# Tackling Traffic Noise Through Plenum Windows – An Application in Hong Kong

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## ABSTRACT

Hong Kong is a very small but hyper-dense city with over 7 million living in 1,100 sq km in which 85% of land is hilly area. Like other metropolitan cities, Hong Kong is facing significant road traffic noise problems. The Government of Hong Kong is committed to addressing road traffic noise problems and has adopted proactive actions like preventing the problems through land use planning and environmental impact assessment process for new roads, implementation of appropriate mitigation measures on existing roads etc. In most cases, measures like roadside barriers / enclosures would be required. However, the majority of residents live in high-rise buildings and such compact urban forms setting would easily be susceptible to road traffic noise problem. To make Hong Kong a livable place with a good acoustic environment, examining other measures on building façade design is necessary. This paper will discuss on the actual application and in-situ tests conducted for plenum type windows in its application at a housing development next to a heavily trafficked road. With careful design and use of absorptive materials, a noise reduction of up to 8 dB(A) can be achieved without compromising sufficient air ventilations meeting local regulations.

Keywords: Traffic noise, acoustic environment, housing development, plenum type windows

## 1. INTRODUCTION

Traffic noise is often a major environmental noise problem in densely populated cities like Hong Kong. Such problem becomes severe where many residential dwellings are built alongside the main traffic networks to satisfy the housing demands of the communities. There are many conventional noise mitigation measures that have been proposed and/or adopted to tackle the road traffic noise problem over the past few

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decades. Roadside barriers, enclosures, building setbacks and extended podia were common approaches that have been used in Hong Kong. However, these measures may not always be applicable because of space limitation, safety, visual intrusion, land ownership etc. Hence, acoustic treatment at building façade has become an alternative way to reduce traffic noise exposure in residential units. While double-glazing is commonly found in some western countries, the warm and humid climate in Hong Kong makes it very expensive for residential use and energy-wise unfriendly due to the need to provide air-conditioning for a "closed-window" environment and it will practically deprive the residents of an "open-window" life style. The local building code also requires natural ventilation for habitable rooms. In view of sustainability, a façade noise reducing device which can offer good sound insulation and at the same time can allow for acceptable level of natural ventilation is in need.

## 2. THE PLENUM TYPE ACOUSTIC WINDOW

The plenum type acoustic window, which resembles an elongated plenum chamber normally used in duct silencing purpose is introduced. This is a double-layer window in which the window at outer layer is a push-open window and the window at inner layer is a sliding window, which the opening could be changed to align with, or offset to, the opening of the window at outer layer. Openings of two windows at aligned position gives maximum air flow while openings at staggering position offers noise reduction as compared with normal window setting. This window's staggered inlet-outlet design leaves an air gap between the two glass panes such that natural ventilation becomes possible under an appropriate outdoor wind pressure. Fig 1 is schematic drawing showing how the special plenum type acoustic window works. The configuration that offers noise attenuation would need to comply with Building Department's ventilation and lighting requirements.

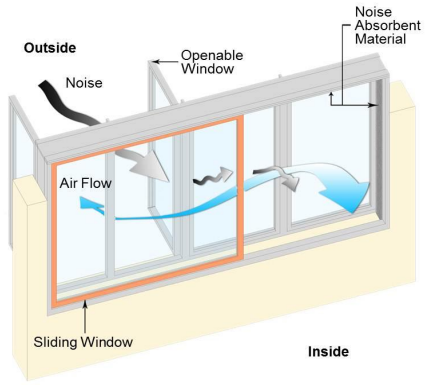


Fig. 1 – schematic diagram showing the working mechanism of plenum type acoustic window

## 3. THE PUBLIC HOUSING DEVELOPMENT IN CONCERN

The Housing Department (HD) being the executive arm of the Hong Kong Housing Authority (HKHA) proposed to build a public housing estate abutting heavily trafficked Prince Edward Road East. Due to heavy traffic flow, the unmitigated noise level at the site boundary was anticipated at 85 dB(A)$L_{10}$(1hr). Practicable conventional noise mitigation measures including low noise road surfacing, building setback & orientation of building block and architectural fin could only provide a noise reduction of 7 dB(A). Under such constraints, HKHA endeavors to develop a public housing estate containing 857 flats accommodating 2,400 tenants. Undoubtedly, this is a big challenge to HD's project team. To meet the Hong Kong Planning Standards and Guidelines (HKPSG) requirement of 70 dB(A)$L_{10}$(1hr), HD looked into the design of the plenum type acoustic windows to further attenuate the traffic noise impact in order to enable the project viable. Fig. 2 shows location of subject site, the building block layout and its designs.

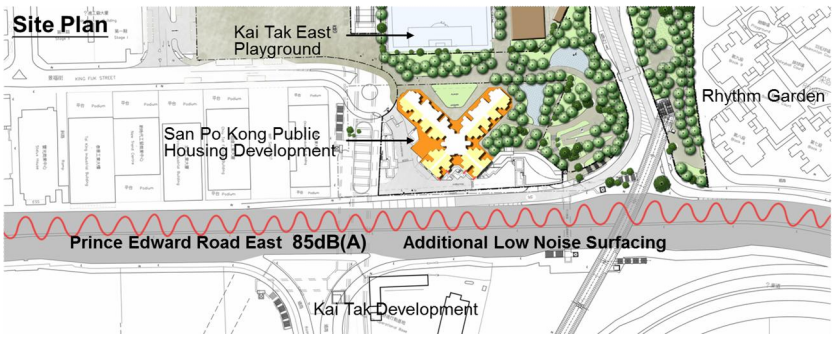


Fig 2 – locations of public housing site and building layout

## 4. THE LABORATORY TESTS

Laboratory tests on the noise reductions of plenum type acoustic windows were conducted in the first place. The measurements were carried out inside a "dual chamber" structure originally designed for sound transmission loss tests. The source chamber was converted into a semi-anechoic chamber, while the receiver chamber remained strongly reverberant. The noise source was a linear array consisted of twenty five 6-inch aperture loudspeakers. There were twelve noise measurement points at 1m in front of the sample plenum type acoustic windows inside the source chamber and nine measurement points which spanned over the volume of the receiver chamber. Fig. 3 illustrates the schematics of the measurement. Measurements were also carried out with the plenum windows replaced by conventional side-hung windows (as the reference base case). The noise reduction (NR) was defined as the reduction of the average noise level inside the receiver chamber when a conventional side-hung window reference was replaced by the corresponding plenum window.

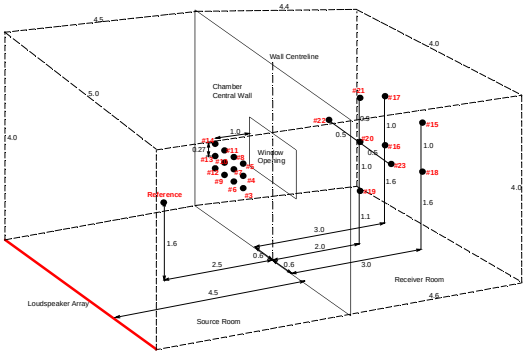


Fig. 3 - Schematics of laboratory test setup
(●: Measurement points;
Chain lines : approximate chamber boundaries; all dimensions in mm)

Since the concern is traffic noise reduction, the normalized traffic noise spectrum was used to estimate a single A-weighted rating for the noise reduction for each plenum window tested. Table 1 illustrates the laboratory test results. TL in Table 1 refers to the average noise level difference (weighted by the normalized traffic noise spectrum) between the two sides of the windows.

| Side-Hung Window (Base Case) | | | Plenum Window | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location | Width (mm) | TL dB(A) | Opening Width (mm) | Overlapping Length (mm) | Gap Size (mm) | Fibreglass | TL dB(A) | NR dB(A) |
| Bedroom | 585 | 6.7 | 560 | 525 | 175 | Yes | 18.3 | 10.4 |
| | | | | | | No | 16.1 | 8.5 |
| Living room | 1320 | 4.2 | 1050 | 340 | | Yes | 16.1 | 11.7 |
| | | | | | | No | 14.2 | 9.9 |

Table 1 : Laboratory measured plenum window noise reductions

## 5. IN-SITU MOCK UP TESTS

The full scale mock-up in this study consisted of two identical side-by-side modular public housing residential units, which were built at the subject building site at 3m from the near edge of the aforementioned very busy and noisy trunk road (Fig. 4). This road was also parallel to the façade of the mock-up. The road traffic was the dominant noise source throughout the site measurement. Measurements were carried out simultaneously inside these test rooms. The mock-up test rooms were 3m above the road surface. Their ceiling heights were 2.54m. The walls, floors and ceilings of these test rooms were made of three layers of 20 mm thick plywood with a sandwich layer made up of 12.7 mm thick gypsum board and rockwool as the in-fill (Sound transmission class STC43). Fig. 5 shows the dimensions and configurations of the plenum type acoustic windows adopted in this study. The glazing was 6 mm thick glass panes. Each plenum type acoustic window consisted of two layers of glazing. The outer layer was made up of two side-hung casement windows and a fixed glazing, while the inner one was a sliding glass pane. The configuration of the window including the opening size, overlapping length and gap width of the layers of glazing were chosen in consideration of lighting and ventilation requirement, anticipated acoustic attenuation as well as ease of operation and maintenance. Fig. 5 illustrates the dimensions of the side-hung casement window design generally adopted by the HKHA. The glazing was again 6 mm thick glass panes.

To facilitate comparison with the plenum window design, only the windows which are shaded in Fig. 5 were opened during the measurements in order to ensure similar façade opening size in the two test rooms. Results of the mockup test revealed that depending on the flat layouts, a noise reduction up to 8dB(A) could be achieved.

Fig. 4 - The mock-up flats for in-situ tests windows

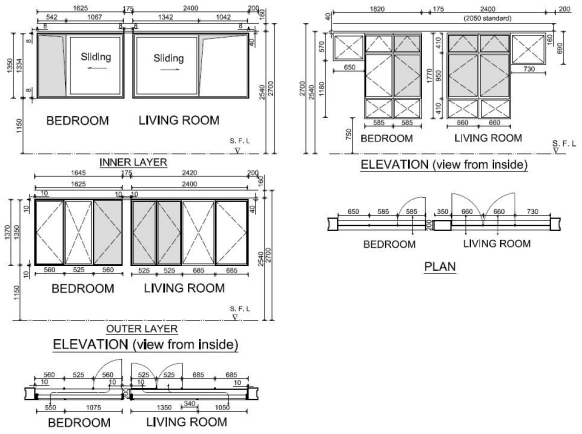


Fig. 5 – Configuration of plenum type acoustic

## 6. NOISE SITUATION OF THE PROPOSED HOUSING ESTATE

With the adopting the plenum type acoustic windows in the proposed building layout (shown in Fig. 2) and incorporation of other noise mitigation measures including building setback, architectural fins and low noise road surfacing ~~e~~ at Prince Edward Road East, 100% noise compliance with HKPSG traffic noise criterion of 70 dB(A)$L_{10}$(1hr) requirement can be achieved for this housing development

## 7. DISCUSSIONS AND REMARKS

The plenum type acoustic window design is relatively new concept for traffic noise mitigation measures. The window if adopted offers good noise attenuation effect and at the same time allowing natural ventilation for the flat. It also provides choice for the residents to have more air flow if noise is not a concern. With the provision of such innovative noise mitigation measures, HKHA can optimize the development potential of public housing site and for improving the built quality of the housing development, with the results that more restricted sites can be productively used for the benefit of Hong Kong as a whole. It is anticipated that developers may also like to adopt this type of special acoustic window in near future.

## ACKNOWLEDGEMENTS

The authors wish to extend their appreciation to EPD and HD of the HKSAR Government for their permission to publish this paper. The opinions in this paper are those of the authors and do not necessarily reflect the views or policies of the HKSAR Government.

## REFERENCES

[1] The Hong Kong Planning Standards and Guidelines, Chapter 9 - Environment, Environmental Protection Department and Planning Department, Hong Kong SAR Government
[2] BS EN ISO 140-3 Acoustics — Measurement of sound insulation in buildings and of building elements — Part3: Laboratory measurements of airborne sound insulation of building elements (BSI 1995).
[2] BS EN 1793-3 Road traffic noise reducing devices – test methods for determining the acoustic performance – part 3. Normalized traffic noise spectrum (ISO 1998)
[3] M.Garai and P.Guidorzi, “European methodology for testing the airborne sound insulation characteristics of noise barriers in situ: Experimental verification and comparison with laboratory data,” Journal of the Acoustical Society of America 108, 1054 – 1067 (2000)