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Evaluation of the Potential Benefits of Superelevation for Mainline Turnouts in Heavy Axle Load Service

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Summary

Transportation Technology Center, Inc.'s (TTCI) evaluation of the effects of adding superelevation to the diverging route of a mainline turnout at the High Tonnage Loop of the Facility for Accelerated Service Testing (FAST) has found that the changes in forces with superelevation are relatively small, with the superelevated region of the turnout being too short to reach steady state conditions and provide significant benefits. A series of performance measurements including wheel/rail forces, track geometry and rail wear have been made during the first 150 MGT of 315,000-pound car traffic over a No. 20 turnout retrofit with superelevation. Field test results of the reduced entry angle, superelevated turnout have been largely as expected. Wear of the superelevated closure rails has been small, with no unusual gage face wear. The practical benefit of the superelevation is in allowing the use of a dynamically better turnout alignment without a penalty in allowable speed. Thus, the addition of superelevation to a low entry angle turnout will allow a railway to obtain the force reduction benefits of the low entry angle design without incurring a penalty in allowable train speed. Currently, there is a penalty in maximum allowable speed when using a low entry angle turnout as compared to a non-tangential alignment (AREMA-style) turnout.

There are two factors that limit allowable speed on the diverging route of turnouts. One is the superelevation unbalance in the diverging curve. This originated as a ride quality requirement for all curves on the railroad. The second is the potentially high lateral forces that can result from the large entry angle alignment typical in a freight railroad turnout. This is a safety limit that affects high entry angle alignment turnouts.

The addition of superelevation to compensate for smaller radius curvature that results from lower entry angle, and longer switch points can increase maximum allowable speed to near that of the AREMA-style turnout alignment. The proposed reduced entry angle turnout design with superelevation in the closure curve is expected to perform better than AREMA alignments, and it will allow the railways to operate at closer to maximum allowable speeds. The main speed limiting factor in loaded traffic for AREMA-style turnouts is lateral-to-vertical or L/V ratio (due to higher lateral loads) at switch point entry. The proposed reduced entry angle turnout design will perform better at all speeds modeled. It has the limitation of having a lower maximum allowable speed due to smaller radius curves on the diverging route. A demonstration of this concept was conducted by modifying a No. 20 turnout at FAST. Superelevation was added through the use of transition rails and wheel/rail forces were measured before and after the addition of the superelevation. Long-term monitoring of turnout dynamic performance and wear will continue.

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INTRODUCTION

Turnout alignment design is a complex problem, requiring consideration of technical, regulatory, and logistical issues. The railway goals of safety, reliability, and efficiency must all be met while also maximizing the capacity of the line. New designs are usually required to fit in the footprint of the previously used turnouts, limiting what can be done to improve performance. In the same regard, the lengths of individual components such as switch points may also be limited by shipping or handling requirements of the railway.

The allowable speed through a turnout is often limited by the smallest radius curve in the turnout on the basis of cant deficiency or unbalanced superelevation (as is done with other curves on the railway). This limit caused designers of turnouts to optimize designs for allowable speed by using nontangential alignments, which has resulted in turnout designs that generate high lateral forces and the resultant degradation that follows. This research reviewed potential alignments within the AREMA style turnout footprint to develop an improved performance turnout that would also have a higher allowable speed under the current cant deficiency rule.

As with the rest of the track, the allowable speed in a turnout curve is governed by the maximum cant deficiency limit in the Federal Railroad Administration (FRA) track safety standards. For example: for an AREMA 20 curved point turnout with 156-foot lead length, the maximum allowable speed is 49 mph (assuming 3 inches cant deficiency).[1] AREMA designs are biased toward high allowable speeds by having a large closure curve radius at the expense of a large switch entry angle. However, higher peak lateral forces due to the alignment kink (entry) angle can cause increased alignment degradation, increased lateral accelerations, reduced ride quality, and higher maintenance. Therefore, the speeds are normally restricted to about 40 mph through the turnouts. Thus, a turnout may have speed limits of 40 mph in the middle of 60 to 70 mph track.

In this Transportation Technology Center, Inc. (TTCI) project, the alignment of the standard AREMA turnout was modified to reduce lateral loads at switch points by reducing the entry angle. *Technology Digest* TD-13-022 describes the results of simulations of alignment changes and the addition of superelevation.[2] The results of the simulations suggested that the combination of a low entry angle switch alignment and superelevation in the diverging route curve can provide better dynamic performance with no penalty in allowable speed, as compared to the currently used designs. In the analytical study, the entry angle was reduced by incorporating several circular curve segments of different radii (i.e., a segmented spiral). In addition, superelevation was incorporated in the diverging route by lowering the low rail. Dynamic vehicle simulations were conducted using NUCARS®, TTCI's dynamic modeling software,* and the results were compared with standard AREMA turnouts.

The results show that various types of trains can run through the diverging route of the turnouts at, or very close to, the design speed of the tangent track. Lateral-to-vertical (L/V) ratios were reduced significantly. Both modifications stay within the dimensions of the current standard AREMA turnout.

FIELD TEST UNDER HEAVY AXLE LOADS

TTCI is conducting a field test of superelevation on the diverging route of a turnout on the High Tonnage Loop at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. A No. 20 turnout with a tangential, spiral alignment was selected for retrofitting with superelevation. This was done in 2013, using transition rails in the diverging route closure curve. These rails with longitudinally sloped profiles are similar to the transition rails now used to match new and worn rail in track. The 136RE rail turnout received a 141RE "high rail" and a 132RE with an additional 0.1875-inch milled off the "low rail." The raising of one rail and lowering of the other is likely to be dynamically better than only raising one rail (due to a smaller change in the vehicle center of gravity).[3] Figure 1 shows the test turnout. The rails have ramped ends so that each end can be matched and welded to 136RE. In a new installation, the superelevation can be provided by varying tie plate thickness or using dapped crossties, so that one may use the same rail section throughout.

Figure 1. No. 20 Turnout with 0.5-inch Superelevation on the Diverging Route

FIELD TEST RESULTS

The turnout has performed well after about 12 months in service. Wheel-rail forces have been measured as have rail wear in the superelevated closure curve. Figure 2 shows a time series of profiles for the closure rails of the turnout with 0.5-inch of superelevation. The profiles look similar to profiles taken on the closure curve rails of similar turnouts without superelevation. Note, there is little gage face wear in these spirals (where the radius is as short as 2,700 feet). The different 0 MGT shapes for the high (left) and low (right) rails are due to the use of transition rails to add superelevation to the turnout. The high rail is a 141RE section at this location. The low rail is a 132RE section with additional height milled off the surface and the 132RE profile reground on the surface.

**NUCARS® is a registered trademark of TTCI, Pueblo, Colo.*

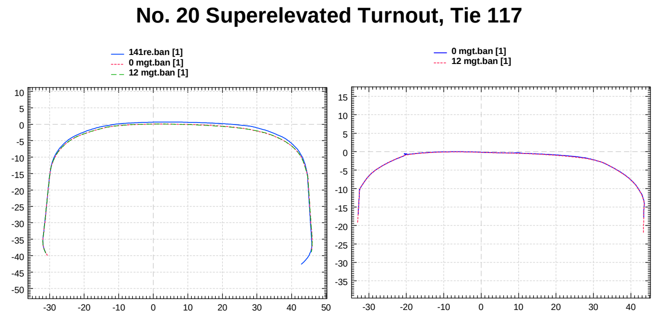

Figure 2. Time Series of Closure Curve Rail Profiles in Superelevated Turnout

Figure 3 shows running surface profiles of the outside and inside rails at the same place in the closure curves of two No. 20 turnouts at FAST. The left profile is from a turnout with no superelevation. The right rails are from the turnout with superelevation.

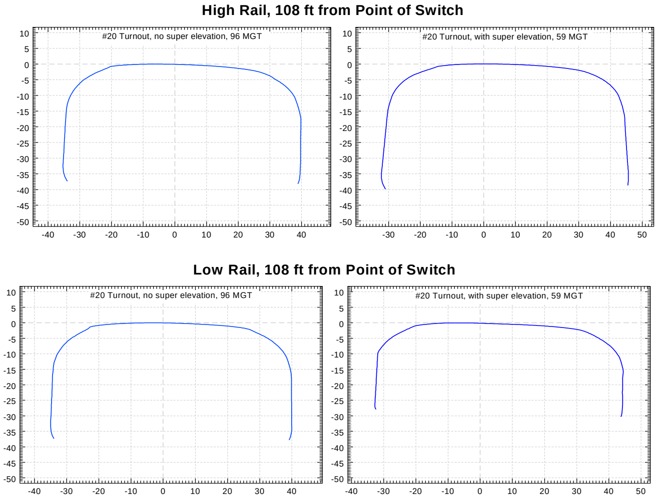

Figure 3. Closure Curve Rail Profiles in Flat (Left) and Superelevated (Right) Turnout

Wheel-rail forces have been measured in the turnout before and after the installation of superelevation. Figures 4a and 4b show predicted lead axle, outside wheel-rail lateral and vertical forces for a 40-mph facing point, diverging move under a 315,000-pound gondola car before installation of superelevation. This plot shows the typical behavior of a vehicle going through a turnout. These simulation results, and the model that produces them, have been verified by field testing many times. An example validation is given in the references.[4] As the vehicle encounters the diverging switch point, there is a lateral load spike where the switch is doing work to turn the wheelset to the diverging route. This is accompanied by a larger vertical load on the outside wheels as the carbody rolls in reaction to the lateral loading. The limits of the superelevated area are shown indicated by blue vertical lines on the figures. On the lateral force plot (Figure 4a), measured lead outside wheel lateral forces from both the tangential spiral and an AREMA, larger entry angle turnout are shown.

The key points to recognize are:

- The AREMA turnout has a much larger maximum force in the switch, and
- The low entry angle switch has lower lateral forces, but lateral forces in the closure curve are somewhat higher. It is the shorter radius in the closure curve that limits allowable speed in the turnout.

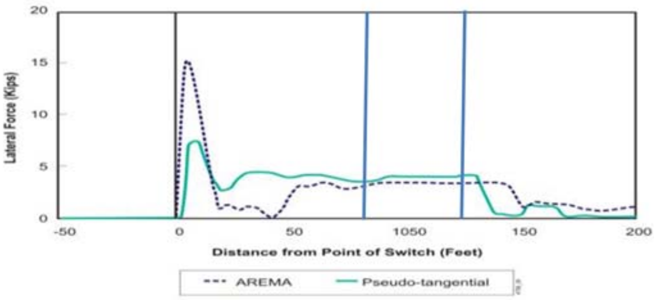

Figure 4a. Typical Outside Rail Lateral Wheel/Rail Forces versus Distance for a No. 20 Turnout with Fixed Point Frog – 40 mph Facing Point Diverging Move

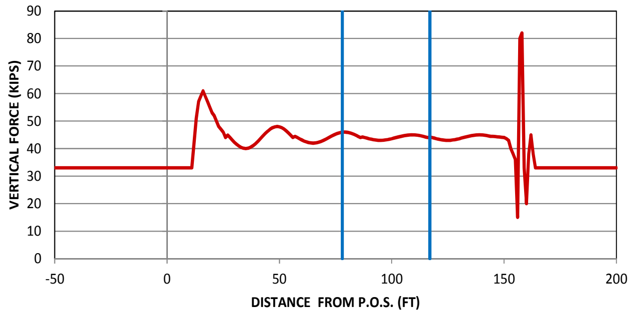

Figure 4b. Typical Outside Rail Vertical Wheel/Rail Forces versus Distance for a No. 20 Turnout with Fixed Point Frog – 40 mph Facing Point Diverging Move

Figures 5a and 5b show actual measured wheel-rail forces in the superelevated area of the turnout. Again, the limits of the 0.5-inch superelevation area are shown as blue vertical lines. The ramps extend a few more feet on either end. Note that the outside wheel vertical force is higher for the superelevated turnout near the beginning of the elevated area (Figure 5a). The modeling predicted this would occur as the wheels climb a longitudinal ramp. For the inside wheel, the opposite occurs. Forces are lower as the wheel initially descends a vertical ramp. It has higher vertical forces near the end of the superelevated zone as it starts to climb the low rail ramp that makes the track level again at the frog (Figure 5b).

The ramps and superelevated curvature are quite short in the closure curve of the turnout. Thus, the transient end effects likely overwhelm any steady state benefits from superelevation.

Table 1 contains the average and 95th percentile vertical forces for the closure curves of the turnouts with and without superelevation measured during 40-mph operations.

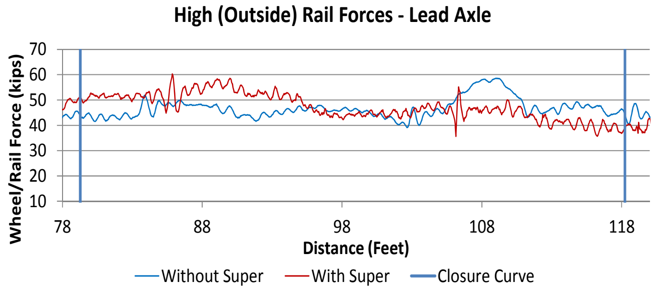

Figure 5a. Lead Axle High (Outside) Rail Forces versus Distance in Closure Curve of Turnout

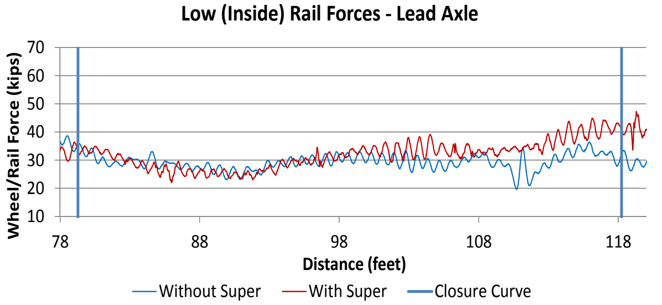

Figure 5b. Lead Axle Low (Inside) Rail Forces versus Distance in Closure Curve of Turnout

Table 1. Measured Vertical Wheel Forces in Flat and Superelevated Turnout

	Average Vertical Force		95th Percentile Vertical Force	
	Inside Rail	Outside Rail	Inside Rail	Outside Rail
No Superelevation	30.1	47.9	41.0	57.0
With Superelevation	30.9	48.4	41.2	54.6

CONCLUSIONS

The addition of superelevation in low entry angle turnouts to compensate for smaller radius curvature can increase maximum allowable speed to near that of the AREMA-style turnout alignment. The proposed reduced entry angle, superelevated turnout design is expected to perform better than AREMA alignments; enabling railways to operate at closer to maximum allowable speeds. The main speed limiting technical factor in loaded traffic for AREMA-style turnouts is L/V ratio (due to higher lateral loads) at switch point entry. The proposed reduced entry angle turnout design will perform better at all speeds modeled. Without superelevation, it has the limitation of having a lower maximum allowable speed due to smaller radius curves on the diverging route.

The field test results of the reduced entry angle, superelevated turnout have been largely as expected. The changes in forces with superelevation are relatively small, with the superelevated region of the turnout being too short to reach steady state conditions and provide significant benefits. Wear of the closure rails has been small, with no unusual gage face wear. The practical benefit of the superelevation is in allowing the use of a dynamically better turnout alignment without a penalty in allowable speed.

FUTURE WORK

Additional tonnage is needed to determine the long term performance and life cycle costs of the superelevated turnout. It is unknown, for example, how durable the superelevation in the closure curve will be. Additionally, a revenue service test should be conducted to evaluate a wider range of train operating conditions. This would also allow for an application with purpose built platework and the same rail section throughout.

REFERENCES

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4. Handal, Stephen, “Partial Validation of a Generalized Turnout Model Based on NUCARS.” Research Report R-797, Association of American Railroads, Washington, DC. March 1992.