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Vibration protection for Birmingham’s Arena Tunnel

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In the so-called Arena tunnel, right in the heart of the City of Birmingham (UK), the padded wooden sleepers of the ballasted track were replaced by concrete sleepers fitted with under sleeper pads. Vibration measurement at the lining of the tunnel following track renewal showed that the under sleeper pads delivered by the Getzner company were able to prevent any increase of train-born vibration.

Renewal of the tracks in the Birmingham Arena Tunnel was carried out at the beginning of 2010. This included replacing the rails, sleepers and ballast. In the course of the project, the old wooden sleepers featuring 20 millimetre rubber cork sleeper pads were replaced with new padded concrete sleepers. The use of under sleeper pads should provide a specified level of elasticity for the superstructure.

There were no data available concerning the elasticity of the rubber cork pads in combination with the wooden sleepers. In retrospect it is nearly impossible to isolate and evaluate the effect of those pads.

The newly built ballasted track with its concrete sleepers should have such properties (elasticity and damping) that no increase in vibration propagation from the heavy trafficked railway line to the surrounding buildings would occur.

Experts from railway engineering specialist DeltaRail took vibration measurements before and after the track renewal to determine whether this goal had been achieved.

1 Details of the reconditioned line

The renovated line is part of the two-track Stour Valley line running west from Birmingham New Street Station to Wolverhampton.

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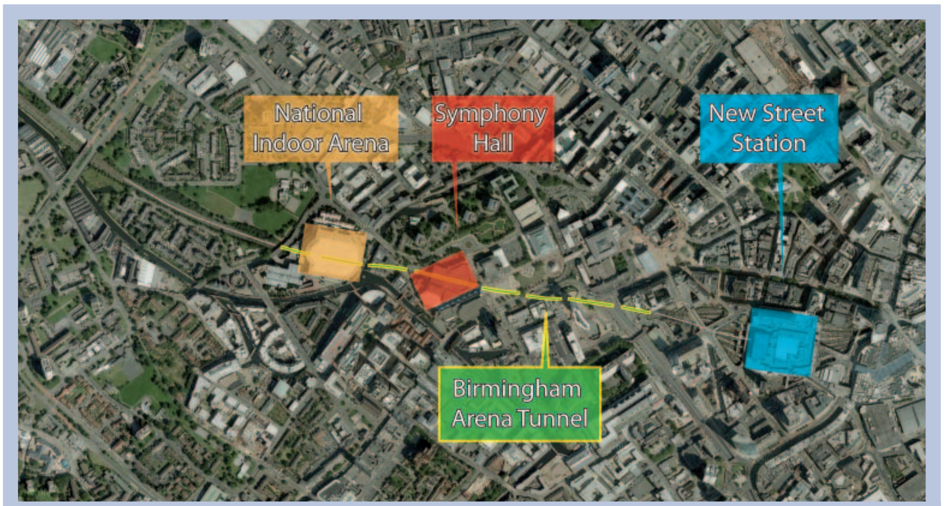

Fig. 1: Situation of the Birmingham Arena Tunnel

The 161-metre long tunnel runs directly beneath the International Convention Centre, Symphony Hall and the National Indoor Arena (Fig. 1). The entire length is walled and runs through sandstone at a depth of about 25 metres. Both tracks are used by various types of trains. To account for differences in the vibration spectrums, measurements were performed for diesel trains (DMU), electric trains (EMU) and the Class 390 Pendolino train. The maximum train speed allowed in this track section is 64 km/h (40 mph). Renewal work on the track heading to New Street Station was performed on the 24 and 25 January 2010. The tracks, rail pads and ballast were replaced with similar new components, and padded concrete sleepers were installed in place of the previous padded wooden sleepers.

2 Sleeper pads compared

The original pads were made of a 20 millimetre thick rubber cork mat, protected against the ballast on the underside by a geotextile layer. This protective layer extends to the sides of the wooden sleeper where it was clipped in place. This means that the protective layer also served to fix the under sleeper pad. During the renewal it was discovered that some of the pads had separated from the sleeper. As a result, bedding material had become lodged between the geotextile layer and the sleeper. An example is shown in Fig. 2. According to information from Network Rail, the sleeper pads had been in service since 1991.

These were replaced with concrete sleep-

Fig. 2: Removed wooden sleeper with damaged mounts

ers equipped with 10 millimetre thick polyurethane pads. The elastic sleeper pads feature Getzner's Sylomer® SLS 1010 G. The static stiffness (bedding modulus) of this model, determined in accordance with DIN 45673-1 (Secant bedding modulus between 0.02 N/mm³ and 0.16 N/mm³), is 0.1 N/mm³. Geotextile has again been used to protect the resilient layer of the pad against perforation by the ballast, while an installation grate secures the pad to the concrete sleeper. The pad is pressed directly into the wet concrete during the production process to join it to the sleeper (Fig. 3).

3 Vibration measurements

3.1 Measuring technique

To determine the effect of the track work on vibration emissions, measurements were performed before and after the track renewal. The automatic measuring equipment was installed next to the rebuilt track on the tunnel wall, adjacent to a safety niche. In doing so, the accelerometer was aligned vertically, laterally and longitudinally to the track. The measuring equipment was installed in a metal box affixed to the tunnel wall using plaster at a height of about 0.1 metres (Fig. 4). The control unit, data logger and power supply were fitted in the adjacent niche.

In order to compare vibration levels before and after renewal, a reference target value was determined on 17 January 2010. A measuring system was then installed on the same day and removed at the start of the renewal work on January 24. To ensure consolidation of the tracks, comparison measurements were performed ten weeks after project completion on 6 and 7 April 2010. During the measurement process, the vibration spectrums were calculated for

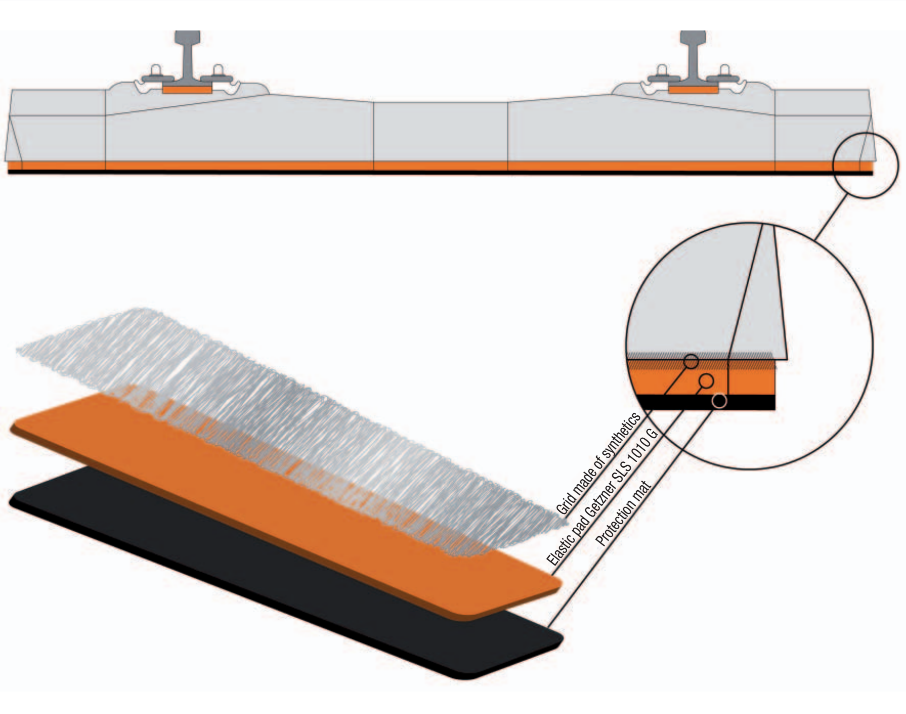

Fig. 3: Sylomer® SLS 1010 G sleeper design

Fig. 4: Measuring equipment

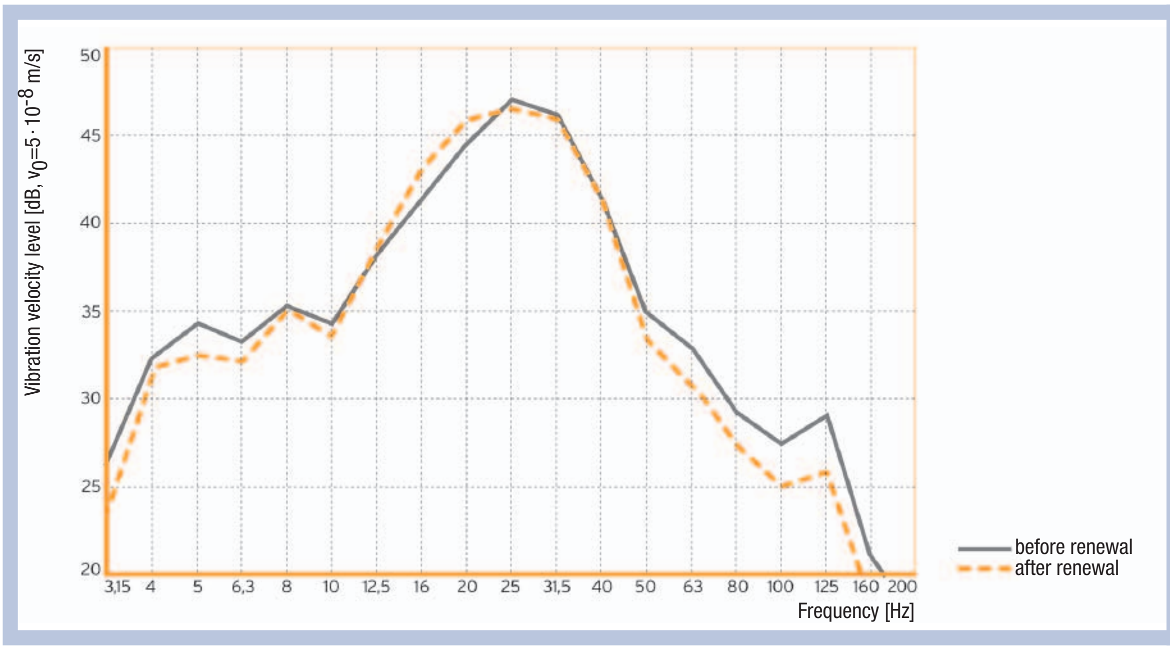

Fig. 5: Vibration spectrum measured before and after track renewal – EMU class 323 only

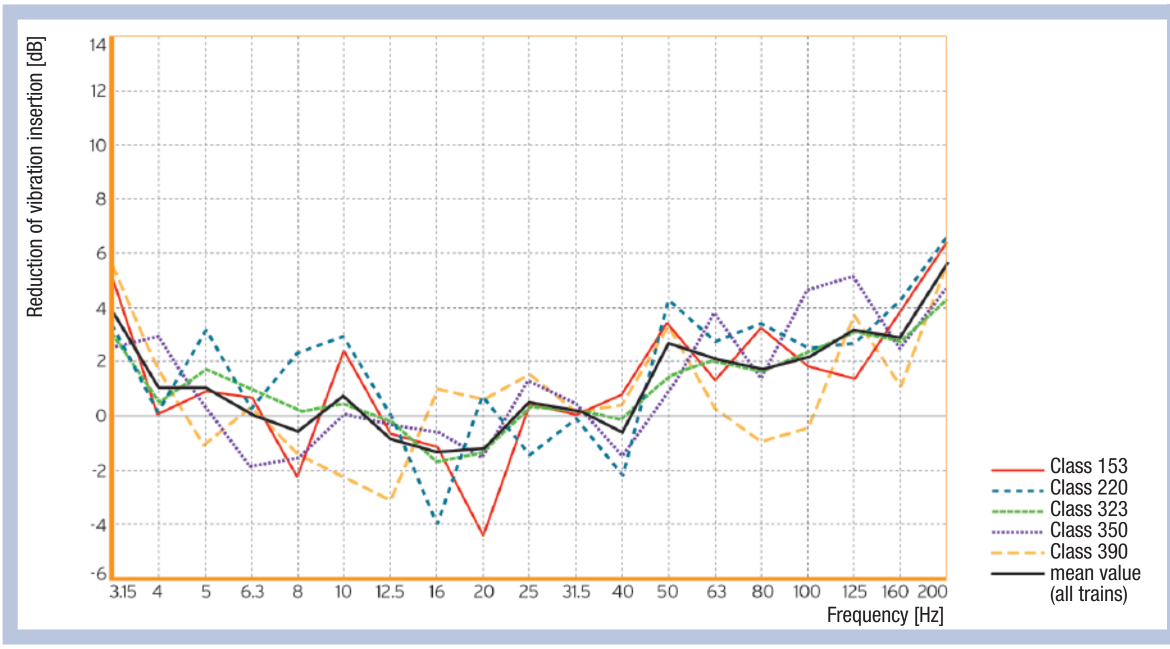

Fig. 6: Reduction of vibration energy insertion due to track renewal – five types of trains and mean values

Train type	recorded train speed [km/h]	
	before renewal	**after renewal**
Class 153 DMU	51	46
Class 220 DMU	39	49
Class 323 EMU	59	57
Class 350 EMU	50	46
Class 390 EMU	38	30

Tab.1: Train types and speeds

five different train classes and averaged in order to estimate variations in emissions. To establish a correlation between the individual types of trains and the measurement results, the trains travelling through the tunnel were observed and documented from a public space next to the tunnel opening. Additional measurement of the transit time made it possible to determine the speed of each train.

3.2 Results

The acceleration data collected were used to calculate the vibration velocity spectra. The results were grouped according to train type and speed for comparison (Tab. 1).

Since vertical acceleration is dominant, these values were used as the basis of comparison. The majority of the vibration energy has a frequency of between 12.5 Hz and 40 Hz. Fig. 5 shows the vibration velocity levels recorded at the wall of the tunnel when an EMU class 323 passes by, measured before and after the track renewal. Prior to renewal, the peaks ranged from 25 Hz to 31.5 Hz, but after completion of the work, they stood at 20 Hz to 31.5 Hz. This indicates a slight downward shift in frequency. Very remarkable reductions in vibration were measured for frequencies below 6.3 Hz and above 40 Hz.

The reduction of vibration insertion (sometimes also called "insertion loss") can be calculated using these two spectra for each train. Fig. 6 shows this difference in vibration levels before and after the renewal. Positive values report that reduced vibration levels at the tunnel lining were detected after completion of the track renewal work. The mean reduction is a calculated value, derived from the arithmetic mean of the vibration level of the five train classes.

4 Conclusion

A very remarkable reduction of the insertion of vibration energy into the tunnel structure due to the new track construction featuring concrete sleepers fitted with under sleeper pads was measured for frequencies below 6.3 Hz and above 40 Hz. Furthermore there was virtually no change recorded in the insertion of frequencies between 6.3 Hz and 40 Hz. So the objective of the project was achieved by using Getzner Sylomer under sleeper pads.

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