Track 5: Innovation for Wellbeing

Session 1.8: Innovations for Occupant Wellbeing (1)

Research and Development of Noise Mitigation Measures for Public Housing Development in Hong Kong

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ABSTRACT

Hong Kong is a high density living environment. With scarce land sources, residential developments, including public housing developments, may be located in close proximity to heavily trafficked roads or other noise sources. Embracing a caring attitude to create a healthy living environment to our residents in public housing estates, the Hong Kong Housing Authority has applied a host of noise mitigation measures to reduce the impact and nuisance. Depending on the individual site characteristics, noise mitigation measures can be applied at source, at propagation path and/ or at receiver end. Apart from these measures, where the noise impact is too severe for these mitigation measures to be adequate, more innovative building design in a cost effective manner becomes essential particularly for difficult public housing sites. This paper will highlight our recent research and development of innovative building designs on noise mitigation by making reference to some public housing projects in Hong Kong. A detailed case study will be presented holistically on the evolution of the acoustic balcony from its conceptual arc-screen form to the first generation of acoustic balcony and lately to an enhanced configuration to tackle the most severe noise challenge without compromising the performance of natural ventilation for the flats.

Keywords: *noise mitigation measures, high-performance building, acoustic balcony*

1. INTRODUCTION

Under the land use planning mechanism, the public housing development need to have noise assessment conducted to demonstrate compliance with the criteria under the Noise Control Ordinance and Hong Kong Planning Standards and Guidelines (HKPSG), especially for sites requiring rezoning to residential use.

Many public housing sites are subject to severe noise impact from the environment such as roads, railways and mechanical plants at industrial/ commercial buildings. Various design measures like single-aspect design, optimized block disposition, architectural fins, noise barriers, non-noise sensitive podiums and buildings such as multi-storey car parks or retail facilities as noise buffers will be applied to address the traffic noise impact. While each measure has its own merits and demerits, 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 under collaborative approaches with our stakeholders in tackling severe noise issues in our developments.

2. SPECIFIC DESIGN TO TACKLE NOISE ISSUES

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

2.1 Special noise cover for public transport interchange (PTI)

A number of our public housing sites are located very close to PTIs. Noise barriers are sometimes ineffective in blocking the line-of-sight to the noise source at the PTI as recommended in the HKPSG. Noise cover has to be used instead. To avoid the use of mechanical ventilation and fire services installations in association with a full cover which will increase the future maintenance costs, we designed a special cover with appropriate openings and orientation with minimal maintenance requirement for the PTIs at Hung Fuk Estate (Figure 1) and Shui Chuen O Estate, allowing the use of natural light and ventilation to minimize energy consumption.

Figure 1: Special noise cover with openings for PTI at Hung Fuk Estate

2.2 Specific building block design

While noise impact is more effectively mitigated at source, such mitigation measures may not always be practical for reasons such as lack of space for noise barrier erection. Hence, mitigation measures at the receiver end need to be considered to overcome the noise impact. These measures are based on three types of acoustic principles – screening, setback and reducing view angle.

For some specific sites, the building blocks may be designed to set back from noisy roads and disposition at a skewed angle and farthest away from the noise source to reduce the impact on the building façade. Sometimes, vertical fin walls may also be added adjacent to windows to reduce the view angle towards the noisy roads, thus lower the noise levels at the flats. Single-aspect building design with non-sensitive receivers, such as kitchen and bathroom, facing the noise sources could be a very effective measure to solve severe noise issues. Long Ching Estate in Yuen Long (Figure 2) is an example of successfully mitigating noise impact with passive design and planning.

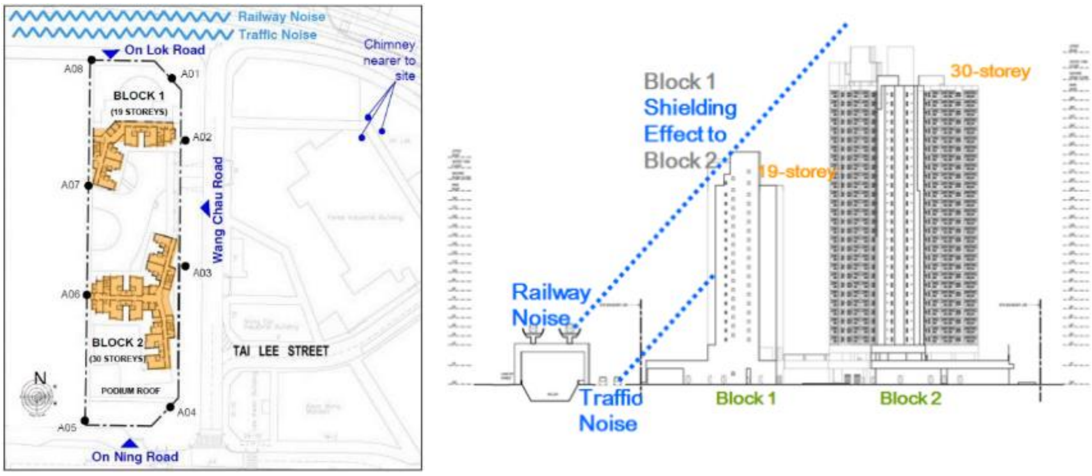

Figure 2: Long Ching Estate

Under extremely severe conditions, indirect mitigation measures in the form of window insulation and air conditioning could be considered as the last resort. However, it would be at the expense of natural ventilation.

3. INNOVATIVE MITIGATION MEASURES

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

3.1. Acoustic window

For San Po Kong public housing development which abuts heavily trafficked Prince Edward Road East, the unmitigated noise level at the site boundary was anticipated at 85 dB(A). Apart from other conventional measures, the project team needed to work out innovative measure to further attenuate 8 dB(A) in order to meet 70 dB(A) noise standard as a rezoning requirement. Hence, we collaborated with Environmental Protection Department (EPD) and the Hong Kong Polytechnic University (HKPolyU) to form a Research Team to work out the design of acoustic window, which would function as a modified double-glazed window with offset openings to allow natural ventilation (Figure 3). In mid 2009, we commenced our exploration by conducting laboratory tests on this window design concept with various window configurations, noise source orientation, use of sound absorption material in the window system etc. to verify the noise attenuation performance of the design. The laboratory testing provided very promising results.

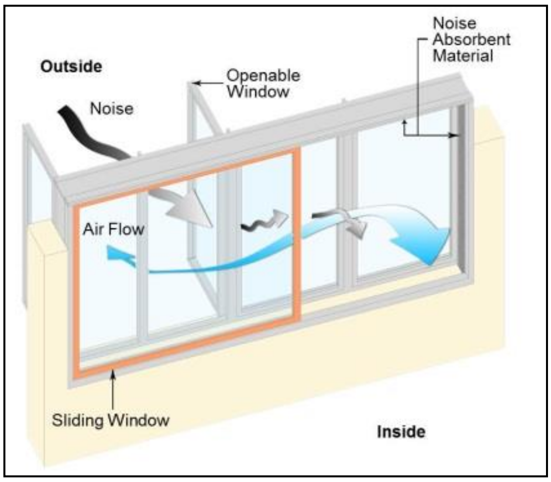

Figure 3: Configuration of acoustic window system

Subsequently, full scale mock-up flats installed with prototype acoustic window was set up on site for in-situ acoustic monitoring (Figure 4). Upon testing of the acoustic window for direct comparison of performance against conventional window, it was established that the acoustic window could achieve noise attenuation up to about 8 dB(A).

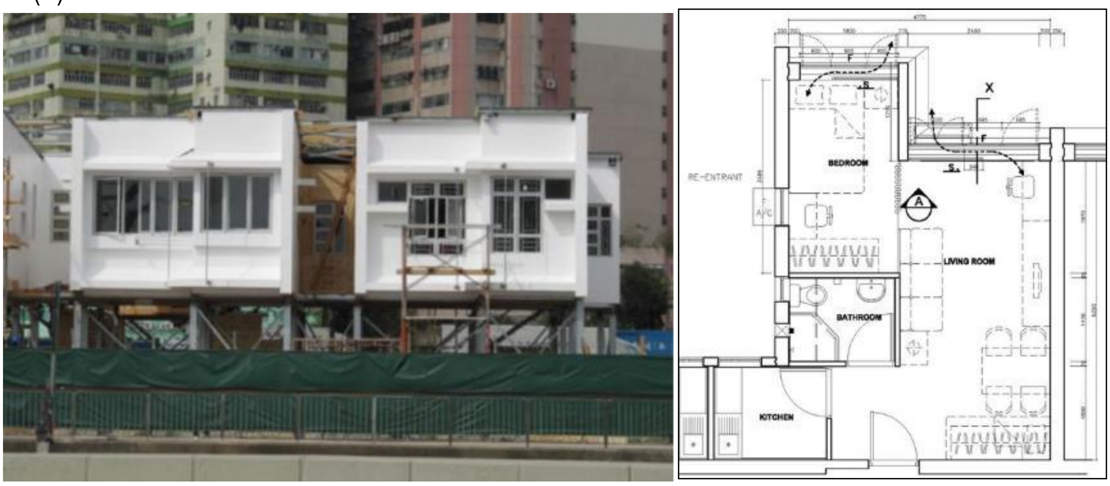

Figure 4: Mock-up flats for comparison of the performance of conventional window and acoustic window

With the employment of acoustic window system, 100% predicted noise compliance with the noise standard can be achieved to enable the San Po Kong project to proceed. Upon completion of the project, further noise monitoring would be arranged in completed flat for verification. During the design process, ventilation and other operational factors like window cleansing, clothes hanging and long term maintenance have been carefully considered from the residents' perspectives.

4. A CASE STUDY OF ACOUSTIC BALCONY

4.1 Acoustic balcony (Arc-screen to first generation)

Wing Cheong Estate development, abutting the elevated West Kowloon Corridor, is exposed to severe road traffic noise impact. Since the site and road configuration rendered conventional noise measures impractical, the project team came up with an innovative arc-screen design concept for shielding noise impact in front of the windows.

Desktop numerical analysis was first conducted to explore the effectiveness of the measure. With the promising desktop results, the project team subsequently proceeded with a 3-storey full scale model prototype installation for the in-situ noise measurements. Various arc-screen options, different materials and test scenarios have been worked out for testing (Figure 5). Results demonstrated the effectiveness of noise attenuation by the arc-screen.

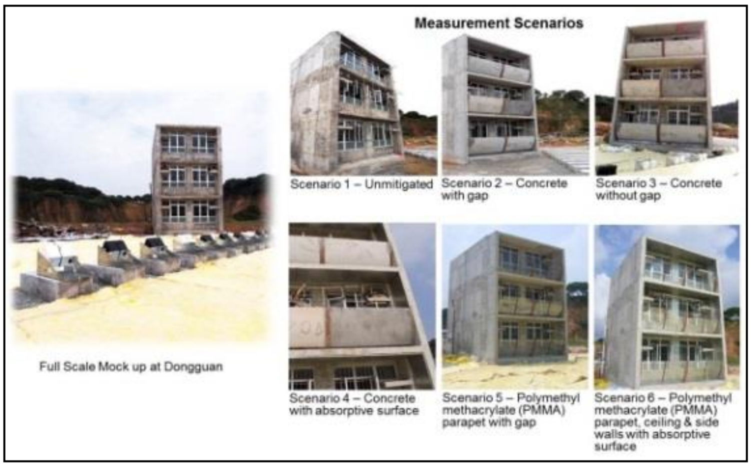

Figure 5: Site mock-up model at Dongguan and measurement scenarios

Upon further consultation with various stakeholders, this arc-screen design concept finally evolved in the form of an acoustic balcony for use in the project, as shown in Figure 6.

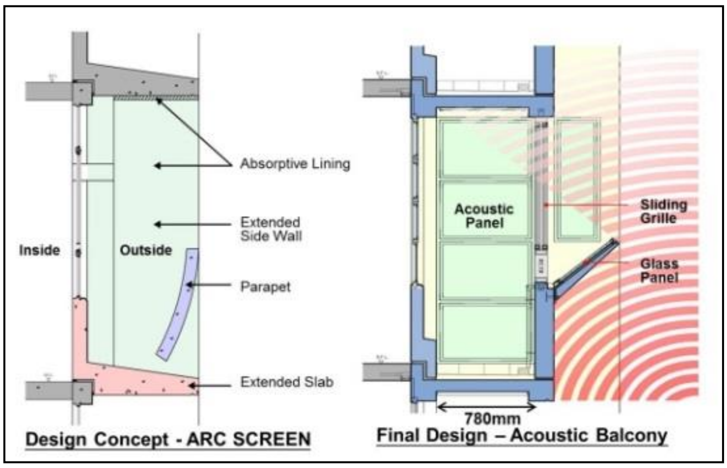

Figure 6: Initial arc screen design concept and first generation of acoustic balcony design

Together with the application of noise absorptive linings, the Acoustic Balcony could achieve maximum noise reduction up to 6.4dB(A). After completion of the building works in July 2013, on-site noise verification has been conducted, confirming the predicted noise reduction could be achieved.

Use of Acoustic Balcony has enabled the Wing Cheong Estate development to proceed amidst the severe noise impact. Consideration has been given to facilitate associated daily operation such as clothes hanging and window cleaning as well as long term maintenance. According to the resident survey taken after its occupation in 2013, this Acoustic Balcony design which could effectively reduce noise by about 2 to 6 dB(A) were much to the satisfaction of the tenants.

4.2 Acoustic balcony (Enhanced design)

Although successful in developing the innovative measures of acoustic window and acoustic balcony (Arc-screen to First Generation), we are not complacent. We looked into an enhanced Acoustic Balcony design (Figure 7), which amalgamates the acoustic window concept in the first generation of Acoustic Balcony. To ameliorate the incidence of noise through the balcony door into the flat, a sliding screen is installed in front of the balcony door in the balcony. This arrangement allows the ventilation path to be of decent width. Other auxiliary feature like noise adsorptive material at the wall and ceiling of the balcony and inclined panel projecting from the parapet would be provided on a site-specific basis for further noise mitigation enhancement. Apart from the noise aspect, other factors such as natural ventilation have to be carefully considered in the enhanced version.

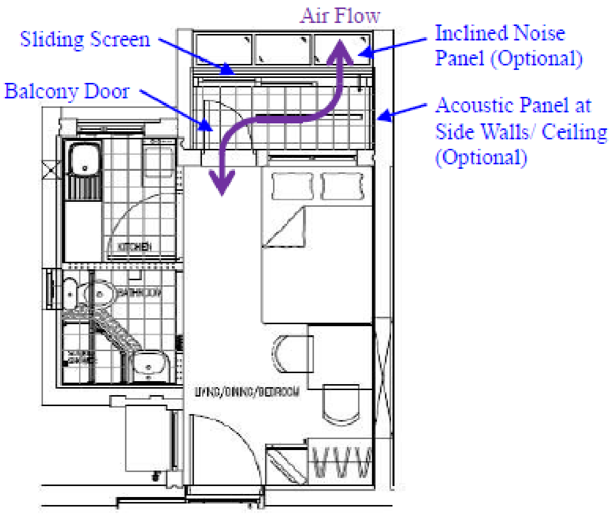

Figure 7: Layout of enhanced acoustic balcony design

In July 2015, we set up full-scale mock-up flats for the test case unit with prototype acoustic balconies and the base case unit with conventional window inside an existing vacant school building at Yue Wan Estate to verify the effectiveness of the noise reduction effect by in-situ acoustic measurements (Figure 8). The existing vacant school building would be demolished and the site would be developed for a public rental housing development providing some 800 flats for 2019/2020. This housing development is the first pilot project adopting the enhanced Acoustic Balcony design. Both in-situ traffic noise source and loudspeaker noise source had been used for the measurements.

Figure 8: Mock-up flats for comparison of the performance of enhanced acoustic balcony and conventional window

At least 20 microphones were employed to measure simultaneously the exterior and interior noise levels of the mock-up flats under 23 scenarios of different flat/ enhanced balcony settings. Besides, loudspeaker arrays at different offset distance representing different inclination angle of noise source were employed to simulate the flats at various levels. Upon testing for different flats and enhanced balcony scenarios, it was established that, the enhanced Acoustic Balcony with the fittings as stated above could achieve relative noise attenuation up to around 10dB(A), which was even higher than Acoustic Window and the first generation of Acoustic Balcony. It would be an effective design for noise mitigation whilst at the same time allow desirable natural air ventilation for the habitable area of the flat. At the moment, we are still refining the design to meet other aspects like buildability and other balcony orientation with respect to road alignment. But this noise mitigation design feature is now being adopted in some of our housing projects with acute noise issue.

5. COLLABORATION WITH EPD AND OTHER STAKEHOLDERS

Over the years, we have 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 Window and Acoustic Balcony, 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. Experience indicates that collaboration approach with other stakeholders is essential and practicable to develop innovative measures for the benefit of the community.

6. CONCLUSION

The HKHA's mission is to implement the subsidized public housing programme in meeting the housing needs of those who cannot afford private housing in Hong Kong in support of the Government policy on housing. Yet land has always been a precious and indispensable ingredient in HK's housing, economic and social development. Owing to the limited land supply, we need to make the best use of every piece of land, optimise the development potential and provide as much as domestic flats as practicable within the shortest possible time. All the mitigation measures discussed above, enable us to build more in areas with undesirable noise environment, without compromising the environmental quality of housing estates.

Gaining from past experience, through the development of various innovative noise mitigation designs and measures, we have optimised the development potential of several difficult public housing sites, and holistically improved the environmental quality of these estates at the same time. Looking ahead, we will continue working closely through close collaborations among stakeholders in the academic institutes, regulatory authorities and construction industry to overcome these challenges.

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