inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 46

MANCHESTER CONCERT HALL:VIBRATION ISOLATION

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1. INTRODUCTION

The Bridgewater Hall in Manchester forms the new home for the Hallé orchestra and a major international venue for symphonic and classical music. The hall comprises a 2400 seat auditorium together with orchestral accommodation and backstage facilities.

The site is approximately 30m from the Metrolink railway (see Figure 1) and both the railway and the hall are founded on the sandstone bedrock. The potential for disturbance to the hall due to groundborne vibration from the railway was investigated early in the design process in 1989. As a result, it was decided that the entire structure should be isolated on springs with a natural frequency of 3.5Hz.

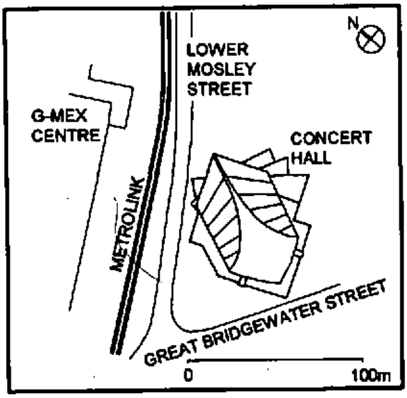

FIGURE 1: Site Location

The railway did not commence operation until 1992, so the assessment and design were based on predicted levels of railway vibration and ground attenuation. The noise level criterion for the auditorium is PNC15. The limit for maximum re-radiated noise levels from trains was set at slightly above PNC15, based on experience of similar projects. The predicted levels of vibration and re-radiated noise are shown in Table 1.

	Octave Band Centre Frequency, Hz		
	31.5	63	125
Metrolink Vibration level at 10m, dB re 1×10^{-9}m/s	80	95	90
Metrolink Vibration level at 30m, dB re 1×10^{-9}m/s	80	83	75
Predicted re-radiated noise level in auditorium, dB re 20μPa	63	66	57
PNC 15 (limit for continuous noise), dB re 20μPa	58	43	35
Limit for train noise, dB re 20μPa	63	50	40

TABLE 1: Predicted noise and vibration levels (no isolation)

2. DESIGN

It was clear from the noise predictions (Table 1) that the auditorium would need a substantial degree of protection from groundborne railway vibration. Vibration isolation at source was investigated but could not be incorporated due to the imminent start of railway construction. Design of an isolation system for the building was therefore carried out. The aim was to design a system providing the best practical isolation performance.

Although the auditorium was the only space requiring protection from the railway vibration, it was decided that all of the accommodation would be isolated. This approach was adopted to avoid the need for an extensive (and costly) isolation joint between sensitive and non-sensitive structure.

The main heating, cooling and ventilation plant is located in a separate building as part of the strategy for controlling noise ingress into the auditorium. The plant tower building is not isolated from the ground (as it contains no sensitive accommodation) and all services (ducts, pipes, cables, etc) connecting with the isolated structure therefore require resilient joints.

Detailed consideration was given to the use of elastomeric pads and helical steel springs for the building isolation. To date, elastomeric pads have typically been used in building isolation systems with natural frequencies of 10Hz to 15Hz, with one or two applications at approximately 7Hz. Proposals for an elastomeric system achieving a natural frequency of approximately 4Hz have been developed but have yet to be used in a building.

When used for a building isolation system, steel springs are most cost effective in the 3 to 5Hz natural frequency range. (Higher natural frequencies require stiffer springs, while lower natural frequencies can compromise spring stability.)

While single degree of freedom theory suggests that isolation performance at a given excitation frequency increases as the natural frequency of the system is reduced, the vibration response of building structures is complex and significantly affects the overall performance achieved. Indeed, in a previous project carried out by Arup Acoustics [1], a 3.5Hz spring isolation system was chosen to provide protection from low frequency vibration (less than 20Hz) rather than for enhanced performance in the audible frequency range (above 20Hz).

For this project however, it was decided that, maximum performance would be achieved in the audible range by a combination of careful control over the vibration response of the structure and the use an isolation system with the lowest practical natural frequency. A 3.5Hz spring system was adopted. The re-radiated noise level predictions were revised accordingly and still indicated that levels would exceed the design target in the 63Hz octave band.

3. VIBRATION MEASUREMENTS

The first railway vibration measurements were carried out on site in July 1992, shortly after the Metrolink system began operation. Construction of the concert hall had not yet commenced so a concrete foundation pad was constructed at bedrock level on the site for the location of vibration transducers. Vibration measurements were also carried out on the ground surface at approximately 10m from the track. The results are shown in Table 2.

	Octave Band Centre Frequency, Hz		
	31.5	63	125
Metrolink Vibration level at 10m, dB re 1 x 10^{-9}m/s	96	95	78
Metrolink Vibration level at 30m, dB re 1 x 10^{-9}m/s	81	75	44

TABLE 2: Measured vibration levels

An extensive vibration survey was carried out on site after the completion of the building substructure. The results highlighted a small number of foundation columns subject to vibration levels significantly higher than the typical case. These columns were located near to the alignment of a disused canal which had been buried by previous development of the site, but the substantial masonry walls remained intact. It was suspected that these walls formed a structural link between the railway and this part of the site. The walls were therefore excavated and a moderate reduction in vibration was achieved on the relevant foundation columns.

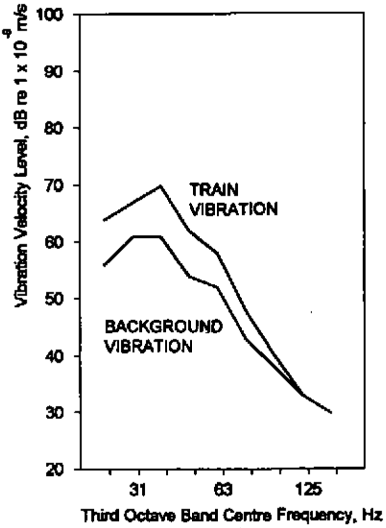

FIGURE 2: Vibration Levels

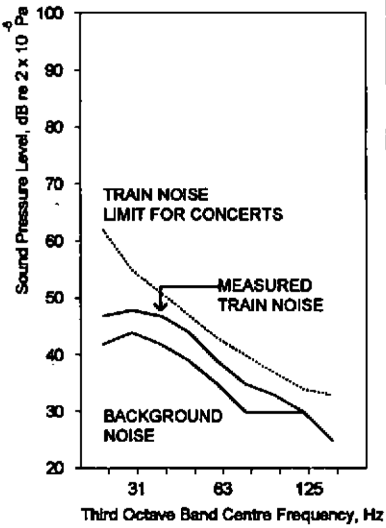

FIGURE 3: Noise Levels

With the building nearing completion, noise and vibration measurements were carried out in the auditorium. The results from the stalls are shown in Figures 2 and 3 and indicate that the train noise limit has been met. The spring isolation system has surpassed the expected performance.

4. CONCLUSIONS

The vibration isolation system of the new Bridgewater Hall in Manchester has successfully protected the auditorium from disturbance due to groundborne noise from the Metrolink railway.

Railway vibration generation and propagation is a complex mechanism and each stage of the prediction process is associated with significant uncertainty. While the overall result of this project has been a success, it is notable that the measured source vibration levels, ground attenuation values and spring isolation performance varied from the predictions.

REFERENCE

[1] CJ Manning, Noise and Vibration from Ludgate Railway Works, Proc IOA 13 (5) (1991)