Acoustic Metamaterials

A large-scale design of acoustic noise barrier adopting 3d printed modularity for customisable acoustical performance.

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Noise barriers are commonly seen around Singapore especially at construction sites and along MRT tracks. The purpose of noise barriers is to reduce the level of unwanted noise and minimise disturbance to the nearby residents. A design limitation of such noise barriers is that the acoustical performance is not customisable. If the frequency content of the noise environment changes, the same noise barrier may no longer be able to reduce the noise level effectively. Moreover, most of the commercially available noise barriers may not be effective if the noise environment is predominantly low-frequency (< 500 Hz).

To address the issue, this work [1–3] has proposed a new generation of noise barrier (referred to as the meta-panel), which adopted the concept of modularity for customisable acoustical performance. The proof-of-concept design is realized by two key components—a wooden host structure and noise attenuating blocks. The noise attenuating blocks, which were 3D-printed, are slotted into the openings on the host structure to form the meta-panel (Figure 1). The customisation in acoustical performance lies in the design of the noise attenuating blocks in which each of their noise attenuation properties collectively contribute to the overall noise attenuation characteristic of the meta-panel. This characteristic is insensitive to the orientation and the distribution of the noise attenuating blocks.

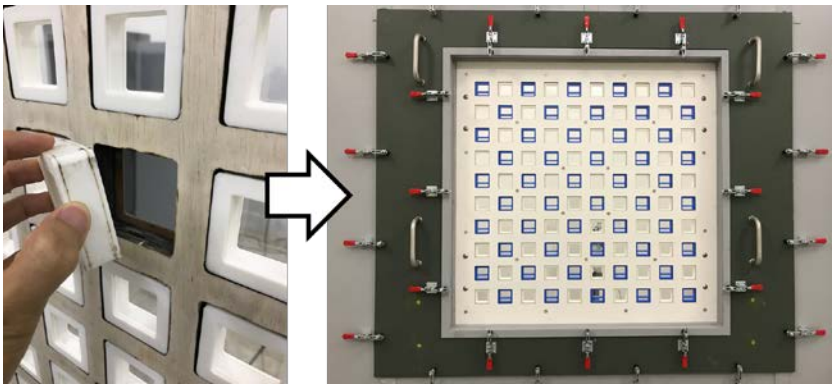
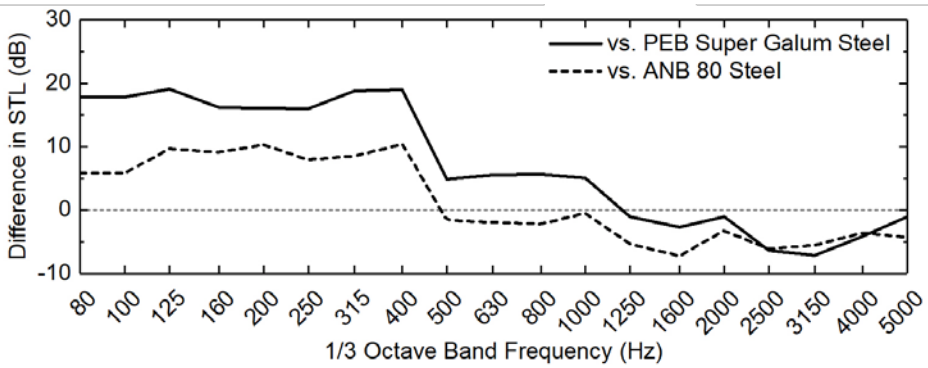


Figure 1: (left) Noise attenuating blocks slotted into the openings of the host structure. (right) Overview of the meta-panel with different noise attenuating blocks slotted into the openings of the host structure.

Moreover, the noise attenuating blocks can be designed to exhibit good acoustical performance at low-frequencies (< 500 Hz), leading to a configuration that is superior to the existing noise barriers installed around Singapore (Figure 2). Figure 2 shows the difference in sound transmission loss (an indication of how much noise is reduced) between the meta-panel and the two commercially available

noise barriers. A positive difference indicates the superiority of the meta-panel, while a negative difference indicates the inferiority of the meta-panel. Compared to the PEB Super Galum Steel, the meta-panel could reduce low-frequency noise by up to around 19 dB. Compared to the ANB 80 Steel, the meta-panel could reduce low-frequency noise by up around 10 dB.



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The Sound Transmission Class (STC)—widely used in the industry to rate building elements—can be used to rate the acoustical performance using a single-value. The meta-panel, the PEB Super Galum Steel, and the ANB 80 Steel have a STC of 33, 25, and 33, respectively. Despite the superiority of the meta-panel at 80–400 Hz over the ANB 80 Steel, both has the same STC (33) because the meta-panel is poorer in acoustical performance over a wider frequency bandwidth (500–5000 Hz). However, problematic noises are usually predominantly low-frequency (< 500 Hz). In this case, the meta-panel may be more suitable despite having the same STC as the ANB 80 Steel, not to mention that it is lighter and thinner by 18% and 68%, respectively (Table 1). Comparing between the meta-panel and the PEB Super Galum Steel, the superiority of the meta-panel is shown in which its STC is 8 points higher. Since the meta-panel is only a proof-of-concept design, future work will explore avenues to reduce the weight and the thickness further without compromising on low-frequency acoustical performance.

Product Name	Thickness (mm)	Surface Density (kg/m^2)
Wooden Meta-Panel	26	16.4
ANB 80 Steel [4]	80	20.0
PEB Super Galum Steel [5]	30	10.1

References:

[1] Ang, L.Y.L., Y.K. Koh, and H.P. Lee, *Plate-type acoustic metamaterial with cavities coupled via an orifice for enhanced sound transmission loss.* Applied Physics Letters, 2018. **112**(5): p. 051903. doi: 10.1063/1.5019602.

[2] Ang, L.Y.L., Y.K. Koh, and H.P. Lee, *A note on the viscous boundary layer in plate-type acoustic metamaterials with an internal tonraum resonator.* Applied Acoustics, 2018. **140**: p. 160–166. doi: 10.1016/j.apacoust.2018.05.021.

[3] Ang, L.Y.L., Y.K. Koh, and H.P. Lee, *Plate-type acoustic metamaterials: Evaluation of a large-scale design adopting modularity for customisable acoustical performance.* Applied Acoustics, 2019. (Accepted: Article-in-press)

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