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The Effect of Track Cant on Vehicle Curving: In-service Site Selection & Analysis Part II of III

Harry Tournay, Muhammad Akhtar, Sabri Cakdi, Kenny Morrison

Summary

A revenue service test site was chosen to verify conclusions drawn from a theoretical study and limited tests conducted at the Transportation Technology Center (TTC) near Pueblo, Colorado. Transportation Technology Center, Inc. (TTCI) identified the site as having the following suitable characteristics:

- Relatively tight curvature to maximize the lateral components of the coupler forces and the influence of these forces on wheel/rail forces
- Appreciable grade where all locomotives in the train are operating consistently at maximum power, tractive effort and, consequently, constant speed
- Relatively consistent train configurations with predominantly similar cars so that results from the instrumented cribs could be analyzed statistically

In analyzing the site requirements, a review of current superelevation practices was made, and it was concluded that some railroads have superelevation design practices inducing predominantly excess cant conditions. Theoretical studies suggest that balance-to-cant deficiency conditions are preferable.¹

This *Technology Digest* (TD) is the second of three TDs reporting the effect of superelevation on vehicle/track interaction.

The first TD reports on wheel/rail forces developed from theory and from limited parametric testing conducted (at the TTC) at both balanced and imbalanced speed operation.

The third TD reports on in-service tests and report overall conclusions.

TTCI was tasked by the Association of American Railroads to research the effect of superelevation on vehicle/track interaction, particularly under heavy axle load conditions.



INTRODUCTION

TTCI was tasked by the AAR to research optimum heavy haul design, operating, and maintenance practices for curves negotiated by trains with 286,000-pound car loads. TTCI has conducted:

- Theoretical studies of vertical and lateral loads on single cars under different cant conditions¹
- Tests on single cars in curves at the TTC¹
- In-service tests at an instrumented crib in a 4.5-degree curve on a 1.22 percent grade with 3.5 inches cant²

The theoretical studies and single car tests¹ suggested that wheel/rail forces can be minimized if:

- Curves are superelevated considering:
 - The *spectrum* of prevailing train speeds
 - Where possible, the speed of the prevailing *maximum* tonnage
- Heavy trains curving with excess cant generally impose high vertical and lateral loads on the low rail. This is associated with low rail rolling contact fatigue (crack formation, material flow and wear).
- Heavy trains curving with cant deficiency will impose higher vertical loads on the high rail; however, theory suggests that under cant deficiency, cars and trucks curve with:
 - Reduced angles of attack
 - Lower high rail L/V ratios (because of the higher vertical load, V)

Consequently, it is preferable to have the heavier traffic running under conditions of cant deficiency rather than with excess cant

This TD reports on the choice of an in-service test site to locate instrumented cribs with the following objectives:

- Verify the conclusions of the theoretical study and TTCI on-site tests
- Measure the influence of coupler forces on wheel/rail forces and infer benefits of specific train configurations (specifically distributed power)

A further TD reports on the results obtained.²

TEST SITE

A test site was sought having the following characteristics:

- Relatively tight curvature to maximize the lateral components of the coupler forces and the influence of these forces on wheel/rail forces
- Appreciable grade where all locomotives in the train are operating consistently at maximum power, tractive effort, and, consequently, constant grade-balanced speed
- Relatively consistent train configurations with predominantly similar cars so that results from the instrumented cribs could be analyzed statistically

Details of the chosen test site are as follows (Figure 1):

- Instrumented cribs placed on Track 1
- 4.5-degree curve
- Cant = 3.5 inches
- 1.22 percent grade

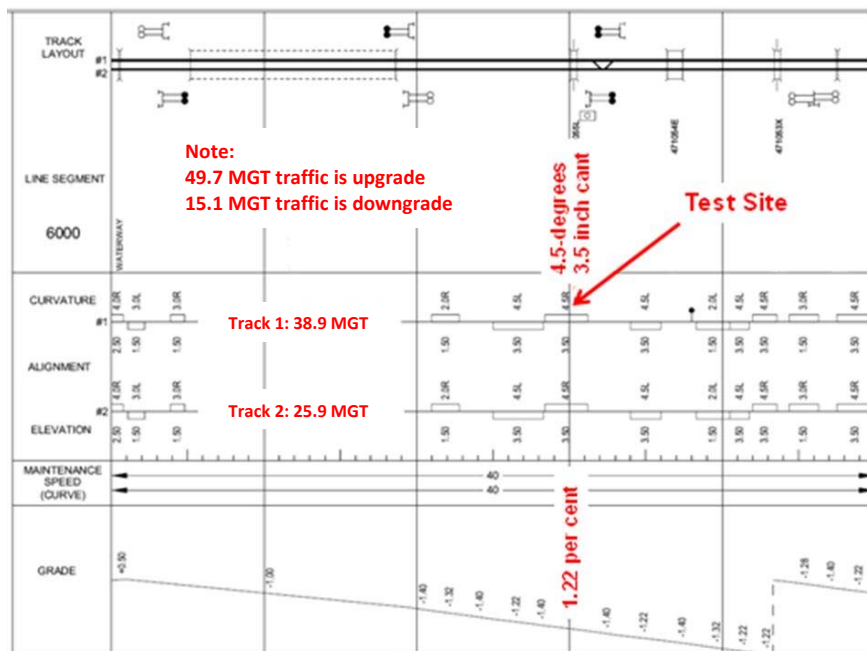


Figure 1. Test Site Location

Operating conditions:

- Track speed: 40 mph
- Balance speed for 3.5 inches cant: 33.3 mph
- Annual MGT per track:
 - Track 1 (instrumented crib): 38.9 MGT
 - Track 2: 25.9 MGT
- Annual MGT per direction:
 - Upgrade: 49.7 MGT
 - Downgrade: 15.1 MGT

Although the predominantly loaded traffic travels upgrade, there is a more even loading balance between Tracks 1 and 2 than might be expected (38.9 MGT on Track 1 vs. 25.9 MGT on Track 2). Track 1 was chosen for instrumentation, because it carries the greater upgrade traffic.

TRAIN OPERATIONS ACROSS THE TEST SITE

Train configurations across the revenue service test site:

- Predominantly loaded coal trains against the ascending grade with empty returns downgrade
- Double-stack container trains in both directions
- A statistically usable number of 100- to 110-car loaded coal trains with distributed power configured with two locomotives at the head end and two locomotives trailing (Figure 2)



Figure 2. Train Consist Configuration

The following is an analysis of the train configuration:

- The majority of coal trains passed the site within a 2 mph speed range, as the locomotives were operating at maximum power (notch 8).
- Cars and locomotives were generally of consistent type.
- It could be assumed that coupler forces varied linearly from maximum tension (draft) on the lead car, through zero at mid train, to maximum compression (buff) at the trail car in the consist.

DISCUSSION OF TEST SITE DESIGN

Prevailing Standards

The cant in the curve at the test site is applied according to the following internal instructions of the railroad:

- Curves shall be superelevated for the maximum allowable speed of trains in accordance with the (curve, speed, and elevation) table.
- Consequently, for a track speed of 40 mph and a curvature of 4.5 degrees, the table indicates a cant of 3.5 inches. The table uses a 2-inch cant deficiency for freight trains.

This standard gives no latitude to adjust the cant to prevailing train speeds and tonnages. A survey of practices indicates most freight railroads allow this latitude to varying degrees.

Figure 3 shows the approximate MGT and speed for trains on Track 1 based on two weeks of measured train speeds at the instrumented crib.

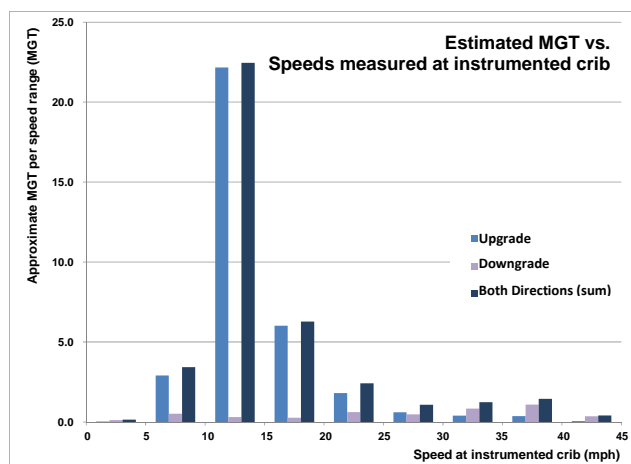


Figure 3. Train Speed Distribution (MGT)

For a given curvature, cant is proportional to the square of the speed. Figure 4 shows this relationship for a 4.5-degree curve.

At this site:

- The balance speed for a 4.5-degree curve, superelevated to 3.5 inches, is 33.3 mph.
- The balance superelevation for 40 mph in a 4.5-degree curve is 5 inches.

In addition, a 3-inch range of cant imbalance provides (Figure 4):

- A 31 mph speed range from zero mph
- A 13 mph speed range from 30 mph

Consequently, it becomes more difficult to optimize cant conditions for higher track speeds (this also applies for sharper curvatures).

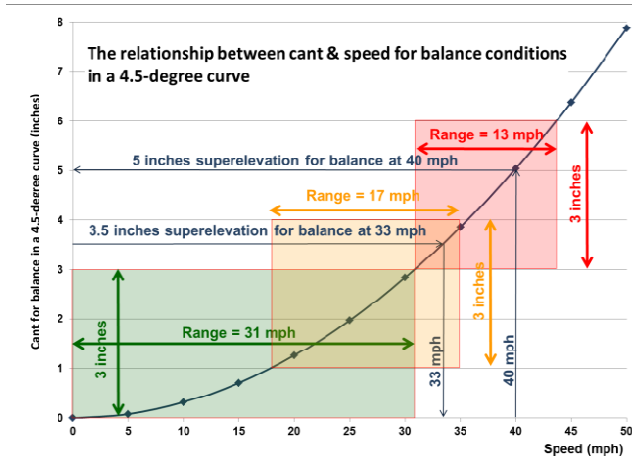


Figure 4. Relationship between Cant and Speed for Balance Conditions in a 4.5-degree Curve (The green, orange, and red boxes show the allowable speed ranges for elevations of 0, 1, and 3 inches using 3 inches cant deficiency)

Figure 5 shows the tonnage at the site as a percent of train passes: 83 percent of tonnage travels at speeds between 5 and 20 mph with only 8 percent of traffic traveling above 35 mph.

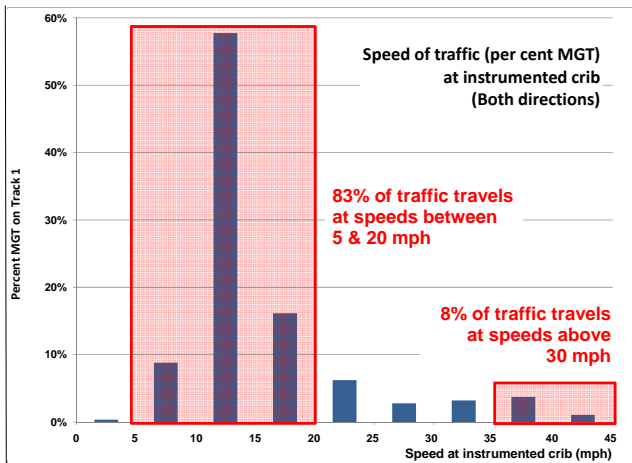


Figure 5. Train Speed Distribution (percent of total train passes)

Referring back to Figure 4, it can be seen that if the test curve was superelevated to 1 inch and the track speed was reduced by 5 mph to 35 mph, improved balance conditions would be obtained for the majority of the tonnage passing the curve without appreciably compromising the throughput of the higher speed trains.

CONCLUSIONS

A revenue service test site was identified having the following suitable characteristics:

- Relatively tight curvature to maximize the lateral components of the coupler forces and the influence of these forces on wheel/rail forces.
- Appreciable grade where all locomotives in the train are operating consistently at maximum power, tractive effort and, consequently, constant speed.
- Relatively consistent train configurations with predominantly similar cars, so that results from the instrumented cribs could be analyzed statistically.

A review of the test site design, referencing current railroad practices, suggests that these practices can introduce conditions of excess cant. Excess cant introduces undesirably high forces on the low rail.

Theoretical studies suggest that balance conditions are optimal, but that, if imbalance does occur, cant deficiency is preferable to that of excess cant.¹ An analysis of the site parameters suggests an improved approach; this is described.

Test results are reported in a separate TD.²

REFERENCES

1. Tournay, H. et al. July 2014. "The Effect of Track Cant on Vehicle Curving (1): Theory and Single Car Test Results," *Technology Digest* TD-14-013. Association of American Railroads, Transportation Technology Center Inc., Pueblo, Colo.
2. Tournay, H. et al. July 2014. "The Effect of Track Cant on Vehicle Curving (3): In-service Test Results," *Technology Digest* TD-14-015, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colo.