A Possible Mitigation Measures for Urbanized Residential Development -
Acoustic Window with Natural Ventilation
Grace KWOK1; Tin Kit HO2, Andy LAI3; Frank CHEUNG4, Joanne NG5
Allied Environmental Consultants Limited, Hong Kong

ABSTRACT
Similar to many metropolitan cities, noise pollutant is one of the biggest problems in Hong Kong. More than one million people in Hong Kong are affected by excess traffic noise according to the Environmental Protection Department of Hong Kong. Poor planning in the past and the fast growing economy during the 1980s and 90s has resulted to this severe problem. Extensive noise mitigation measures are essential when designing a new development particularly in the residential point of view. Special designed window which refers to “Special window” is proposed by arranging two glass panels parallel to each other with openings at alternative sides, traffic noise can be screened off while allowing natural ventilation at the same time. In this paper, field tests were carried out to analyze the acoustic performance of the Special window. Test results shown that the Special window is effective in mitigating substantial traffic noise while providing reasonably amount of ventilation while further reduction could be achieved by the addition of sound absorbers within the cavity between the two panels of windows.

Keywords: Noise Insulation, Insertion loss, Acoustic window

1. INTRODUCTION
Similar to many metropolitan cities, noise pollutant is one of the biggest problems in Hong Kong. More than one million people in Hong Kong are affected by excess traffic noise according to the Environmental Protection Department of Hong Kong. Poor planning in the past and the fast growing economy during the 1980s and 90s has resulted to this severe problem.

Extensive noise mitigation measures are essential when designing a new development particularly in the residential point of view. Moreover, where most residential buildings in Hong Kong are naturally ventilated to reduce electricity load from mechanically ventilation and enhance sustainability, domestic dwellings facing major roads are bounded to be affected by traffic noise.

Being such a congested city with limited land areas like Hong Kong, the implementation of source mitigation such as noise barriers, enclosures or road surface improvement works may not be an easy task due to many constraints such as space, safety, visual and ventilation issues. Since mitigation at source is not a viable option in many occasions, mitigations at receivers may often be considered during the early stage of a project design.

Effective façade treatments such as horizontal / vertical fins are often proposed to reduce the angle of view towards the nearby major roads. Other than that, a specially design window which refers to “Special Window” in this study is proposed by arranging two glass panels parallel to each other with openings at alternative sides, traffic noise can be screened off while allowing reasonable degree of natural ventilation.

1 gk@aechk.com
2 htk@aechk.com
3 al@aechk.com
4 fc@aechk.com
5 jn@aechk.com
In this paper, noise measurement were carried out in a full scale mock up and an in-situ testing unit to analyze the acoustic performance of this Special window; as well as the acoustic benefit of sound absorption materials.

2. Off-site mock up

2.1 Mock up model

The mock-up unit was erected at the rooftop of a low-rise building; its location is shown in Figure 1. To simulate the actual noise reduction, the mockup room was constructed in 1:1 in scale.

![Figure 1 – The location of Mock-up Unit](image)

The mockup room was enclosed with full height drywalls and solid ceiling and floor, with internal wall finishing. The drywalls were composed of 0.4mm steel plate, 1 layer of gypsum board and layer of 50mm rockwool and 2 layers 12mm gypsum, which lead to the overall sound transmission class of at least STC43. No opening was allowed in the mockup room, except windows and entrance door in order to eliminate any possible flanking path. Multilayer material supported by steel frames in the drywall would further minimize the flanking transmission. In addition, silicon sealant was applied when gap was identified to cutoff the flanking path.

No furniture was provided in the mockup room, whereas typical wall finishing (i.e. plaster finishing) and carpet flooring was applied in the mockup room. Photographs of the mock-up unit are shown in Figure 2a and Figure 2b.

![Figure 2a – Front View of Mock-up Unit](image) ![Figure 2b – Back View of Mock-up unit](image)

Special window was installed at the interior side of the window opening to enhance the acoustic performance of the window system. The detail layouts are shown in Figure 3a – Figure 3d. These windows were installed with sound absorption features for additional sound absorption if necessary.
2.2 Mock up Measurement procedures

A series of loudspeakers with white noise were used as a source to simulate the noise from outdoor traffic, ISO 140-5:1998(E) specifies where the loudspeakers should be placed with respect to the mock-up building façade. The distance from the sound source to the center of the testing façade was at least 7m, and the angle of the sound incidence was 45±5°.

The loudspeakers were placed at 6 positions horizontally outside the mockup unit in order to simulate the traffic noise source (i.e. line source) as given in Figure 4. Each of the loudspeakers had a 5m separation distance to reflect the distances between vehicles moving on the road. The simulated traffic noise at 1m façade was measured by sound level meter with extended microphones mounted in front of the testing specimens as given in Figure 5.

Noise levels inside the mock-up testing room were measured by 5 microphones with at least 1m and 1.2m away from walls and floors respectively as given in Figure 6. No two microphone position was laid on the same plane. The layout and section plan of mockup test setting out are illustrated in Figure 8a – Figure 8c. Background noise measurement was taken for 5 minutes while the noise
level generated by the loudspeakers was at least 10 dB higher than the background noise level. The impact noise level by the loudspeakers was measured at sampling time of 5 minutes at each position to minimize the measurement variables, uncertainties and errors since the noise source was a steady source.

Measurements were carried out with rockwool as addition of sound absorber within the cavity between the two panels of Special windows as given in Figure 7.

The measured noise levels were computed using a normal traffic noise spectrum according to British Standard BS EN 1793-3:1998. The noise reduction was regarded as key sound isolation performance of the Special window over a conventional operable window and was defined as following:

\[ \Delta = [SPL_{(a)} - SPL_{(c)}]_{\text{inside}} - [SPL_{(a)} - SPL_{(c)}]_{\text{façade}} \]  

where

- \( \Delta \) = additional noise reduction by Special window
- \( SPL_{(a)} \) = energy average sound pressure level taken in acoustic mode
- \( SPL_{(c)} \) = energy average sound pressure level taken in conventional mode
- \([ \cdot ]_{\text{inside}}\) = measurement sets inside receiving room
- \([ \cdot ]_{\text{façade}}\) = measurement sets at the external facades of receiving room
3. On-site verification

3.1 On-site Verification Detail

To verify the performance of the Special window installed on site, in-situ field verification was carried out to demonstrate the noise reduction performance of the Special windows after the installation of the Special windows. The configuration of in-situ testing unit with Special window configuration for verification test is illustrated in Figure 9a – Figure 9b.
3.2 Verification Measurement Procedure

Outdoor traffic noise was measured by sound level meter with extended microphones mounted at 1m of façade as illustrated in Figure 10. Indoor traffic noises were measured by 5 microphones with at least 1m and 1.2m away from walls and floors respectively as illustrated in Figure 11 and Figure 12. No two microphone position was laid on the same plane.

The impact noise level from the nearby Tate’s Cairn Highway about 50m away from the testing unit was measured at sampling time of 5 minutes at each position to minimize the measurement variables, uncertainties and errors since the traffic noise was measured during peak hour.

Measurements were carried out with addition of sound absorbers within the cavity between the two panels of Special windows as illustrated in Figure 13.
Similar to Section 2.2, the noise reduction was regarded as key sound isolation performance of the Special window over a conventional operable window and was defined by Equation (1).

### 3.3 Specification of absorption materials:

For Mock-up units, 50kg/m³ density rockwool was used to indicate the benefits of noise absorptions installed in the cavity in between two sliding panels. As rockwool may cause allergy to the residents, a more realistic material was chosen as the absorptive material, the absorptive material was installed at all 4 sides of the cavity in between the two sliding panels.

The absorptive material consists of a 1mm thick Pomute aluminum outer layer, 12 micron Melinex film to fully warp the infill and ~50mm thick polyester fibre infill as shown in Figure 14 below. The Melinex film is an acoustically permeable material which offers good water resistance protection to the polyester fibre infill without greatly restricting the acoustic performance of the material which it encloses. The acoustic performance and photo of sound absorptive material are illustrated in Figure 15 and Figure 16 respectively.
Testing in accordance with ASTM C423-09a Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.

**Figure 15 Acoustic Performance of Sound Absorption Material**

**Figure 16 Photograph of the installed sound absorption material**
4. Results and discussions

The noise measurements conducted for the mock-up units both with and without installation of Rockwool as sound absorption at the cavity is summarized in Table 1.

Table 1 – Noise Measurement Level for Mockup Units with and without Rockwool Installation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Conventional window</th>
<th>Special Window</th>
<th>Noise Reduction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>out</td>
<td>in</td>
<td>in-out difference</td>
</tr>
<tr>
<td>Mock-up testing without absorptions</td>
<td>78.2</td>
<td>72.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Mock-up testing with Rockwool installed at top and bottom of cavity</td>
<td>78.2</td>
<td>72.1</td>
<td>6.1</td>
</tr>
</tbody>
</table>

As shown in the above result, a noise reduction of 4.6 dB could be achieved with the basic special window configuration; a further 1.4dB reduction could be achieved with sound absorption material installed at the top and bottom of the cavity between two sliding panels.

As design development went on, slight changes to the Special window configuration occurred as discussed in previous Section 3.1. The in-situ noise measurements conducted for the testing unit both with and without installation of sound absorber at the cavity is summarized in Table 2.

Table 2 – In-situ Noise Measurement Level for Testing Units with and without Sound Absorber Installation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Conventional window</th>
<th>Special window</th>
<th>Noise Reduction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>out</td>
<td>in</td>
<td>in-out difference</td>
</tr>
<tr>
<td>in-situ testing (without absorption)</td>
<td>72.9</td>
<td>64.6</td>
<td>8.3</td>
</tr>
<tr>
<td>in-situ testing (with absorption)</td>
<td>72.9</td>
<td>64.6</td>
<td>8.3</td>
</tr>
</tbody>
</table>

As shown in the above measurement result, a 3dB noise reduction could be achieved with the modified Special window configuration and a reduction of 6.3dB could be achieved with sound absorption material installed at all 4 sides of the cavity between two sliding panels.

5. Further findings

Upon completing the mock up and in-situ testing, it is found that certain design elements pay heavy contribution to the overall acoustic performance; such as the overlapping distance of the two sliding panels, thickness of the glazing or separating distance of the two sliding panels. These elements may not necessarily be beneficial to the overall acoustic performance of the Special window and could be
site specific. Therefore, designer should provide a margin when designing similar Special windows and verifications should be carried out to justify the acoustic performance of the design.

6. Conclusion

A full scale mock up measurement and in-situ measurement were conducted in this study to analyze the acoustic performance of the Special Window. The benefits of sound absorption material installed at the cavity between the two sliding panels were also analyzed.

The present study shows that the final setup of the Special window can achieve a sound attenuation of 3.0 dB. The sound attenuation can be improved to 6.3dB with the installation of sound absorption in the cavity between the two sliding panels.

While the proposed Special window can provide a fair level of sound attenuation with reasonably amount of natural ventilation, the window is an effective measure to mitigate substantial traffic noise in densely populated urban areas like Hong Kong.

REFERENCES

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