STUDY ON SOUND ATTENUATION OF PLENUM WINDOWS WITH DIFFERENT OVERLAPS BETWEEN THE DOUBLE GLAZING BY FULL-SCALE MODEL LABORATORY MEASUREMENTS

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Road traffic is a major concern in urbanized cities. In this paper, to reduce the indoor noise nuisance, a special-designed double glazing plenum window with an air gap between the two glass panes is proposed to mitigate traffic noise from propagating directly towards residence. Each plenum window consisted of two layers of glazing. The outer layer was made up of fixed windows and a casement window, the inner one was a sliding glass pane with Micro-Perforated Absorber (MPA) fixed. The sound attenuation is defined as the additional sound reduction of the special-designed window over the conventional window which was simulated with an opening hole. The size of the opening hole was equal to one sixteenth of the room area. With different overlaps of the double glazing measured, test results show that the relative orientation of the linear array speakers mimicking traffic noise and the plenum window has great influence on the result of sound attenuation which could achieve 2.9-8.4dBA. The sound attenuation has optimum result when the width of overlap is 200mm. Around 1KHz, the sound attenuation of the plenum window is minimal.

Keywords: traffic noise, double glazing plenum windows, sound attenuation, full-scale model

1. Introduction

Traffic noise is a big problem in Hong Kong. Many residential dwellings are built alongside the main traffic road because of the convenience of transportation, so residents are highly exposed to road traffic noise. Traffic noise is adverse to the health of the residents, it causes the person's mood to be agitated, and the sleep is not good. How to reduce traffic noise effectively is one of the main problems to be solved by architectural design in Hong Kong. Acoustic treatments in the balcony and the plenum window at building facade have been widely applied to reducing traffic noise exposure in residential units. As is known to all, when window is closed, the single glass window has more than 30dB in term of weighted sound reduction index (Rw), and double-glazing windows can produce insertion loss of more than 40 dB in term of weighted sound reduction. However, fresh air is an essential part of indoor health. In view of sustainability, a plenum window which can offer good sound insulation and can meet acceptable level of natural ventilation at the same time is needed. A lot of previous studies discussed sound attenuation of plenum windows. The sound...
transmission loss of a kind of partially opened double glazing window was first tested by Ford and Kerry\(^1\). J. Kang studied the use of Micro-Perforated Absorber (MPA) in the double glazing plenum window to improve the noise attenuation \(^2\). Y.G. Tong and Tang used a 1:4 scale model to study on the acoustical performance of the plenum window in a semi-anechoic chamber\(^3\). Y.G. Tong also built two identical mock-up test rooms with dimensions the same as those commonly adopted for Hong Kong public housing side-by-side next to a busy trunk road to study sound transmission of plenum window \(^4\). Yeung. M studied tackling traffic noise through the plenum type acoustic window by laboratory and in-situ experiments\(^5\). In this study, full scale experiments were carried out in the South China University of Technology (SCUT) to analyze the sound attenuation of specially designed plenum window. The baffle type acoustic plenum window comprises two glazing, which are the outer window system with side hung openable window and the inner sliding panel. Parameters affecting the acoustic performance of this window include: the outer and inner opening area, gap between two glazing, overlapping width, etc. Sound attenuation of this kind of plenum window with different overlap width between the double glazing by full-scale model laboratory measurements was analyzed in detail. Sound attenuation here means the additional insertion loss due to the use of the specially designed acoustic window when compared with the counterpart using ordinary (conventional) window system. In other words, it is the “relative” insertion loss by comparing the acoustic window and ordinary window. The sound attenuation is normalized using international noise spectra described in EN1793-3 \(^6\) to represent road traffic noise source for different frequencies before the overall sound attenuation level is determined.

2. Laboratory settings and equipment for acoustic testing

2.1 The testing chambers

Noise measurements were carried out in the multi-purpose acoustic testing facility which was designed for ISO140-3 test and consisted of two isolated chambers with a wall of area about 3.5 m (width) x 3 m (height) where the plenum window was installed. The chambers are designed so that they are capable for insertion loss measurement for upper limit of Sound Transmission Class (STC) 65. The two isolated chambers are semi-anechoic (source room) and reverberation (receiver room) chambers which simulate the outdoor and indoor environment, respectively. The volumes of the source and receiver rooms are 300 and 145 m\(^3\), the source room which simulates the outdoor environment will have 50mm thick fiberglass curtains lined to cover all surfaces except for the floor, and the thick fiberglass curtains were put up at more than 1 m away from the wall and the room ceiling. The laboratory noise test was based on full scale 1:1 model.

2.2 Plenum windows and conventional windows setup

The acoustic plenum window and conventional window will be installed at the common wall location which separates the source room and receiver room. The configuration of the acoustic plenum window and conventional window are very different. With the source even with constant sound level setup, the noise level outside the facade of the acoustic plenum window and conventional window would be different due to different extent of facade reflection. Therefore, it is not appropriate to estimate the “insertion loss” of different window systems for comparison purpose by measuring the difference of noise level outside the facade and in indoor environment. As the objective is to measure the additional noise reduction in indoor environment of the acoustic plenum window when compared with conventional window, it is recommended to preset a constant noise level of the source and measure the noise level inside the receiver room for comparison purpose. The measured difference is regarded as the sound attenuation effect. For reference purpose, noise level in the source room will also be measured. The noise level at-source is simulated by array of speakers and the noise strength is under control. The noise strength will be maintained the same for testing of conventional window and acoustic plenum window. Noise level inside the source room will be measured and for control purpose to identify abnormality, if any. The noise level inside the
receiver room (after noise propagation from source room to receiver room through the conventional window and acoustic plenum window) will be determined and the difference will be regarded as the sound attenuation effect. For testing purpose, the source room should present two surfaces with no absorption – the wall in which the window system is located and the floor.

The dimensions of conventional and acoustic plenum window which is typical for Hong Kong public housing buildings are showed in Table 1. Walls around the window was made of 120mm thick double-layer calcium silicate board sandwich wall with 100mm thick fibreglass (density 32 kg/m$^3$) inside. The window was made of 12mm thick glass. Each plenum window showed in Figure 1 consisted of two layers of glazing. The outer layer was made up of fix windows and a casement window whose dimensions were shown in Table 1, the inner one was a sliding glass pane with Micro-Perforated Absorber (MPA) fixed. The overlap between the sliding window and the fix window are shown in Figure 1.

Table 1  Dimensions of Conventional and acoustic plenum window for Test Measurement

<table>
<thead>
<tr>
<th>CASE</th>
<th>Width of Casement Window (mm)</th>
<th>Height of Casement Window (mm)</th>
<th>Width of Conventional Windows Opening(mm)</th>
<th>Height of Conventional Windows Opening(mm)</th>
<th>Area of Conventional Window Opening($m^2$)</th>
<th>Room Area ($m^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>700</td>
<td>1195</td>
<td>580</td>
<td>900</td>
<td>0.52</td>
<td>8.35</td>
</tr>
<tr>
<td>2</td>
<td>700</td>
<td>1195</td>
<td>580</td>
<td>555</td>
<td>0.32</td>
<td>5.10</td>
</tr>
</tbody>
</table>

Note: The sizes of the opening holes were equal to one sixteenth of the room areas.

2.3 Measurement, Sound Source and Microphone Setting

The acoustic analysis system is B&K 3560C PULSE System with 11 channels constant percentage bandwidth. Road traffic noise source were mimicked as linear array made up of 24 numbers of 6' powering speakers capable of producing sound from 20 to 10 kHz. One microphone inside the semi-anechoic chamber for reference were located 1m in front of the window. Another microphone was placed at 1.0m away (and 1.2m above floor) from the line source. The reference microphones in the semi-anechoic chamber were used to check any variation in the sound source spectral strength and derive the corresponding spectral corrections to the measurements if necessary. The
other microphones are set at 9 locations inside the reverberation chamber (receiver room) with different separation from wall and elevations. Figure 2 shows the measurement locations. Figure 3 shows the relative orientation of the linear array speakers mimicking traffic noise and the middle of a plenum window in the semi-anechoic chamber.

3. Results and discussion

The sound attenuation for every individual frequency is determined by subtracting the logarithmic average noise level inside the reverberation chamber of conventional window with that of plenum window. The sound attenuation is normalized using international noise spectra described in EN1793-3 to represent road traffic noise source for different frequencies before the overall sound attenuation level is determined. The sound attenuation of conventional window and plenum window with different overlap has been tabulated in Table 2. The sound attenuation result has been normalized based on spectra with respect to road traffic noise but not adjusted based on room characteristics. Field test photos of conventional window and acoustic plenum window are shown in Figure 4.

<table>
<thead>
<tr>
<th>CASE</th>
<th>Orientation of noise sources</th>
<th>Width of overlap (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0°</td>
<td>-45°</td>
</tr>
<tr>
<td>1</td>
<td>8.0</td>
<td>4.3</td>
</tr>
<tr>
<td>1</td>
<td>8.4</td>
<td>4.8</td>
</tr>
<tr>
<td>1</td>
<td>8.4</td>
<td>4.7</td>
</tr>
<tr>
<td>2</td>
<td>6.7</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>6.7</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>6.8</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>6.4</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Results not adjusted to reflect individual habitable room characteristics (room size, room constant, etc.)

As shown in the table 2, the plenum windows have the sound attenuation ranges about 2.9 to 8.4 dBA, and the overall sound attenuation level is increasing with the widen of the overlap, when the overlap width increase to 250mm, the sound attenuation is reduced instead. The sound attenuation
has optimum result when the width of overlap is 200mm. Figure 5 illustrates the characteristics of sound transmission which is opposite to sound attenuation with one-third frequency change. It is easy seen that sound transmission is maximum in 1kHz for this type of plenum window with 100mm airspace.

![Figure 5–The one-third band sound transmission](image)

4. CONCLUSIONS

With different overlaps of the double glazing measured, test results show that the relative orientation of the linear array speakers mimicking traffic noise and the plenum window has great influence on the result of sound attenuation which could achieve 2.9-8.4dBA. The sound attenuation has optimum result when the width of overlap is 200mm. Around 1KHz, the sound attenuation of the plenum window is minimal.

REFERENCES