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# The development of sound absorber material from green composites: The effect of volume fraction on noise reduction and thermal conductivity performances for ship engine room application

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ABSTRACT

One of the most critical parts of ship structure is the sound absorber on the ship structure, particularly in the ship's engine room, which is a dominant contributor to ship noise. The development of sound absorber materials from natural fibre composite is becoming more varied as material technology develops. This study investigated the sound absorber and thermal conductivity performances of developed sound absorber material. This study used the two-microphone impedance tube method to compare the effectiveness of composite sound absorbers made from three different compositions of water hyacinth fibre, coconut fibre, and sengon wood powder. The coefficient of sound absorption (α), transmission loss, noise reduction, and thermal conductivity (λ) values of three different material compositions become parameters to measure the efficiency of the developed material. The results show that Specimen A (20% hyacinth fibre, 15% coconut fibre, 15% sengon wood) has the highest sound absorption coefficient of 0.57, with stable transmission loss and noise reduction values. The optimum thermal conductivity is found in Specimen C, with the lowest thermal conductivity value.

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## 1 Introduction

During a sea voyage, vessel crew members are constantly subjected to physical stress caused by noise, vibration, and heat. Ship operation, loading and unloading (especially on container ships) during the port stay, port facilities (cranes, for example), and environmental noise (wind and sea) all contribute to high noise levels during operation [1,2]. The engine room, engine control room, and other areas with increasing distance from the ship's engine are expected to have exceptionally high noise levels at work. The engine rooms, machinery, and living spaces with an International Maritime Organization (IMO) noise regulation are one of the areas on the ship that produces excessive noise [3].

The engine room is the most crucial room on board because it houses the main engine, which is necessary for the ship's operation. There is an auxiliary engine in addition to the main engine to assist the main engine in electrical operation if the main engine fails. Because of the ship's reliance on multiple engines, the engine room is the loudest place on board. According to a noise level analysis on the cargo ship, the average sound produced by the ship's engine room ranges from 99 to 105 dB. The engine room produced the most noise at 560, 800, and 2500 Hz [4]. In a previous investigation to measure noise in the engine room, the highest sound intensity produced at a frequency of 1600 Hz was 95.58 dB [5]. Wibowo et al. [6] measured noise in the KMP Muria's engine room using an environment meter and a noise level of 102.9 decibels. Meanwhile, Hendrawan [7] used a sound level meter to determine that the average sound intensity in the engine room was 102.7 dB. This value is expected to exceed the International Maritime Organization (IMO) and American Bureau of Shipping (ABS) limits.

To reduce noise levels, sound absorber material must be installed in every engine room on a ship. Glass wool and rock wool are two common materials used as sound absorbers. Glass wool and rock wool, two commonly used sound-absorbing materials can reduce engine room noise by 102.9 dB, 31.22 dB, and 39.58 dB, respectively [8]. Glass and rock wool, on the other hand, have sound absorption coefficients ranging from 60 to 100% [9]. Current sound absorber materials have a high cost and negative environmental and health effects. Because the current sound absorber is made at high temperatures and with synthetic materials, it emits a significant amount of carbon dioxide [10]. As a result, a replacement for the existing sound absorber is required. One of the substitute materials for sound absorbers currently being investigated is a green composite of natural fibres with low-cost and simple manufacturing process.

Natural fibres are typically made from plants. Natural fiber's wide availability and abundance can relieve some of the pressure on the agricultural and forestry sectors. Utilizing a variety of natural fibers as raw materials will help maintain the ecological balance of the environment [11]. Due to the multiple benefits, including easy availability, lightweight, nonabrasive nature, low cost, low $CO_2$ emission, recyclable, renewability, and biodegradability, there has been an increase in the use of composites reinforced with natural fiber [12-15]. Various treatment processes may be required to obtain this fibre, depending on the material's properties. Plant fibres are typically extracted from materials such as banana stems, coconut husks, hemp, water hyacinth fibre, and others. This natural fibre is commonly used in household items and handicrafts. However, as time passes and material technology and characterization improve, natural fibres are used to make more valuable items. One of the types of materials has been developed as a sound-absorbing material for ship structures. Several types of material, including sengon wood, coconut fibre, and water hyacinth fibre with different compositions, were investigated as sound absorber materials in this study. A prior investigation established that natural fibre composites with fibre fillers had an absorption coefficient that complied with ISO 11654 with a minimum sound absorption value of 0.15 [16]. In a study by Sukhawipat et al. [17] utilizing a polyurethane foam matrix, water hyacinth fibre generated a sound absorption coefficient of 0.92. Setyowati et al. [18] indicated that a mixture of ceramic water hyacinth had an absorption value of 0.29 and an average transmission loss (TL) of 59.1 dB while utilizing the ASTM 1050-98 and ASTM E 2611-09 standards.

Additionally, 20 mm thick coconut fibre with a porous layer demonstrated a maximum value of 0.97 at a frequency between 2750 and 2825 Hz of coconut fibre with a porous layer and perforated panels [18]. The maximum value for coco fibre with perforated panels for the frequency range of 2600-2700 Hz is approximately 0.94-0.95. Further, Elang & Karlinasari [19] found that particle board made from sengon wood powder had average sound absorption coefficients at low (100-400 Hz), medium (400-1000 Hz), and high frequencies (1000-4000 Hz) of 0.3, 0.19, and 0.38, respectively. Meanwhile, the average TL was 14.2 dB, 19.3 dB, and 24 dB at low, medium, and high frequencies.

Further research is required to assess the effectiveness of sound absorption in various material combinations based on previous findings. To calculate the sound absorption coefficient, the developed material combined sengon wood, coconut fibre, and water hyacinth fibre with a polyester resin matrix at various compositions. This investigation used three different mixtures with various filler material volume fractions. This study evaluated the transmission loss, noise reduction, thermal conductivity, and sound absorption coefficient factors to determine the optimum material combinations to replace the existing absorbers. The ISO 11654 standard for sound absorption coefficient factor of 0.15 was used [20]. For conductivity thermal using the ASTM E1225 [21].

## 2 Material and method

This study is an experiment-based investigation that begins with the materials' production and ends with the specimens' testing. This study's key components were natural fibres from water hyacinth fibre, coconut fibre, and sengon wood, blended with a polyester resin matrix under a predefined composition. After the specimen was created, it was evaluated for thermal conductivity, density, and sound absorption to ensure that the results were promising compared to previous well-known sound absorber materials often used in ship engine rooms.

### 2.1 Material characteristics

Several constituent materials are required for developing the sound absorber composites used in this work. Figure 1 illustrates the major components as water hyacinth fibre, coconut fibre, and sengon wood powder. Water hyacinth fibre is usually used as a raw material for such items as chairs, tables, ropes, bags, decorations, furniture, etc. One of the abundant sources of water hyacinth raw materials was found in the Rawa Pening area, Semarang Regency. The water hyacinth in Rawa Pening has now reached a huge number of species. Research conducted by Soewardi and Utomo [22] showed that the chemical composition of water hyacinth is 13.03% crude protein; crude fibre 20.6%, 1.1% fat, BETN 25.98%, ash 23.8%, and the rest is a vortex containing polysaccharides and minerals. Water hyacinth is a very potential material to be used as an organic material because, based on the results of the analysis in the laboratory, it contains, among others: 1.681% N, 0.275% P, 14.286% K, 37.654% C, with a C/N ratio of 22,399. Sengon wood (*Albizia chinensis*) collected from Klaten, Indonesia, was a fast-growing plant with a tree height of 30-45 m. Sengon wood belongs to the Fabaceae

**Table 1** Properties of different material components

| Mechanical Properties | Water Hyacinth fibre | Coconut fibre [27] | Sengon wood powder [28] |
|---|---|---|---|
| Density (gr/cm$^3$) | 0.4-0.9 [24] | 0.67-10 | 0.33 |
| Tensile strength (MPa) | 11.4 [25] | 108-225 | 8.4-14.45 |
| Water absorption (%) | 71.3 [26] | 85-135 | 13-19 |

**Source:** Author's collection based on several material properties data from reference numbers [17,24-27]

(a) (b) (c)

**Figure 1** Three main material components: a) water hyacinth fibre, b) coconut fibre, and c) sengon wood powder.

**Source:** Authors

family. Sengon produces light to moderately light wood with a density of 320-640 kg/m$^3$ at a moisture content of 15%. Sengon wood has a glossy yellow to brown-red-ivory colour. The strength and durability of this wood were classified into Indonesia Bureau Classification (BKI) class III-IV and BKI class III-IV. The tensile strength of sengon wood was 100% of 8.11 MPa. Subterranean termites did not attack this wood due to the presence of extractive substances in the wood [23]. Coconut fibre collected from Tembalang, Semarang, Indonesia, is a waste produced from coconut plants. If left untreated and incinerated, this waste occupies usable land and poses serious environmental and health problems such as water pollution by leaching, foul odors, microbial growth, and increased amounts of greenhouse gases. Coconut coir is composed of organic and mineral elements, namely: pectin and hemicellulose (which are water-soluble components), lignin and cellulose (components that are not soluble in water), potassium, calcium, magnesium, nitrogen, and protein. Coconut fibre has a physical density of 12 g/cm$^3$ and a tensile strength of 175 MPa. Table 1 shows the different material properties of each component.

Yukalac 157 BTQN-EX series from Justus Kimiaraya, Semarang, Indonesia, was used as a matrix component. Yukalac 157 BQTN-EX Series is a fast-drying, thixotropic, pre-accelerated, and non-waxed type of general ortophtalic resin, especially suitable for fiber reinforced plastic (FRP) products applications with hand-lay-up and spray-up molding processes. This type is very commonly used as a structural material in the manufacture of yachts, fishing boats, sanitary wares, bathtubs, building materials, and other FRP products. This type is specially developed for hand lay-up and molding applications in hot weather. The Yukalac 157 BQTN-EX Series meets the requirements of Lloyd's Register's (LR) Rules & Regulations, US Food and Drug Administration, and BKI certification. Moreover, MEPOXE catalyst was used to speed up the resin set, a release agent was used to coat the mold for easier removal, and a thinner was used to clean used molds.

## 2.2 Material preparation and specimen manufacture

This study used three specimens with different filler compositions with a ratio of 1:1 between filler and matrix. Table 2 compares the volume fraction between filler and matrix. Specimen A comprised 20% water hyacinth fibre, 15 coconut fibre, and 15% sengon wood powder. Specimen B comprised 15% water hyacinth fibre, 20 coconut fibre, and 115% sengon wood powder. The last specimen, Specimen C was composed of 15% water hyacinth fibre, 15 coconut fibre, and 20% sengon wood powder. In the fibre preparation, water hyacinth fibre, coconut fibre, and Sengon wood powder were soaked in 4% NaOH for 2 hours. Water hyacinth fibre was dried under the hot sun for ± 10 number of days. The dried water hyacinth stems were shaved using a wire brush to get the fibres. The fibre that had been shaved was cut using scissors with a size of ± 1 cm. Coconut fibre was soaked in water for 24 hours to facilitate the separation of the coir

**Table 2** Composite volume fraction ratio

| Specimen types | Water hyacinth fibre (%) | Coconut fibre (%) | Sengon wood powder (%) | Resin matrix (%) |
|---|---|---|---|---|
| Specimen A | 20 | 15 | 15 | 50 |
| Specimen B | 15 | 20 | 15 | 50 |
| Specimen C | 15 | 15 | 20 | 50 |

**Source:** Authors

fibre from the binding husk. After soaking, the coconut skin was brushed using a wire brush to get the fibres. Then the fibre was cut using scissors with a size of ± 1 cm. In the treatment of the sawdust material, it was dried first until it was completely dry. The dried specimens were then smoothed with sandpaper so that they could enter the testing equipment and produce the best results. Figures 2 and 3 show the sound absorption and thermal conductivity testing specimen between different volume fractions.

## 2.3 Apparent density test procedure

To determine the weight of the material, a density test was performed. Density testing was performed in accordance with ASTM C 134-95 for material geometries in cylinders, cubes, or blocks using Eq. 1 [29]. A specimen with a diameter of 10 x 2 cm was used for the density test. The specimens were weighed using the FUJITSU FSRB1200 in an air-dry state, and the mass of the fibre volume was recorded before calculating the density.

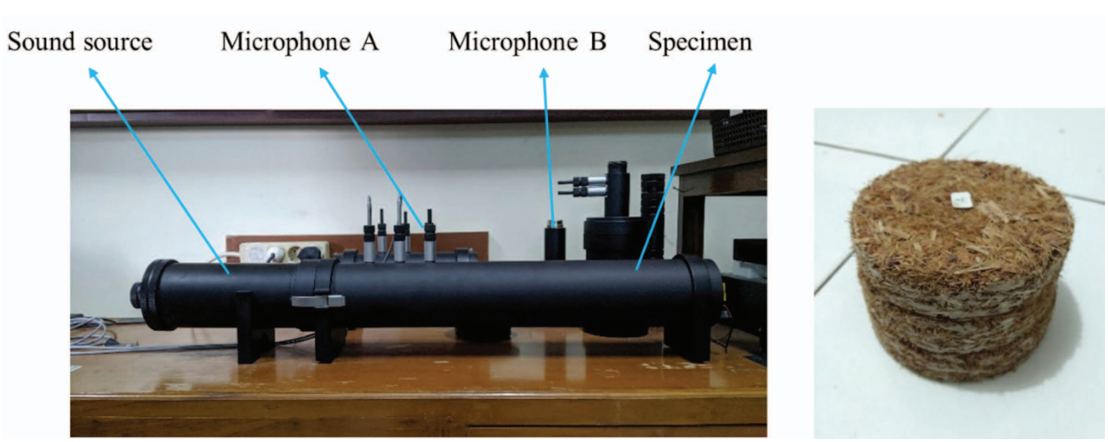
$$\rho = \frac{m_k}{V} \tag{1}$$

where $\rho$ is apparent density (gr/cm$^3$), $m_k$ is specimen mass (gr), $V$ is specimen volume (cm$^3$).

## 2.4 Sound absorption test procedure

An impedance tube tester using ASTM E1050-1990 standard was used for sound absorption testing at the iARG Laboratory, Universitas Sebelas Maret, Indonesia [30]. A sizable impedance tube with a frequency range of 0 to 1600 Hz was used. The source distance to microphone A was 0.15 m, the sample distance to microphone B was 0.1 m, and the distance between the microphones was 0.05 m. The tube has an inner diameter of 10 cm and the lowest frequency limit of 50 Hz. Atmospheric pressure in the testing environment was 1013.25 hPa with a temperature of 20°C and relative humidity of 80%. The air density was 1202 kg/m$^3$, and the sound speed was about 343.24 m/s. In comparison, the air had a typical impedance of 412.6 Pa/(m/s).

As illustrated in Figure 2, the impedance tube consisted of many circuits, including a tube with two microphones for acoustic material testing and a computer for processing and visualizing data. The frequency was adjusted after inserting the test subject into the impedance tube. The information on the absorption coefficient for each frequency was then acquired. Result graphics were created from the test's data after processing it. The transmission loss from the sound absorption coefficient test was required to calculate the sound energy lost after passing through the barrier using Eq. 2 [31].




(a) (b)

**Figure 2** a) sound absorption testing equipment, b) testing specimen

**Source:** Authors

$$TL = 10\,log\left[1 + \left(\frac{\pi f M_s}{\rho 0_c}\right)^2\right] - 5 \quad (2)$$

where $f$ is the frequency (Hz), $M_s$ is the density of the material (kg/m$^3$), and $\rho 0c$ is the characteristic impedance.

Transmission loss is related to noise reduction (*NR*), the difference ratio between the sound source space and the receiving room. *NR* is obtained by using Eq. 3 [32].

$$NR = TL - 10log\left[\left(\frac{1}{4}\right) + \left(\frac{S_w}{R_2}\right)\right] \quad (3)$$

where $S_w$ is the area of the partition, $R_2$ is a room constant with the formula $\frac{s\alpha}{1-\alpha}$ where $s$ is the surface area of the room (m$^2$), $\alpha$ is the sound absorption coefficient.

## 2.5 Thermal conductivity test procedure

The thermal conductivity test measures the quantity of heat transmitted through a unit thickness of a material in a direction normal to a surface of a unit area due to a unit temperature gradient under steady-state conditions. Thermal conductivity testing was conducted at Mechanical Engineering Laboratory, Universitas Gadjah Mada, Indonesia. The test used the ASTM E 1225 standard test method for solids' thermal conductivity, employing the guarded comparative longitudinal heat flow technique [21].

The equipment used for measuring the thermal conductivity measuring apparatus, type OSK 4565, model HVS – 4000SE, Tokyo Meter Co., was utilized to assess thermal conductivity. As shown in Figure 3, this tool contained 12 thermocouples and was constructed with standard material at the top, test material with a thickness of 4 mm, test material with a thickness of 2 mm, and standard material inserted at the bottom. The specimen needed to be powdered to cover its pores before being put into the testing apparatus. The test apparatus's initial temperature was set to 29°C following the ambient temperature. At last, check the output temperature to determine the tool's temperature variation was needed.

The material being tested must closely fit the reference materials. It may impact the surface contact of the object's heat resistance. The temperature was then set to 40°C based on International Association of Classification Socie-

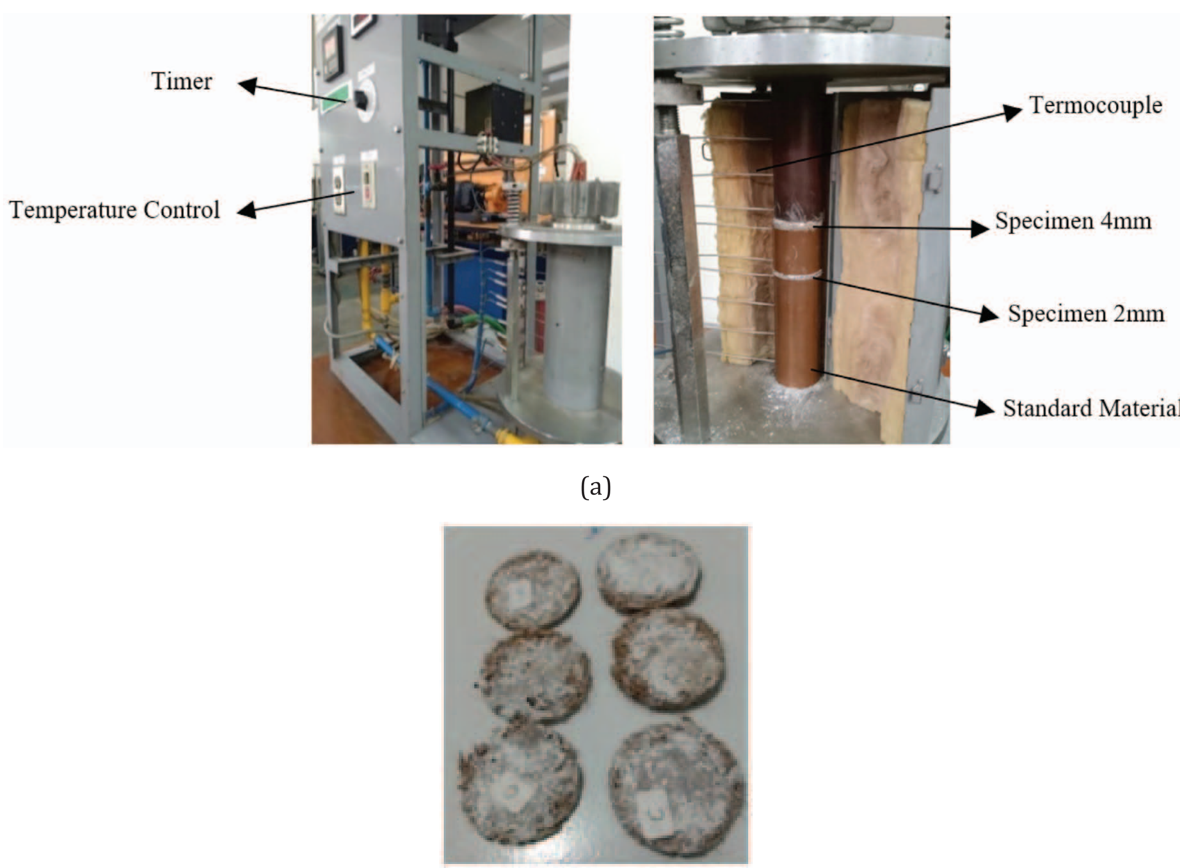



**Figure 3** a) thermal conductivity test equipment, b) testing specimen

**Source:** Authors

ties (IACS) standard [33], 45°C per BKI standard [34], and 50°C, which was rounded up from the ship's normal engine room temperature of roughly 47°C. To get the data for each thermocouple, wait 15-30 minutes for each temperature till it became steady. The information was then saved, and a temperature graph was created. To determine the thermal conductivity of each specimen at each temperature, use the graph's values of $\Delta a$ and $\Delta b$ or graph different temperatures from specimens 2 mm and 4 mm. Eq. 4 is used to calculate the formula for determining a material's thermal conductivity (λ).

$$\lambda = \frac{L_b - L_a}{\left\{\frac{L_b}{\lambda b} - \frac{L_a}{\lambda a}\right\}} \text{ (kcal/m hour °C)} \quad (4)$$

where $L_a$ is a specimen with a thickness of 2 mm, $L_b$ is a specimen with a thickness of 4 mm, $L_R$ = 30 mm, $\lambda_R$ is absolute value 320 kcal/m°C, $\lambda_a = \frac{\Delta t_R L_a}{\Delta t_a L_R} \lambda_R$, $\lambda_b = \frac{\Delta t_R L_b}{\Delta t_b L_R} \lambda_R$.

## 3 Result and discussion

### 3.1 Result of apparent density test

According to the test findings shown in Figure 4, Specimen C, which has a composition of 15% water hyacinth fibre, 15% coconut fibre, 15% sawdust, and 50% resin, has the greatest density value of 0.5 gr/cm³. The specimen with the lowest density, Specimen A, has a composition of 20% water hyacinth fibre, 15% sengon wood powder, 15% coconut fibre, and 50% resin. The various fibre volume fraction variants result in the density difference between each specimen. The pressing process additionally impacts the density of the material. Compared to glass wool and rock wool, which have a density of 25-100 gr/cm³, the specimens have a lower density [35]. The research specimen's density value, which ranges from a minimum of 0.4 gr/cm³ to a maximum of 0.9 gr/cm³, have met the requirements of Japanese Industrial Standards (JIS) A5908 [36].

### 3.2 Result of sound absorption test

Figure 5 shows the results of all tested specimens of developed sound absorber composites using a two-microphone impedance tube. As a result, as frequency increases, so does the sound absorption coefficient. It can be found that the largest absorption coefficient ($\alpha$) at a frequency of 1600 Hz. Specimen A has the highest sound absorption coefficient compared to Specimen B and C. In addition, Specimen C experiences the lowest sound absorption coefficient. The highest sound absorption coefficient is obtained by Specimen A, with a value of 0.57 at the frequency of 1600 Hz. In contrast, the lowest absorption coefficient is found in Specimen C, with a coefficient value of 0.023 at a frequency of 250 Hz. Specimen C has the lowest value because most constituent materials are sawdust with short fibres. The density of each fibre is different based on the length of the fibre, where the longer fibre has a higher sound absorption coefficient ($\alpha$) than the short fibre.

Specimen A, with a volume fraction of 20% water hyacinth, 15% coconut fibre, and 15% sengon wood, has the lowest coefficient value of 0.033 at a frequency of 250 Hz and the highest value of 0.57 at 1600 Hz. While at frequencies of 500 Hz and 1000 Hz, the values are 0.08 and 0.13, respectively. These results show that at the frequency of 900 Hz, there is a decrease in the frequency of 960 Hz from 0.139 to 0.127. After decreasing to 960 Hz frequency, there was an increase to 1600 Hz frequency. Moreover, Specimen B, with a volume fraction of 15% water hyacinth

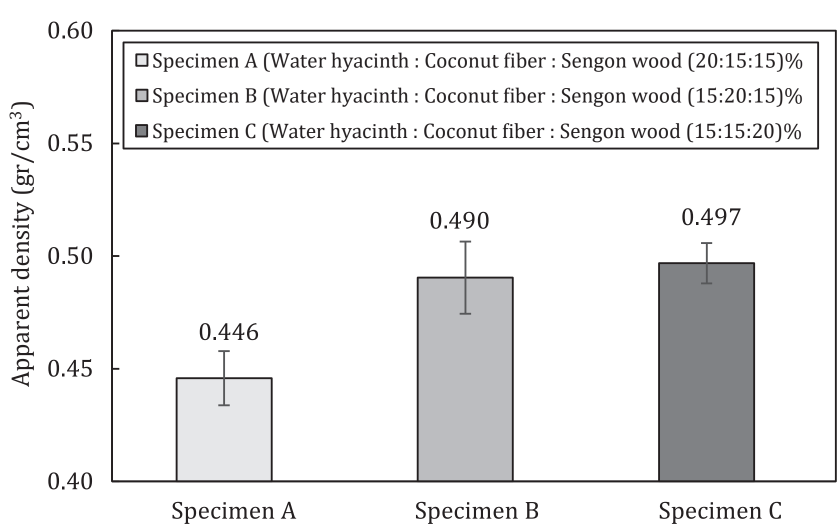



**Figure 4** Comparison of density value under different material compositions.

**Source:** Authors

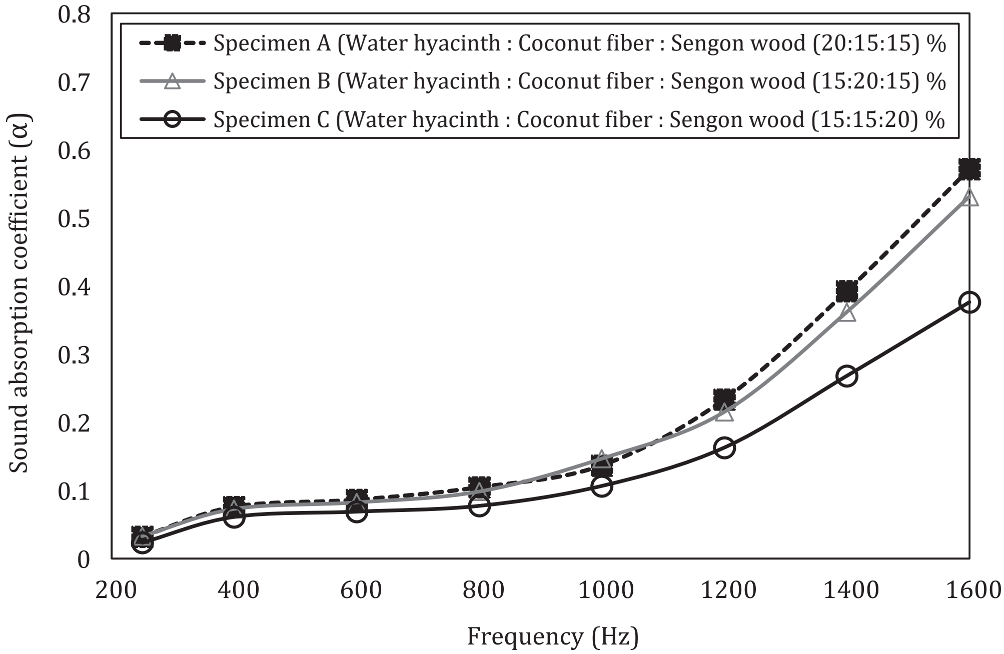



**Figure 5** Comparison of the sound absorption coefficient.

**Source:** Authors

fibre, 20% coconut fibre, and 15% sengon wood, has the lowest absorption coefficient of 0.033 at a frequency of 250 Hz. While in the frequencies of 500 Hz, 1000 Hz, and 1600 Hz, the values are 0.07, 0.14, and 0.53, respectively. The absorption coefficient value of Specimen B is unstable at frequencies ranging from 0 to 200 Hz because it exhibits a significant increase and decrease trend. There is a slight decrease in value at 1000 Hz, but it is not significant. Further, Specimen C, with a volume fraction of 15% water hyacinth fibre, 15% coconut fibre, and 20% sengon wood at a frequency of 250 Hz, has the lowest absorption coefficient compared to other specimens at 0.023. Moreover, at frequencies of 500 Hz, 1000 Hz, and 1600 Hz, the values are 0.067, 0.106, and 0.37, respectively. The value of the sound absorption coefficient of Specimen C tends to be a stable increase from low to high frequencies.

From the obtained result, Specimens A, B, and C at a frequency of 250 Hz, 500 Hz, and 1000 Hz have a low absorption coefficient and are unqualified by the ISO 11654:1997 minimum standard of 0.15. It is caused by the sound absorption coefficient having an optimum value at a specific frequency due to the distribution of fibres in the specimen. The sound waves that propagate in the tube have a long wavelength at a frequency of 250 Hz, so the reflected waves are larger than the waves absorbed by the material. At a frequency of 1600 Hz, energy is dissipated in the material, causing an increase in the sound absorption coefficient. The absorption coefficient of the three specimens is lower than that of glass wool and rock wool, which have average absorption coefficients of 0.6-1.0, but higher than that of plywood.

Based on the obtained results, the sound absorption coefficient increases with frequency. The higher the coefficient absorption, the better the material. The material being tested is a fibrous material made up of one laminate with fibre reinforcement. Fibrous materials are typically effective at high frequencies. This study employs a large impedance tube with a frequency range of 0-1600 Hz. A small impedance tube with a frequency capacity of 0-6400 Hz must be tested to obtain a high absorption coefficient value. Aside from fibrous materials, other materials that can be used to absorb sound include panels and resonators, each of which has a unique curve pattern on the sound absorption coefficient gradient. Panels and resonators are sound-absorbing types that are suitable for low frequencies.

From the sound absorption test, the transmission loss (TL) value result for each testing specimen can be calculated using Eq. 2. Figure 6 shows the result of the transmission loss calculation for three different samples. The higher the transmission loss, the better the material. The results indicate that the material with high density (Specimen C) will have a high transmission loss. Specimen A has the lowest transmission loss value. Furthermore, the transmission loss value will also increase as the frequency increases. Analyzed at the highest frequency 1600 Hz, the three specimens have the highest transmission loss values with 35.72 dB, 36.54 dB, and 36.66 dB, respectively. Compared with other material types, the three developed specimens have lower TL values than rock wool material by 39.58 dB and higher than glass wool and plywood materials by 31.22 dB [6].

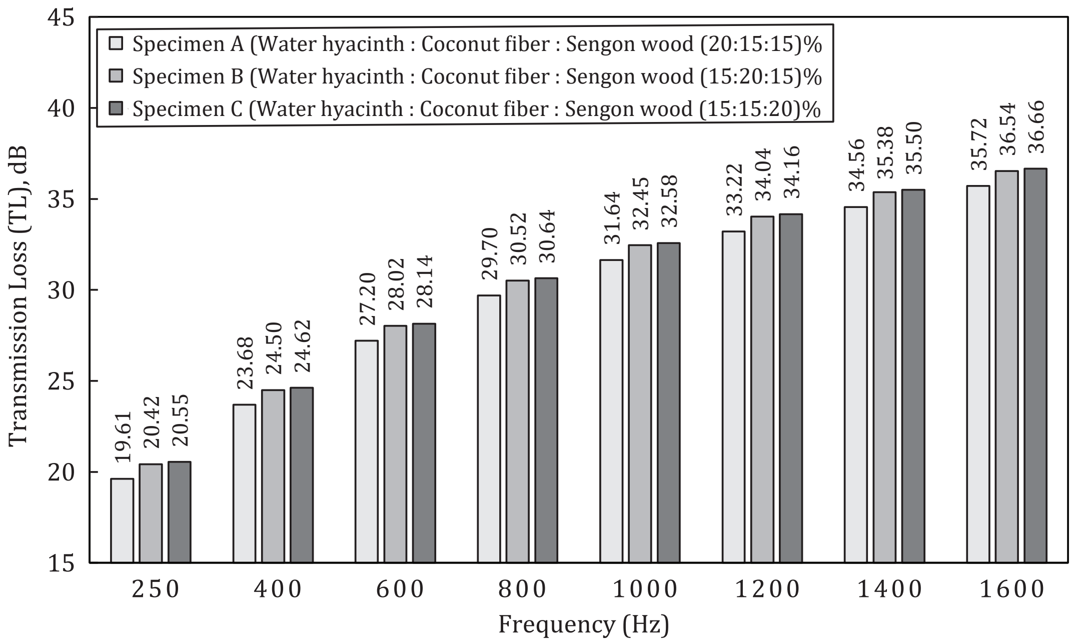



**Figure 6** Comparison of transmission loss under different material combinations.

**Source:** Authors

The NR value also determines the difference between the sound source and receiving rooms. The difference is the amount of sound the barrier/absorber material has blocked or absorbed. The noise reduction value computes the volume of reduced sound that travels from the source room to the receiving room. The better the material, the greater the noise reduction. NR values below a certain threshold indicate low absorption performance. Figure 7 depicts the NR value, with Specimen C having the lowest sound absorption coefficient value. Specimens A and B, on the other hand, have better noise reduction performance, as evidenced by higher NR values than Specimen C.

Figure 8 compares NR and TL values analyzed at the frequency of 1600 Hz. Specimen A has the highest sound absorption coefficient ($\alpha$) but has the lowest TL value of 35.72 dB, while Specimen C has the lowest $\alpha$ value but has

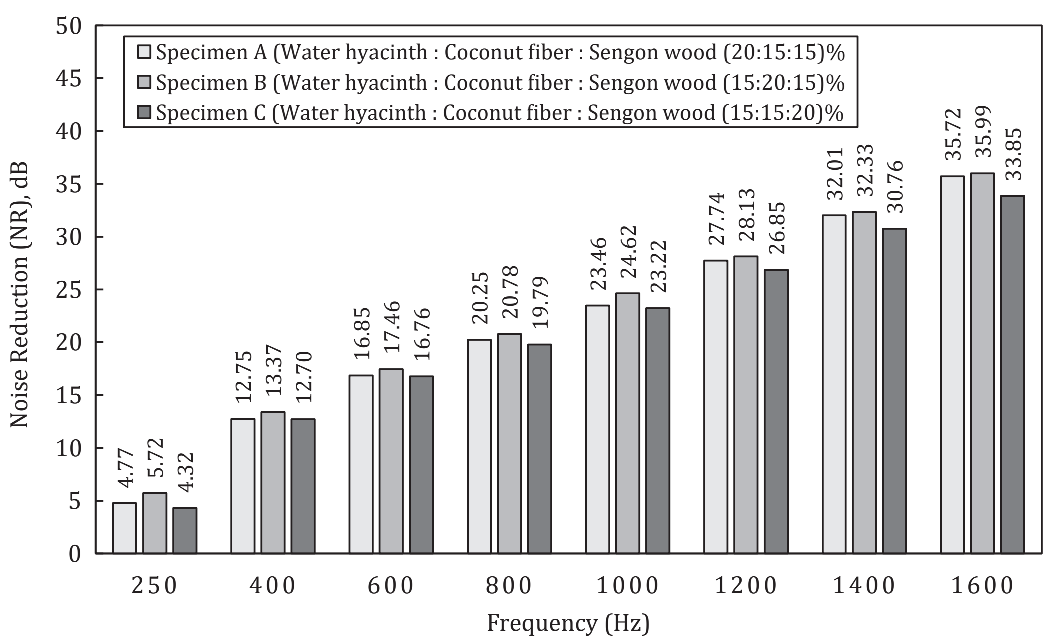



**Figure 7** Comparison of noise reduction under different material combinations.

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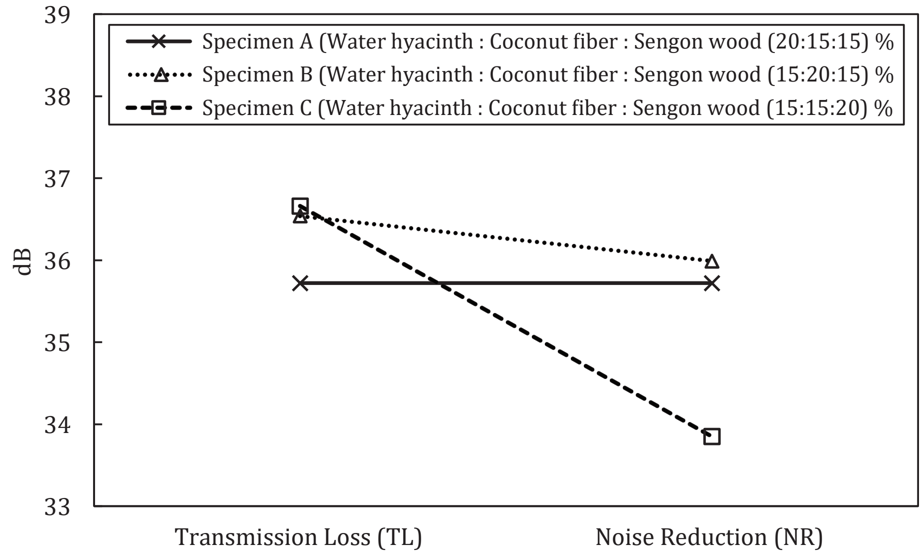


**Figure 8** Relation of TL and NR at frequency of 1600 Hz.

**Source:** Authors

the highest TL value of 36.66 dB. It has been discovered that having the highest value does not imply having a high TL value, or that the value is not comparable to the TL value. This is because the density of the developed material influences the TL value. Specimen C has a high TL value but a low α value because most of the sound is reflected, resulting in a low absorption capacity of the Specimen C at 37% value. In Specimen A, 57% of the sound that is not transmitted is absorbed by the material and slightly reflected. For analyzing the correlation between each TL and NR. The TL and NR values have similar value in specimens A and B, but there was a significant decrease in the NR compared to TL values in specimen C. This demonstrates that sound absorption performance of Specimen C is lower because some of the sounds are reflected rather than transmitted. Furthermore, Specimen A is the best material because its TL and NR values are the most stable. The best specimen is a noise absorber with a slight difference in TL and NR.

### 3.3 Result of the thermal conductivity test

The ability of a material to transmit heat is measured using thermal conductivity test. Thermal conductivity testing equipment is used in this test with specimen thicknesses of 4 mm and 2 mm at a room temperature of 29°C.

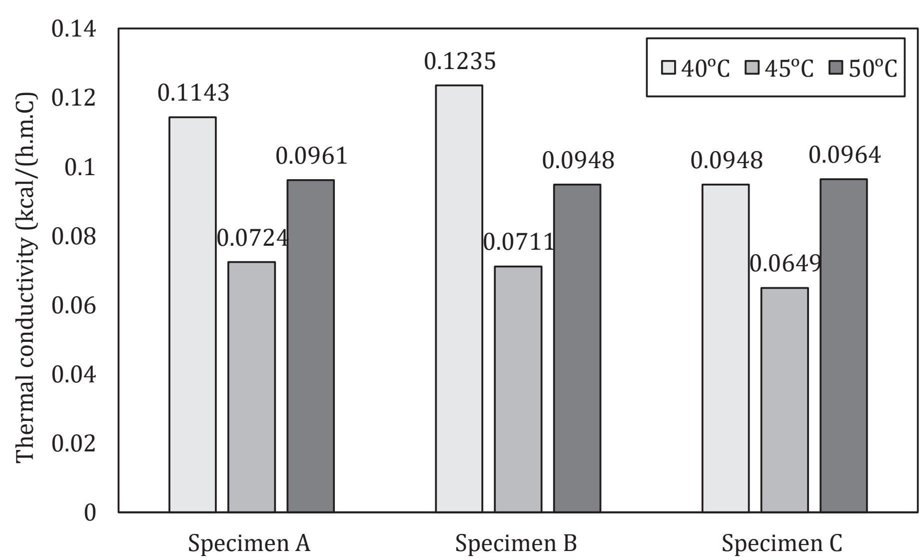


**Figure 9** Comparison of thermal conductivity under different material compositions.

**Source:** Authors

Three different temperatures are used in the test: 40°C based on the IACS standard [33], 45°C based on the BKI standard [34], and 50°C based on the highest average temperature in the ship's engine room. The results of the thermal conductivity test are shown in Figure 9. Eq. In Figure 9, the thermal conductivity is determined using Eq. 4. According to the data, the best thermal conductivity value for Specimen C at 45°C is 0.065 kcal/g (h.m.C). Specimen C comprises 50% polyester resin and 20% water hyacinth fiber, 15% coconut fiber, and 15% sengon wood powder.

To reduce the total coefficient of heat transmission, the best insulation materials should have the lowest thermal conductivity. As a result, less insulating material will be needed. This is based on the idea that low thermal conductivity reduces a material's ability to conduct heat. The engine room specimens must have low heat conductivity so that heat is not transmitted outside the engine room, keeping passengers comfortable. According to the results, Specimen C still has a higher thermal conductivity value than other materials, including glass wool and rock wool materials, with thermal conductivity values of 0.04 w/m.K and 0.045 w/m.K, respectively, or 0.34 kcal/(h.m.C) and 0.38 kcal/(h.m.C) [37].

## 4 Conclusions

Several tests, including density, sound absorption, and thermal conductivity, are conducted to investigate the performance of sound absorption and the thermal conductivity of the developed material for the ship engine room. A total of three different filler materials are developed based on the variation of volume fractions.

The highest sound absorption coefficient is found in specimen A while the lowest is in Specimen C. It can be concluded that Specimen A comprised of 20% water hyacinth fibre, 15 coconut fibre, and 15% sengon wood powder, has better absorber properties. However, the absorption coefficient of the three developed materials is still lower than glass wool and rock wool. Moreover, the optimum thermal conductivity is found in Specimen C, with the lowest thermal conductivity value. Specimen C has a higher thermal conductivity value than other materials compared to previous research.

This finding could be the focus for further research. One possibility is to conduct several physical and mechanical tests using different filler materials with comprehensive volume fraction variation and compare them with the current absorber material used in the ship structure.

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