Noise Pollution Shield System for Pedestrians for Coach Termini/Stops in Hong Kong

Design Strategy for a new Generic Environmental "Shield" as Bus Stops

Fernando Nohrá Castro

School of Architecture, The Chinese University of Hong Kong, April 22rd 2016

ABSTRACT: *The need to move around the city is making a deep imprint in the way that people have to take public transport along District and Local Distributors Roads where the demand of routes generates tens of bus stops located on pedestrian walk platforms.*

For everyone that uses public transport is not a secret the proximity those users must tolerate in the majority of bus stops while standing and queueing just next to the intermittent passing by of big, hot and noisy transport machines.

In the present dissertation I want to reflect as close as possible to practical reality while focusing on an immediate environment analysis designing a proposal to help to mitigate and inquire a problem that affects Hong Kong society in general known as traffic noise pollution.

For the preparation of this study has been choose the Sham Shui Po District focused along a busy segment of the Cheung Sha Wan Rd. and in order to obtain a sound knowledge of the environmental situation of the urban noise is taken as reference some data provided by the Environmental Protection Department (EPD), the Civic-Exchange Organization and other independent studies on the sound map of Hong Kong and all over the world. In the development of this paper, it has been conducted a series of measurements on existing bus stops to determine accurate levels of affectation and the involvement of the transport users to the previously expressed problematic on majority of bus stops.

Basically, the research process in my dissertation seeks to find and share to the general public the extent of noise pollution on the specific population group of this city and its potential impacts on their standard of living, health, relationships with others, etc. leading to a feasible design strategy to mitigate the increasing issues overlooked by the environmental and transport institutions of Hong Kong and in consequence, by the users their selves when exposing directly 'by the culture' and been unaware of the health (environmental, physical and psychological) consequences over time.

Various studies have proven that the perception of the environment is 'intersensory'[1]. However, studies analyzing the response of the population to the sound environment

[1] Information and the transmission of it from one sensory source into the association cortex, with information that can be integrated from another source that is sensory.
Source: psychologydictionary.org

rarely consider the influence of other sensory information from the environment and in that response; the visual and aural stimuli are present individually and in combination. This ratio is significant and complex, depending mainly on the degree of comfort in relation to both stimuli. It is also considered that an overall assessment of the environment depends on the interaction between the two, visual and aural and then is when design and environmental architecture come into play… To reflect and call the attention within these matters, I'm basically proposing to put together the same principles of sound barriers that are widely applied to counteract interfaces between important road lines and human activity settlements into the human scale as a reference, not the 'machine' scale as happen as per regulations already.

Designing a simple sustainable shield system at bus stops could provide positive environmental effects and improve the quality of life of the bus users and any pedestrian that uses these noise polluted spots.

Keywords: *Sound Environment, Urban Context, Noise Pollution and Audiovisual perception and interaction.*

1. INTRODUCTION

Noise pollution is considered by most population of large cities as an important environmental factor, which affects primary their quality of life. Urban environmental pollution or environmental noise is a direct unwanted consequence of the main activities taking place in large cities which has made already an impact to inure already the society to its presence.

The term sound contamination refers to noise when it is considered a pollutant, i.e., an annoying sound that can produce harmful physiological and psychological effects on a person or group of people. The main cause of noise pollution is human activity; transportation, building construction and public works, industry, among others. The effects of noise can be physiological, such as hearing loss, and psychological, such as excessive irritability. "*Noise is measured in decibels (dB); most used instruments for measurement are the sound level meters."*[2] A report by the World Health Organization (WHO) considers 50dB as the desirable upper limit.

Technically, the noise is a type of secondary energy generated from processes or activities that propagates in the environment as complex undulatory waves from a source to the receiver at certain speed decreasing its intensity within distance and its physical environment.

The noise disturbs the various community activities, interfering spoken communication (that is the basis of human coexistence), disrupting sleep, rest and relaxation, preventing concentration and learning, and what is worse, creating states of tiredness and tension which can lead to diseases of the nervous and cardiovascular type.

[2] www.otc-cta.gc.ca/eng/railway_noise_measurement

There is documentation about the inconvenience of noise in cities since ancient times, but from the past century as a result of the Industrial Revolution, the development of new means of transport and the growth of cities and societies is when it really starts to show the problem of urban noise pollution. The root causes are, among others, the dramatic increase of the automotive fleet in recent years and the particular fact that the cities were not really designed to withstand transportation growth and demand. In addition to these sources of noise in our cities where Hong Kong protrudes, it is listed a variety of other noise sources, such as industrial, public works, construction, cleaning services and waste collection, sirens and alarms, as well as leisure and recreation activities among others, which together come to cause what is known as urban noise pollution.

This paper tries to reflect the impact caused by the immediate noise pollution in the Castle Peak Rd. at Cheung Sha Wan district's pedestrian population (focused study) and its potential impact reflected in the whole Hong Kong bus users.

2. BACKGROUND

2.1. The Urban Noise Pollution caused by traffic in Hong Kong

The Transport and Housing Bureau has published in figures as well with other recent press releases the need of effective strategies to mitigate the increasing numbers of complaints that the Transport Complains Unit of the Transport Advisory Committee receives every year showing that the 76% are related to transport services, 14% to enforced matters and 6% to traffic conditions where the number of cases on public transport services increased by 14.1% from 3685 to 4206 within 3 months. (Press release thb.gov.hk November 21, 2006).

As well, "*the EPD says that more than one million people are affected by the excess of traffic noise alone making it the biggest noise problem in the SAR*"[3] (Fig.1 Sham Shui Po District). It is clear that the growth of the economy during the 80's and 90's has contributed to the issue regarding poor planning and cramped development. However most forms of environmental noise are under statutory control like construction, commercial and industrial activities but neighborhood type noise like motor vehicles supposed to meet specific noise emission standards for registration which seems this regulatory measures does not apply for coaches or double deck busses that generates the highest noise pollution to immediate users while queueing for the service.

The main and controlled cases are within the use of noise barriers erected in specific locations along new expressways basically, where, as the EPD stablishes, from 1990 more than 80Km of barriers and screens has been installed, benefiting around 300.000 people but understand that the noise from more than 600 existing roads exceeds the 70dB that the same

[3] Environmental Protection Department, "An Overview on Noise Pollution and Control in Hong Kong", http://www.epd.gov.hk/epd/english/environmentinhk/noise/noise_maincontent.html

department stablished in the planning standard as: The traffic noise planning standard, which is *L_{10} (1 hour) of 70 dB(A), means that when this limit is just met, traffic noise will exceed 70 dB(A) for 10% of an hour. The Hong Kong noise map, published on the EPD web site in 2006, shows that 1.14 million people are exposed to traffic noise exceeding 70dB(A).* (See Fig.2) From: www.epd.gov.hk

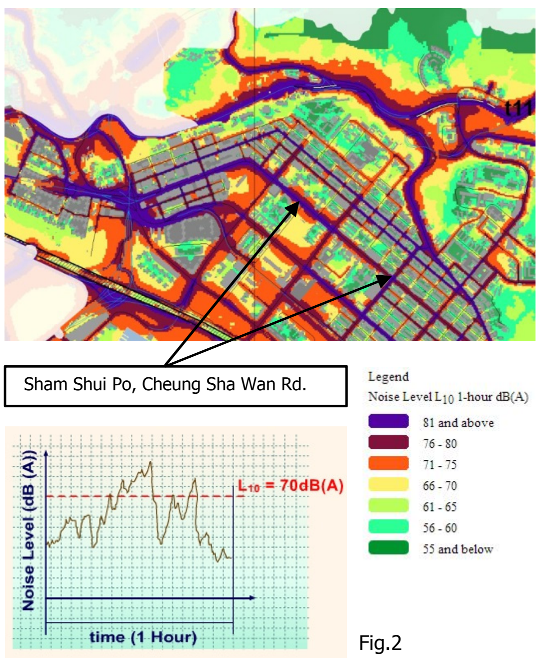


Fig 1. Spatial Distribution of Traffic Noise Problem in Hong Kong, Sham Shui Po District at 4M Height (2015)
Fig 2. Use of L10 to Describe Traffic Noise
Source: Environmental Protection Department

There are three main areas where the noise pollution is assessed in Hong Kong: Traffic Noise, Construction Noise and Aircraft and Other Noise. Even these areas contain the *'big picture'* regarding planning and regulations for control, the Pedestrian Scheme complies only the addecuation of vehicular roads to pedestrian exclusive use known as 'Pedestranization' either temporary or permanent depending on the increase and demand of commercial or cultural needs. However, the scheme openly exposes the lack of measurements or solutions for immediate noise pollution to first hand users of the public transport and bus stops immediate neigburs stating that "*Non-engineering solutions such as traffic management and pedestrian schemes have been explored to reduce traffic noise to nearby residents*". (EPD. Problems & Solutions, Environmentally Friendly Noise Measures)

Anyways Hong Kong Government is addressing the main issues for management of environmental noise pollution with The *'out of date'* Noise Control Ordinance (NCO, Cap.400) for legal purposes. But some basic and out of range situations like the one I have been encouraged to pursuit due to the granted day to day exposure of people in its majority workers and young students to the annoying and stressful moment of waiting for the bus to go around.

2.2. Other Studies

According to a recent study (2013) from the Department of Geography and Resource Management, The Chinese University of Hong Kong, analyzed by a recognized south China newspaper, shows a huge increase from the data published by the EPD compared with the Police Department that an overall of 15692 noise complaints were made in 2012 in the Central District only and these details has not been giving to the general public formally. This approach to statistics shows that the immediate noise pollution is grater and close to the daily life to the Hong Kong society. (See Fig.3)

Population Exposed to Traffic Noise > 70dB (A)L10 all Disrticts in Year 2000			
District	District Total Population	People exposed to > 70dB(A)L10	% > 70dB(A)L10
YAU TSIM MONG DISTRICT	276,800	102,700	37.1
KOWLOON CITY DISTRICT	376,200	99,200	26.4
SHAM SHUI PO DISTRICT	345,900	90,200	26.1
TSUEN WAN DISTRICT	272,100	71,100	26.1
WAN CHAI DISTRICT	164,500	40,900	24.9
KWUN TONG DISTRICT	549,700	116,700	21.2
KWAI TSING DISTRICT	470,900	83,600	17.8
TAI PO DISTRICT	308,500	53,800	17.4
WONG TAI SIN DISTRICT	432,300	73,500	17.0
CENTRAL & WESTERN DISTRICT	259,400	40,800	15.7
SHA TIN DISTRICT	621,000	96,500	15.5
EASTERN DISTRICT	608,100	93,900	15.4
NORTH DISTRICT	295,900	42,700	14.4
TUEN MUN DISTRICT	478,600	53,800	11.2
YUEN LONG DISTRICT	444,500	44,100	9.9
SOUTHERN DISTRICT	285,900	17,900	6.3
SAI KUNG DISTRICT	328,700	18,700	5.7
ISLANDS DISTRICT	81,200	< 100	<0.1
TOTAL	6,600,200	1,140,100	17.3

Fig.3 Source: EPD

Another interesting and more scientific study dated on 2002 by the Department of Mechanical Engineering, Hong Kong University of Science & Technology, concludes, after have conducted an exhaustive roadside noise survey in heavily *'built-up'* urban areas in 1999, that relatively high L_{10} noise levels from 73.4 dB(A) to 91.4 dB(A) were recorded where the total traffic flow was between 540 and 4836 vehicles per hour in 18 major roads with continuous tall buildings (10 stories or more) are flanking on both sides of the roads. (8) Using international standards of noise measurement and sound meters endorsed by the Acoustical Society of America and analysis of variance (ANOVA) (Ronald Fisher). The study reveals that the total traffic flow and heavy vehicles are the most significant factors of urban noise pollution knowing that pedestrians are affecting silently in their health and states that a set of audiovisual recording equipment can allow engineers and I include designers, to have a "*feel*" again in the laboratory environment and provide a great opportunity for data re-analysis. (5) This statement corroborates as said in the abstract of this review, that perception of the environment is 'intersensory'.

And further understanding of the implications of exposure to the noise and heat produced by double decker busses at street's 'naked' bus stops is an important issue to address in Hong Kong to help to mitigate the general discomfort at those locations for general public.

Other studies globally talking, says that it makes good sense to include local residents and authorities in the planning of barriers at the earliest stage possible, as is the case in the Netherlands or Denmark.

This is beneficial in terms of cost and the smooth running of the project. It also avoids misunderstanding if planners work within a framework of trust and consultation. At present in Hong Kong the public is included in this process too late stage and consequently feels marginalized and helpless to participate. A major sea-change is needed to ensure that local people are involved in this process early enough. Of course, the design process should not be annexed by the public, nor should barriers be designed by a committee of lay people; nevertheless, people affected by new or extended traffic systems should feel that they have a say in the solutions and should be kept fully informed about developments.

When considering the problems of noise and visual intrusion, it is also important to look at alternative methods of mitigation other than through the use of barriers, including the use of quiet road surfaces, the insulation of properties or even tunneling as Hong Kong does pretty well.

predicted a 50% increase in the number of people being exposed to excessive traffic noise. Ho et al. reported that this worst case scenario seems to have improved, but it does seem that there could still be a 10% increase by 2016 in the number of people exposed to excessive traffic noise (11).

3. METHODOLOGY FOR A URBAN NOISE MITIGATION DESIGN

3.1. Strategy and Methodology:

Basically it is two main stimuli to address or measure on specific bus stops

TABLE V. Traffic data, the measured L_{10} noise levels, and the predicted L_{10} noise levels using Eq. (3).

Site no.	Road	Hourly total veh. Q	Hourly heavy veh. H	% of heavy veh. P	Ave. speed (km/h) V	Measured L_{10} (dBA)	Predicted L_{10} using Eq. (3) (dBA)	Difference
N1	Hennessy Road	984	552	56.1	26.9	82.9	79.9	−3.0
N2	Des Voeux Road	780	492	63.1	26.3	81.9	78.6	−3.3
N3	Lai Chi Kok Road	1088	332	30.5	35.9	79.4	76.7	−2.7
N4	Cheung Sha Wan Rd	2692	1031	38.3	31.7	84.9	85.2	0.3
N5	Nathan Road	1604	524	49.2	30.8	80.9	81.0	0.1
N6	Waterloo Road	1412	260	18.4	30.4	78.4	78.3	−0.3
N7	Kwun Tong Road	3144	1124	35.8	34.9	81.9	85.5	3.6
N8	Ma Tau Chung Rd	1920	560	29.1	36.9	78.4	80.7	−2.3
Mean								−0.9
Sample standard deviation								2.4

Fig.4 TABLE V. Source: A Multiple regression model for urban traffic noise in Hong Kong. W.M. To and Rodney C. W. Ip. Gabriel C.K. Lam and Chris T. H. Yau, 2002 Acoustical Society of America.

For the reduction of noise, all these options need to be considered individually and in conjunction with one another, as the optimum noise and landscape mitigation strategy (10).

It is important to highlight that the government's Third Comprehensive Transport Study (CTS-3), which was conducted in 1999 based on the 1997 baseline figures (Fig.4), predicted a dire situation would arise by 2016. It also

at Cheung Sha Wan Rd. to give a general idea of the real situation lived every day by users in all bus stops that resembles with the same characteristics than the Sham Shui Po ones and, by antonomasia, all over Hong Kong dynamics.

The 'Intersensorial' term means that the visual and green aspects interacting together with the aural and thermal conditions are design considered.

3.1.1. A field measurement using the Hong Kong minimum standard L_{10} as described in numeral 2 that states that per 6 minutes within an hour the noise levels shall be as or below 70 dB(A) using a calibrated SML (Sound Meter Level) along a segment of approximately 100 meters and measuring every minute (90) from 18:30 to 20:00 hours (peak hour) every day for the week of the 18th to 24th February 2016 at 'naked' bus stops is shown as follows in Fig.5 below:

CHEUNG SHA WAN RD. Peak Hour
DATA: MON 18-24 FEB 2016 - 18:30 - 20:00

TIME (Min)	MON LEVEL dB(A)	TUE dB(A)	WED dB(A)	THU dB(A)	FRI dB(A)	SAT dB(A)	SUN dB(A)
1	78.9	80.5	72.3	76.8	76.1	78.5	73.2
2	80.2	72.2	82.1	66.2	80.7	68.7	73.5
3	72.2	72.5	82.2	72.2	84.5	70	80.2
4	84.5	80.2	76.7	68.7	70.5	72.2	81
5	78.1	82	79.1	70.9	78.5	78.2	72.6
6	81.8	79.2	70.9	69.2	77.3	65.3	72.5
7	73.1	77.9	70.5	71.1	70.5	76.7	72.3
8	77.3	74.7	79.9	84.5	78.8	80.4	71.4
9	75.3	81.7	84.4	74.3	67.4	77	82.7
10	77.2	80.4	72.2	74.9	85	70.5	78.1
11	75.8	67	70.5	82.8	79.2	68.7	72.2
12	79.9	68.7	79	73.5	75.3	71.4	73.1
13	81	70	81.8	67.4	75.7	80.4	78.9
14	79.1	74.9	76.8	76.7	72.2	72.2	68.7
15	73.2	66.2	67	75.7	71.4	81.3	72.2
16	69.6	72.6	75.8	72.5	84.7	75.7	73.9
17	72.5	84.7	80.5	80.4	78.2	72.5	67.4
18	73.5	81.1	76.1	85	81.3	82	78.8
19	80.6	77.3	73.2	77	83	71.1	67
20	82.1	70.5	72.5	84.7	82.8	77.3	80.4
21	78.4	71.7	77.2	80.2	72.5	80.7	71.4
22	70.9	79.1	78.2	81.7	67	85	81.1
23	72.9	84.5	82.9	72.2	80.4	70.9	79.9
24	70.5	68.7	72.6	68.7	73.1	71.7	72.7
25	71.1	70.5	81	73.2	76.1	82.9	70.9
26	73.2	70.9	73.2	72.3	81.7	84.7	76.7
27	80.6	73.2	69.2	70.5	82.4	74.3	81.3
28	74.9	67.4	84.5	73.1	81	82.8	78.5
29	72.2	71.4	70.9	84.4	76.3	70.9	69.2
30	67.4	80.2	71.4	81.3	77	80.5	76.3
31	66.2	76.2	80.4	72.9	74.1	75.7	80.6
32	81	70.9	72.2	73.9	72.2	66.2	79.1
33	82	72.2	73.5	82.7	70.9	79.2	72.2
34	82.7	74.3	78.4	76.1	78.5	76.1	70
35	81.7	75.8	68.7	78.2	78.1	81.1	78.1
36	71.4	76.8	82.7	81	72.5	74.9	81.8
37	72.6	72.3	73.9	80.9	72.5	80.2	76.7
38	72.5	75.3	78.5	76.3	77.2	73.1	75.3
39	72.2	72.9	66.2	80.3	75.8	70.5	75.7
40	75.8	72.5	74.3	79	76.7	73.5	70.5
41	78.8	80.3	80.2	69.6	73.5	74.7	72.5
42	74.3	84	80.2	77.2	72.9	81.7	68.7
43	82.8	81.8	80.3	78.5	75.9	80.9	74.7
44	70.9	82.2	78.5	72.2	80.9	72.5	82.7
45	68.7	73.9	77.3	72.5	72.3	67	75.7
46	67	76.7	78.1	79.1	75.7	78.8	80.9
47	77	80.4	80.6	82.1	69.2	72.5	75.8
48	84.5	73.2	74.9	76.7	76.6	80.6	81.1
49	76.8	72.3	81.3	71.7	72.7	75.8	73.2
50	81.3	78.5	78.8	72.3	78.9	78.4	75.8
51	76.6	83.8	75.8	76.2	65.3	78.5	80.3
52	76.2	80.9	81.7	71.4	80.6	75.3	79.2
53	74.9	73.5	76.2	78.1	81.1	78.1	76.2
54	84.4	78.2	84.7	80.7	82	77.2	78.5
55	78.5	77.2	71.1	82.2	80.9	80.9	71.1
56	80.9	78.8	67.4	82.9	82.7	76.6	80.2
57	76.7	82.1	71.4	80.2	80.2	82.7	81.7
58	85	81	80.9	74.7	73.9	76.7	74.9
59	80.9	80.2	79.2	76.6	82	72.2	79
60	80.4	71.4	82.8	77.3	80.3	82.2	83
61	82.2	80.6	81.1	81.8	68.7	72.3	78.4
62	81.1	78.9	71.7	72.7	71.1	84.5	70.9
63	72.7	76.1	72.5	65.3	81.8	74.9	74.3
64	84.7	72.5	70	73.2	69.6	81	82.9
65	80.3	65.3	73.1	80.4	80.4	72.6	76.8
66	76.1	74.9	72.5	78.4	78.8	71.4	66.2
67	79.2	77.9	80.7	81.1	81	80.2	82
68	82.9	79.9	81	67	72.2	76.8	70.5
69	78.2	76.3	72.3	71.4	75.8	79	80.7
70	80.4	80.6	85	81	70	84.4	84.4
71	73.9	72.2	75.7	80.9	77	81.8	78.2
72	76.7	82.7	78.9	72.5	80.5	73.2	72.5
73	80.2	84	75.3	78.5	72.6	76.3	78.5
74	80.7	81.7	82	72.6	71.4	81	82.8
75	68.7	85.4	74.9	78.8	84.4	67.4	80.6
76	71.4	75.7	76.6	78.9	74.9	79.1	74.9
77	69.2	69.6	65.3	75.7	76.2	80.3	82.5
78	65.3	75.7	80.6	80.5	74.3	69.2	77
79	78.5	76.7	69.6	70.9	82.2	79.9	77.2
80	71.7	71.1	76.3	70	73.2	82.1	77.3
81	74.7	82	80.9	79.2	74.9	69.6	80.4
82	76.3	69.2	72.9	75.8	78.4	72.3	69.6
83	72.5	82	74.7	79.9	82.9	73.2	71.7
84	70	78.5	75.7	82	68.7	80.6	72.9
85	75.7	73.1	72.7	80.6	81	73.9	76.1
86	72.3	78.1	77	75.8	82.1	72.9	82.2
87	75.7	72.7	72.2	70.5	84.2	76.2	76.6
88	72.3	78.4	68.7	75.3	82	78.9	72.3
89	70.5	75.8	76.7	74.9	80.2	75.8	65.3
90	79	83	80.4	76.6	73.2	72.7	77.9
AVG	**76.3**	**76.4**	**76.2**	**76.8**	**76.8**	**77.4**	**75.2**
AVG/WEEK	**76.4**						

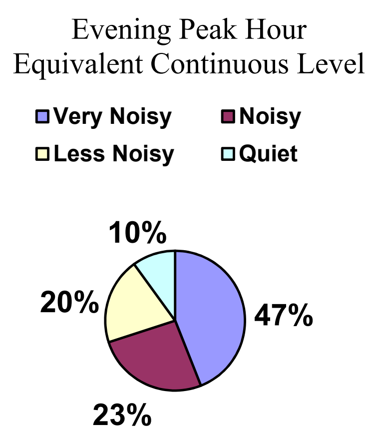
Result for SML Measurement Points at Actual Bus Stops in dB(A).

Total Average/Week: **76.4 dB(A)**

*Peak Hours

Fig.6 Field Measurement: Cheung Sha Wan Rd.

Fig.7 Users at bus stops during measurements.



3.2. Measurement Conclusions:

It is a clear intermittent and fluctuating observation in the sound level pressure during the site measurements. The average result in the preliminary study of +/- 6 points over the permitted level indicates a continuous noise that is present during the day and evening peak hours that corroborates the need of a design strategy to help to mitigate the impact of users while their bus waiting time.

3.2.1. Acoustical Design Considerations: *"Material, location, dimensions, and shapes do affect the acoustical performance. Figure 8.1 shows what happens to road traffic noise when a noise barrier is placed between the source (vehicle) and receiver.*

Original straight line path from the source to the receiver is now interrupted by the noise barrier. Depending on the noise barrier material and surface treatment, a portion of the original noise energy is reflected or scattered back towards the source. Other portions are absorbed by the material of the noise barrier, transmitted through the noise barrier, or diffracted at the top edge of the noise barrier. The transmitted noise, however, continues on to the receiver with a "loss" of acoustical energy (acoustical energy redirected and some converted into heat). The common logarithm of energy ratios of the noise in front of the barrier and behind the barrier, expressed in decibels (dB), is called the Transmission Loss (TL). The TL of a barrier depends on the barrier material (mainly its weight), and the frequency spectrum of the noise source.

The transmitted noise is not the only noise from the source reaching the receiver. The straight line noise path from the source to the top of the barrier, originally destined in the direction of A without the barrier, now is diffracted downward towards the receiver (Fig 8.2). This process also results in a "loss" of acoustical energy."[4]

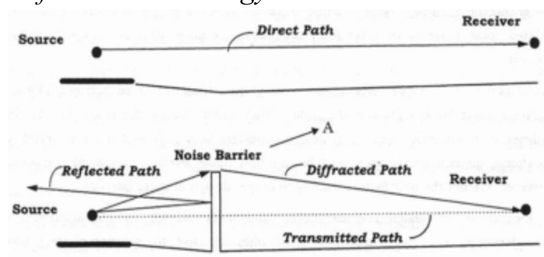


Fig.8.1 Alteration of Noise Paths by a Noise Barrier (Source: EPD)

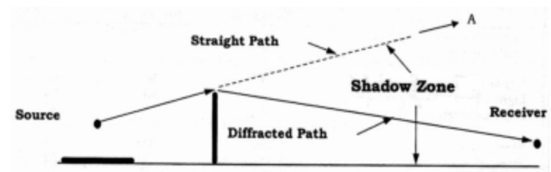


Fig.8.2 Barrier Diffraction (Source: EPD)

3.2.2. Shield Definition and its Philosophical Approach for Design:

A 'Shield', this concept by definition is the most accurate term to be used in this project based in the barrier final need as protection to the potential paroxysm that exist between a passive and helpless pedestrian and the machine itself.

From the Latin word 'scutum' shield[5] is a term with multiple uses and meanings. The concept is used to name the defensive armament that encloses and is used to ward off any attack. The shield is considered one of the more defense weapons in history. Evidence of their use was found in the third millennium BC. Its use was very common until the seventeenth century, a period in which firearms began to become widespread and shields lost profit.

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[4] Environmental Protection Department "Guidelines On Design of Noise Barriers" http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide_ref/files/barrier_leaflet.pdf

[5] http://definicion.de/escudo/shield

If a person bears a shield on his left arm, he can freely use his right arm to launch a counterattack. The shield was essential in the melee and adapted to various technological advances reinforcing materials to withstand the blows of different weapons.
Among the types of shields that have marked history are, for example, 'aspis', which were used by the members of the Greek infantry until the fourth century BC and is characterized by its circular shape and being made from wood and bronze; 'bucklers' made of wood or steel, which were used until the seventeenth century; or the 'scutum'.
These are one of the most significant shields of all time because they were the symbol of the heavy infantry of the Roman Empire. They were characterized as oval or rectangular, to better adapt to the shapes of the bodies of the soldiers and have a central wood core which was then coated with various metal foils.
Currently the shields are used by police forces working to prevent and deter riots. The officers on the front line are carrying shields to protect the rest of the force for eventual release of objects by demonstrators.
By extension, the notion of shield is also used as a synonym for defense, protection or safeguards.
In heraldry, shield (also known as coat of arms) is the place or object in the representation of the coats of arms of a family, a state, a community or a corporation.
We know now that the said shields can be classified based on the elements that shape it.
Thus, for example, it is known as the band split shield the one characterized by the division by a thick colored band.
Also is the so-called 'satin', which is one that does not have any ornaments; the curtain that is identified by being divided by two lines; the 'striped' that is covered by three strips of metal and three of color; or the 'nailed'. This one is formed by two parts, one of which appears mounted on the other.

Fig.9. Pair two Japanese warrior with shield bronze sculpture. Source: http://www.terapeak.com/

A shield is a defensive instrument to avoid and prevent direct, personal or group threats, which can cause a potential damage.
That's basically why it's needed to protect pedestrians at sensitive street spots from the extended noise pollution produced by traffic and the proximity of the double deck buses that stop to pick up passengers every 5~10 minutes during the day and night.

As well with the idea of the implementation of a shield, it is also the idea of a generation of natural sounds at the bus stops using the barrier as an emission entity (the traffic emits pollution, the sound barriers emits its counterweight in sound), and in my belief, a feature that would enhance a 'virtual' isolation and a bit of clear 'denial' about the over-occupation of traffic and its negative consequences in our contemporary cities.

We all understand a failure in the evolution of the cities to create the best environment for the community as main priority and not the automobile as the 'center' of our planning and development regarding basically the urban scale. So nowadays is when the consequences of its occupation are only fixable through the implementation of new 'scaled' programs focused in the "well-being" of the 'organic' population. I can venture to say that the scale of our cosmovision has become; from a balanced ritualistic Gods-Humans, as all native cultures, to the absolute greatness of one unique omnipresent God that creates the concept of a 'centralized' way of develop new cities and societies in the Middle Age and then a kind come back to a more balanced concept of scale with the Renascence that opens the possibilities within the human being capabilities to evolve and God that still in the cathedrals, come down 'closer' to human scale… from which the subsequent Industrial Revolution, product of the Renascence, started to give us the possibilities to reach the comfort we are all 'slaves' nowadays depending on energized objects to keep an unmanageable utopic standard to 'sustain'… and growing.

Thus, the scale became based on the machines that we need to access the realm of comfort we have almost momentarily standardized.

Thus, effective more than elective approaches, in my opinion, are the ones to address; either could change from the core the way of the origin of the needs that today's systems supply and help to the re-creation of the basic needs of our specie within and not manage entirely by the systems that rules. People need to be helped to pay attention to alternatives of –remembering- the lost contact with the natural elements, not from the 'tourist' perspective to called in some way, in how cities' populations approach to nature today.

Nature needs to be back into the city in more intuitive manners than the 'utopic' re-creations of specific 'natures' enclosed within it. A good example of this flagellum in Hong Kong is the great amount of urban 'little' green areas' specific and mandatory rules, like the step-on grass prohibition … It is absurd that land-scape design is used for aesthetical reasons over civic needs like the pleasure to sit down on the grass next to a tree to read a book… or lay down on the grass to watch the clouds patterns… these basic considerations are not part of a design, or if they are, they are based in a controlled type of operation that is by definition, against human basic instincts. Which the people's sense of belonging and responsibility is given to third party thinkers and intellectuals to find the best way to deny it… It is funny the contradiction of being responsible only to pay with your hard works your own comfort and safety but not to be responsible to make it sustainable… 'No, that's the geniuses' job; I do pay my taxes…!' - Ironic isn't?

My theory to bring design to a more intuitive realm on the street touches the importance in how the Sound has an immense power in nature and it is directly connected to our well-being.

The Shields act as a direct demonstration of defense and the fact to bear it on, creates some of the attention that people need, helping them to –re-create- their ‘cosmovision’… because unconsciously you have been, on purpose, protected of something you recognize is a threat but as soon you don’t step on their physical and speed boundaries you are safe. But used to it, the humans allowed the sound pollution traffic spread to go beyond and appropriate the space way beyond physical boundaries.

Then is when the spot that the shield occupies can counterattack the irritable emissions and at the same time ‘romantically’, ‘irradiate’ sound as it has been keeping “absorbing” it and transforming it to the sounds of the wild Hong Kong in the middle of the crowded streets… - Now, the Shields are connected through the net to various ‘Sound-Stations’ located at the most iconic spots in wild life that this geography preserves - .

The people in Hong Kong lives surrounded by the movement of water but no one can listen to it. This basic is the ‘illusions’ that intrinsically can help to recall the lizard brain instincts. The sounds of nature collected are sounding in a quiet level, always giving a bit of ‘unconscious’ awareness of our basics.

The benefits of this kind of urban intrusions can be perceived immediately and slowly integrated with the community to a different approach to perceive the elements that compose the urban-scape as consequence of the idealization of the speed and independence to progress that the machine has created within our evolution.

Someday we will be able to emulate the efficiency that the natural systems are by themselves as we are one of them too… to reach then the greatness of well-surviving. Maybe the term well-being is overestimated by our complex time lines and utopic realism… well-surviving is sustainable lexicon.

3.3. The double decker bus:

As shown in diagrams 1 and 2 below, a generic double deck is the ‘enemy’ to be protected from with the use of a barrier to avoid the excess of noise pollution emitted. It has a powerful engine located at the back of the deck. The source is located at 2.4 meters from the paving and a center of 1.872 meters from the curb line in a generic alignment.

Engine
Cummins ISL8.9E5340B, 6-cylinder turbocharged, after cooled, common rail, diesel engine.
Certified to Euro5 emission standard (2005/55/EEC as amended by 2008/74/EC).

Power:	340 PS (250 kW) @ 2100 rpm.
Torque:	1500 Nm @ 1200 rpm.
Displacement:	8.9 litre

Transmission
ZF Ecolife 6AP1700B, 6-speed, automatic gearbox with 3-button selector. Transmission includes hydrodynamic retarder. TopoDyn software activated. Transmission performance matched with air conditioning and engine software to ensure optimum fuel consumption and consistent vehicle performance under all conditions.

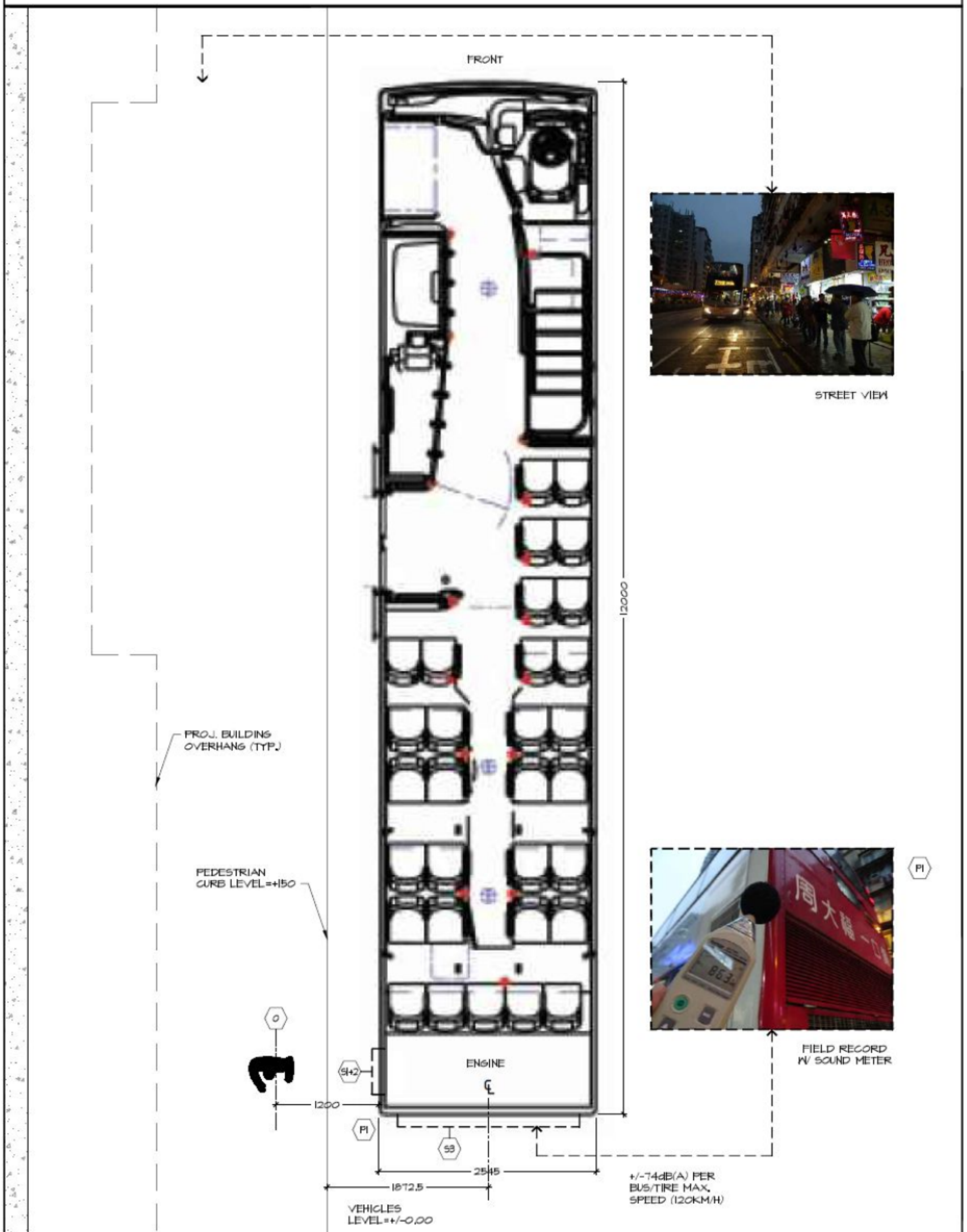
Front Axle:
ZF RL75A deep drop I-beam axle,
7500 kg design capacity.
Steering back/forward lock angle 55°/40°.

Drive Axle:
ZF AV132/90° left side input T-drive dropped centre with hub reduction,
12,000 kg design capacity.
Ratio 6.2:1 (101 kph @ 2100 rpm rated speed, max speed limited to 70 kph).
Option of 5.74:1 ratio.

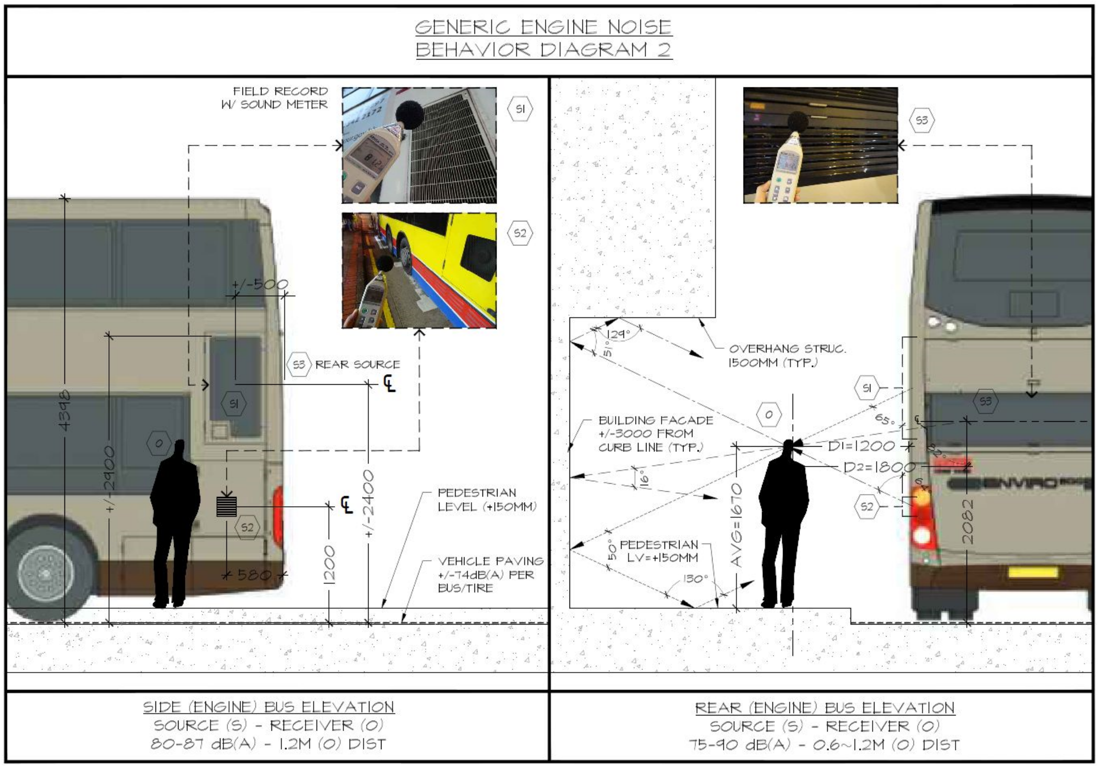
Fig.10. Low Floor High Capacity 12m Double Deck Bus ENVIRO500 Chassis Specs. Source: http://www.alexander-dennis.com/wpcontent/files_mf/1367249425Enviro500AsiaPacificSpec..pdf

3.1.3. Generic Engine Noise Behavior Diagrams:

GENERIC ENGINE NOISE
BEHAVIOR DIAGRAM I



(ENGINE) BUS PLAN
SOURCE (S) - RECEIVER (O)
75-90 dB(A) - 0.6~1.2M (O) DIST



4. SIMULATIONS, CALCULATIONS & RESULTS

4.1. Software & Simulations:

Olive Tree Lab (OTL) has been developed by Pemard a 3D outdoor calculations tool for the various fields of acoustical applications. I found the tool extremely useful to understand the real impact in terms of sound pressure that the Shield can provide in quantitative and simulated scenarios.

First we need to set up out location in Sham Shui Po along the Cheung Sha Wan Rd. as an example of the mentioned conditions. Set up an average year temperature in Hong Kong as the base of 23°C, also set up a relative humidity of 78% per year and an atmospheric pressure of 101.300 Pa.

With the location and meteorological information in the software we can start to build the scenario conditions for running the simulations.

Table 4. Monthly means of daily maximum, mean and minimum temperature recorded at the Observatory between 1971-2000

Month	Mean Daily Maximum (deg. C)	Mean (deg. C)	Mean Daily Minimum (deg. C)
January	18.6	16.1	14.1
February	18.6	16.3	14.4
March	21.5	18.9	16.9
April	25.1	22.5	20.6
May	28.4	25.8	23.9
June	30.4	27.9	26.1
July	31.3	28.7	26.7
August	31.1	28.4	26.4
September	30.2	27.6	25.6
October	27.7	25.3	23.4
November	24.0	21.4	19.4
December	20.3	17.8	15.7
Year	25.6	23.1	21.1

Table 5. Monthly means of relative humidity, dew point temperature, wet-bulb temperature and vapour pressure recorded at the Observatory between 1971-2000

Month	Relative Humidity (%)			Dew Point Temperature (deg. C)	Wet-bulb Temperature (deg. C)	Vapour Pressure (hPa)
	Mean	Mean at 0200 hours	Mean at 1400 hours			
January	73	78	65	11.0	13.5	13.7
February	78	82	71	12.2	14.4	14.8
March	82	86	75	15.5	17.0	18.2
April	83	88	76	19.4	20.5	22.9
May	84	88	77	22.7	23.7	27.8
June	82	86	76	24.5	25.6	30.9
July	81	85	74	25.0	26.1	31.7
August	82	86	75	24.9	25.9	31.5
September	79	83	72	23.4	24.7	28.9
October	74	78	66	19.9	21.9	23.8
November	70	75	61	15.3	17.9	18.1
December	69	74	60	11.6	14.5	14.4
Year	78	82	71	18.8	20.5	23.1

Tables 4, 5 and 8. Source: Hong Kong Observatory

Table 8. Monthly mean of atmospheric pressure recorded at the Observatory between 1971-2000

Month	Mean (hPa)	Mean Diurnal Range (hPa)
January	1020.1	4.1
February	1018.6	4.2
March	1016.1	4.2
April	1012.8	3.9
May	1009.4	3.4
June	1006.2	3.2
July	1005.5	3.4
August	1005.1	3.5
September	1009.2	3.5
October	1014.0	3.6
November	1018.0	3.8
December	1020.5	4.0
Year	1013.0	3.7

I've made a scaled 3D model based on the area to be studied being the same area where the field measurements were taken (Fig.11 below).

Fig.11. 3D model Sham Shui Po, Cheung Sha Wan Rd.

The 3D has been imported to OTL keeping scale, location, orientation and atmospheric data.

All surfaces were assigned with specific materials, from the ground cover as hard surfaces to building walls to be concrete with paint and generic glazing to the barrier itself to be made of PVA composite that I will explain later in this document.

Then, I have created a scaled model of a generic Shield with the following dimensions: H=2.5m, W=4m in an inverted 'L' shape with a full thickness of 0.10m to make it as light as possible, with an eave angle of 225°/135° with 1m cantilever.

Then I've added a noise Source that represents one Bus engine at, as Diagram 2 shows of 2.4m Height from the paving, located more or less at the middle of the barrier at a distance of 1.872m from the curb line (same alignment with the position of the barrier) to the center point of the powered engine source.

And I have positioned 3 numbers of Receivers with different heights of average Hong Kong population: 1.7, 1.6, 1.5m. They are distributed evenly and located 0.6 to 1m behind the barrier, where people use to queue waiting for bus see (Fig.12 & 13. Scenario 1) below that shows the position of Shield in yellow and green (Fig.13), Source in red and Receivers behind. Also shows the type of barrier with an inverted 'L' shape and flush to the curb level to avoid sound intrusion from below.

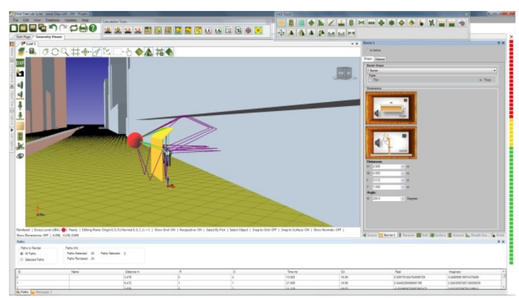
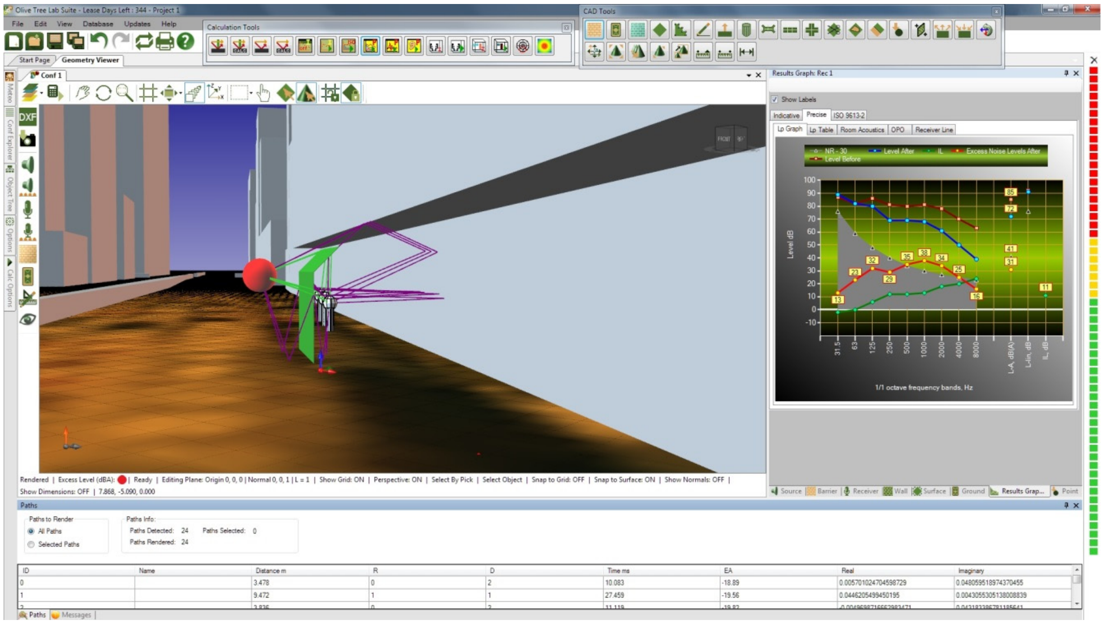


Fig.12. OTL simulation - Scenario 1

The next step was to calculate the paths that sound will make in this specific scenario 1 as shown in purple as reflection paths and green as direct paths. Then run a precise calculation for sound pressure measured in dB(A) as following results.

Fig.13. Simulation Enlarged Scenario 1



At the graph at the right are the precise calculation results with (blue) and without (dark red) the Shield showing an important reduction from 85dB(A) average coming from the source to 72dB(A) average using the Shield.
Scenario 1, as shown in diagrams 1 and 2 has an overhang structure as typically occurs in Hong Kong but the results are very positive and promissory.

The following graphs show in more detail the level that the Shield reduces going up to 10dB(A). A considerable noise reduction has been implied indeed. The 3 receivers are expressed in different colors in the graph to understand some minor differences for individual sound paths incidence.

Fig.14. Simulation Results Scenario 1, before Shield

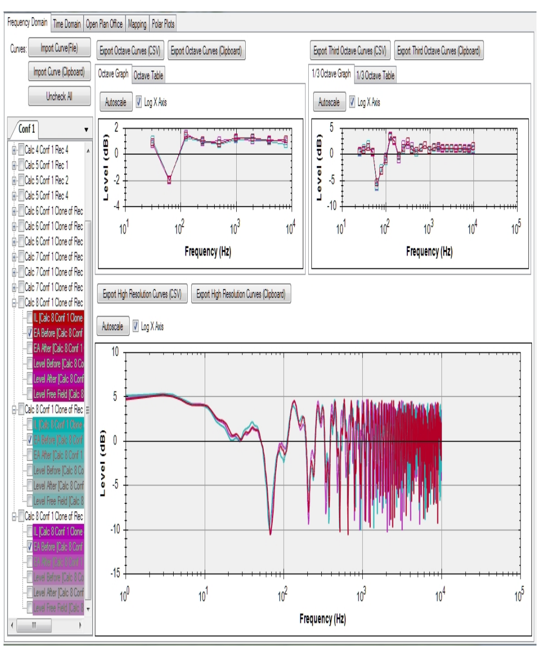


Fig.15. Simulation Results Scenario 1, after Shield

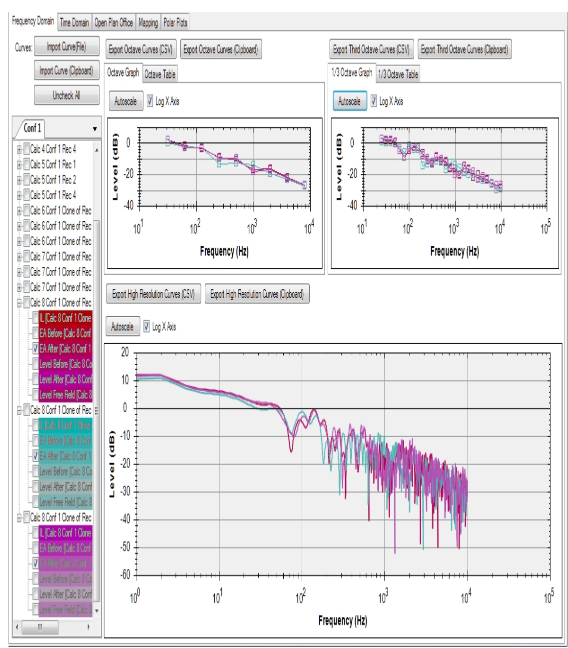
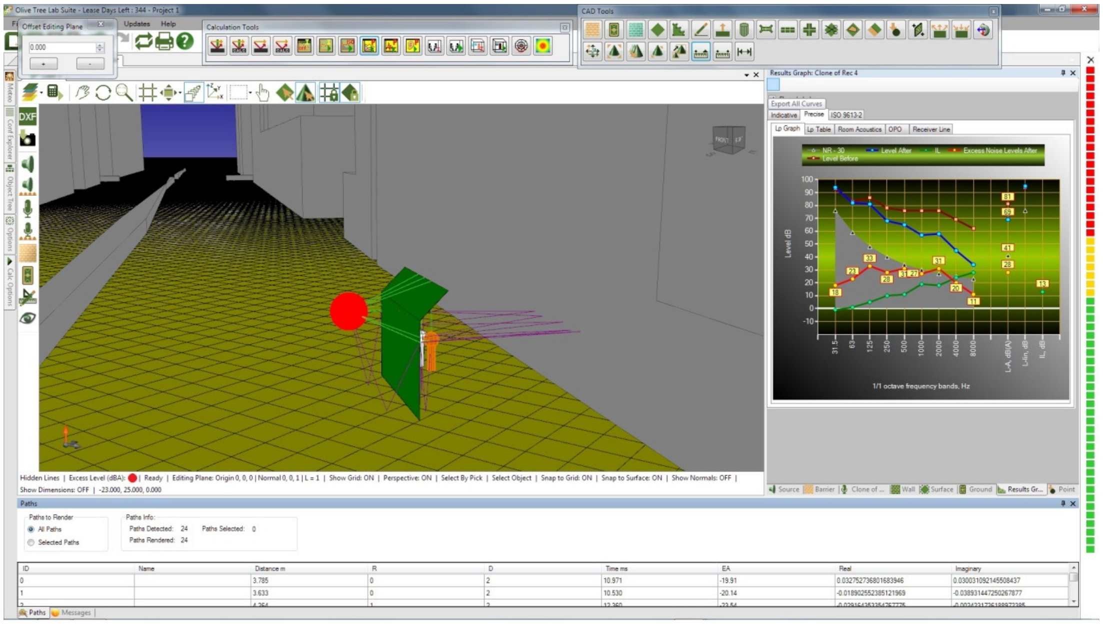


Fig.16. Simulation Enlarged Scenario 2



Scenario 2 (Fig.14) has been located at the same line but in an area without any overhang structure and as average the Shield is located 4 to 5M from the building line (same as Scenario 1) and the results are pretty even from 81dB(A) to 69dB(A) showing the effectiveness to reduce sound pressure for pedestrians using a shield build with sustainable materials and located in strategic locations around Hong Kong.

4.2. Conclusion:

Analysis of results provide a positive output towards the proposed design. The use of a 4 meters long x 3.2 meters height x 10 mm THK Shield at bus stops will reduce a considerably 5 to 10 dB(A) to pedestrians circulating and waiting for their transport. As well as protecting the excess of noise transmission to ground floor inhabitants and their interior uses.

Fig.17. Simulation Results Scenario 2, before Shield

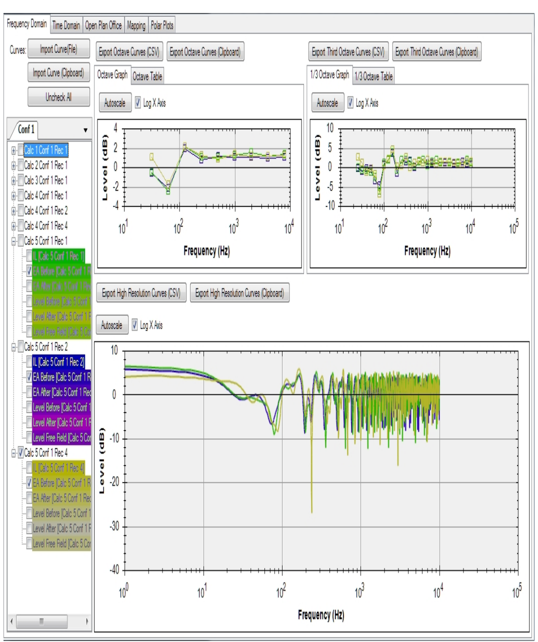
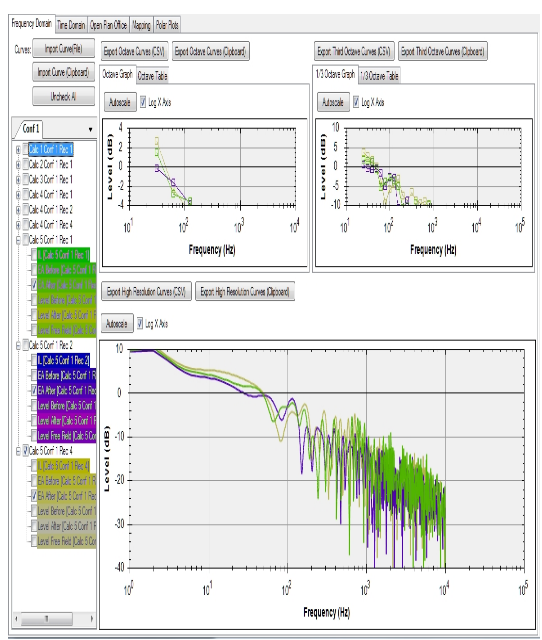


Fig.18. Simulation Results Scenario 2, after Shield



5. SHIELD DESIGN

5.1. Design Considerations:

In respond to increasing environmental noise concerns have to comply with improved noise attenuation guidelines and a more demanding legislation. The acoustic and aesthetic standards of barriers have improved considerably and will continue to improve at an accelerated rate as information and expertise is disseminated. These pressures for change will be given added impetus as design standards are being developed and international working groups such as the Organization for Economic Co-operation and Development (OECD) research the problem.

It is tempting to regard that traffic noise is a twentieth century phenomenon, but nothing could be further from the truth. The Romans were all too familiar with the unwanted noise of wheels on stone streets and issued a decree which banned the use of chariots on the streets of Rome at night. Sadly for the Romans, their leaders did not have a monopoly of acoustic wisdom: Julius Caesar passed a law which required all goods deliveries in Rome to be made at night. Not content with creating this noise nuisance, Claudius subsequently extended the law to all towns in Italy and Marcus Aurelius imposed it on every town in the Roman Empire.

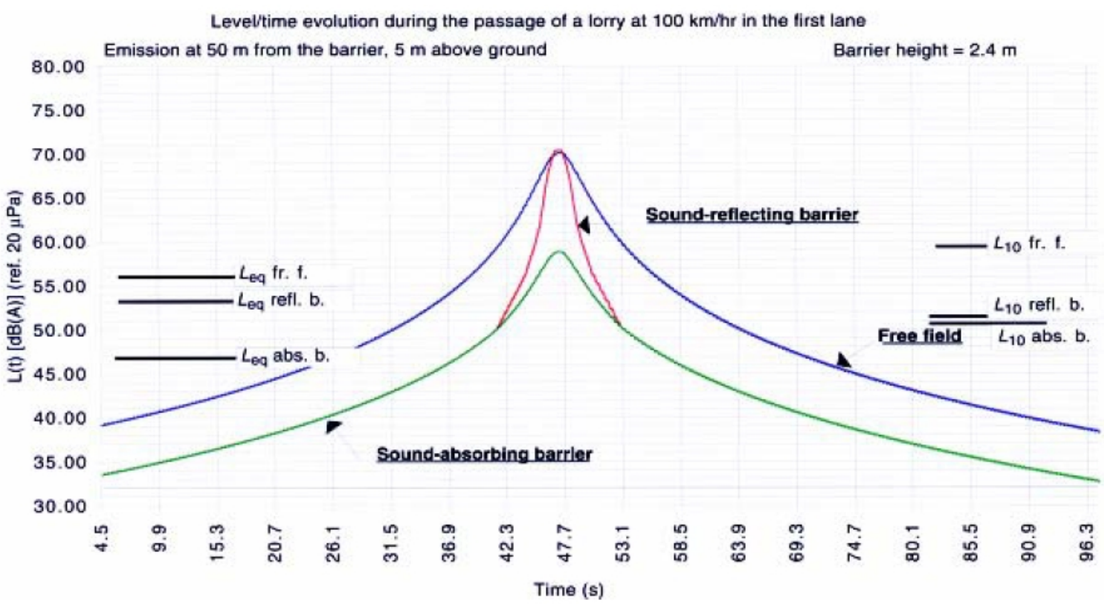
Noise Insulation Regulations that the qualification threshold noise level has become a de facto design target level in the absence of any other official guidance. In contrast, many other European countries have introduced legislation on design targets which are often significantly lower than the 68 $dB(A)_{10,18hr}$ level used in the UK and HK been 70 $dB(A)_{10,12hr}$. Notable amongst these are the Netherlands and Denmark, where the permitted level is 55 $dB(A)_{eq,12hr}$ (a notional steady A-weighted sound pressure level of equal energy to the time varying noise over a 12 hour period, usually between 0800 and 2000 hours), a target which results in environmental noise which is, subjectively, only half as loud as the level permitted in Hong Kong.

Where target levels are lower, it follows that screening will be more robust and substantial. It also means that in those countries the use of screening is more widespread and that greater experience has been gained in the design, manufacture and construction of noise barriers.

New major roads are generally planned to avoid residential areas and, therefore, the communities exposed to the highest levels of traffic noise are often found along established, heavily trafficked roads within cities and other developed areas. In these situations housing is often very close to the road and reducing noise would require the use of tall barriers.

This problem has been recognized by the authorities in those countries which try to control noise in these areas, and thus a range of more suitable materials and barrier forms has been explored and developed.

Fig.19. Effect of reflective and absorptive barriers on single vehicle pass-by.



Noise is also a landscape issue, in that it has a great impact on the perception of the character and quality of the landscape[10].

The experience of sitting in a garden, listening to bird song, is quite different from and more pleasant than sitting in a garden which is dominated by the roar of traffic noise. In rural environments too, enjoyment of the landscape and leisure activities may be diminished by the presence of noise.

Although the reduction of noise in a given location through the use of barriers could help to improve the problem that a development has caused to the environment, it may create others.

It is important to acknowledge the effect these often large and imposing barriers may have on other environmental issues. They may affect views, light, microclimate, access, wildlife and birds. These structures, which may be 5–10 m high, or even in exceptional circumstances up to 20 m, should be integrated, as far as possible, into the local surroundings and all environmental issues relating to them be properly examined.

A barrier should reduce noise to the required levels, and be acceptable to the planning authorities but, to be truly successful, it must merit approval from local inhabitants. In order to satisfy these conditions, the barrier must be designed to integrate well into its surroundings.

Figure 19. The graph shows the A-weighted sound pressure level (relative to the standard reference pressure) during a single vehicle pass-by. The equivalent continuous sound levels (Leq) for the pass-by are shown on the left for free field (fr.f.), i.e. without a barrier, with a reflective barrier (refl.b.) and with an absorptive barrier (abs.b.). The corresponding A-weighted sound pressure levels exceeded for 10% of the duration of the pass-by (L10) are given on the right-hand [10. P.44]

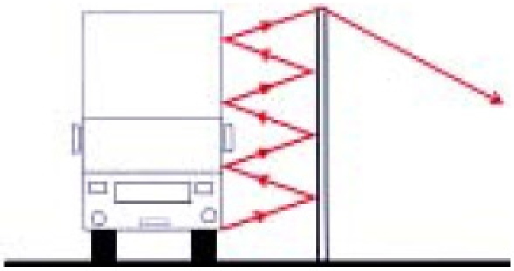
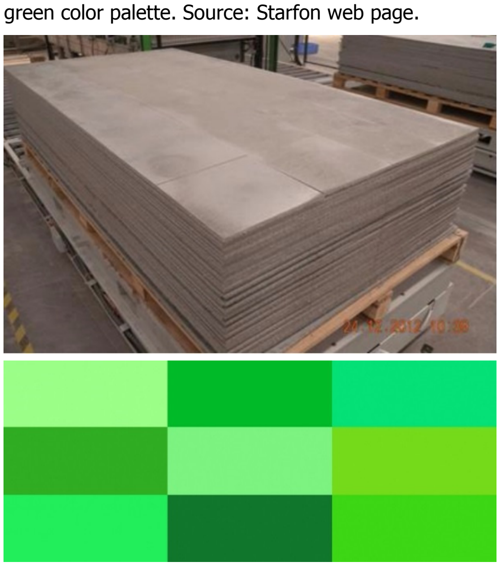


Fig.20. Multiple reflections between a barrier and a high-sided vehicle.

5.2 Sustainable Materials:

Using the opportunity to propose a different type of sound barrier for a punctual situation as bus stops in Hong Kong and regarding the importance of an urban landscape impact for a highly densified society and consequent streets, the material to be used need to project as well as an accurate performance extenuating of the traffic noise, a proper example of environmental intervention for public environmental psychological awareness. In this respect, I've choose the use of Starfon^{TM} Monotone panels, which are low carbon green building material, produced from recycled concrete of nontoxic and low CO2 emission.

Fig.21. StarfonTM Monotone panels from factory and green color palette. Source: Starfon web page.



•Innovative extruded cementitious composite technology.

•Made with up to 50% recycled materials; Over 50% LEED compliant materials.

•High performance fiber-reinforced concrete products extruded and molded for paneling/cladding shapes.

•Superior properties over other competing products, including resistance to water, weather, mold, color fading and reduced weight.

•Aesthetic and adaptable in finish and texture with integral color (green).

•Lighting transmittance as a unique feature of the decorative/acoustic board.

•True possible replacement product of existing construction material for noise barriers.

•PVA (Polyvinyl Alcohol) fiber are unique in their ability to create a fully-engaged molecular bond with mortar and concrete that is 300% greater than other fibers.

5.2.1. PVA Acoustic Properties:

"Highly efficient sound absorption materials derived from finer fibers are required to absorb lower frequency sound. A study on the sound absorption of PVA (polyvinyl alcohol) nanofibrous resonant acoustic membraned showed that the resonant frequency of the nanofibrous membrane decreased with increasing area density of the membrane and increased with decreasing average diameter of the nanofibers. Kalinova[13] *proved that the nanofibrous materials are highly efficient sound absorbers. For low-frequency absorption, structures based upon the resonance principle are employed in which the resonance of*

some elements allows acoustic energy to be converted into thermal energy. Kalinova also studied sound absorption behavior of PVA nanofibrous membrane with different structures. Water vapor was applied to the surface of nanolayers (for 10 to 120 s) in order to change the structure of membranes containing nanofibers. Sound absorption coefficient of thin PVA nanofibrous membranes and foil was compared with each other. The result of the experimental study showed that the shapes of frequency functions are analogical for thin polymeric foil as well as for nanofiber PVA membrane. Furthermore, as the time of water vapor action to PVA nanofibers layer is increased, the number of local place with different mass increased and merged fibers should increase too which resulted in an increase in the absorbed frequency range. In another study on the comparison of sound absorption behavior of nanofibrous layer and polyethylene foil with the same area weight, she found that nanofibrous layer had higher sound absorption coefficient than foil.

There are also other reports on the acoustic properties of nanofibrous membranes. Sound absorbents based on nanofibers can have a higher absorption factor compared to traditional absorbents especially in lower frequencies"[6] *(Fig. 22.).*

5.2.2. Transmission Loss (TL)

"For a barrier to be fully effective the amount of sound energy passing through it must be significantly less than that passing over the top (or around the edge). When noise levels of two sources L_A and L_B are added, a difference between them larger than 10 dB adds less than 0.5 dB to the higher level.

For example: $L_A = 70$ dB $L_B = 60$ dB

$$L_{A+B} = 10 \times \log_{10} [\log_{10}^{-1}(70/10) + \log_{10}^{-1}(60/10)] = 70.4 \text{ dB}$$

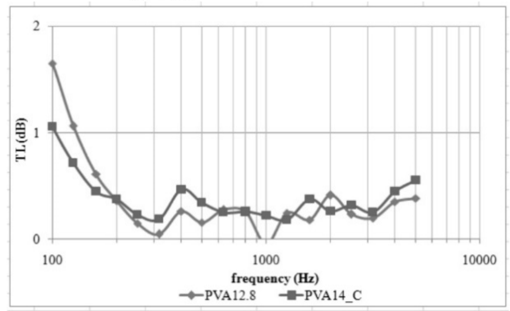


Fig.22. Measured TL of PVA12.8 and PVA14 nanofibrous membranes as a function of sound frequency. Source: (13)

through the barrier is 10 dB lower than that which goes over the barrier, the overall sound received is essentially determined by the energy travelling over the barrier."[7]

5.2.3. Retrofitting Noise Barriers/Enclosures:

When it comes to noise barrier retrofitting, the EPD reported (as of August 2012) that "some 600 roads generate noise greater than 70 decibels" 105 and 40 of these noisy road sections were identified as technically feasible places in which to install noise barriers or enclosures. It is estimated that this project, after completion, could help to lower the noise level experienced by

[6] (13) Effect of Fiber Diameter and Air Gap on Acoustic Performance of Nanofibrous Membrane. Merve Küçükali Öztürk, Banu Nergis, Cevza Candan and Klara Kalinova. http://www.davidpublisher.org/Public/uploads/Contribute/55543933454ea.pdf

[7] Environmental Protection Department "Guidelines On Design of Noise Barriers" http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide_ref/design_barriers_content2.html

30,000 flats in the vicinity by one to over 20 dB, while the noise level along the roads would be reduced to lower than 70 dB(A). The relevant work has been completed for eight road sections; work on nine other road sections is underway.

Despite these efforts, however, the percentage of noisy roads currently included in this retrofitting project is very low, representing only about 6% of the roads with noise in excess of the noise limit. Such a low percentage is believed to be due to the various policy and engineering constraints, including the following:

•The barriers/enclosures must not block any emergency access or fire-fighting.

•The barriers/enclosures must not obstruct pedestrian or vehicular movement, or cause any road safety concern.

•The barriers/enclosures must not interfere with commercial activities or cause social disruptions

•There must be adequate space to support the barriers/enclosures and their installation must be technically feasible

As to the effect of noise barriers/enclosures, they are actually of limited benefit for residences on the upper floors of buildings that overlook roads, and generally only protect lower floors from the impact of noise.

(Info extracted from the Search for Quiet, Darlene Lee, Civic Exchange, HK 2013.p.23-24).

5.2.4. Treated Bamboo (Bambusa or Moso in Asia):

5.2.4.1. Overview:

Guadua ("narrow leaf") or Bamboo is a renewable natural material that grows almost everywhere in the world except Europe and Antarctica. There are many species, but the most important, and most used is the Guadua angustifolia in America or its counterpart in Asia, Moso (Phyllostachys Edulis) (scientific name).

Since 3,000 years ago in Japan and China, the bamboo has been strongly linked to the principles of Feng - Shui, those who suggest harmony in all things, a balance with nature as a concert between man and his environment.

This broad and intelligent vision to assess the bamboo has allowed them to find countless possibilities and advantages applied to the industrial field, with excellent financial results, huge profitability, broad role of products in international markets and an effective technology development for processing, perhaps the best in the world.

This hollow cross section plant, grows from the soil without changing its diameter too much, reaching its maximum height (15 to 30m) and up to 230mm Dia. in its first six months.

Bamboo is made up of several parts, root, stem, leaves, flowers and fruits.

Fig.23. Bamboo. Natural state.

5.2.4.2. Structural behavior:
•Tensile Strength: It has longitudinal fibers that make it highly resistant, which usually is called "vegetable steel."
•Possessing a tubular cross section resists torsional forces.
•For required compression elements no more than 3 meters long, there is a large aspect ratio with respect to an axis passing through its center.
•Possessing great inertia, it has no buckling instability problems.
•Resistance to Shear: It depends if the load is applied in a knot or a segment between nodes, and its section as the lower section are more resistant to cutting by having a greater number of external fibers.

5.2.4.3. Constructive Method:
As the bamboo does not have a good performance against forces perpendicular to the fibers or parallel to these cutting drive, it should be especial care at junctions. As it is the trickiest part of the structure, its required specialized performance skilled

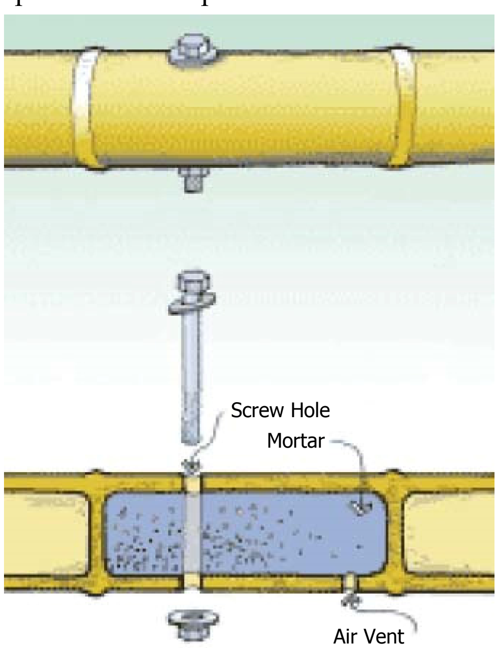
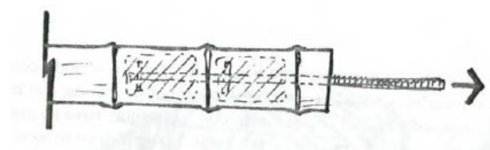


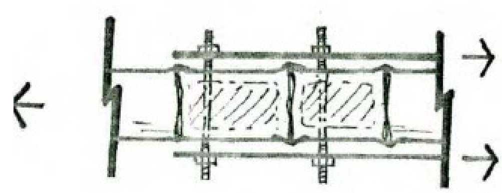
Fig.24. Detail for Typical Bamboo Stem Treatment[14]

workmanship to perform properly all assemblies as accurately as possible. One of the great discoveries of Simón Vélez was the grouting Portland cement in internodes of bamboo (thereby converting the bamboo as solid material), also using plates and screws for union points.
Functions of the elements of this union:
•Screws: are used in two ways that work in differently:

1. The first way is to place a screw as not to tear the walls of bamboo, but the returned force is transferred to the partitions as shown below in Fig.25.



2. The second option is to drill the bamboo to introduce transferred bolts efforts to longitudinal external metal plates as shown below in Fig.26.



•Mortar: Internodes are filled with mortar 1:2 when they contain screws or pins thereby avoid displacements while helping the stem to possess better integral structure resistance.
The drawback is that the set can decrease its volume and the structure could not have immediate respond to the requirements. Also increases the weight of the structure and some placement is complicated.

Fig.27. Detail Bonding Anchor Type. Simon Velez[14]

Fig.28. Detail Triangular Plate Type. Simon Velez[14]

5.2.4.4. Conclusion:

Above is the type of ensembles to be used in the Shield, these concepts are based in the previous explanations. These methods has been used in North and South America for more than 30 years.

The mixture of rigid and natural elements provide a conscious design strategy to use different resources to transmit also to the society a better bonding between the urban and natural scenarios.

5.3. Shield Design:

5.3.1. Overview

The light and environmentally friendly noise barrier module to be installed at the actual bus stops located to cover the double decker bus engine to help to mitigate the fluctuating excess of sound pressure and promote sociological awareness towards responsible environmental urban equipment design in Hong Kong.

5.3.2. Design Description:

The Shield proposed consists in a treated bamboo frame/structure with GMS (Galvanized Steel) fixing points and brackets using anchor bolt system at specific location avoiding the need of underground footings regarding structural considerations for permanent structures by the Building Department of Hong Kong.

The main acoustical screen consist of 8 Nos. of 'Starfon' ™ panels made of light GRC (Fiberglass Reinforced Concrete and PVA fiber) acting as a sound barrier (Shield) at the side of the road facing the busses and providing a possibility to increase 'Green' awareness among population while protecting users from noise and heat excess in summer especially (intermittent over heat).

The treated bamboo structure contains a type of 'trays' that contain light recycled composite planters with native outdoor species that does not require intensive maintenance or constant irrigation (no irrigation system is needed). These species would be:

-Duranta Erecta

-Grevillea Banskii

-Aglaia Odorata and

-Rhododendron Pulchrum among others.

In addition, a couple of panels for identification of locations and bus routes information are attached to the structure as well with specific bus stop signage for easy identification from distance for users. Also 8 Nos. of Photo Voltaic (PV) panels attached to one section of the angular PVA panels at the top. The PV is provided for powering 3 or more outdoor light fixtures, a Wi-Fi system for specific or public networks unifying the use of a smartphone/tablet application developed by Transport Department for easy access to web information for users. Also the PV powers a little sound amplifier with 2 Nos. of speakers for sound projection as mentioned in chapter 3.

The Shield is not interfering with the existing structures that in few places are already installed with the exception of hand rails that the structure will replace when necessary for optimal positioning of the noise barrier to comply with numeral 5.2.3 Retrofitting Noise Barriers/Enclosures above.

A treated bamboo resting bench is provided with its independent GMS structure fixed to the core structure.

Because the screen and green curtain will block the direct traffic view, a concave safety mirror of about 400mm Dia. is provided for user's easy reference of coming busses. This will require the buses electronic sign system to show routes numbers forwards and backwards, similar than ambulance regulations.

Two outdoor speakers located beneath and behind the bench are provided to comply with my theory of sound comfort, projecting or playing natural landscape sounds to resembling the 'soundscape' concept also connected to the Internet providing necessary audio information for blind people if required.

The Shield is a modular system (4000mm L x 3214mm H per module) so it can be extended to areas that may require longer interventions. Its width is not exceeding 500mm (without the bench).

As said above, the 6 main GMS brackets for fixing points of the structure are installed directly to the paving to its structural slab using anchor bolt system or as specified by structural engineering design.

The modules won't need any connection to district main services and utilities like water drainage or electricity and the entire structure can be mounted and dismantled on site within 5 to 8 hours as well as shipped to site in separated pieces for on-site assemble by 5 to 10 skilled installers.

5.3.3. Shield 3D Model and Graphics:

Fig.29, 30 & 31. Concept Rendered Graphics

5.3.4. Marked Up Drawings & Specs:

Fig.32. Front View (N.T.S.)

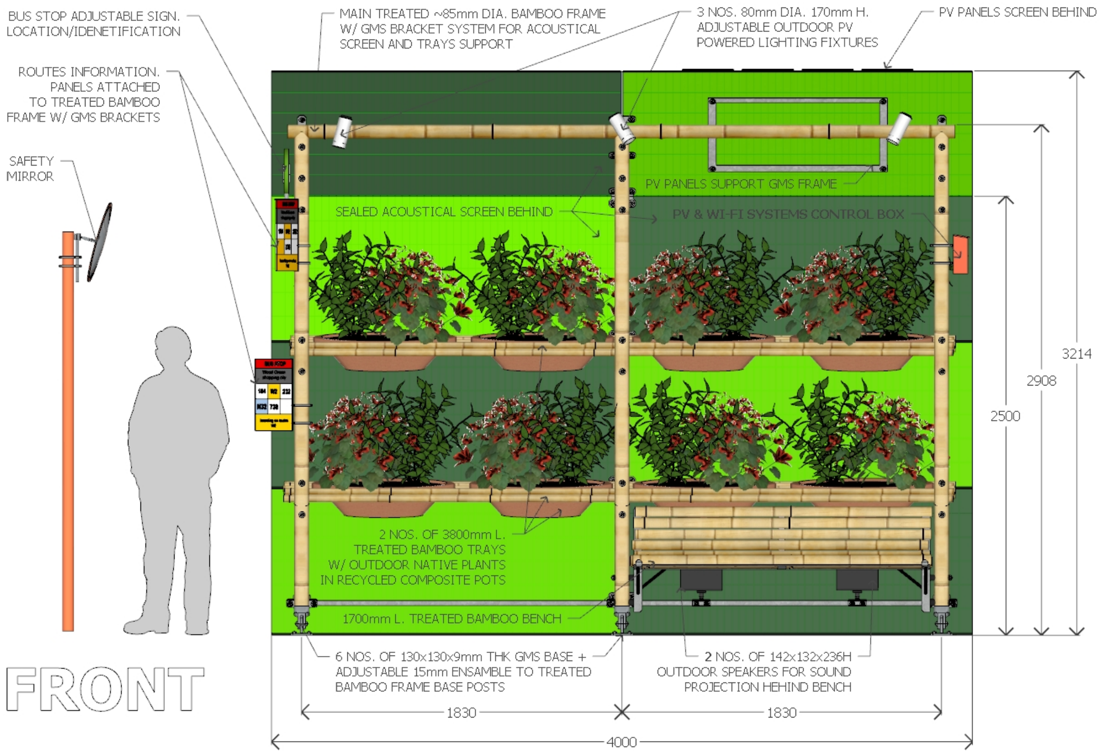


Fig.33. Back View (N.T.S.)

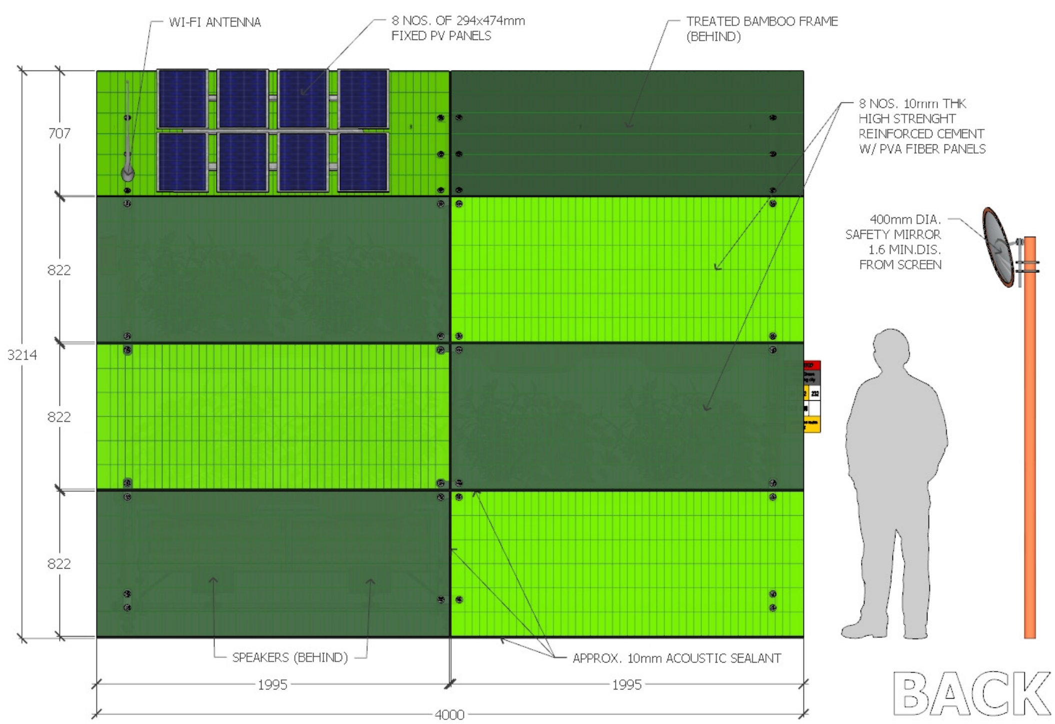
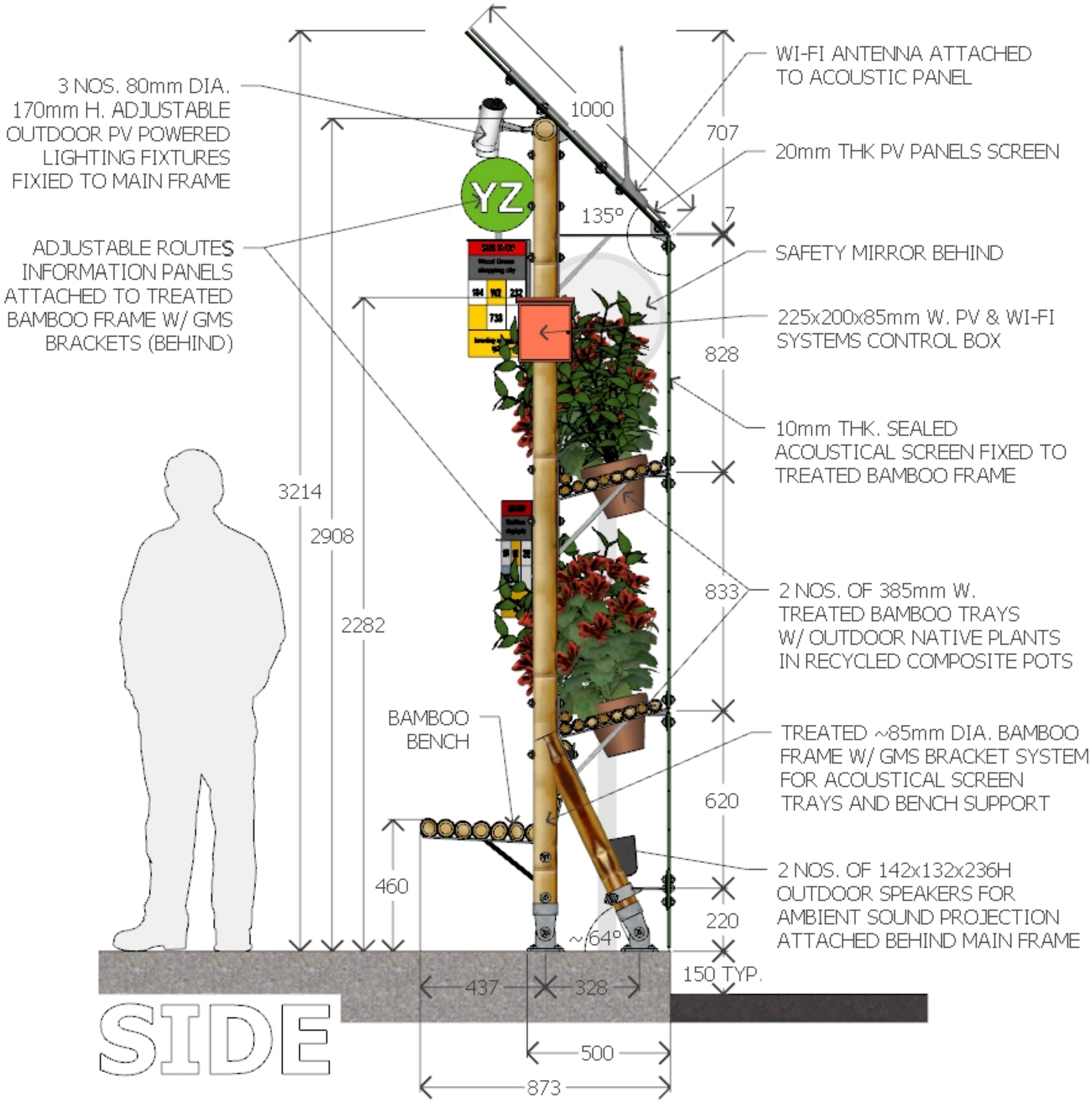


Fig.34. Side View (N.T.S.)



5.3.5. Concept Details:

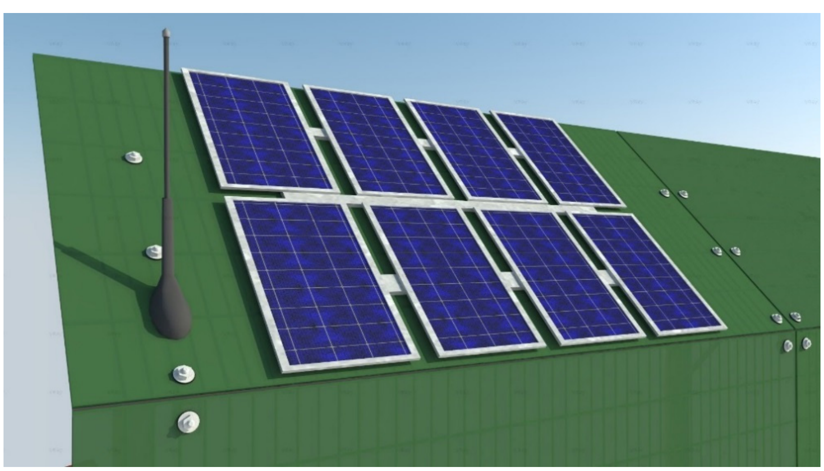


Fig.35. Photo Voltaic Panels and Wi-Fi Antenna

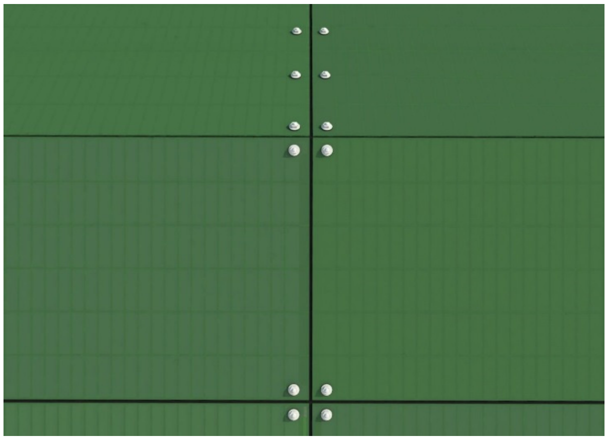


Fig.36. PVA Panels with Stainless Steel Bolts for 4 Panels Union. Back View.

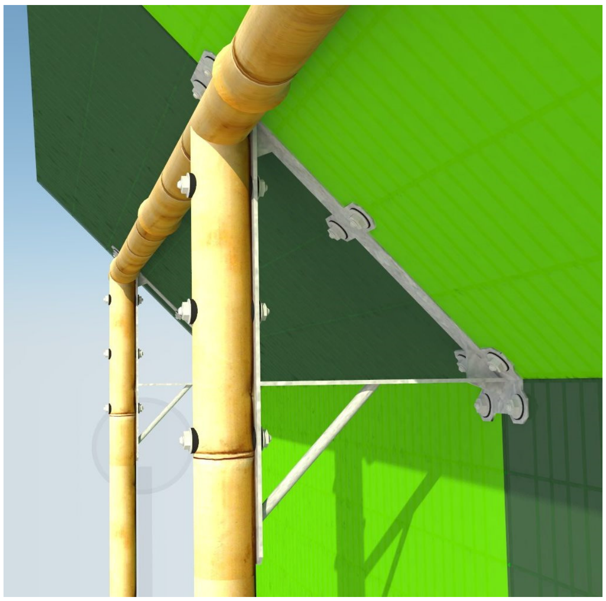


Fig.37. Center GMS Bracket Angle with Stainless Steel Bolts for 4 Panels Union. Front View.

Fig.38. (Mirrored) PV Panels Supporting Stainless Steel Frame behind PVA Upper Panel and Lighting Fixtures Attachment to Treated Bamboo Frame. Front View.

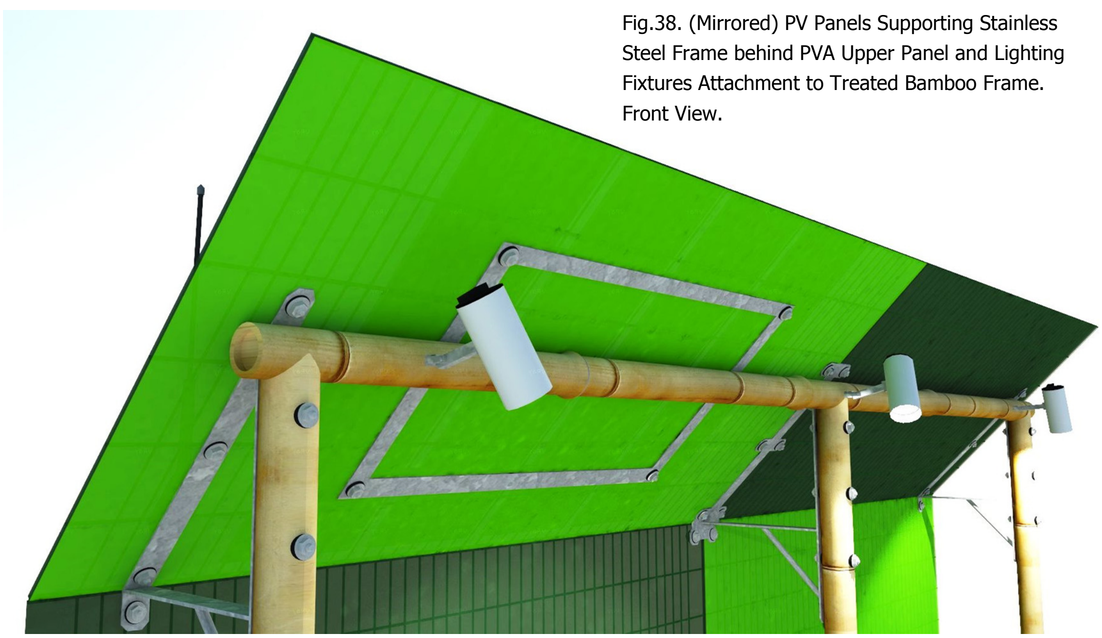


Fig.39. Information Sign Panels with GMS Attachment System to Main Frame.
GMS Angle Bracket Detail for PVA Panels Support Fixed to Main Bamboo Frame.
Side View.

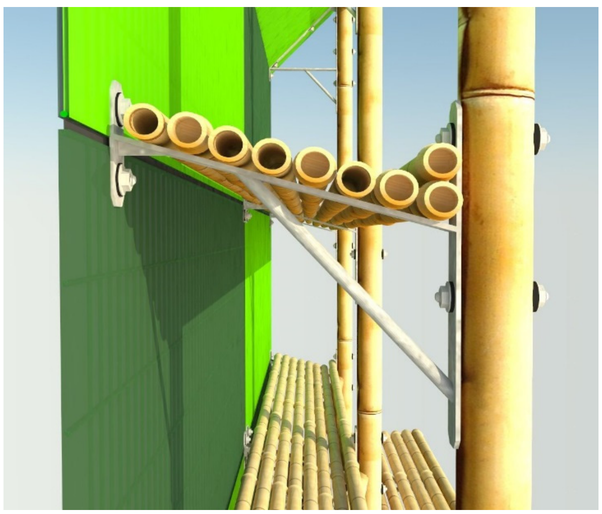
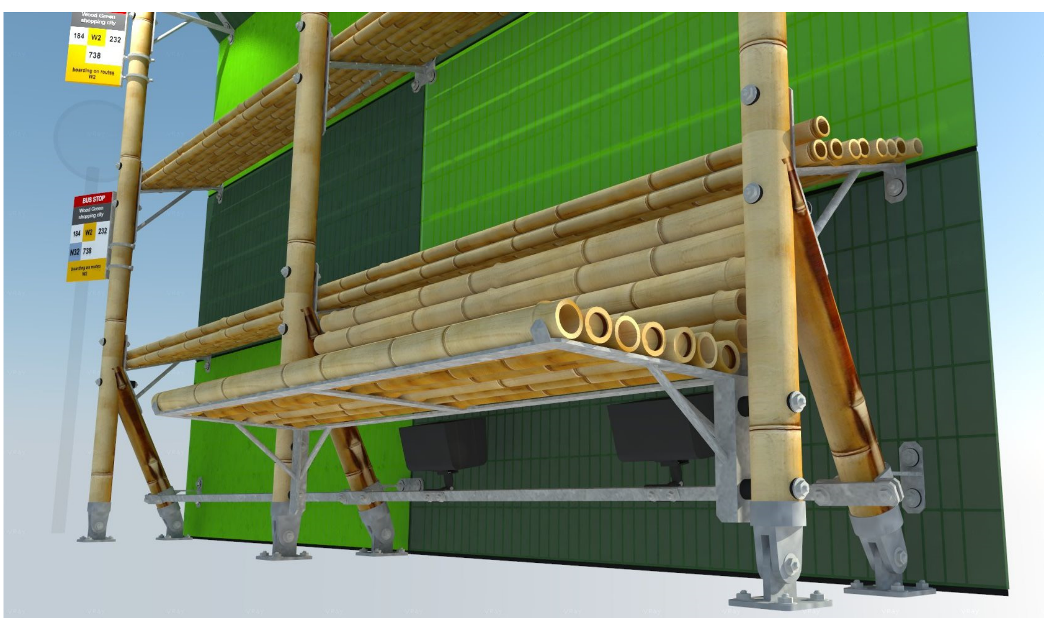


Fig.40. Bamboo Tray Typical Detail GMS Bracket Fixed to Treated Bamboo Frame Supporting PVA Screen.
Side View.

Fig.41. Detail for Fixed Bench Frame Attached to Main Frame.
Speakers Support Beam Behind with GMS Attachment Detail to Main Frame Back Support Legs
Tray Typical GMS Bracket Only for Lower Tray Support and Lower PVA Screen.



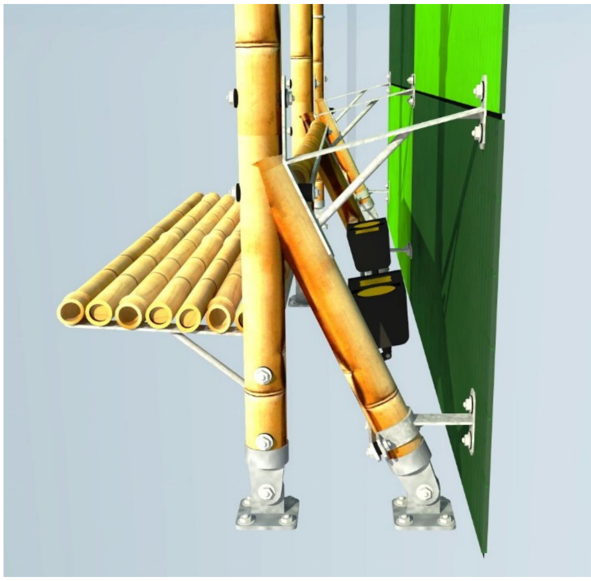


Fig.42. Side Detail for Fixed Bench Frame Attached to Main Frame.
Speakers Support Beam Behind with GMS Attachment Detail to Main Frame Back Support Legs
Tray Typical GMS Bracket Only for Lower Tray Support and Lower PVA Screen.
Main Bamboo Frame GMS Fixing Point to Paving.

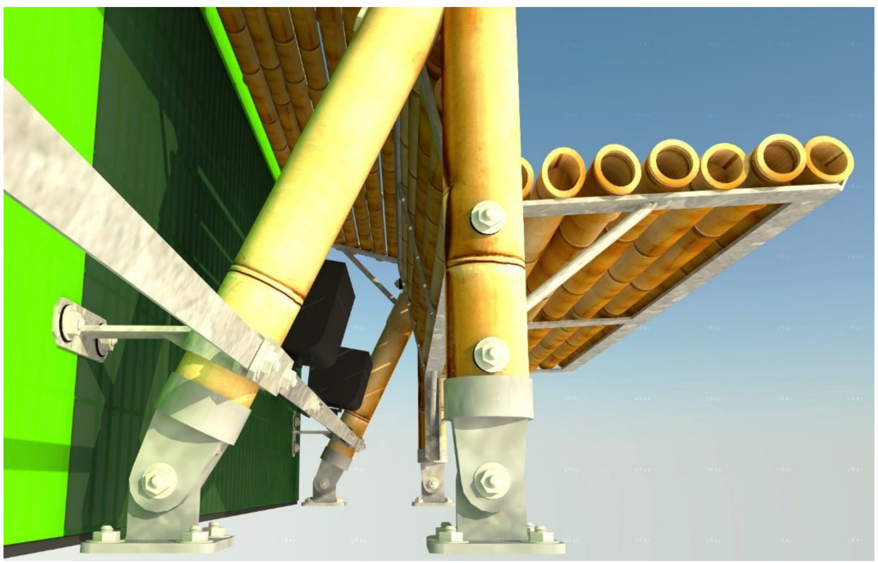


Fig.43. Detail for Fixed Bench Frame Attached to Main Frame.
Center Speakers Support Beam Behind with GMS Attachment Detail to Main Frame Back Support Legs.
Main Bamboo Frame GMS Fixing Point to Paving.
Side View.

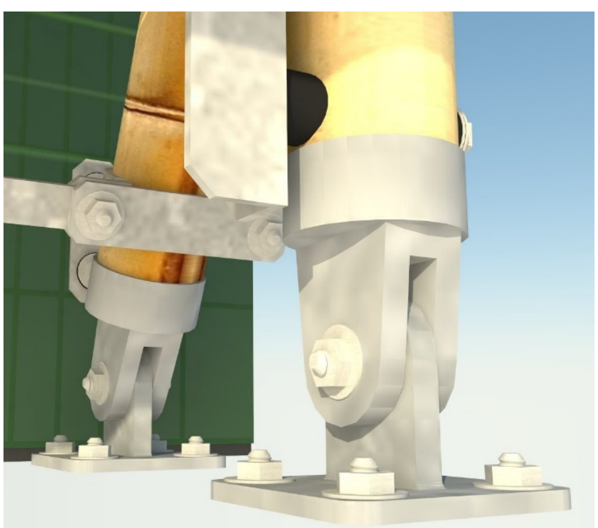


Fig.44. Detail of Main Bamboo Frame to Adjustable GMS Fixing Point to Paving.

6. FINDINGS AND CONCLUSIONS

If was found that the addition or installation of noise barrier Shields to help in the mitigation of an important issue as a generalized traffic noise pollution for Bus Stops in Hong Kong could be a positive matter, first to realistically protect the bus users to the constant engine noise pollution in specific locations while has been proven that a considerable reduction of sound pressure can be up to 10dB(A) from the average level found in Sham Shui Po bus tops of 76dB(A) using these Shields. This fact that was achieved with the help of a simulation software (OTL) to understand that the performance in a 'L' shape with minimum 4 meters long and 3.2 meters height Shield made of sustainable acoustic materials together with a conscious site measurement, is a must to consider in the efforts that the EPD in Hong Kong is doing to enhance the quality of living of the society.

It is clear that after a long design process, this dissertation together with my previous work for SENV7700 have measurable statistics regarding that the use of Shields on the streets is indeed a feasible strategy to follow up with a plan to educate the general public in the awareness for a better way of living the existing and polluted urban scape.

I can conclude proudly that such a simple idea based in a responsible design strategy will reduce the levels of stress and anxiety in crowded bus stop all over the city and it can be an example in how, with the use of sustainable native materials together with technology advances like nanofibers and IT, the society can learn, appropriate and respect new equipment and provisions that can be built to generate a more sustainable Hong Kong.

This study has proven that it is a real need to pay attention to the noise pollution and a good start is focused in this punctual intention where people must stay and tolerate whatever the traffic roads provide regarding their need for transportation.

I believe that we, designers, have to be creative and innovative using the resources that cause the minimum impact to the environment and move based and towards the people needs. The society is a living entity that requires care but their voice, education and respect in how to use and how demand for better contributions is within our own hands and senses, all as one, as 'intersensory' beings.

7. IMPACT AND FURTHER STUDIES

The Impact of this little (in size) and simple project could be the first step of a conscious detailed project all over the city to make us all understand the critical point we are now with noise pollution. This issue is in front of our doors and in every street, our kids must learn to tolerate the supremacy of machines over the quality of living that we all want to have.

The fact that society is enclosed indoors to feel relaxed is one of the unhealthiest factors that families been grow up teaching their children as a cultural phenomenon…

A full plan to "deny" traffic noise pollution in Hong Kong should be priority for future development of stronger policies, and small efforts, are the key to people to encourage them to become participants in the change and stop waiting for others to do these changes in their behalf.

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