Prediction of rolling noise from ballast and slab track at speeds up to 360km/h

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Abstract

The total noise generated during the passage of a high speed train results from different noise sources including traction and auxiliary systems, wheel/rail interaction (rolling noise) and, at high speeds, aerodynamic noise from the lower and upper regions of the train. This paper focuses on the contribution of rolling noise to the total noise. Slab track is conventionally considered to radiate more noise than ballast track. This paper presents the results of studies undertaken to better understand the performance of high speed slab track using parameters relevant to High Speed Two (HS2). The approach was validated with a comparison between predictions and measurement data from high-speed trains running on ballast track at speeds of up to 350km/h. The predictions indicate that slab track could result in rolling sound pressure levels of the order of about 1 dBA greater than for the ballast track. The similarity in noise emission is a result of the dual stage fastening system. The upper pad fitted above the base plate on the fastening has the effect of increasing the decay rates at higher frequencies compared with a notional slab track with a single layer soft fastener. This compensates for the increased radiation, particularly from the rail, due to the absence of ballast absorption. Considering the total noise, at speeds above 300 km/h the total noise including other sources is expected to be similar for ballast and slab track. At lower speeds, ballast track is expected to be somewhat quieter. This study identifies that the relative differences between slab and ballast tracks are highly dependent on the precise characteristics of the systems being compared.

Keywords: rolling, noise, slab, ballast, fastening

1. Introduction

High Speed Two (HS2) is a new high speed railway that, under current plans, will connect the UK city centres of London, Birmingham, and Manchester. Work on 170 miles of new high-speed line is already under way. A large proportion of these lines are expected to be constructed from slab track. A key concern for HS2 is environmental noise and HS2 has committed to reduce as far as reasonably practicable [1]. The total noise generated during the passage of a high speed train results from different sources including traction, wheel/rail interaction (rolling noise) and, at high speeds, aerodynamic noise [2]. This paper focuses on rolling noise. Slab track is conventionally considered to radiate more noise than ballast track [3]. This was thought to be for two reasons; firstly, the ballast absorbs sound radiated by the wheel and rail and, secondly, softer rail pads which tend to be used on slab track reduce the rate of decay of vibration along the track. Predictions of HS2 noise made for the environmental statement assumed that slab track would radiate more noise than ballast track, by up to 3dB(A) [4]. A previous study investigated noise from slab and ballast tracks at speeds up to 300km/h [5]. For the cases considered, the study concluded that noise from slab track was about 3dB higher than ballast track with stiff rail pads, but only 0-1dB higher than ballast with soft rail pads, hence indicating that the conclusions were dependent on the precise parameters of the different systems. This paper presents the results of studies undertaken to better understand the performance of high speed slab track using a similar methodology supplemented with acoustic characteristics relevant to HS2 operation, including rail roughness and rail decay rates measured on high speed slab track incorporating dual stage rail fastenings, a wheel representative of a high speed train and speeds up to 360km/h, the planned maximum operational speed of HS2. Predictions are made for slab and ballast tracks, the relative differences are considered and compared to assumptions made for environmental impact assessment.

2. Methodology

2.1 Track Wheel Interaction Noise Software (TWINS)

In this paper the characteristics of high speed ballast and slab track in terms of the rolling noise levels have been investigated using the TWINS model [6,7], updated to model the influence of the ballast absorption and influence of the ground on noise radiation [8,9,10].

Two track systems have been modelled:

- Ballast track with mono-block sleepers and moderately stiff rail pads (Acoustic stiffness approximately 550MN/m); and
- Slab track fitted with a dual stage fastener system comprising a stiff (approximately 650MN/m) rail pad, baseplate and soft (approximately 50MN/m) baseplate pad (Figure 1).

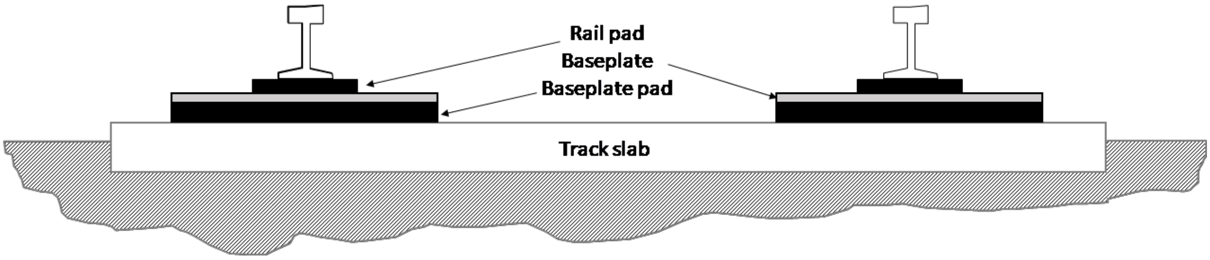

Figure 1: schematic of a dual stage rail fastening used on slab track

The following parameters were considered to be consistent between the two track systems:

- A straight-webbed 920 mm diameter wheel representative of modern distributed power high speed rolling stock with wheel roughness representative of disc-braked wheels [11];
- rail roughness representative of high speed slab track [4] (roughness measurements made on tunnelled slab track on High Speed 1 in the UK, for wavelengths longer than 1m, and roughness measured on ballast track on a high speed railway in Italy for wavelengths shorter than 1m). Figure 2 shows the roughness values compared to the TSI curve [12]; and

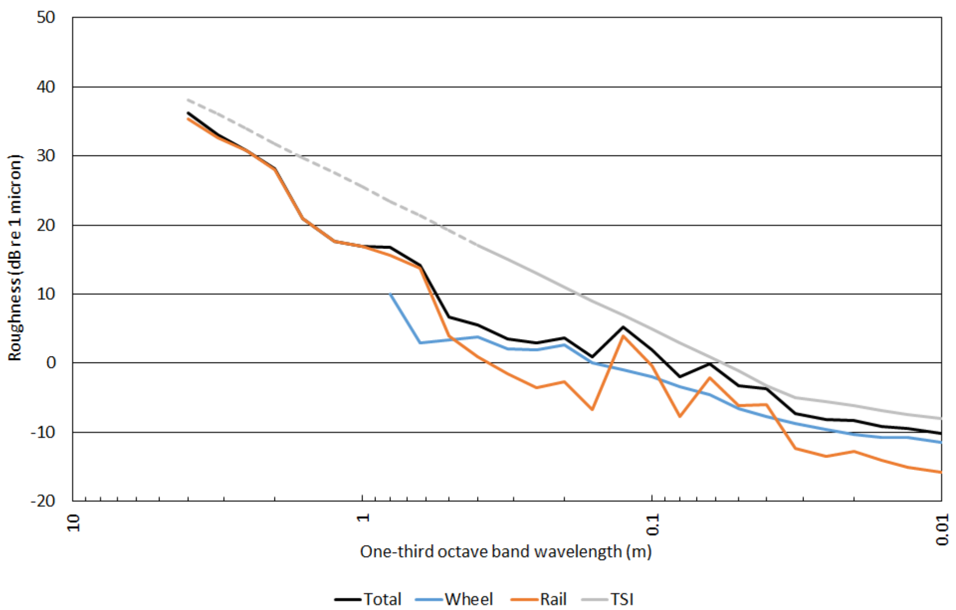

Figure 2: roughness values used in the study

- noise was predicted at a receiver location 25 m away from the track centre and 3.5 m above the rail head. This is a standard position specified in ISO 3095 [13]. For the propagation model, ground properties have been selected that are typical of grass, and at a height of 0.5 m below the rail head.

The characteristics of the tracks were accounted for using measured decay rates in the TWINS model. For the ballast, track decay rates measured on high speed ballast track in Germany were used. For the slab track, decay rates measured on a high speed slab track fitted with a dual stage fastening system in Germany were used. The vertical and lateral decay rates for both systems compared to the TSI curves are shown in Figure 3 and Figure 4 respectively. The average of the left and right rails is shown.

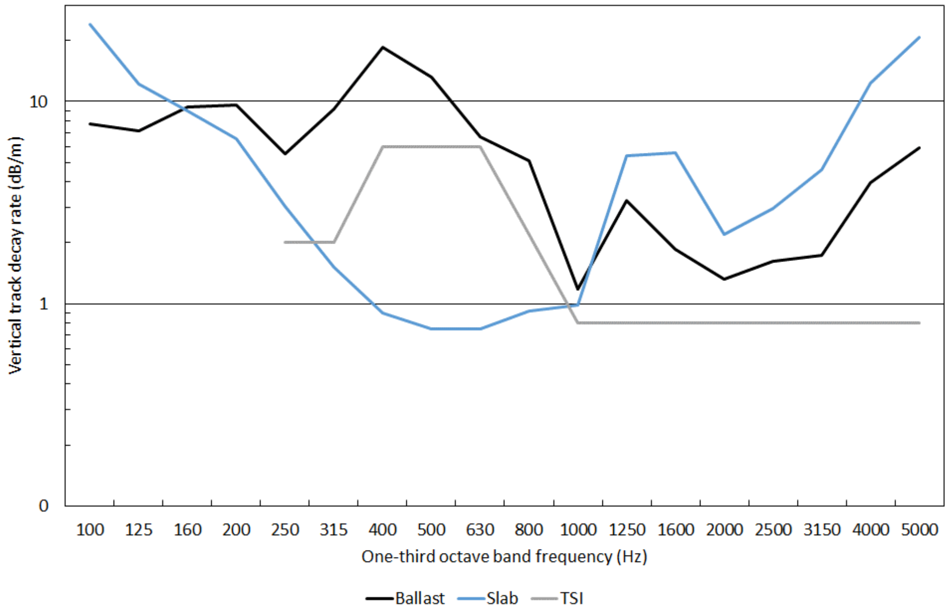

Figure 3: vertical decay rate values used in the study

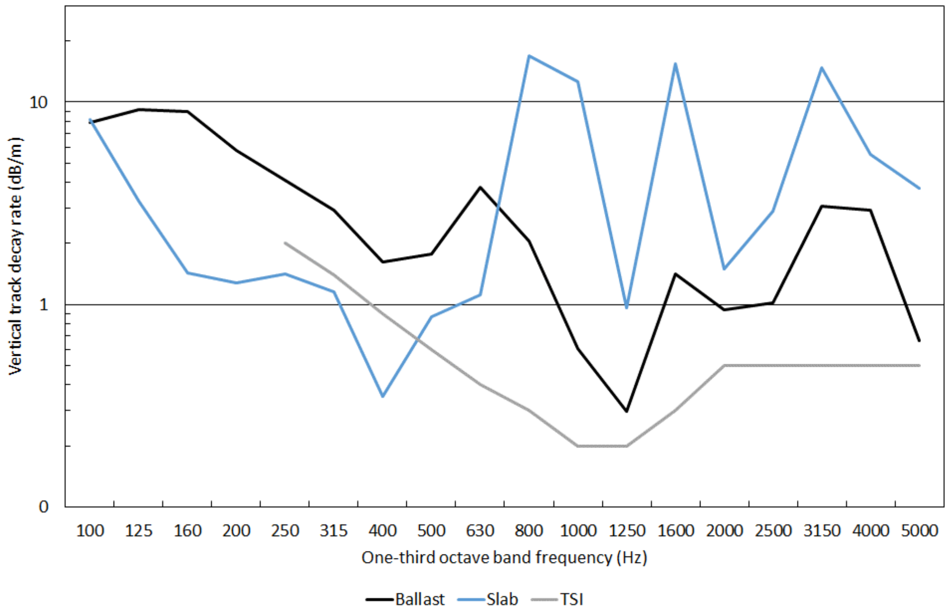

Figure 4: lateral decay rate values used in the study

2.2 Validation of approach

In order to provide further validation of the TWINS calculation approach, a comparison was made between predictions and measurement data from noise measurement trials of high-speed trains running on ballast track at speeds of up to 350km/h in Las Invernias, Spain in 2018 [14]. The rail roughness and track decay rates were measured on site. Results are compared for a microphone positioned at 25 m from the track centre, 3.5 m above the rail, with the train travelling at speeds between 250 and 350 km/h. The measured and calculated results are plotted in Figure 5. The results show similar values at 250 km/h but deviate at higher speeds due to the increased importance of aerodynamic noise that is present in the measurements but not in the model. Calculated noise levels follow approximately a 30 log10V dependence on speed V, as expected for rolling noise, whereas the measured levels increase more rapidly with speed.

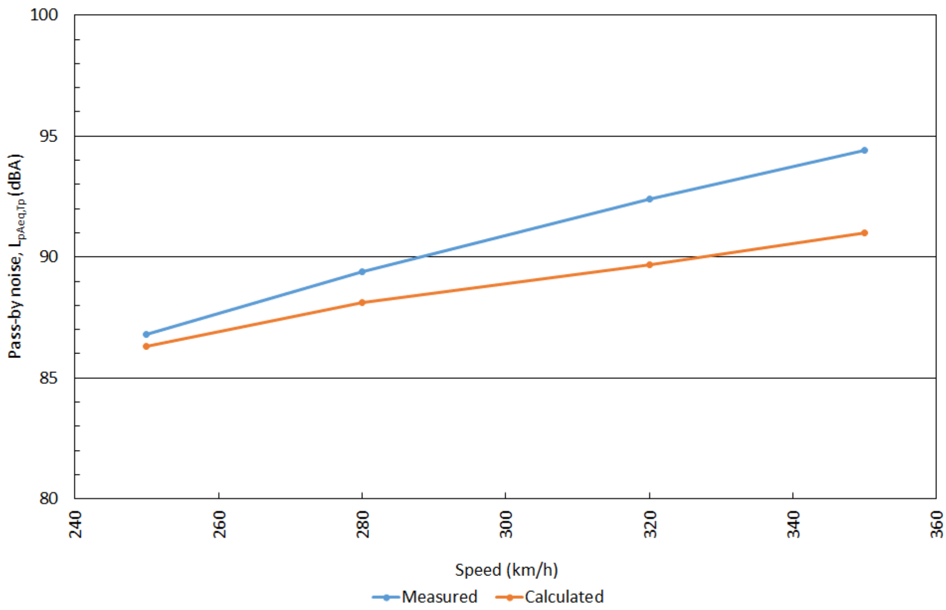

Figure 5: Measured and calculated overall A-weighted sound pressure levels at 25 m with speed, Spanish trial

3. Results

3.1 Comparison of ballast and slab predictions

Figure 6 shows a direct comparison of the total predicted rolling sound pressure levels for tracks at 330 km/h and 360 km/h. The predictions indicate that slab track could result in rolling sound pressure levels of the order of about 1 dBA greater than for the ballast track.

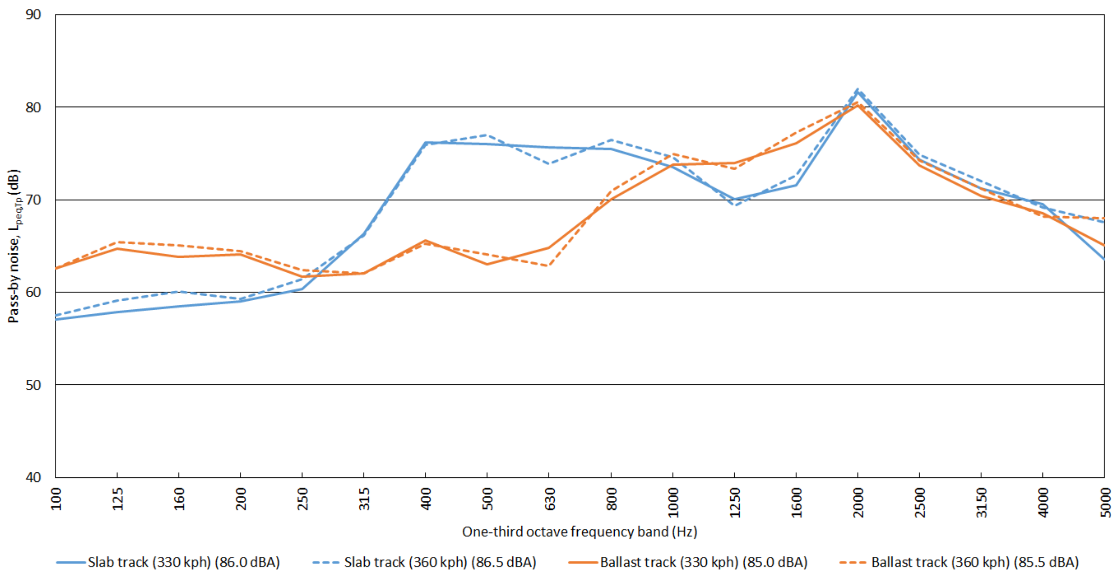

Figure 6: Unweighted sound pressure spectra at 25 m for train running on slab and ballast tracks at 330 and 360 km/h (overall A-weighted values in legend)

3.2 Comparison of predictions to environmental impact assessment assumptions

Table 1 shows the effect of speed on the rolling noise predictions. The values are compared to the assumptions made for rolling noise, traction noise, aerodynamic noise and pantograph noise made for the purpose of environmental impact assessment (EIA) [4]. Comparisons of the total noise considering the different rolling noise predictions are also given.

Speed (km/h)	150	200	250	300	330	360
Rolling (EIA)	81	85	88	90	91	92
Rolling slab track predicted	*78*	*81*	*83*	*85*	*86*	*87*
Rolling ballast track predicted	*75*	*79*	*82*	*84*	*85*	*86*
Aerodynamic (EIA)	63	72	78	84	87	89
Starting (EIA)	71	71	71	71	71	71
Raised pantograph (EIA)	49	58	65	70	73	76
Total (EIA)	81	85	88	91	93	94
Total slab track predicted	*79*	*82*	*85*	*88*	*90*	*91*
Total ballast track predicted	*77*	*80*	*84*	*87*	*89*	*91*

Table 1: TWINS predictions for noise contributions to total noise (L_{AeqTp}) compared to EIA assumptions for HS2 trains. TWINS predictions in *italics*.

For rolling noise, slab and ballast predictions are below the EIA assumptions for all speeds. At 150 km/h the rolling noise contribution of slab track is 3 dB higher than ballast. With increasing speed the relative difference diminishes so that at 360 km/h their rolling noise contributions are within 1dB. Table 1 also shows that with TWINS predictions for rolling noise, on both ballast and slab track, aerodynamic noise is likely to be dominant at speeds over 300 km/h. This compares to 330 km/h using the rolling noise source terms used for EIA.

4. Conclusions

In order to better understand the noise performance of high speed ballast and slab track predictions of rolling noise have been made using parameters which are expected to represent the operation of HS2 at speeds of up to 360km/h. To provide validation of the calculation approach, a comparison was made between predictions and measurement data from trials of high-speed trains running on ballast track in Spain. The predicted total noise agreed well with measurements at the lowest speed (250 km/h), but the measured noise increases more rapidly at higher speeds. This was expected due to the aerodynamic noise that is present in the measurements. For both types of track the predicted rolling noise is lower than the assumptions made for environmental impact assessment. In the case of the ballast track, the reason that the predictions are lower than these assumptions is a result of the low assumed rail roughness input. This roughness level is lower than typically encountered in the UK but, based on measurements made on slab track in Germany [15], it is believed that it can be achievable with a suitable maintenance strategy. At 360 km/h, the noise levels from the slab track are found to be similar to the ballast track. This is as a result of the dual stage fastening system. The upper pad fitted above the base plate on the fastening has the effect of increasing the decay rates at higher frequencies compared with a notional slab track with a single layer soft fastener. This compensates for the increased radiation, particularly from the rail, due to the absence of ballast absorption. At speeds above 300 km/h, the total noise including other sources (i.e. aerodynamic and traction), is expected to be similar for ballast and slab track. At lower speeds, ballast track is expected to be somewhat quieter e.g. at 150 km/h by around 2 dB. This study identifies that the relative differences between slab and ballast tracks are highly dependent on the precise characteristics systems being compared. Some of these characteristics, such as rail roughness, may vary over time. The effect of these parameters on the total noise will be lessened due to influence of other (non-rolling) sources, particularly at higher speeds where aerodynamic sources are more dominant. None-the-less work is ongoing to further understand and validate the assumptions that resulted in the conclusions presented here.

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