International Journal of Engineering & Technology, 7 (2) (2018) 444-448

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i2.8972
Research paper

Comparison of the acoustic behavior between paper waste of HVS and carton in similar composite

Hidjan [1] *, Sutanto [2]

[1] *Deaprtment of Civil Engineering State Polytechnic of Jakarta PNJ, Depok 16425 West Java Indonesia*
[2] *Department of Electrical Engineering State Polytechnic of Jakarta PNJ, Depok 16425 West Java Indonesia*
**Corresponding author E-mail: hidjan@sipil.pnj.ac.id*

Abstract

One of the hazardous environmental pollution that harms human health is Noise. Porous and vibrous materials are considered can be used for reducing noise. The purpose of the investigation is synthesizing and characterizing two kinds of acoustical composites based on Activated Zeolite with Carton and Activated Zeolite with HVS Paper Waste as building material components for noise reduction. Synthesizing each composite was conducted by chemical and mechanical mixing, and characterizing process was carried out by using EDS, FTIR, SEM and Impedance Tube. The absorption coefficient was measured in the frequency range between 125 Hz up to 6000 Hz. The results show that both have significant values for absorbing noise at the audible frequency range between 1200 Hz to 2200 Hz.

Keywords: *Activated Zeolite; Carton; HVS Paper Waste; Noise.*

1. Introduction

Noise pollution has significant impact on human health that can cause hearing loss and interferes brain, eyes, and many kind of human nervous system. It is one of the problems of daily life everywhere escpecially in the big cities and industrial areas. Due to the fact that noise effects are rarely visible and difficult to quantify it is given a lower priority than other economic or environmental impacts. Noise control play an very important role in creating an acoustically pleasing environment. Exposure to noise pollution is a bigger problem than ever before according to the increasing of human population and activities. Various materials were investigated and modified by many researchers for reducing noise. The more interesting material to be investigated is zeolite. It is one of the matters that allegeded as acoustic component. It is crystalline, highly porous material. The specific porous structure of zeolite gives natural zeolites various application possibilities. Amount of investigations have confirmed their excellent performance on many aims including the removal of metal cations from waste waters. It can be physically and chemically modified. The pore size of common natural zeolite is microporous and can be changed to mesoporous level by calcination and ion exchange process. Martinez revealed that zeolites in the strict sense are highly porous crystalline aluminosilicates that comprise tetrahedrally-connected three dimensional frameworks and extra-framework charge balancing cations. The frameworks contain pores that are able to take in molecules of up to 1 nm in size (depending on the structure type) and the pore geometry can include cages and/or channels, and be one, two, or three-dimensionally connected. The chemical composition of both framework and extra-framework components can extend very widely whilst retaining „zeolitic" character. This chemical variation can arise directly during synthesis [1]. Many researchers investigated and defined properties of zeolites. Peng Guo expressed that they are crystalline microporous alumino silicates with well-defined cavities or channels of molecular dimensions that widely used for applications such as gas adsorption, gas storage, ion exchange and catalysis. The size of the pore opening allows zeolites to be categorized into small, medium, large and extra-large pore zeolites [2]. One kind of zeolite is clinoptilolite that is more appropriate to adsorb molecules whose kinetic diameter is lower than 3 nm because the most pores are located in the microporous range; molecules with bigger diameters are not penetrable for the clinoptilolite microporous channels. The acid treatment increases micropore volumes and the specific surface area of clinoptilolite as explained by Mansouri, therefore it would improve adsorption efficiency. Heating at 400 °C eliminates water molecules existing in clinoptilolite channels which may unblock the channels and increase sorbate penetrating through channels, improving adsorption [3]. Another alternative acoustic absorber is paper. It is a vibrous material and can be used for reducing noise by vibration dumping process. In the case of paper waste, Kulkarni concluded that it is worthless material that cause environmental pollution. It can be recycled in concrete also biofuel synthesis, production of ceiling boards, bioelectricity production, and fuel gas generation [4]. Sahin investigation showed that a paper based product typically contains 90-99% cellulose fibers which are the primary structural element and the most important component influencing end use properties. A network of self-bonding cellulose fibers within network structure affects chemical and physical characteristics of the paper products [5]. Yilmaz presented that paper has an indisputable place in establishment of civilizations, saving information and passing it to next generations. Paper in today's world is used in everyday life for countless purposes so its consumption has been increasing. In order to solve the problem of sourcing raw material for paper production, it is better to develop technologies for sustainable recycling rather than sustainable forestry, and separating all the components of waste paper except for fibers using the most economical and environmentally friendly methods and recycling are crucially important. As the demand for paper has increased, paper producers are now forced to use waste paper as the raw material [6]. Abdullah demonstrated that recycled paper mill sludge has potential and can be used as a fertilizer applied for soil amendment. The application of recycled paper mill sludge to tropical acidic soils can provide substantial benefits such as neutralization of soil acidity, increased organic matter and other essential nutrients. Composting may be a viable option for recycled paper mill sludge as it can enhance its quality, since the physical properties of paper mill sludge are practical [7]. Another kind of acoustic material has been set forth by Bolton that microperforated panel (MPP) is recently regarded as one of the most promising absorption materials for next generation [8]. A majority of sustainable materials for noise control as explained by Azimi can be divided into three main categories: - Natural materials; - recycled materials; - Mixed and composited materials. There is a great variety of natural fibers which can be used for thermal and acoustical applications [9]. Asdrubali described that the interest in the acoustic performance of green materials seems to be increasing in technical and scientific literature. Many researches have been recently investigated a structured session on "Sustainable Materials for Noise Control [10]. Kuczmarski expressed that not all highly porous materials are suitable as acoustic absorbers. If the mean free path of air is on the order of that of the mean distance between pore walls, pressure waves will not be able to efficiently penetrate the material [11]. Therefore, activating zeolite by calcination and ion exchange was carried out at this study in order to enlarge the size of zeolite pores and raise it's ability to absorb noise. According to Limin's investigation, sound absorption mechanism following some aspects: when acoustic waves propagated into the fibrous material, the air in the fiber pores vibrated and rubbed against cell walls. The generated viscous resistance turned the acoustic energy into thermal energy attenuation, so the air in the pores was heated when compressed and it cooled when expanded. The thermal conduction in the materials made acoustic energy transform into thermal energy gradually and it was irreversible [12]. Malawade described that porous materials used for preparing sound absorbers are glass or rock wool which has high acoustic absorption properties. Specimens used in present work give remarkable sound absorption coefficients especially rice straw samples and sample made from combinations of wood dust and rice straw for the frequency range of 125 Hz to 1500 Hz. Maximum coefficient of sound absorption was for Rice straw and Composition of Rice straw and Wood dust which was estimated to be 0.29 [13]. In the case of ecological damage created by papermaking Smith noticed that it is alarming because the production of paper products requires too many toxic chemicals, is energy intensive, and impacts water supplies [14]. Stanciu revealed that the use of composite materials based on textiles residues and wood chips or flacks for noise reduction have two major advantages in order to protect the environment on one hand by recycling [15]. Several wastes were used by Elena's research on developing new types of composite materials with sound absorbing and thermal insulating properties, in order to improve the acoustic and thermal comfort of an enclosure, and in order to achieve these materials. Results show that the achieved materials have very good acoustic and thermal properties and that these properties vary according on the nature of the waste used as raw matter in producing these materials [16]. Many kinds of materials have been investigated by researchers for absorbing noise. The unique present research as set forth by Kehagia is that rubberized bituminous mixtures could be a good solution for the re-surfacing of any street which is in poor condition, since it can reduce noise generation [17]. Acoustic materials play a very important role in design of automobile interior, factories, workshops etc., as studied by Arumkumar and acoustic materials are most commonly used now a day in passive noise control to prevent unwanted noise. Many new acoustic materials are discovered day by day for this application. Finding out the characteristic of those acoustic materials before using it in the application is so mandatory. Absorption coefficient of a material at various frequency ranges has to be known since absorption coefficient varies at various frequencies [18]. Jadidi performed that acoustic quality is defined as the degree to which the totality of the individual requirements made on an auditory event is met. It comprises three different kinds of influencing variables: physical, psychoacoustic and psychological [19]. The new model on acoustical formula of material was presented by Komatsu [20], as he described that the acoustical properties of a porous sound absorbing material that is the characteristic impedance Z_c and the propagation constant γ can be given as the complex expressions as follows: $Z_c = R + jX$ and $\gamma = \alpha + j\beta$, The presented formula as follows:

$$R = \rho_o c_o\{1+0,00027(2 - \log f/\sigma)^{6,2}\} \quad (3)$$

$$X = - \rho_o c_o\{0,0047(2 - \log f/\sigma)^{4,1}\} \quad (4)$$

$$\alpha = 0,0069\ \omega/c_o(2 - \log f/\sigma)^{4,1}\} \quad (5)$$

$$\beta = \omega/c_o\ \{1 + 0,0004(2 - \log f/\sigma)^{6,2}\} \quad (6)$$

Where R is the real component, X is the imaginary component, α is the attenuation constant in nepers/m, $\beta = \omega/c$ is phase constant in rad/s, ω is the angular frequency and c_o is the speed of sound in air. The aim of this research is synthesizing composite that consist of activated natural zeolite and various paper waste for absorbing noise that it never be done before.

2. Material and method

The experiment basically started by synthesizing composite that consists of activated natural zeolite, crushed carton and HVS paper waste. The activation of natural zeolite have been done to improve the quality of zeolite as porous material using HCl. The procedure of activation of natural zeolite as follows: 50 gram zeolite as powder is submerged during 24 hours in 500 cc HCl (30%) that added by 825 cc aquadest, concentration of HCl 2,72 M. After activation process, each activated zeolite is filtered, washed by aquadest three times then calcinated at temperature 245°C during 60 minutes. Another components for synthesizing composite is Carton and HVS paper waste. Both were submerged one month in water, then crushed by blender as pulp, pressed, crushed again to become soft particles and dried. There are two kinds of synthesized composite: Composite-1 consists of activated zeolite and HVS paper waste, and Composite-2 consists of activated zeolite and carton. Fig.1 shows crushed submerged HVS paper waste and Fig.2 performs HVS paper waste as particles. The same treatment was done for carton as shown at Fig.3 and Fig.4. The procedure for creating zeolite as powder was done by crushing, blending and sifting zeolite, the each product is indicated at Fig.5, Fig.6, and Fig.7. Chemical substances were used in activation process of zeolite and synthesizing composite are HCl, aqudest, and foam agent as shown in Fig.8. The molded samples performed at Fig.9 and the last producted samples are shown at Fig.10.

Fig. 1: Crushed HVS.

Fig. 2: HVS Particles.

Fig. 3: Crushed Carton.

Fig. 4: Carton Particles

Fig. 5: Zeolite.

Fig. 6: Blended Zeolite.

Fig. 7: Sifted Zeolite.

Fig. 8: HCl Foam Agent.

Fig. 9: Molded Samples.

Fig. 10: Samples.

The synthesized composites are shown in table-1.

Table 1: The Synthesized Composites

No.	Name of Synthesized Samples	Composition
1	Composite-1	10 gram HVS, 10 gram Activated Zeolite, 10 gram PVAc, 10 cc Foam Agent
2	Composite-2	10 gram Carton, 10 gram Activated Zeolite, 10 gram PVAc, 10 cc Foam Agent

The procedure of synthesis of each composite as follows:
Composite-1 : 10 gram partikel of HVS paper waste mixed with 10 gram activated zeolite, 10 gram PVAc and 10 cc foam agent then stirred and molded in a mold that has size 3 cm in diameter and 2 cm in thickness. There are 3 samples for every kind of composite. After that it was dried under halogen lamp in 5 hours then removed from the mold and ready to be tested. The same procedure was done for synthesizing Composite-2. The acoustical characterization of every sample was conducted by Impedance Tube in order to investigated the most significant capacity of each sample in absorbing noise. The composition test then conducted by SEM, EDS and FTIR.

3. Results and discussion

The instrument that was used in the experiment to test the acoustic properties of the samples is shown in Figure 11. Absorption coefficient measurement (α) of every sample was performed according to ASTM E 1050-98 by using Impedance Tube 4206 T. Based on experiment results the Composite-1 (Figure 12) higher in the capacity of absorbing noise then Composite-2 (Figure 13), but both perform significant results in absorbing noise, escpecially at the frequency range between 1200 Hz – 2200 Hz. Composite-1 has α maximum = 0, 63 and Composite-2 has α maximum = 0,42.

Fig. 11: Impedance Tube Type 4206 T.

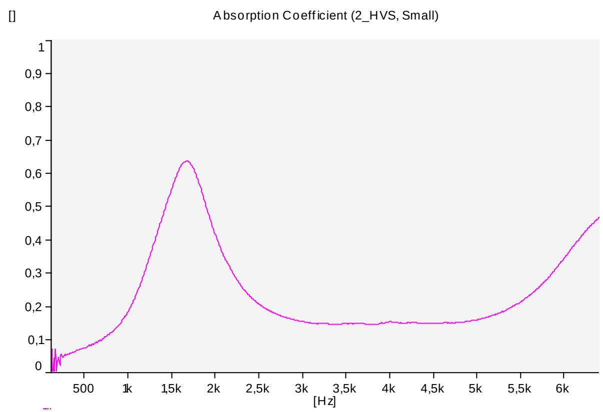

Fig. 12: Absorption Coefficient of Composite HVS- Zeolite as Function of Frequency.

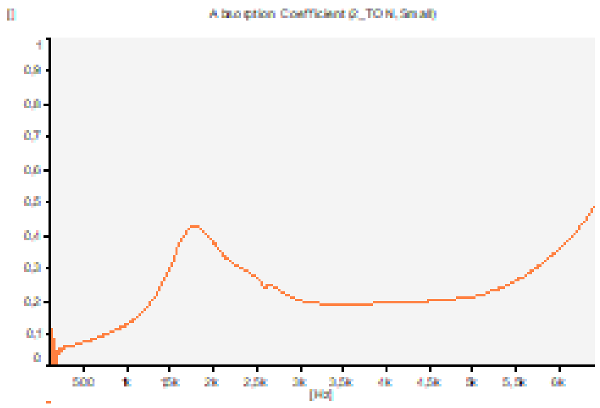

Fig. 13: Absorption Coefficient of Composite of Carton-Zeolite as Function of Frequency.

The chemical composition of Composite-1 was tested by FTIR Perkin Elmer Spectrum Version 10.03.02 and Energy Dispersive X-Ray Spectroscopy (EDS). Fig.15 is FTIR spectrum of Composite-1 shows the peaks of transmittance of samples as function of wavenumber. The each peak describes that: 455,46 cm^{-1} is at C-I area, 1000 cm^{-1} at C-F area, 1372 cm^{-1} at CH_3 area, 1434,45 cm^{-1} at C=C area, 1737 cm^{-1} at C=O area, 2921 cm^{-1} at C-H area, and 3341 cm^{-1} at N-H area. It means that there are Carbon, Fluor, CH_3, Oxygen, Nitrogen and Hydrogen in the Composite-1.

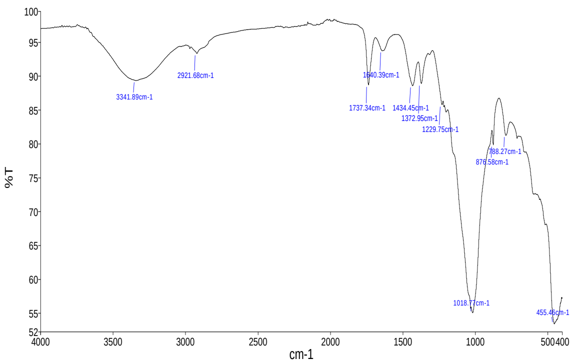

Fig. 15: FTIR Spectrum of the Composite HVS-Zeolite.

SEM was used to invstigate the crystallography, morphology, topology, or composition of a sample. Fig.16 shows the morphology of composite-1.

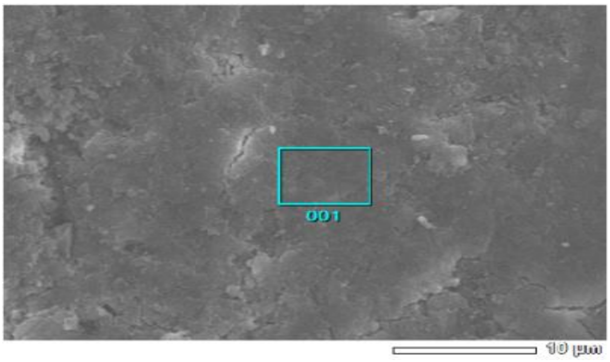

Fig. 16: Morphology of the Composite HVS-Zeolite Magnified 3000 X.

EDS used for the elemental analysis or chemical characterization of the sample. Fig.17 shows EDS Spectrum of Composite-1. It contents: Oxygen, Aluminium, Silicon, and Calcium.

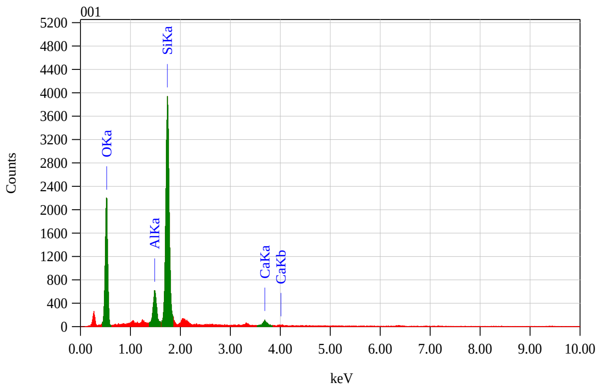

Fig. 17: EDS Spectrum of the Composite HVS-Zeolite.

The chemical composition of Composite-2 was also tested by FTIR Perkin Elmer Spectrum Version 10.03.02 and Energy Dispersive X-Ray Spectroscopy (EDS). Fig.18 is FTIR spectrum of Composite-2 shows the peaks of transmittance of samples as function of wavenumber. The each peak describes that: 3334,6 cm^{-1} is at O-H area, 2959,17 cm^{-1} at C-H area, 1732,5 cm^{-1} at C-O area, 1635,15 cm^{-1} at N-H area, 1451,14 cm^{-1} at CH_2, CH_3 area, 1159,59 cm^{-1} at C-N area, and 875,02 cm^{-1} at N-H area. It means that there are Oxygen, Hydrogen, Carbon, CH_2, CH_3, and Nitrogen in the Composite-2.

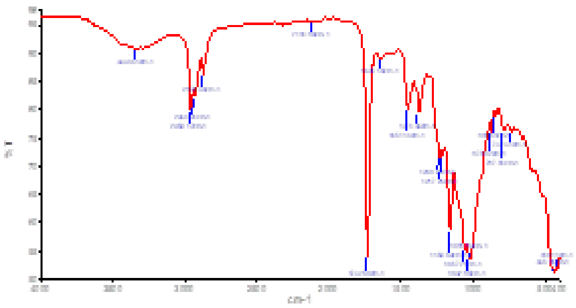

Fig. 18: FTIR Spectrum of the Composite Carton-Zeolite.

SEM was used to invstigate the crystallography, morphology, topology, or composition of a sample. Fig.19 shows the Morphology of composite-2.

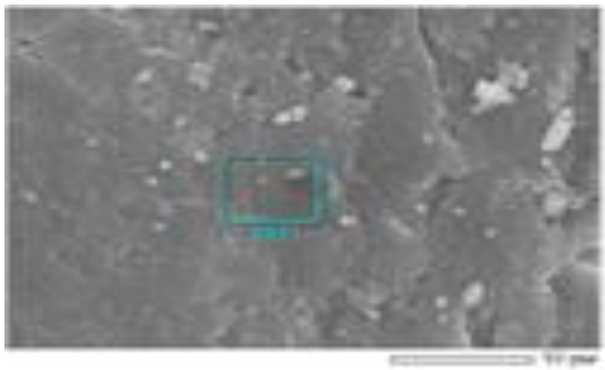

Fig. 19: Morphology of the Composite Carton-Zeolite, Magnified 3000 x.

EDS used for the elemental analysis or chemical characterization of the sample. Fig.20 shows EDS Spectrum of Composite-2. It contents: Carbon, Oxygen, Aluminium, Silicon, Natrium, and Kalium and Calcium.

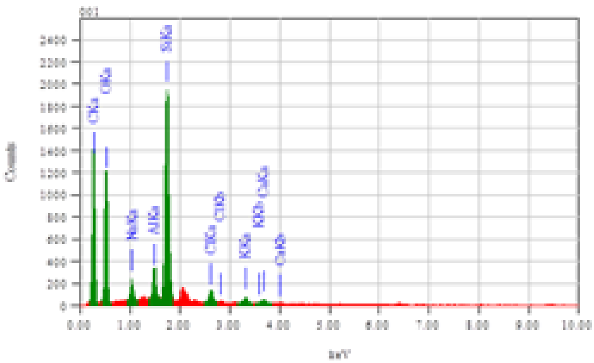

Fig. 20: EDS Spectrum of the Composite Carton-Zeolite.

4. Conclusion

The synthesized composite that consists of activated natural zeolite and HVS paper waste performs significant sound absorption coefficient in the frequency range between 1200 Hz – 2200 Hz and 5500 Hz – 6000 Hz. It shows better capacity in absorbing noise than the composite that consists of activated natural zeolite and carton. Nevertheless, both investigated composites have significant capacity in absorbing noise escpecially at frequency range between 1200 Hz – 2200 Hz. It has been noted that one of the most important factor that affects acoustic properties of composite is the type of binder. Different binder causes different ability in absorbing noise and strengthening composite. By using typical binder that keeps the pores of composite still open the ability of composite in absorbing noise will be better. The use of binder instead PVAc is needed in the next experiment for improving this investigation. The combination of zeolite and paper waste exhibits promising prospect in developing building material components for reducing noise because both are inexpensive and can create comfortable acoustic environment for supporting health safety and tranquality. Recycling paper waste also helps government in overcoming problem of environmental pollution.

Acknowledgements

The authors wish to acknowledge Ministry of Research and Technology-Directorate General of Higher Education of the Republic of Indonesia for the financial support awarded to carry out this research, also SEM-Laboratory FMIPA ITB, Acoustic Laboratory IARG UNS, and CPFMA Laboratory Faculty of Engineering University of Indonesia UI those have helped a lot in the data collection required.

References

[1] Martinez, C and Pariente, J.P., Zeolite and Ordered Porous Solids: Fundamentals and Applications, Universitat Politechnica De Valencia, 2016.
[2] Peng Guo, Structure Determination of Zeolites Com bined Study by Electron Diffraction and Database Mining, Doctoral Thesis, Department of Materials and Environmental Chemistry Arrhenius Laboratory, Stockholm University SE-106 91 Stockholm, 2016.
[3] Mansouri, N., et al., Porosity Characterization and Structural Properties of Natural Zeolite – Clinoptylolite as a absorbent, Environmental Protection Engineering, Vol. 39, No.1, 2013.
[4] Kulkarni, S., Paper Waste Recycle and Its Sludge Reduction, Int. Journal of Research and Review, Vol.4 Issue 10, 2017.
[5] Sahin, H.T., and Arslan, M.B., A Study Physical and Chemical Properties of Cellulose Paper Immersed in Various Solvent Mixtures, Int. J. of Molecular Sciences, 2008, 9, 78-88. https://doi.org/10.3390/ijms9010078.
[6] Yilmaz, M., Recycling Costs: A Research in the waste Paper Industry, European J. of Accounting Auditing and Finance Research, Vol.3, No.4, pp 58-68, 2015.
[7] Abdullah, R., et al., Characterization and Feasibility Assessment of Recycled Paper Mill Study for Land Application in Relation to the Environment, Int. Journal of Environ, Research Public Health, 2015, 12, 9314-9329.
[8] Bolton, JS, and Toyoda, M., Noise: Acoustics of Microperforated Materials, The journal of The Acoustical Society of America, Vol. 140, No. 4, 2016.
[9] Azimi, M., Noise Reduction in Building using Absorbing Materials, Journal of Architectural Engineering Technology, Vol. 16 Issue 2, 2017.
[10] Asdrubali, F., Green and Sustainable Materials for Noise Control in Building, Int. Congress on Acoustics, Madrid, September 2007.
[11] Kuczmarski, M., Acoustic Absorption in Porous Materials, National Aeronautics and Space Administration, NASA/TM-2011-216995, Glenn Research Center, Cleveland Ohio, 2011.
[12] Limin Peng, et al., Mechanic and Acoustic Properties of the Sound Absorbing Material Made from Natural Fiber and Polyester, Advances in Materials Science and Engineering, 2015. https://doi.org/10.1155/2015/274913.
[13] Malawade.UA, et al., Investigation of Sound Loss Potential of Natural Fibers and Their Compositions, Department of Mechanical Engineering Jayawantrao Sawant College of Engineering, Maharashtra, Journal of Engineering and Technology, Vol.6 Issue 3, 2017.
[14] Smith, R., the Environmental Sustainability of Paper, Graduate Study Journal of Organizational Dynamics, Vol.1 Issue 1 University of Pennsylvania, 2011.
[15] Stanciu, MD., Curtu, L, Casereanu, C and Nastac, S., Research Regarding Acoustical Properties of Recycled Composites, 8th International DAAAM Baltic Conference “Industrial Engineering”, Tallin Estonia, 2012.
[16] Elena, A and Moga, L., Improvement of Acoustic and Thermal Comfort by Turning Waste into Composite Materials, RJAV Vol. x, issue 2, 2013.
[17] Kehagia F and Mavridou S., Noise Reduction in Pavement Made of Rubberized Bituminous Top Layer, Open Journal of Civil Engineering, Vol.4, 198-208, 2017. https://doi.org/10.4236/ojce.2014.43017.
[18] Arunkumar, B and Jeyanthi, S., Design and Analysis of Impedance Tube for Sound Absorption Measurement, ARPN Journal of Engineering and Applied Sciences Vol.12, No.5, 2017.
[19] Jedidi, M. and Boulila, A., Acoustic Study of an Auditorium by the Determination of Reverberation Time and Speech Transmission Index, International Journal Architect Engineering, Urban Plan, 26 (1), 25-32, 2016.
[20] Komatsu, T., Improvement of the Belany Bazley and Miki models for fibrous sound absorbing materials, Acoust. Sci. and Tech., 29. 2, 2008. https://doi.org/10.1250/ast.29.121.