Article

Acoustic Properties of Composite Synthesized from Activated Zeolite and Fibre

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The potential application of the work is utilization of activated zeolite for absorbing noise

Abstract: The unique porous crystal structure of zeolite offers various important utilizations, it is one of the considerations in selecting zeolite at this study as component of composite for restraining noise. It so happens, previous experiments show that banana stem has porous structure, fibrous, high flexibility and can be applied as material for many various products including as component of acoustic material. The combination of both is alleged that it has capability in absorbing noise. This paper presents an investigation on the composite that it was synthesized of Activated Zeolite and Banana Stem Fibre in various weight for determining its sound absorption coefficient alpha (α). Activating natural zeolite was conducted by using 6M HCl in order for enlarging zeolite pores. The sound absorption coefficient was measured in the frequency range between 125 Hz up to 6000 Hz. The results show that the different weight of banana stem fibre as component of the synthesized composite affects the value of alpha and shifts the frequency area.

Keywords: Sound Absorption Coefficient; Noise; Activated Zeolite; Banana Stem Fibre; Acoustical material

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1. Introduction

The new model on acoustical formula of material was expressed by Komatsu [1], as he revealed that the acoustical properties of a porous sound absorbing material that is the characteristic impedance Z_c and the propagation constant γ can be presented as the complex expressions as follows: $Z_c = R + jX$ and $\gamma = \alpha + j\beta$, The presented formula as follows:

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

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

$$\alpha = 0,0069\ \omega/c_o(2 - \log f/\sigma)^{4,1}\} \quad (3)$$

$$\beta = \omega/c_o\ \{1 + 0,0004(2 - \log f/\sigma)^{6,2}\} \quad (4)$$

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.

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The ability of a material in absorbing noise is indicated by its value of alpha (α). Jimenez, N. et al. [2] presented that for a stiffly backed porous body of total thickness L with a complex and frequency dependent effective wave number and characteristic impedance k_e and Z_e respectively, the absorption coefficient ◎◎◎at normal incidence is performed by equation (5) as follows :

$$\alpha = 1 - [\, (i\, Z_e \cot k_e L - Z_o)/(i\, Z_e \cot k_e L - Z_o)]^2 \qquad (5)$$

where, Z_o = impedance of the surrounding fluid ;
$i\, Z_e \cot k_e L$ = acoustic impedance of the rigidly backed material.

Feizhabr, et al [3] described that the interaction of waves with perforated material has been investigated by many researcher, it shows that perforated material delivers damping effect by absorbing and dissipating the wave. Umar Salihi, et al [4] performed that the adsorbents can be of various kinds of material including zeolites. In this research activated zeolite and banana stem fibre were synthesized as a composite for absorbing noise. Esfandian, et al [5] explained that adsorption process is the forceful way for eliminating pollutants from the environment and zeolite has good capability for adsorbing of organic substances. Regarding on environmental pollutions, Heydari and Khavarpour [6] reminded that industrial waste including hazardeous materials bring about contamination of the ecosystem. The preparatory results by Bennet, G.J. [7] revealed that the existence of foam at the trench entrance mitigate the duct over pressure (DOP) when the foam fills the everywhere trench, an intense attenuation on the ignition over pressure (IOP) and duct over pressure is examined on the environment of launchers at lift off purpose at controlling the explosion wave generated at ignition of solid rocket motors. Montello, N.Z. [8] performed that the experimental research shows the possibilities of efficiently applying sound absorbing shading instruments to attenuate average sound pressure level (SPL) over building facades. Kinnane, O. [9] expressed that hemp presents intense sound absorption when combined with calcium oxide (CaO) ground granulated explosion slag binder. Tholkappiyan et al [10] demonstrated that natural fibre reinforced composites are well utilized for sound attenuation in many places including conference halls, auditoriums, factories, theatres, universities, hospitals, offices, many kinds of vehicle. The application of coir fibre was described by Sholehudin,[11], it can be used as sound absorber material to act in place of the synthetic material such as glass wool which is widely have been applied recently. Shiney, A. [12] explained that coir mats are suitable body for acoustic absorption purposes that non dangerous and fully ecofriendly with moderately good sound absorption. The investigation by Mukhtar F.N. [13] indicated that utilizing recycled rubber tire products as a noise dumping component in fence sound barriers is one of successful rubber waste material utilizations. Koussa, F. [14] concluded that Gabions barriers can be utilized as effective noise barriers. In a case, their application and maintenance are very submissive and there are wide alternatives of useful material of construction. They are promising candidates as useful invention devices for environmental noise abatement. In case of fully open cell porosity of 88 – 90 % the alumina foams, Zielinsky T.G. [15] demonstrated that it performs outstanding sound absorbing properties comparable with the best sound insulating polyurethane foams. The research that was done by Zhu, et.al. [16] performed that the investigation of the acoustical characteristics of a range of natural fibres has corroborated their capability as porous sound absorbers. Samsudin, E.M.[17] concluded that most of natural fibres are effective for absorbing sound in wide range frequency. Regarding on banana trunk, Yasim, N.S. [18]

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found that it has potential to be an forceful and economically feasible adsorbent in eliminating heavy metal. Alarcon, L.C.[19] set forth that the characteristics of the pulp from the pseudo stem of the plant banana perform that it is possible to its implementation for the manufacture of paper container board. Anupriya, J. [20] demonstrated that if banana stem extract is mixed to waste water the amount of suspended solids decreased due to the adsorption capacity of the banana stem extracts. Permanasari, M.D. [21] revealed that banana bark's porous characteristics could potentially be improved as an acoustic material. The study on zeolites by Ismail, H. [22] delivered a conclusion that they are microporous crystalline aluminosilicates, Si, Al, and O are settled in a regular structure of [SiO_4] and [AlO_4] tetrahedral units that a framework with regular pores shape of channels, tunnels, or cavities of about 0,1 – 2 nm diameter running to the material. It has been utilized as ion exchange and molecular sieves in the separation and removal of gases and solvents. Amin et al [23] presented the characteristic of adsorption favor natural zeolite as an potential adsorbent for dye dismissal for example from the waste water of the textile industry. The acquired sorbents those were investigated by Plaza, A. [24] indicated good structural properties and high removal efficiency for heavy metal ions from dirty water and waste water. Eskandari, A. [25] demonstrated that reduction of the particle size from micrometer to nanometer attained in increasing the adsorption capacity for carbon dioxide on the X zeolite nano particles. The highest reduction of Pb content was investigated by Radziemska [26] in soil from pots to which 80 and 160 $mgkg^{-1}$ of Ni containing an addition of modified hallosyte. The intense effects were brought about by natural zeolite which significantly reduced the average content of chromium. The results of study by Babak, K. [27] performed that the Iranian zeolite was a better adsorbent for Zn than the Chinese zeolite at PH 5 and 7. Sapawe, N. [28] explained that the cost effective and abundance of NaA cause this material particularly promising for the removal of cationic dyes in industrial waste water management. Based on Sangeetha's research [29], zeolite are recommended in agriculture because of the large porosity, cation exchange capability and selectivity for ammonium and potassium cations . Kuczmanski, M. [30] expressed that it is necessary to be aware of that not all highly porous materials are fitting as acoustic absorbers. If the mean free path of air is on the order of that of the mean diameter pores, pressure waves will not afford to efficiently penetrate the material. In this case, even if the material has an o pen-cell structure, it will act like a closed-cell material. Sakagumi, et al [31] revealed that the rectangular Micro Perforated Panel (MPP) space sound absorbers are useful as an alternative sound absorption treatment to manage the acoustic environment in many places.

The main purpose of this study is investigation on the influence of different weight of banana stem fibre as composite component on the sound absorption coefficient alpha (α) of the composite that made from activated zeolite and banana stem fibre. introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be reviewed carefully and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the principal conclusions. As far as possible, please keep the introduction comprehensible to scientists outside your particular field of research. References should be numbered in order of appearance and indicated by a numeral or numerals in square brackets, e.g., [1] or [2,3], or [4–6]. See the end of the document for further details on references.

2. Materials and Methods

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The material components used for synthesizing the investigated composite consist of: Natural Zeolite, Hydrogen Chloride, Banana Stem Fibre, Calcium Oxide, Polyvinyl Acetate and Aquadest. The steps for production of the samples were done as follow:

2.1. Process of Creating Banana Stem Fibre

Chop the banana stem as raw material then it is cut into small pieces and shattered by blender. Afterwards the crushed banana stem is pressed and filtered by perforated plastic, it remains as banana stem fibre, then it is dried as shown at Figure 1

Figure 1. Banana Stem Fibre

2.2. Process of Activating Natural Zeolite

The natural zeolite as pebble that obtained from Tasikmalaya area is crushed then sieved by sifter. It is made as powder that performed at Figure 2.

Figure 2. Natural Zeolite as Powder

The activation process is conducted by soaking 450 gram of zeolite in 1 liter of 6M HCl in 13 hours as shown at Figure 3. After that the activated zeolite is sieved by Whatman Paper, it is performed at Figure 4. Then the activated zeolite repeatedly cleaned by aquadest for eliminating the remnant of HCl. At last the clean activated zeolite is calcinated by oven at the temperature 225^{o}C along 5 hours. The dry activated zeolite is shown at Figure 5.

Figure 3. Activated Zeolite in 6M HCl

Figure 4. Sieved Activated Zeolite

Figure 5. Dry Activated Zeolite

2.3. Process of Synthesizing the Composite

The combination of Polyvinyl acetate (PVAc), Calcium Oxide (CaO), and aquadest was used as binder in synthesizing the composite. PVAc has beneficial adhesive strength and toughness but the disadvantage of using this kind of glue is it evokes pore clogging of the composite. Regarding CaO in aquadest that form Calcium Hydroxide $Ca(OH)_2$, it is not a strong binder but porous substance. The combination of both is alleged that it delivers beneficial binder for this synthesized sound absorber composite. There are two kinds of the synthesized composite for investigation. The first composite is performed at Table 1 and the second composite is performed at Table 2.

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Table 1. Composition of the Composite 1

No.	Name of Component of Composite	Mass (g)
1	Activated Zeolite	22
2	Banana Stem Fibre	11
3	Polyvinyl Acetate	33
4	Calcium Oxyde	11
5	Aquadest	20

Table 2. Composition of the Composite 2

No.	Name of Component of Composite	Mass (g)
1	Activated Zeolite	22
2	Banana Stem Fibre	6
3	Polyvinyl Acetate	33
4	Calcium Oxyde	11
5	Aquadest	20

All components of composite that consists of Activated Zeolite, Banana Stem Fibre, PVAc, CaO and Aquadest were combined by mechanical mixing. The product then molded and dried by infra red radiation in 4 hours as shown in Figure 6. After that the contents were taken out from the mold. The samples that presented at Figure 7 were ready to be tested by Impedance Tube that informs their characteristic in absorbing noise as performed at Figure 8.

Figure 6. Molded and Dried Composites

Figure 7. Synthesized Composites as Samples Made of Activated Zeolite, Banana Stem Fibre and Binder (PVAc and CaO)

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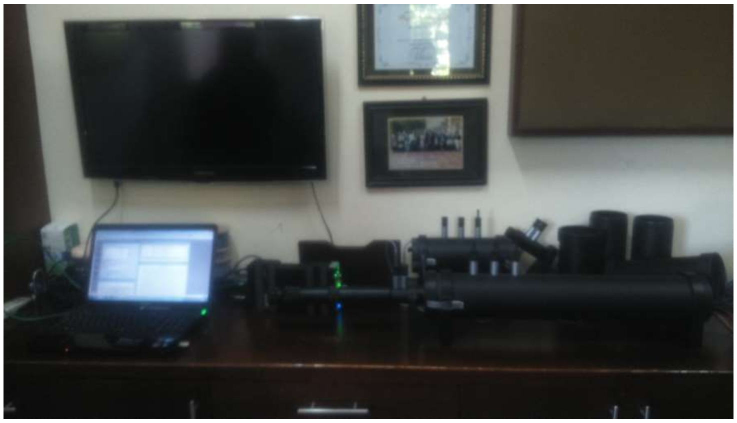

Figure 8. Impedance Tube Type 4206 T.

3. Results

This There are five apparatus used for investigating the characteristics of the synthesized composites : EDS, SEM, FTIR, XRD, and Impedance Tube.

The semi-quantitative elemental analysis provided by EDS (Energy Dispersive X-Ray Spectroscopy) detected several elements involved in creating the synthesized composite as sample which are : C, O, Al, Si, and Ca, Al as performed at Figure 9. The composite contents: Carbon, Oxygen, Aluminium, Silicone, and Calcium at mass percentage (%) for each element: 39.30, 45,18, 0,94, 6,86, and 7,73. EDS spectra of the investigated sample perform strong elemental signal of carbon, and oxygen, weak signal for Silicone and Calcium, very weak signal of Aluminum.

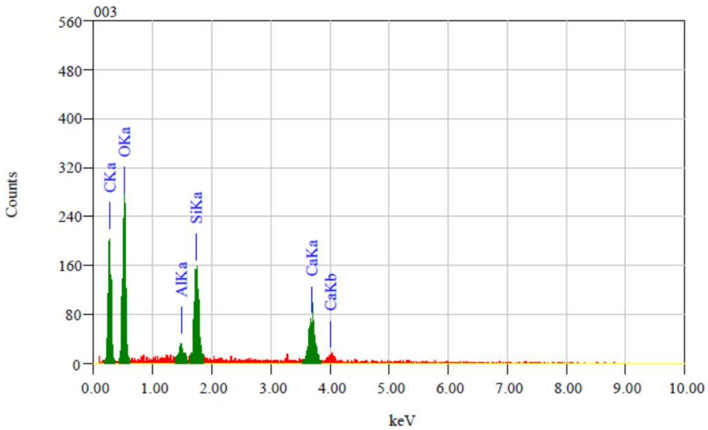

Figure 9. EDS Spectra of Composite of Activated Zeolite and Banana Stem Fibre

SEM (Scanning Electron Microscope) was commonly used to investigate the morphology, topology, crystallography and composition of the sample. The SEM image in Figure 10 indicates the formation of some crystals and amorf. The combination of activated zeolite as powder, banana stem fiber, and binder has accured. It can be clearly seen that SEM image performing surface morphologies of the banana stem fibers, smooth activated zeolite and polyvinyl acetate as component of binder.

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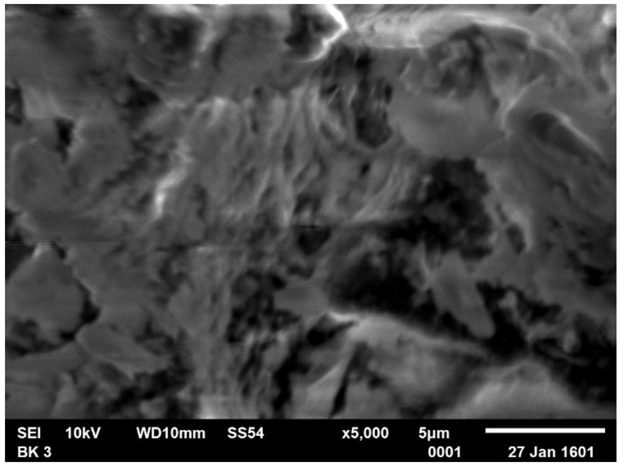

Figure 10. SEM Morphology of the Composite of Activated Zeolite-Banana Stem Fibre, magnified 5000 x

The FT-IR (Fourier Transform - Infra Red) spectra of synthesized composite by using activated zeolite and banana stem fibre is indicated in Figure 11. According to previous studies, IR results confirm that bands close to (560 cm^{-1}), for this description according to appeared peak the band close to 465,95 cm^{-1}. The chemical composition of the synthesized composite that tested by FTIR reveals peaks of transmittance of specific molecule as function of wave number. The each peak at the spectra describes an absorption in this region, that: 3246,97 cm^{-1} is attributed to O-H, 1533,86 cm^{-1} at Aromatic Nitro Compound area, 1412,25 cm^{-1} at Organic Sulfate area, 1022,98 cm^{-1} at Si-O-Si area, 956,87 cm^{-1} at Silicate Ion area, 670, 63 cm^{-1} at C-S stretch area, 614,09 cm^{-1} at S-S stretch area, and 465,96 cm^{-1} at S-S stretch area. Every peak at an area indicates the existence of specific substance. This FTIR spectra shows the existance of Hidrogen, Nitrogen, Oksigen, Carbon and Silicone in the composite.

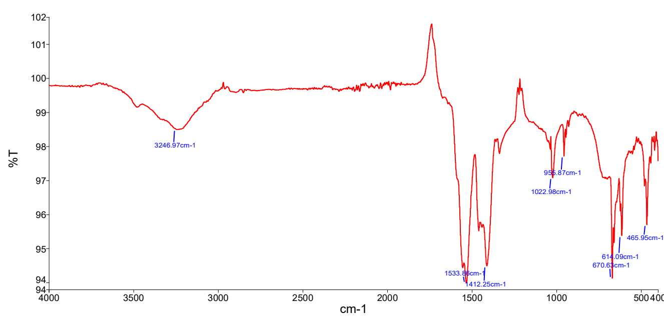

Figure 11. FTIR Spectra of the Composite

XRD (X-Ray Diffraction) characterization revealed the occurrence of the peaks of some compounds as performed at Figure 12. The presence of Clinoptilolite, Mordenite and Calcium silicate are presented at Table 3. By analysis of the XRD patterns of the spectra can be indicated that the crystal system of Clinoptilolite is Monoclinic, Mordenite is Orthorhombic, and Calcium silicate is Anorthic. Based on scale factor, the percentage of each compound in the composite as follows: Clinoptilolite 13,9 %, Mordenite 12,9 % and Calcium silicate 73,2 %. The existence elements those are analyzed by XRD is in good agreement with the mentioned elements in EDS and FTIR characterization.

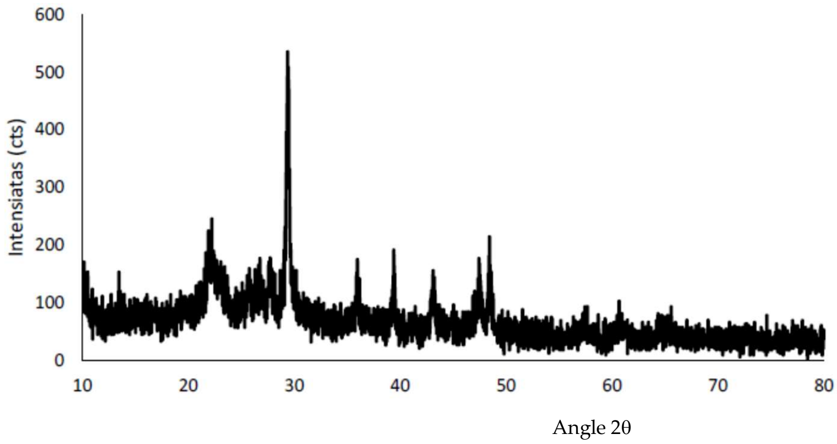

Figure 12. XRD Spectra of the Composite

Table 3. Structure of the Composite by XRD

No	Compound Name	Chemical Formula	Scale Factor	Crystal System
1	Clinoptilolite	H46.24Na4.12O95.12Si36	0,46	Monoclinic
2	Mordenite	H64Al4.96Na4.670.128Si43.04	0,322	Orthorombic
3	Calcium Silicate	CaSiO3	0,144	Anorthic

This investigation was aimed to find out the influence of different weight of banana stem fibre on the capacity of sound absorption coefficient alpha (◎) on the synthesized composites by using Impedance Tube Apparatus Type 4206 T. The diameter size of synthesized composite as sample is 3 cm and its thickness is 2 cm. There are three samples for composite 1 and three samples for composite 2 those were tested. All sample has same size, shape and composition. The results of sound absorption coefficient versus frequency for composite 1 and composite 2 are performed at Figure 13 and Figure 14. The maximum ◎◎for average value of the composite 1 is about 0,3 at the frequency 1600 Hz, it so happens the maximum ◎ for average value of the composite 2 is 0,21 at the frequency 1200 Hz. By determining the value of Absorption Coefficient (◎) as function of frequency, the maximum value of ◎◎◎is 0,3 at the frequency 1700 Hz for composite 1, and the maximum value of ◎ is 0,22 at the frequency 1300 Hz for composite 2. There is performed that by decreasing the weight of banana stem fibre from the composite, the capacity of composite in absorbing noise decreases at the smaller frequency area.

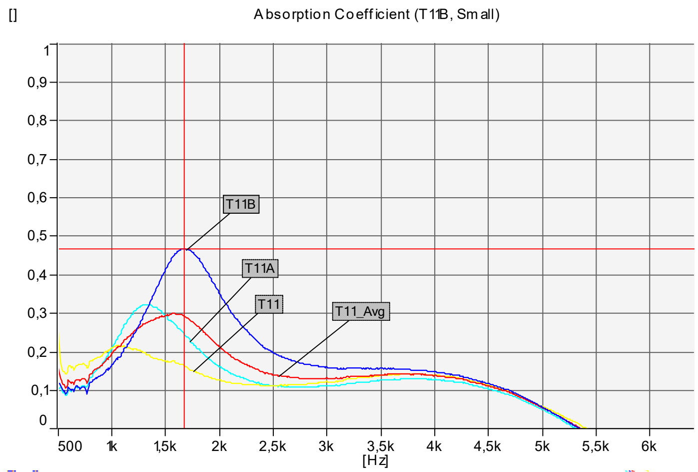

Figure 13. Curve of Absorption Coefficient of the Synthesized Composite versus Frequency

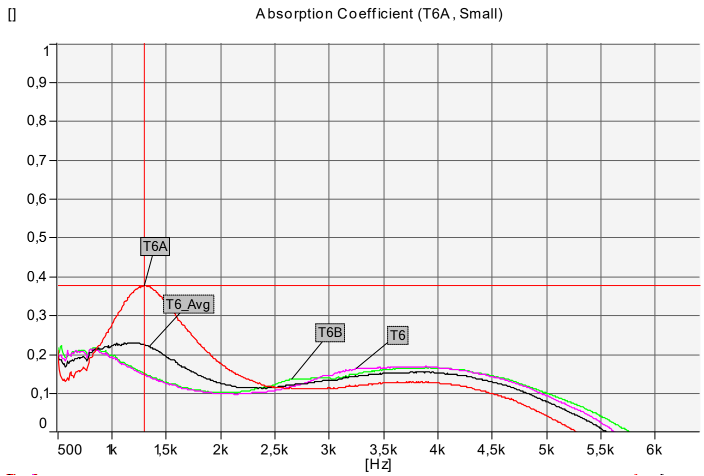

Figure 14. Curve of Absorption Coefficient of the Synthesized Composite versus Frequency

5. Conclusions

The authors conclude that zeolite and banana stem fibre both are the promising alternative material for noise abatement. Although natural zeolite is micro porous material that has diameter pores under 2 nm in average, and for this reason it is never used as noise absorber, by modifying physical and chemical properties of zeolite including activation and calcination process it can be synthesized as component of composite for absorbing noise at specific frequency. Kuczmarski revealed that if the mean free path of air which the noise passes is on the order of the mean diameter pores, pressure waves of noise will not afford to efficiently penetrate the material. It means, the larger diameter pore, the more efficient of pressure wave in penetrating material. The future method for enlarging pores diameter of zeolite from microporous to mesoporous scale is promising defiance in order to synthesize new acoustic composite because zeolite is relatively not expensive material. Regarding banana stem which is currently wasted after felling, it is fibrous material and cellulosic source that can be utilized as noise absorber. Based on the results of investigation on the composite that made of activated zeolite and banana stem fibre, there is an alternative material that beneficial for absorbing noise because it is easy to be produced, low in cost and free of environmental pollution.

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Patents

Synthesis of the composite from activated zeolite and banana stem fibre for absorbing noise is never done before, therefore the best result of this kind of composite at the next research will be promising composite as protected product by a patent.

Author Contributions

1. Hidjan: Methodology, Formal Analysis, writing, review and editing
2. Sutanto: Data Curation, supervision and validation
3. Nanang Rohadi: Investigation, project administration and funding management.

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