Design for Noise Mitigation Measures for Public Housing Developments in Hong Kong

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ABSTRACT

Hong Kong is renowned for its high density living where we commonly find residential developments, including public housing developments, located close to roads with heavy traffic. To protect the residents from noise nuisance, the Hong Kong Housing Authority (HKHA) has applied a series of noise mitigation measures including low noise road surfacing, noise enclosures/barriers, building setback, orientation and vertical fins etc., to reduce the noise impact. Where the impact is found too severe for the above noise mitigation measures to be adequate, we need to develop more innovative building design to improve the building efficiency and enhance the built environment.

In this paper, we share our experience in the research and development of innovative building design to mitigate noise problems. We also give an account on how the noise challenges are tackled in recent projects by making use of the above measures plus innovative designs such as acoustic balcony and acoustic window.

Keywords: Acoustic Balcony, Acoustic Design, Acoustic Window, Innovation, Noise Mitigation

1. INTRODUCTION

Under the land use planning mechanism, HKHA as a developer, needs to conduct noise assessments to ensure the public housing developments comply with the requirements of the Hong Kong Planning Standards and Guidelines (HKPSG) and the Noise Control Ordinance Cap. 400 (NCO). During the preparation of planning briefs, HKHA needs to demonstrate that there are effective noise mitigation measures in the design of new public housing developments to the satisfaction of the Environmental Protection Department (EPD).

Many public housing sites are subject to severe noise impact from various sources including heavily trafficked roads, railways, public transport interchanges, depots and mechanical plants at industrial/commercial buildings. In particular, some of these sites require rezoning and we need to prove the environmental acceptability of these sites from the perspective of noise compliance. In order to mitigate the noise impact and meet the relevant statutory requirements and guidelines, we apply various passive design measures ranging from the use of single aspect design, optimized block disposition, non-noise sensitive buildings such as multi-storey carpark or commercial building acting as noise barriers, podiums, architectural fins and noise barriers in our developments. While there are merits and demerits with each of these measures, site constraints often restrict their full application, and more innovative measures are required at particularly difficult sites. In recent years, we have carried out research and development on innovative mitigation measures and explored practicable approaches with our stakeholders in resolving the noise issues for our developments.

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2. ASSESSMENT CRITERIA AND NOISE CONTROL STANDARD

HKPSG sets out the road traffic noise standards whereas the railway noise and industrial/commercial noise are controlled under statute, ie. the NCO. The noise standards/statutory requirements are summarised as follows –

(a) Regarding road traffic noise, the assessment criteria are stipulated in the HKPSG which also stipulates a set of standards applicable to different land uses, ranging from 55dB(A) to 70dB(A). It is (i) 70 dB(A) for domestic premises, hotels and offices; (ii) 65 dB(A) for educational institutions; and (iii) 55 dB(A) for hospitals and clinics;

(b) Regarding noise from railways and fixed noise sources from industrial/commercial premises, the statutory requirements under the NCO range from 50 dB(A) to 70dB(A), depending on the background noise of the area, the nature of land use in the vicinity and the time period (day, evening or night) under consideration; and

(c) Regarding noise from other specific sources including bus depots/termini, wholesale markets and container terminals etc, it is required under HKPSG to consider locating these facilities so that there is no line-of-sight of the noise sources from the noise sensitive receivers or to provide screening to the noise sources.

3. NOISE MITIGATION MEASURES

There are three generic types of noise mitigation measures to protect the noise sensitive receivers from the noise impact, namely (a) at source, (b) at path of propagation, and (c) at receivers.

3.1 Mitigation Measures at Source and at Path of Propagation

In general, mitigation at source and at path of propagation are the most effective ways for easing the noise problem. The choice of suitable mitigation measures at source depends on site constraints and the required acoustic performance for individual housing project. These include the following:

3.1.1 Off-site Noise Barriers for Road/Railway Noise

Off-site noise barriers to mitigate the noise impact have been used for many public housing projects. Although such barriers may take up ground space, they reduce noise by interrupting the propagation of sound waves towards the sensitive receivers. In order to be effective, the barriers should be able to shield the receivers from the noise source through the direct-line-of-sight such that these receivers fall within the acoustic "shadow zone" of the noise source. Examples of these noise barriers used in recent public housing projects include the construction of off-site noise barriers along a public road at Tuen Mun Area 54 Site 2, and the provision of a track side noise barrier to abate the railway noise at Tung Chung Area 56 which abuts the Tung Chung railway line (Figure 1).

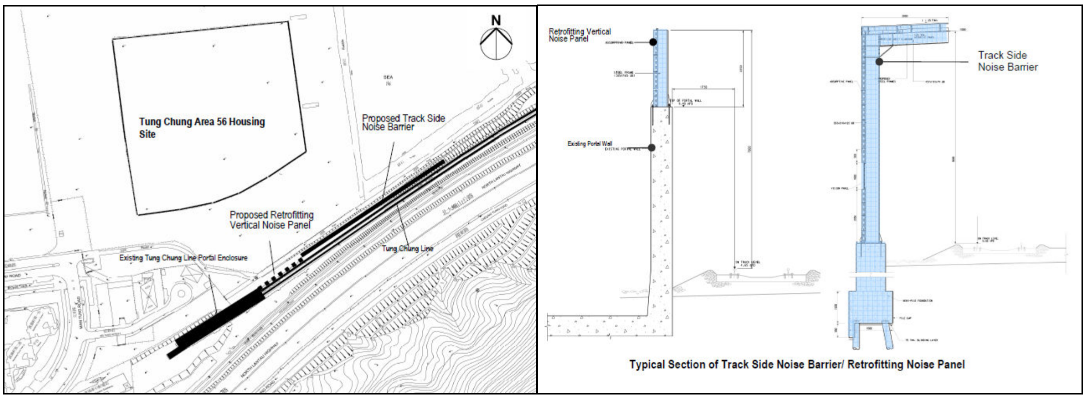

Figure 1: Trackside Noise Barrier for Tung Chung Area 56 Public Housing Site

3.1.2 Mitigation Measures at Fixed Noise Source

The resolution of noise problems is required for rezoning of a site for residential use. Upon rezoning of potential public housing sites for residential use, any excessive fixed noise generated from mechanical plants in its proximity cannot be tolerated. Acoustic mitigation measures at source are most effective to mitigate the fixed plant noise. In such circumstances, acoustic enclosure and louvers will have to be installed to shelter existing chiller plants or cooling towers at the roof of commercial buildings located close to the public housing developments. We need to engage the owners of these fixed plants for the installation of the at-source mitigation measures. In the public housing development project at Ex-Kwai Chung Police Married Quarters, we have liaised with concerned Government departments for the replacement of the existing cooling fans at the police station building adjacent to the development. With their collaboration, the at-source measures will be implemented before the completion of the housing development.

3.1.3 Noise Covers for Public Transport Interchange (PTI)

A number of our public housing sites are located very close to PTIs. Noise barriers are sometimes not effective to meet EPD's requirement of avoiding line-of-sight of the noise source at the PTI. Noise cover has to be used instead. To avoid the use of mechanical ventilation and fire services installations which will increase the future maintenance costs, we especially design the covering deck punctuated with openings at suitable spacing and orientation. These PTIs with such special noise cover can be constructed together with the public housing project, and handed over to the relevant Government departments for management and maintenance upon completion. Examples of these noise covers are the construction of the PTIs at Hung Shui Kiu Area 13 and Shui Chuen O public housing developments (Figure 2).

Figure 2: Noise Cover for PTI at Hung Shui Kiu Area 13

3.2 Mitigation Measures at Receivers

While noise impact is more effectively mitigated at sources, there are circumstances where at-source mitigation measures could not be practically implemented for reasons such as lacking space for noise barriers. Hence, mitigation measures at the receiver end have to be considered to overcome the noise impact. These measures are based on three types of acoustic principles – screening, setting back and reducing the angle of view.

Taking into account the site conditions and configuration, the building blocks may be designed to set back away from the noisy roads and at an acute angle to the noise source as far as possible to reduce the noise impact on the building façades. Sometimes, vertical fins may also be added adjacent to windows to reduce the angle of view towards the noisy roads, thus lowering the noise levels at the receivers. Single aspect building design with non-sensitive receivers, such as kitchens and bathrooms, facing against noise sources can be a very effective measure to solve severe noise issues. However, single aspect is not an efficient building design and it is not suitable for use at sites having a pleasant view toward the direction of the noise source. After all, indirect mitigation measures in the form of window insulation and air conditioning could be considered as the last resort, despite it would deprive the enjoyment of natural ventilation for achieving a quiet living environment.

Apart from the above traditional noise mitigation measures, we have recently developed more innovative measures at the receiver end for mitigating road traffic noise and railway noise in order to fully utilize the site development potential and to improve the living environment. These are described in details as follows.

4. INNOVATIVE MITIGATION MEASURES

4.1 Adoption of Site Specific Modular Flat

To suit site constraints, public housing projects sometimes have to use site specific modular flat design to achieve self-screening effect for traffic noise. Subject to the compliance of the Building Regulations, the environmental performance can be enhanced by repositioning the windows in tailor-made flat layout. The site-specific modular flat design was first adopted in the Ex-Cheung Sha Wan Police Quarters public housing site. This design has further been used in the Tuen Mun Area 54 Site 2 public housing site, in which fixed windows are positioned at protruded rooms facing major traffic noise source and openable side windows are provided with lower noise impact to meet the noise standards. These protruded rooms could also reduce the angle of view of the adjacent recessed rooms for noise protection. A comparison of a typical layout of this site specific modular flat with standard modular flat is shown at Figure 3. Such specific design can ameliorate noise impact by 2 to 3 dB(A). In the use of this design, various operational factors including field of vision, ventilation, natural lighting, and window cleansing requirements have to be carefully considered.

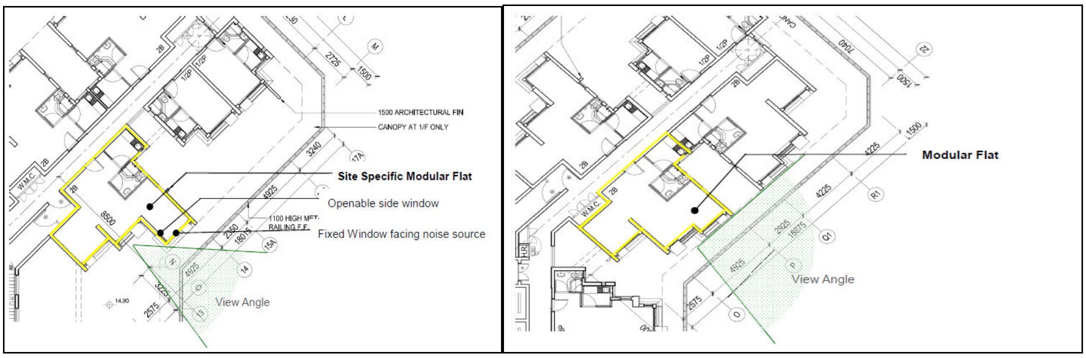

Figure 3: Site Specific Modular Flat against Standard Modular Flat

4.2 Arc-screen Balcony

The proposed Sai Chuen Road public housing development in Sham Shui Po is exposed to severe road traffic noise impact due to the heavy traffic at the West Kowloon Corridor at some 35m away from the site. Although Y-shaped block design was adopted to reduce the angle of view to the West Kowloon Corridor and provide some self screening effect, initial road traffic noise assessments indicated that the unmitigated case would achieve a noise compliance of only 46% with a maximum noise level of 78dB(A). Due to the site and road configuration, other conventional noise mitigations such as building setback, fins and barriers etc., are not practicable.

In order to alleviate the noise problem, we came up with an innovative arc-screen design for shielding noise impact in front of the windows. Desktop numerical analysis was then conducted to investigate its noise mitigating effect. After reviewing the findings with EPD, it was considered necessary to verify the effectiveness of the measure and evaluate its in-situ noise reduction effect by on site measurement using prototype installation.

In mid 2008, a 3-storey full scale model prototype installation was constructed at Dongguan in Mainland China, simulating the development's configuration for the in-situ noise measurements. In collaboration with EPD, various arc screen options using different materials and testing scenarios have been worked out for testing. A total of about ten thousand acoustic measurements have been taken in the Dongguan model (Figure 4). Testing results indicated that the noise attenuation by the arc screen was effective for use in the project.

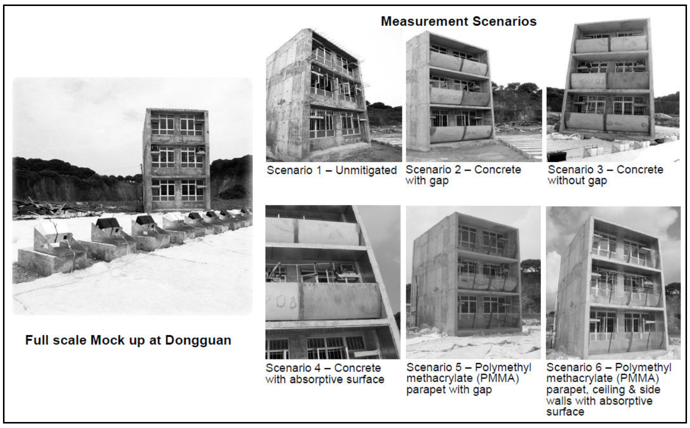

Figure 4: Mock-up Model at Dongguan and Measurement Scenarios

Upon further consultation with various stakeholders, this arc screen design concept finally evolved in the form of an acoustic balcony. The original arc-screen design concept and the final balcony design are shown in Figure 5.

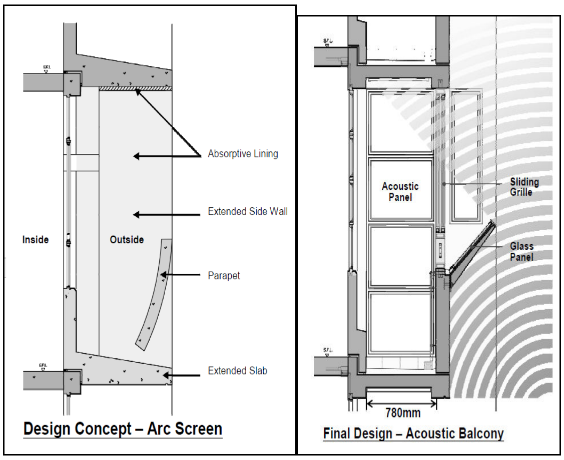

Figure 5: Arc Screen Design Concept and Final Acoustic Balcony Design

Together with the application of noise absorption linings at the balcony, the balcony could achieve a noise reduction up to 6.4 dB(A) for the proposed development at Sai Chuen Road. With the provision of the balcony structure and other mitigation measures, the noise compliance rate was significantly improved to 90% and the maximum noise level was reduced to 75 dB(A). In-situ noise measurements had been conducted at the completed housing blocks to verify the noise attenuation effectiveness at as-built floors.

4.3 Acoustic Window

At sites which are close to very noisy roads such as the San Po Kong public housing development abutting the Prince Edward Road East, even balcony structures would not be sufficient to abate the noise impact. To support the rezoning, EPD requested for 100% noise compliance with the HKPSG's requirement of 70 dB(A) for traffic noise impact. Due to the heavy traffic flow at the Prince Edward Road East, the unmitigated noise level at the site boundary was anticipated at 85 dB(A). Practical measures could provide a noise reduction of only up to 7 dB(A) and we needed to work out some innovative measures to further attenuate 8 dB(A) in order to enable the project viable.

In collaboration with EPD and the Hong Kong Polytechnic University (HKPolyU), we looked into the design of acoustic window, which would function as a modified double-glazed window with offset openings to allow natural ventilation (Figure 6). In mid 2009, we commenced our exploration by conducting laboratory tests on this window design concept in the laboratory of HKPolyU. The purpose of this laboratory exploration was to verify the sound attenuation performance of the window system and how its performance would be affected by other parameters including configuration of the window pane and openings, separation and overlapping of the panes, angle of sound incidence and use of sound absorption materials in the window system.

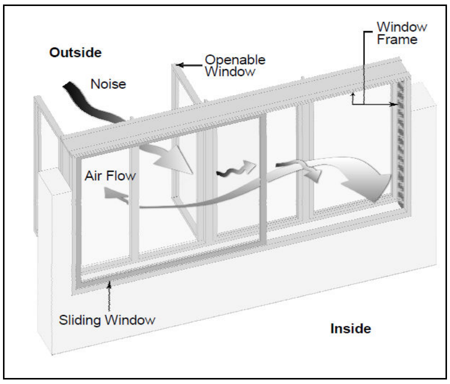

Figure 6: Configuration of Acoustic Window System

A total of 20 window casement designs and over 200 testing scenarios with variations of noise from line sources and point sources have been carried out in the laboratory. Test findings indicated that the acoustic window system should be capable of mitigating noise with very effective attenuation.

Further to the laboratory exploration, detailed assessments had to be undertaken to evaluate the sound attenuation which could be applied to the proposed acoustic window sets to be installed in the housing project. It was considered that the effective sound attenuation of the acoustic window should be established by direct comparison of its performance with that of an equivalent conventional window under in-situ traffic noise environment. Full scale mock-up flats installed with prototype acoustic windows were subsequently set up at the San Po Kong site to facilitate in-situ acoustic measurements (Figure 7).

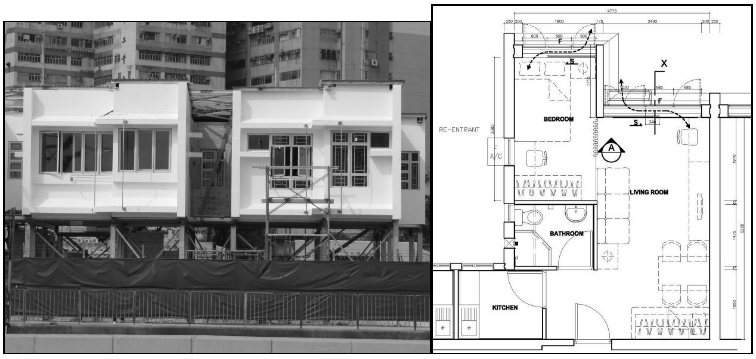

Figure 7: Photos and Layout of Mock-up Flats

A total of 34 microphones were employed to measure simultaneously the exterior and interior noise levels of the mock-up flats under 20 flat/window scenarios during peak hours of traffic. Upon testing for different scenarios, it was established that the acoustic window with noise absorption materials at the inner window frame could achieve noise attenuation up to about 8 dB(A). With the use of acoustic window and other noise mitigation measures, 100% noise compliance with the HKPSG requirement can be achieved to enable the housing project to proceed. Besides meeting the noise requirement, compliance of the window design under the Buildings Regulations is equally necessary, either in terms of openable window parts in the glazing area or achieving the minimum ventilation rate of 1.5 air change per hour, when the inner sliding window is at closed position behind the opened window in front. On top of all these criteria, other operational factors in the use of this window system like window cleansing, clothes hanging installations and long term maintenance have to be carefully considered.

4.4 Special Design for Modification of Existing Balcony in a Graded Building

The site at Chai Wan Factory Estate (CWFE), which is occupied by a 6-storey factory building built in 1959, is proposed to be converted for public housing development (Figure 8). Being located in close proximity to the existing Mass Transit Railway (MTR) Chai Wan Station with elevated semi-open station platform, the site is subject to severe railway noise impact arising from the sound emission from the air conditioning units of the trains when they are waiting at the platform. The unmitigated railway noise at the nearest flats of the CWFE was measured up to 64 dB(A) during night time. To comply with the NCO requirement of 55 dB(A) at night time for railway noise, an effective noise mitigation measure to achieve some 9 dB(A) reduction is required.

Figure 8: CWFE site located adjacent to MTR Chai Wan Station

The CWFE is the last H-shape factory building in Hong Kong and has been graded as a historical building with special merits. In this regard, special challenges went to the conservation of the existing building structure as well as its aesthetic appearance during the design of noise mitigation measures. First of all, all domestic flats are oriented to face towards an internal courtyard, and the existing corridors facing the courtyard are converted to balconies to reduce noise impact. Despite these measures, there are still residual noise impacts at flats facing the railway station.

In collaboration with EPD, we looked into the possible modification of the balcony to enhance the noise abatement effect. We proposed an acoustic balcony design by installing acoustic panels with low-frequency sound absorption materials at the internal walls and ceilings to absorb the operation noise from the air-conditioning units. In addition, light transparent noise panels would be installed on top of the existing parapet of the acoustic balcony to increase acoustic path-difference from the noise source to the receivers (Figure 9). Full scale mock-up flats were subsequently set up to verify the effectiveness of the noise reduction effect by on site measurements. Apart from the noise aspect, other factors such as lighting and natural ventilation have to be carefully considered in the design.

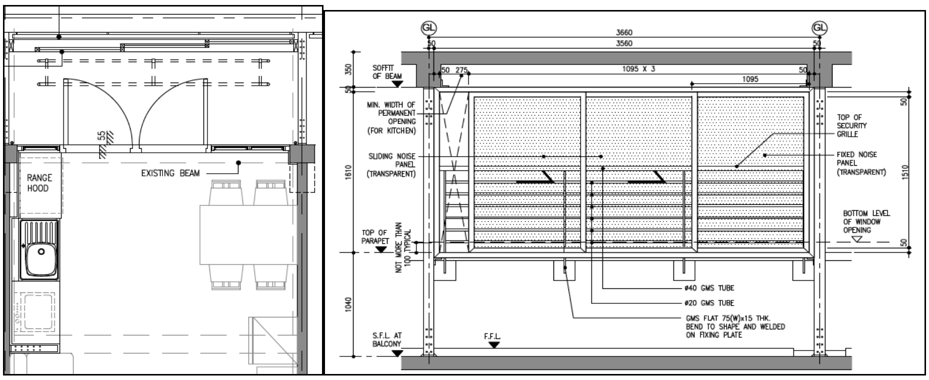

Figure 9: General Layout and Elevation of Balcony

5. COLLABORATION WITH EPD AND OTHER STAKEHOLDERS

Over the years, HKHA has been working in close collaboration with EPD and other stakeholders of expertise such as environmental consultants and tertiary educational institutes in the exploration of various innovative measures to mitigate noise impact to our public housing developments. During the research and development of acoustic balcony and acoustic window, EPD gave valuable advice on the knowledge and experience in similar research projects together with the regulatory requirements of noise control whereas the environmental consultants and tertiary educational institutes were capable of providing acoustic expertise in the investigation and testing. HKHA being the developer is better familiarised with the design, construction and operation aspects and have undertaken the project manager and designer roles of these innovation projects. Experience demonstrated that such a collaboration approach with other stakeholders is essential and practicable to develop innovative measures for the benefit of the community. HKHA welcomes collaboration with other stakeholders in the construction industry to further explore innovations and to share and exchange the experience gained during the research and development processes.

6. CONCLUSION

Given the high density urban setting in Hong Kong, it has been a great challenge in striving for a healthy and sustainable living environment against various pollution sources, with noise nuisance being one of the major pollution aspects. Over the years, through close collaborations among stakeholders in the academic institutes, regulatory authorities and construction industry, HKHA has successfully developed various innovative noise mitigation designs and measures for optimizing the development potential of public housing sites and for improving the built quality of the housing development, with the results that more constrained land, which is a scare resource in Hong Kong, can be more effectively used. It is to the benefit of Hong Kong as a whole.