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Attenuation of Noise by Using Absorption Materials and Barriers: A Review

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ABSTRACT

Problem Statement: The high level noise is harmful for all people especially in heavy factories. In accordance with ear human biodynamic response, health damages of body are resulting of hearing loss, with increasing blood pressure ,weakness and tired.

Approach: This paper holds three works. First, it reviews an introduction on synthetic materials for absorption. Second, it summarizes on organic materials considerations for acoustic absorber in currently. Finally, it offers a review on research of using barrier and screens.

Results and Conclusion: It is obvious that the need of absorption materials for attenuation noise via development and regeneration along with the need for innovative natural materials of their essential properties so as to meet the high level noise is today greater than ever. The motivation behind of this project is based on the fact that during the last few decades synthetic material has been used for sound absorption, but the study area has been dramatically changed. However at the same time there is a realization that certain parts of the synthetic material has been left because it causes many problems in health. Therefore, currently organic materials present good alternative to synthetic material providing good health with green environment as well as enhancing natural agricultural and growth.

Keywords: *synthetic material, organic material, barrier and screen.*

1. INTRODUCTION

A comfortable environment free from unwanted noises is always dream of every person. One of the sources of unwanted noises is the sound emitted by vehicles, heavy construction machine, and heavy factories like electrical power plant. In heavy factories, workers are exposed to continuous noises the whole work day. This discomfort may leads to some injuries such as hearing loss (temporary or permanent), weakness in nerve, pain in internal tissues, heart problems, and even higher blood pressure in long term. The most prominent physiological problem caused by unwanted noises is ear pain (HL). Not only that chronic contact to high noise levels, a common characteristic of many workplaces has also been linked to excess danger of acute myocardial infarction (Babisch,; 2000,; Davis, et al.,; .2003).

The effect on blood pressure of occupational noise irritation and its mutual effect with social support at work, nightshift work, and work contentment were studied and an obvious effect of noise annoyance on diastolic blood pressure (DBP) was found. A long exposure to noise over 85 dB (A) might be a dangerous factor for high blood pressure (BP), and it may induces major increases of (BP) among sensitive individuals. Studies on the effects of workplace factors and sources of unwanted noises and the characteristics of emitted noises on risk of injury have revealed that along hour exposure to constant noise may result in hearing loss and pain. Workers working in factories face higher risk, for example the boiler workers that are exposed to high level of noise while do their jobs. (Pan, et al., 2003; Fechter, et al., 2004; Pouyatos and Gearhart, 2005). This type of negative exposure to high levels of noise not only leads to psychological and physiological problems; it also brings different kinds of negative influences. As a result, it will cause deterioration in working efficiency.

2. SYNTHETIC ABSORPTION MATERIALS

Utsuno et al. (1989) improved the measurement of sound absorption properties in the “two- cavity" of two different porosity substances. By using the transmission function way for the wide frequency zones, it becomes easier for

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measure impedance properties and propagation. In addition, the thickness of the porous substances and deepness of the vacuum antenna are two acoustic absorber factors that can affect sound impedance.

Takahashi (1997) presented a novel theory to predict the organization of acoustic absorber with random mix of air gaps layer backing the rigid frame. The impact of the diffraction phenomenon in this form is due to the interruption of surface resistance on the borders, which was neglected in previous studies. Nevertheless, the empirical outcomes were consistent with the numerical outcomes within all the frequencies used empirically.

Braccesi and Bracciali (1998) examined acoustic properties of porous materials, the effects of reflection coefficient of resistance to flow, and structural composition of porous materials though a simple test experimental. The results were verified using the least square method. Kung and Fuchs (1999) presented the way theory to predict absorb interlace texture and envelope of synthetic materials with micro- holes backed via space air. Using the structures cited above, the outcomes showed full compatibility with the measurement, this means the absorption is high. Normally, a multi-layer porous material can increase the noise absorption range to 4-5 octaves instead of 3-4 octaves.

Subsequently, Gardner et al. (2003) studied of neural networks of polyurethane foam to expect the acoustic characteristics. He and his co-workers suggested a neural network model to gauge multiple parameters such as frequency, the flow of air resistance, and acoustic density. Meanwhile, Kosuge et al. (2005) examined sound absorption materials with non woven fabric and are composed of para-aramid fiber and polyester fiber instead of conventional materials such as glass wool, flame-retardant foam, and flame-retardant PET fiber. The flame-retardant properties were investigated using ISO 9237 and Federal Motor Vehicle Safety Standard FMVSS 302. The sound absorption properties by normal incidence can be found in ISO10534-1.

Chen et al. (2000) studied the sound absorption of porosity substance on different surfaces. The sample panels were perforated using the efficiency of finite element formula derived from Galerkin residual method and Helmholtz wave propagation equation. Microphones were used to test the impedance tube which is in turn used for measuring absorber coefficient parameter important for Ingard and Dear impedance tube system. The selection of porosity substances at four various forms such as triangular form, arc, curved, oblong and panel form appears to influence the flow resistance of sound.

Yang et al. (2001), on the other hand, tried to improve the performance of a new component named porosity coated components substances (PLCM) which has lower melting point. This type of component is very thin and light if compared to other materials. Although prediction on the inflow resistance to further calculate the acoustic absorber characteristics can be done mathematically, the validation was done by simulating a model. Then, a comparison was done between experimental outcomes and simulated model. Lee and Chen (2001) developed an analytical acoustic transmission analysis to evaluate the acoustic absorption of a multi-layer component which is consisted perforated plates, air spaces, and porous materials. The velocity and the effects of continuity particles are taken in to account. This successful development has demonstrated the design of multi-layer acoustic absorbers.

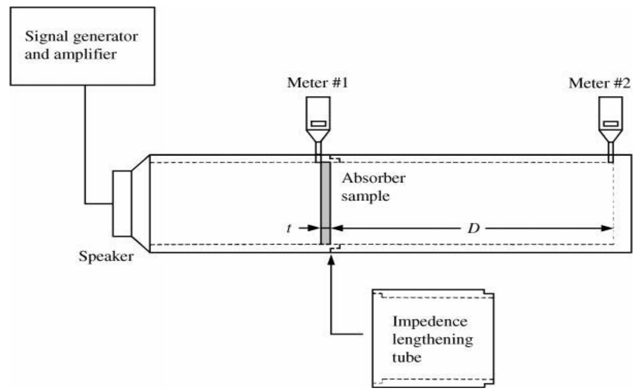

Figure 1: The modified Ingard and Dear impedance tube system.

Lee and Kwon (2004) investigated the validity of the performance of sound absorption coefficient for perforated plate by comparing the analysis of acoustic and electrical circuits using the matrix transfer method. The results were also compared with the absorption coefficient which was analytically calculated using the tube resistance of two microphones. The two results were in complete agreement at low-pressure sound. Furthermore the arrangement and dimensions of the plate and the number of holes effectively influenced the sound performance of perforated plate. Congyun and Qibai (2005) calculated the acoustic impedance for multi-layer absorbers such as perforated plates and air space or perforated plates and porous materials by using an iterative method of three types of multi-layer absorbers to calculate the absorption coefficient. Validated experimental results indicated that this method was feasible.

Lee et al. (2005) studied the absorption of acoustic perforated panel using the analytical model and a suitable simplified formula. The results were comparable with each other except for frequencies resonant to the higher values of the influence sound as the acoustic media was parallel to the surface of the perforated panel. This caused the measurements and theory outcomes to be consistent. Hence, to diffuse the vibration energy, a suitable thickness, hole diameter, and the spacing between holes need to be selected to increase the sound absorption capability. Also, the impact of structural damping can increase the absorption performance of resonance frequencies. Meanwhile, Wang and Cho (2005) studied on the development of a theoretical formulation to find out the spreading of sound through a solid yet porous anisotropic material. Based on the findings of the Amedin et al. where the results of isotropic and anisotropic materials were made and evaluated using the numerical analysis, the frequency and density of materials affect the spreading of sound and in addition, the anisotropy effect cannot ignore.

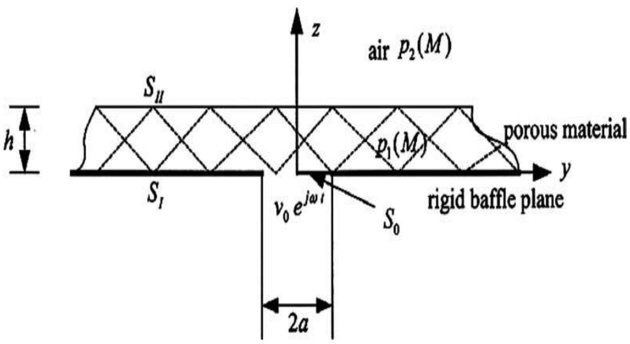

Figure 2: Configurations of the problem

Sgard et al. (2005) presented establish rules for the development of practical design solutions of optimal noise control using two models: the analytical model based which is based on" homogenization techniques", and the numerical models depends which depends on "finite element individualized domains". Selection is made based on the assessment criteria, for example "resistance, porosity, tortuosity, microscopic medium". These parameters are connected to the mesoporous materials' thickness which in turn governs the appropriate choice of microscopic medium.

Murugan et al. (2006) used recycled substances by conducting waste operations and re-casting the polyolefin mixture with metal chips. With reduce volume bigger than 30 times using two re-casting operations, the resultant product exhibited good characteristics of sound absorption and sound attenuation by adding 2-3% by weight coconut fiber core and polystyrene. Pfretzschner et al. (2006) also suggested the use of alternatives to help increase the absorption process of plate and the design of these alternatives practically involves the selection of two plates different which both contain numerous and distributed holes over the surface of plates. The holes should not affect the structural mechanism.

On the other hand, Zhou et al. (2006) estimated the performance micro-perforated absorber by equivalent circuit. There is also another method that adopted the coefficient absorption of double layer micro perforated using impedance transfer. When these two methods are compared, experimental monograph showed that the impedance transfer method was better than equivalent circuit.

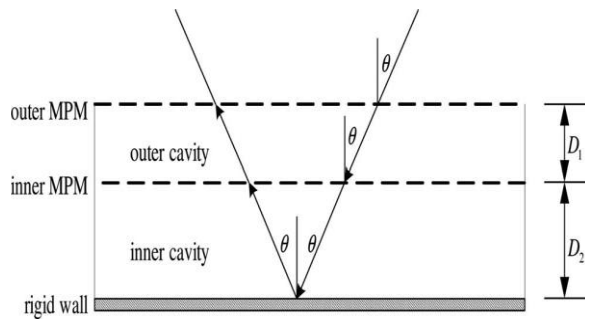

Figure 3: Schematic of double-layer micro-perforated membrane (MPM) of oblique incidence

Kino and Ueno (2007) proposed a new model which is more accurate than "Johnson-Allard" and suggested normal incidence for prediction of absorption coefficient. This is because the "Johnson-Allard" model, which is of rigid framed fibrous materials, can only measure related to the normal absorption coefficient. These parameters are" porosity, flow resistivity, tortuosity, and two characteristic lengths". The outcome was relatively poor and to obtain more precise and better low flow resistivity, seven glass wool and six polyester fiber samples were tested.

Panteghini et al. (2007) clarified their engineering analysis using the finite element method (FEM) to find out the absorption coefficient of ply wood, glass wool and perforated panel. The test was done in a mid-size room and the response frequencies layer was less than 200 Hz. Using numerical methods, in perforated panels, the result is presented through describing the particles' motion in term of their pressure-velocity relationship. Meanwhile, plywood and glass wool showed similar results.

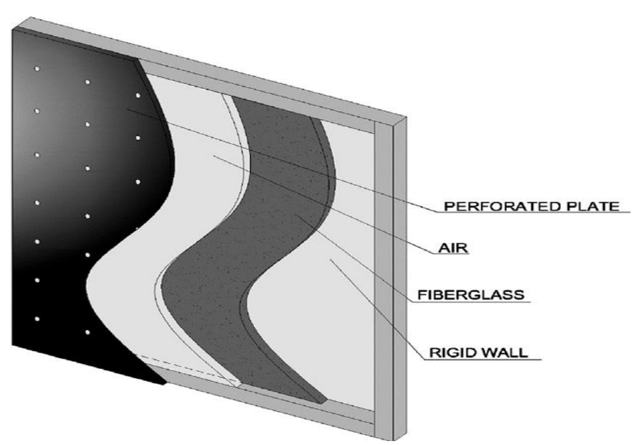

Figure 4:Typical structure of a perforated panel.

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Despite the fact that many studies on the synthetic absorption materials have been published, Hong et al. (2007) presented a new type of acoustic absorption by designing identical impedance to develop susceptibility acoustical absorbing ability. The impact damping of effect follows the basic of resonance through the visco-thermal mechanism.In this paper, it was stated that the impact of second- hand rubber particles are on the characteristics of compound acoustic absorption and estimation. The sound impedance was confirmed by analyzing the transport sound of components and coefficient of sound absorption in lower frequencies.

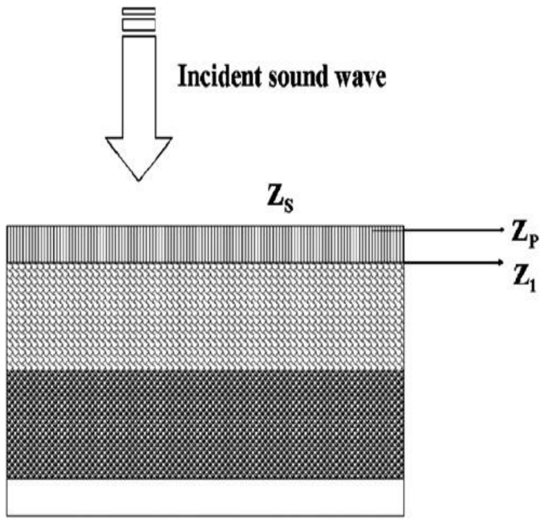

Figure 5: Generalization of acoustic transmission analysis diagram of composite absorber.

Meanwhile, Jaouen et al. (2008) provided an experimental method to characterize the acoustic properties of melamine foam. The acoustical effectiveness depends on the frequency and damping characteristics. The testing was done in five ways, and the deflection between of the melamine foam was recorded. The experimental outcome is not applicable to all porous materials, but it gives a preliminary estimate of the accuracy of the parameters. Also the testing procedure may be applicable for many substances through trial and error method.

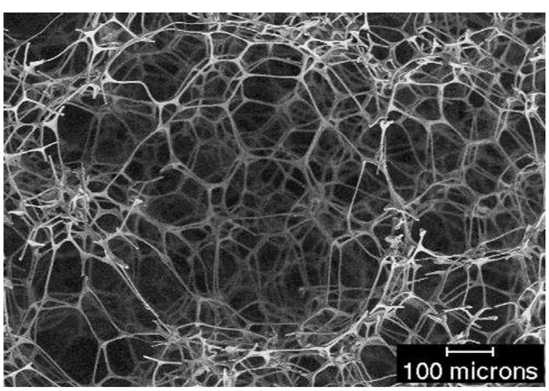

Figure 6:Electron microscope picture of the tested melamine foam. The solid phase, or skeleton, of the foam appears in white.

3. NATURAL FIBER ABSORPTION MATERIALS

In practical applications, most sounds absorbing materials are synthetic materials because they are available in the markets, but they induce health risks to lungs and eyes. Therefore, researchers have looked into natural and agricultural waste to find alternative materials. This type of material has many benefits, for instance they are cheaper, nonabrasive, and renewable. Also, these organic substances impose less health and safety issues during processing. However, Jan et al. (2004) reviewed on the environment impact of natural fibers and concluded that the impact of waste generation such as organic production was found more than the synthetic products.

Khedari et al. (2003) studied on new particle boards manufactured using durian peel and coconut coir fibers in order to achieve the lowest thermal conductivity to decrease heat transferred into space. In terms of heat reduction, these agriculture wastes are an economical and interesting option that could be utilized for insulating ceiling and walls. After a year, Khedari et al. (2004) discovered a particle board of low thermal conductivity manufactured using a mixture of durian peel and coconut coir, at an optimum ratio of 90:10 (coconut coir to durian) by weight. The density was 856kg/m³, thickness was 10 mm, and the ratio of extracted coconut coir and durian fiber was quite low, with their differences between 0.0728 and 0.1342 W/m K.

Zulkifli et al (2008) studied on the transmission loss index and acoustic absorption coefficient and made a comparison between them by using natural organic fiber perforated panels with or without filler. The result from experimental works and simulation of multi-layer coir fiber showed good absorption coefficient in reducing noise in all spaces.

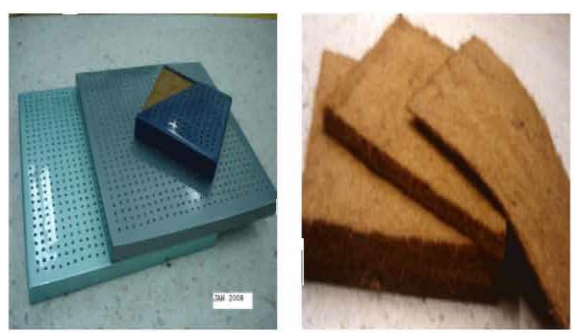

Figure 7: Perforated panel using coir fiber as an absorption material

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Meanwhile, Ersoy, and Kucuk (2009) investigated the sound absorption of an industrial tea leaves waste developed into three different layers with or without single backing layer of woven textile cloth to test experimental properties of sound absorption. The data indicated that the sound absorption properties increased by increasing the thickness of the layer with single backing cotton cloth layer. This means that the natural material and renewable material has positive sound attenuation properties and most importantly, it poses lesser or no harm to human health.

On the other hand, Ayub et al. (2009) investigated the sound absorption capability of coir fiber and considered the effect of adding air gap to increase absorption at lower frequency range. Experimental measurements by using impedance tube and calculated using Delany- Bazley equation at three different thickness 20mm, 35mm, and 50mm with air gap of 20mm for panel, showed higher absorption coefficient when the air gap is from 0.6 to 0.95 at low frequency range (1000Hz to 1500Hz). The" Johnson-Allard "model of perforated and multi-layer plate has been reported to give the best sound absorption capability at lower frequency.

Figure 8: Experimental set up for experiment in impedance tube.

In the same year, Zulkifli et al. (2009a,2009b) investigated on the effect of various sizes and air gap thicknesses on perforated plate in receiving a sound emitted according to ISO standard 354(1985) for noise absorption in low and high frequencies. Sakagami et al. (2009) considered analyzing model for the acoustic absorption of vibration on the microscopically perforated membranes plates' surface. "Using an electro-acoustical equivalent circuit model". He indicated that the plates can be converted through the control of ratio of perforator to understand the phenomenon of absorption through the plates.

Boonen et al. (2009) presented the calibrating way to increase the precision analogy of sound impediment on the basis of measured impediment of the solid wall at different sites of the original section. The transmission of many identical waves will get rid of the acoustic speed. Some sensors showed nil record when it is determining the properties of transport function among earphone in numerous original sites. The result showed impedance between 30-40 dB.

Figure 9: Laboratory setup for acoustic impedance measurement

Ayub et al (2009) explored the capacity of sound absorption of natural coir fiber using Delany-Bazley-model for three coir fiber samples by increasing the thickness, which means increasing the absorption coefficient. The performance is more promising at lower frequency. Increasing the air gap gives almost the same noise coefficient at lower frequency too, and by comparing the performance of samples with and without air gap, the result indicated that by increasing the thickness of sample with air gap, the absorption coefficient increases more than that without air gap.

Yang et al. (2011) studied the absorption coefficient of four fiber assemblies, cashmere, goose down, and kapok. These are natural and acrylic fiber. The natural fibers had distinctive internal structures which would influence the sound absorption coefficient, which were measured according to their mass, sound frequency, and air gap to check the contribution of solid fiber against air. These fibers showed good performance at low to medium frequency, but the performance deteriorated at higher frequency. Therefore, at lower fiber density, and smaller diameter as well, the fibers are able to show good absorption coefficient performance.

Fouladi et al. (2010) investigated the arrangements suitable to enhance the sound absorption. The results showed that when perforated plate is backed by coir fiber and air gap, porosity of plate has great influence on the sound absorption capability at low frequency. It was also derived that perforated plate might improve the low frequency absorption of coir fiber, but at the same time the medium frequency absorption was reduced. This effect was noticed previously in coir fiber-air gap structures, when the air gap thickness increased. The advantage of using perforated plate was that it assisted in greatly reducing the air gap thickness under the same acoustical performance. Hence, it is an efficient tool to

reduce the thickness of acoustic isolators in practical purposes.
In recently investigation, Zulkifli et al. (2010) analyzed the compression effect of porous layer on absorption feature of coir fiber, which can be used for automotive acoustical application. Meanwhile, Jailani et al. (2010) explored and analyzed the effect of various factors of coir fiber by using "Johnson-Allard" rigid frame modeling on the acoustic absorption. The results indicated that the layer's thickness and fiber diameter have an important effect on the absorption behavior of coir fiber, while the effect of density has no any important effect. Mahzan et al. (2010), on the other hand, investigated the feasibility of composite from coconut coir, with addition of second-hand tube rubber, for sound absorption material, as possible substitute of industrial and metal fibers.

Arenas and Crocker [2010] compared among ancient and new substances for their acoustic porosity. New substances are developed at higher quality and perfected to become safer and thinner, thus they are more effective in decreasing noise.

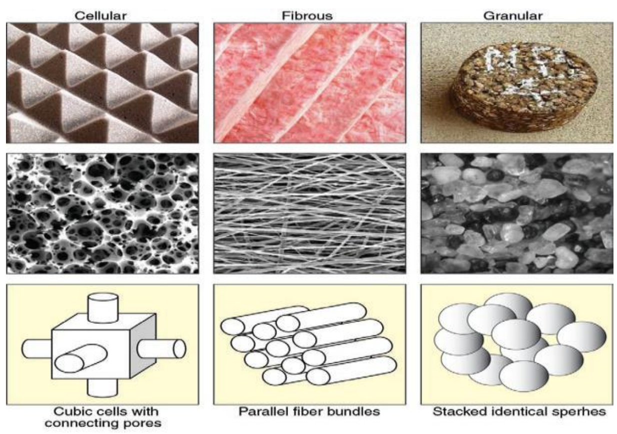

Figure 10: The three main types of porous absorbing materials.

Fouladi et al. (2011) studied on absorption coefficient for fresh and synthetic coconut fibers, mixed with a binder, and the analysis was performed using the typical "Delaney-Bazley and Biot-Allard analysis". Study found that the binder additive is not sufficient to improve the absorption coefficient for lower frequencies, so to improve the properties of the absorption sound, the added materials must be able to improve properties such" stiffness, fire retardant, anti-fungus and flammability".

4. BARRIERS AND SCREENS

Barriers and mufflers are relatively new in noise attenuation research, but; serious effort has been intensively started on this subject. A previous study was conducted using the barriers for the attenuation of noise emitted through highway by Kurze (1974). Some experts in this field have worked on a full review of sound attenuation for the past twenty years, but Michael J. Kodaras is the one who made significant contributions during the last three years. For example, he had authored a book entitled. "How to handle the road noise, via planning highway". In this book, the basic elements like the barrier length; height, thickness, and material density until the extent of its performance and effectiveness are investigated in -depth. Finally, emphasis was placed on further research that focuses on the materials used in barriers and standard designs, as stated by May and Osman (1980).

Chen (1996) discussed the calculation of sound transmission loss of a perforated screen at frequencies below 4 KHz by using a" two-dimensional plane wave theory and laboratory measurements from 125 to 4000 Hz". The results showed that transmission loss through a perforated screen agrees well with measurements at frequencies above 315 Hz. The transmission loss depends on the thickness and the percentage of perforation.

Bies and Hansen [1995] calculated the insertion loss of a single indoors and outdoors barrier according to" ISO 9613-2, ISO 10847, and ISO 11821". They discovered that the barriers were ineffective in higher reverberant environment, but the efficiency of barriers at indoors improved by hanging absorption baffles from ceilings or by putting sound absorbing materials directly on the ceiling.

Choi et al. [2004] suggested on how to integrate the elements of the noise in the context of analyzing direct current, through noise level prediction, which include traffic noise model (TNM) to get the best design through a series of successful noise barrier analyses. To best address the environmental side of noise in traffic, the valuation set up cost of the barriers to reduce noise is easier than evaluating other cost regions such as air pollution.

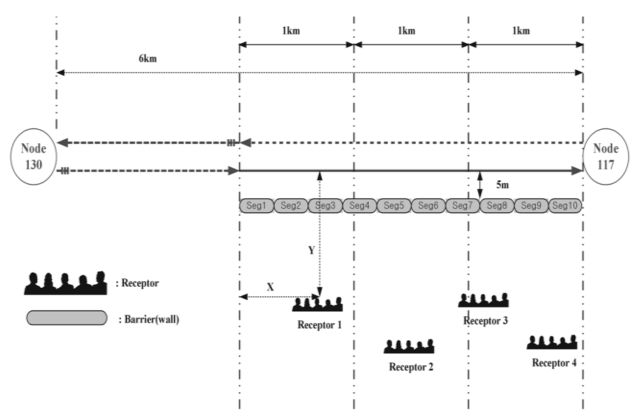

Figure12: Overall Input Layout for S1

Toyoda et al. (2007) suggested numerous structures to improve the performance of sound insulation. They were assumption panels supported in a channel of a limited cross section and using a force point harmonic. The acoustic emission was studied beginning from point of sound power. On mitigation properties, the device was support via simple supporting circular form. The effect of a simple rectangular form as support was also investigated. In the end, they suggested a novel method which uses air cavity in perforated models as an alternative. The comparison was done between theory outcomes and obtained data in echo room in 1/5 scale. The outcomes are compatible.

Egan et al. (2006) investigated on the upper edges of the barriers and how to improve the noise attenuation of these barriers using different forms of barriers and at different lengths. The length of the barrier is a factor that influences the noise attenuation. The experiment was conducted using the "Boundary Element Method" which takes into consideration the cost for the barrier as well as the "degree of visual sequence" by adding absorber substance and geometric configuration. The results and published data were compatible.

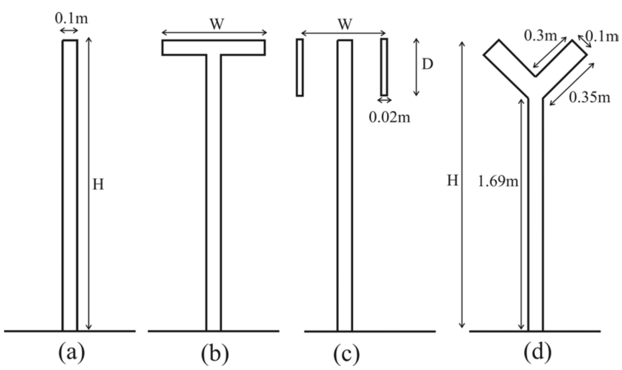

Figure 13: Barrier configurations

In recent researchers, there are a few researchers that used reeds as natural porous materials. Espada et al. (2007) found that the reed mats material have cavity between reeds especially when air paths were connected along the reeds mats. Meanwhile, Chilekwa et al. (2006) investigated the characteristic of small reed and discovered that they are good sound absorber. The samples were investigated using impedance tube method by arranging the reed mats horizontal, vertical and perpendicularly. The vertical direction gave the best results because it is parallel to the incident sound. Furthermore, Espada et al. (2006) carried out the procedures of measuring the acoustic absorption coefficient of reed mats in reverberation room by using EN ISO 354-2003 standard and the results indicated that the reed mats are good and can be used for acoustical enclosure.

Greiner et al. (2009) investigated the shape of barrier to get the optimum shape that reduces noise especially near urban population. The first step is to look for "a single robust shape design" that stops the noise mitigation simultaneously at various locations. The second step is to use the boundary element method to design the optimum Y-shaped barrier. In addition, the calculation of cost to the length of barrier is also essential to decrease its environmental brunt. Atalla and Sgard (2007) presented a pure and generous forms equivalent to air form for perforate plate theoretically similar to the "Allard Johnson" model. In order to find the exemplary conditions, the perforated plate has multi layers of air and cavities. The coefficient of acoustic absorber for different forms is validated through comparison of assumed and experimental data.

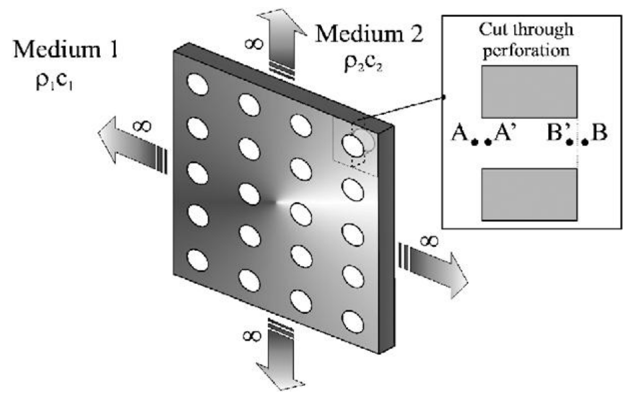

Figure 14: Configuration of perforated plate excited by a plane wane and backed by an infinite fluid medium.

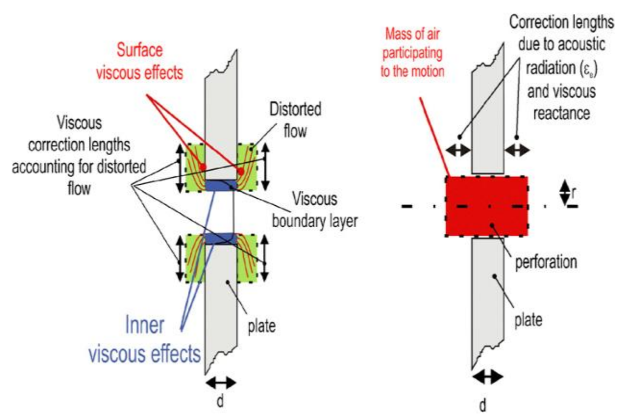

Figure 15: Physical phenomena involved in a perforated plate.

Li et al (2007) investigated three types of polymeric micro- particle substance wasted rubber granulates polypropylene and polystyrene. These substances have a good acoustic absorption when their thickness is altered.

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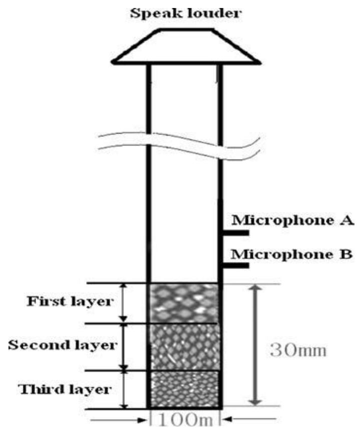
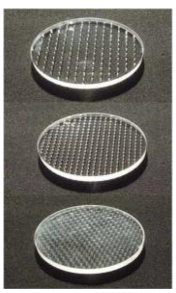
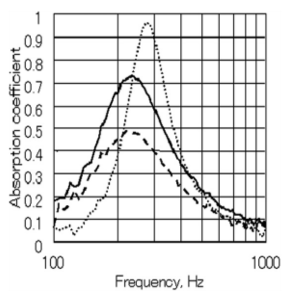


Figure16: Experiment setup and the assembled method of matching material

Sakagami et al (2008) studied the experimental production of an acoustic absorber named "Micro perforated panel" which is a slim panel of metal or plastic. It is not enough for absorbing acoustic in the interior walls and increasing the thickness did not show better results. Therefore,” tapered perforation profile” has been suggested instead.





(a) **(b)**

Figure 17: (a) Photograph of specimens. (b)Results of normal absorption measurement

Kavraz and Abdulrahimov (2009) studied the mitigation of noise in the workshops that have machines that emitted loud noises by placing barriers between these machines in various in various forms in U and L shapes made of one material or different materials, in multiple layers and also different lengths. These barriers have been designed to be easily carried and transported from one place to another and the experimental results showed that the U barriers are better than L barriers. Also, barriers made from perforated gypsum performed than glass wool barriers.

Greiner et al (2010) described the optimum model of barrier via applied Boundary Element Method to mitigate acoustic, whereas the upper edge of figuration - Y working to absorbed sound, also reduce the value of the amounts of the barriers at minimum acoustic pressure .

The outcomes compare among the systematic perfect is more efficiency and successes to develop designer of barrier robust.

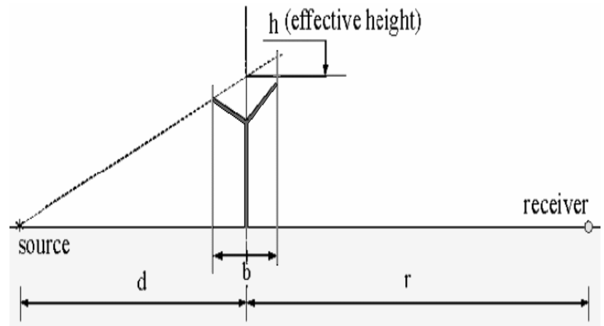


Figure 18: Problem topology representation

5. CONCLUSION

A comfortable environment free from unwanted noises is always dream of every person. One of the sources of unwanted noises is the sound emitted by vehicles, heavy construction machine, and heavy factories like electrical power plant. In heavy factories, workers are exposed to continuous noises the whole work day. This discomfort may leads to some injuries such as hearing loss (temporary or permanent), weakness in nerve, pain in internal tissues, heart problems, and even higher blood pressure in long term. Hence, the understanding of noise elimination becomes an important issue to be studied. This paper has concentrated on noise attenuation consideration of absorption materials (synthetic, organic) or by using barriers. These research works have come into view in the principal journals in this area in purpose of increasing the usage of organic materials which provide green and sustainable environment. It was concluded (from the review) that studying on noise eliminations by innovative material (date palm fiber) in experimental approach becomes a new area of study.

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