Investigation of the Six Composites Based on Magnesium Sulfate as Acoustic Absorber Material

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Abstract: A number of manuscripts reveal that Magnesium Sulfate is the primary substance that causes the absorption of sound in sea water. The aim of the investigation is producing an acoustical composite based on Magnesium Sulfate as building material component for absorbing noise. Six kinds of composite were investigated in their acoustic properties for absorbing noise. The method was conducted by fabricating and characterizing six kinds of samples to know their chemical and physical properties by using FTIR and Impedance Tube. Each investigated composite is: $MgSO_4$, Paper waste, Polyvinyl Acetate (PVAc), and Cement; $MgSO_4$, Paper waste, and Cement; $MgSO_4$, Paper waste, Bentonite, and Cement; $MgSO_4$, Glass Wool, Bentonite, and Cement; $MgSO_4$, Glass Wool, PVAc, and Cement; then, $MgSO_4$, Glass Wool, and Cement. The results show that the composite consists of $MgSO_4$, Paper waste, PVAc and Cement has highest sound absorption coefficient (α) in the range 350 Hz –800 Hz.

Keywords : Noise, Health, $MgSO_4$, Paper waste, Polyvinyl Acetate

1. Introduction

One of the hazardous environmental pollution that harms human health is noise. It can cause hearing loss and interferes brain, eyes, and many kinds of human nervous system. Industrialization and development of many fields for human needs as automotive production, oil drilling, ore mining, building components industry, electronic instruments fabrication etc. in a country have caused environmental pollution including noise and automatically increase the risk to human and environmental health [1]. Noise has significant effect on human health and behavior. World Health Organization (WHO) working group expressed that noise must be confessed as a great threat to human life and the criteria of health includes total physical and mental well being. According to WHO's program, development in health technologies is conducted to overcome health problem and rise the human welfare [2]. In extremely noisy work environments as in steel factory, building construction, and many other industrial areas, hearing protection for noise abatement is necessary [3]. Many kinds of effort have been carried out by researchers to solve human problems by using various composites, devices, and investigation. Among of them is the application of coir fiber reinforced polymer for audio spectrum attenuation that takes into account the sound [4]. Then, the producing of ultrasonic sensor system for solving invalid persons problem that consists of voice alert, part for blind persons and vibration part for deaf persons [5]. Thus, it gives valuable contribution for their life. In an investigation on acoustics of the ocean, the results show that the sound speed in the ocean depends on temperature, salinity, pressure, and depth [6]. The observations on magneto-acoustic waves in coronal loops also conducted, they describe that there is numerous examples of small amplitude waves and oscillations in different coronal structures are mainly in the form of slow magneto-acoustic waves [7]. In building design, the result of using diffusive architectural surfaces informs some of their effects on spatial perception [8], and building structural has many degrees of freedom in its oscillation behaviour due to their connection [9] Many manuscripts describe that porous materials can effectively absorb noise. Pumice is a porous solid produced as a result of volcanic activation; it has high porosity, very low density, and strong absorption [10]. In the investigation on the effect of pumice rate on the gamma absorption parameters of concrete shows that increasing pumice rate decreases the value of attenuation coefficients because the addition of pumice increases porosity and decreases density of the concrete [11]. As for Alumina, the infrared spectra measurements shows that it improves the properties and depresses the devitrification of soda-lime-silicate glasses, this case mainly caused by strengthening effect of the added Al_2O_3 [12]. There is an acoustic investigation reveals that acoustic impedance for Al_2O_3 is 42, 08 Mrayls, Stainless steel 45, 24 Mrayls, and Air 0, 0004 Mrayls [13]. The study on alumina trihydrate (ATH) shows that the tensile modulus and hardness increased with increasing ATH content [14]. While alumina foam, it indicates excellent sound absorbing properties comparable with the best sound insulating polyurethane foams [15]. A binder is extremely important factor for fabricating acoustical composite because the composition of binders has a great influence upon the acoustical properties of the materials including absorption coefficient, impedance ratio, and reflection coefficient [16]. Poly Vinyl Acetate (PVAc) is an important binder exhibiting piezoelectric, pyro-electric and ferroelectric properties. The specific advantages of PVAc are flexibility, formability and low density [17]. Based on its properties, PVAc was used for binding powdered pumice and alumina in this research. The absorption coefficient alpha (α) is a ratio of the absorbed and incident energy enables the following expression to be derived: $\alpha = 1 - |R|^2$, where $|R|$ is the magnitude of the pressure reflection coefficient. The flow regime in a porous solid is directly related to the pore size of the material and thus can give an indication as to how easily pressure waves can penetrate the material. The Knudsen number (K_n) can characterize the flow regime in porous solids which it equate to mean free path (l_{mfp}) of air molecule per characteristic length. (l_{har}). The l_{har} for this application is often taken to be the mean distance between pore walls. For the case of a spherical pore this would equate to the pore diameter. The dominant flow regime through the material may be characterized as follow [18]:

K_n<<1: viscous flow dominates
K_n = 1: viscous flow and molecular flow happens
K_n>>1: molecular flow dominates

Assuming spherical solid particles, the mean free path of gas molecule λ_{mfp} in free space can be determined from the next equation:

$$\lambda_{mfp} = 1/(\sqrt{2} n_g \pi d_g^2 + S_s \rho_s/\phi)$$

where:
n_g = number density of gas molecules (molecules/m^2)
d_g = diameter of gas molecule (m)
S_s =specific area of solid (surface area per mass, m^2/g)
ρ_s = solid density (kg/m^3)
ϕ = porosity (dimensionless)

Acoustic impedance decreases with increase in temperature and it increases with increase in concentration [19]. The Transmission Loss values of vegetated roofs are greater than those of non vegetated reference roofs by 10 and 20 dB in the low and mid frequencies ranges, respectively [20]. Absorption is one of the most commonly used parameters in linear acoustics. It is well known that the absorption for any material will differ when the properties of the material change. These properties include: thickness, density, flow resistivity, method of mounting [21]. It has been known that the acoustic absorption behaviour of a porous material depends on the porosity, the tortuosity, the flow resistivity and on the thickness of the layer. When the sound propagates in the interconnected pores of a porous material, energy is lost. This lost of energy is due to the complex heterogeneous microstructure and the viscous boundary layer effects (the surface of interactions between the two phases through viscous and thermal losses. The air is a viscous fluid so sound energy is dissipated via friction with the pore walls. As well as viscous effects there are losses due to thermal conduction from the air to the porous material although is more important at low frequencies. As the thickness of the samples increases, the absorption at low frequency usually increases [22]. A wave controlled sonic crystal switch device that exhibits a destructive interference-based wave to wave reverse switching effect. By applying control waves, this acoustic device, composed of a two-dimensional square lattice sonic crystal block, reduces acoustic wave transmission from input to output [23]. Variation of impedance with concentration of polyvinyl acetate-polyvinyl chloride blend shows same trend as that of velocity u [24]. Vessel noise typically increases with speed5 and size (length, tonnage). Large merchant vessels can exhibit source power density spectrum levels of 150 to 185 dB in the frequency band 70 to 100 Hz.. Floating Production Storage and Off Loading vessels, unless in transit or using dynamic positioning, are quieter [25]. One of the investigated components of samples in this study is $MgSO_4$ (Magnesium Sulfate). It is highly soluble in water. The anhydrous form is strongly hygroscopic. It is predicted as the primary substance that causes the absorption of sound in seawater. Then, paper products are essential elements of today's society, and most of them can be recovered for recycling. Paper makes up municipal solid waste and office paper waste is a secondary raw material which may be used as component of acoustic material. Fadila, R [26].expressed that paper waste can be used for strengthening concrete and absorbing sound. There are a lot of kinds of material can be used as noise absorber. However, none of these studies uses composite that consists of $MgSO_4$, Paper Waste, Polyvinyl Acetate, and Cement for absorbing noise. The aim of the research is producing an acoustical composite by fabricating some kinds of crushed materials based on $MgSO_4$ then characterizing the products to know their physical and chemical properties especially their ability in absorbing noise, then select the best tested composite.

2. Material and Method

The 6 (six) tested composites is shown in table-1. Every composite consists of some components based on $MgSO_4$. The procedure of the experiment basically started by measuring chemical properties of each main component by FTIR as shown in Fig.1, Fig.2, Fig.3, Fig.4, and Fig.5. Then every variation of sample was mixed, crushed by blender, moulded, and then dried by infrared in 3 x 24 hours. The six fabricated composites each has round shape, diameter 10 cm and thickness 2 cm as shown in Fig. 6. Scanning Electron Microscope image is shown in Fig.7.

Table 1: The six tested composites

No	Name of Material	Mass (gram)
1	$MgSO_4$ Glass Wool PVAc Cement	150 150 60 120
2	$MgSO_4$ Office Paper Waste Cement	150 150 100
3	$MgSO_4$ Office Paper Waste Bentonite Cement	150 150 60 120
4	$MgSO_4$ Glass Wool Bentonite Cement	150 150 60 120
5	$MgSO_4$ Glass Wool Cement	150 150 100
6	$MgSO_4$ Office Paper Waste PVAc Cement	150 150 60 120

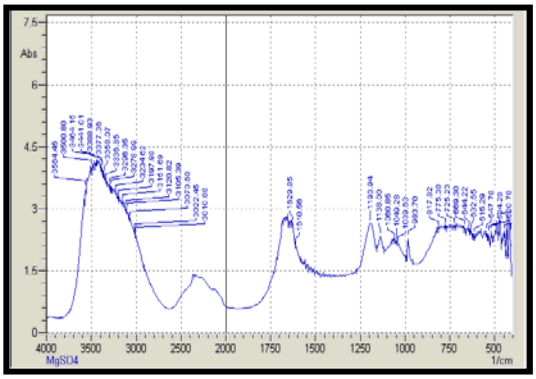


Figure 1: Infrared Spectrum of $MgSO_4$

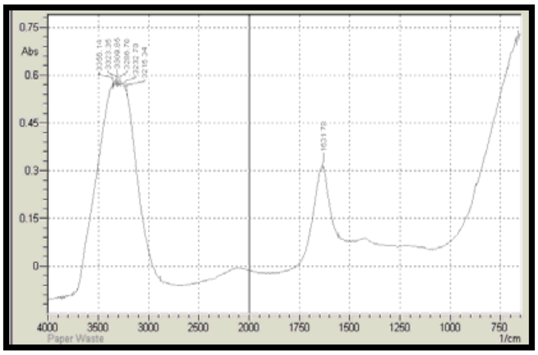


Figure 2: Infrared Spectrum of Paper Waste

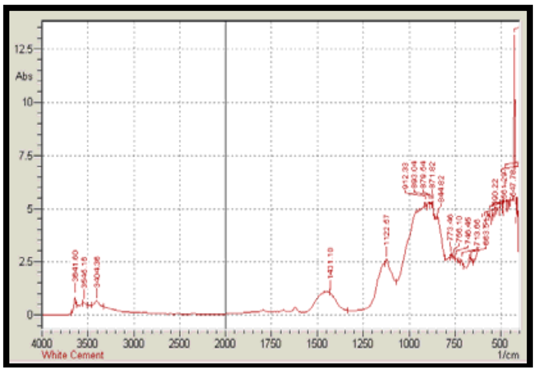


Figure 3: Infrared Spectrum of Cement

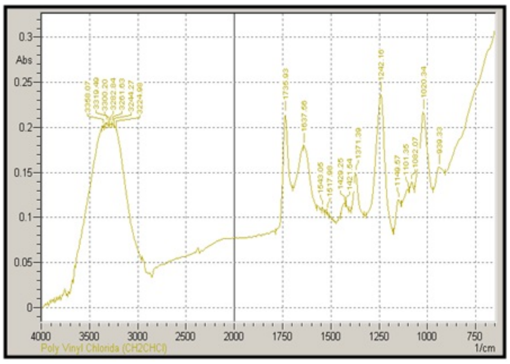


Figure 4: Infrared Spectrum of PVAc

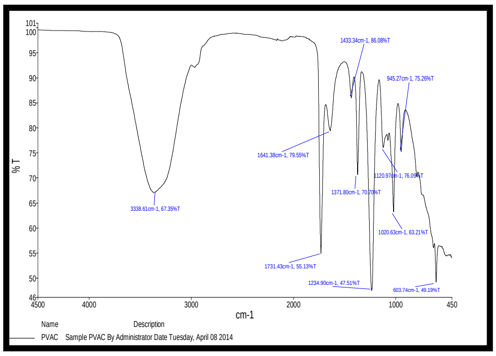


Figure 5: Infrared Spectrum of PVAc

Figure 6: The six kinds of composites

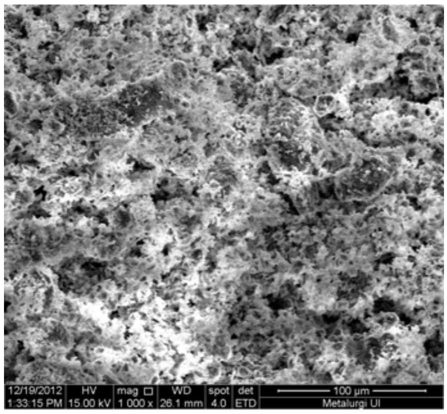
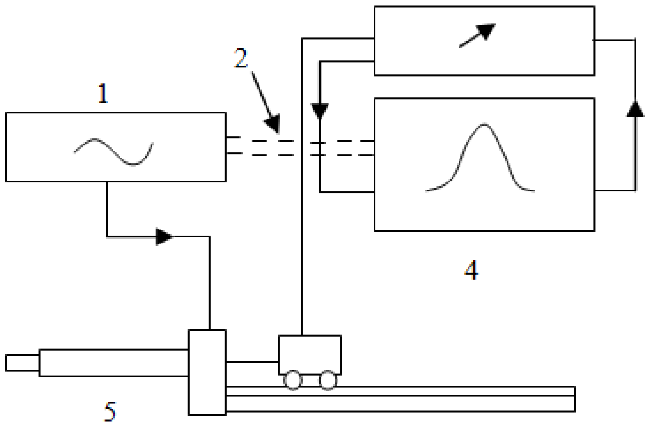


Figure 7: SEM image of The Chosen Composite (Contains $MgSO_4$, Office Paper Waste, PVAc, and Cement)

The instrument used in the experiment to test the acoustic properties of samples. Absorption coefficient measurement (α) of every sample was performed according to ASTM E 1050-98 by using Standing Waves Apparatus Type 4002 as shown in Figure 8.



1. Sine Generator 1023
2. Filter Tunneling Signal
3. Measuring Amplifier 2606
4. Heterodyne Slave Filter 2020
5. Small Tube

Figure 8: Schematic Representation of Typical Measuring Arrangement of Standing Waves Apparatus 4002

Figure 8 shows a complete measurement of acoustic absorption coefficients. The loud speaker of Standing Wave Apparatus Type 4002 is fed from the Sine Generator Type 1023 covering the frequency range from 125 Hz to 1800 Hz.

The microphone output voltage is indicated on the measuring Amplifier Type 2606 which is made selective by the addition of the Heterodyne Slave Filter type 2020. Of The filter is tuned automatically from the Generator 1023 to follow the frequency of this. The meter scales of the Frequency Analyzer and Measuring Amplifiers enable the absorption coefficient (α) to be read directly.

3. Results and Discussions

FT-IR spectroscopy is a well-known technique that is easy to operate and relatively fast when compared with the other techniques for chemical analyses. For this reason, it was used in this investigation for detecting the chemical composition of the fabricated composites. The chosen composite (has highest α) that measured by FTIR is consists of: $MgSO_4$, Paper Waste, Cement and PVAc.

The infrared spectrum of FTIR for $MgSO_4$ has four dominant peaks of absorbance in the frequencies area:

3500 Hz – 3200 Hz: O-H stretch vibration
2500 Hz – 2000 Hz: S-H stretch vibration
1750 Hz – 1500 Hz: C=O stretch vibration
1250 Hz – 1000 Hz: C=N stretch vibration

Paper Waste has two dominant peaks of absorbance in the frequencies area:

3500 Hz – 3200 Hz: O-H stretch vibration
1750 Hz – 1600 Hz: C=O stretch vibration

Cement has four dominant peaks of absorbance in the frequencies area:

3700 Hz – 3500 Hz: N-H stretch vibration

1500 Hz – 1200 Hz: C-H bend vibration
1200 Hz – 1100 Hz: C=S vibration
1000 Hz – 1850 Hz: C-H & CH_2 vibration

Polyvinyl Acetate was measured two times; one for absorbance and another for transmittance, both are equals. It has five dominant peaks of absorbance in the frequencies area:

3500 Hz – 3100 Hz: O-H stretch vibration
1750 Hz – 1700 Hz: C=O stretch vibration
1700 Hz – 1550 Hz: C-C stretch vibration
1300 Hz – 1100 Hz: CH bending vibration
1050 Hz – 1000 Hz: CH_2 twisting vibration

There are more complete peaks of transmittance for PVAc:

3338, 61/cm: O-H stretch vibration
1731, 43/cm: C=O stretch vibration
1641, 38/cm: C-C stretch vibration
1433, 34/cm: CH_2 asymmetric vibration
1371, 80/cm: CH_3 asymmetric vibration
1234, 90/cm: CH bending vibration
1209, 70/cm: C-O vibration
1020, 63/cm: CH_2 twisting vibration
945, 27/cm: CH_3 wagging vibration
603, 70/cm: C-H bending vibration

The results of sound absorption coefficient of each sample are shown in the following description:

Composite-1: the maximum absorption coefficient is 0, 38 in the frequency range 350 Hz – 450 Hz. Composite-2: the maximum absorption coefficient is 0, 47 in the frequency range 400 Hz – 720 Hz. Composite-3: the maximum absorption coefficient is 0, 41 in the frequency range 350 Hz – 800 Hz.

Composite-4: the maximum absorption coefficient is 0, 37 in the frequency range 350 Hz – 800 Hz. Composite-5: the maximum absorption coefficient is 0, 29 in the frequency range 350 Hz – 600 Hz. Composite-6: the maximum absorption coefficient is 0, 52 in the frequency range 350 Hz – 800 Hz.

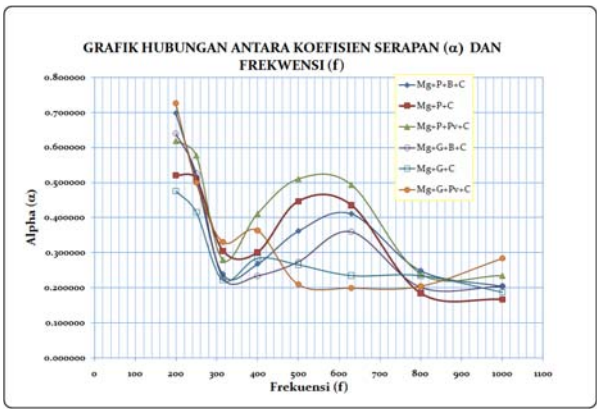


Figure 8: The graph of absorption coeffisien (α) versus frequency of 6 tested composites

The highest sound absorption coefficient among six tested composites is the composite-6 that has α = 0, 52.

It is interesting that three composites which each contains paper waste component have higher sound absorption coefficient compared to the three compo-sites which each contains glass wool component in the frequency area between 350 Hz – 800 Hz.

4. Conclusion

The fabricated composites that consists of $MgSO_4$, Office Paper Waste, Polyvinyl Acetate, and Cement has highest Sound Absorption Coefficient compared to the other tested composites, and all tested composites contain paper waste have better ability in absorbing noise compared to all composites contain glass wool in the frequency range between 350 Hz – 800 Hz. The combination of $MgSO_4$ and office paper waste for fabricating composite as noise absorber is interesting because it exhibit promising properties in absorbing noise. It has been noted that one of the most important factor in acoustic properties of composite is the type of binders. Different binders perform different abilities in absorbing noise and in strengthening composite. The use of binder instead PVAc is needed in the future for improving this investigation.

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References

[1] Pramila S., Fulekar M.H., and Bhawana P., E-Waste-A Challenge for Tomorrow, Research Journal of Recent Sciences, 1(3), 86-93, (2012)
[2] Kalpa S., Health IT in Indian Healthcare System: A New Initiative, Research Journal of Recent Sciences, **1(6)**, 83-86, (2012)
[3] Tufts, J.B., Chen, S. and Marshall, L., Attenuation as a function of the canal length of custom molded ear plug : a pilot study, J.Acoust.Soc.Am, 133(6), (2013)
[4] Balaguru I., Sendhilkumar S., and Sridhar K., Investigation on Stealth Strategies in Coir Fiber Reinforced Polymer Composites, Research Journal of Material Sciences, 1(1), 6-10, (2013)
[5] Safaa A.M., Asaad H.M., and Ali A.I., Using Ultrasonic Sensor for Blind and Deaf persons Combines Voice Alert and Vibration Properties, Research Journal of Recent Sciences, 1(11), 50-52, (2012)
[6] Hemmati F., Influence of Internal Waves on Underwater Acoustic Propagation, Research Journal of Recent Sciences, 1(1), 73-76, (2012)
[7] Pradeep K, Bhupendra S., Rajmani C. and Anil K., Propagation and Dissipation of Slow Magneto-Acoustic Waves in Coronal Loops, Research Journal of Recent Sciences, 1(2), 34-41, (2013)
[8] Robinson, P., Patynen, J. and Lokki, T.**,** The effect of diffuse reflections on spatial discrimination in a simulated concert hall, J.Acoust.Soc.Am, 133(5), (2013)**,**
[9] Ashari E.E., Calculating Free and Forced Vibrations of multi-story Shear Building by Modular method, Research Journal of Recent Sciences, 3(1), 83-90, (2014)
[10] Manguriu, G.N., et al., Properties of Pumice Weightlight Aggregate, Civil and Environmental Research, 2(10) , (2012)
[11] Akkurt, I., et al, The Effect of Pumice Rate on the Gamma Absorption Parameters of Concrete, Acta Physica Polonica A, .1(121), (2012)
[12] Huali Liu, Ruijuan Yang, Yinghui Wang, Shiquan Liu, Influence of alumina additions on the physical and chemical properties of lithium-iron - phosphate glasses, Physics Procedia, 48, 17-22, (2013)
[13] Bottiglieri, S., The Effect of Microstructure in Aluminium Oxyde Ceramics on Acoustic Loss Mechanism, Dissertation, Graduate School New Brunswick Rutgers, The State University of New Jersey, (2012)
[14] Farzad, R.H., Hasan, A. Jawaid, M. and Piah, M.A.M., Mechanical Properties of Alumina Trihydrate Filled Polypropylene/Ethylene Propylene Diene Monomer Composites for Cable Applications, Sains Malaysiana, 42(6), 801-810, (2013)
[15] Zielinski, T.G., Potoczek,M., Sliwa,R.E., Nowak,L.J., Acoustic absorption of a new class of alumina foams with various high porosity level, Archieves of acoustics, 38(4), 495-502, (2013)
[16] Stanciu, M.D., Curtu, I., Cosereanu, C., Lica, D., and Nastac, S. , Research regarding acoustical properties of recycled composites**,** 8th International DAAM Baltic Conference "Industrial Engineering**",** Tallinn, (2012)
[17] Devi, K.B.R. and Madivanane, R., Normal coordinate analysis of polyvinyl acetate, IRACST- Engineering Science and Technology (ESTIJ),**2(4),** 795-799, (2012)
[18] Kuczmanski, M.A. and Johnson, C.J., (2011), Acoustic Absorption in Porous Materials, NASA Glenn Research Center, NASA/TM-2011-216995, Ohio.
[19] Singh, P.K., Investigation of acoustical parameters of polyvinyl acetate, Applied Physics Research, Vol. 2 No.,1 Srinagar 246174, (2010)
[20] Connelly, M.R., Acoustical characteristics of vegetated roofs contributions to the ecological performance of building and the urban soundscape, Disertasi tidak diterbitkan, The Faculty of Graduate Studies, The University of British Columbia, Vancouver, (2011)
[21] Mc Grory, M., Sound absorption coefficient measurement : re-examining the relationship between impedance tube and reverberant room methods, Proceeding of Acoustics, Fremantle (2012)
[22] Maduruelo, R., Morillas, J.M.B., Castizo, M.M., Escobar, V.G. and Gozalo, G.R., Acoustical performance of porous absorber made from recycled rubber and polyurethane resin**,** Latin American Journal of Solids and Structures, 10, 585-600, (20013)
[23] Alagoz, S. and Alagoz, B.B., (2013), Sonic crystal acoustic switch device, J.Acoust. Soc.Am., 133(6).
[24] Tabhane, P.,Chimankar., O.P. and Tabhane, V.A., Phase separation studies in polyvinyl chloride-polyvinyl acetate blend by ultrasonic technique, Journal of Chemical and Pharma-ceutical Research 2012, 4(6):3051-3056, (2012)
[25] Erbe, C., and Cauley, R.M., Under water noise from offshore oil production vessels, J.Acoust.Soc.Am., 133(6),(2013)
[26] Fadila, R., Sulaiman, M.Z., and Noordin, N.M, Paper Fiber reinforced foam concrete wall panelling System, 2nd International Conference on Built Environ ment in Developnig Countries (ICBEDC 2008).

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