Lightweight noise barrier

Wilson HO[1]; Wylog WONG[2]; Yasir NAVEED[3]
[1 2 3] Wilson Acoustics Limited, Hong Kong

ABSTRACT

Conventional noise barriers of 3m to 6m height either have a structural foundation or a heavy base in order to sustain occasional and short-lived heavy wind loading from gusts. The lightweight noise barrier, currently on trial for construction noise control in Hong Kong, employs an automatic mechanism to relieve such occasional excessive wind load. Therefore, the structural loading requirement is reduced to approximately 1/10 of conventional noise barriers and a lightweight structure with density less than $4kg/m^2$ (including structure but excluding base) and height of up to 8m can be achieved. Noise insulation panels are designed to be installed upwards from ground level without the use of cranes. Components within 1.35m width and 2m height are designed in modular form for easy transportation and erection. The entire installation process of one 8m high barrier unit can be completed within 15 minutes by two people and it is quiet enough to be conducted at night. Noise barrier structure is mounted to a simple metal frame or a water barrier with 1m to 2m wide extended base. Insertion loss of 12 to 20dB(A) were tested.

Keywords: Noise Barrier, Insertion Loss, Light-weight

1. INTRODUCTION

There is a growing demand for construction noise control in urban areas due to increasing public awareness on noise nuisance (1, 2). However, conventional noise control measures are not suitable for short-term construction projects in which Powered Mechanical Equipment (PMEs) are used. During typical PME operations, the noise source lasts only for a short period of time or moves every few hours. In such cases, using conventional high noise barriers is not practical as they are made of very heavy structures and cannot move along the PME. These heavy structures are designed to withstand high wind loads under very heavy wind conditions. Due to the weight, the erection process of conventional barriers requires use of PMEs and high ladders which are not allowed in certain situations such as during nighttime work in Hong Kong.

Moreover, conventional noise barriers require concrete foundation, but there may also be difficulty in obtaining permission to lay a concrete foundation at certain locations. The process may also not be allowed at day time due to road congestion, and may be feasible only at night time within a few limited hours. Therefore, it is very inconvenient for contractors as it incurs massive cost for scheduling and manual labor.

In order to provide a practical solution to the problems highlighted above, the Lightweight Noise Barrier has been invented. It is easy to erect, mobilize and dismantle. Its noise insulation panels can be installed upwards on the structure from ground level. The erection process does not require use of any PME or high ladder and can be done by manpower only within a few minutes. It may be used as a temporary structure for a short period of time and does not require any foundation construction on ground for its erection as well.

It incorporates an automatic wind load relieving mechanism such that the barrier panels can allow passage of wind under heavy wind conditions when the speeds reach above a pre-specified wind loading threshold. This automatic control mechanism relaxes the structural requirement of the barrier to 1/10 of conventional noise barriers such that a lighter and less heavy duty structure can be achieved.

The project is being trial in HK and not completed. Further results will be presented.

[1] who@wal.hk
[2] wwong@wal.hk
[3] yasir.naveed@wal.hk

2. CONSTRUCTION NOISE CONTROL IN HONG KONG

Construction noise is regulated in Hong Kong by the Environmental Protection Department (EPD). All activities involving use of PME must obtain a Construction Noise Permit (CNP) prior to operation. Using elevated platforms in open spaces at night is considered as a Prescribed Construction Work (PCW) and not allowed under the CNP.

Any erection process involving PMEs and elevated platforms is not allowed and, therefore, the Lightweight Noise Barrier is adopted.

For special CNPs issued under the unavoidable constraints on working hours (3), one of the criteria for successful grant of CNP is use of quietest practicable noise mitigation method available. Using Lightweight Noise Barrier has been accepted as one of the best practicable mitigation measure by EPD and it is now being used for noise control at various sites.

3. WIND LOAD REDUCTION MECHANISM

3.1 Theory

To be able to use a lightweight structure, wind load acting on noise insulation panels is limited to not exceed the maximum load limit of barrier structure. This maximum load limit is set to be half of the yield strength of the structure components. With this, the barrier panels are able to sustain wind loads of up to a pre-specified threshold – 40 kph – until which the structure remains safe and undamaged. Upon reaching the threshold, the panels relieve wind load by automatically opening and allowing passage of wind. Wind load can be computed with the following formula:

$F = \frac{1}{2} \rho V^2 A C_d$ ---- (Eq. 3.1)

Where;
ρ = Density of air; V = Wind speed; A = Cross sectional area orthogonal to wind speed
C_d = Coefficient of drag; F = Force of wind load

As threshold wind speed is reached noise insulation panels rotate, their 'A' decreases to almost nil and a passage for wind is created. This relieves the wind load acting on the lightweight structure and it remains undamaged.

3.2 Material Selection and Working Mechanism

U-channels are used in conjunction with magnets to prepare a recessed lock mechanism as shown in Figure 3.2a as follows. To maintain light weight, Aluminum is used.

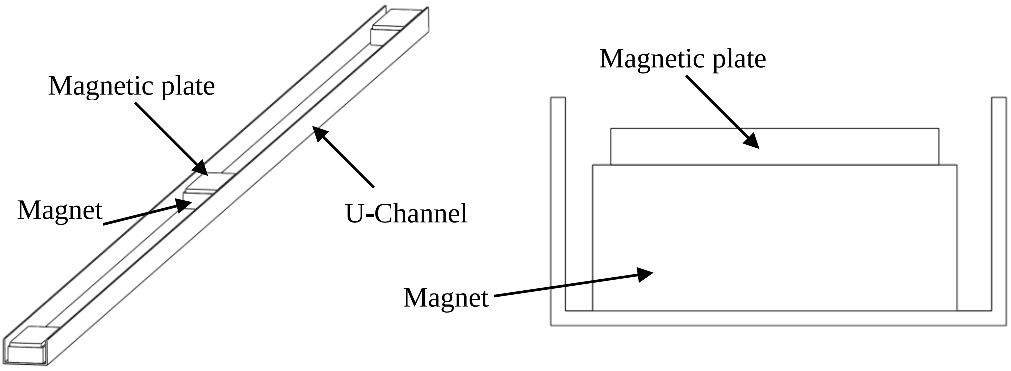

Figure 3.2a – U-channel with magnet and magnetic plate for recessed lock

As shown above, magnets are smaller in height than the u-channel so that the metal plate - labelled above - is attracted inside the web. The system dictates that in order to go out of the u-channel, any metal plate attracted to the magnets will have to overcome the magnetic attraction as well as move upwards along the u-channel web. Due to this recess, a stronger locking force is achieved for the panels than the attraction force of magnets only.

As described in Figure 3.2b, the sleeve of each panel is installed with a magnetic material. The free-swinging vertical side of the panel, which is distal from the sleeve, is also installed with a magnetic material. Therefore, for two laterally adjacent panels, vertical side of one panel is under magnetic attraction with the sleeve of the adjacent panel. The magnetic attraction keeps the panels stationary in a closed position, which forms a continual wall for blocking sound. During occasional strong gusts, wind load may be high enough to overcome the magnetic attraction so that each panel may swivel into an open position relative to the mounting pole inserted through the panel sleeve. Wind load threshold at which the magnetic attraction is broken can be adjusted by changing the number, size and type of these magnets

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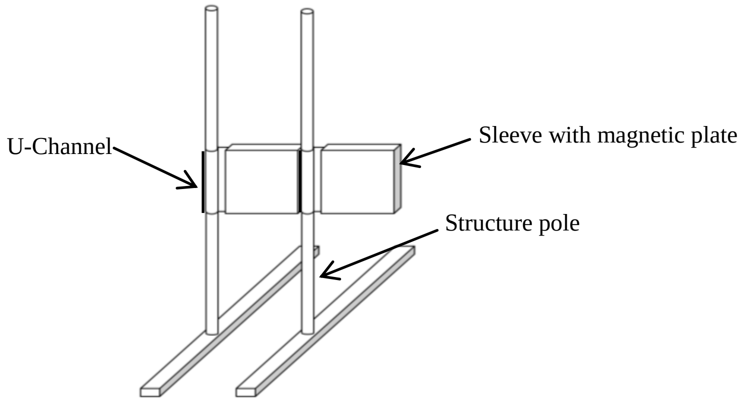

Figure 3.2b – Module of two panels showing position of u-channel and sleeve with magnetic plate

3.2.1 Wind speed measurements

A measurement setup was installed to measure wind speeds in urban areas with high density of tall buildings because these are the expected installation sites for Lightweight Noise Barrier. The study was conducted to find the highest wind speeds that occur during gusts and typhoons in urban locations. Most of the wind measuring setup by local observatory is installed in outlying or less densely populated areas of Hong Kong where the wind speeds are too high, but due to the high rise buildings such heavy wind loads are not present in the populous areas. The measurements were conducted over a period of 6 months and the distribution of speed duration is shown in Figure 3.2.1.

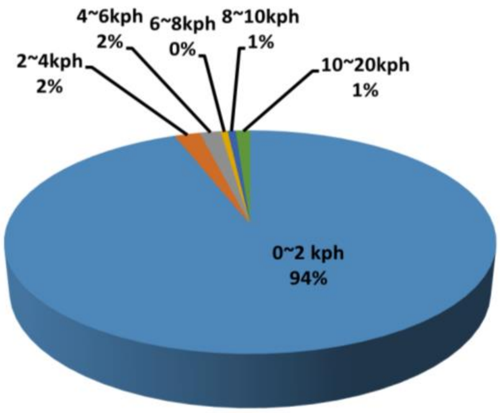

Figure 3.2.1 – Wind speed distribution in high-rise urban area of Hong Kong for 6 months

It was found that the wind loads of 20 kph or above occurred only twice over the course of 6 months and lasted for not more than a few seconds. These short lived gusts occur very occasionally and according to local observatory the maximum gust speed is usually around 40 kph in urban areas (4). This implies that a barrier designed to open at maximum wind speed of around 40 kph would be conservative. So, calculations were made to study the corresponding wind load at which the magnetic attraction force should break and allow panels to make passage for air as described in following section 3.2.2.

3.2.2 Wind load calculation

Standard noise insulation panels are 1.35m wide and 1m high because most commonly used water barriers available in Hong Kong are 1.35m wide. Several wind speeds and their corresponding wind loads were computed as follows based on Eq. 3.1.

Wind Speed (kph)	Type of Drag	Magnitude
25	Form Drag of Panel (N/m)	50.2
	Form Drag of Rod (N/m)	1.2
	Total Wind Load (N/m)	51.3
35	Form Drag of Panel (N/m)	98.3
	Form Drag of Rod (N/m)	2.3
	Total Wind Load (N/m)	100.6
40	Form Drag of Panel (N/m)	128.4
	Form Drag of Rod (N/m)	3.0
	Total Wind Load (N/m)	131.4

Table 3.2.2 – Wind load on panel under different wind speeds

As shown in table 3.2.2, total wind load at 40kph wind speed is 131.4N. The magnetic attraction must be not less than this value as dictated by the design requirement

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3.2.3 Selection of magnets and plates

The attraction force between the magnets and the plates must be equal to the wind load value highlighted above. With the help of K&J online magnetic strength calculator (5), the following table was created to compare magnetic strength to weight ratio of several N35 type cylindrical (see table 3.2.3a) and cubical (see table 3.2.3b) magnets.

Cylindrical Magnet Size (D(mm)x H(mm))	Weight (g)	Attraction Force Per Magnet (N)	Total Attraction Force of 3 magnets(N)	Magnetic Attraction to Weight Ratio
10x10	6	32	98	5.4
10x5	3	24	72	7.9
15x10	13	67	202	4.9
12x10	8	45	137	5.2

Table 3.2.3a – Comparison of various properties of cylindrical magnets

Cubical Magnet Size (L(mm)x W(mm)x H(mm))	Weight (g)	Attraction Force Per Magnet (N)	Total Attraction Force of 3 magnets (N)	Magnetic Attraction to Weight Ratio
10x10x10	8	41	123	5.3
10x12x10	9.4	48	144	5.2
10x12x8	7.5	43	130	5.8
10x10x12	9.4	43	129	4.6

Table 3.2.3b – Comparison of various properties of cylindrical magnets

Cubical magnet highlighted above is selected because of the best magnetic attraction to weight ratio.

4. DESIGN OF NOISE INSULATION PANELS

Noise insulation panels can be installed on the structure without using any PME or high ladders by 2 people only. They are lightweight and easy to handle. The panels have to be pushed up from ground level as a column at each structural pole before fixing to the recessed lock on the other side.

Several types of noise insulation materials were tested in several arrangements for noise insulation characteristics, material density, ease of handling and aesthetics. Panels with air capsules were found to be the most relevant to the design requirements.

4.1 Panel with Air Capsule

This noise insulation panel design is light (~2 kg/m surface density) and provides noise insulation of ~15 dB(A) for white noise spectrum sound source. Gas inflatable capsules are used as the core of these panels as shown in figure 4.1a.

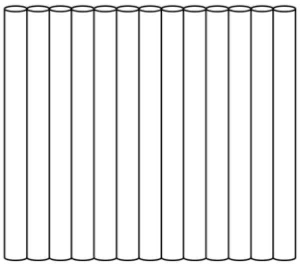

Figure 4.1a – Inflatable air capsules

This segmented configuration in capsule form prevents a bulge from forming at the centre of the panel, as is the case often seen in un-segmented air panels. The gas-inflated tubes are light, bulky and flexible with 0.3 kg/m surface density. Flexible barrier mats of 0.4 kg/m surface density are attached on both sides of the panel as shown in figure 4.1b.

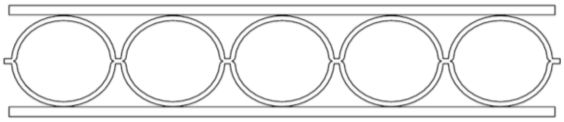

Figure 4.1b –Air capsules with flexible barrier mat on both sides

A Styrofoam frame of 0.3 kg/m^2 density is also glued around the capsules to provide structural stiffness as shown in figure 4.1c.

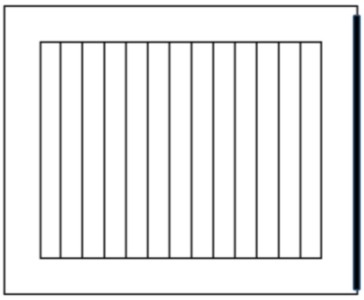

Figure 4.1c – Styrofoam frame around the panel

This structure is glued inside a bag of 0.4 kg/m surface density. The bag has a pocket for mounting and sliding on the structural pole on one side, and sleeve for magnetic plate on the other side as shown in figure 4.1d:

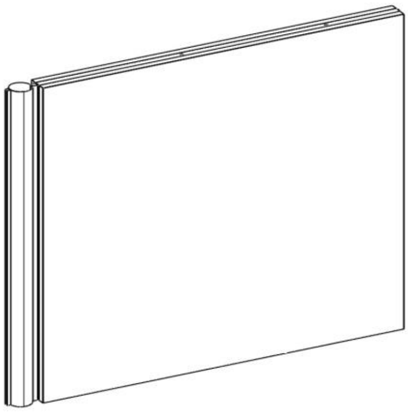

Figure 4.1d – Bag with pole pocket and sleeve for magnetic plate

5. INSERTION LOSS TESTS FOR LIGHTWEIGHT NOISE BARRIERS

5.1 Specification of lightweight noise barriers

Two 11m long and 3m high movable noise barriers were built to test the noise insulation performance of the Movable Noise Barrier as shown in Figure 5.1.

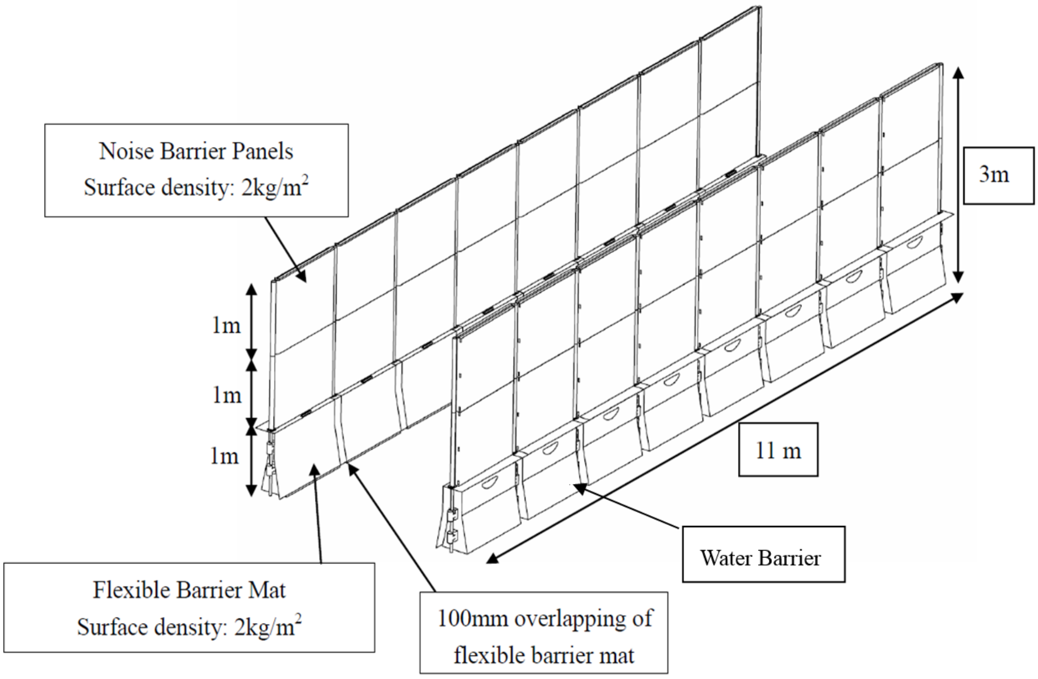

Figure 5.1 – Movable noise barriers for noise insulation test

5.2 Instrumentation

Field calibration of sound level meter was conducted using an acoustic calibrator before and after measurements, see Table 5.2. The field calibration confirmed that there was no shift on the sensitivity of the sound level meters at the calibration frequency.

Measurement Equipment	Brand Name & Model No.	Serial No.	Calibration Expiry
Sound level meter	Svantek - SVAN958A	34507	3 Jul 2015
Sound level meter	Svantek - SVAN958	28422	13 Sep 2014
Acoustics calibrator	Larson Davis – CAL200	10478	28 July 2014
Loudspeaker	QSC K12	GDD540957	N/A

Table 5.2 – Measurement Equipment for noise insulation test

5.3 Insertion Loss Measurement Methodology

ISO 10847: 1997 - In-situ determination of insertion loss of outdoor noise barriers of all types was employed. The Insertion Loss (IL) of noise barrier was determined by comparison of sound pressure levels (SPL) measured with and without the noise barrier.

IL = L (with barrier) – L (without barrier)

Where; L (with barrier) = L (ref, with barrier) – L (rec, with barrier)
L (without barrier) = L (ref, without barrier) – L (rec, without barrier)

L (ref, with barrier) is the noise level at reference microphone when loudspeaker with noise barrier.
L (rec, with barrier) is the noise level at receiver microphone when loudspeaker with noise barrier.
L (ref, without barrier) is the noise level at reference microphone when loudspeaker without noise

barrier.

L (rec, without barrier) is the noise level at receiver microphone when loudspeaker without noise barrier.

5.4 Loudspeaker and Microphone Locations

A schematic concept of IL measurement is presented in Figures 5.4a and 5.4b. Total 10 points were measured at 2 elevation levels (5 points at 1.5m & 3m). A high-power loudspeaker was placed between 2 noise barriers facing upward to simulate the real PME operation.

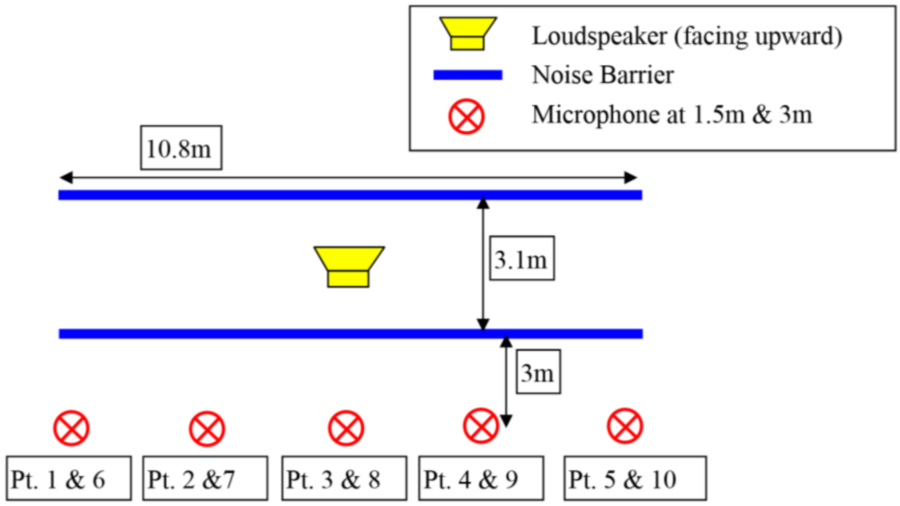

Figure 5.4a – IL measurement location (top view).

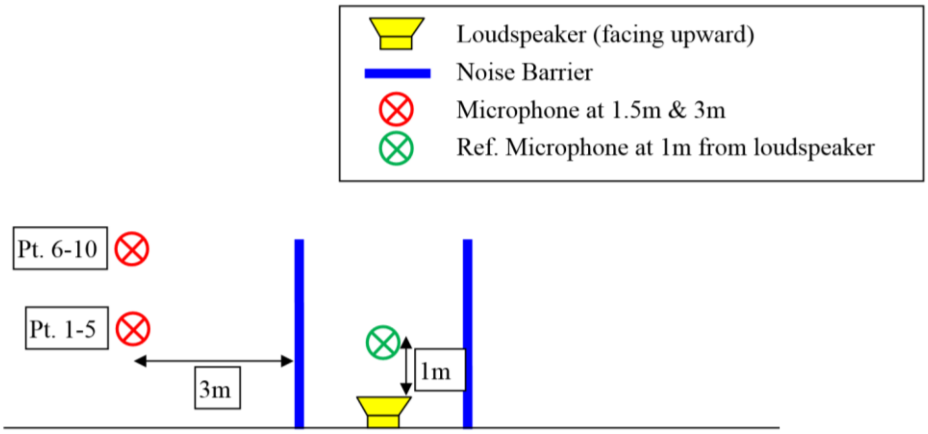

Figure 5.4b – IL measurement location (cross sectional view).

5.5 Noise Playback of White Noise

White noise were recorded and played back by a high-power loudspeaker to provide steady continuous noise source for accurate IL measurement. Reference noise level was measured at 1m from the loudspeaker to monitor the loudspeakers output variation.

5.6 Measurement Results

5.6.1 Background noise measurement results

Background noise measurements were conducted without loudspeaker operation. For conservative approach, background noise correction was conducted with the minimum background $L_{eq,30s}$, see Table 5.6.1.

B/G Noise, $L_{eq,30s}$, dB(A)						Minimum B/G, dB(A)
55.6	**55.0**	56.2	56.7	56.1	55.7	**55.0**

Table 5.6.1 – Background (B/G) Noise Measurement Results, $L_{eq,30s}$, dB(A)

5.6.2 Insertion loss measurement results

The IL of noise barrier were represented by the measurement results at the centre location (points 3 and 8). For 1.5m high point 3 and 3.0m high point 8, 11dB(A) of insertion loss were measured. A summary of IL measurement result is shown in Table 5.6.2.

Measurement location		Noise Insulation dB(A)
Height	Point	
1.5m	1	6
	2	9
	3	**11**
	4	10
	5	8
3.0m	6	6
	7	9
	8	**11**
	9	9
	10	7

Table 5.6.2 – Summary of Insertion Loss (IL) Measurement Results, $L_{eq,30s}$,dB(A)

6. APPLICATION OF MOVABLE NOISE BARRIER IN OTHER PROJECTS

Lightweight noise barrier is still under research and constant improvement. It is becoming readily acceptable by contractors in Hong Kong. The most common reasons for the use of lightweight noise barrier are as follows:

- Construction site is on a road and the work can only be carried out at night. So barrier structure that can be assembled and disassembled readily is required.
- There is an existing barrier on site which is not high enough. The base is not strong enough to sustain extra wind load on a higher level, so barrier panels that can reduce excessive wind loads and prevent the base from damaging are required.
- The location is in densely populated area and using PME for permanent barrier construction is not allowed. So a barrier structure that can be installed without PME is required.

Photo of installation are given in figures 6.1 to 6.2 as follows:

Figure 6.1 – Installation of barrier on site

Figure 6.2 – Installation of barrier on one lane of the road.

7. FURTHER IMPROVEMENT

Noise insulation panels are made of air capsules in the recent design. The insertion loss measurement reveals that there is limited absorption and a new design is required to improve. There are a few upcoming designs that are expected to provide greater absorption. Also, it is relatively easier for air capsules to be popped by flying debris in a construction environment or deflate due to environmental effects. Therefore, more research will be conducted to improve the panel design. Moreover, the installation procedure will be simplified and strengthened so that the barrier could remain erected for a longer time too instead of just for a short-term project.

8. CONCLUSION

Lightweight Noise Barrier is a new type of temporary noise barrier that does not involve use of any PME and PCW during erection process. Its lightweight panels can be installed from ground level and are incorporated with reduced wind load mechanism to relieve excessive wind load on the barrier structure. Hong Kong's construction noise control has been discussed to provide the reader of a sense of stringent noise regulations governing the construction industry in the city. Reduced wind load mechanism has been described. Design of noise insulation panels has been briefly discussed. In the end, barrier noise test and a project example have been brought to light for the reader.

The lightweight noise barrier structure has density less than 4kg/m^2 (including structure but excluding base) with customizable height of up to 8m. Noise insulation panels are installed upwards from ground level without the use of cranes and all components are within 1.35m width and 2m height for easy transportation and erection. The entire installation process of one 8m high barrier unit can be completed within 15 minutes by two people and it is quiet enough to be conducted at night. Noise barrier structure is mounted to a simple metal frame or a water barrier with 1m to 2m wide extended base, subject to the height of the noise barrier. Insertion loss of 12 to 20dB(A) were tested.

It is expected that this technology would be adapted and improved significantly in near future to improve the construction noise control scenario worldwide. More specifically in Hong Kong, due to the stringent noise control regulations such as CNP process, the lightweight noise barrier holds a bright future. For PME and PCW activities, the barrier is treated as a *best practicable method for unavoidable constraints* and expected to be widely adapted.

9. REFERENCES

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