The effect of pumice composition upon transmission loss and impact strength of pumice hybrid composite–coconut fiber/gypsum

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Abstract. Voice could not be separated from ears, but there is other sound called noise. Soundproofing panel in a room is highly important to hold and absorb sound in order to prevent sound to come and out of the room so the room will be comfortable. The objective of this study is to find the characteristic of transmission loss and the value of impact strength caused by the effect of pumice and gypsum composition. This study used 2 mm pumice combined with coconut fiber in 20% of fiber volume fraction, by using gypsum and glue matrix. The varied composition of this study used two comparisons Gypsum: Pumice: Glue of 1:1:1/2, and 1:2:1/2. Transmission loss was tested by using test equipment (ASTM-E-1050) and Sound Level Master (SL-4011), while the impact strength was tested by using Charpy Impact test equipment (ISO179-2). Result of this study showed that the lowest transmission loss occurred in specimen with composition 1:1:1/2 with value 13.48dB, while the highest transmission loss occurred in specimen with composition 1:2:1/2 with value 25.21dB. The lowest impact strength occurred in specimen with composition 1:2:1/2 with value 4.293kJ/m², while the highest mean value for impact strength was 5,534 kJ/m² which occurred in composition 1:1:1/2.

1. Introduction
By the advanced development of technology, the human tools development is improving as well. The variations are in form of information, communication, production, transportation or entertainment equipment. Most of the equipment produce unwanted sounds that cause noises. To have comfortable room which is far away from noises becomes everyone desire. Controlling is done to block sounds in room so the sound intensity becomes weak. Therefore, the room should have wall cover to muffle sounds. The existing silencer are the porous material, resonator, and panel [1]. Some researches have been done before about silencer by using different materials such as: developing silencer material from bamboo fiber as good as glasswool [2], developing silencer from recycled polyester fiber.

Until today, coconut fiber is only developed to be many industrial products such as carpet, mat and other functional handicraft. Few people know that coconut fiber can be used as reinforcement in composite. Processing coconut fiber become effective as new engineering material are producing
nature-friendly new composite, cheaper with high economical value. Pumice is one of materials originated from volcano eruption. Then it has natural cooling process and sediment in the subsoil for years. Pumice and pearlite can be used as main material to make light concrete, because it has some characteristics such as high porosity, low density, high thermal insulation, and shock resistant as earthquake. So, there should be improvement by changing conventional concrete material (cement) with a polymer composite material [3].

Gypsum (CaSO$_4$.2H$_2$O) is a chemical compound arranged from calcium, sulfate group and water. Gypsum is not heavy and fire proof, with density 2.32g/cm$^3$. Gypsum is chosen as silencer composite material because it has characteristic of noise reduction and good sound absorber. The alternative material that can be used as absorber panel based on pumice hybrid as filler and combined with coconut fiber volume of 20% and then bounded by gypsum and glue as matrix upon loss transmission loss and impact strength. It is expected from this research, there will be new innovation in technology development of composite material reinforced with natural fiber and pumice stone in the application as sound absorber.

2. Research Method

2.1 Process of Making Pumice Particle and Coconut Fiber Treatment

Pumice was cleaned to remove dust and dirt by using clean water by rubbing with brush to get cleaner and fast result. After that, pumice was rinsed by aquadest and then dried by using oven on 70°C for 24 hours. The dried pumice was pounded to be in smaller size ($\pm$ 2mm) by sieving machine.

The process of coconut fiber treatment was done through the following some steps. Firstly, to remove impurities, the coconut fiber was washed until clean. Secondly, coconut fiber was boiled on 100°C for 15 minutes to reduce the impurities attached on the coconut fiber, then it was dried for 24 hours in oven on 70°C. Thirdly, the fiber was cut into 10mm, and treated with NaOH with concentration 5% for 2 hours and then it was washed so it was really clean. Finally, the fiber was dried again on 70°C for 24 hours.

2.2 The Process of Making Composite Mold

Ceramic mold in square shaped 400 x 400 mm was prepared for the composite pedestal and cover. Mold dimension 300 x 300 mm with 10 mm thickness was prepared as well. Before molding, ceramic surfaces were cleaned with clean water to reduce impurities factor. The mold was placed based on composite thickness that was 10 mm and glued. The mold was ready to process molding as shown by Figure 1.
Figure 1. The series of Composite Mold.

Table 1. Transmission Loss and Impact Strength values.

| Composition of Gypsum:Pumice:Glue | Fiber volume fraction (%) | Mass of Fiber (gram) | Gypsum Volume (cm³) | Gypsum Mass (gram) | Volume of Pumice (cm³) | Mass of Pumice (gram) | Glue Volume (cm³) | Glue Mass (gram) |
|----------------------------------|--------------------------|----------------------|---------------------|--------------------|----------------------|----------------------|------------------|------------------|
| (1:1:1/2)                        | 20                       | 226.8                | 288                 | 668.16             | 288                  | 184.60               | 144              | 241.92           |
| (1:2:1/2)                        | 20                       | 226.8                | 206                 | 477.92             | 411                  | 263.45               | 103              | 173.04           |

2.3 Composite Molding and Post Curing Process
Gypsum and glue were mixed and stirred until evenly distributed. The pumice that was filtered by using 2 mm sieve was poured with gypsum and glue mixture, and then stirred until evenly distributed. Coconut fiber was added so it became hybrid composites into container based on the compositions as mentioned in Table 1. The mold was smeared with glycerin evenly and thinly. The mixtures were poured into the mold and close the upper mold cover slowly. If there are some voids, direct the trapped voids by pressing and then provide loading which possibly pressed it thoroughly for 24 hours. The other specimen variance could be done by repeating the processes from the beginning. After being dried, the composite was taken from the mold by using a tool slowly and carefully. The flat of released composites was checked by using flat glass and then the composite was ready to be treated, cut, and tested. Process of treatment by post curing process was done by putting the composite into oven on 70°C for 2 hours. It is intended to remove bubbles and steam trapped in the composite and to know whether the composite was homogeneous or not, i.e. the composite sheet did not bend. Every half of hour, composite sheet should be flipped to spread the heat on the sheet surface which was intended to avoid the bending of the sheet.

2.4 Method of Transmission Loss Test
Testing method was done by placing acoustic panel on the test tool in which acoustic panel would be placed between earpiece-in and earpiece-out. The sound sources were in frequency of input 125Hz, 250Hz, 500Hz, 1000Hz, 1500Hz, 2000Hz, 2500Hz, 3000Hz, 3500Hz and 4000Hz. The further step was data collection in earpiece-in by sound level meter for 150 seconds, with data collection interval of 5 seconds and continued to collect data in earpiece-out with the same way.
3. Result and Discussion

3.1 The Result of Transmission Loss Test
The transmission loss test of hybrid composite of pumice-coconut fiber/gypsum was calculated using formula so the final result was in form of transmission loss material value by using the following formula:

\[ TL = I_0 - I \]  

Description:
- \( TL \) = Transmission Loss (dB)
- \( I_0 \) = Sound In (dB)
- \( I \) = Sound Out (dB)

The mean value data of transmission loss test of composite can be seen in the following table:

| Composition of Composite with Fiber Volume Fraction 20% | Transmission Loss (dB) |
|--------------------------------------------------------|------------------------|
| 1:1:1/2                                                | 13.48                  |
| 1:2:1/2                                                | 25.21                  |

From the above result, the data were plotted into bar chart to describe the mean value of transmission loss of the specimen.

![Figure 2. Relation Graph of Frequency and Transmission Loss on composite.](image-url)
Figure 4. It can be seen that composition composite 1:2:1/2 shows more porous and the surface of specimen is fragile or not real.

Figure 5. It can be seen that composition composite 1:1:1/2 shows evenly surface of the specimen.

From this specimen test data, the content of pumice in composite as well as gypsum comparison also affected the improvement of transmission loss in high frequency, and from these 2 material or specimen compositions that have been tested in all frequencies, it can be seen in Figure 2. It was found...
that the highest mean score of the transmission loss was in volume fraction 20% with comparison (1:2:1/2) with transmission loss 25.21 dB, while the lowest transmission loss was 13.48 dB with comparison (1:1:1/2).

3.2 The Result of Impact Test

The result of impact test upon the composite specimen to know the impact strength energy was described by the following Table and Figure:

Calculating the Impact Strength:

\[ I_s = \frac{\Delta E}{A} \]  \hspace{1cm} (2)

Description:

- \( I_s \) = Impact Strength (Nm/mm\(^2\))
- \( \Delta E \) = Impact Energy (Nm)
- \( A \) = Cross-sectional area (mm\(^2\))

3.2.1 Discussion of Impact Test.

Based on the calculation, the result of impact test can be seen in the following Figure 6. From the result of impact strength on hybrid composite of pumice and coconut fiber with fiber volume fraction 20% with matrix gypsum, it was found that the highest impact strength improvement was in composition (1:1:1/2) with the value of impact strength 5.534 kJ/m\(^2\), in composition (1:2:1/2) the impact strength was 4.293 kJ/m\(^2\) (Figure 6). The improvement of impact strength on fiber volume fraction 20% with composition (1:1:1/2) was caused by the appropriate combination of decreasing the number of pumice, so the gypsum and glue could bind the whole fiber and pumice optimally, and it increased the impact strength.

The decrease of impact strength on composition (1:2:1/2) because the content of gypsum in this composition was lesser than pumice, so this composition composite specimen was more fragile and uneven, in this composition, the gypsum matrix could not bind all of the pumice and fiber. It is also due to the characteristic of pumice more porous so it lowers the impact strength. This results is also agree with research [5] of pumice stone which concluded that the increasing of pumice stone can decrease the impact strength of material, which can be seen in Figure 7 and Figure 8.
The gypsum characteristic of which easily hardening and the level of hardening is high, so the addition of gypsum impacted the level of impact strength \( (Is) \). The brake of gypsum specimen includes broken damage and damage that only causes cracking. For the gypsum specimen which was not strengthen by fiber, the impact strength was lower than the gypsum specimen with fiber [7].

![Figure 7. The fracture of impact specimen with composition 1:1:½ shows the gypsum matrix binds pumice and coconut fiber well so the density was very good.](image1)

![Figure 8. The fracture of impact specimen with composition 1 : 2 : 1/2 shows more pores and the surface is fragile or uneven because in this composition, gypsum matrix could not bind the entire pumice and fiber well.](image2)

3.3 SEM

![Figure 9. SEM photo of hybrid composite of pumice with composition (1:1:½) (Magnification 150x).](image3)

SEM test was done to know the characteristic of composite specimen and see with 5.534 kJ/m\(^2\) clearly the existing mixture on the specimen. In the Figure 9, can be seen that density between gypsum matrix and pumice particle is very tight, and the coconut fiber attached well, so it made this composition became strongest.
Figure 10. SEM photo of hybrid composite of pumice in composition (1:2:1/2) (Magnification 150x).

Figure 10 shows SEM photo by using magnification 150x. In the above Figure, it can be seen that there are more cavities because the gypsum and glue could not bind entirely the fiber and pumice, so this composition is more fragile from the other composites.

4. Conclusion
Based on the data analysis and discussion, it can be summarized that:
The lowest transmission loss occurred in fiber volume fraction specimen 20% in composition 1:1:1/2 with mean value 13.48 dB. The highest transmission loss with mean value 25.21 dB occurred in comparison composition 1:2:1/2. The lowest impact strength occurred in fiber volume fraction specimen 20% with impact strength mean value 4.293 kJ/m$^2$ in comparison 1:2:1/2, while the highest impact strength occurred in comparison 1:1:1/2 with value 5.534 kJ/m$^2$.

5. References
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