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## Dynamic Simulation of Improved AREMA No. 24 Turnout Alignment

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### Summary

Transportation Technology Center, Inc. has modeled a reduced entry angle AREMA No. 24 switch design. The improved performance design is intended to reduce lateral forces at the switch point entry and allow higher speeds in capacity constrained turnouts and crossovers. The design is expected to significantly reduce maintenance while enhancing the safety of train operations through turnouts. The project is funded under the Association of American Railroads' Strategic Research Initiatives Program.

The AREMA 24 switch allows speeds in excess of 60 miles per hour (mph). However, most railroads limit the speeds to 45 mph or even lower due to the high lateral forces generated. These forces can result in rapid degradation of the turnout and also pose an increased potential for wheel climb at switch points caused by higher lateral to vertical loads.

Potential alignments within the AREMA 24 turnout footprint were examined and used to develop an improved performance turnout that would also have higher allowable speeds under the current cant deficiency rule. To reduce maximum lateral forces, various switch point entry angles have been proposed in the past. One method of reducing entry angle without lengthening the turnout is to create a "spiral" by dividing the constant radius closure curve into smaller segments, each with a tighter radius (going towards the center of the turnout). While this approach reduces the forces at the switch point, it also reduces the allowable speeds through the turnout, which are governed by the smallest radius in the closure curve.

The proposed design uses the approach described above and it reduces the entry angle to one-third of the AREMA 24 design. It adds superelevation to compensate for the reduction in speeds due to tighter curve segments, allowing train speeds of about 60 mph.

Modeling shows that the loaded car lateral forces from the proposed entry angle are only 4,000 pounds compared with 16,000 pounds from the AREMA 24 standard entry angle. The significant reduction of lateral forces and the provision of additional superelevation in the turnout can increase the allowable speeds.



## 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, narrowing what can be accomplished 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 (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 24 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 FRA track safety standards. For example, for an AREMA 24 curved point turnout, the maximum allowable speed is 62 mph (assuming 3 inches cant deficiency).<sup>1</sup> AREMA designs are biased towards 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 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 project, the alignment of the standard AREMA turnout was modified to reduce lateral loads at switch points by reducing the entry angle. In the first modification, the entry angle was reduced by incorporating several circular curve segments of different radii. In addition, in the second modification, superelevation was incorporated in the diverging route by lowering the low rail. Dynamic vehicle simulations were conducted using NUCARS<sup>®\*</sup> 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 rest of the tangent track. Lateral to vertical (L/V) ratios were reduced significantly. Both modifications stay within the dimensions of the current standard AREMA 24 turnout.

## BACKGROUND

As result of the strong partnership of railroad track engineers, trackwork suppliers, and researchers, turnout performance has improved significantly over the past 30 years. The improvement came largely through improved materials, quality control, maintainable designs, and new designs. However, turnouts are still major bottlenecks, requiring speed restrictions for diverging traffic.

The major cause of higher lateral loads is the entry angle of the switch. The entry angles have been reduced significantly using tangential and low entry angle alignments.<sup>2,3</sup> Curve spirals and pseudo tangential designs have been used to minimize the increases in turnout length caused by low entry angle alignments. But, this is mostly limited to new tracks. In existing tracks, implementation of these designs is rather limited, because the new turnout must fit into an existing footprint due to track layout and/or switch machine and signal locations. Thus, such designs may be installed in new track, but not in existing tracks where the space is limited to AREMA standard lead length.

## TURNOUT DESCRIPTION

Three turnout alignments of the same length were modeled for the purpose of this analysis:

- AREMA 24 – 0° 32' 46" switch entry angle with two curve segments
- Mod 24.1 – 0° 09' 16.21" switch entry angle with five curve segments
- Mod 24.2 – 0° 09' 16.21" switch entry angle with five curve segments, partly superelevated to 1.0 inch.

Mod 24.1 has about one-third of the entry angle of the current AREMA 24 turnout. This reduction was achieved by reducing the switch and closure rail radius. The sum of the curve segments' angles is equal to the frog angle. In Figure 1, each turnout begins at 50 feet and ends at 217 feet. A penalty for reduced entry angle is the shorter radius curve needed to complete the turnout. As a result, the maximum allowable speed (3 inches cant deficiency) is reduced from 62 mph for AREMA 24 alignment to 51 mph for Mod 24.1 alignment. A 1.0-inch superelevation was added to the diverging route for Mod 24.2 alignment, which increased the maximum speed limit to 59 mph.

Turnouts are installed without superelevation to simplify crosstie, plate work, and frog designs at the expense of greater cant deficiency. The outside rail of the sharpest curved segment was superelevated by 1.0 inch. The superelevation started just after the switch heel block, and increased to 1.0 inch over a length of 31 feet. Superelevation remained uniform for some distance and finally ended a few feet before the point of tangency of the frog. This actual superelevation raised the maximum allowable speed to about 59 mph (Figure 2).

\* NUCARS<sup>®</sup> is a registered trademark of TTCI, Pueblo, CO

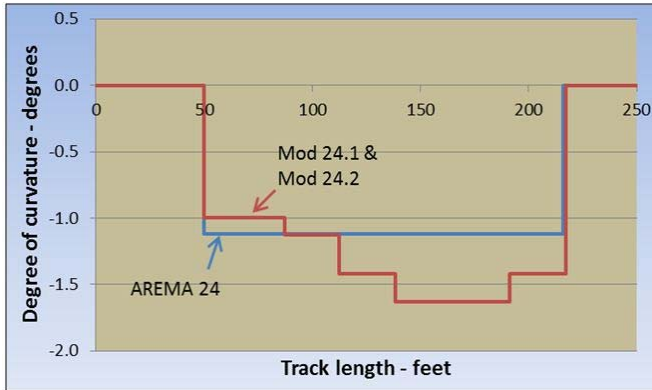


Figure 1. Turnout Geometry

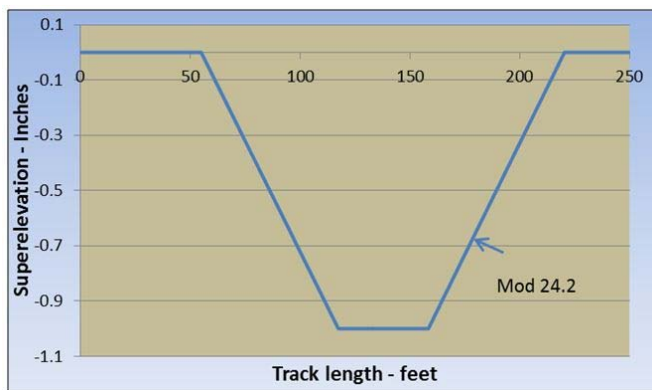


Figure 2. Turnout Superelevation

### Vehicle Description

The following three vehicles, loaded and empty, were modeled on all three turnouts to simulate a wide range of North American railroad freight traffic:

- Loaded hopper car (LH) – 263,000 pounds
- Empty hopper car (EH) – 63,000 pounds
- Loaded autorack (LAR) – 220,000 pounds
- Empty autorack (EAR) – 68,000 pounds
- Loaded tank car (LT) – 263,000 pounds
- Empty tank car (ET) – 68,000 pounds

Based on experience, the longer (autorack) and rotationally stiffer (tank) cars are most likely to have performance issues negotiating turnouts.

### Methodology

All three vehicles were modeled on all three turnouts at speeds ranging from 5 to 60 mph. Effects of lateral forces, vertical forces, L/V, and axle lateral movement (hunting) were studied. New 136RE rail and AAR1B wheels were used for this analysis. The results presented in this analysis are of the stated

case scenario, but other wheel/rail conditions may produce different results.

### Lateral Forces

Figure 3 shows the reduced entry angle effect on lateral forces of the leading wheel for all three turnouts under a loaded hopper car at 60 mph. A reduction in entry angle from 0.54 to 0.15 degrees has resulted in three-fourths reduction in the lateral forces. The lateral peak force due to reduced entry angle of Mod 24.2 is about equal to the curving force at the sharpest curved segment. The data suggests that it might be possible to operate over the new design turnout at higher speeds while still benefiting from reduced wear and degradation.

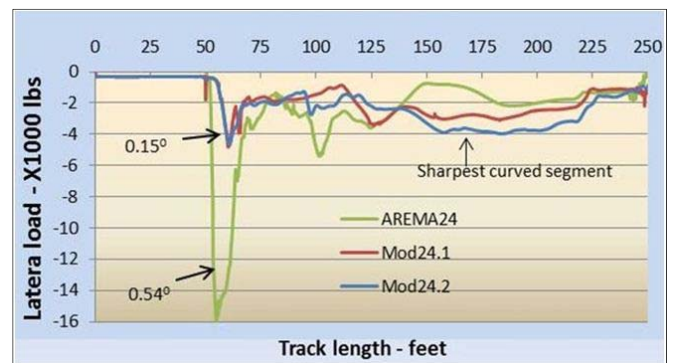
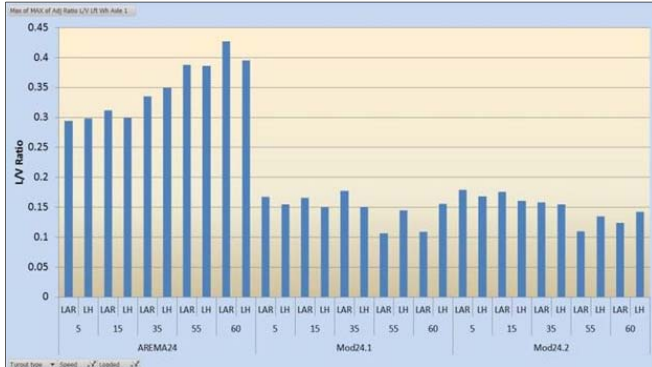


Figure 3. Predicted Lateral Wheel Forces for Loaded Hopper at 60 mph

The reduced lateral peak force of the modified designs compared with the AREMA 24 design holds true over all modeled speeds for all vehicle types.

Similarly, the L/V force ratio for the modified designs is up to two-thirds lower than AREMA 24 design at various speeds. The L/V ratio is an indication of the propensity for rail rollover and flange climb. The modified turnout designs improve safety by reducing L/V ratio throughout the wide range of operating speeds. A 45 mph speed for loaded coal train operations through the AREMA 24 turnout corresponds to an L/V ratio of 0.35. TTCI's experience with AREMA turnouts suggests this L/V ratio at this speed is acceptable. Modified turnouts can accommodate speeds up to 60 mph at half the perceived lower L/V ratio at a much lower wear rate.

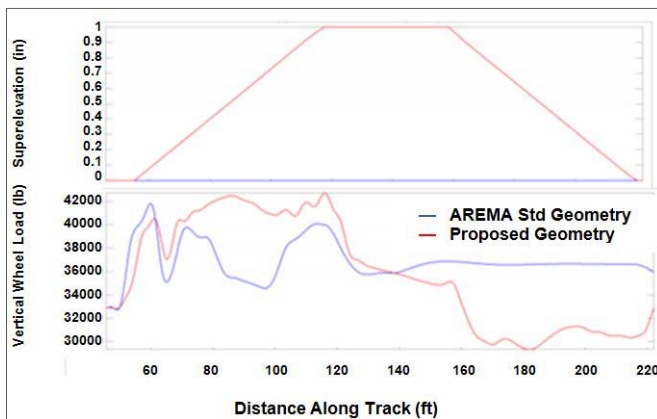
Figure 4 is a summary of predicted maximum L/V versus speed for the three turnout alignments (AREMA 24, Mod 24.1, and Mod 24.2) for the loaded autorack and loaded hopper cars.



Note: LAR = loaded autorack; LH = loaded hopper car

**Figure 4. Predicted Maximum L/V vs. Speed for Three Turnout Alignments**

Note that the two modified alignments produce similar dynamic performances and L/V ratios in the simulations conducted. The effect of adding superelevation is relatively minor on both lateral and vertical forces. The superelevation increases vertical forces in the closure curve as elevation is increased. Figure 5 shows vertical force versus distance for the outer wheel of the vehicle on the diverging route move. The outer wheel is climbing a ramp. From a vehicle dynamics perspective, it hits a “bump.” The lateral force increases due to the smaller radius curvature resulting from the spiral. Similarly, as the elevation ramps back down, the vertical force is decreased. Lateral force decreases here as the second spiral radius increases.



**Figure 5. Predicted Vertical Wheel Force vs. Distance for Two Turnout Alignments**

Additional review of the predicted dynamic performance of the modified turnout alignments suggests they will have stable vehicle behavior throughout the range of speeds allowed by the cant deficiency rule.

## Future Work

A field test of superelevation on the diverging route of a turnout will be conducted at the Transportation Technology Center. Two methods are being considered to add the superelevation. These are: (1) plate work risers and (2) machined closure rails. The latter will use rails with longitudinally sloped rails similar to the transition rails now used to match new and worn rail in track. This approach is more amenable to a retrofit in track, as the existing plate work can be used.

## CONCLUSION

L/V ratio (due to higher lateral loads) at switch point entry is the main speed limiting factor in loaded traffic for AREMA style turnouts. 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. The addition of superelevation to compensate for spirals can increase maximum allowable speed to near that of the AREMA alignment. This design is expected to perform better than AREMA alignments; allowing the railways to operate at closer to maximum allowable speeds.

## REFERENCES

1. Federal Railroad Administration. 2007. Track Safety Standards Part 213 Subpart A to F Class of Track 1-5. Washington, D.C.
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