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The Sound Absorption Coefficient and Noise Reduction Coefficient of Rice Husk Silica

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Abstract – This paper presents the acoustical behavior of rice husk silica samples in various composition and thickness by using epoxy and methyl ethyl ketone peroxide (MEKP) as binder. Rice husk is one of agriculture waste materials that can be obtained in a large quantity which have the potential in the application of sound absorber. Rice husk silica samples were fabricated in various composition and thickness by using epoxy and methyl ethyl ketone peroxide (MEKP) as binder. Impedance tube testing and physical test were conducted to obtain the properties of rice husk silica. The testing results found that specimens with higher composition of rice husk silica and using MEKP as binder have the lowest density, highest porosity and give a better sound absorption coefficient. The increment of thickness can produce a greater sound absorption at lower frequency. The results also demonstrate 20 mm is the best thickness for a better noise reduction coefficient.

Keywords: Crack propagation trajectory, Kenaf fibre composite, Random woven

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1. Introduction

The massive expansion and development of industrial operation and transportation may lead to the sound pollution issues especially in urban district. Sound pollution induces the physiological effect to human such as sleep disturbance, annoyance, stress, insomnia and headache. According to World Health Organization (WHO), sound pollution also can caused some severe health risk especially in ischemic heart disease [1].

In present, natural fibre such as wood, tea, kenaf leaf, and jute is being widely used all around the world due to their mechanical properties and availability in large quantity. The utilization of natural fibre can help to reduce the negative impact towards environment. Currently, natural fibres are becoming an ideal option for acoustic treatment [2]. Moreover, the development of plant fibre in reinforcement of composite is increasing significantly [3]. The applications of natural fibre in the reinforced polymer have been replace the synthetic polymer.

There are many agricultural waste products in one year. Generally, agriculture waste can be used as biomass adsorbents in order to cure the pollutions. Rice husk is one of the plant fibres that produced in a huge amount annually. Rice husk is considered as agriculture residue after the extraction of grain or rice from paddy plant. Rice husk is being further process in order to produce rice husk silica. Rice husk silica has the potential in the uses of acoustic absorption application. Their advantages such as low price, safe to be process, high availability and abundance lead to the research for reuse purpose.

The development of rice husk silica in acoustic field can serve as replacement material for sound absorption material. Rice husk silica can be produced or extracted with an environment friendly process or method. Since natural plant-based material contributed less carbon footprint, thus the production of these materials rarely relies on petrochemicals and consumes less energy and fossil fuels. This is a big contrast compare to conventional synthetic material. Sound absorber with the material of rice husk silica also can overcome the issue related to health risk especially for human respiratory system. The production of sound absorber by using rice husk silica also reduced the agriculture waste that being burnt and results in air pollution.

Rice husk silica is classified as a renewable source for us to obtain in the future. This high sustainability material can help to avoid the excessive consume of non-renewable energy as the production of synthetic material may spend a lot of fossil fuel.

2. Methodology

2.1. Material preparation

The rice husk silica we used in this research is ready-made from the supplier. The rice husk silica is well blended into small grain as shown in Figure 1. For binder, epoxy mix with its hardener at ratio 2:1 in binding with the rice husk silica. While MEKP require chemical reaction between peroxide and hardener at ratio 100:1.

Figure 1. Rice husk Silica

2.2. Composition preparation

Three different thickness of specimen need to prepare for each type of composite which is 10 mm, 20 mm and 30 mm. However, the composition of the material for each thickness is same. The weight percentage of rice husk silica were varied from 10 wt% to 30 wt% with the increment of 10 wt%. Table 1 show the summary of weight percentage for the rice husk silica and epoxy or MEKP.

Table 1. The summary for the composition of rice husk silica composite.

Sample Set	Rice Husk Silica (RHS)	Epoxy or MEKP
Set 1	10 wt%	90 wt%
Set 2	20 wt%	80 wt%
Set 3	30 wt%	70 wt%

2.3. Mixing process

The mixing process carries out firstly before pouring into the mold. Rice husk silica, epoxy and MEKP are weighted accurately in advance based on their percentage or ratio that fixed in the previous section. After that, the rice husk silica and epoxy are mixed together in a small container. Then, the mixture is stirred until it is integrated and uniform. The same step goes to the composite of rice husk silica and MEKP where epoxy is replaced by MEKP

2.4. Hand lay-up fabrication

The rice husk silica mixture goes through a hand lay-up fabrication process to form the sample specimen in different thickness. The mold is sprayed with some silicon spray before pouring the mixture on it so that the specimen can be removed in an easy and convenient way. Then, the mixture of rice husk silica and epoxy is poured into the mold cavity for further forming purpose as shown in Figure 2. The mold and mixture are then left for cooling around 24 hours at the room temperature. After cooling, the specimen can be taken out from the mold and it is ready for the further testing process. The well fabricated specimen is as shown in Figure 3.

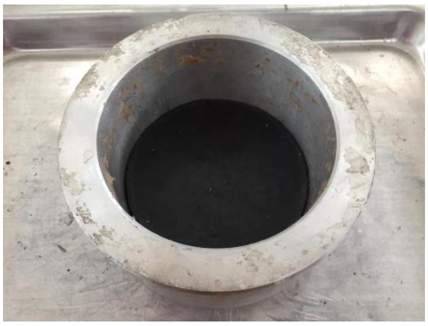


Figure 2. Mixture poured into mold cavity

Figure 3. Rice husk silica specimen

2.5. Acoustic Testing

Acoustic properties of rice husk silica composite were determined by using impedance tube. Impedance tube can used to measure the sound absorption coefficient of material at normal incidence. In this research, the experiment are carried out based on the procedure and standard in ASTM E1050-98. Hence, two microphones and a digital frequency analysis system are required.

The impedance tube used (model SCS9020B) in this research is as shown in Figure 4. There were two microphones attached in the impedance tube in order to receive the response sound wave reflected from the testing material. . The final sound absorption coefficient of the testing specimen is show in the digital frequency analysis software.

The noise reduction coefficient is further calculated by using the formula shown Eq.(1).

$$NRC = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4} \quad (1)$$

where α is sound absorption coefficient.

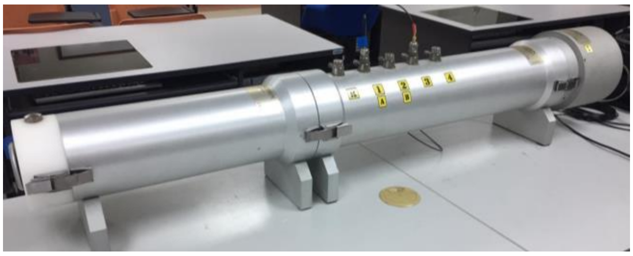


Figure 4. Impedance tube apparatus

2.6. Physical Test (Density and Porosity Test)

The physical test is carried out by using the Mettler Toledo Density Tester (AG2007 series). The test carried out according to ISO5017 standard in order to obtain the density and porosity of the samples. This testing is important for the verification of results in acoustic testing as the porosity is direct proportional to the sound absorption. A further calculation is needed in order to obtain the density and porosity value. The formula for calculation is showed in Eq.(2).

$$Density = \frac{W_d}{W_d - W_s} \quad (2)$$

$$Porosity = \frac{(W_w - W_s) - (W_d - W_s)}{W_w - W_s} \times 100 \quad (3)$$

where; W_d = Weight of dry sample
W_s = Weight of floating sample
W_w = Weight of wet sample

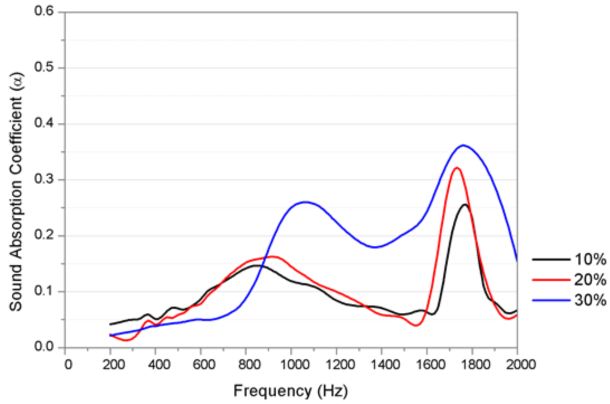
3. Results and Discussion

3.1. Sound absorption coefficient

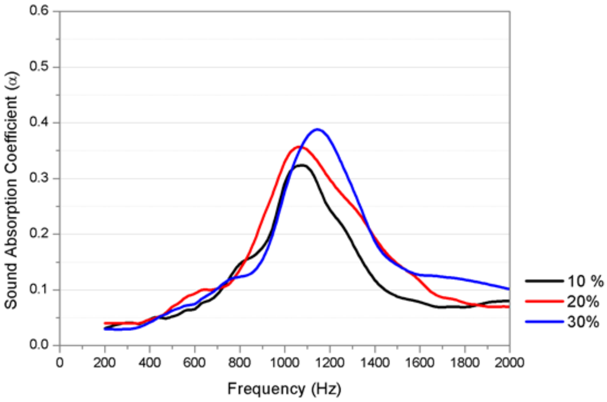
The sound absorption coefficient of rice husk silica sample which used the epoxy as binder was shown in Figure 5. From Figure 5(a), all the 10 mm thickness specimens showed a low sound absorption coefficient when below 800 Hz. All the 10 mm thickness samples revealed that the peak sound absorption coefficient was between the frequencies from 1700 Hz to 1800 Hz. The specimen with 30 wt% rice husk silica had the highest sound absorption coefficient which was 0.37. This result indicated that adding weight percentage of rice husk silica can improved the sound absorption.

While Figure 5(b) shows the sound absorption coefficient for all the 20 mm thickness specimens increased gradually until reach the peak at around frequency of 1100 Hz. After frequency 1100 Hz, the coefficient started to decline steeply. The sample with 30 wt% rice husk silica had the highest sound absorption with the value 0.38. In these results, it noticed that there was only minor improvement in the increasing for rice husk silica composition compare to the specimens with 10 mm thickness.

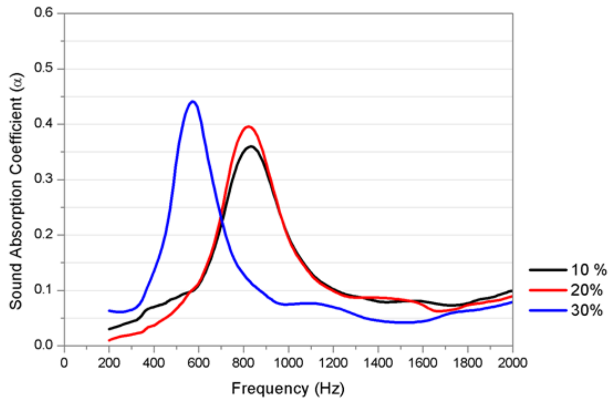
Figure 5(c) indicated the drastic incline of sound absorption coefficient before reaching for their peak point. All the 30 mm thickness specimens had their peak coefficient at frequency range between 500 Hz to 900 Hz. The peak sound absorption for 10 wt%, 20 wt% and 30 wt% of rice husk silica specimen were 0.36, 0.39 and 0.44 respectively. The peak coefficient for the 30 wt% rice husk silica specimen shifted to the lower frequency at 500 Hz yet the other two at around 850 Hz. However, the sound absorption dropped to a low coefficient which is around 0.1 after 1100 Hz frequency.



(a)



(b)



(c)

Figure 5. Sound absorption coefficient of rice husk silica sample using epoxy as binder in thickness of (a) 10 mm, (b) 20 mm and (c) 30 mm.

Overall, the results obtained from the testing showed the similarities to the previous study where adding the composition of natural fibre enhance the pores in the specimen to increase the sound absorption [4]. The reduction of sound energy was through the air viscous resistance, heat transmission and interface friction in the pores. Hence, it led to a higher sound absorption. Furthermore, increasing in rice husk silica composition for 10 mm thickness specimen gave the most significant increment as the coefficient increase by 0.12 which is the highest among the other specimens with different thickness.

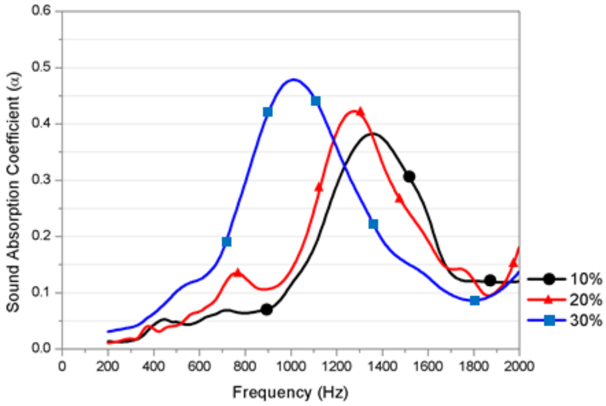
Moreover, the results showed that each specimen only achieved their peak sound absorption coefficient at only a small range of frequency which was consistent with the research done by Tang et al.[5] . In the other words, the application of rice husk silica in sound absorber at different frequency required a specific composition and thickness in order to obtain the highest performance. Lastly, the epoxy specimen with 30 wt% of rice husk silica at 30 mm thickness showed the best performance at sound absorption as the coefficient reached to 0.44.

Next, the specimens that used methyl ethyl ketone peroxide (MEKP) as binder were graphically illustrated in Figure 6. Figure 6 (a) shows that all the mixture sample of rice husk silica and MEKP with thickness 10 mm showed the sound absorption coefficient rose gradually until a peak point and started to decline steadily. However there were another marked inclinations of sound absorption start from frequency 1900 Hz. Among the samples, the 30 wt.% rice husk silica reached the optimum point with value 0.48 at frequency 1000 Hz.

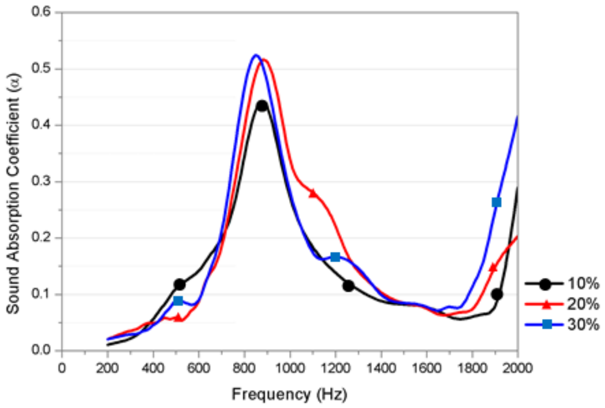
Figure 6(b) depicts with 20 mm thickness MEKP samples, the graph showed direct proportional relationship between sound absorption coefficient and frequency from 200 Hz to 850 Hz. The sound absorption coefficient rose as the frequency increased until a maximum value at the frequency around 850 Hz. Then, the sound absorption coefficients started dropping until the value below 0.1 within the range of 900 Hz to 1500 Hz. The results showed that the 20 wt.% and 30% rice husk silica specimen performed well in the sound absorption with the coefficient 0.51 and 0.52. Then, all of the specimen showed a second inclination start from 1700 Hz.

Graph in Figure 6(c) showed an interesting results as the graphs pattern for each specimens were almost the same. All of them increased dramatically until 700Hz and started to decline substantially after reaching the peak sound absorption coefficients. The highest sound absorption coefficient was recorded at frequency 750Hz with the value 0.6 which is indicated by 30 wt.% rice husk silica specimen at 30mm thickness. The sound absorption coefficient increased significantly again at 1850 Hz. The 30 wt.% rice husk silica specimen can absorbed 35% of sound at 2000 Hz.

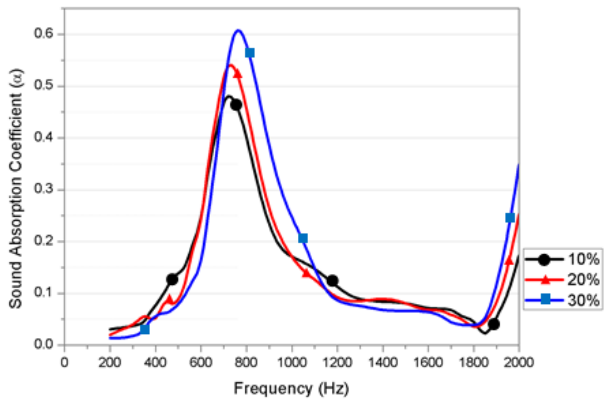
The findings of these testing showed a similar results whereas adding the weight percentage of rice husk silica specimens provided an enhancement on sound absorption coefficient. The effect of adding the rice husk silica composition in MEKP specimen showed a major improvement in sound absorption coefficient at 30mm thickness. This result was different compare to epoxy specimen where the 10 mm thickness samples gained the largest improvement in acoustic properties.



(a)



(b)



(c)

Figure 6. Sound absorption coefficient of rice husk silica sample using MEKP as binder in thickness of (a) 10 mm, (b) 20 mm and (c) 30 mm.

The results from MEKP specimen indicated that the sound absorption coefficient may incline again to reach multiple peak as the frequency increase. This results were in the agreement with Xu et al. [6] finding. The research revealed the sound absorption coefficient increases after dropping to a certain level which was also test at frequency below 2000 Hz. In short, the testing revealed 30 mm thickness with 30 wt% of rice husk silica specimen as the best sample which could absorb the sound up to 60%.

3.2. Comparison of thickness

Comparison of thickness of specimen regarding the acoustic properties was made by analyzing the graph in Figure 7 and Figure 8. From Figure 7, the results reflected that increased the thickness of samples can made an improvement in the sound absorption. In this study, the testing showed the sound absorption coefficient can rose from 0.37 to 0.44 by increased the thickness from 10mm to 30mm. At the same time, the results indicated that increasing in thickness can induced the peak sound absorption shift to lower frequency. The sound absorption coefficient peak of 10mm, 20mm and 30mm thickness sample were at frequency 1750 Hz, 1100 Hz and 550 Hz respectively.

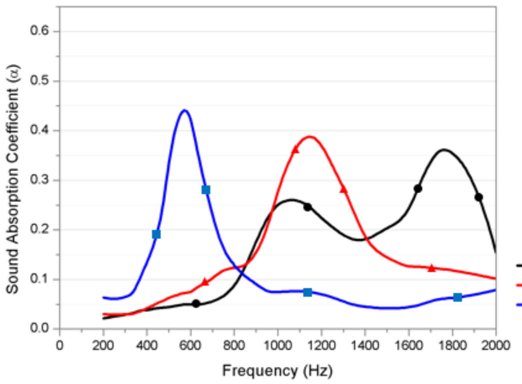


Figure 7. Sound absorption coefficient of rice husk silica sample using epoxy as binder (30 wt% rice husk silica, 70 wt% epoxy) with different thickness

For the samples bind with MEKP, it showed the similar trend where increase in thickness enhanced the sound absorption and moved the peak to a lower frequency. The variation of thickness in MEKP specimens gave a more effective and remarkable results. The sound absorption coefficients increased from 0.48 to 0.52 and 0.6. In contrast, it was ineffective in shifting the peak to lower frequency. The sound absorption coefficient peak only shift within the range from 750 Hz to 1000 Hz.

Both of the results in the testing were in line with the previous study where the increment in thickness shift the sound absorption to a lower frequency [7]. Zunaidi et al. [8] gave a possible explanation as the thicker samples have a better sound absorption at higher wavelength which exist in the sound with low frequency. Similar behavior also appeared in ceramic materials [9].

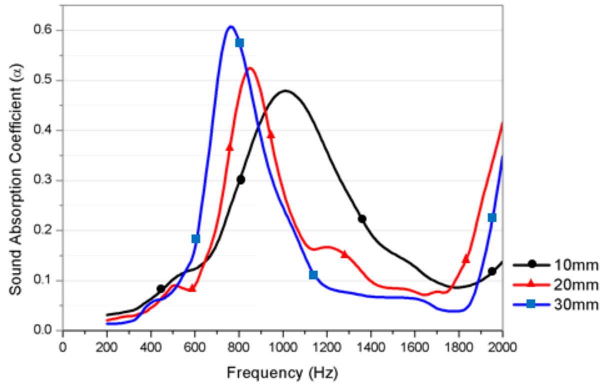


Figure 8. Sound absorption coefficient of rice husk silica sample using MEKP as binder (30 wt% rice husk silica, 70 wt% MEKT) with different thickness.

3.3. Comparison of binder

Comparison binder material can be seen from Figure 9. The sound absorption coefficient of MEKP sample was 0.6 which was much higher than epoxy samples with the coefficient 0.44 Moreover, it showed that MEKP sample performed well at a higher frequency which is at 750 Hz while epoxy sample showed the peak sound absorption coefficient at 560 Hz. These result may effected by the high fluidity of MEKP that make the rice husk sinking and cause uneven mixture.

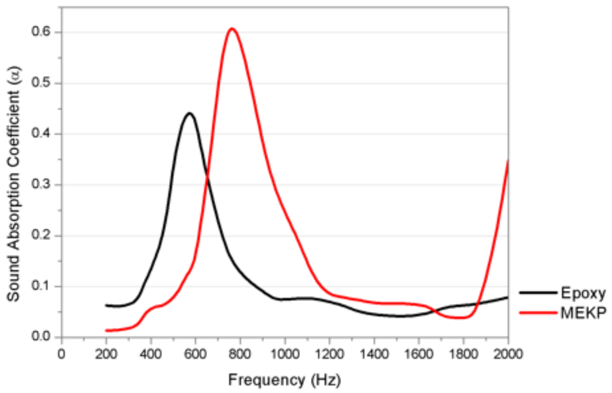


Figure 9: Sound absorption coefficient of 30 wt% rice husk silica sample using epoxy and MEKP as binder

Table 2: Summary of peak sound absorption coefficient of each samples

Binder	Thickness	Composition of rice husk silica		
		10 wt.%	20 wt.%	30 wt.%
Epoxy	10 mm	0.25	0.31	0.37
	20 mm	0.32	0.35	0.38
	30 mm	0.36	0.39	0.44
MEKP	10 mm	0.38	0.42	0.48
	20 mm	0.42	0.51	0.52
	30 mm	0.48	0.53	0.60

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The summary for each samples peak sound absorption coefficient were recorded in Table 2. The highest sound absorption coefficient peak was represented by 30mm MEKP samples with 30 wt% of rice husk silica which can reached to 0.6.

3.4. Noise Reduction Coefficient (NRC)

Based on Figure 10 and Figure 11, the NRC fluctuated as varying the thickness, composition of rice husk silica and binder material. However, most of them showed that adding the composition and thickness can help in enhancement of NRC. The column graphs surprisingly indicated that the NRC obtained from the samples was low and not expected in this testing. The NRC of the samples was within the range from 0.07 to 0.21.

The best performance samples among epoxy binder samples was 30wt% rice husk silica composition with thickness 20 mm specimen that obtained 0.19 as NRC. Similarly, the highest NRC achieved by 20mm thickness MEKP binder samples with 30wt% rice husk silica at the value 0.21. In overall, this result revealed that all the 30 wt% rice husk silica and 20mm thickness samples had a better NRC.

These unexpected results may due to the sound absorption performance for each sample was at different frequency. Furthermore, the NRC calculation was based on 250 Hz, 500 Hz, 1000 Hz and 2000 Hz only. Therefore, the samples with high sound absorption other than the specific frequency result in a low NRC value.

3.5. Density Test

Figure 12 showed the density decreased as the increased of rice husk silica weight percent in the composition. This was because the rice husk silica being added was at low density which reduced the overall samples density. However, the increment of density was not constant due the mixture did not distributed homogeneously during the fabrication process. The lowest density sample was presented by sample with 10 wt% rice husk silica mix with MEKP which was with the value 0.51 g/cm^3.

3.6. Porosity Test

Figure 13 indicated that porosity was proportional to rice husk silica weight percentage composition. The highest porosity obtained from the result was 17.32 % which showed by samples mixture between 30 wt% rice husk silica and MEKP. These results made an important verification to the acoustic testing that done in previously. The samples with higher rice husk silica composition gave a higher porosity and led to a higher sound absorption coefficient. As mention previously, the result may effected by high fluidity of MEKP. It caused the rice husk sinking and led uneven mixture and higher porosity.

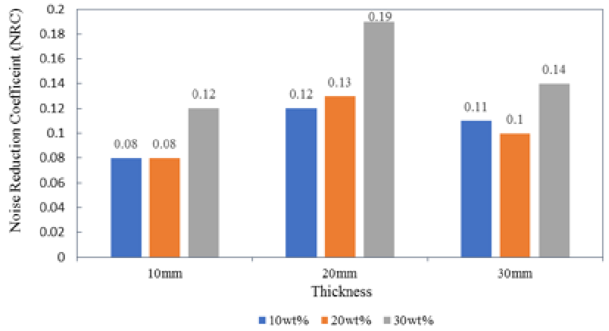

Figure 10. Noise reduction coefficient for epoxy binder samples

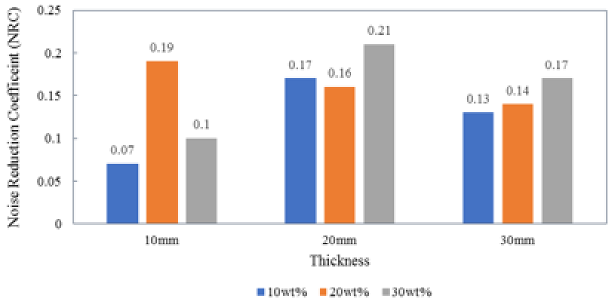

Figure 11. Noise reduction coefficient for MEKP binder samples

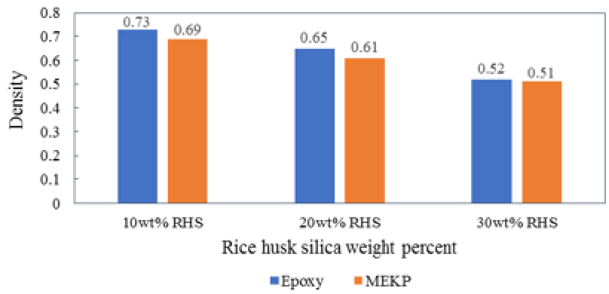

Figure 12: Density of rice husk silica samples

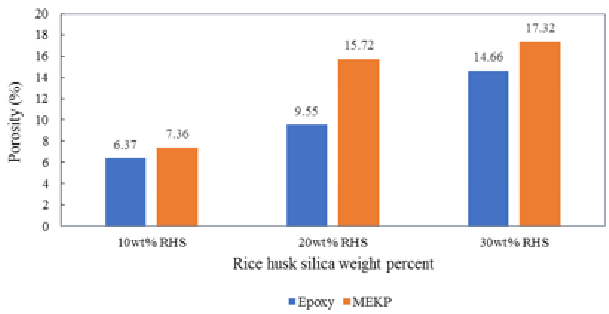

Figure 13: Porosity of rice husk silica samples

4. Conclusion

The acoustic testing result showed that the performance of every samples were different. Overall, the sound absorption coefficient peak were in the range from 0.25 to 0.6. All the sound absorption peak were obtained in the range of frequency from 500Hz to 1800Hz. The analysis revealed that the increment of specimen thickness enhanced the sound absorption and shifting the best performance of sound absorption to the lower frequency. Furthermore, the higher weight percent of rice husk silica specimens indicates a better sound absorption. Most of the specimens showed that increment of rice husk silica composition were more effective compare to increment in thickness in order to improve acoustic properties. Based on the comparison between two binders, MEKP specimens had a higher sound absorption. The highest sound absorption were obtained from 30 wt.% rice husk silica with MEKP binder at 30 mm thickness with the value 0.6 while the sample bind by epoxy got the value 0.44.

Density and porosity test gave a verification for the acoustic testing. The results showed that increased of rice husk silica weight percent induced a lower density yet a higher porosity. The MEKP 30 mm thickness with 30 wt.% rice husk silica specimens had the lowest density and highest porosity at 0.51 g/cm^3 and 17.32% respectively. Therefore, it achieved the highest sound absorption.

Rice husk silica is acceptable for the sound absorption application in order to maximize the usage of this agriculture residue and create a better environment by reducing the wastage of rice husk silica.

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