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DESIGNING A BETTER PLENUM WINDOW OR BALCONY FOR HIGHER NOISE REDUCTION AGAINST OUTDOOR NOISE

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ABSTRACT

Plenum windows have been used as innovative measures to reduce traffic noise in recent decade. Nowadays, they are also used in mitigating more serve traffic noise, railway noise or even fixed noise which require different noise reduction characteristic and enhanced performance.

To enhance the noise reduction performance of the plenum windows and balconies, different kinds of absorption treatment like micro-perforated absorbers and perforated absorption panels had already been used and tested. They could provide around 1dB of improvement. Meanwhile, window designers are finding alternative ways to further enhance the performance, such as by changing the physical design and dimensions. The most common changes are to increase the overlapping length of the plenum of the window or by adding a solid parapet in front of the plenum balcony door.

Numerous designs of windows and balconies with different dimensions have been tested, with different overlapping length, different acoustic treatment and even different outer window or balcony door design. The tests were done in full scaled mockup using linear array of loudspeakers mimicking traffic noise source. The effects in noise reduction of implementing these design changes to plenum windows/balconies are being studied by comparing the measurement results in this paper.

Keywords: Plenum Window, Façade Device

1. INTRODUCTION

Hong Kong is a vibrant city with a very dense population. The demand of residential space is always high. More and more residential buildings are built in response. At the meantime, the ballooning population also brings more traffic to the city. These newly planned residential projects are facing more and more challenging traffic noise problems.

In recent decade, a few different plenum windows have been used in different residential projects to mitigate different kind of environmental noise. Offsite mockup tests are commonly used to determine the noise attenuation performance of specially design acoustic windows and balconies in Hong Kong.

In order to find ways to further improve the noise attenuation of plenum windows, three different plenum windows were tested with different overlapping length and other window designs, ie. side hung and top hung window and the results is presented and discussed in this paper.

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2. CURRENT PLENUM WINDOW DESIGN

The plenum window is formed by placing a sliding panel as a noise screen behind an opened window to block the direct path of the noise from outside to entering the indoor habitable space. The sliding panel is wider than the width of the window opening to create an overlapping of a minimum of 100mm. A 100mm separation between the outer window and the sliding panel is maintained to allow natural ventilation. Currently, most sliding panel are having an overlapping of 100mm to 300mm and fitted with micro-perforated absorber on the side facing outward. Sometimes, absorption materials are also added to the top and the vertical sides of the plenum. The MPA and absorption materials are incorporated to increase the absorption of the plenum to further reduce the sound energy being transmitted through the plenum windows.

Previous laboratory and mockup testing have been done to study the incorporation of microperforated absorber (MPA) to the sliding panel and adding absorption material to the air gap of the plenum.(1)

3. DETERMINATION OF NOISE REDUCTION

To describe the traffic noise attenuation performance of plenum windows, insertion loss and transmission loss are the two major terms used in Hong Kong(1,2). In determining the insertion loss, the performance of the window is compared with the performance of a conventional window, ie. a side hung swing window of the same size or smaller size. The Transmission Loss (TL) is determined by comparing the measured indoor and outdoor noise level difference and weighted with normalized traffic noise spectrum(3).

3.1 Mockup Test

Full scaled off site mockup tests were carried out to study the impact of the change in design parameters. The mockup was constructed in a factory site in Mainland China, with a 3-storey building fitted with the test window at the façade of tests rooms with size similar or smaller to the room that the window is designed to be built with. Line source was used as the sound source to mimic the carriageway generating traffic noise to residential buildings. White noise was used as testing signal and the measured results were weighted with the normalized traffic noise spectrum as stated in BSEN1793-3(3) to determine the traffic noise attenuation of the specially designed plenum window.

Figure 1 Set up of the Off-site mockup test. The array of loudspeakers is placed parallel to the testing façade, which create a 0º line source angles

4. IMPROVEMENT MEASURES

In designing the special acoustic windows for mitigating environmental noise in residential buildings, architects and the clients take the leading role. It is a pre-requisite to provide the minimum natural light and ventilation by the window. Followed by the aesthetic concern and construction constraints, there is little room for huge changes made to the window design dimensions. The usability of the windows, such as with a very long sliding panel taking up footprint and being not able to fully open the outer window for maintenance and cleaning, is concerned during design.

There are few changes that can be possibly done currently. Increasing the overlapping length, adding more absorption material to the plenum have the least impact in changing the design. Switching the outer window design from side hung to top hung are huge changes which may turn over the whole façade design.

5. RESULTS AND DISCUSSION

Two side hung type plenum window was measured to study the effects of increasing overlapping length. A top hung type plenum window was tested to demonstrate the benefits of using top hung window as the outer window instead of a side hung outer window. Traffic noise weighted transmission losses ($TL_{traffic}$) are used to represent the traffic noise attenuation of the tested windows. Window 1 in Table 1 was tested with 2 line source angles while window 2 and window 3 in Table 2 and Table 3 was tested with 1 line source angle.

5.1 Increasing overlapping

Table 1 shows the measured transmission losses weighted with traffic noise spectrum of window 1 with an outer window of 1165mm(H) x 600mm(W) tested with increasing overlapping length from 300mm to 565 mm. Table 2 shows the measured results of window 2 with larger opening size, 1600mm(H) x 700mm(W), with 450mm and the very wide 800mm overlapping. The difference of results is also shown in Table 1. Each transmission losses measured were compared with that of the 300mm and presented in form of the delta of transmission losses.

Figure 2 Window 1 tested with increasing overlapping. The view from outside shows the outdoor microphone location and the largest overlapping length

From Table 1, it can be observed that increasing the overlapping length, from 300 mm to 565mm in a steps of around 50mm, gives better improvement to the TLs when the line source is at 45º with the building façade. The TLs increased with the increase in overlapping length. The improvement ranges from 0.4 to 0.9 dB(A) with a parallel line source and that with a 45º inclined source ranges from 0.6 to 1.2dB.

Table 2 shows the increases in $TL_{traffic}$ of window 2 by increasing the overlapping from 450mm to 800mm. The 800mm overlapping is the maximum overlapping length that can be allowed within the 2.4m wide room. Window 2 was tested with different absorption settings. The tremendous increase in overlapping length at window 2 gives surprising increases in $TL_{traffic}$s, especially when there are MPA incorporated on the sliding panel. The improvement ranges from 2.2dB(A) to 4.2dB(A).

Table 1 Dimensions, different settings, measured traffic-weighted TLs and differences of TLs of window 1, a side hung plenum window with 100 air gaps

Window 1	Overlap (mm)	MPA	Absorption material	Source Angle	$TL_{traffic}$ dB(A)	$\Delta TL_{traffic}$
1165(H) x 600(W)	300	Yes, with 40mm airgap, absorptive mounting box, NRC 0.5	Yes, at ceiling and vertical side of the opening	0º	16.6	
	365				16.9	0.4
	415				17.1	0.6
	465				17.2	0.6
	515				17.5	0.9
	565				17.4	0.8
	300			45º Non-favorable	16.8	
	365				17.4	0.6
	415				17.7	1.0
	465				17.5	0.7
	515				17.8	1.1
	565				17.9	1.2

Table 2 Dimensions, different settings, measured traffic-weighted TLs and differences of TLs of window 2, a side hung plenum window

Window 2	Overlap (mm)	Gap (mm)	MPA	Absorption Material	Line source angle	$TL_{traffic}$ dB(A)	$\Delta TL_{traffic}$ dB(A)
1600mm(H) x 700mm(W)	450	100	No	No	0º	10.3	--
			Yes	No		11.4	--
			No	Yes		11.2	--
			Yes	Yes		12.1	--
	800		No	No		13.1	2.8
			Yes	No		15.6	4.2
			No	Yes		13.4	2.2
			Yes	Yes		15.7	3.6

5.2 Using top hung window as outer window

A 700mm wide top hung type plenum window was used in the tests. The window opening size, the line source setting, overlapping length and the absorption material provisions were the same as window 2 in previous section. hence, the results of window 2 and window 3 can be compared directly. The measured results are tabulated in Table 3. The measured $TL_{traffic}$s of a top hung window (window 3) are at least 4dB(A) larger than those of a side hung window (window 2) of the same size. The difference ranges from 4dB(A) to 5.1dB(A). This brings a very good improvement as a small design change. Like window 2, the improvement with the presence of an MPA is larger than those cases without this relatively large absorption surface.

Figure 3 The view of window 3, a top hung plenum window, from inside

Table 3 Dimensions, opening width, absorption materials, measured traffic-weighted TLs and differences of TLs of window 3, a top hung plenum window

Window	Dimensions (mm)	Overlapping (mm)	MPA	Absorption material	$TL_{traffic}$ dB(A)	$\Delta TL_{traffic}$ dB(A)
Side Hung	1600(H) x 700(W)	450	No	No	10.3	--
			Yes	No	11.4	--
			No	Yes	11.2	--
			Yes	Yes	12.1	--
Top Hung		450	No	No	14.4	4.1
			Yes	No	16.4	5.1
			No	Yes	15.1	4.0
			Yes	Yes	17.0	4.9

6. CONCLUSION

Mockup tests were done to study the effect of increasing the overlapping length of the plenum windows and by changing the outer window from a side-hung swing window to a top hung window of the same size. Increasing the overlapping length can bring up to 1.2 dB(A) by increasing the overlapping from 300mm to around 650mm. it can bring a maximum of 4.2dB(A) improvement when the overlapping is increase from 450mm to 800mm. changing the outer window from side hung window to top hung window can improve the $TL_{traffic}$ by at least 4dB(A). The tested results suggested more feasible ways to further improve the noise attenuation performance of plenum windows when a very large noise attenuation is required.

7. REFERENCE

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