BLOCKING MASS FOR ARCHITECTURAL VIBRATION ATTENUATION – A CASE STUDY

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1 Introduction

In the modern urban environment, noise-sensitive operations are sometimes forced into close quarters with inherently noisy neighbouring tenants/owners.

This case study reports just one of the challenges associated with the retrofitting of an old theatre which was repurposed and split into two adjacent properties: a large music venue on one side, and a gaming facility on the other. Specifically, this paper addresses the continuous metal roof deck between the rooms, which is the primary noise flanking path. To help mitigate this issue, two different blocking mass solutions were designed to reduce roof deck vibration transmission. The predicted vibration attenuation is discussed, along with the two proposed designs.

2 Methodology

2.1 Description of scenario

The music venue and gaming spaces are separated by an existing demising partition, and the transmission loss is increased by the addition of a gypsum wall board (GWB) partition on the music venue-side (Figure 1). The space between serves as a crossover corridor for the music venue.

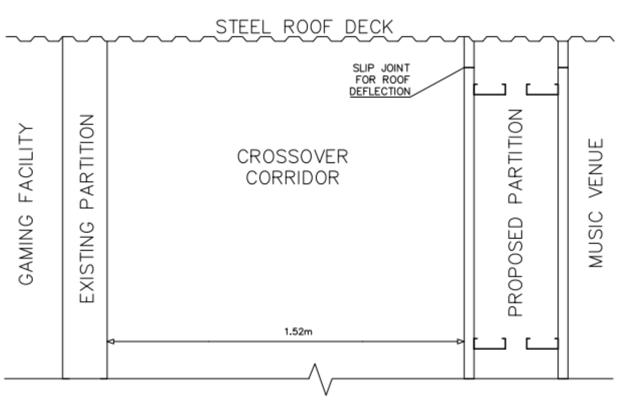

Figure 1: Demising partitions between music venue and gaming facility, arranged to create a crossover corridor. The proposed partition includes a slip joint designed for roof deflections.

The estimated partition transmission loss (not discussed as part of this paper) between the music venue stage and the gaming facility is such that the music noise level intruding on the gaming facility does not exceed the existing background sound level in the space, especially critical at low frequencies (125 Hz and below).

With the transmission loss through the partitions having been addressed, it is anticipated that the primary flanking noise issue is via the continuous metal roof deck (shown in Figure 1). Noise energy from the music venue excites the common roof deck, allowing vibration to travel across the demising partition and into the gaming facility, where it is re-radiated as structure-borne noise at the point of reception. As such, a blocking mass is proposed to mitigate the issue, with a target insertion loss of approximately 40 dB at 50 Hz. This targeted roof deck flanking path attenuation is based on our estimate of the partition transmission loss at low frequencies. In short, the estimate of the partition transmission loss at 50 Hz is 40 dB; as such, the goal is to offer as much sound attenuation via the roof deck flanking path as is anticipated through the partitions.

2.2 Calculation method

The transmission loss, τ, of bending waves travelling along a plate and across a blocking mass is given in [1] as:

$$\tau = 1, \text{for } f < 0.5 f_s$$
$$\tau = [1 + f/f_u]^{-1}, \text{for } f > 2 f_s$$
$$f_s = \frac{1}{2\pi}\frac{K_1}{K^2}\sqrt{\frac{E_1}{\rho_1}};\; f_u \approx \frac{2\rho_1 {S_1}^2 K_1 \sqrt{E_1 \rho_1}}{\pi m^2}$$

f_s and f_u must be calculated and are functions of the steel deck's Young's Modulus (E_1), density (ρ_1), cross-sectional area (S_1), radius of gyration (K_1), mass of the blocking mass (m) and the radius of gyration of the blocking mass (K). A similar theory is given in [2]. Since the building structure exists, these variables are given and shown in Table 1.

Table 1: Constants used to estimate transmission loss across blocking mass.

Variable	Description	Value
E_1	Young's Modulus of steel	2.00 x 10^{11} Pa
ρ_1	Density of steel	7900 kg/m^3
S_1	Cross-sectional area of steel deck	0.00091 m^2
K_1	Radius of gyration of steel deck	0.01033 m

The blocking mass-related values m and K are dependent on the materials and geometries used, discussed in Section 3.

Assumptions made in order to implement this methodology include: 1) plate material with a "rib" blocking mass configuration; 2) full moment connection between plate and rib; 3) plate and blocking mass rib materials are the same. In practice, these could not be satisfied.

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3 Results

A roof deck blocking mass could be made of a row of concrete masonry unit (CMU) blocks installed directly on the rooftop, collinear with the demising partition below (Figure 2). In the case of the blocking mass being located along only one side of the plate under analysis, K can be integrated and simplified to yield the following formula:

$$K = 0.333L$$

Where L is the height of the blocking mass.

Assuming a CMU surface density of 341 kg/m^2 (per metre length of wall), calculations were undertaken showing that a row 7 courses high, weighing approximately 477.4 kg (per metre length of wall), would offer roof deck vibration attenuation of 74 dB at 50 Hz.

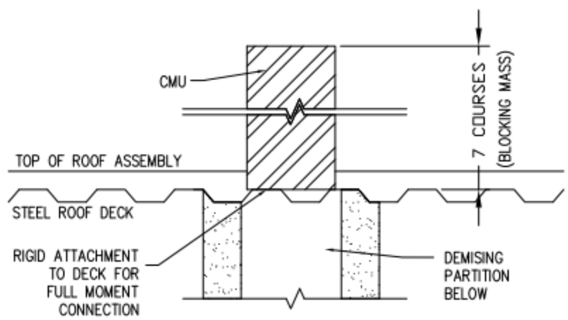

Figure 2: Proposed CMU blocking mass installed directly on the roof deck.

A second blocking mass design is also considered, where part of the demising wall is rigidly attached to the underside of the roof deck. In order to achieve this, the slip joint planned for the proposed double-stud partition shown in Figure 1 is moved from the interface of the wall top and roof deck, to a location "X" metres below (Figure 3).

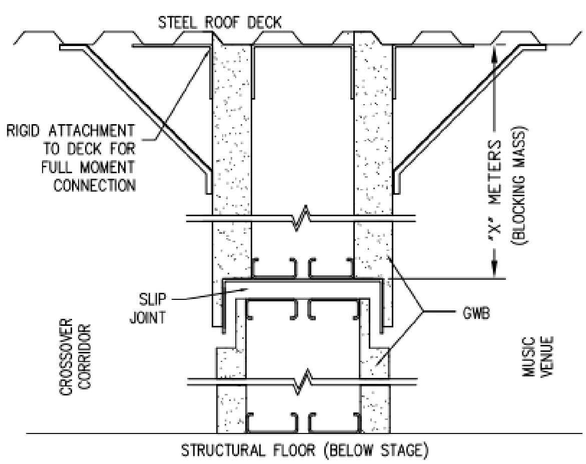

Figure 3: Proposed crossover corridor GWB partition with blocking mass suspended from the roof deck above.

This design decouples the top "X" metres of the partition from the rest of the partition below, effectively suspending part of the proposed crossover corridor partition from the roof deck above. Assuming a GWB density of 962 kg/m^3 and height of blocking mass of X = 1.75 metre, calculations similar to the CMU blocking mass were undertaken, showing that 6 layers of 16mm Type 'X' GWB per side of the blocking mass, weighing approximately 323.2 kg (per metre length of wall), offer a roof deck vibration attenuation of 70 dB at 50 Hz, approximately the attenuation achieved using the CMU block wall on top of the roof deck. Of note, this large number of GWB sheets can be reduced by using a material with a higher density, such as cement board.

At the time of writing, neither of these blocking mass designs or the crossover corridor has been built; therefore, measured data is not yet available. The intention is to measure the transmission loss of the partition and insertion loss of the roof deck blocking mass once implemented.

4 Discussion

The results obtained and discussed herein are considered an approximation of the actual transmission loss. Despite the assumptions made in Section 2.2, which were made in order to mathematically model this scenario, a very high transmission loss is calculated; as such, we can be satisfied with even half of the calculated transmission loss of vibrations travelling along the steel roof deck, resulting in transmission losses of approximately 35 to 37 dB at 50 Hz. With this safety factor, the calculated transmission loss is within 8-12% of the targeted attenuation; thus, the design is considered reasonable from an acoustic perspective and from a constructability perspective.

5 Conclusion

Blocking masses for attenuation of roof deck borne vibration have been designed and theoretically can provide high attenuation. In this case study, two proposed designs, including CMU blocks as well as a suspended GWB blocking mass as part of a demising acoustic partition, were found to be an effective, albeit theoretical way of greatly reducing noise flanking via the steel roof decks. The theoretical construction is much simpler than would be in practice, so the calculated attenuations are not expected to be realized; however, even if greatly reduced, the blocking mass designs will provide more than sufficient attenuation. Field measurements of the as-built condition, once the final design is built, will allow verification that the targeted attenuation has been achieved, and the empirical data will also allow to validate and potentially critique the modelling method described in this paper.

References

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