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HYBRID ACOUSTIC PANEL: THE EFFECT OF FIBER VOLUME FRACTION AND PANEL THICKNESS

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Abstract. The composite panel test were made of gypsum, pumice powder, and glue with composition of 1:2:1/2 and coconut fiber with volume fraction variation of 10%, 15%, 20%, 25%, and 30% by using Hand lay-up technique. The sound absorption panel was tested for acoustic and mechanical characteristic using test standard with ASTM E1050, ASTM D256, and ASTM D790, respectively. The result of data analysis was presented graphically and the bounding of composite materials was analysed by using SEM photograph. From the data analysis for 10mm thickness of composite with 30% fiber volume fraction gained the highest sound absorption coefficient, the highest impact strength occurred on composite with 25% fiber volume fraction. Meanwhile, the strength and modulus of bending occurred on composite with 15% fiber volume fraction. Sound absorption coefficient for composite with 15mm thickness was higher than 10mm for 10% fiber volume fraction.
Keyword: pumice waste, coconut fiber, gypsum, acoustic and mechanic

1. Introduction

Comfortable and soundproof room is highly needed in the factory, hotel, office or in private room. Soundproof material has an important role to absorb sound so it will decrease the sound resonance intensity to the ears so there will be more comfortable for the user.

The soundproof material is in form of porous material, resonator and panel [1]. Type of the existing soundproof material is a porous material such as foam, glass wool, Rockwool, and resonator. These material usage is relatively expensive and could not be exposed because resulting irritation on skin and respiration.

Development of soundproof with natural material becomes the best choice because it is environmental friendly by improving the usability of wasted material. Some researches on soundproof have been conducted by [1], who develops soundproof from recycled polyester material.

Abundant pumice waste becomes economic consideration to engineer this rock to be more useful material. Pumice has porous structure which is the same with the existing soundproof material. This rock has characteristics of porous structure, light, easy to be gained and cheap but fragile. The abundant pumice waste comes from the result of pumice sieve of unused pumice since the size does not fulfil the criteria of packaging to be marketed (aggregate size of pumice waste less than 10 mm).

Coconut fiber waste is also abundant but it is used for mat, or becomes traditional firing. Coconut fiber is a Lignocellulosic fiber, brittle and possibly modified chemically, non-toxic [2,3] and biodegradable, low density, not abrasive on the tool to work it [3]. Moreover, the coconut fiber waste does not impact the environment. It has holes in the fiber axis [4] so it is

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suitable for soundproof material and decrease the density type of the formed material [5]. Research about multi-layer coconut fiber with little latex binder as soundproof shows sound absorption coefficient of 0.7-0.85 for frequency 500-2500Hz which is competitive with the marketed material such as rock wool and other fiber synthetic [6].

This research reviews how pumice hybrid and coconut fiber as amplifier and gypsum as the binder could absorb sound well so it can be applied as acoustic wall.

2. Purpose of the Research

The use of industrial waste is one of the good ways to maximize the existing natural resources so it can be beneficial for human life. The abundant pumice and coconut fiber wastes in Indonesia are highly potential to be developed for composite material of soundproof. This research has specific purposes as follows:

a. Determining the acoustic characteristic of sound absorption of the pumice-coconut fiber hybrid composite as the effect of coconut fiber volume fraction variation.
b. Determining mechanical strength of impact load and flexibility of the pumice-coconut fiber hybrid composite as the effect of coconut fiber volume fraction variation.

3. Research Method

The research procedures are firstly the pumice was cleaned by pure water to get clean particles; secondly it was heated with 65°C for 24 hours to get dried pumice. The pumice was sifted to get ≤ 1mm pumice size. The coconut fiber treatment was done by cleaning coconut fiber, boiling the coconut fiber to remove the dirt and then it was dried in 70°C for 24 hours. The fiber was cut off into 10-15mm in length. The fiber was treated by 5% NaOH concentration in 50°C for 2 hours and then cleaned. The fiber was dried in 70°C for 24 hours.

The composite moulding process was done by using hand lay-up method, with 100mm in diameter of mould with 10mm and 15mm thickness. The mould surface was cleaned from any dirt by using tissue and tinner to reduce impurity factor and then covered by glycerine. Afterward, mixed gypsum with glue, and then the pumice was mixed into this mixture. The coconut fiber was poured into this mixture to be hybrid composites in container based on composition of gypsum mixture: pumice: glue 1:2:1/2. Meanwhile, volume fraction of coconut fiber was varied on percentage of 10%, 15%, 20%, 25% and 30%.

Testing of specimen sound absorbtion coefficient was done by using test machine of impedance tube standing wave method with specification of Measuring Amplifier Brüel & Kjær type 2636, Sine Generator Brüel & Kjær type 1054. The test was done on frequency 120-4000 Hz (ASTM C 423-66). Impact and bending test was done by using Impact (Charpy Type) test and bending test of Tensilon Universal Testing Machine with type RTG 1310. The data analysis was done by using graphic analysis. The final result was in form of data trend which was plotted to be a frequency graphic (**Hz**)-Coefficient sound absorption ($\boldsymbol{\alpha}$).

4. Result and Discussion

Based on Figure 1 of relationship diagram of frequency with sound absorption coefficient for composite 10%, 15%, 20%, 25% and 30% coconut fiber with 10mm thickness, there are no trend since the data are random and fluctuating. It is caused by the effect of back cavity depth on sound absorption characteristic of all composite samples. It can be seen that the pick sound absorption happened in some certain frequencies which is possibly caused by back cavity depth, which is similar with the research result of other researchers [7,8]. However, sound absorption coefficient from all specimens had sound absorption coefficient (α) > 0.8, which means that the sound absorptions are excellent.

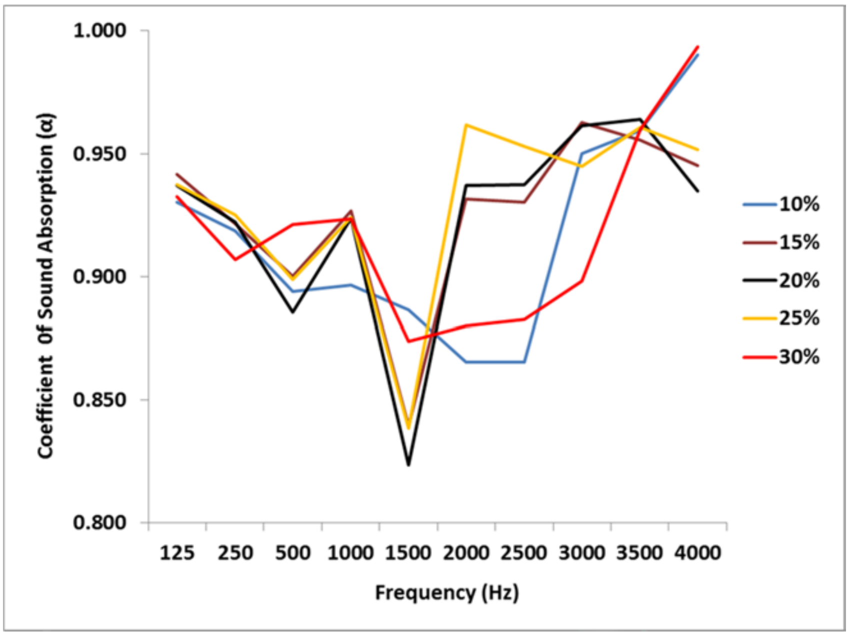

Fig. 1. The effect of frequency on sound absorption coefficient for composites 10%, 15%, 20%, 25% and 30% coconut fiber with 10mm thickness

Coconut fiber addition on the composite improved the sound absorption coefficient. This condition is caused by the absorber characteristic of the fiber and micro pore structure of pumice and gypsum. Besides that, addition of fiber could increase the number of micro empty spaces among the fibers or improving composite porosity so it can improve interaction between sound wave and composite material which causes friction improvement which finally increase the change of sound energy to be lost heat energy [9].

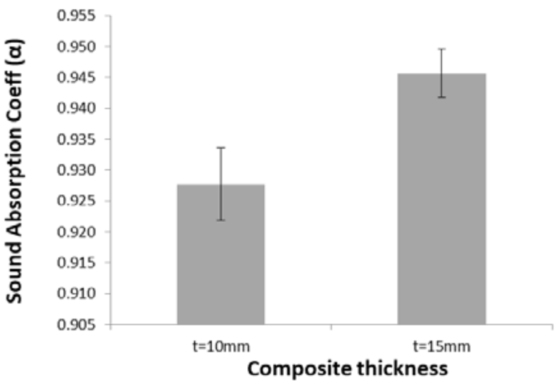

Fig. 2. Comparison diagram of sound absorption coefficient for composite of 10mm and 15mm thickness for 10% fiber volume fraction

Figure 2 shows that thicker composite has bigger sound absorption coefficient than thinner composite. It is because of the thicker of the composite the more spaces or micro spaces owned so the bigger sound energy that could be absorbed. But the addition of thickness will increase the weight of the material and narrow the space. So that future research, how to make thin material with high sound absorption will be done.

Figure 3 shows that the highest impact strength occurred on specimen of 25% volume fraction and then followed by 15% and 20% of fiber volume. It occurred because the matrix binds almost all fiber surface as shown by Figure 4c in which the matrix still fully attaches on the fiber while on the 15% fiber volume fraction the matrix still attaches on the fiber but mostly detached (Fig. 4a), as well as on 20% fiber volume fraction the matrix does not attach on the fiber well (Fig. 4b). From the data, there is possibility that 25% volume fraction is the highest limit of volume fraction to get the highest specimen impact strength. This explanation is supported by SEM photo of Fig. 4c in which the matrix is still intact binding fibers.

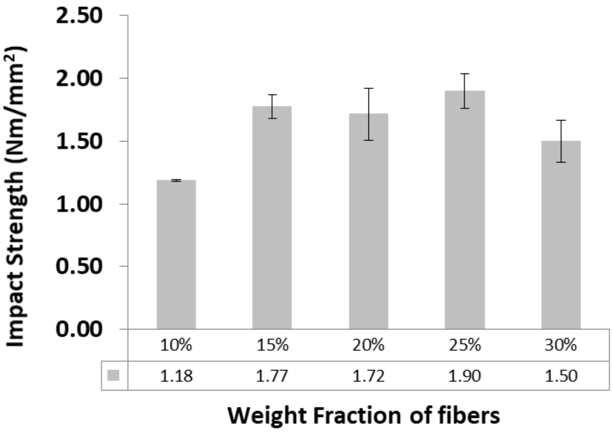

Fig. 3. The effect of coconut fiber volume fraction on composite impact strength

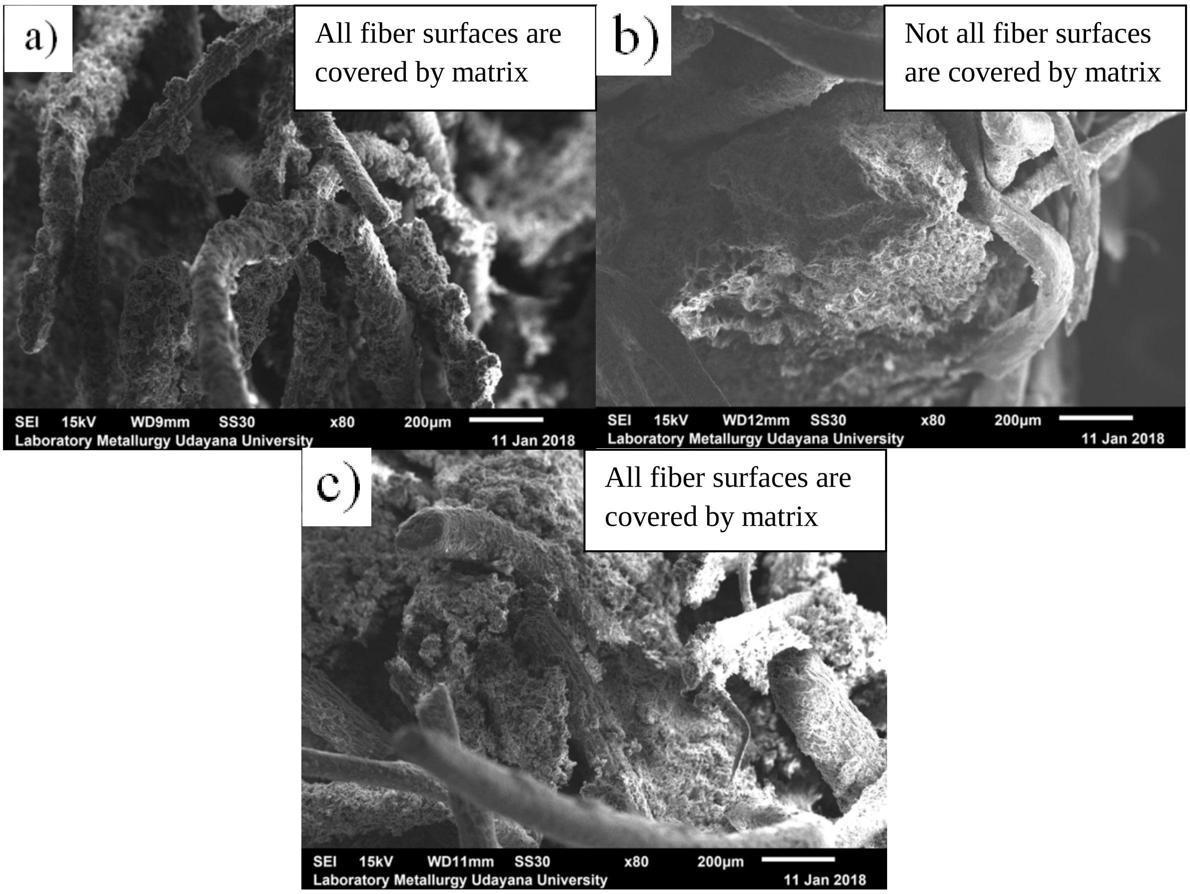

Fig. 4. SEM Photo of composite fraction with fiber volume fraction:
a) 15%, b) 20% and c) 25%

Figure 5 shows that the highest bending strength and modulus bending occurred on specimen of 15% fiber volume fraction and the lowest score gained by 25% volume fraction. It is caused by bending behavior in which in this specimen, the matrix bonding rigidity with pumice takes the most important role which is different with impact in which matrix and pumice are fragile so the fiber takes more roles on it. In other words, bending strength and modulus bending increases with the decreasing fiber volume fraction of coconut fibers. As a result, the increase of gypsum and pumice stone that has more rigid properties than fiber on the composites were concluded to enhance bending strength and modulus.

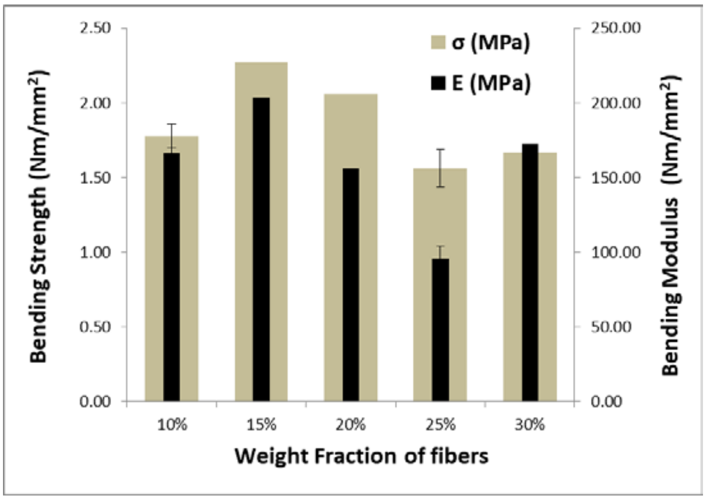

Fig. 5. The effect of coconut fiber volume fraction on composite bending strength

5. Conclusion

This study aimed the investigation of the effect of fiber volume fraction and panel thickness of hybrid acoustic panels which are made of gypsum, pumice powder, and glue with composition of 1:2:1/2 and coconut fiber with volume fraction variation of 10%, 15%, 20%, 25%, and 30% on sound absorption, impact strength and bending strength. According to this study and analysis, that can conclude that the sound absorption coefficient (α) is bigger than 0.8 for all specimen which means that the sound absorption is categorized as excellent, since good material for sound absorption at least α=0.3. The thicker the composite, the sound absorption coefficient increases as well. For mechanical properties, the highest impact strength occurred on composite with 25% fiber volume fraction. The highest bending strength and modulus bending specimen occurred on 15% volume fraction. Thus, optimum volume fraction for composite pumice/gypsum/glue to have high sound absorption coefficient, high impact strength and high modulus bending is 15%.

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