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THE ANALYSIS OF ATTENUATION COEFFICIENT AND ACOUSTIC IMPEDANCE OF CEILING PANEL USING IMPEDANCE CHAMBER METHOD

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ABSTRACT

The purposed of this research is to determine the attenuation coefficient and acoustic impedance of ceiling panel like plywood, calsiboard and bamboo woven. The influence thickness, paint coated, air cavity increment of the attenuation coefficient and acoustic impedance of these ceiling panel are also mesured. The impedance chamber method with range of frequency 100 Hz – 5000 Hz are used here. The result shows that the average of attenuation coefficient for plywood panel, calsiboard panel and bamboo woven panel are 0,37 Npmm^{-1}, 0,62 Npmm^{-1} and 0,28 Npmm^{-1} respectively. In addition, the acoustic impedance of these panel is 1,33 x 10^{6}kgm^{-2}s^{-1}, 3,74 x 10^{6}kgm^{-2}s^{-1} and 1,15 x 10^{6}kgm^{-2}s^{-1}. The attenuation coefficient is decreased with the increasing thickness of the panel and the same trend is founded of the acoustic impedance. Meanwhile, the paint coated can increase attenuation coefficient and acoustic impedance. For the air cavity increment ceiling panel, the attenuation coefficient and acoustic impedance are less than the solid panel.

Introduction

Noise is a problem facing Indonesia society. Noise caused hearing disturbance such as deafness [1]. For health and comfort reasons, all buildings should implement a design strategy to suppress the entry of noise. One solution is the use of acoustic material in the design and manufacture of the room. The quality of the acoustic material is determined from the attenuation coefficient and the acoustic impedance [2]. The attenuation coefficient describes the ability of a material in reducing the sound energy or the energy loss through the medium. The energy loss is caused by reflection and absorption by the medium.The acoustic impedance is the obstruction bythe medium to the propagation of sound [3].

The most widely used acoustic material in the design of the room is the ceiling. Ceiling is a building component that restrict the height of a room and serves as a silencer. This type of acoustic material is widely used as ceiling are plywood, calsiboard and bamboo woven [4]. For the purpose of sound suppression, the attenuation coefficient and the acoustic impedance of the ceiling materials should be known. The determination of attenuation coefficient and acoustic impedance can be done using impedance chamber method.

Information about the attenuation coefficient and acoustic impedance is very important as part the design of a room. On the other hand, the attenuation coefficient and acoustic impedance are no attached to the ceiling in the market, so that the acoustic characteristic information of the ceiling material is not known by the public. Therefore, the research for determining attenuation coefficient and acoustic impedance should be done as an effort to provide related information and as consideration to design a good room.

Theory and Calculation

The characteristic of acoustic material in solid depends on modulus of elastic. The modulus of elastic can be expressed in equation 1 [5].

$$E = \frac{\sigma}{\varepsilon} \quad (1)$$

The flexible modulus of elastic values can be given by equation 2 [6].

$$E = \frac{F{L_p}^3}{4\delta b h^3} \quad (2)$$

Therefore, to determine the speed of sound in solid medium can be through equation 3.

$$v = \sqrt{\frac{E}{\rho}} \quad (3)$$

where v is speed of sound in solid (ms^{-1}), E modulus of elastic (Nm^{-2}), ρ density of material (kgm^{-3}), σ stress (Nm^{-2}), ε strain, F force (N), L_p length support (m), b material width (m), h material thickness (m), δ deflection (m).

The principle of chamber method is utilizing reflection and transmission when sound waves through the medium [3]. The impedance chamber method uses the theory of transmission loss, as shown in figure 1 [7].

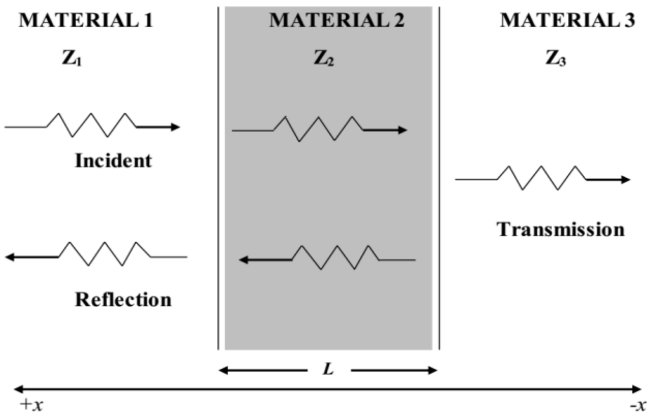


Figure 1. Transmission loss while through a medium

The mathematically of transmission loss (TL) can be stated as equation 4.

$$\text{TL} = TI_i - TI_t = 10\ \log(I_i/I_t) = 8{,}7\alpha L \quad (4)$$

Where TI_i is incident intensity level (dB), TI_t is transmission intensity level (dB), L is material thickness (mm) and α is attenuation coefficient ($Npmm^{-1}$). The intensity level (TI) in decibel unit can be stated as equation 5.

$$TI = 10\ \log(I/I_{ref}) \quad (5)$$

Where I isa sound intensity (Wm^{-2}) and I_{ref} sound intensity reference (10^{-12} Wm^{-2}). The transmission loss depends of acoustic impedance material 2, acoustic impedance is Z ($kgm^{-2}s^{-1}$), where Z = p/u or Z =ρv, $p$is sound pressure (Nm^{-2}), u is particle velocity (ms^{-1}),

ρ material density (kgm-3), v is speed of sound in material (ms-1). The attenuation coefficient of material 2 (α) can be defined in equation 6.

$$I_t = I_i e^{-2\alpha L} \quad (6)$$

Where I_i is incident sound intensity (Wm-2), I_t is transmission sound intensity (Wm-2), L is material thickness (mm) and α is atenuation coefficient (Npmm-1). While the sound energy through 3 medium assumed material 1 and 3 is same (air), material 2 is solid panel, where $Z_1 = Z_3$ (in chamber temperature acoustic impedance of air = 410 kgm-2s-1) [7], so the intensity transmission coefficient $\left(a_t = \frac{I_t}{I_i}\right)$ become equation 7.

$$a_t = \frac{4}{4\cos^2(k_2L) + \left(\frac{Z_1}{Z_2}+\frac{Z_2}{Z_3}\right)^2 \sin^2(k_2L)} \quad (7)$$

For determination of acoustic impedance of medium (material 2), where $k_2L = \frac{2\pi f L}{v_2}$ in radian, for approach$\cos(k_2L) \approx 1$, $Z_1 = Z_3$ and $Z_2 \gg Z_1$, so the equation 7 becomes [8].

$$a_t = \frac{1}{1 + \frac{1}{4}\left(\frac{Z_2}{Z_1}\right)^2 \sin^2(k_2L)} \quad (8)$$

Experimental Method

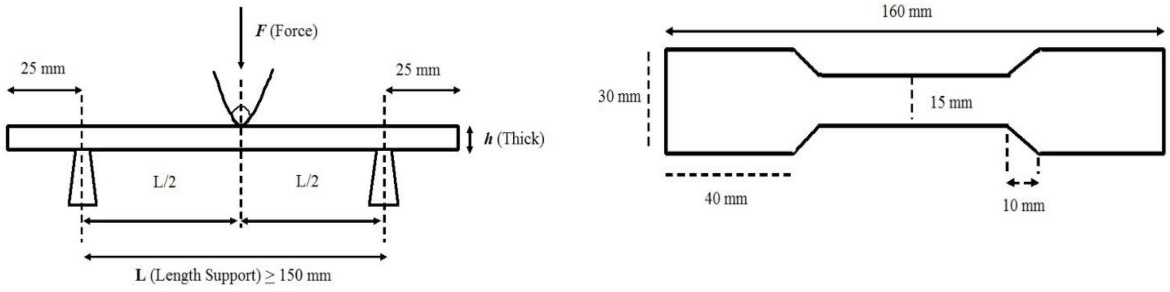
The sample is made of a plate area cross section of the impedance chamber. Acoustic materials used are three types of ceilings; plywood, calsiboard and bamboo woven. The panel is made in three variations of thickness that is 4 mm, 8 mm, and 12 mm, then measured the mass and dimension to obtain the density of the material. For the treatment of the ceilings, we addedpaint coated and air cavity. The air cavity treatment used as much twelve holes with each diameter 8 mm.

(a) (b) (c)

Figure 2. Sample test acoustic material ceiling (a) plywood, (b) calsiboard, (c) bamboo woven

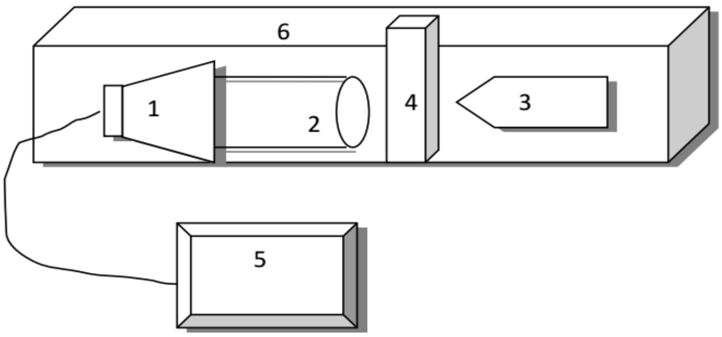
The mechanical test is performed to find out the modulus elastic of the ceiling material so that it will be obtained by using the equation 3. Mechanical testing is done by RTG-1310 Universal Tensile Machine (UTM). The flexibilty of Panel plywood and bamboo are tested based on SNI 03-2105-2006 standard (Figure 3a) and the tensile of calsiboard panel is tested based on the DIN 50125 standard (Figure 3b).

The acoustic test is to determine the attenuation coefficient and the acoustic impedance of the ceilings using impedance chamber method shown in Figure 4.The loudspeaker is connected to the function generator as a sound energy source. The mmeasurements of sound intensity level before putting the panel sample (incident sound energy) and after putting the panel sample (transmission sound energy), are done using sound level meter. The range of frequency used here are 100 Hz - 5000 Hz.



(a) (b)

Figure 3. (a) Specimen flexible test, (b) Specimen tensile test



Explanation:

1. Loudspeaker
2. Organa Pipe
3. Sound Level Meter
4. Panel Medium
5. Function Generator
6. Box

Figure 4. The diagramof impedance chamber method

Result and Discussion

Speed of Sound in Material

The results of mechanical testing and density measurement can be used to determine the value speed of sound in the material. Speed of sound is calculated using equation 3.

Table 1. Speed of Sound in Material

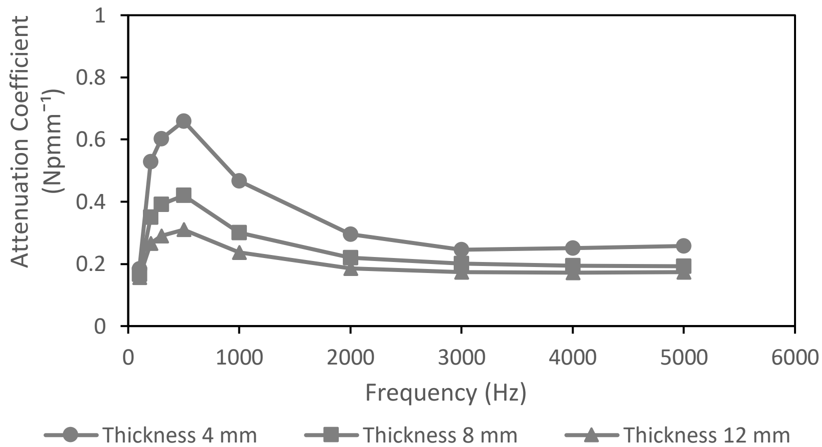
Material	Density (kg/m³)	Modulus of Elastic (Mpa)	Speed of Sound (m/s)	Average Speed of Sound (m/s)
Plywood	402	4901,29	3491,74	3404,36
Plywood	404	4429,09	3311,05	
Plywood	399	4640,40	3410,29	
Calsiboard	1306	11899,83	3018,55	3012,87
Calsiboard	1298	11270,29	2946,66	
Calsiboard	1239	11703,32	3073,39	
Bamboo	342	10340,60	5498,69	5407,49
Bamboo	363	9790,67	5193,41	
Bamboo	352	10765,90	5530,36	

The speed of sound in bamboo is higher than plywood and calsiboard, this is because the density of particles in bamboo is higher than plywood and calsiboard. While the speed of sound in calsiboard is the lowest compared to plywood and bamboo, this is because the calsiboard materials have water content so the density of particles on the calsiboard lower than plywood and bamboo.

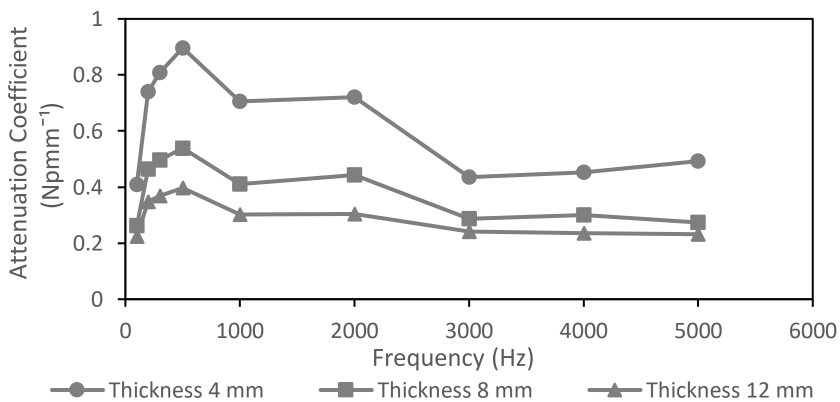
Attenuation Coefficient in Material (α)

The attenuation coefficient of the ceilings acoustic material was calculated using the equation 6.

(a)



(b)



(c)

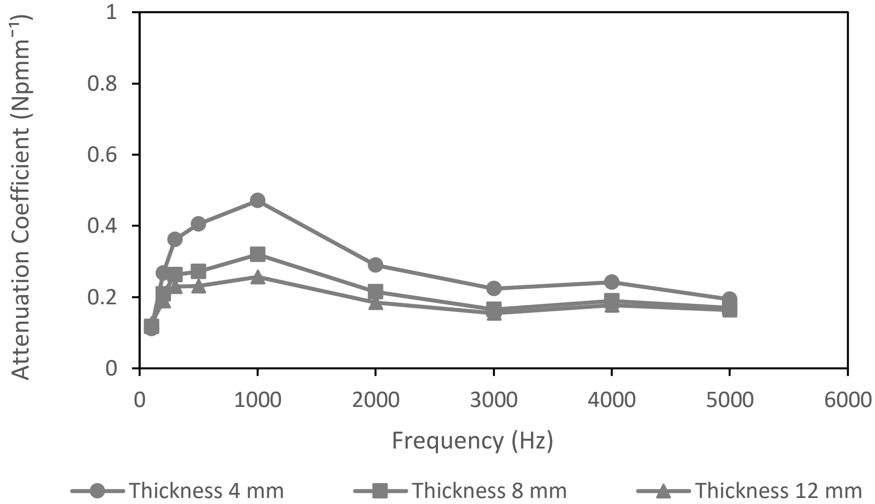


Figure 5. The attenuation coefficient of the ceilings (a) panel plywood, (b) calsiboard, (c) bamboo woven treatment less with the thickness variation

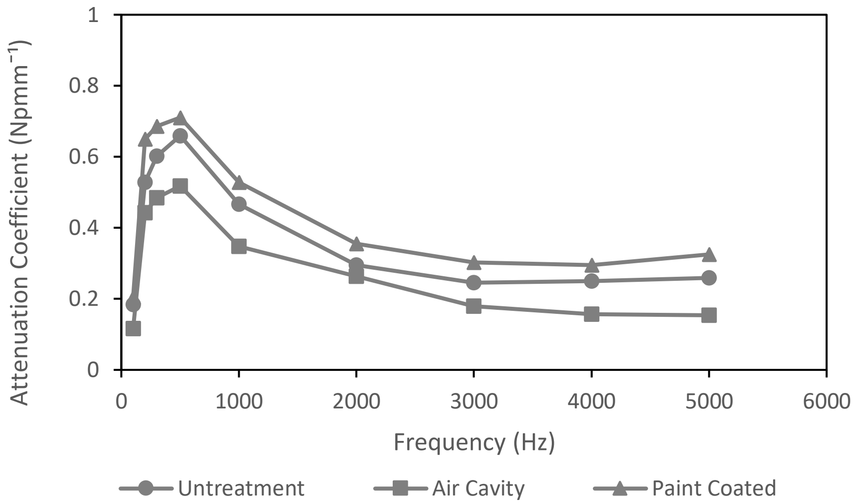
The coefficient attenuation trends to decrease when the thickness increase. This is because when the thickness of material increase, its porosity decreases so the sound pressure and particle velocity on the medium weakened. In plywood material it is seen that the coefficient attenuation has increased at low frequency (0-500 Hz) soiIt is possible for plywood to reduce well at low frequency. At frequency above 500 Hz the attenuation coefficient decrease. This is because the plywood is not good to muffle at high frequency. The average attenuation coefficient in plywood is 0,37 Npmm^{-1}. On calsiboard it can be seen that the attenuation coefficient has more increased than plywood. This is because calsiboard material can muffle the sound energy. The average attenuation coefficient in calsiboard is 0,62 Npmm^{-1}. In bamboo woven, the attenuation coefficient of material increase in frequency range 100 - 1000 Hz. This is possible because the frequency is the natural frequency of the bamboo so it is good to muffle at that frequency on high-intensity level. The average attenuation coefficient bamboo woven is 0,28 Npmm^{-1}. Meanwhile for attenuation coefficient on the three ceilings with the paint coated and the addition treatment of air cavity are shown in Figure 6.

In these ceilings, the paint coated will increase the attenuation coefficient at all frequency. This is because paint coated can increase the mass and reduce transmission sound energy in chamber. In the addition of air cavity, the attenuation coefficient decreased. This is because the addition of air cavity will cause the sound energy to resonance so that the intensity of the sound will be larger.

Acoustic Impedance in Material (*Z*)

Based on the calculation using equation 8 to obtain the acoustic impedance, it is found the higher frequency, the acoustic impedance is lower. This is because the high frequency will cause the energy loss in the chamber. The acoustic impedance of the ceilings with thickness variation untreated has the same value, shown in Figure 7.

(a)



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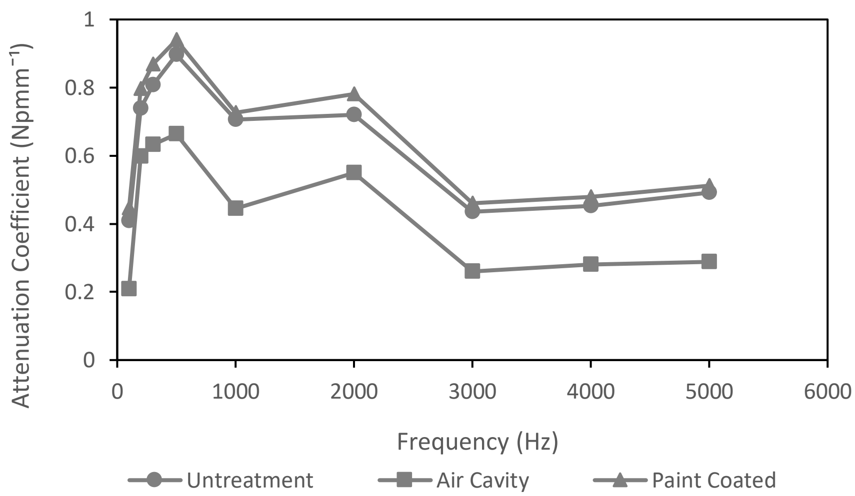

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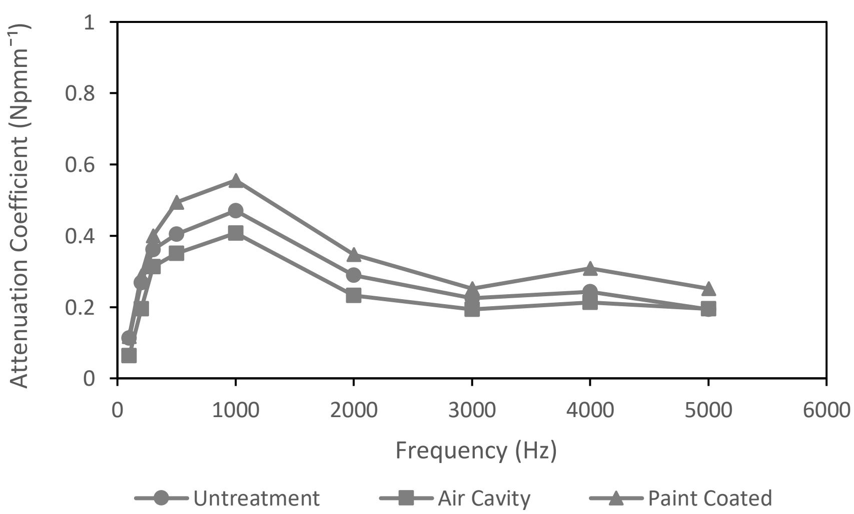


Figure6. The attenuation coefficient of ceilings panel (a) plywood, (b) calsiboard, (c) bamboo woven with addition treatment paint coated and air cavity

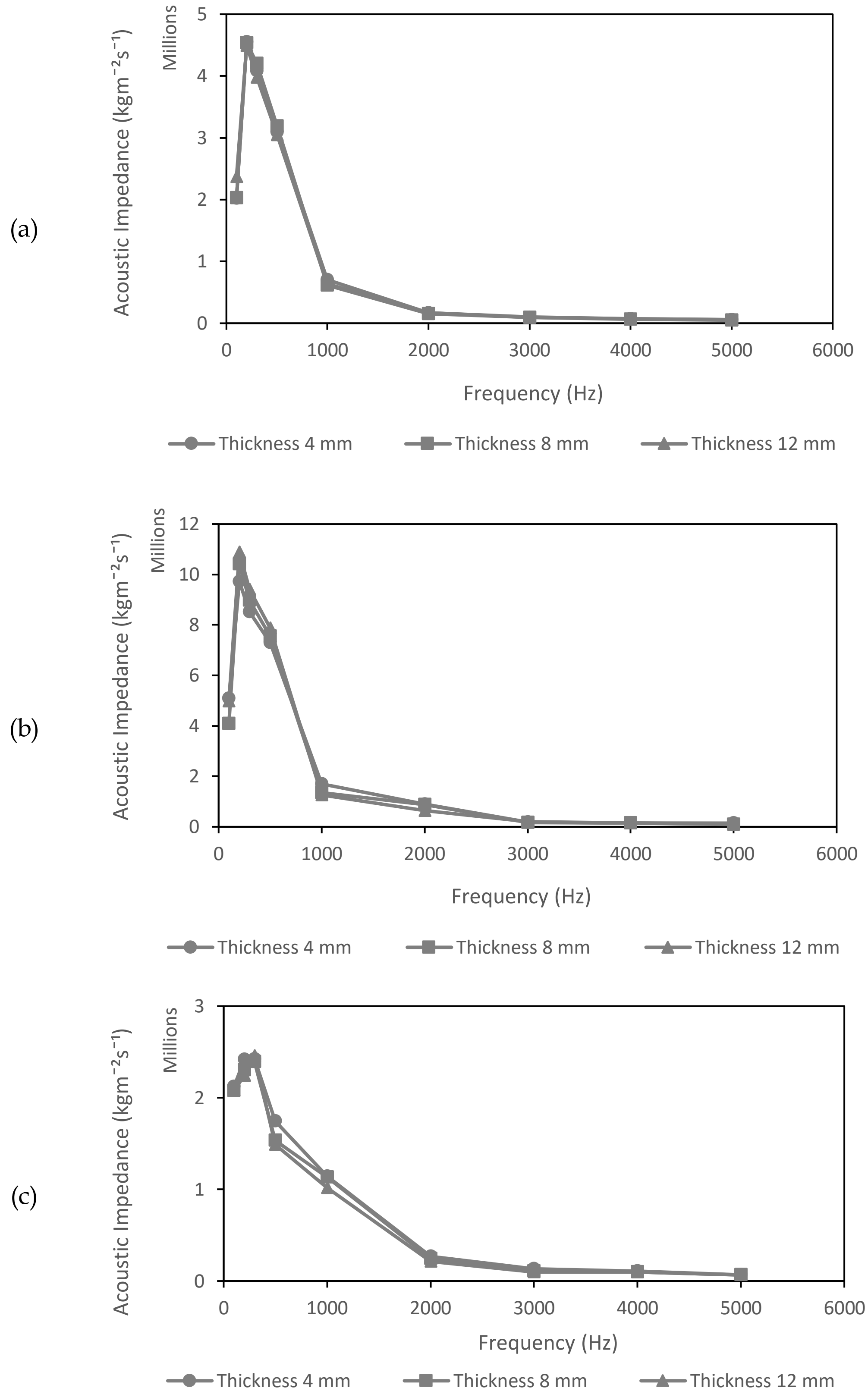
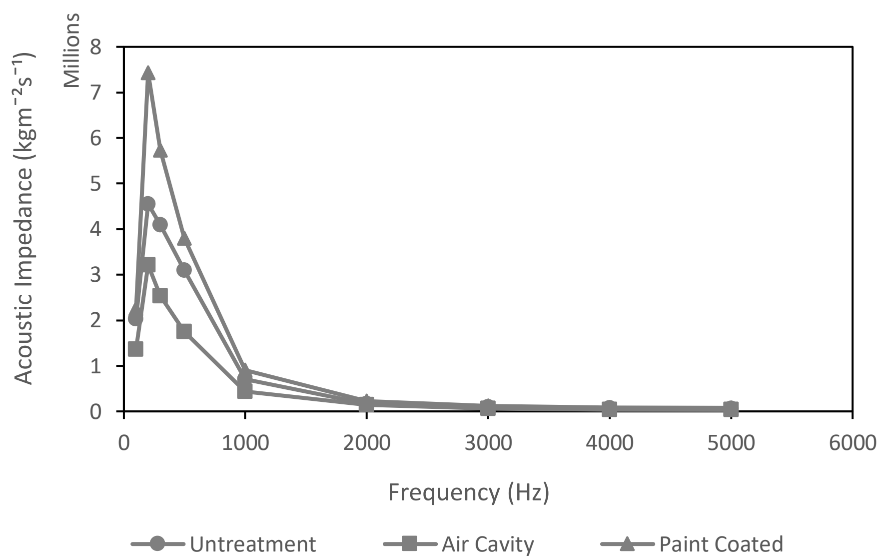


Figure7. The acoustic impedance of ceilings panel (a) plywood, (b) calsiboard, (c) bamboo woven treatment less with the thickness variation

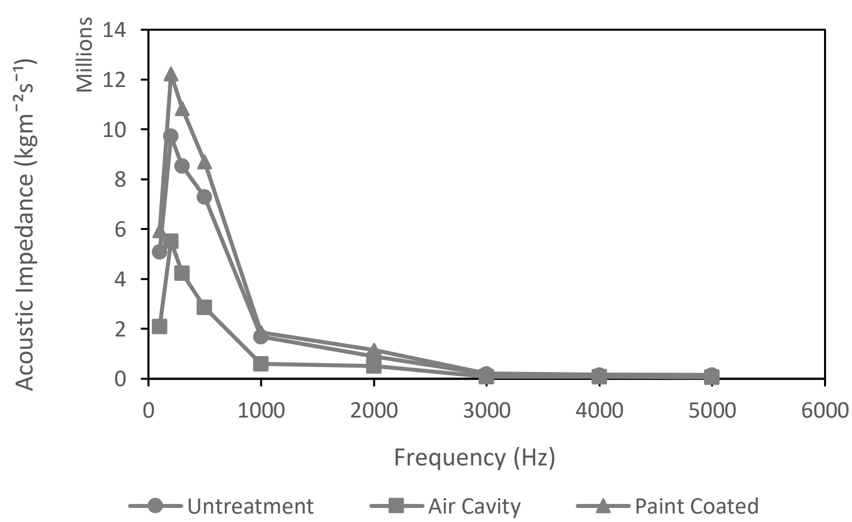
In the ceilings with thickness 4 mm, 8 mm and 12 mm, the acoustic impedance tends to be the same. This is because it is the same material. The acoustic impedance has no effect when the constituent material is same so that the thickness not influences the acoustic impedance. The average of acoustic impedance in the plywood, calsiboard and bamboo woven are 1,33 x 10^{-6} $kgm^{-2}s^{-1}$, 3,74 x 10^{-6} $kgm^{-2}s^{-1}$ and 1,15 x 10^{-6} $kgm^{-2}s^{-1}$ respectively.

In the paint coated, it is seen that the acoustic impedance has increased in all test materials. This is because the paint coated will cover the rift and increase the density of the material so that the intensity decreases in the chamber. In addition of air cavity, we obtained the acoustic impedance is decreases. This is because the transmission intensity is increased compared to treatment less of the ceilings panel and also the acoustic impedance in the panel's mixes with the air acoustic impedance. The acoustic impedance of the density type is very importantto the acoustic impedance. The acoustic impedance affects the sound intensity and proportional to the density of a material. The large the density of a material, the acoustic impedance tends to be large as well.

(a)



(b)



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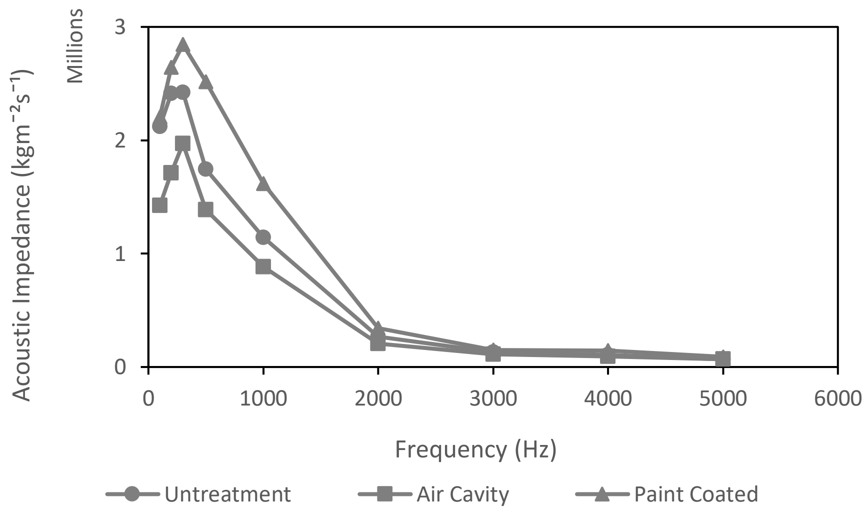

Figure8. The acoustic impedance of ceilings panel (a) plywood, (b) calsiboard, (c) bamboo woven with addition treatment paint coated and air cavity

Conclusion

Based on the research used impedance chamber method with range of frequency are 100 Hz – 5000 Hz, acoustic material of ceilings panel are plywood, calsiboard and bamboo woven. The attenuation coefficient decreased with the increasing thickness of the panel. The same trend is found in the acoustic impedance. Meanwhile, the paint coated can increase attenuation coefficient and acoustic impedance. For the cavity increment ceiling panel, the attenuation coefficient and acoustic impedance are less than the solid panel.

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