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Research article

Application of *Scirpus grossus* fiber as a sound absorber

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ABSTRACT

The application of *Scirpus grossus* (SG) fiber as a sound absorber is important to reduce the level of noise affected the physical and mental wellbeing of people. The sound absorption coefficient (SAC) and noise reduction coefficient (NRC) of the SG specimen were evaluated based on a typical model-based design using the data analysis with MATLAB. The results showed that SG specimen with a thickness of 20 mm coated with the perforated aluminum sheet (PAS) compared to that without coating can improve the capability of sound absorption by 14% at the frequency of 4000 Hz. SG specimen coated with PAS that has a NRC value of 0.39 can absorb 39% of sound and thus reflects 61% of sound wave while SG specimen without coating that has a NRC value of 0.23 absorbs 23% of sound and can reflect 77% of sound wave. The sound absorption class of D for SG specimen coated with PAS should be better that of E for SG specimen without coating, which permits us to get better understanding on the applications of SG fiber as a sound adsorber in the future.

1. Introduction

The application of the natural materials attracted significant interest for more than a century could be due to the physical properties of natural plant fibers offer opportunity of sound absorbers potentially used in acoustic engineering to reduce noise pollution [1]. The manufacturing of natural materials possessed good absorption capacity could be similar to the commercial products usually made of the expensive synthetic materials used for the reduction of noise [2]. Noise pollution associated with several negative effects on both land and in the sea can cause health problems for people and wildlife, contributing to the cause of heart attacks affected an annoyance and sleep disturbance [3–5]. Impact of noise and vibratory disturbance on the residential areas built near highways, railways, or industrial facilities can be mitigated by insulating the walls sufficiently with sound-absorbing materials (SAMs) [6,7]. The development of guidelines designed to protect individuals from occupational noise exposure is needed due to approximately 16% of hearing loss as estimated by the World Health Organization is stemmed from a noise pollution of the workplace [8]. A continuous noise pollution has the physiological and psychological impacts on the comfort levels of sound for human [7,9]. Social and healthcare costs of noise pollution have a significant negative impact to the economy. For example, the economic burdens of heart disease derived from exposure to daytime traffic noise, tinnitus from traffic/leisure noise, and hearing loss from loud music in the United Kingdom have been predicted to cost approximately £1183 million, £52 million, and £38 million per annum, respectively [10]. Exposure in daily life

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to high levels of noise in the workplace can cause the permanent hearing loss [11]. The workplaces with a persistent noise required to protect with the noise-dampening materials of sound absorbing panel aim to reduce noise pollution that avoids serious problems of hearing.

Commercial sound-absorbing materials are typically classified into three categories of fiber, granular, and cellular. SAMs of fibers are categorized into two types: the synthetic and natural fibers [12]. The application of synthetic fibers cannot be ignored the potential human health risks of skin irritation and lay-down in the lung alveoli caused by inhaling fiber particles [13]. The application of natural fibers as green materials could be the best potential alternatives of sound absorbers because of low toxicity and harmless to human beings. Strategies of mitigating the health problems caused by the impact of noise pollution using the natural fibers could be an intriguing issue for further investigation. The control of sound by a sound absorber made of the natural or synthetic fiber can be addressed using a high efficiency of the SAMs. The use of many synthetic materials improperly disposed as solid waste into the environment or open burning poses a significant threat to land, sea and the atmosphere. The use of the natural materials provided an alternative can replace the synthetic materials to reduce noise pollution [14]. The use of the natural fibers derived from the plants of such as the leaf and bast fibers has a great potential in the production of the rope, geotextile, tying thread, filter, and fabric. Using the natural fiber of sustainable material to absorb sound energy could be easily available in the nature and has the advantages of low-cost, lightweight, renewability, biodegradability, and high specific properties of an environmentally friendly product [15]. Many efforts made of developing a new fiber of the sound adsorber can be focused on the use of the biodegradable materials [16].

The use of *Scirpus grossus* (SG) fiber interested to produce a weaving cloth has the potential to increase economic value of the surrounding communities and could be useful to develop as a SAM for the various applications. The mechanical properties of composites made of SG fiber have been evaluated for the reinforcement of polyester resin filler material for fishing net showing a great potential to the future applications of sound absorber [17]. The physical characteristics of SG fiber are almost similar to those of coconut coir, abaca, pineapple, and other natural fibers possessed a sound absorption capability. The potential of SG growth considered as one of the promising methods to reduce water pollution has been explored to ensure the effectiveness of phytoremediation for the treatment of sago mill effluent [18].

Perforated aluminum sheet (PAS) with its various hole sizes and sheet thicknesses is a prime selection for multiple applications that offering good corrosion resistance and formability of acoustic elements. The consideration of PAS as an economical choice for coating the SG fiber must be of sufficient ability to diffuse light, air, and sound for the application of airflow resistance in the sound absorption and noise control [19]. Created by precise punching of thin PAS plate to form a round hole pattern can be driven by the need for both functionality and aesthetic appeal of being inherent qualities of light weight, durability, and anticorrosion making it an excellent base for coating SG fiber [20]. PAS is the answer to combine high-end design and functionality for coating the specimen of SG that having the benefit of running an experiment.

Even though the sound absorption properties for several natural SAMs of the renewable fibers have been analyzed to replace the synthetic SAMs that associated health risks [4,5,12–17], the potential applications of SG fiber as one of the natural SAMs with an abundant availability of the plants in Asia for sound absorber are still not fully understood. The use of SG fiber as an acoustic absorber needs to be verified for the future applications of giant bulrush. The objectives of this study are: (1) to prepare the test specimens of SG fiber covered with PAS and (2) to investigate the sound absorption capability of SG fiber from the analysis of sound absorption and noise reduction.

2. Materials and methods

2.1. Preparation of test specimen

This study used the species of *Actinoscirpus grossus* L.f. or *Scirpus grossus* (SC) of greater club rush or giant bulrush originally coming from Calang District of Aceh Jaya Regency to produce the SG test specimens (see Fig. 1a). SG as one species of the sedges of tropical plant native to Southeast Asia that having a triangular-shaped non-hollow stem (see Fig. 1b) can be easily found in Cambodia, China, India, Indonesia, Malaysia, Philippines, Sri Lanka, and Thailand. Approximately 2 kg of the SG stem were immersed in the solution of

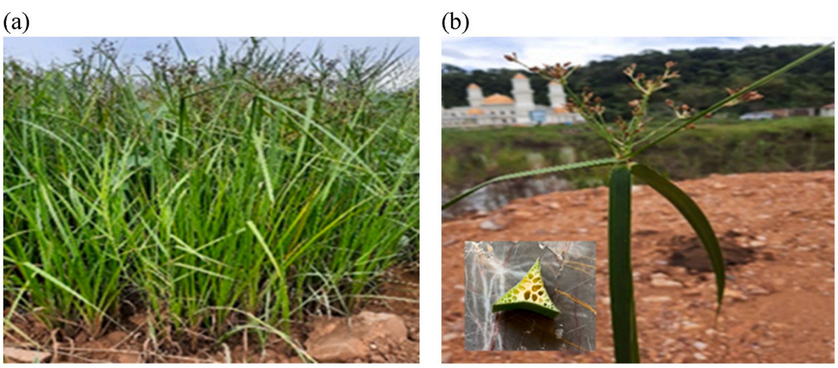

Fig. 1. Pictures of (a) SG giant bulrush and (b) horizontal cross-section of SG stem.

5% NaOH, soaked for 2 h aimed to chemically modify the surface properties, to remove impurities, and to reduce hemicellulose and lignin [12,21], and then heated at 70 °C for 4 h aiming to increase the strength and cleanliness of the SG fibers [22]. The experiment of sound absorption associated with an impurity content of the SG specimen could indeed be valid without being reliable. The fibers length of SG averaged 150.3 mm, and 67.6% of the SG fibers had lengths ranging from 147 to 157 cm with a stem width range of 0.8–1.2 cm and a diameter range of 0.01–0.1 cm. The dried SG fibers were cleaned and cut to have an average length of 50 mm and then weighed to ensure an accurate weight of 50 g (see Fig. 2a).

The fabrication of SG composite by the hand lay-up was required to form a SG test specimen by laminating a polyester resin on the surface of SG fiber. The equipment of Wabash G150H hot press machine combined with the specimen mold of having a precision scale of 1 g was used to form the test specimen of SG fiber. The test SG specimen was placed in a metal mold that having a diameter of 10 cm (see Fig. 2b) and then pressed using the Wabash G150H hot press machine at 200 °C for 10 min and then flipped and pressed again to have the desired thicknesses of both 10 and 20 mm (see Fig. 2c). The compression of dried SG fiber aimed to form a desired thickness was to ensure the size of SG specimen aligned with the diameter of impedance tube. Aluminum sheet with a diameter of 10 cm and thickness of 0.03 cm was perforated each to create 88 of holes. Hole diameters each of 0.00, 0.10, 0.15, and 0.25 mm separated with a space of 10 mm were perforated by a drilling machine into the aluminum plate (see Table 1). Then PAS was placed in the front to cover the test specimen of SG fiber (see Fig. 2d). The test specimen of SG fiber fully covered with PAS has a total surface area of 7850 mm^2. The test specimen areas of 69.08, 155.43, and 431.75 mm^2 received sound wave from a loudspeaker were used to analyze the sound absorption capability of SG specimens covered with the hole PAS diameters of 1.0, 1.5, and 2.5 mm, respectively. The pressed SG specimens of having a weight of 50 g for the thicknesses of both 10 and 20 mm were covered with the PAS hole diameters each of 0.0, 1.0, 1.5 and 2.5 mm (see Table 1).

2.2. Experimental procedure

By analyzing the sound absorption coefficient (SAC) of SG specimen measured using the method of impedance tube conducted at the Acoustic Laboratory, Faculty of Engineering - Universitas Syiah Kuala, permits us to evaluate the capability of sound absorption. Configuration of the experiment to record the SAC data of SG specimen coated with PAS at the front in direct incidence with the sound wave was set at the frequency range of 100–4000 Hz (Fig. 3a). The transfer function method of Brüel & Kjær impedance tube kit type 4206 with a diameter of 100 mm equipped with two fixed microphones at distances P1 and P2 was used to acquire sound pressure near the specimen of SG permitted to record the data of SAC (see Fig. 3b). The specimen of SG was placed between the microphones and the inner wall of the impedance tube. By turning on the loudspeaker produced a white noise hit the SG specimen can happen the absorption, transmission and reflection of the sound wave. Investigating the effect of sound in the impedance tube of Brüel & Kjær on the absorber made of SG fiber at the frequencies of 100, 125, 250, 500, 1000, 2000, and 4000 Hz was carried out by generating the amplitudes of sound wave using the loudspeaker to record the sound reflection of SG specimen at the position of P1 and P2. The measurement of sound reflection recorded using the dedicated computer at the distances of P_1 and P_2 to the SG specimen was denoted as X_1 and X_2, respectively, while the distance of P_1 to P_2 was denoted as S where $S = X_1$-X_2, as shown in Fig. 3b.

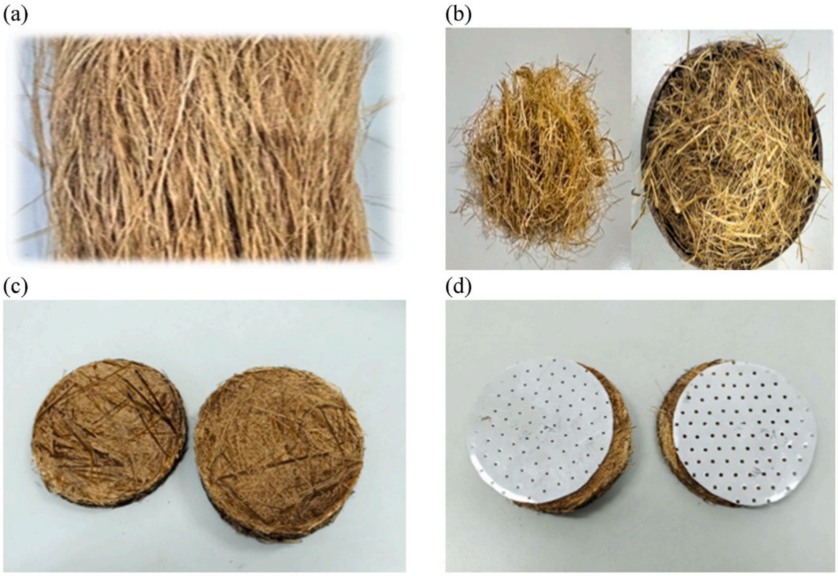

Fig. 2. Test SG specimens of (a) dry SC fiber with its average length of 5 cm and weight of 50 g, (b) 50 g of dry SC fiber placed in a metal mold before pressing, (c) pressed SG specimens without covered with PAS and (d) pressed SG specimens covered with PAS.

Table 1
Testing of the sound absorption capability of SG specimen.

SG specimen		Hole diameter of PAS (mm)
Weight (g)	Thickness (mm)	
50	10	0.0
50	10	1.0
50	10	1.5
50	10	2.5
50	20	0.0
50	20	1.0
50	20	1.5
50	20	2.5

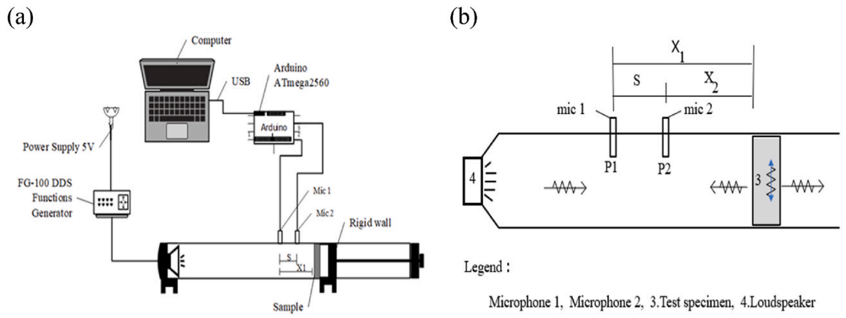

Fig. 3. Configuration of the experimental design with (a) the configuration of experiment for testing sound absorption capacity of SG specimen and (b) the distances of two microphones to the test SG specimen.

2.3. Data simulation

The implementation of MATLAB computer program has been proposed to analyze the SACs of pineapple leaf fiber compared with commercial rock wool fiber and synthetic polyurethane foam [4], the sheep wool compared with mineral wool and recycled polyurethane foam [3], the experimental data of AgNPs adsorption on the natural and synthetic adsorbent materials [23], and the natural date palm fiber considered as agricultural waste [21]. In this study, the application of MATLAB program allowed us to perform the SAC data analysis of SG specimen can be simulated using the equation [24,25] of:

$$\alpha = 1 - |R|^2 \tag{1}$$

where α is the sound absorption coefficient and R is the sound reflection coefficient.

The value of noise reduction coefficient (NRC) ranged from 0.0 to 1.0 that represents the capability of absorber reduced noise by absorbing sound energy can be calculated based on the SAC value as the percentage of sound energy absorbed by SG specimen. Higher NRC value of SG specimen is related to better capability of sound absorption. The NRC value of 0.90 for soundproofing panel made of SG fiber can absorb 90% of sound while the remaining 10% is reflected sound [26]. The calculation of NRC value takes into account the thickness and density of the SG fiber. The value of NRC provided an easy visual comparison among the specimens of SG fiber is defined as the arithmetic mean of SAC value at the sound frequencies of 250, 500, 1000, and 2000 Hz, which can be calculated using the equation [27] of:

$$C_{nr} = \frac{(\alpha\ 250 + \alpha\ 500 + \alpha\ 1000 + \alpha\ 2000)}{4} \tag{2}$$

where C_{nr} is the noise reduction coefficient and α is the sound absorption coefficient.

Table 2
Sound absorption classes of *Scirpus grossus* fiber.

Sound absorption class	Value of SAC
A	0.90, 0.95, 1.00
B	0.80, 0.85
C	0.60, 0.65, 0.70, 0.75
D	0.30, 0.35, 0.40, 0.45, 0.50, 0.55
E	0.15, 0.20, 0.25
Not classified	0.00, 0.05, 0.10

The average SAC values of SG specimen divided into the sound absorption classes of A, B, C, D, E, and unclassified accorded to Istana et al. [28], are depicted in Table 2.

3. Results and discussion

3.1. Sound absorption coefficient of SG specimen without coating

The amplitude data of sound pressure recorded at P1 and P2 can be simulated using the MATLAB program showing the variations of SAC value for SG specimen with the thicknesses of 10 and 20 mm without coating, as shown in Fig. 4. The peaks of SAC increased to 0.40 and 0.41 at the frequency of 125 Hz and then decreased to around 0.21 along the frequency ranged from 100 Hz to 2000 Hz and then increased again to 0.33 and 0.47 at the frequency of 4000 Hz for SG specimen with the thicknesses of 10 and 20 mm, respectively, without coating. An increase in the sound absorption at the frequency of 125 Hz attributes to more sound energy of longer wavelength absorbed by SG specimen without coating [29]. The dissipation of sound energy passed into thermal viscous motion increases with increasing of the SG specimen thickness leading to an increased value of SAC [30]. The value of SAC for SG specimen with its thickness of 20 mm increased to 0.47 higher than that with its thickness of 10 mm increased to 0.33 at 4000 Hz could be due to an increased SG thickness of 10 mm leads to a 14% increase in the value of SAC.

3.2. Sound absorption coefficient of SG specimen coated with PAS

3.2.1. SG specimen with a thickness of 10 mm

The coating of PAS placed in the front of SG specimen without an adhesive material influenced absorption capacity can lead to shift the peak of SAC value and to decrease the NRC of the SG fiber [31]. The variations of SAC for SG specimen of 10 mm coated with PAS that having the hole diameters each of 0.0, 1.0, 1.5 and 2.5 mm were investigated along the sound frequency ranged from 100 to 4000 Hz (see Fig. 5a). The values of SAC averaged 0.395 at the frequency of 125 Hz decrease to around 0.23 observed along the sound frequencies ranged from 250 to 1000 Hz and then increase again, higher than 0.5 especially for SG specimen coated PAS with its hole diameter of 1.0 mm at frequency of 2000 Hz. The SAC values of 0.56, 0.42, and 0.32 for SG specimen coated PAS with the hole diameters of 1.0, 1.5 and 2.5 mm, respectively, are all higher than SAC value of 0.23 for SG specimen without coating at frequency of 2000 Hz. The SAC value of the SG specimens coated with PAS significantly decrease but that of SG specimen without coating increases at frequency of 4000 Hz (see Fig. 5a). Effect of coated SG specimen with PAS can lead to increase the peak of SAC value at 2000 Hz. The capability of sound absorption by the SG specimen coated with PAS that having a hole diameter of 1.0 mm is better than that of 1.5 mm and is better than that of 2.5 mm while the sound absorption capability of SG specimen without coating is lower than that coated PAS at 2000 Hz. The response of microorganism attached SG specimen to sound has been suggested as an artefact associated with applying sound to different PAS hole diameters externally via transmission through air [32]. The loss of sound energy when sound waves coming into contact with the SG specimen coated with PAS of having a hole diameter of 1.0 mm is higher than that of having a hole diameter of 1.5 mm and is higher than that of having a hole diameter of 2.5 mm. This indicates that the sound reflection of SG specimen of having a large surface area is higher than that of having a small surface area [33]. The total PAS surface area of 7850 mm^2 for SG specimen without coating deducting the perforated areas of 69, 155, and 432 mm^2 for the specimen of SG coated PAS with the hole diameters of 1.0, 1.5, and 2.5 mm, respectively, has the ratios each of 113.8, 50.6, and 18.2.

3.2.2. SG specimen with a thickness of 20 mm

The variations of SAC for SG specimen of 20 mm coated PAS with the hole diameters each of 0.0, 1.0, 1.5 and 2.5 mm investigated at the frequency of sound ranged from 100 to 4000 Hz are shown in Fig. 5b. The values of SAC averaged 0.4 at 125 Hz decreased across the frequency range of 250–2000 Hz and then increased again, with the SAC value of 0.47 observed at 2000 Hz for SG specimen coated PAS with a hole diameter of 1.0 mm. The performance of SG coated with PAS reached to a SAC value of 0.47 at 2000 Hz could be a suitable adsorber material for office wall applications [34]. The SAC value of 0.56 at 2000 Hz for specimen of SG coated PAS with a

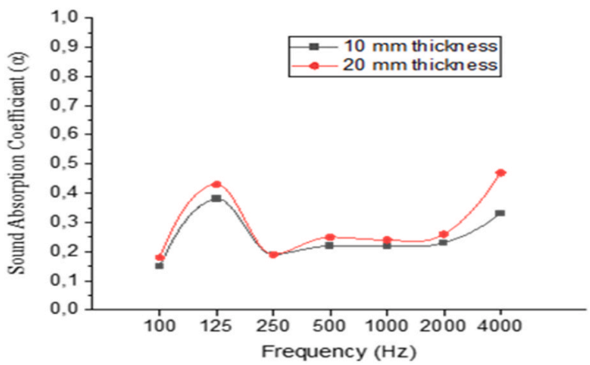

Fig. 4. Variations of SAC for SG specimen with the thicknesses of 10 and 20 mm without coating.

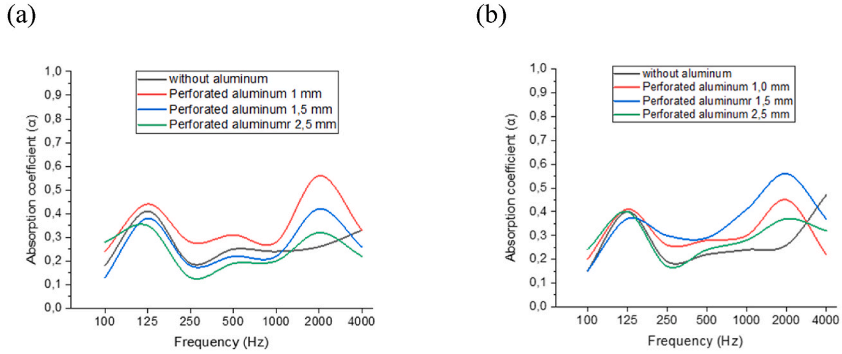

Fig. 5. Variations of SAC for SG specimen with the thicknesses of (a) 10 mm and 20 mm.

hole diameter of 1.5 mm could be twice as big as that of 0.26 for SG specimen without coating. This means that SG specimen coated PAS with a hole diameter of 1.5 mm can reduce sound level twice comparing with SG specimen without coating. The design aspect of an absorber allows absorbing surface of SG specimen to be integrated with PAS, while increasing the acoustic performance and the specific aesthetic features of the coated SG fiber [35]. The SAC value of SG specimen coated with PAS of having a hole diameter of 1.0 mm decreases from 0.47 to 0.22 and that of SG specimen without coating increases from 0.22 to 0.49 at the frequency of 4000 Hz (see Fig. 5b). This could be due to SG specimen without coating can absorb sound energy by twice at 4000 Hz compared to SG specimen after covering with PAS that having a hole diameter of 1.0 mm [36]. The sound absorption of SG specimen without coating is better than specimen of SG coated with PAS while the coating of SG specimen with PAS has an important role in shifting the peak of SAC value at the frequency of 4000 Hz. The value of SAC observed at 4000 Hz for SG specimen without coating increases from 0.33 to 0.49 with increasing of the SG thickness from 10 to 20 mm showing that the capability of sound absorption for SG fiber of thick specimen could be higher than that for SG fiber of thin specimen.

3.2.3. Sound absorption coefficient of SG specimens thicknessed 10 and 20 mm

The thermal conductivity of wall panel calculated by a method of the equivalent thermal conductivity could be useful to determine the value of SAC in the middle and low frequency ranges [37]. The variations of SAC observed for the SG thicknesses of 10 and 20 mm coated PAS with the hole diameters each of 1.0, 1.5 and 2.5 mm are shown in Fig. 6. A trend in the values of SAC varied with multiple peaks at two frequencies of 125 and 2000 Hz are almost similar for all SG specimens. Effect of SG thickness on the sound absorption can be evaluated using the graphs of solid line and dotted line to represent the specimen of SG had the thicknesses each of 10 and 20 mm, respectively, coated with PAS. Proper choice of PAS hole size can avoid the resonance frequencies of SG fiber that provide the loss of high sound transmission [38]. Peak of SAC at the sound frequencies of 125 and 2000 Hz decreases with increasing of PAS hole diameter from 1.0 to 1.5 and to 2.5 mm for SG specimen of having a thickness of 10 mm (see Fig. 6). The peaks of SAC at two frequencies of 125 and 2000 Hz for SG specimen of having a thickness of 10 mm coated PAS with a hole diameter of 1.0 mm are higher than those with a hole diameter of 1.5 mm and then are higher than those with a hole diameter of 2.5 mm. This means the capability of sound absorption decreased with increasing of the SG thickness. A dense specimen of SG thicknessed 10 mm coating with PAS that having a narrow hole can absorb more sound energy due to the resonating air frictional loss is low [39]. The peak of SAC at 2000 Hz for specimen of SG

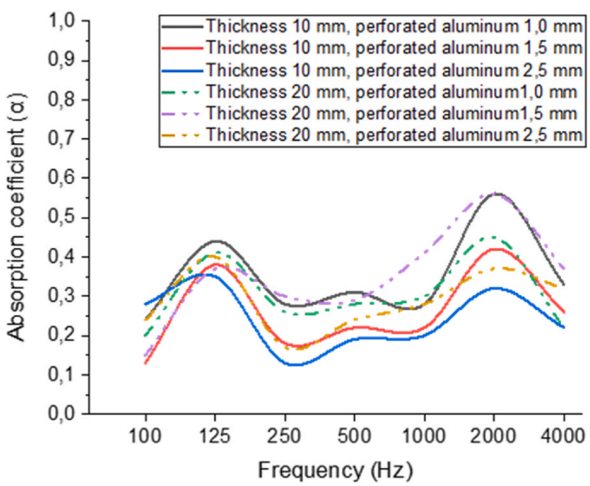

Fig. 6. Comparison of the SAC values for SG specimens thicknessed 10 and 20 mm.

thickened 20 mm coating with PAS having a circular hole of diameter 1.5 mm is higher than that having a diameter of 1.0 mm and is higher than that having a diameter of 2.5 mm. The maximum SAC value of 0.56 exhibited best sound absorption at 2000 Hz for specimen of SG with its thickness of 10 mm coated with PAS of 1.0-mm diameter is similar to that for specimen of SG with its thickness of 20 mm coated with PAS of 1.5-mm diameter. This could be due to the sound waves absorbed by a low density of SG loosely packed together with a plenty of space transferred through a larger size of PAS hole is approximately similar to that absorbed by a high density of SG densely packed together with a limited space transferred through a narrow PAS hole size [2]. A difference in the SAC value of SG specimen coated PAS with the hole diameters each of 1.0, 1.5 and 2.5 mm at 2000 Hz could be more significant compared to that at the sound frequency of 125 Hz. The peaks of SAC for specimen of SG thicknessed 20 mm are close to each other at the sound frequency of 125 and are clearly different from each other at 2000 Hz. The influence of PAS hole size on SAC depending on the thickness of SG specimen could be the feature of the sound vibration patterns and inherent nonlinear phenomena [40]. In conclusion, the efficiency of sound absorption could be related to the factors of SG density and PAS hole diameter.

3.3. Noise reduction coefficient of SG specimen

An uncertainty analysis of the acoustic and non-acoustic parameters to estimate the intrinsic properties of fibrous and porous materials based on the experimental data obtained by a four-microphone impedance tube has shown the measured transfer functions of noise wave affected by an uncertainty influence of the environmental and spatial conditions [41]. The empirical formulation of energy absorption has been proposed as a function of the geometrical factors to predict noise reduction with high accuracy [42]. The calculation of NRC value accorded to Eq. (2) could be based on the values of SAC recorded at the sound frequencies of 250, 500, 1000, and 2000 Hz. The value of NRC indicated the level of lessening echo and noise within a space is subjected to sound absorption [43]. The maximum NRC value of 0.39 for specimen of SG thicknessed 20 mm coating with PAS of having a hole diameter of 1.5 mm represents a sound absorption of 39% and sound reflection of 61% (see Fig. 7). The NRC value of around 0.23 for specimen of SG thicknessed both 10 and 20 mm without coating represents a sound absorption of 24% and sound reflection of 76%. The NRC value of 0.21 for SG specimen with a thickness of 10 mm is almost similar to that of 0.23 for SG specimen without coating. The NRC value of 0.36 higher than that of 0.26 and higher than that of 0.21 for the specimens of SG thicknessed 10 mm and coated with PAS having the hole diameters of 1.0, 1.5 and 2.5 mm, respectively, shows that the sound absorption decreases with increasing of the PAS hole diameter. The NRC value of 0.39 higher than that of 0.32 and higher than that of 0.27 for the specimens of SG a thicknessed 20 mm and coated with PAS having the hole diameters of 1.5, 1.0 and 2.5 mm, respectively, indicates that the use of SG specimen coated with PAS having a hole diameter of 1.5 mm is more suitable to the sound absorption applications. Higher density and higher areal density of the SG specimen can lead to an increased NRC value of absorber material [44]. The level of noise within a space can be lessened depending on how to choose the thickness of SG and the hole size of PAS by recognizing structural vibration in a complicated environment [45]. Sound absorption of SG fiber can be classified based on the value of SAC at the frequency range of 100–4000 Hz, as shown in Table 2. The specimens of SG thicknessed 10 and 20 mm coated with PAS of having the hole diameters of 1.0 and 1.5 mm together with SG specimen thicknessed 20 mm coated with PAS of 2.5-mm hole diameter can be included into sound absorption class of D (see Table 2) since the value of SAC is in the range of higher than 0.26 and below that 0.55. The effectiveness of SG resonant surface can be predicted using the model of describing sound wave interaction [46]. The specimen of SG thicknessed 10 mm coated with PAS of having a diameter of 2.5 mm and the specimens of SG thicknessed 10 and 20 mm without coating can be included into sound absorption class of E because of the value of SAC is in the range of 0.15–0.25. The strengths of this work could be due to the application of SG fiber as a reinforcing material has been promoted to composite manufacturing but has not been investigated of its capability of sound absorption. The implementation of MATLAB computer program permits us to perform the SAC data analysis and NRC data analysis of the SG fiber automatically recorded by a dedicated computer. The limitations of the study are related to the formation of SG specimen without adhesive strength and the method of impedance tube using with the design of SG specimen coated with PAS influenced the interpretation of the results.

4. Conclusions

The results of this study showed that SG thickness and PAS hole size affect the values of SAC and NRC. The SAC value of SG specimen without coating PAS at the sound frequency of 4000 Hz increases by 14% with increasing of SG thickness from 10 to 20 mm. The specimens of SG coated with PAS can have two peaks of SAC at the sound frequencies of 125 and 2000 Hz while those without coating have two SAC peaks at 125 and 4000 Hz, showing that the use of PAS for coating SG fiber plays an important role of shifting the peak of SAC from 4000 to 2000 Hz. The maximum NRC value of 0.39 for the specimen of SG coated with PAS and that of 0.23 for the SG specimen without coating show that the role of PAS is able to improve the sound dampening of SG absorber increased by 16%. The sound absorption classes of D and E have been verified for the specimens of SG coated with PAS and for those without coating, respectively, contributing to the future applications of SG fiber. Investigating the effect of density by scrutinizing various thicknesses of SG fiber on the values of SAC and NRC affected by air gap and non-acoustic can be suggested to the future research of exploring the benefits of giant bulrush for office wall applications to reduce the noise pollution in workplace.

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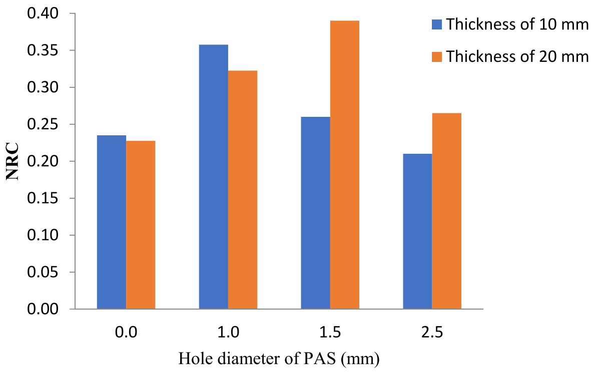

Fig. 7. NRC value of SG specimens coated with PAS and without coating.

Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

CRediT authorship contribution statement

Suhaeri Suhaeri: Writing – original draft, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohamad Ali Fulazzaky:** Writing – review & editing, Visualization, Supervision, Investigation, Formal analysis. **Husaini Husaini:** Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Muhammad Dirhamsyah:** Resources, Methodology, Investigation, Formal analysis, Data curation. **Iskandar Hasanuddin:** Validation, Project administration, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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