UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF BUILDING APPLICATION NOISE BARRIER USING SANDWICH STRUCTURE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree of Mechanical Engineering Technology (Maintenance Technology) with Honours

by

MUHAMAD RIDZUAN BIN MAT RADZI
B071310834

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor's Degree in Mechanical Engineering Technology (Maintenance Technology) with Honors. The member of the supervisory is as follow:

………………………………

(Mr. Muhamad Azwar bin Azhari)

ABSTRAK

Salah satu isu yang dihadapi oleh manusia setiap hari di seluruh dunia adalah pencemaran bunyi. Pencemaran bunyi boleh dianggap sebagai bunyi yang tidak dingini dan memberi kesan kepada manusia dari segi fizikal dan fisiologi. Kajian ini akan merangkumi tentang cara untuk mengurangkan pencemaran bunyi dengan pengubahsuaian yang dilakukan pada laluan penghantaran bunyi dengan menggunakan penghadang pencemaran bunyi khusus untuk kegunaan bangunan. Oleh itu, kajian ini bertujuan mencari alternatif yang mampan dan mesra alam sebagai penghadang pencemaran bunyi dengan menggunakan sisa buangan tekstil dan gabus polyurethane yang boleh mengurangkan bunyi. Melalui keputusan yang diperolehi daripada ujian, bahan yang terbaik akan digunakan untuk pembuatan penghadang bunyi yang direka. Tambahan lagi, pengukuran In-Situ (In-Situ Method) akan memeriksa kecekapan halangan bunyi untuk mengurangkan pencemaran bunyi berdasarkan tahap tekanan bunyi dikurangkan yang dihantar dari sumber bunyi kepada penerima. Hasil yang sangat baik dimana kebisingan yang dihantar melalui penghadang pencemaran bunyi banyak berkurang malah dengan drastik selepas kehilangan kadar tekanan bunyi yang dihilangkan pada struktur sandwich dalam penghadang pencemaran bunyi.

ABSTRACT

One of the common problems that need to be faced by the people is noise pollution. Noise pollution can be describe as unwanted sound that effect human in physically and physiologically. The study will cover the way to reduce noise pollution by adjustment of the sound transmission through the transmission path from the development of the building application noise barrier. Therefore, this project found the alternative sustainable and environmentally friendly as noise barrier using textile waste and polyurethane foam which can reduce noise. From the result obtained, the best material are being be used in the noise barrier application. In addition, In-Situ measurement will check the efficiency of the noise barrier to reduce the noise pollution based on sound pressure level reduced that transmitted from the source of noise to the receiver. The result was excellence which the noise transmitted through the noise barrier reduced drastically and tremendously after sound pressure level is reduced due sandwich structure inside noise barrier.

DEDICATION

This thesis is dedicated to my parents for their love, endless support and encouragement.

ACKNOWLEDGMENT

Assalamualaikum w.b.t

Very grateful to Allah S.W.T because of Allah S.W.T endowment, I can execute this Final Year Report at the right time. I would like to take this opportunity to express my deepest heartfelt and thank to all those who have guided and supported me during my Final Year Project either directly or indirectly.

First of all I would like to express Allah S.W.T. for this opportunity, and to my parents and siblings for their love and support. I would like to express my sincere gratitude to my supervisor, Mr. Ahmad Yusuf Bin Ismail and Mr. Muhamad Azwar bin Azhari for preliminary ideas, invaluable guidance, continuous encouragement and unselfish support in making this research. Not forgotten to all lecturers with respect to their direction, guidance and assistance.

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LIST OF ABBREVIATIONS, SYMBOL AND NOMENCLATURES

A	-	Absorption Value after Treatment with Sound-absorbtive Materials
A0	-	Absorption Value Before Treatment with Sound-absorptive Materials
BK	-	Bilik Kuliah (Lecture Class)
d	-	Distance
dB	-	decibels
FTK	-	Fakulti Teknologi Kejuruteraan
Hz	-	Hertz
h	-	Height
Ks	-	Spring Constant
Kg/m^3	-	Kilogram per meter cube
LPF	-	Light Poly-urethane foam
M	-	Mass
m	-	Meter
NR	-	Noise Reduction
NRC	-	Noise Reduction Coefficient
R_M	-	Damper Constant
R_W	-	Rating of Sound Insulation Performance
SPL	-	Sound Pressure Level
S	-	Surface Area
TL	-	Transmission Loss
t	-	Thickness
UTeM	-	Universiti Teknikal Malaysia Melaka
WHO	-	World Health Organization

w	-	Width
α	-	Absorption Coefficient
α_w	-	Rating of Sound Absorption Coefficient
δ	-	Density
µm	-	Micro Meter
%	-	Percent
Ø	-	Diameter
Θ_i	-	Incident Wave Angle
Θ_R	-	Reflected Wave Angle
Θ_T	-	Transmitted Wave Angle

CHAPTER 1

INTRODUCTION

1.1 Vibration

Vibration occurs when something oscillates about a static position. The altering transfer of energy between its potential and kinetic forms involves in the vibration of a system. Besides that, vibration is also being known as the physical movement or motion of a rotating machine. A study by Taylor (2003), he state that since the vibration cannot be measured by sight or touch, employed should change the vibration into a usable product that can be measured or analyzed (Taylor, 2003). In our daily life routine, people were always exposed to the vibration which enviable or non-enviable. For example the reed in a woodwind instrument or harmonica, noise vibration from vehicles on the streets and mostly vibration comes from industrials.

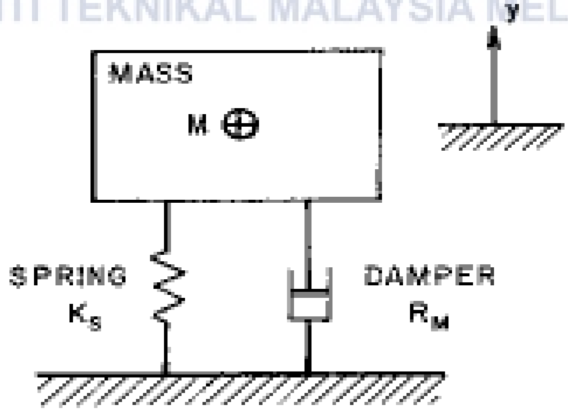

Figure 1.1: Single degree of freedom with damping system (Barron, 2003).

By referring to the figure above, in order to reducing the noise level, damping materials are used to dissipate the mechanical energy from being radiated into noise that transmitted into the air (Barron, 2003). According by Taylor (2003), he state that vibration can be divided into three types which are harmonic motion, periodic motion and random motion. Harmonic motion is the simplest periodic motion that shows displacement as a harmonic function of angular velocity and time. It is periodic, meaning it repeats at some point in time.

Vibration can also be seen as a periodic motion that moving repeatedly after a certain interval time. Random motion occurs in an erratic manner and contains all frequencies in a particular frequency band. It is a motion that not repeatable (Taylor, 2003).

Besides that's, vibration also will contribute to the deterioration of working environment. Workers exposed to occupational vibration are also often exposed to excessive noise. Worker will get hearing problem especially in cochlea. Cochlea will damage when exposed to excessive noise and worker become deaf (Futatsuka et al., 1991).

1.2 Noise

Nowadays, one of the environmental problems that will affect human health is noise. Noise can be describe as unwanted sound that effect human in physically and physiologically and destroying environmental properties will develop environmental pollution (Atmaca et al., 2005). Moreover, noise can cause heartbeat acceleration, increase of blood pressure and ringing or other noises in the ear or head known as tinnitus. The psychological effects of noise are more common compared to the psychological ones and they can be seen in the forms of annoyance, stress, anger and concentration disorders as well as difficulties in resting and perception (Cheung, 2004). Hearing loss will occur when there is continuous exposed to excessive noise at a level higher than 85 dB (Atmaca et al., 2005).

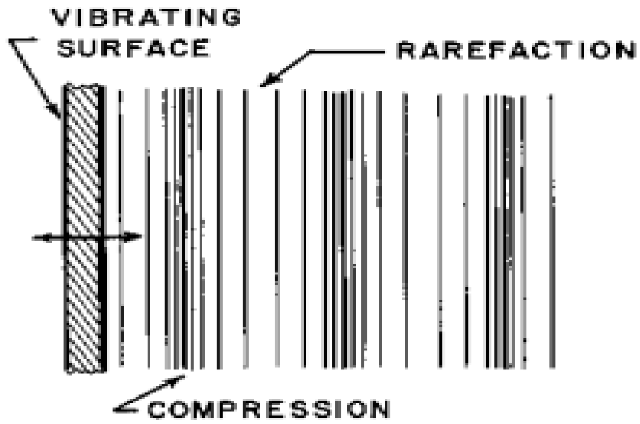

Figure 1.2: Sound waves in material (Barron, 2003).

Noise also can be defined as any perceived sound that is objectionable or damaging for a human. Noise is somewhat subjective, because one person's ''music'' may be another person's ''noise.'' Some sounds that could be classified as noise, such as the warning whistle on a train, are actually beneficial by warning people of potential dangerous situations (Barron, 2003). The sound wave in various materials is given in Figure 1.2.

1.2.1 Machinery Noise

The most unwanted hazard in the industry is noise. A lot of machinery in industry produces a lot of sound. Machines such as motor, pump, turbine and generator will produce noise while operating. Continuous exposure to the noise level above 85 dB is considered hazardous because the standard limit of daily noise exposure at the workplace for most countries is 85 dB for an 8 –hour (Amedofu, 2007). Machinery noise should be reduce to protect worker from continues hearing excessive noise. Noise can be controlled by noise control at the source and modification along the sound transmission path (Fard et al., 2013).

1.2.2 Building Acoustics

It's a noisy world. Twenty-four hours a day, seven days a week, we are exposed to sounds we do not want, need, or benefit from. When the surrounding noise level is same as speech level, the intelligibility rates would be decrease to 95% due to redundancy of speech that lead to unpleasant conversation because of sound interference (Lazarus, 1986, 1987). The study of sound propagation is not only focusing only at acoustical design of large performance halls but it is also concern about acoustical comfort surroundings where people spend lot of times either in the workplace, homes, hotels and restaurants (Bennet, 1975).

1.2.3 Noise Reduction Method

It is compulsory to eliminate or at least reduce the source of noise in order to protect humans from continually exposed to the noise. Manipulating the source of the noise or by modifying the receiver of the sound can secured the sound easily. (Barron, 2003). Occupational Safety and Health Administration (OSHA) sets the admissible noise exposure limit in the room 85 dB for an eight hour period. In order to create an acoustically pleasing environment for the human, noise control and its principles play a very important role to bring down the intensity of sound to a safer level for human ears.

1.3 Sound Absorption

Materials that have low absorption ability have a chance to reflect most of the acoustical energy. Sound absorption is a capability of a material to convert sound energy into other energy. This energy is usually converted to heat energy (Kuttruff, 1995).

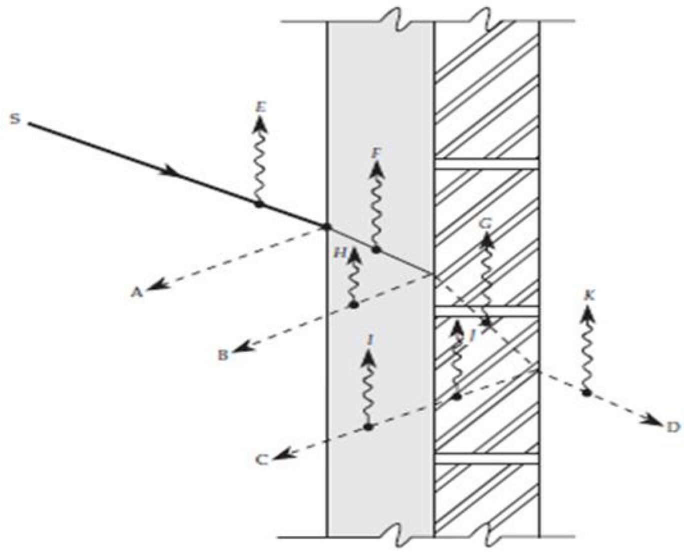

Figure 1.3: Sound absorption through a wall (Fallis, 2013).

Fallis (2013) stated that, a sound ray reflecting away from its original path into different directional as the sound ray impinging on the surface with different reflection angles and sound absorptions into the air and through the absorption material. All sound waves naturally fading by the medium along the transmission path (Fallis, 2013). Different conditions such as in large area hall and at increasing frequencies condition this would be different as it is significantly become noticeable (Bennet, 1975). The fraction of incident sound energy introduced from the absorption coefficient of a boundary that is not reflected by incident of sound energy, and the quantity are rely on the frequency value and the sound incidence. There are three types of sound absorber as stated by (Bennet, 1975), they are Absorption by Yielding Walls, Absorption by Porous Materials, and Resonance Absorbers.

1.4 Sound Transmission Loss

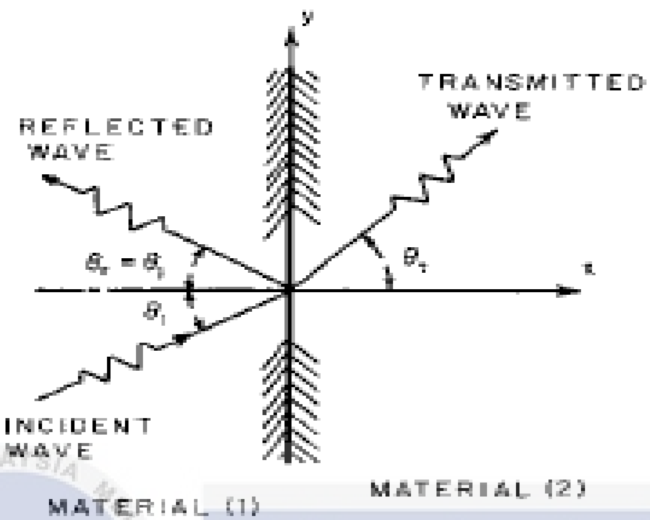

Figure 1.4: Transmission loss in sound wave (Barron, 2003).

Noise can be control by changing at the beginning stage of its transmission starting from source of sound, the transmission path or controlling the noise by modify the receiver of the sound (Barron, 2003). There are two methods that can be applied in reducing noise, they can be done by using sound absorption technique and the other one is by applying the transmission loss control. One of the main factors in controlling noise pollution to be considered is determination the sound energy transmitted through a wall (Barron, 2003). Acoustic barrier or acoustic wall is one of the procedures for noise control in order to reduce noise pollution from being transmitted through a medium. In purpose for designing noise barrier, the designer should be know and have sense to predict the transmission loss through the wall over a broad range of frequencies (Barron, 2003).

1.5 Problem Statement

Human especially students need to focused when studying. Persistent expose to noise can give negative effect to the student such as disturbance noise from another class. Now, this situation has been face by students and lecturer in FTK, UTeM Industrial Campus. They have feeling annoying due to noise interference from another class while learning section is being conducted. A study by Zaheerudin (2008), normal acceptable distance for good interaction in ambient environment should be not more than 65 dB for young and teenagers while 55 dB for old people. The students are having resistance on their focusing on learning process due to noise interference from another class. Interaction between people in speech is ascendant method, noise interference significantly effect on the communication (Zaheerudin, 2008). Noise barrier control the unwanted noise by reducing direct contact of sound pressure to human. There are two types of method to reduce noise which are sound absorption and sound time loss or reflection of sound. Materials that have tendency to reduce noise in large scale become priority for development of noise barrier.

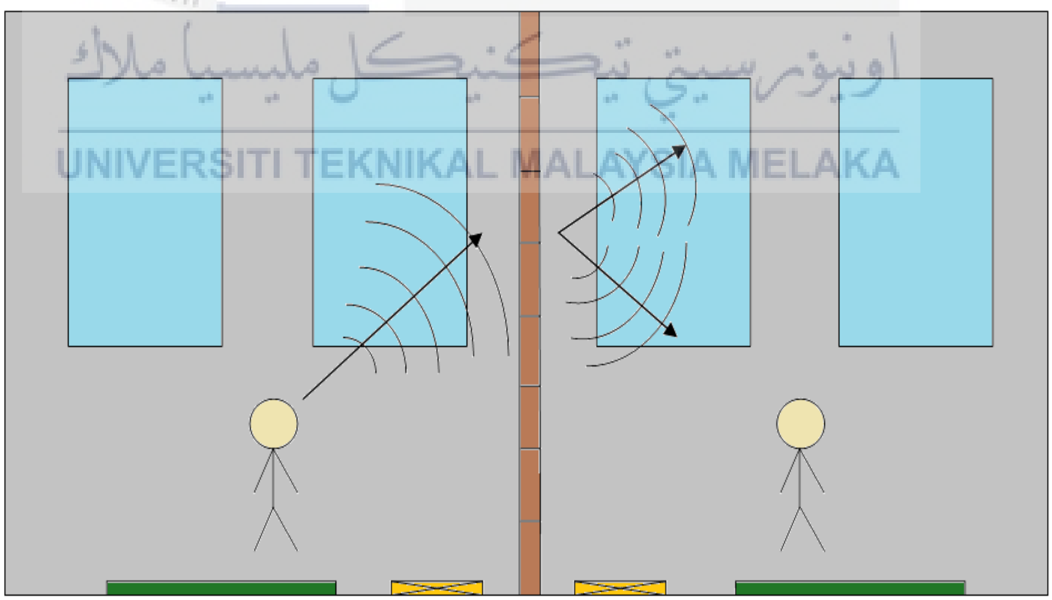

Figure 1.5: Illustration of noise pollution from BK37 to BK38, Factory 3, and Industrial Campus UTeM.

Figure 1.5 shows noise pollution disturb the lectures session are being conducted between these two classes at the same time. The students and lecturers in FTK, UTeM Industrial Campus having experienced on feeling annoyance due to noise interference while the learning session are being conducted. Voice coming out from human voice projection in BK38 possibly leaks into BK37 at some of times during lectures session that being conducted surely will bring an annoyance condition to the students and the lecturer that affected by the noise pollution.

1.6 Objectives

The objectives of the project are:

- To develop noise barrier for building application using sandwich structure design.
- To test the effects of noise barrier in the class by using In-situ measurement method with different angles.

1.7 Scopes

The scopes of the project are:

- Developing noise barrier using sandwich structure as the design of the barrier.
- Testing noise barrier based on sound transmission loss and sound absorption rate by using In-situ measurement method with different angles.

CHAPTER 2

LITERATURE REVIEW

2.1 Building Noise

The acoustical environment on the whole buildings is affected by numerous interrelated and interdependent factors associated with the building planning, design and construction process. The architect, the engineer, the building technologist, and the constructor all play a part in the control of the acoustical environment. With some prepared knowledge of basic acoustical principles on how materials and structures control the sound, many problems can be avoided altogether or, at least, solved in the early stages of the project at greatly reduced cost. ‘‘Corrective” measures are inevitably more costly after the building is finished and occupied (Cavanaugh and Wilkes, 1998). Sometimes, unwanted sound from railroads, road traffic, construction area and recreation will cause annoying sound to the people inside the buildings (Barron, 2003). Some cases occur when people are complaining about piling works that annoying them to change in normal condition either in temporary and short time due to intense and sudden noise that received by the people (Head and Jardine, 1992).

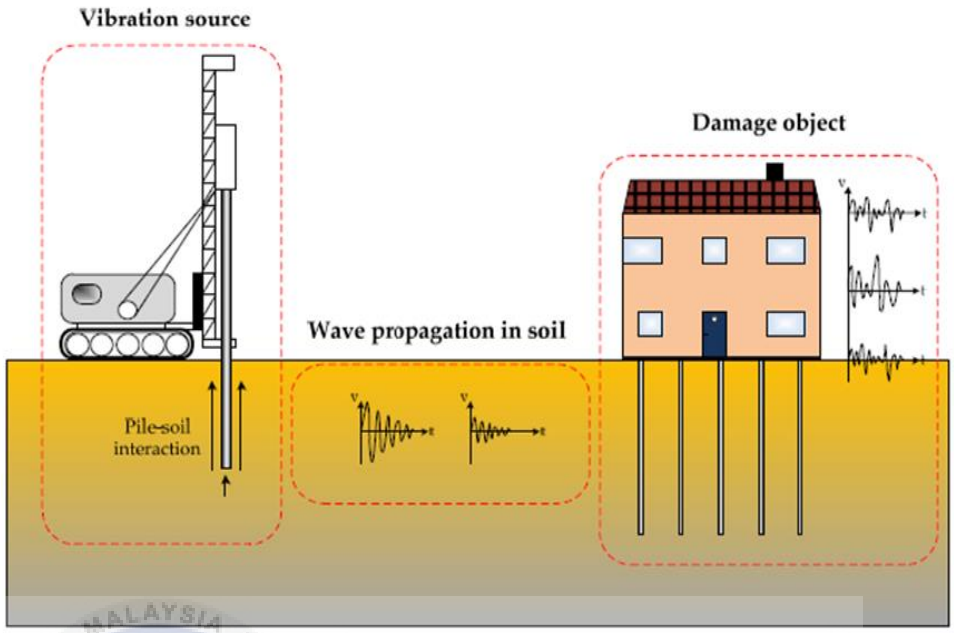

Figure 2.1: Diagram shows wave propagation from piling source to building (Deckner, 2012).

A study by Deckner (2012), it shows that the vibration source, the propagation of wave in soil, and building damage from piling process are the main three parts in wave propagation process. Barron (2003) stated that, energy that is radiated from vibrating solid surfaces produces a sound. The vibrations primly transmitted from driving equipment either from impact or vibratory to the pile cap and vibration moves deep into the pile shaft that transfer the vibration to the ground. The vibration that propagate through the soil would be interact with the nearest building or can be named as the affecting or damage object as shown in the image illustrated by Deckner (2012).

Vibration energy that radiated from the outside sources converted into sound pressure to the receiver buildings, and it is also influenced by the coupling of the soil, the building foundations, and room's acoustic characteristics. In addition, general vibrations wave propagates through a medium such as soil and rock, thus the amplitude usually reduced depends on the distance from the sources of noise to the receiver in the building (Davis, 2010).

According by Wang and Mak (2015), vibration sources coming from outside of the building and from the inside of the building. Outside sources vibration contributed through the activities that are coming from the construction site area that generate vibrations and unwanted noise that cause annoyance to the nearest people. The vibrations possibly transmitted to the buildings around the area through the ground. For vibrations that are sources inside of building, sound that produced in a room having a possibility to passing through a medium in various ways of transmission path. The sound possibly transferred through the walls, floors, building frameworks, and sometimes it could be transmitted via the interconnecting ducts. People activities in buildings contributes in affecting of sound transmission in buildings, this kind of sound usually brings annoyance to the people in the building. The reduction of the sound could be achieved by controlling and adjusting the sound transmission path from one room to another room by "air-borne sound insulation" .In neighboring rooms, for sound insulation purpose people usually consider with the single-leaf and double-leaf partitions, also the multilayer of materials. For instance, rooms that are separated by a homogenous, nonporous, single-leaf wall is the simplest example to relates (Wang and Mak, 2015).

2.2 Noise Reduction Method

By knowing the noise reduction value in the machinery room, this would be useful to reduce the desired for transmission loss in the machinery room either the HVAC equipment room. In addition, sound–absorbing materials can be applied for the interior and ceiling of the room with example of material such as fiber glass that will help to reduce the noise level. The noise reduction can be calculated from the formula as shown above (Fallis, 2013).

The noise control can be secured by the acoustical adjustment to the surfaces of the room. There are several types of area that should be control their noise levels which are the noise in commercial area, industrial site, and residential buildings. This area should be protected from the both sources of outside and inside sources which coming from road traffic and construction site for outside source while inside source might be contributed by the heating, ventilation, air-conditioning and it is also may coming from plumbing systems. Through the building shell, reduction of noise transmission from the external sources includes in the sound control measurement as this is also a way that should be considered in order to reduce the noise transmission (Barron, 2003).

According to Ku and Kim (2015), windows have important function that acting as the sound insulation and heat insulation in a building. Noise much easier through into a building that transferred from external sources, so it can be easily transmitted into a building compared to the heavier material such as concrete wall. Windows normally assembled with a small clearance that allows the inserting of windows frame into the outside frame. The small clearance space will acting as a role in effecting the performance of the heat and sound insulation factors to a building. In addition, it also will show that how a small clearance could be an opportunity that contributes into noise leaking into a building. By controlling the clearance, it would be very helpful in order to provide better environment without any noise pollution leakage (Ku and Kim, 2015).

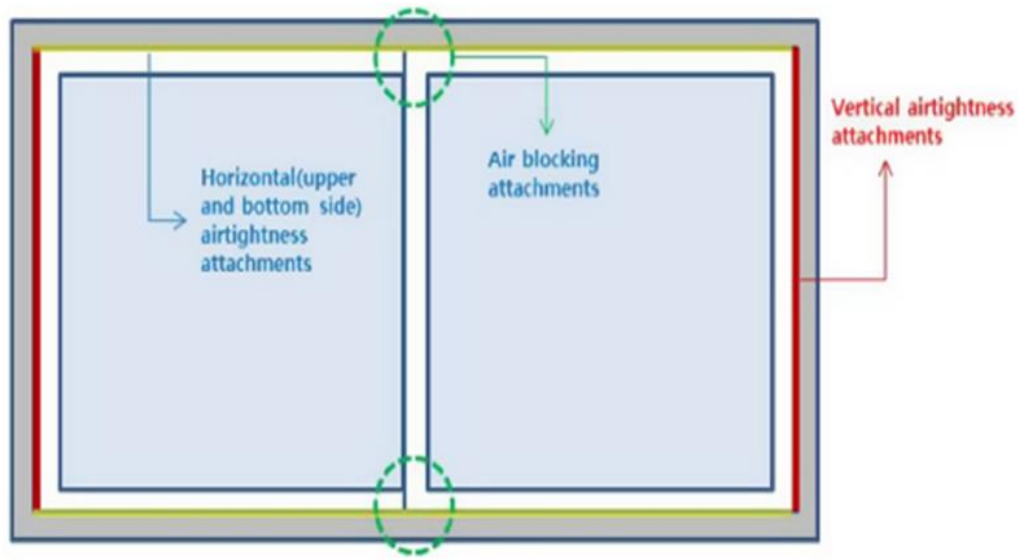

Figure 2.2: Illustration of airtight structure installation for windows in Horizontal, Vertical, and Gap – Sealing Position (Ku and Kim, 2015).

Reducing the noise generated by the main source is one of reducing noise in building. Furthermore, noise also could be reducing by change the work into better and quieter methods of work. People can minimize noise propagation in a building to lower down the noise level in a building. As a study by Bruel and Kjaer (1986), building elements should be put away in position from equipment that vibrates and installed with a joint of elastic elements. Apart from that to reduce noise in building, the selection of walls, ceiling construction, windows, doors and any other material that contributes in leaking of noise from being transmitted to keep the buildings with good sound insulation. The other way, noise reduction also could be achieved by avoiding the mounting of noise equipment to the movable partitions. For example if the ventilation of the cooling systems must be attached to the light foundation, some extra work can be made to isolate the vibrations that coming from the ventilation of the cooling system (Bruel and Kjaer, 1986).

2.2.1 Sound Absorption

Noise is vibration energy and by using absorbent particles, vibration energy can disappear in form of heat. Thus, noise energy can be reduced. The amount of the heat generated by noise absorption is extremely small (Alton and Ken, 2009).

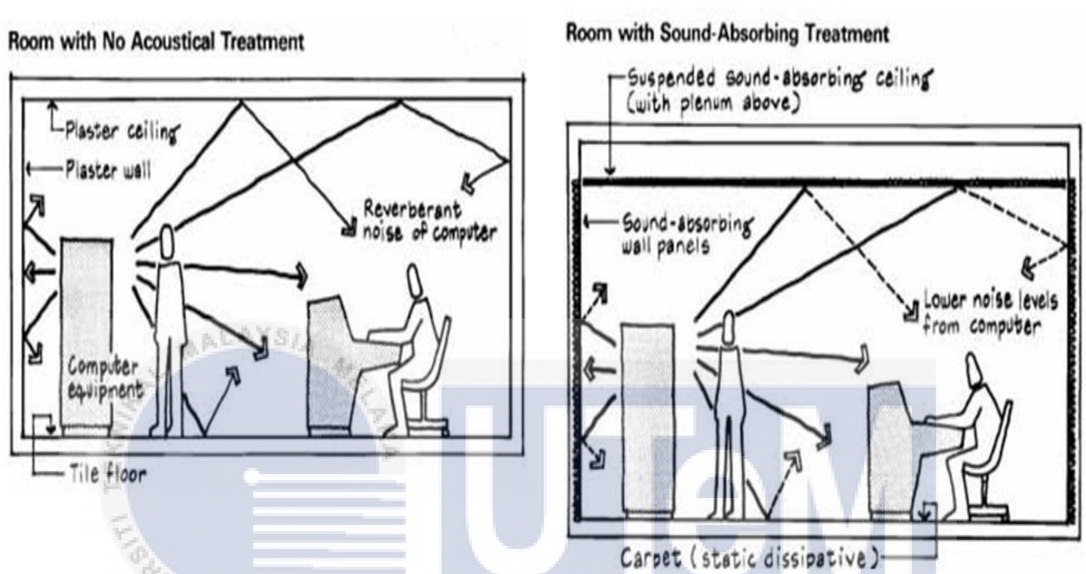

Figure 2.3: Rooms with and without sound absorptive treatment (Egan, 1988).

A study by Egan, in large auditorium, the echo in audience areas near to the stage can be optimally reduced by adding sound absorption material at rear and sides. When a sound source is enclosed in a room, the level of sound inside the room is changed. The level of the sound depends on how much the surfaces of the room absorb sound shown in figure 2.3 (Egan, 1988). The level of the sound depends on how much the surfaces changed. When a sound wave strikes one of the surfaces of a room, some of the sound energy is reflected back into the room and some penetrates the surface. Parts of the sound wave energy are absorbed by conversion to heat energy in the material, while the rest is transmitted through. The level of energy converted to heat energy depends on the sound absorbing properties of the material. A material's sound absorbing properties are expressed by the sound absorption coefficient, α, (alpha), as a function of the frequency. α ranges from 0 (total reflection) to 1.00 (total absorption).

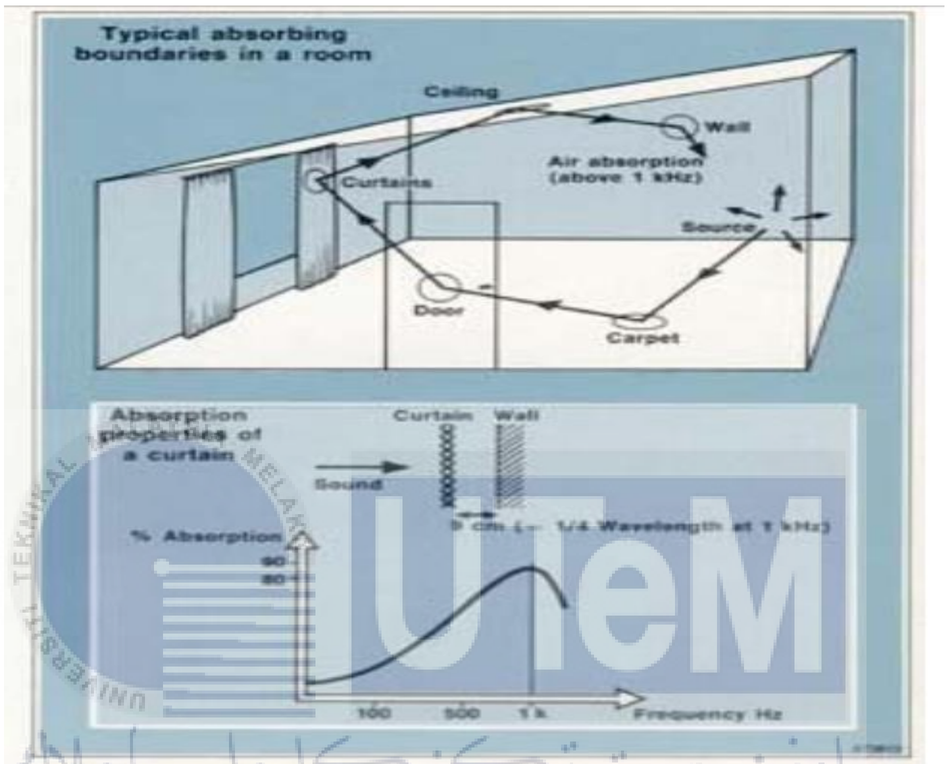

Figure 2.4: Typical absorbing boundaries in room and absorption properties of a curtain (Bruel and Kjaer, 1986).

According to Bruel and Kjaer (1986), instead of rising indefinitely as an increasing number of reflections arrive at the measuring position, the sound pressure level should be stabilizes. This situation state that the rate of energy input is exactly compensated by the rate at which the energy is absorbed by the different surfaces of the room. If more absorption material is put in the room, the sound pressure level is less because the energy in the reflections is reduced. Typical absorbing surfaces in a room include carpets and curtains.

These are simple porous absorbers which absorb sound energy by restricting the movement of air particles, the frictional forces causing the dissipation of energy as heat. Porous absorbers are most effective when placed at a point on the sound-wave which has maximum particle velocity. This position is a quarter wavelength away from a reflecting surface and frequency dependent. A carpet is an example of a porous absorber close to a reflective boundary. It absorbs best at high frequencies because the dimensions of the quarter wavelengths are then comparable with the thickness of carpet.

2.2.2 Sound Transmission Loss

Transmission Loss is the ratio of the sound power of the incident (progressive) pressure wave at the inlet of the muffler to the sound power of the transmitted pressure wave at the outlet of the muffler.The benefit of TL is that it is a parameter of the muffler alone and the source or termination properties are not needed. Because of the simplifications, the TL is the most common parameter for muffler performance. Insertion loss is defined as the difference between the acoustic pressure radiated from the source with and without the muffler attached. The TL is a more accurate method of determining muffler performance as it is measured in actual operating conditions with the source properties applied (Daniel, 2005).

A study by Robin et al. (2015), sample size has a significant effect on the measured sound transmission loss above and below the critical frequency. The construction of the sample was found to influence the variance caused by the changes in sample size. This interaction between the construction and the observed size effects makes the development of any correction factors to allow for small sample results difficult.

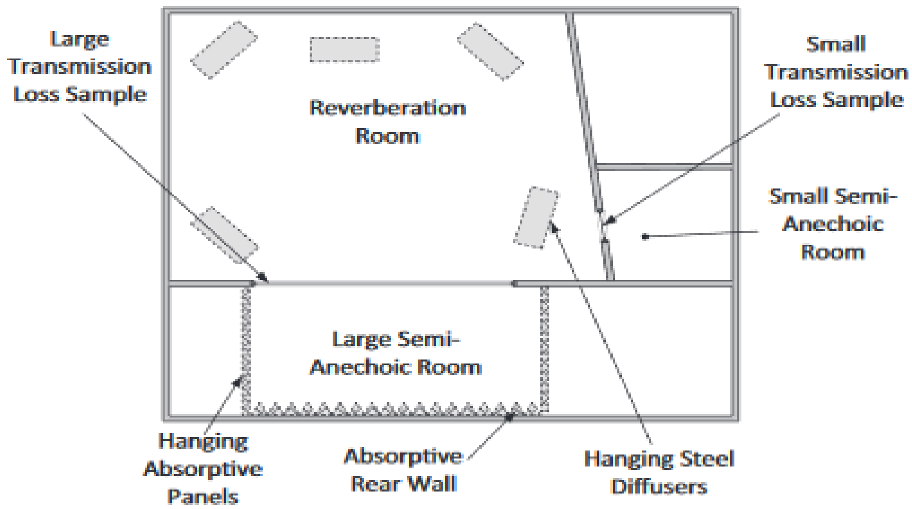

Figure 2.5 Schematic of test rooms used for transmission loss evaluations (Robin et al., 2015).

According to Sousa and Gibbs (2014), prediction of airborne and impact sound transmission at mid and high frequencies, typically above 200 Hz, diffuse field conditions often are assumed, particularly for the sound pressure in rooms. Similarly, for impact sound transmission, vibration fields are assumed diffuse, thus neglecting the effects, on sound pressure, of the location of the impact, and the size and edge conditions of the floor. Typically, at frequencies below 200 Hz, the sound and vibration fields in dwellings exhibit modal behavior and a systematic investigation of measurement and prediction uncertainty especially on the location of the impact in floor construction likes material properties, dimensions and edge conditions while in room dimensions likes surface absorption, and listener/microphone location (Sousa and Gibbs, 2014).

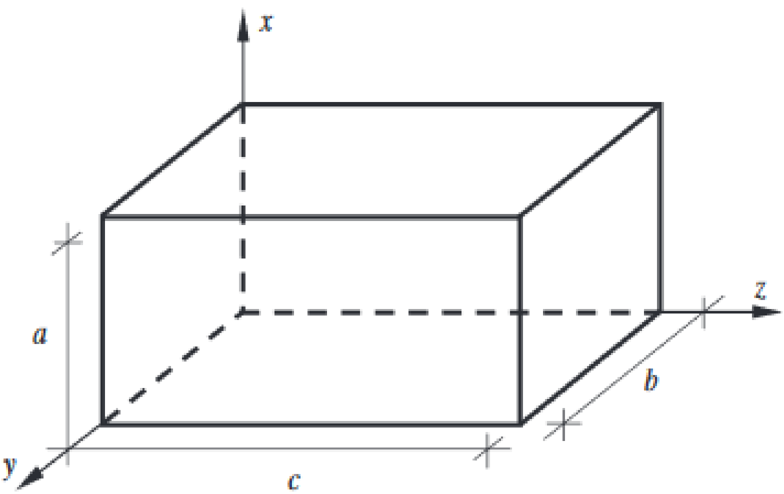

Figure 2.6: Room Dimension (Sousa and Gibbs, 2014).

2.3 Previous Research on Reducing Building Noise

Factors likes building planning, design, and construction process can contributed to interrelated and interdependent factors of acoustical environment around buildings. Reducing noise on building can be control with understanding acoustical principles, know appropriate materials and structures to control the sound. Green Infrastructure is one of the invention to control and reduce noise around the buildings. It shows some acoustic insulation at building and city noise reduction at urban scale. In addition, it also contribute to ecological, economic and social benefits through natural solutions for the built environment. Combination of green construction system that can absorb sound and hard surfaces of urban area to reflect sound will tending block lower sound frequency and latter higher ones. Use vegetation on the green roof is one the green construction system that tend to reduce noise on buildings. For examples, use of vegetation in order to improve the acoustic insulation of a building is the Almeida Theatre in London. To achieve the required level of sound insulation, the roof and gables of the building were turfed in Sedum, a hardy cactus-like plant. The resulting pitched roof garden, full of wild flowers in the center of a busy urban block, has become a local landmark (Perez et al., 2016).

Figure 2.7: Building greenery as acoustic insulation. Almeida Theatre. London (Perez et al., 2016).

Human activity on the outside buildings or unpleasant outdoor sound will contribute to noise pollution. Noise transport likes road traffic, aircraft and railways noise will tends as a main source of outside noise pollution. This pollution will bother acoustic comfort in the buildings. Acoustic barrier becomes existing tool to reduce noise. Uses of acoustic barrier in urban areas is associated with several drawbacks, the placement of continuous walls in cities presents aesthetic and communication problems related to both the breakdown of the cityscape and the physical isolation of the acoustically protected areas. This resistance has been solved by using new material which is Sonic Crystal that formed periodic arrays of acoustic scatters separated by a predetermined lattice constant and embedded in air. This mechanism overcome ranges of frequencies where the wave propagation through Sonic Crystal is forbidden, called band gaps and their existence can be explained using a Bragg scattering process .Both the size and the position of the band gaps in the frequencies domain basically depends on the geometrical characteristics of the array, the lattice constant p, and the radius of the cylinders r (Castiñeira-Ibañez et al., 2015).

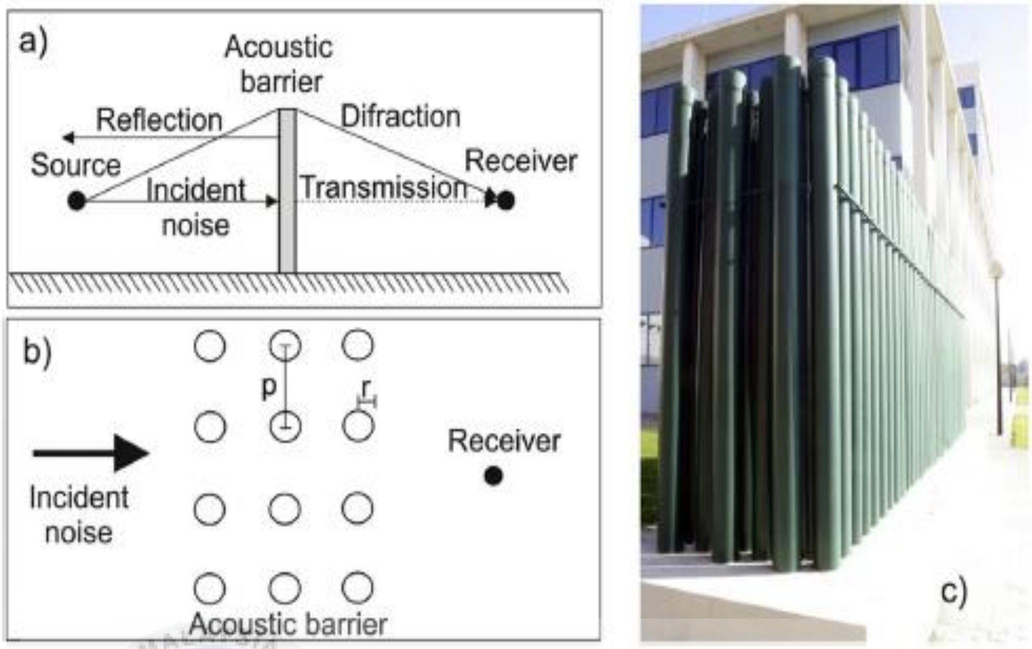

Figure 2.8: Acoustic performance using Sonic Crystal scatterers (Castiñeira-Ibañez et al., 2015).

2.3.1 Materials

Nowadays, demand for growing offer of acoustic materials becomes famous because extremely development of acoustic building standards. Prediction for characteristic of acoustic material behavior becomes easily cause by implied the necessity to face the implementation of models. Unwanted noise can be control by using sound absorbing materials likes porous materials. A porous material is a solid that contains cavities, channels or interstices so that the sound waves are able to enter through them. Based on their microscopic configurations porous materials can be classified as cellular, fibrous, or granular. The example of porous materials are basalt, rock wool and glass fibre. Interaction of propagation and sound absorption inside materials can be predict by using basic macroscopic models which are two fundamental magnitudes as characteristic wave impedance and propagation constant (Rey et al., 2012).

A study by Hung et al., (2014), interaction of fluid and solid for sound absorbing materials will affect the difference between the noise reduction mechanisms of sound reflection for sound insulating materials and sound energy loss. The measurement of sound absorption coefficient and sound transmission loss will evaluate the efficiency of noise reduction for sound absorbing and insulating materials. Porosity and pore size distribution will cause by sound absorption coefficient of a material while controlled by its density as well as thickness, namely its surface density will generate sound transmission loss. Fibrous materials, such as glass wool, rock wool and natural plant fibers, and highly porous materials, such as polymer, aluminum, glass and cement foams, are often used as sound absorbing and insulting materials (Hung et al., 2014).

Zwikker and Kosten (1949) stated that, sound absorbing materials and dampening applications always softer than solid materials and have a porosity higher than 90 %. Due to their predicted, two longitudinal waves can propagate in such a medium apart from a shear wave when material is insonified at oblique incidence. Due to the high difference in density between the frame and the air in the pores, the properties of one mechanical wave is mainly determined by the apparent elastic module and the apparent density of the material, the air in the pores having only a minor effect of the wave properties. The second wave is air wave mainly propagates in the air in the pores, but its properties are strongly determined by the pore geometry due to inertial, viscous and thermal effects in the pores. The material parameters can thus be divided in ‘mechanical parameters’ and ‘acoustic parameters’.

The papers published by Sikora and Turkiewicz (2007), presenting the findings of preliminary research on acoustic properties of the selected granular materials, aroused interest among the manufacturers of noise control, including acoustic screens. Granular materials makes from processed solids that it would be possible to use them as the sound absorbing core in protection walls that limit the excessive acoustic activity of internal and external noise sources. New acoustic panels have been created, with layers of various using granular materials, and the results shows very good acoustic insulation.

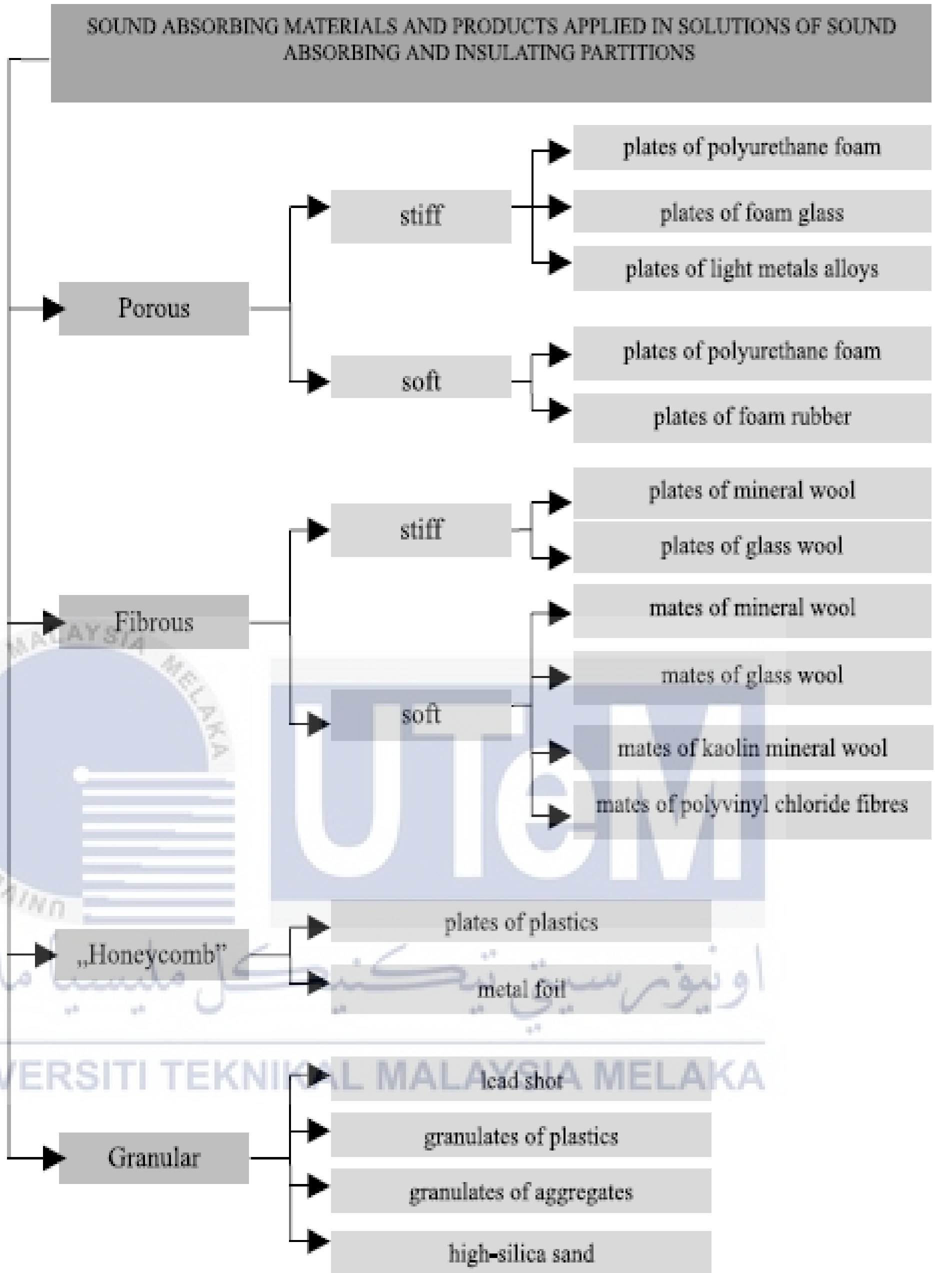

Figure 2.9: Classification of sound absorbing materials (Sikora and Turkiewic, 2007).

Berardi and Iannace (2015) stated that, fibers can be seperate into natural and artificial fibers in which artificial fibers consists fiberglass, mineral wool, glass wool or polymer (polyester). Natural fibers likes stalk or wood fiber, bast fiber or skin fiber, leaf fiber, fruit fiber and seed fiber such as cotton consists cellulose (Chandramohan and Marimuthu, 2011). A study by Berardi and Iannace (2015), natural fibers becomes as the valid raw materials for the sound barrier cause by producing low cost of sound barrier (Berardi and Iannace, 2015). Advantages likes provide an optional of no harmful effects on health and it is also can be treated from waste product of the other production cycles makes raw materials having good characteristics in thermal insulation properties.

Table 2.1: Sound absorption coefficient values of natural fibers as studied by Berardi & Iannace (2015).

Material		Thickness [m]	Frequency [Hz]					NRC
			125	250	500	1000	2000	
Kenaf	(Light)	0.06	0.09	0.19	0.33	0.68	0.90	0.55
	(Dense)	0.04	0.08	0.18	0.32	0.70	0.94	0.55
	(Dense)	0.06	0.10	0.30	0.61	0.99	0.95	0.70
Wood	(Fibers)	0.06	0.20	0.40	0.50	0.65	0.91	0.60
	(Mineralized)	0.03	0.05	0.10	0.10	0.20	0.40	0.20
Hemp		0.03	0.01	0.15	0.25	0.51	0.70	0.40
Coconut		0.05	0.10	0.20	0.34	0.67	0.79	0.50
		0.10	0.25	0.42	0.83	0.81	0.94	0.75
Cork		0.03	0.01	0.02	0.10	0.30	0.86	0.30
Cane	(Mixed)	0.04	0.05	0.10	0.35	0.54	0.58	0.40
	(Mixed)	0.08	0.10	0.21	0.56	0.52	0.68	0.50
	(Only wooden)	0.04	0.01	0.06	0.12	0.47	0.43	0.25
	(Only wooden)	0.08	0.07	0.15	0.46	0.39	0.66	0.40
	(Only bark)	0.04	0.10	0.12	0.38	0.64	0.62	0.45
	(Only bark)	0.08	0.10	0.26	0.63	0.54	0.89	0.60
Cardboard		0.10	0.10	0.27	0.48	0.54	0.66	0.50
Sheep wool		0.04	0.10	0.14	0.36	0.73	0.94	0.55
		0.06	0.15	0.28	0.66	0.95	0.94	0.70

2.3.2 Design

Mass loaded barriers with different weights limp spaced off a panel is a method of treatment for sound insulation. Sound insulation barrier has combination of different thickness of open celled foam layer. Moreover, relationship and big effect on the sound transmission loss of the system will overcome attachment method and the thickness of the open celled foam used between the treatment and the panel. Sound insulation panel has been invention using plywood, decoupling foam with mass loaded barrier as a treatment for sound insulation barrier design. Davy's models that manipulating the airborne and the structure-borne transmission path for this panel becomes reference for developing model that generated from sound transmission through cavity walls. In each of the increases thickness of decoupling layer, would increases also the frequency range from 250-1250Hz frequency range. For every increasing in the stiffness value, this fixture method decreased the sound transmission loss about 250-1250 of frequency amount (Wareing et al., 2015).

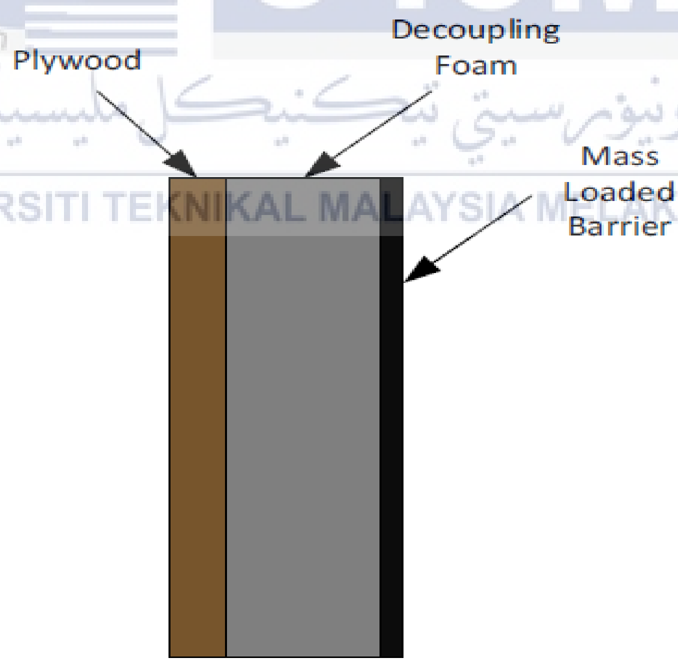

Figure 2.10: Sound insulation panel design by (Wareing et al., 2015).

A study by A. Jolibois et al, (2015), the tramway body and the barrier is multiple attenuate when face of the barrier directly exposed to the noise sources radiation with absorptive materials. T-shape design has been shown to be quite efficient. Therefore, an inverted L-shape covered on its interior part by fiberglass is proposed. Indeed, preliminary calculations showed that the difference between the T-shape and the inverted L-shape has a limited influence on the acoustic performance, but the L-shape barrier is significantly easier to handle and to transport. Besides, one can point out that if a long-term barrier was set-up, it would be necessary to consider a sustainable absorptive material or to properly package the fiberglass in order to avoid any health hazard related to its presence (Jolibois et al., 2015).

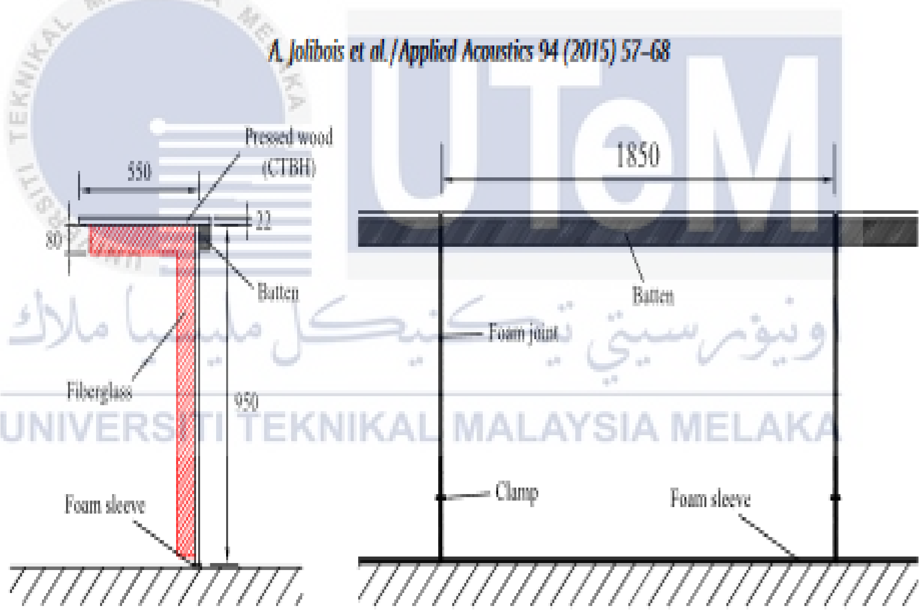

Figure 2.11: Schematic of the low – height barrier prototype (Jolibois et al., 2015).

Portability, affordability, recyclability, lightweight, and cost are few aspects that appraised enhance the acoustic performance all the design. Acoustic performance of sound absorption coefficient for sound absorption materials, sound reduction index or the weighted reduction of impact sound pressure level for every sound insulation materials is important option for designing noise barrier. Thompson has patented in England in 1875 of several different design of corrugated board that are mentioned in Secchi et al., (2016) studies for a new sound-absorbing and insulating elements in recycled cardboard design. This shows that determine the sound absorption coefficient influence by arrangement of absorption materials.

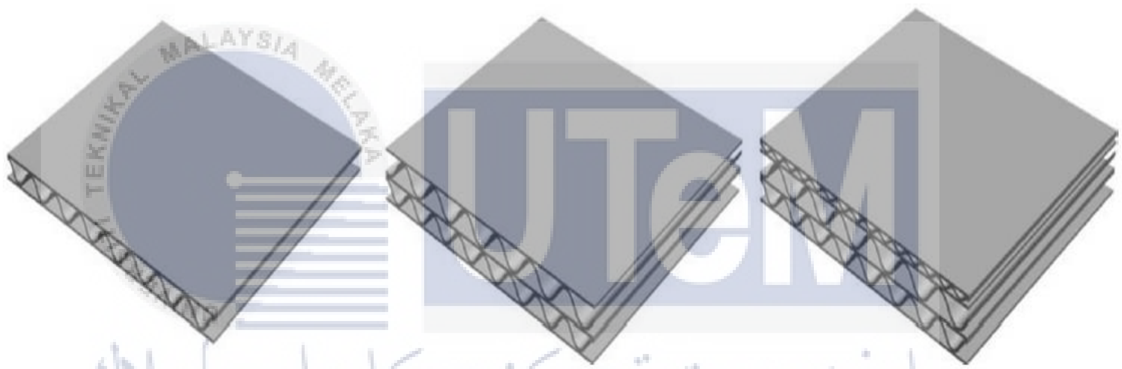

Figure 2.12: Image of different types of corrugated board, from left to right: single, double and triple wave corrugated board patented by (Thompson , 1875).

CHAPTER 3

METHODOLOGY

3.1 Research Design

To ensure the research and conducted the project going excellent and properly based on flow chart in Figure 3.1, research design is planned. The process started with material selected and noise barrier design for design process. Then, polyurethane foam becomes the main selected material and develop fabricate according the design. After that, the designed will be tested by using impedance tube and in – situ measurement to get the data resulted that are required for the experimental. Lastly, all the research planned data, resulted and analyzed will be wrote in the final report.

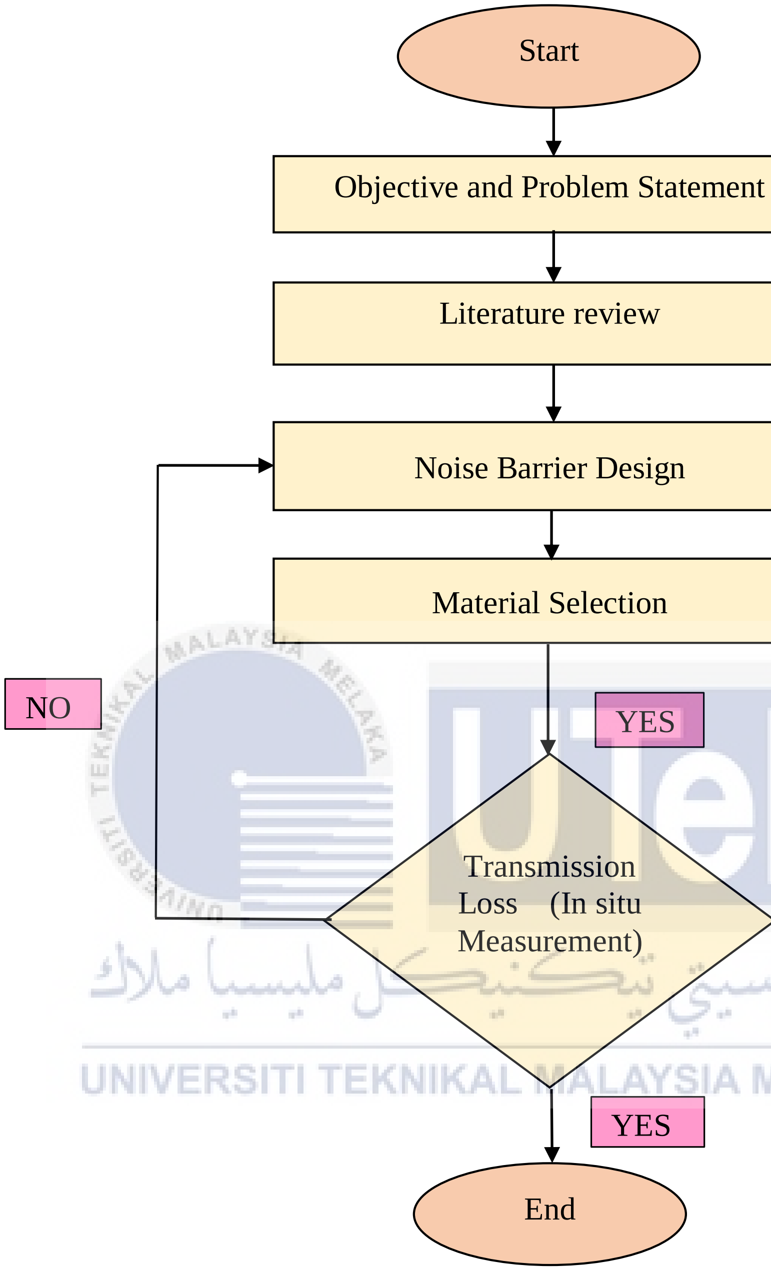

Figure 3.1: Flow chart of the research.

The overall flow chat is represented in Figure 3.1 which indicated the general research flow in this project. The process flows arrangement can be shown at foundation from the top to the bottom.

The research will be started by obtaining all information that related to this project by various sources such as journals, articles, book, handbook and many more. The information will be critically reviewed from literature focusing on noise barrier. Then, it would be used in developing a new innovative idea for the current study.

Then, the second phase will be carried out by selecting of specific materials that have possibility to give an improvement on a new design in noise barrier. The possible materials that will be used in this project as insulation of sound are polyurethane foam and textile waste material for modification transmission loss. Then, the selected materials will be applied in designing the project.

The study moves on to the third phase by focusing on developing the noise barrier consisting of perforated sheet application. At this stage, the new design of noise barrier will be created and tested for the effectiveness and performance analyses. This will be performed by cutting the perforated sheet, plastic gauze in certain diameter with drilled holes in micrometer size.

Next, the fourth phase will be started by testing the modification of sound transmission loss at plastic material as perforated sheet in sided the noise barrier. The instrumented for tested to get the resulted and data are from microphone, sensors, analyzer and computer monitoring. The result will be expected seen in spectrum analysis. If the performances shows a great improvement, the study will be proceeded to the next stage which is analysis of results and data. If not, it needs to start again at fabrication stage until get the significant results.

The study will end by analyzing the results critically in a discussion part and conclusion will be formed based on the achievement of the objectives. The most significant achievement will be highlighted at the end of this study.

3.2 Material Selection

3.2.1 Textile Waste

Textile waste usually comes from the clothes that are not in used anymore or from textile industry. According to Briga-Sá et. al (2013), building construction and in any other applications will integates recyclable material as textile waste (Briga-Sá et. Al, 2013). This material is very cheap and can be easily found at discarded from the industrial waste. Textile waste has potential to be sound absorption material based on their advantages that can be recycling into new form of woven fiber. This form will easily to be tested for noise barrier application.

Figure 3.2: Textile waste as absorption material (Gabor, 2016).

3.2.2 Polyurethane Foam

Polyurethane foam can perform greatly as an effectiveness noise absorption material when the high volume of open pores based on effective sound damping, low density, malleability in style and shape, and easy production. In addition, acoustic properties can be controlled due to cavities with interconnecting open pores and cell structure of polyurethane foam. Typical sound absorption materials, and various studies for determining the non-acoustic parameters of the foam have been performed to understand its acoustic behavior by polyurethane foam open cellular structures. Modification of cellular structures of polyurethane form can increase the efficiency of sound absorption. Moreover, polyurethane foam can reduce sound pollution by hybridizations of various nano and micro-particles in polyurethane foams (Gwon et al., 2016).

Figure 3.3: Polyurethane Foam (Tiuc et al., 2016).

3.3 Conceptual Design

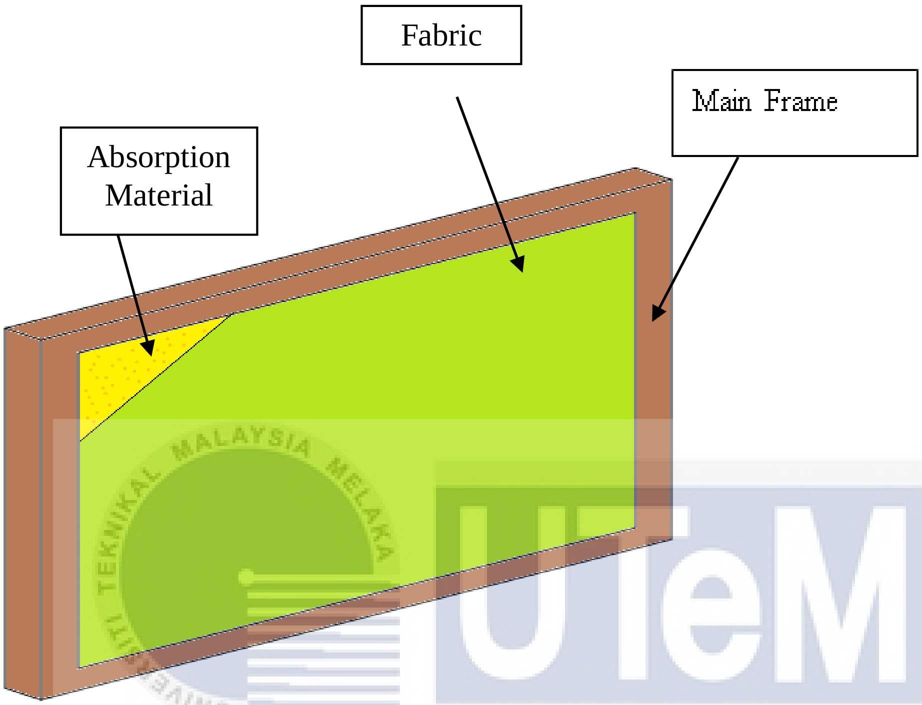

Figure 3.4: Conceptual design of noise barrier.

Developing a new noise barrier that attached to a wood frame to be hang up on the class in between the wood panel that segregate the two classes chosen for study. The main parts of the noise barrier are main frame, sound absorption material, and fabric. Main frame is made up by wood material because it is cheap and light in weight. Light in weight is very important criteria because this is become safety to the students. Students that seated around the wood panel have chance to get injuries if the noise barrier fall down around the area where the noise barrier will be hang up. This selected material of the main frame will contribute as a support to hold the sound absorption material and to attach the fabric together.

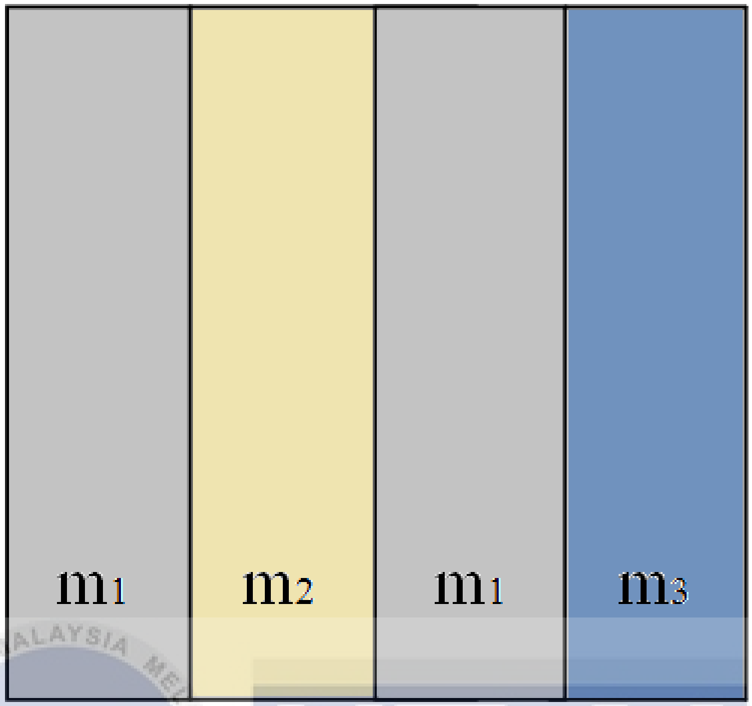

Figure 3.5: Sort of different material for sound absorption material arrangement.

Testing has been made on the arrangement of the absorption material for the noise barrier. Figure 3.5 shown the material that have been tested will be arrange in a few arrangement and lastly the final arrangement of sound absorption material will be used in the final noise barrier design to be tested by using the in-situ method in final test. Sound absorption coefficient and sound transmission loss will be the criteria for the material to be selected. The sound absorption coefficient and sound transmission loss value will be measured by using the impedance tube and in – situ measurement to ensure the best design of noise barrier could be developed.

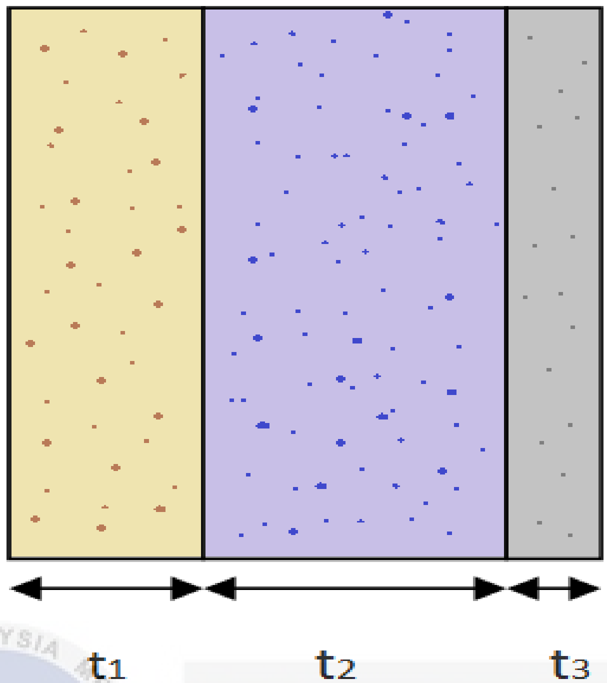

Figure 3.6: Different thickness of absorption materials.

In – situ method will be the final test after the arrangement test of the material. The arrangement of the material will be continue to the material thickness and layer arrangement of the absorption material. Figure 3.6 shown the different thickness for noise barrier design will be decided upon the sound absorption coefficient and sound transmission loss value for each of the material selected.

3.4 Measurement Procedure

3.4.1 In - Situ Measurement

According to Watts, G., and Morgan, P. (2007), CEN/TS 1793-5 is an in – situ measurement method for sound reflection. Moreover, intrinsic acoustic characteristics of an installed noise barrier and verify their compliance to design specifications after its installation aside of a road or a railroad can be identify by using this measurement. Quality of the installed barriers after some years of life also can be check by using same method. In addition, two signals that equivalent in normal condition can provide information for acoustical characteristics of a noise barrier. For example, discrepancies may occur between the acoustic characteristics of the same noise barrier in the same conditions secured using the two mentioned signals when excessive background noise or time variation of the system under test due to local meteorological instability.

Figure 3.7: Image of speaker placed in front of noise barrier.

In - situ measurement use loudspeaker and microphone for the test. The measurement were carried out to measure sound reflection. Based on the figure 3.7, set of loudspeaker and microphone is set up for the test includes in the testing method as the loudspeaker will engenders a sound that transmitted through the barrier to the microphone. The speaker is placed at five different angles position at 0°, 22.5°, 45°, 67.5° and 90° from the noise barrier. While, microphone will is placed at constant distance of 2m from the wall. Microphone functioning to record sound pressure level transmitted from the loudspeaker. By assume the Sound Pressure Level (SPL) equal to the sound pressure at receiver, the Sound Transmission Loss (TL) value can be calculated by using the equation (Eq 3.1) as follows:

TL = SPLsource – SPLreceiver **(Eq 3.1)**

Where, SPLsource = Sound Pressure Level at Source

SPLreceiver = Sound Pressure Level at Receiver

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and Discussion

This chapter will be focused on the analysis and interpretation of data collected from the experiment that has been done based on the methodology in Chapter 3. From the data, the discussion can be described by analyzing the reasons and factors for the occurrence of this result. This research aims is to test new develop noise barrier according In – Situ Measurement. To achieve the objective of this study, the selected material which are polyurethane foam and textile waste has been used as a sandwich structure. There are five tests that have been prepared. The noise barrier have been test in different angles which are 0°, 22.5°, 45°, 67.5° and 90°. The test is to know the sound pressure level that can reduce by noise barrier at different angles. The result for this study as tabulated in table 4.1.

4.2 Sound Pressure Level of Noise Sources

4.2.1 Sound Pressure Level with Panel and Without Panel at 0°

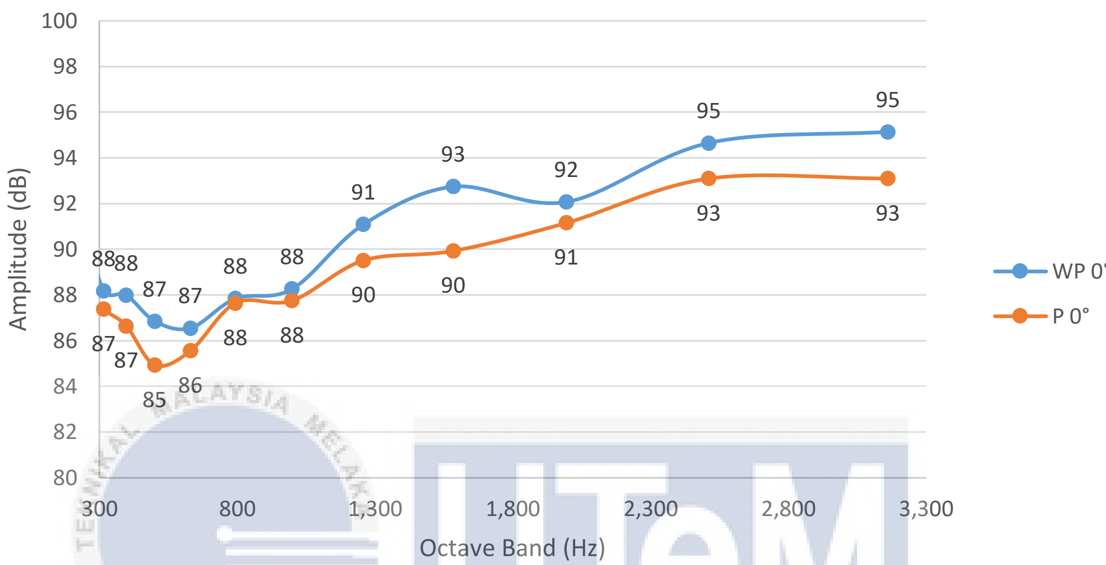

Figure 4.1: Sound Pressure Level with Panel and Without Panel at 0°.

The figure 4.1 has shown the comparison between sound pressure level (SPL) of white noise with and without panel at 0°. It interprets the noise pressure level in certain frequencies which start with 300 Hz until 3300 Hz. The highest the sound pressure level (SPL) for without panel is at frequency 3162 Hz and it eventually constant when frequency increases. While the highest the sound pressure level (SPL) for with panel is at frequency 2512 Hz and continue little decrease. The highest amplitude of sound level for without panel is 95 dB at 3162 Hz when refer to the graph spectrum. Moreover, the highest amplitude of sound level for with panel is 93 dB at 2512 Hz. Both of this result has different spectrum affected by alternative such as absorption, transmission and reflection. This spectrum will be compare with other spectrum by using noise barrier at different angles as reflection alternatives to losses and reduces the sound pressure of noise.

4.2.2 Sound Pressure Level with Panel and Without Panel at 22.5°

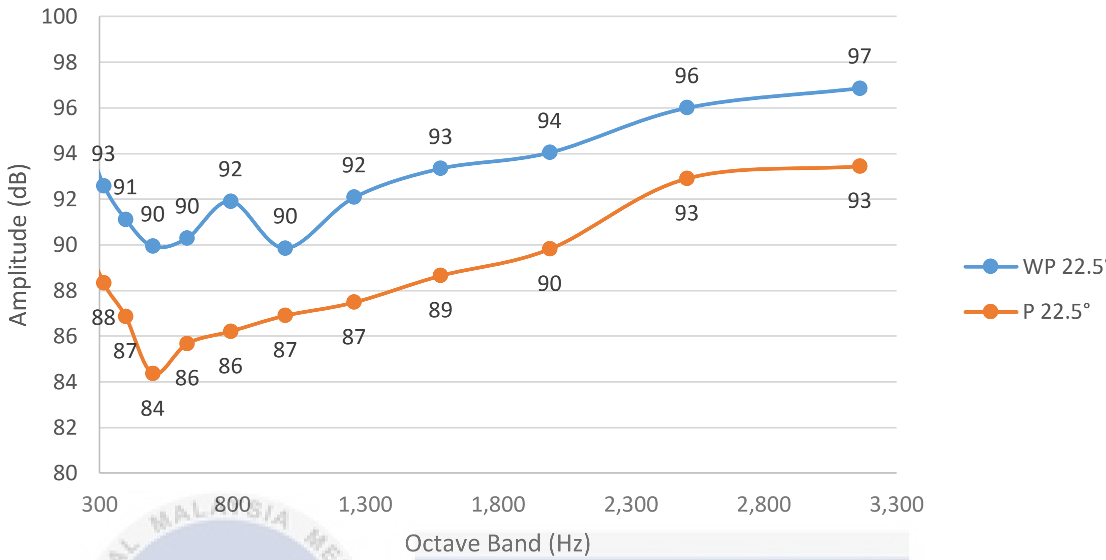

Figure 4.2: Sound Pressure Level with Panel and Without Panel at 22.5°.

The figure 4.2 has shown the comparison between sound pressure level (SPL) of white noise with and without panel at 22.5°. The highest amplitude of sound for without panel when refer to the spectrum is 97 dB at frequency 3162 Hz while the highest amplitude of sound for with panel is 93 dB at frequency 2512 Hz. Both spectrum it eventually becomes increase due increase of frequency. It seen a lot reduces of sound pressure noise when the noise barrier at position 22.5°. The maximum amplitude of noise is decrease to 93 dB from 97 dB when make comparison. For high frequency the SPL increase rapidly start from 800 Hz to 3300 Hz. Although the frequency increase but it has big gap reduction for amplitude.

4.2.3 Sound Pressure Level with Panel and Without Panel at 45°

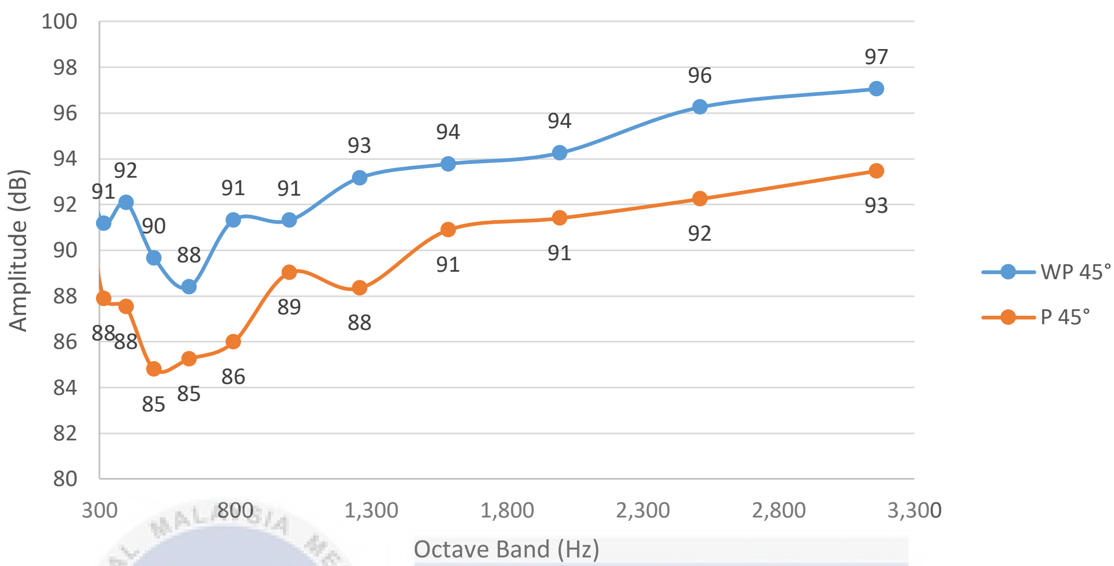

Figure 4.3: Sound Pressure Level with Panel and Without Panel at 45°.

The figure 4.3 has shown the comparison between sound pressure level (SPL) of white noise with and without panel at 45°. The highest amplitude of sound for without panel when refer to the spectrum is 97 dB at frequency 3162 Hz while the highest amplitude of sound for with panel is 93 dB at frequency 3162 Hz. Both spectrum it eventually becomes increase due increase of frequency. It seen a lot reduces of sound pressure noise when the noise barrier at position 45°. This situation same like position at 22.5°. The maximum amplitude of noise is decrease to 93 dB from 97 dB when make comparison. . For high frequency the SPL increase rapidly start from 1300 Hz to 3300 Hz. This means high reduction of noise is achieved at this frequency range.

4.2.4 Sound Pressure Level with Panel and Without Panel at 67.5°

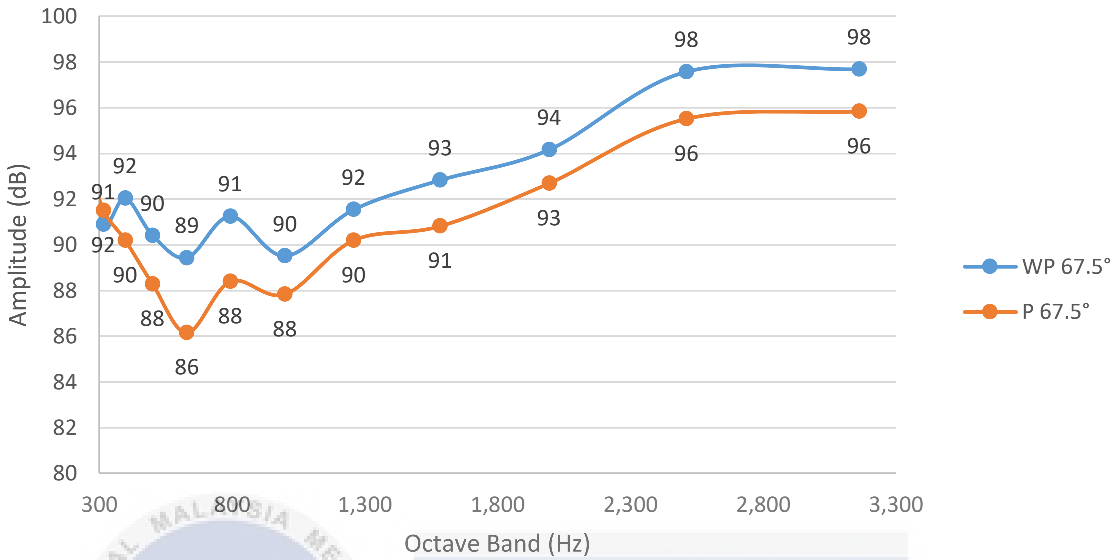

Figure 4.4: Sound Pressure Level with Panel and Without Panel at 67.5°.

The figure 4.4 has shown the comparison between sound pressure level (SPL) of white noise with and without panel at 67.5°. The highest amplitude of sound for without panel when refer to the spectrum is 98 dB at frequency 2512 Hz while the highest amplitude of sound for with panel is 96 dB at frequency 2512 Hz. Both spectrum it eventually becomes increase due increase of frequency. The maximum amplitude of noise is decrease to 96 dB from 98 dB when make comparison. For high frequency the SPL increase rapidly start from 1000 Hz to 3300 Hz. This means high reduction of noise is achieved at this frequency range.

4.2.5 Sound Pressure Level with Panel and Without Panel at 90°

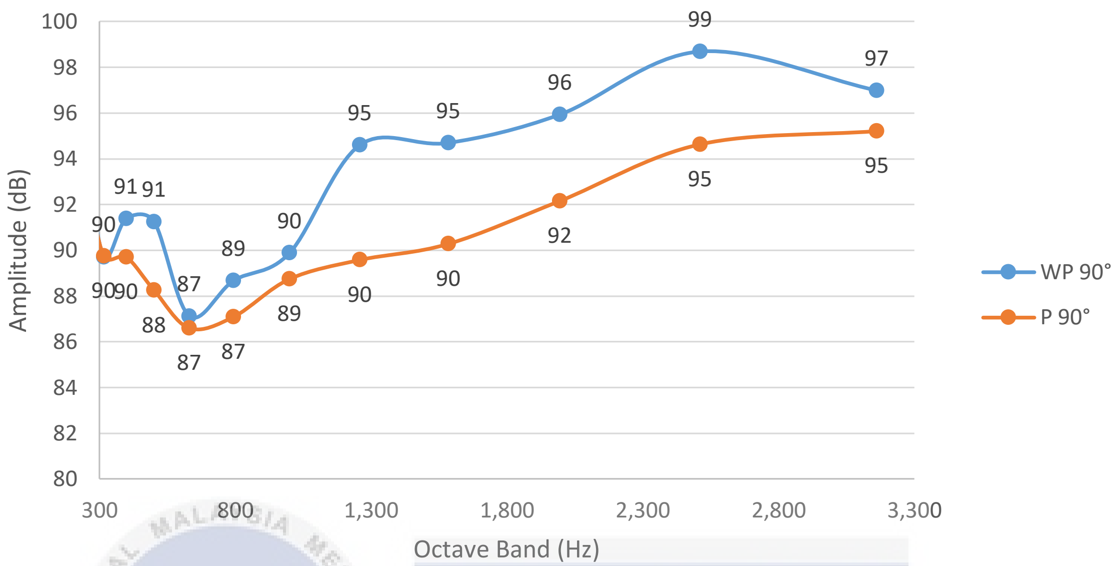

Figure 4.5: Sound Pressure Level with Panel and Without Panel at 90°.

The figure 4.5 has shown the comparison between sound pressure level (SPL) of white noise with and without panel at 90°. The highest amplitude of sound for without panel when refer to the spectrum is 98 dB at frequency 2512 Hz while the highest amplitude of sound for with panel is 95 dB at frequency 2512 Hz. Both spectrum it eventually becomes increase due increase of frequency. The maximum amplitude of noise is decrease to 95 dB from 99 dB when make comparison. This spectrum shows the highest amplitude with 99 dB among with others spectrum. For high frequency without panel shows that the SPL increase rapidly start from 631 Hz to 2512 Hz. However, it turn decrease when continue frequency to 3300 Hz. In addition, for high frequency with panel shows that the SPL increase rapidly start from 631 Hz to 3300 Hz.This means high reduction of noise is achieved at this frequency range.

4.3 Comparison Sound Pressure Level without Panel

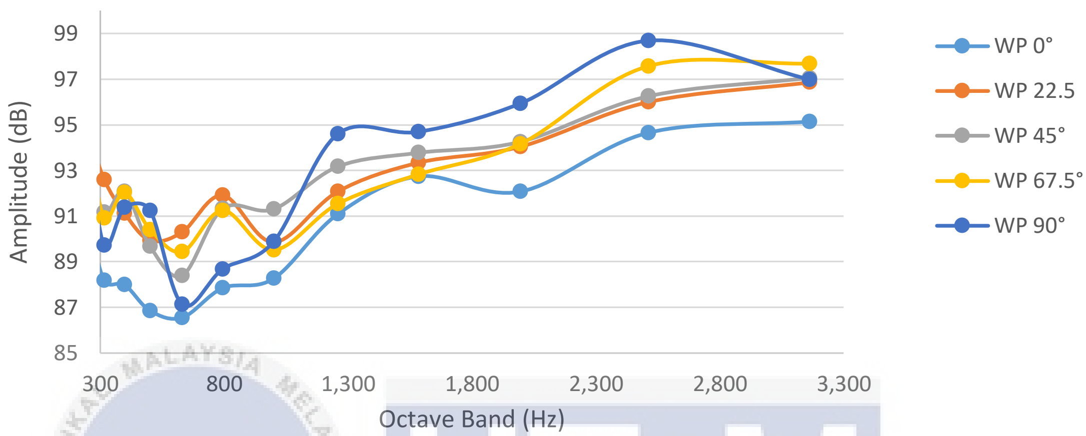

Figure 4.6: Comparison of Sound Pressure Level without Panel at 0°, 22.5°, 45°, 67.5° and 90°.

As stated by Bruel and Kjaer (1986), reducing noise in building at the beginning by planning the building at the beginning. It is added that, important details of the building's load bearing structure and work site must be measured and calculated to be solved any potential risk that might be exist in future by eliminating the possibility of the problem in the planning level (Bruel and Kjaer , 1986). The spectrum analysis based on Figure 4.6 shows the results of comparing sound insertion losses from the sound of noise transmitted without panels at different position of angles .The graph shows 5 line spectrums in different colors representing their analysis of comparing insertion losses. The measurement is not considered at 0 Hz to 300 Hz because of the limitation of the acoustic microphones sensitivity.

From the graph, after make comparison between five different lines color of the graph, the highest peak of amplitude is at 2512 Hz (position 90°) and with the 99 dB of insertion loss of noise. While other lines graph show the highest achieved of insertion loss of noise are 98 dB but differences of octave band which (position 67.5°) at 2512 Hz. Moreover, other lines graph show the highest achieved of insertion loss of noise are 96 dB but differences of octave band which (position 45°) and (position 22.5°) at 3162 Hz. The results indicate different impact of noise that influenced in increment of insertion loss sound of noise or decrement sound of noise.

4.4 Comparison Sound Pressure Level with Panel

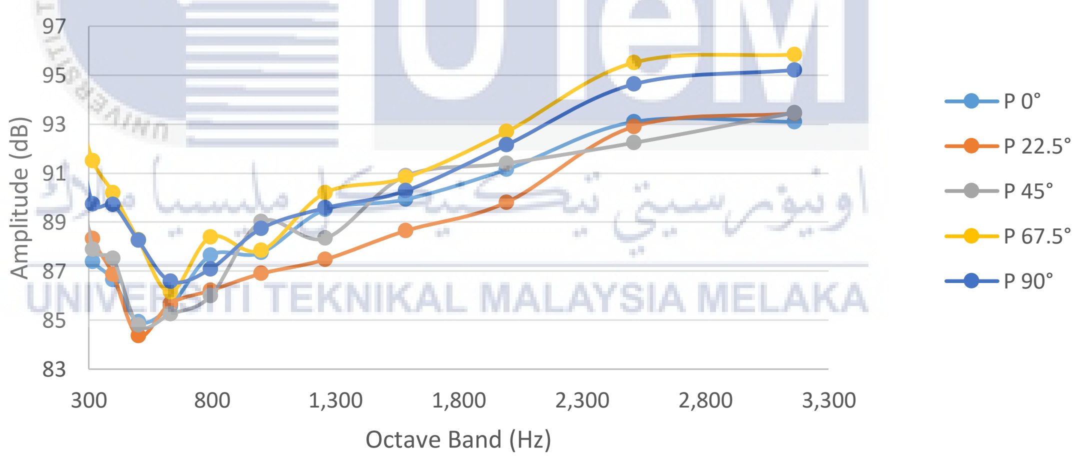

Figure 4.7: Comparison of Sound Pressure Level with Panel at 0°, 22.5°, 45°, 67.5° and 90°.

Bruel and Kjaer (1986), mention that building elements should be put away in position from equipment that vibrates and installed with a joint of elastic elements. Apart from that to reduce noise in building, the selection of walls, ceiling construction, windows, doors and any other material that contributes in leaking of noise from being transmitted to keep the buildings with good sound insulation (Bruel and Kjaer , 1986). The spectrum analysis based on Figure 4.7 shows the results of comparing sound insertion losses from the sound of noise transmitted with panels at different position of angles .The graph shows 5 line spectrums in different colors representing their analysis of comparing insertion losses. The measurement is not considered at 0 Hz to 300 Hz because of the limitation of the acoustic microphones sensitivity.

From the graph, after make comparison between five different lines color of the graph, the highest peak of amplitude is at 2512 Hz (position 90°) and with the 99 dB of insertion loss of noise. While other lines graph show the highest achieved of insertion loss of noise are 98 dB but differences of octave band which (position 67.5°) at 2512 Hz. Moreover, other lines graph show the highest achieved of insertion loss of noise are 96 dB but differences of octave band which (position 45°) and (position 22.5°) at 3162 Hz. The results indicate different impact of noise that influenced in increment of insertion loss sound of noise or decrement sound of noise.

4.5 Sound Transmission Loss

Noise pollution in building closely associated with human. When the surrounding noise level is same as speech level, the intelligibility rates would be decrease to 95% due to redundancy of speech that lead to unpleasant conversation because of sound interference (Lazarus, 1987). The Sound Transmission Loss (TL) measurement is used to identify the acoustic characteristics of noise barrier by measure sound pressure level of no panel and with panel. The Sound Transmission Loss from the noise barrier application is derived by using the equation (Eq 4.1).

TL = SPLwithout panel – SPLwith panel **(Eq 4.1)**

Where, SPLwithout panel = Sound Pressure Level Without Panel
SPLwith panel = Sound Pressure Level With Panel

Table 4.1: The results of transmission loss of noise barrier with panel and without panel at 3100 Hz frequency.

Angle Speaker to the Wall (°)	**Distance Microphone to the Wall**	**SPL without panel (dB)**	**SPL with panel (dB)**	**Transmission Loss (dB)**
0°	2m	95	93	2
22.5°	2m	97	93	4
45°	2m	97	93	4
67.5°	2m	98	96	2
90°	2m	97	95	2

From the Table 4.1, at 3100 Hz the sound transmission loss can be range from 1 dB to 4 dB. The transmission loss at 0°, 67.5° and 90° angle of speaker to the wall shows the same small amount of noise transmission loss reduce by the noise barrier at 2 dB. While the highest amount of transmission lost shows 4 dB of reduction which is at 22.5° and 45°. This proves that by choose appropriate position angles of noise barrier will affect the transmissin path in order to reduce noise.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

Students and lectures has been exposed to the noise pollution disturb the lectures session are being conducted between these two classes at the same time. The students and lecturers in factory 3 FTK, UTeM Industrial Campus having experienced on feeling annoyance due to noise interference while the learning session are being conducted. Voice coming out from human voice projection in BK 38 possibly leaks into BK 37 at some of times during lectures session that being conducted surely will bring an annoyance condition to the students and the lecturer that affected by the noise pollution. The wood panel that separated between two classes not be able to reduce noise. Based on the results obtained after the experiment carried out by referring to the several literature reviews, the work of this research can be concluded that:

1. Noise barrier panel has been designed by using sandwich structure design by insert recycle fabric layer in between the polyurethane foam. Polyurethane foam has been chosen based on the result from impedance tube testing. Impedance Tubes can accurately measure sound absorption coefficients and impedance according to ISO or ASTM standards. Polyurethane foam has been selected as a material chosen because it characters that very high volume of open pores based on effective sound damping, low density, malleability in style and shape, and easy production.

2. Testing the performance of noise barrier by using in-situ measurement. The testing has been held at BK 37 to BK 38 by using set of speaker, laptop and acoustic microphone. Set of speaker will generate white noise at BK 37 then the sound will be transmitted in angles position through the wall into BK 38 to the acoustic microphone. The speaker has been placing at 5 different angles position distance measured of 0°, 22.5°, 45°, 67.5° and 90°. The testing has been conducted in two conditions which are hanging the noise panel to the wall and without hanging the noise panel to the wall. Good results has been shown by polyurethane foam in high frequency as referred to the result of the sound pressure level transmitted from BK 37 to BK 38 from range of 2000 Hz to 3200 Hz. Normal human sound intelligibility can be ranges from 1000 Hz to 2000 Hz. With the added of recycle fabric in between the polyurethane foam shows that it is effectively reduce the amount of sound pressure level at 1000 Hz to 2000 Hz as well. The result was successful based on the testing which is the noise barrier success to reduce noise between 1 dB to 4 dB.

5.2 Future Works

In order to reduce disturb the sound transmission from being fully passing through to the wood panel in BK37 to BK38, noise barrier becomes main idea to interrupt. Noise panel will be hanging on the wood panel as function to eliminate excessive noise from being transmitted sources into receiver. After the noise barrier have been developed there are some points that could be bold and considered to be includes in future works, in order to have effective noise barrier. The recommendations are listed as below:

1. Ensure the material in the sandwich structure on the noise barrier fit, no space or gap in combination between parts with parts. This means make sure no air space out and in. From that sound entry inside silencer cannot easily pass through gap between combination parts. When this problem happened it will affect the spectrum and waveform of sound graph. To make better result every edges and circumferences between combination parts put more adhesive or clay, so no sound entry can go through outside.

2. Use different type of material on noise barrier panel influence the sound absorption coefficient of the noise barrier. In order to reduce noise pollution in human intelligibility, the materials that need to be used can be selected by the materials that good in absorbing the sound transmission at range of 1000 Hz to 2000 Hz in frequency. Thus, the materials would be more specifically good for reducing noise in the class room purpose.

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