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Synthesis and Characterization of the Composite Based on $MgSO_4$ and Paper Waste for Noise Abatement

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Abstract

Several manuscripts reveal that magnesium sulfate ($MgSO_4$) is the primary substance that causes the absorption of sound in sea water. The purpose of the investigation is synthesizing an acoustical composite based on magnesium sulfate and office Paper Waste as building material component for noise abatement. The method was conducted by synthesizing and characterizing the sample to know its chemical and physical properties by using FTIR, SEM andTwo Acoustic Rooms each containing noise source and receiver. The results show that the produced composite has positif transmission loss value above STC contour standard at the frequency range between 800 Hz to 4000 Hz.

Keywords: Noise, health, magnesium sulfate, office paper waste, PVAc.

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 behaviour. 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 solids 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 measure-ments 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 Stainless steel 45,24Mrayls, and Air 0,0004 Mrayls[13]. Investigation 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]. Double-walled panels are used in many engineering applications because they possess insulation properties over a wide frequency range compared to single-wall panels

(Jiezhou)[18]. 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[19]. 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[20]. 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[21]. Variation of impedance with concentration of polyvinyl acetate-polyvinyl chloride blend shows same trend as that of velocity *u*[22]. Vessel noise typically increases with speed[5] 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[23].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 important 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. The effect of Portland cement porous concrete on tire pavement noise abatement was measured in lab, for porous concrete material representing combinations of various maximum aggregate sizes, gradation, layer thickness and composition of layers. The results indicated that porous concrete with a maximum aggregate size of 9,5 mm had the highest noise reduction. The field measured tire pavement noise clearly indicated that the porous cement concrete significantly attenuated the tire pavement generated noise by 4 to 8 dB[24]. This work uses statistical anergy analysis to study noise transmission loss (SEA) and sound pressure level (SPL) through intake system of an engine. Porous material is used at duct wall in order to reduce air resonance in the air intake duct. In addition, the effects of porous materials on noise transmission loss through duct of intake system of engine are studied[25]. The sound insulation properties of natural fiber based composites are controlled by inter fiber voids and within fiber voids. Variable densities my result in different behaviour of noise reduction since the density has great influence on the porosity of fibrous assemblies[26].Theoritically, one common model of construction consists of elements in composite material, and the total power transmitted through the material was as given by Randall F. Barron that the sum of the power transmitted through every element by the reason that the incident acoustic intensity is the same for all elements, according to equation (1),(2) and (3):

$$W_{tr} = \sum W_{tr,j} = a_t W_{in} = a_t S I_{in} = I_{in} \sum a_{t,j} S_j \quad (1)$$

The quantity $S=\sum S_j$ is the sum of surface area, and $a_{t;j}$ is the sound power transmission coefficient for each individual element. The transmission coefficient of total sound power for elements in parallel in a composite wall is given by the following:

$$a_t = \sum a_{t,j} S_j / S \quad (2)$$

Transmission Loss (TL) is the parameter that compares the amount of intensity of the signal at a specific range from the source to the source intensity, or it represents the amount of sound in *decibels* (dB) that is isolated by a material orpartition in a particular octave or one-third octave frequency band. The sound power transmission coefficient for normal incidence is related to the transmission loss for normal incidence:

$$TL = 10\log_{10} 1/a_t \quad (3)$$

Sound Transmission Class (STC) is a single-number rating of how effective a material or partition is at isolating sound, In general, a higher STC rating blocks morenoise from transmitting through a material, for example, at STC 25 normal speech understood quite easily and distinctly through material but for STC 45 loud speech not audible. There are a lot of kinds of material can be used for noise abatement. However, none of these studies uses composite that consists of $MgSO_4$, Paper waste, polyvinyl acetate, and cement for noise abatement. The aim of the research is fabricating an acoustical composite by synthesizing crushed materials based on $MgSO_4$ and office paper waste then characterizing the product to know its physical and chemical properties especially its ability in attenuating noise.

Material and Method

The experimental method was started by identifying the chemical composition of every component of the composite by FTIR Perkin Elmer Spectrum Version 10.03.02, then synthesizing the composite. It consists of5 kg magnesium sulfate (powder), 5 kg crushed office paper waste (pulp), 2 kg polyvinyl acetate and 4 kg cement. All were mixed and crushed strongly by blender then moulded as a plate that has area size 70 cm x 70 cm and 4 cm of thickness. It was dried by red infra in 4 x 24 hours, then tested in acoustic laboratory by method of two adjacent rooms to know its transmission loss value. The synthesized composite is shown in Figure-1, and the measurement by SEM is shown in figure-2.

Figure-1
Synthesized Sample

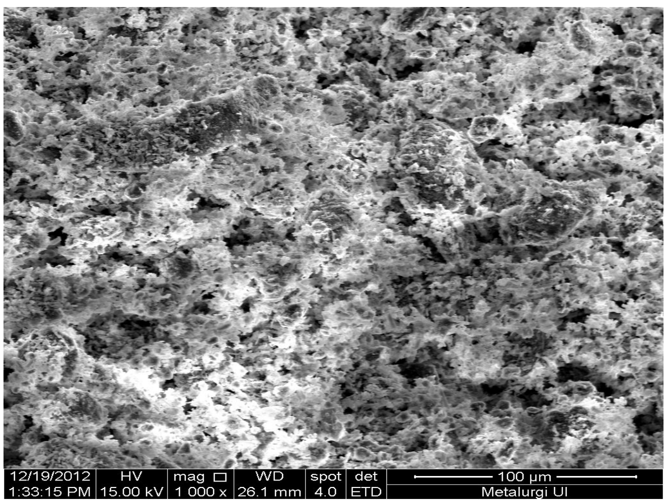

Figure-2
SEM image of the Tested Sample

The instruments used in the experiment to test transmission loss of the samples. The transmission loss facility has two adjacent rooms, as shown in figure-3. A test window is located between the two rooms where tested sample is placed for testing as in figure-4. White noise source (has wide band of frequency) is generated in the one room and the sound transmitted through the sample to another room that equipped by receiver (special microphone) and connected by cable to computer out of the room, as shown in figure-5. Measurement was made with ASTM E 90 – 09 and STC rating is assigned in accordance with the requirement of ASTM E 413.

The sample as illustrated in figure-4 is inserted in window located in the joining wall. Speaker placed in one room generated a white noise with a band width of 125 – 4000 Hz. The noise level for 16 point of frequency are recorded in both rooms. The difference of this measurements gives contour of transmission loss of the sample.

Figure-3
Two Adjacent Rooms

Figure-4
Installed Sample between Two Adjacent Rooms

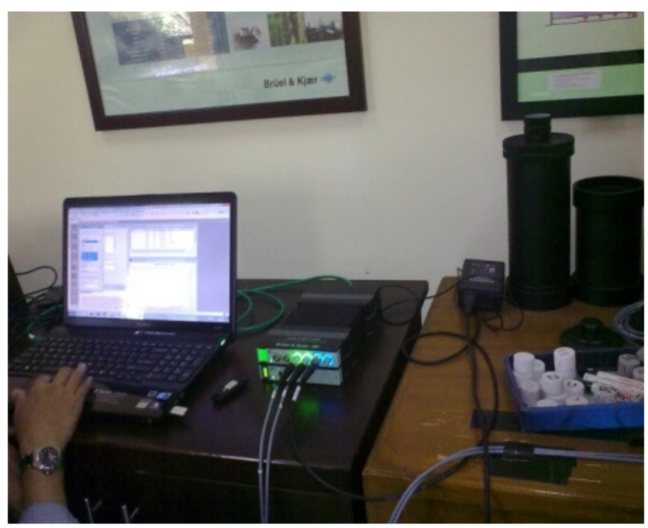

Figure-5
Transmission Loss Measurement

Results and Discussions

The results of measurement by FTIR are shown in figure-6, figure-7, figure-8, figure-9, and figure-10 (PVAc was measured 2 times). For this study, one sample was synthesized and characterized. It consists of5 kg magnesium sulfate (powder), 5 kg crushed office paper waste (pulp), 2 kg polyvinyl acetate and 4 kg cement. All were mixed and crushed strongly by blender then moulded as a plate that has area size 70 cm x 70 cm and 4 cm of thickness. It was dried by red infra in 4 x 24 hours, then tested in acoustic laboratory by method of two adjacent rooms to know its transmission loss value.

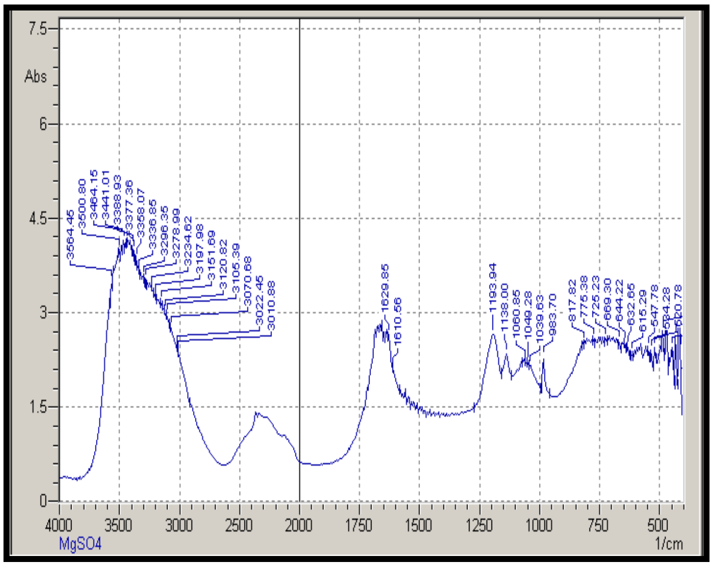

Figure-6
Infrared Spectrum of $MgSO_4$

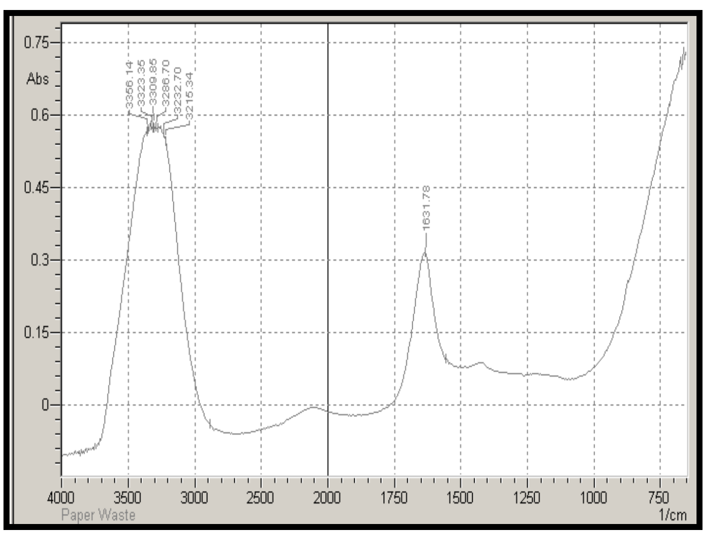

Figure-7
Infrared Spectrum of Paper Waste

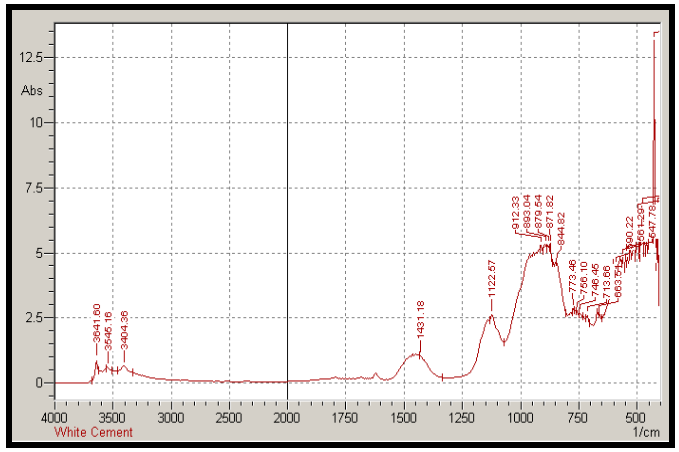

Figure-8
Infrared Spectrum of Cement

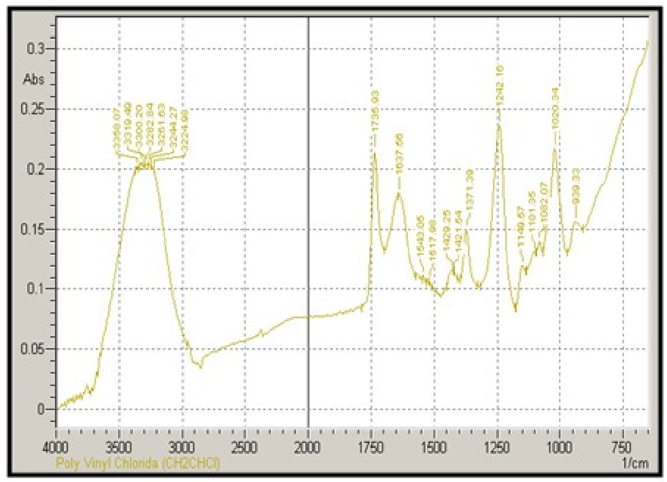

Figure-9
Infrared Spectrum of PVAc

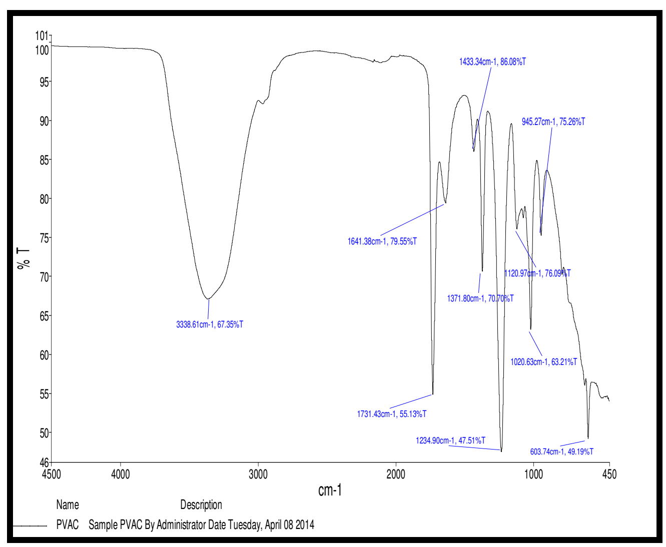

Figure-10
Infrared Spectrum of PVAc

FT-IR spectroscopy is a famous technique that is easy to operate and relatively fast when compared with the other techniques for chemical composition analyses. For this reason, it was used in this investigation for detecting the chemical composition of the fabricated composites. The chosen composite (has highest □) 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 and 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_2asymetric vibration; 1371, 80/cm: CH_3asymetric 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 transmission loss measurement of the tested sample is shown in the following description : Table-1 presents the correlation of sound pressure level (SPL) and frequency, and figure-11 shows that he tested composite synthesized by magnesium sulfate, office paper waste, PVAc and cement has significant value of transmission loss above standard contour and has maximum transmission loss about +9 dB at the frequency range 800 Hz – 4000 Hz, but there is transmission loss about -8 dB at frequency 200 Hz below standard contour.

Table-1
Sound Pressure Level (SPL) at 16 points of Frequency

Frequency	125	160	200	250	315	400	500	630
SPL	16	19	11	21	25	29	30	30
Frequency	800	1000	1250	1600	2000	2500	3150	4000
SPL	32	35	36	38	39	41	40	39

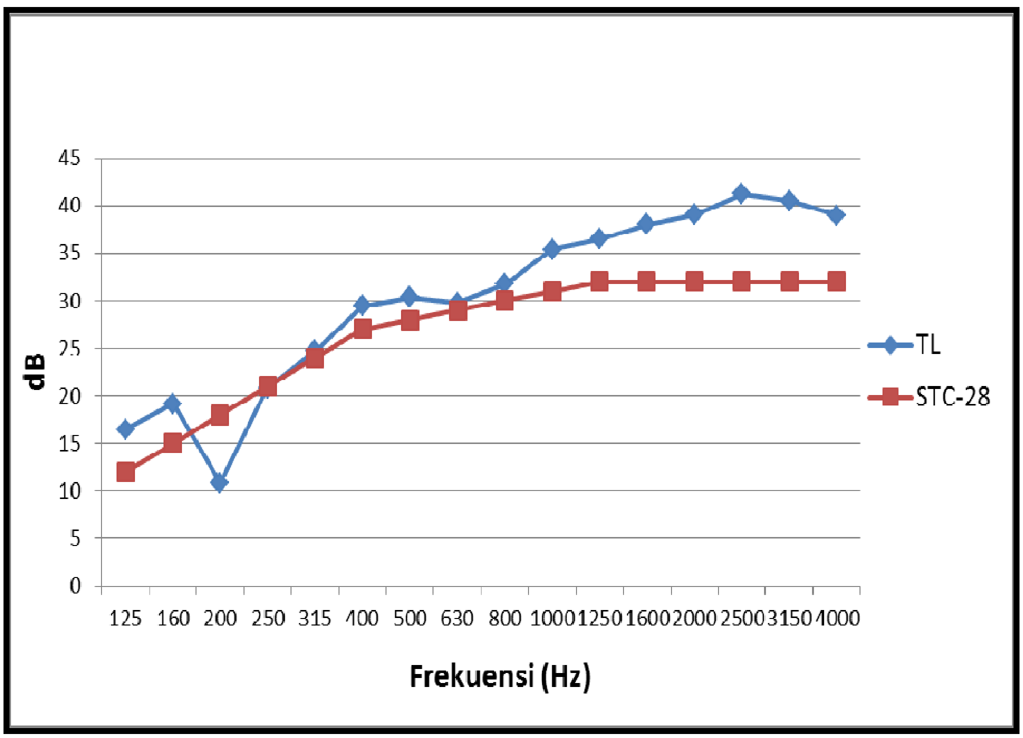

Figure-11
STC rating is determined by adjusting the standard contours to the measured transmission loss values and reading the contour intercept at 500 Hz. The vertical axis is Transmission Loss in decibel (dB)

The value of transmission loss above standard contour indicates that the synthesized composite is promising to be applied as component of building material for reducing noise at the frequency range between 800 Hz – 4000 Hz. It so happens that the negative value of transmission loss about -8 dB below standard contour at frequency 200 Hz is disadvantageous, it may caused by the equality in frequency of incident noise and natural frequency of the sample. This case can be solved by changing the density of material that means changing its natural frequency.

Conclusion

The investigation on the acoustic composite that fabricated from magnesium sulfate enriches possibilities in developing building materials and creates a comfortable acoustic environment especially in the big cities and industrial area. for supporting health safety and. tranquility. So, recycling paper waste can enhances the value of worthless thing and helps government in overcoming environmental pollution.

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References

1. Kalpa S., Health IT in Indian Healthcare System: A New Initiative, *Research J. of Recent Sci.,***1(6)**, 83-86, **(2012)**

2. Pramila S., Fulekar M.H. and Bhawana P., E-Waste-A Challenge for Tomorrow, *Research J. of Recent Sci.,* **1(3)**, 86-93, **(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 J. of Mat. Sci.,* **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 J. of Recent Sci.,* **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 J. of Recent Sci.,* **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 J. of Recent Sci.***, 3(1),** 83-90**, (2014)**

10. Manguriu G.N., et al., Properties of Pumice Weight light 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. and 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. Jiezhou Bhaskar A., Xin Zhang, Sound Transmission through a double panel construction lined with poroelastic material in the presence of mean flow, *Journal of Sound and Vibration,* **332,** 3724–3734**, (2013)**

19. McGrory M., Sound absorption coefficient measurement : re-examining the relationship between impedance tube and reverberant room methods, Proceeding of Acoustics, Fremantle **(2012)**

20. Maduruelo R., Morillas J.M.B., Castizo M.M., Escobar V.G. and Gozalo G.R., Acoustical performance of porous absorber made from recycled rubberand polyurethane resin**,** *Latin American Journal of Solids and Structures,* **10,** 585-600**, (20013)**

21. Alagoz S. and Alagoz B.B., Sonic crystal acoustic switch device, *J. Acoust. Soc. Am.,* **133(6), (2013)**

22. 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 Pharmaceutical Research 2012,* **4(6),** 3051-3056, **(2012)**

23. Erbe C., and Cauley R.M., under water noise from offshore oil production vessels, *J. Acoust. Soc. Am.,* **133(6), (2013)**

24. Tian B., Liu Y., Niu K., Li S., Xie J. and Li X., Reduction of tire pavement noise by porous concrete pavement, *J. Mater. Civ. Eng.,* **26(2),** 233-239, **(2014)**

25. Shojaeefard M.H., Talebetooti R., Molla M.A.R. and Ahmadi R., Noise Transmission with Porous Insulator Using Statistical Energy Analysis, *International Journal of Automotive Engineering,* **2(1)**,8–20, **(2012)**

26. Xiaodong Zhu, Birme June Kim, Qingwen Wang and Qinglin Wu, Recent Advances in the Sound Insulation Properties of Bio-based Materials, *J. Bio Resources,* **9(1),** 1764–1786, **(2014)**