Ground-Borne Vibration Measurements of High-Speed Trains

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Abstract: Ground-borne vibration measurements of high-speed train operations were carried out in France for the TGV (Nord) and Eurostar trains, in Italy for the Pendolino ETR-450 trains and in Sweden for the X2000 trains. The results indicated a wide spread in the vibration data between the trainsets, and suggested that much of the difference is due to variations in the site geology rather than differences in suspension, axle load or wheel conditions of the trainsets.

BACKGROUND

Ground-borne vibration measurements of high-speed train operations were carried out in Europe for the TGV (Nord), Eurostar, Pendolino ETR-450 and X2000 trainsets. The objective of the measurements was to develop vibration-prediction models for a new guidance manual to be published by the U. S. Federal Railroad Administration on "High Speed Ground Transportation Noise and Vibration Impact Assessment." The tests included measurements of ground-borne vibration at various distances from the track as well as an experimental method to characterize the ground vibration propagation characteristics at each measurement site (1).

The propagation test procedure consists of dropping a weight on the ground and simultaneously measuring the impact force and the vibration pulses at various distances from the impact point. The transfer functions between the vibration pulses and the force impulse are then used to characterize vibration propagation. Assuming a linear system, these transfer functions define the relationship between any type of exciting force and the resulting ground vibration. The end result is a measure of ground vibration transmissibility, or "line source transfer mobility," as a function of distance from the train. Measurements of train vibration and line source transfer mobility at the same site can be used to derive a "force density" function that characterizes the vibration forces of a train independent of the site geologic conditions.

RESULTS

An overview of the measurement results is given in Figure 1 in terms of maximum overall ground vibration velocity level as a function of distance, normalized to a train speed of 145 km/h (90 miles/h). Vibration levels are presented in terms of rms velocity measured over a one-second period, expressed in decibels (VdB) relative to one micro-inch per second; this descriptor most accurately describes human response to vibration (1). Also shown in Figure 1 are best-fit vibration level versus distance curves developed from measurements conducted in the USA for the German ICE, Swedish X2000 and U. S./French RTL-2 Turboliner trainsets as part of the Northeast Corridor (NEC) Project (2).

FIGURE 1. High-Speed Train Ground-Borne Vibration Levels as a Function of Distance
The results in Figure 1 indicate that the TGV and Eurostar trains generated nearly identical ground vibration levels at the same site in France. These levels were roughly 10 decibels less than the lowest ground vibration levels measured at the NEC site in the USA for the X2000 and RTL-2 trainsets, with a similar rate of attenuation with distance. Figure 1 also shows that although the ground vibration levels for the Pendolino operations in Italy were all lower than those for the trains measured in the USA, the Pendolino ground vibrations dropped off more gradually with distance. Beyond 30.5 m (100 ft) from the track, the highest ground vibration levels were generated by the X2000 trains in Sweden; these data exhibit minimal attenuation with distance compared to the other test sites.

The wide spread in the vibration data shown in Figure 1 is not surprising, given the differences in the train equipment, track condition and site geology. To approximate what the ground vibration levels would be if several of the trainsets were operating on the same track in the same location, the force density functions derived from the measurements for the X2000, Pendolino, TGV and Eurostar trainsets were combined with the transfer mobility from a single site in Sweden. The resulting projections of overall ground-borne vibration levels are shown in Figure 2.

![Figure 2](image_url)

**FIGURE 2.** Projected Ground-Borne Vibration Levels for Various High-Speed Trains at the Same Site

The results in Figure 2 show that using the same transfer mobility, in effect normalizing the ground vibration from the trainsets to one site, substantially reduces the differences in the overall vibration levels. Using the transfer mobility from a measurement site in Sweden, the TGV, Eurostar and X2000 ground vibration levels are all within about 2 decibels of each other, and the Pendolino ground vibration levels are 3 to 4 decibels lower. In this case, the range of ground-borne vibration from the different trainsets, normalized to a reference speed of 240 km/h (150 miles/h), is limited to a narrow range between 75 VdB and 80 VdB at 30.5 m (100 feet) from the track. The overall conclusion drawn is that much of the spread between the ground vibration levels measured for the different trainsets is likely due to variations in site geology rather than differences in suspension, axle load or wheel conditions of the trainsets.

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**REFERENCES**