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NOISE CONTROL FOR A BETTER ENVIRONMENT

The Development of an Innovative Noise Mitigation Measure for a Luxury Seaview Residential Development

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ABSTRACT

Hong Kong, a densely populated area, has an ever-growing housing demand. In recent years, both public housing and luxury residential developments face the identical traffic noise problem, causing a need for innovative mitigation measures not only fulfilling regulatory compliance but also achieving aesthetic aspects towards property market expectations.

The residential development in this study is directly fronting the sea and a heavily trafficked trunk road. Traditional noise mitigation measures have been applied but are not sufficient to reduce the impact to a statutory acceptable level. An innovative noise mitigation measure has been designed to reduce traffic noise from the initial early planning stage up to the occupation of the development, which lasts for over three years.

To enhance the applicability of the innovative mitigation measures for different noise reduction requirements of the development, various design options of the plenum windows have been formulated and its efficiency tested in an acoustic laboratory, which is also followed by on-site verification.

The design is proven to be a successful mitigation measure according to the laboratory test and on-site field measurement. It is then being widely adopted by environmental professionals for mitigating traffic noise impact for many future projects in Hong Kong.

Keywords: Traffic Noise, Sound Attenuation, Baffle Type Window

I-INCE Classification of Subject Number: 38

1. OBJECTIVES

The objective of the on-site acoustic test is to investigate the sound attenuation performance of the baffle type acoustic window and door system, which would be demonstrated by the additional noise reduction under indoor environment when compared with conventional window/door system.

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2. BAFFLE TYPE ACOUSTIC SYSTEM

2.1 System

Baffle type acoustic system is made up of two layers of glass pane. The outer layer provides opening for natural ventilation while the inner layer is a sliding panel situated behind to shield noise. Acoustic performance of the system could be enhanced through applying transparent micro-perforated absorber (MPA) (Noise Reduction Coefficient = 0.5) panel to the inner sliding panel for sound absorption.

The two-layer baffle type system can create an air path for natural ventilation yet able to reduce noise entering indoors. In this study, acoustic performance of different types of baffle type acoustic system: outer window with one opening and sliding panel (baffle type system 1), outer window with two openings and two sliding panels (baffle type system 2), as well we balcony door with sliding panel (baffle type system 3).

Sound attenuation of the three systems was determined through laboratory test followed by on-site noise measurement.

2.2 Test Case and Conventional Case

Sound attenuation of baffle type acoustic window/door is the relative insertion loss of the baffle type acoustic system when compared with conventional window/balcony system. The conventional window/balcony systems have been adopted in order to evaluate the additional sound attenuation effect of baffle type acoustic window and door provided.

Conventional window/door system represents the system typically implemented to habitable rooms (i.e. bedroom and living room) when noise is not regarded as a design constraint. Balcony is a typical feature employed in living rooms whereas window system is usually employed in bedrooms.

3. SOUND ATTENUATION DEFINITION

3.1 Definition

In an attempt to determine the sound attenuation, the insertion loss of baffle type acoustic window / door system (ILs) and conventional window / door system (ILc) should be determined, and the sound attenuation will then be equal to the insertion loss difference (RIL) between the two systems. It can be represented by the formula below:

RIL = relative insertion loss (sound attenuation of the baffle type acoustic window/door system)

RIL = ILs – ILc = (LOs – LIs) – (LOc – LIc)

ILs (insertion loss of baffle type acoustic window/door system) = LOs – LIs where

LOs = noise level outdoors before penetrating through the baffle type acoustic window/door system

LIs = noise level indoors after penetrating through the baffle type acoustic window/door system

ILc (insertion loss of conventional window/door system) = LOc – LIc where

LOc = noise level outdoors before penetrating through the conventional window/door system

LIc = noise level indoors after penetrating through the conventional window/door system

4. NOISE MEASUREMENT

4.1 Laboratory Test

These baffle type acoustic systems with MPA panel (applied to inner sliding panel) have undergone laboratory tests and the estimated noise reduction ranges from 4.5 to 6.5 dB(A). The laboratory test was carried out based on a full-scale 1:1 model and the testing facility consisted of two isolated chambers with a common wall area of approximately 10m^2. The chambers were designed so that they are suitable for insertion loss measurements for the upper limit of Sound Transmission Class (STC) 55.

The isolated chambers were semi-anechoic (source room) and reverberation (receiver room) chambers, to simulate the outdoor and indoor environment, respectively. Fiberglass with 2” thickness was applied to the source room to cover the ceiling and three sides in order to fully absorb within the considered frequency range to avoid noise reverberation. Baffle type systems and their conventional cases for tests were installed at the common wall location, which separates the source room and the receiver room. For testing purpose, the common wall surface where the acoustic balcony system is located, and the floor surface of the source room, have no absorption material. An array of speakers was employed to represent road traffic noise. Similar set up has also been adopted in other acoustic testing (Yeung, M. et al., 2014).

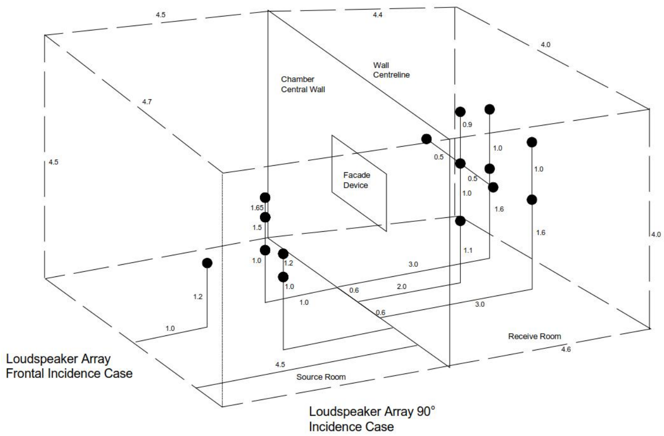

Fig.1 – Microphone Settings for Laboratory Test.

4.2 On-site Noise Measurement

On-site noise measurement has been conducted to further verify the effectiveness of baffle type acoustic system following the laboratory test.

A residential block located beside the trunk road and designed with baffle type acoustic systems was targeted for the measurement. For on-site noise measurement, habitable rooms with direct line of sight to the trunk road and significantly impacted by traffic noise have been chosen. Baffle type acoustic window and door systems on lower floor level (i.e. 2nd Floor) were designated for the on-site test, while the corresponding conventional window and door were located on the floor above acoustic windows (i.e. 3rd Floor). This ensures that similar separation from the traffic noise source could be attained. Both acoustic and conventional systems have the same orientation except that the inner sliding panel in the conventional system was removed.

The adopted baffle type acoustic window/door system can generally be categorised into: baffle type acoustic door (outer and inner opening of same height) in living room; baffle type acoustic window for main bedroom (with 2 openings); and baffle type acoustic window for other bedroom of smaller size (with 1 opening).

4.3 Room Setting

For each habitable room designated for on-site noise measurement, wooden floor and furniture was provided to mimic the ordinary future occupancy conditions. Carpet and sofa are provided for living room, while carpet and bed are provided for bedroom. The rule of thumb is to provide the same settings for rooms with baffle type acoustic window/door and with conventional window/door.

To represent conventional window/door setting, the inner sliding panel was not installed to indicate window/door without acoustic design. Other details will be the same as baffle type acoustic window/door setting.

4.4 Monitoring Equipment and Location

Calibrated sound level meter (e.g. B&K 22335, 2250, 2270) which is capable of measuring environmental noise level has been adopted for the on-site measurement. All sound level meters adopted comply with the international standard IEC 651:1979 (Type 1) and 804:1895 (Type 1). Prior to each noise measurement, the accuracy of the sound level meter has been checked with an acoustic calibrator generating a known sound pressure level at a known frequency. Measurements are accepted as valid only when the calibration levels before and after the noise measurement are within a difference of 1.0 dB.

Measurement locations for selected habitable rooms for baffle type systems 1-3 are shown in Figures 2 & 3. The measurement location was elevated at 1.2m above floor and maintained at a separation of no less than 1m from wall and window/door opening. It was located as near to the inner opening (for baffle type acoustic window/door system) or the opening (for conventional window/door) as possible. An additional location at 1m away from each of the outer openings has been selected for control purpose to observe any significant variation of noise level at different locations.

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For baffle type acoustic window with two openings, two sound level meters were used. In this case, the logarithmically average noise level was regarded as the sound level in the room.

Extraneous noise from the surrounding would affect the accuracy of on-site measurement result. During the on-site noise measurement, the noise level has been logged (every second) for the purpose to edit out any extraneous noise which may significantly affect the noise measurement. Measurement period for occurrence of extraneous noise, has been recorded manually so that noise within such period could be edited out.

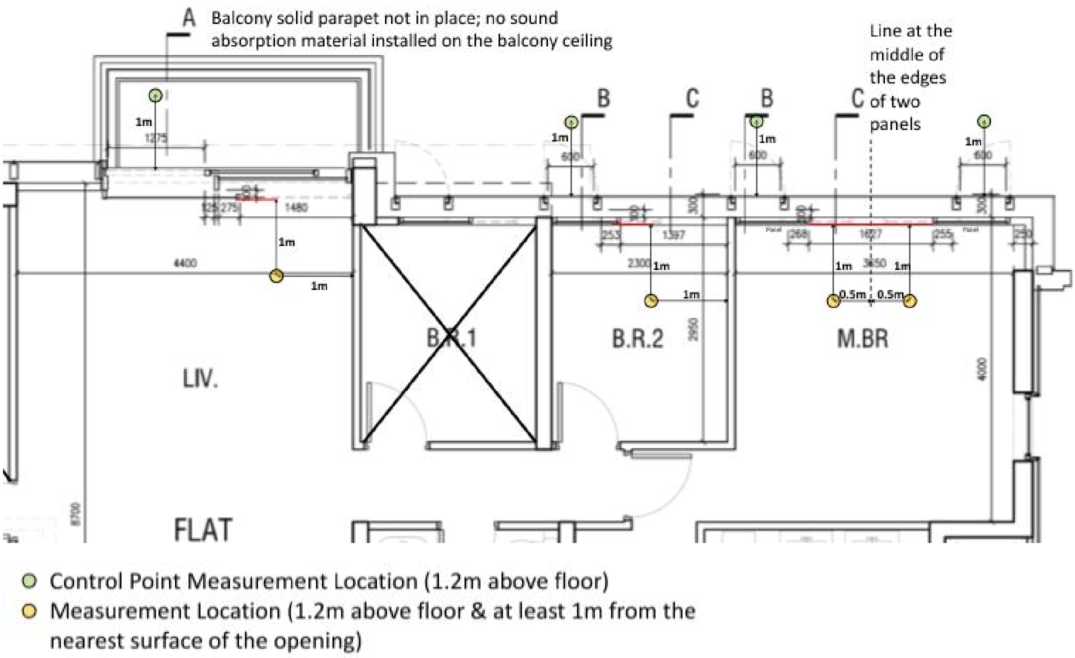

Fig. 2- Microphone Location of test case (baffle type acoustic system)

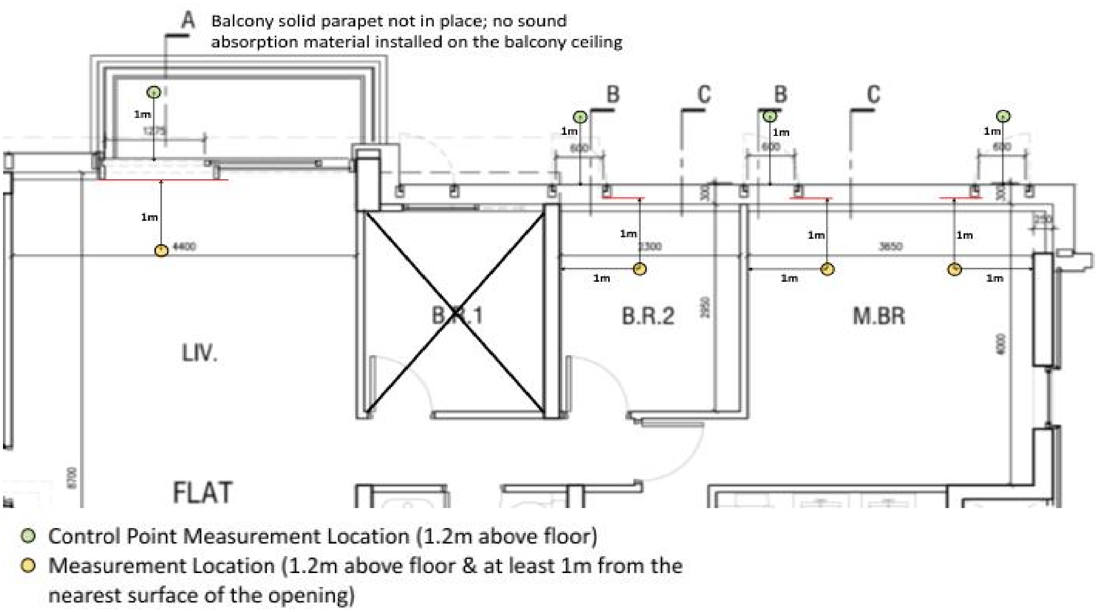

Fig. 3- Microphone Location of conventional case (conventional system)

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5. ON-SITE MEASUREMENT RESULTS

5.1 Results

In the attempt to expand options in acoustical design, three different variations of baffle type acoustic systems were investigated in this research. The first type is the baffle type system with one window opening, while the second type is baffle type system with two openings. The third type of baffle type system involves balcony door with inner sliding panel. Design parameters adopted for each type of baffle type acoustic system and measurement results are presented below.

Table. 1- Design parameters adopted for baffle type acoustic system and on-site measurement results

FLAT	OPTION	Room Area (m^2)	PARAMETERS OF ACOUSTIC WINDOW & HABITABLE ROOM (mm)						Sound Attenuation (dB(A)
			OOW	OOH	G	O	IOW	IOH	
Living Room (Door)	without MPA Panel	38.3	1275	2535	100	275	1480	2535	8.8
MBR (2 outer openings)	without MPA Panel	14.6	600	1165	100	255 & 268	1627	2400	5.1
	with MPA Panel	14.6	600	1165	100	255 & 268	1627	2400	6.7
BR2	without MPA Panel	6.8	600	1165	100	253	1397	2400	4.6
	with MPA Panel	6.8	600	1165	100	253	1397	2400	6.9

Note:

G - gap width, mm

O - overlapping width, mm

OOH - outer opening height, mm

OOW - outer opening width, mm

IOH - inner opening height

IOW - inner opening width, mm

MPA- Micro-perforated Absorber

Considering baffle type acoustic window with one opening (baffle type system 1), the outer opening width of the side hung window is 600mm and the height is 1165mm. The overlapping size of the outer and inner sliding panel is 253mm. There is an air gap between outer and inner sliding panel of 100mm for fresh air to pass through. Inner opening width of the window is 1397mm and the height is 2400mm. For this system, the inner sliding panel is equipped with MPA. The MPA panel is made up of a 1mm micro-perforated plate with acoustic frame. The purpose of the acoustic frame is to maintain a 40mm air cavity between the MPA panel and the surface of inner sliding panel for noise absorption. Apart from the above, perforated acoustic panels are provided to the frame to enhance noise absorption.

Coupled with the above dimension and acoustic material, the sound attenuation of baffle type system 1 could reach 6.9 dB(A) of reduction. Option without MPA panel has also been tested, and the sound attenuation is 4.6 dB(A). Room size implementing this system is $6.8m^2$.

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For Baffle Type System 2, there are two outer openings for natural ventilation and two sliding panels provided behind the window openings. Dimension of the baffle type acoustic system is the same as baffle type system 1, except that the overlapping size of outer and inner panel is 255mm on one side and 268mm on the other side. MPA panel with the same design as baffle type system 1 has also been considered in the on-site test. As referred to the on-site noise measurement result, the noise reduction obtained by applying MPA panels on the inner sliding panels is 6.7 dB(A). The acoustic performance would be reduced to 5.1 dB(A) when the MPA panel has been omitted. Room size of baffle type system 2 is 14.6m^2.

Balcony is a common residential design in Hong Kong. In view of this, baffle type acoustic door (baffle type system 3) has also been targeted for the measurement. It is represented by a balcony with sliding door and inner sliding panel, which the opening size of the door opening is 1275mm width and 2535mm tall. The inner opening width of the balcony is 1480mm and the height is 2535mm. Same as baffle type acoustic windows, the air gap between outer and inner opening panel is 100mm. The overlapping size is 275mm. Room size of the measured balcony is 38.3m^2. Noise reduction level of the baffle type acoustic balcony could reach 8.8 dB(A) without applying MPA panel.

Baffle type acoustic windows (baffle type 1 &2) achieved more than 6.5 dB(A) noise reduction with MPA, whereas the reduction is at least 4.9 dB(A) without MPA. Higher noise reduction is observed for baffle type acoustic door (baffle type 3) in which the noise reduction is 8.8 dB(A).

It is shown that MPA panel would further enhance the performance of baffle type acoustic system. For windows employed MPA panel on the inner sliding panel, the sound attenuation is 1.6-2.3 dB(A) higher than the system without MPA panel.

Overall, sound attenuation of baffle type 1-3 equipped with MPA on inner sliding panel ranges from 6.7 to 8.8 dB(A). Better acoustic performance of baffle type acoustic systems is obtained as compared to the laboratory test results.

6. FUTURE PLANNING

Urban development is required to tackle the growing population in Hong Kong. In terms of urban planning, adverse noise impact on future residents is one of the top concerns in environmental impact assessment. Minimising traffic noise impact becomes a main focus as noise disturbance can degrade city's quality of life.

Baffle type acoustic system is an innovative design that has combined the concept of acoustic and natural ventilation. It could be applied to all kinds of residential development in form of window or balcony door. Based on the laboratory test and on-site noise measurement results, it suggests that baffle type acoustic system could solve the traffic noise problem in residential areas.

To tackle traffic noise impact, the same baffle type design concept could be utilised in future residential developments. Critical window/door parameters including opening size of outer window, overlapping size of both glass panes and the gap between outer and inner sliding panel are important for the performance of baffle type acoustic system.

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Larger outer opening size (i.e. clear opening of outer window/ door) and the gap of the baffle type system will let more sound energy enters indoor area. As a result, the acoustic performance of baffle type acoustic system will be less effective. For example, if the dimension of baffle type acoustic system in a proposed development is larger than that of the tested systems, the sound attenuation performance of such is expected to be lower than the measured result above.

Room size also matters when it comes to sound attenuation of baffle type acoustic window/ door due to the variation in sound reverberation according to different room size (C.B. Pop and D. Cabrera., 2005). Therefore, room size adjustment is required for the determination on sound attenuation of baffle type acoustic system. When both the design case in the proposed development and the reference case adopt acoustic window system of same dimension, and the room size for the design case is smaller, the sound attenuation will be deducted by a factor of 10 x log (Rref/Rdesign) where Rref & Rdesign are respectively area of the room of reference case (i.e. room size of baffle type acoustic system in this study) and design case respectively.

7. CONCLUSION

This study demonstrates the sound attenuation of baffle type acoustic systems (window/ door) supported by acoustic laboratory test and on-site noise measurement. The results show that baffle type acoustic systems could attenuate traffic noise by 4.9 to 8.8 dB(A) depending on the (i) application of MPA panel and (ii) dimension of the baffle type acoustic system.

8. REFERENCES

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