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The Use Of Acoustic Cameras In Assisting The Testing Of Baffle-type Acoustic Windows And Balconies

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ABSTRACT

Innovative noise mitigation devices like baffle-type windows and balconies are tested in full scale mock up or acoustic chamber for the noise reduction performance. Among all relevant testing standards, a higher Sound Transmission Class (STC) of the partition wall or testing facade than the test specimen is required to ensure that the noise reduction ability of the devices is truly reflected. This draws the importance in ensuring the STC of the installation workmanship and design where any gaps and acoustically weak point may hinder the reliability of the testing results. However, these small gaps or weak points are difficult to be observed by visual inspections. In this circumstance, acoustic cameras can be used to identify the problem in an acoustical way by observing the energy distribution the testing specimen and inspect for any unwanted transmission.

This paper will compare the acoustic camera results of different installation methods and explore the possibility of using acoustic cameras in quality control in testing. The possibility of using of acoustic camera in assisting the design modification of baffle-type acoustic windows and balconies in enhancing noise reduction ability will also be discussed.

Keywords: Acoustic Camera, Environment Noise, Plenum Window Testing
I-INCE Classification of Subject Number: 72

1. INTRODUCTION

Baffle-type acoustic windows are being used as innovative noise mitigation measures in high-rise residential buildings in Hong Kong. Full scale mock-up test is required to justify the noise reduction performance of each designs before bulk construction on-site. Currently, the tests are carried out in accordance to various ISO standards including ISO 16283[1] for mock-up tests and ISO 10140[2] for acoustic

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chamber tests. The standards govern most of the testing setup including the source requirements, measurement equipment as well as the façade installation requirements. In actual practice, the tests are conducted with professionals, however, the installations still rely on labours and handy work.

At the meantime, the testing laboratories are finding ways to uphold the quality and the accuracy of the testing. Different ways have been used and recently, acoustic camera was introduced to assist the quality control by the testing laboratory.

Acoustic cameras have been widely used in detecting unusual noise generation in the industries. One of the strongest abilities of acoustic cameras is to detected noise leakage at façade. Therefore, a case study has been done to capture the unusual noise leakage at a testing window and the results are presented in this paper.

2. THE USE OF ACOUSTIC CAMERA

Different forms of microphone arrays have been used to detect noise in a far-field situation like detecting the noise from a vehicle pass-by[3], locating a low frequency break-out noise in an industrial plant or monitoring the condition of running machines [4]. Spherical beamforming uses a far-field beamforming technique suited for free-field conditions in a reflective sound field, like a small room. Spherical beamforming employs a spherical array that helps identify the exact position of a sound source in the surrounding space [5].

The acoustic camera used in this study is a camera-integrated microphone array with a large number of microphones disturbed arranged in a circular manner. It is with a large number of microphones which eliminates the problems of ghost-spots. By having non-uniform element distance the camera avoids problems related to grating lobes. Through clever positioning of the array elements, along with element weighting changing according to the input frequency, the side lobe levels are greatly reduced, along with a sharpened main lobe compared to the beampatterns of the uniformly weighted rectangular and circular array [6].

3. TESTING OF SPECIAL DEVICES

The specially designed facades are usually tested in full scale mock ups and acoustic chambers for their noise reduction performance. The testing facades, either windows or balconies or even a combination of two, are installed on the outdoor façade of the purposely built test buildings in outdoor mock up tests. They are installed at the common wall of the semi-anechoic and reverberation chamber. Linear arrays of loud speakers are used with white or pink noise signal to mimic busy carriageway or railway track in mock-ups or chamber testing. In rare occasion, on-site mock-ups can be done, thus, the actual road or railway track are then used as noise source.

3.1 Full scale mock up test

A full-scale mock-up test are usually conducted at outdoor testing facilities with specimen installed on the façade of a low-rise testing building. One outdoor microphone was located at 1m from the window façade while a minimum of five indoor microphones were located inside the room. Such indoor microphone positions are placed with reference to ISO16283-3 and the averages of the measured sound pressure levels of these microphones can represent the room’s average. The transmission loss (TL) or the Relative Insertion Loss (RIL) of the windows or balcony will be measured. The results for different type of environmental noises are weighted using the traffic noise spectrum as stated in BSEN 1793-3, the A-weighted normalized low-speed train noise spectrum stated in NT

ACOU 061 or the measured noise spectrum of the respectively residential development site.

3.2 Acoustic Chamber Testing

A pair of semi-anechoic chamber and reverberation chamber are used as source room and receiver room in chamber testing. The two chambers are isolated from each other while the testing window or balcony is usually installed on a timber carcass attached to the source room. This is designed to avoid any bridging between the source room and the receiver room and minimise any unwanted structure-borne sound transmission. Similarly, microphones are placed in front of the testing façade in the source room as outdoor microphones and the indoor microphones are placed in the reverberant receiver room as indoor microphones.

4. FAÇADE INSTALLATION FOR TESTING

The wall opening at the test buildings are constructed larger to accommodate testing specimen of different size and design. Hence, temporarily external walls are built while installation the test window or balconies to the test building. To ensure the testing results are truly reflecting the noise reduction performance of the specimen, the test rooms as well as the temporary walls should be constructed with higher sound insulation properties than the test windows or balconies. The testing standards ISO 16283-3 and ISO 10140 govern most of the testing setup including the source requirements, measurement equipment as well as the façade installation requirements. They have stated that the installation of the testing specimen should have a sound transmission class (STC) that is higher than the testing specimen. Nowadays, several installation methods are used to install the testing façade at the test building or acoustic chambers.

4.1 Carcass with acoustic material infill

Figure 1 Test windows installed with brick Walls (left) and carcass made of gypsum boards with infills (right)

Using bricks and cement sand construction is the most traditional way to install any windows and balconies. A properly built brick walls of 100mm could achieve STC 45. It is the cheapest and easiest way to build. With the procedure of grouting with the cement sand rendering, it is the most reliable way to seal all gaps between the specimen and the adjoining wall. However, this method takes very long time to let dry and it is time consuming to demolish and reconstruct with another test specimen. Alternatively, layers of solid timber board and gypsum board with acoustic insulation infill can also be used to construct the carcass for installing the test window or specimen in the acoustic chambers. Timber and gypsum board are indoor material that can only be used at indoor. Sound insulation materials like fibreglass or rockwool are used to increase the transmission loss of the carcass. The testing specimen is then fixed in-situ and grouted with silicon sealant which is a typical final fixing as in installing the window in real construction. **Error! Reference source not found.** shows a curtain wall window installed at a 200mm thick brick wall and a plenum window installed on a 200mm thick wall constructed with 150mm bricks and gypsum boards on both faces.

4.3 Dry-fixed with concrete sandwich panel or metal sandwich panel

Window installation and test room construction is the most time-consuming process in each cycle. To speed up the installation, using dry walls and dry-fixed method is the newest trend. Concrete sandwich panels or metal sandwich panels with metal frame tailored to size are used. Figure 2 shows two windows installed using this method. The construction can be done down on the floor and hoisted up into position for installation. The panels used are of higher STC than the testing specimen. The interfacing of the window frame with the installation are also sealed with silicon sealant to ensure it is gap free.

Figure 2 Test windows installed at testing facades with concrete sandwich panel (left) and metal sandwich panel (right)

5. CASE STUDY SETTING AND DISCUSSION

The quality of the specimen installation is one of the key factors that affect the accuracy of the testing. A defective specimen would also hinder the noise reduction that the window design can achieved. In viewing that an acoustic camera can detect the sound distribution of any surface, a case study has been done to examine the benefit of using it in window tests.

An acoustic camera testing was conducted using a plenum window which is used to test the noise reduction for traffic noise. The window was installed onto the testing façade with metal frame and metal sandwich panels. Three different scenarios have been tested: window fully opened, closed with a very small gap and fully closed as air-tight. A short line source with 3 loud speakers place 2m centre to centre has been used. Pink noise was used as the source signal. The acoustic camera was set up at 2m from the window in the test room, focusing to the middle of the window. Figure 3 shows the set of microphone array and the under used for test. The Nor- 848A-10 acoustic camera was used. It is in 1m diameter array with 256 numbers of digital microphones. It has a mapping frequency range of 220 Hz to 15kHz. The acoustic camera was connected to a computer with its real time recording and analysis software Norsonic Acoustic Camera V2.5.9. The noise contours were mapped onto the real time image from the wide-angle camera integrated at the microphone array.

Figure 3 The Acoustic Camera Measurement Setup in the Test Room

Figure 4a to Figure 4c compare the difference of the contour plots of the A-weighted sound pressure levels captured by the acoustic camera. Figure 4a shows the contour plot with window fully closed and locked while Figure 4b shows that closed with a small gap. Figure 4c shows the plot with the window opened.

Figure 4a is with the same contour level as Figure 4b, as the window was perfectly closed in Figure 4a that not leakage can be detected around the openable windows as well as the interfacing of the installation. The overall noise level measured was low. In Figure 4b, the window was left with a very small gap at top of the window opening by unlocking the window. This gap is not visible from the indoor, there was overlapping between the openable window and the window frame at this point. With the acoustic camera, a small leakage at high frequencies from around 1000Hz to 5000Hz was found.

The contour plot of the open-window case in Figure 4c shows a much higher noise level measured. The direct sound from the line source projecting upward at an angle of 45^{o} hits the ceiling of the test room and form a strong point at the ceiling as shown in the contour plot. This might show the location of where the first reflection occurs.

Some fluctuation of noise was detected at low frequencies at around 200 Hz at the fixed glazing area of the window in all cases mentioned in the previous paragraph. However, as the mapping frequency of the acoustic camera used is from 220 Hz. Therefore, it is inappropriate to draw a conclusion that there were low frequency concentrations at that location.

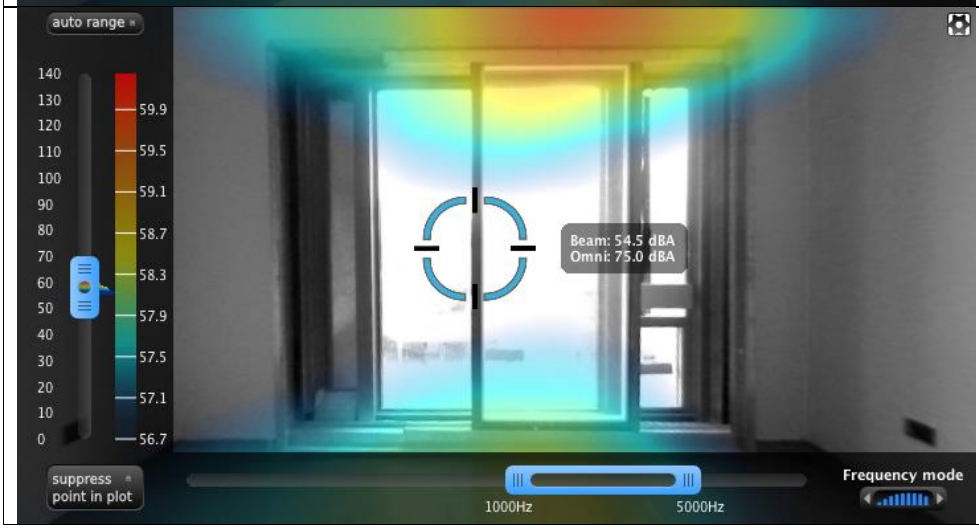
6. CONCLUSION

A case study has been done to demonstrate the use of acoustic camera in assuring the testing quality of installation of testing specimen for test. A real gap cannot be found in this case study, but an invisible gap at the overlapping of the openable window and the window frame could be found in form of a high frequency leakage. This demonstrated that the acoustic camera can be used in checking the air-tightness of the test specimen installation. This could help to ensure the accuracy of the measured transmission loss of the test window or plenum at high frequencies. the acoustic camera could also help to detect any abnormal reflections in the test rooms.

A larger acoustic camera is needed to capture all the noise distribution to lower frequencies like 100Hz which the lower band of frequency of interests for traffic noise is. This may extend the use of the acoustic camera to measure the sound insulation of the façade device directly.

a) Window fully closed and properly locked

b) Window closed, not properly locked, with a very fine air gap at the top



c) Window fully opened

Figure 4 Contour plot of noise measured by the acoustic camera microphone array wtih different window setting

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