, the rail cannot bend abruptly, so the actual occurrence in track resembles Figure 7(b), a ramp.

The ramp is 0.15 inches high, but its length is needed to define the slope (and thus the severity) of the bump. Using simple beam deflection equations, a likely shortest length can be roughly estimated by assuming a fixed end beam, which is actually more rigid than rail in track, but with no support between its ends, which is clearly more severe than the real case. The result is illustrated in Figure 7(c), which shows that the rail requires about 5 feet to make this bend. Thus, under load this stiffness difference creates a ramp in track about 0.15 inches high and 5 feet long. How severe is this?

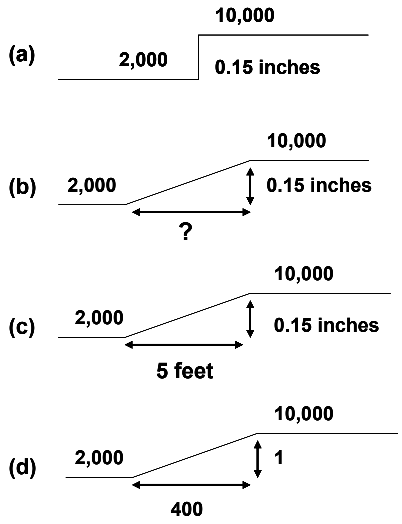

Figure 7. How an abrupt 2,000 to 10,000 change in track modulus appears in track.

Figure 7(d) shows it is equivalent to a 1 in 400 ramp. By comparison, the surface runoff criteria for one large railroad show that a runoff of 1 in 331 is sufficient to create a smooth ride at 60 mph. Thus, the example stiffness bump would allow an equally smooth ride at about 70 mph.

THE TRAIN RIDE TEST

When traveling over recently well-surfaced track at bridges (either open deck or ballast deck), it will be noted that no vertical roughness can be felt, and only a change in sound will be apparent while traveling over the bridge. Thus, the change in stiffness clearly has no effect on ride quality. Regarding vertical force level, the car suspension can filter out forces at frequencies which could transmit to the track, so no clear conclusion can be made about this aspect. It would, however, raise the question of whether forces large enough to cause abnormally greater track settlement could be generated when not even a slight vertical sensation is apparent from inside a passing train.

CONCLUSION

Regarding the magnitude of dynamic wheel-rail vertical forces on a bridge approach produced from crossing a track stiffness change, this analysis indicates that if they occur, these forces are not large enough to be sensed aboard a passing train or to be measured by instrumented wheelsets. Both simple analysis and computer modeling indicate that none are likely to be present. Observations of track profile at bridges indicate that approach settlement is often not greater than in track farther away, which suggests that these approaches are not subjected to higher forces. Thus, the evidence indicates that changes in track stiffness have no practical effect on ride quality or on track settlement at bridge approaches.

FOR FURTHER RESEARCH

A full report covering this phase of research will be available in the future. Subsequent work will include further examination of the factors that affect track settlement at bridge approaches. Work will also include searching for effective and affordable methods for providing and maintaining smooth transitions between the track on and off a bridge.

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KEYWORDS

Bridge approach, track stiffness, track deflection, track modulus