With the introduction of new-generation high-speed trains on the Northeast Corridor, Amtrak faced the challenge of procuring train sets that would minimize the increase in track degradation and maintenance expenditures. As vehicle operating speeds increase, the dynamic wheel–rail impact forces on the track structure increase. High-speed passenger operations can produce significantly greater wheel–rail dynamic forces. These intense forces in turn can accelerate track degradation and component failure, requiring frequent track maintenance and increasing maintenance costs.

Problem

Engineers recognized the potential effect of high-speed operations on track degradation and faced a specific challenge in designing the new equipment. Despite the increase in operating speed from 125 mph to 150 mph, the new equipment would have to avoid increasing the dynamic vertical wheel–rail forces applied to the track. A method for evaluating the potential damage associated with the new high-speed equipment was not available and had to be developed.

Solution

While three vendor consortia worked on alternative high-speed train set designs, Amtrak commissioned the development and implementation of a method to evaluate the potential for track damage associated with the older equipment and the new high-speed equipment. The objective was to quantify the levels of dynamic track loading associated with the 125-mph operations and the levels that would be applied by operating the proposed new generation of equipment at 150 mph. The approach would provide a means for assessing the expected level of track damage and for modifying the proposed designs to minimize or eliminate the increase in dynamic wheel–rail loading.

An analytical–empirical approach was developed and implemented, considering the effects of operating speed, unsprung mass, and track condition, and focusing on the vertical wheel–rail dynamic forces generated by high-speed operations. The $P_1$ and $P_2$ impact forces (as illustrated in Figure 1) are relevant to track deterioration. The $P_1$ forces are high-amplitude, short-duration (high-frequency) dynamic impact forces that usually are attenuated rapidly by the track structure. These forces contribute to the cracking of concrete ties—experienced by Amtrak in the late 1970s and early 1980s. The $P_2$ forces are lower-amplitude, longer-duration (lower-frequency) loads that contribute primarily to the degradation of track geometry, which is the largest maintenance expense on the corridor. As shown in Figure 1, the $P_1$ impact forces could be as high as 3.5 times the static load imposed by the wheel on the rail, and the $P_2$ impact forces could be as high as 2.5 the static load.

Developing the methodology required calibrating the theoretical impact force relationships using actual wheel–load impact data from Amtrak operations in the Northeast Corridor. From the calibrated equations, the dynamic impact forces generated by Amtrak locomotives—specifically the AEM7 and F40—were determined for wood and concrete crosstie track. These forces provided a baseline for comparison with the forces generated by other equipment.

Other impact load limits, such as those established in earlier studies for limiting concrete tie cracking in...
the Northeast Corridor, were used to assess the severity of the forces. The dynamic impact forces generated by nine different high-speed train set configurations proposed by the three vehicle consortia were then calculated and compared with the baseline force levels and specific impact load limits.

Benefits
Analysis of the results showed that four of the nine originally proposed train set configurations required some degree of speed reduction to ensure that no tie cracking damage would occur. The other five configurations generated $P_1$ and $P_2$ force levels within an acceptable range. Using these results and the method for calculating the $P_1$ and $P_2$ forces, Amtrak developed a “go or no-go” criterion for evaluating proposed high-speed train sets and identifying train set configurations that would not accelerate the rate of change to the track structure on the Northeast Corridor.

Although developed to evaluate equipment proposed for operation in the Northeast Corridor, the method also can be used to evaluate other proposed high-speed corridors and equipment to avoid dramatic increases in track damage, degradation, and maintenance expenses.

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