

# ACOUSTIC WALL PANELS CONSTRUCTED FROM PADDY-STRAWS

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**Abstract:** *In the concern of global warming and energy crisis issues, the use of disposal material such as paddy-straws is encouraged. A series of experimental study has been conducted to seek a possibility in using paddy-straws -disposed materials of paddy field- to be constructed as wall panels. The study comprised of seeking suitable characteristics of paddy-straws for panel lamination, structural test and acoustical test. At the first stage, it is reported that for the best lamination, straws must be the cross-fertilization paddy, in medium softness condition, clean, slightly moisturized, and sprayed with an exact proportion of powdered adhesive, i.e. Portland cement. At the second stage, the panels were tested for compression strength (CS) and the best mixture provided CS of 15 N/mm<sup>2</sup>, which met the standard for non-structural component. At the last stage, the panels went through acoustic laboratory test, which indicated Transmission Loss (TL) of 10.4 dB as the minimum, refers to centre band frequency of 500 Hz.*

**Keywords:** *paddy-straws, acoustic wall-panels, compression strength, transmission loss*

**Abstrak:** *Di tengah munculnya persoalan pemanasan global dan krisis energi, penggunaan material limbah seperti jerami padi adalah hal yang positif. Serangkaian penelitian dilaksanakan untuk melihat kemungkinan penggunaan jerami padi sebagai bahan baku panel dinding akustik. Penelitian ini terdiri dari tahap penemuan karakteristik jerami yang sesuai untuk mencapai proses laminasi terbaik, pengujian kekuatan, dan pengujian akustik. Pada tahap awal dilaporkan bahwa jenis jerami terbaik untuk proses laminasi adalah jerami padi varietas persilangan, yang berada dalam kondisi lunak sedang, bersih, sedikit lembab, dan dicampurkan dengan semen sebagai bahan pengikat. Pada tahap selanjutnya, hasil pengujian desak menunjukkan kekuatan sebesar 15 N/mm<sup>2</sup> yang mampu dicapai oleh campuran terbaik. Angka ini sesuai dengan acuan material yang tidak bersifat struktural. Sementara pada pengujian akustik, teruji bahwa panel dinding dimaksud memiliki TL minimum 10,4 dB, mengacu pada frekuensi tengahan 500 Hz.*

**Kata kunci:** *jerami padi, panel akustik, kuat desak, transmission loss*

Environmental noise pollution which is predominantly caused by increment of traffic noise has put building inhabitants as 'noise victims', as it commonly happens in Indonesian major cities. In this case, the use of high quality building materials with high sound insulation is important. However, lack of knowledge about noise impact on daily life and low financial support has put most Indonesians to employ ordinary building materials with low sound insulation. Wall panels proposed in this study is designed to improve insulation capability of building elements commonly used. Element that is readily exposed to noise is wall compares to floor and ceiling/roof. Thus, acoustic materials attached to the main wall or

corresponding wall have to be able to eliminate intrusion of outdoor traffic noise. High quality acoustic walling is costly, which is almost impossible to be applied on low-cost building. An early study in constructing low-cost walling materials with moderate acoustic quality is reported here.

A selection of low cost raw materials for wall panels that meet the theory of insulation has been carried out. The selection comes to paddy-straw which is considered as a very potential raw material. The potency is laid on the air cavities of the straw, which naturally creates air gaps within material when constructed as panels. The presence of air gaps could also meets the theory of wave-

refraction, i.e. sound intrusion is reduced when refraction is maximized. In common walls construction, this is provided by adding air gaps between two or more material layers (refer to Figure 1).

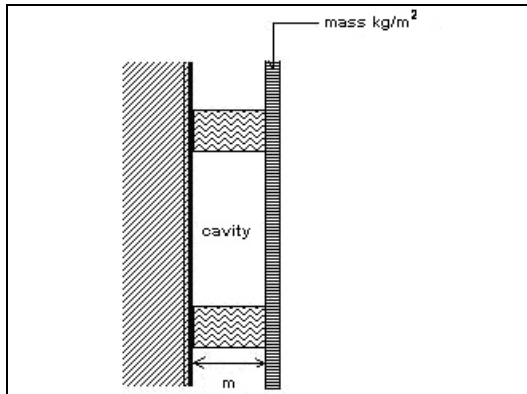


Figure 1. Ordinary wall panel with air gap for better sound insulation.

Source: Private collection

In Indonesian villages, paddy-straw; disposed materials of paddy field; is commonly used for cattle food-supply. In fact, in more developed countries, straw have been utilized for building materials. However, concerning climatic issues in warm humid regions, it is considered rather impossible to use paddy-straw in its natural condition since the climate will easily decompose it and thus becoming non-durable material. But, this is not the case of temperate climates, where straw can be constructed as straw bales in its natural condition [1].

Another challenge in using paddy-straw is the limitation on information and technology among most Indonesian people, which are usually questioning its strength, durability and performance of using such traditional and low-cost materials. Thus at

this stage, the panels will only be constructed for a non-structural material which is attached to main material, i.e. wall. The attachment is aimed to improve insulation values of ordinary walls, which in Indonesia are mostly grey bricks (less dense concretes) and red bricks (less dense compared to red bricks utilized in developed countries). Beside consideration of cost and potency, using paddy-straw will also benefits in earth sustainability by recycling disposed materials, in concern of global warming and energy crisis issues.

## METHODS

### Theoretical Approach

An ideal insulator must comply with aspect of mass/density, thickness, and homogeneity [2]. A higher mass/density, thicker, and more homogenous material with no holes and crack provides better sound insulation. Aspect of material thickness is not always provided by the material itself, but can be substituted by the presence of air gap between material layers. Many research concluded that air gap between layers will increase sound insulation capability of materials more than the thickness of material itself [3]. This is caused by effect of refraction, i.e. bending of sound wave motion while entering materials with different densities (Fig.2). The more bending on sound wave motion, the more energy of sound is reduced, thus less energy will be transmitted through the materials. Air gaps which are naturally existed within paddy-straw are the main aspect when considering straw as raw material for acoustic wall-panels.

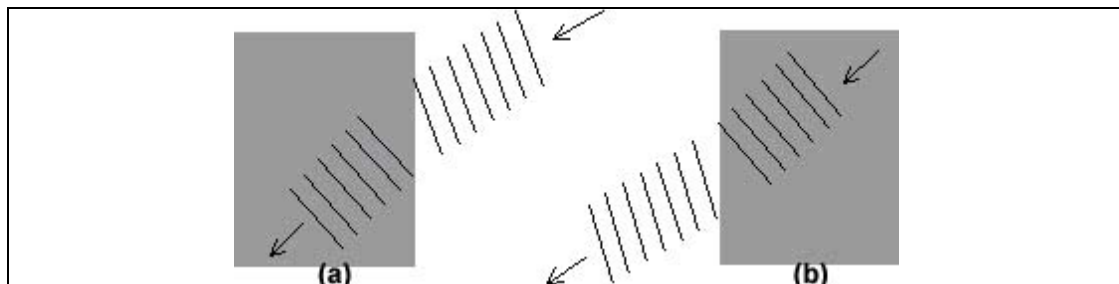


Figure 2. Sound wave refraction, bending downward while entering denser material and bending upward while entering less dense material. Air gap will maximise refraction.

Source: Private collection

### **Pre-Experiment of Straw Characteristics**

Prior to the main experiment, a series of pre-experiment has been conducted, i.e. experiment to seek the most suitable straw characteristic to go into panel lamination and experiment to seek effective proportion of adhesive substance for panel lamination. The experiments use trial and error approach.

There is vast variety of paddy plantations. Referring to the origin, it is grouped into two-major, i.e. local paddy and cross-fertilization paddy. According to field conditions, it is also grouped into two-major, i.e. planted in more watering field and less watering field. Whilst according to rice characteristics, it is grouped into two-major, i.e. ordinary non-sticky rice and sticky rice [4]. All these types of paddy-straw went into pre-lamination process and mixed with adhesive substances. This process indicated that local paddy-straw is too soft, thus easily losing air gaps while being pressed during lamination. Whilst, cross-fertilization paddy-straw is capable to maintain the air gap and thus resulting panels as expected. The less watering paddy is too hard to be laminated thus resulting untidy and fragile panels. This is also the case of sticky rice straw. This pre-experiment concluded that cross-fertilization paddy-straws (which is in coincidence found by more watering and in non sticky rice) performed better as raw material to construct wall panels compared to the rest type of paddy-straw. Prior to lamination process the straw has to be cleaned by water and then dried under the sun in order to kill germs and fungus.

### **Pre-Experiment of Lamination Process**

At second stage, pre-experiment for lamination process was carried out. In response to climatic issues and ease of utilization, paddy-straw is not used as the way it used to before. The straws have to be bounded together with adhesive substances, formed in a panel shape. This process is defined as lamination. The aim of lamination is to bound straws together in form of a panel in order to comply with structural laboratory test and to improve durability. There is a vast variety of adhesive substance in the market,

grouped as natural and synthetic adhesive, but whilst the aim of composing paddy-straw panels is to provide low-price materials, the use of high cost adhesive will be neglected. A moderate price adhesive substance for building construction widely available is Portland cement powder and gypsum powder. While using this type of adhesive, a proportion of water has to be measured carefully prior to mixing process.

There is no such standard of compression strength (CS) when the panel is not use as structural component. In this early research, the panel is aimed only as additional wall layer attached to the main wall construction, thus it is a non-structural element. The CS test conducted is merely aimed to see capability of the panels to carry and maintain its own weight, i.e. for packaging, transporting, up to application as a construction material. However, we use the standard of General Regulation of Concrete Construction in Indonesia (*Peraturan Umum Beton Indonesia tahun 1982*) as a comparison.

Lamination process has to be simple and effective in order to meet lower production cost, and later to be easily carried out by most farmers in their spare-time between planting season. Lamination tray and lid constructed from wood and plywood were used to produce the panels into custom size as it is in the market. Inner dimension of the tray (dimension of the laminated panel), is 30 cm x 60 cm, with two different thickness variant, i.e. 2 cm and 3 cm. During the lamination process, along border-side and on the centre of the tray, a compression of 120 N was employed to produce uniformity in panel thickness. Lamination in panel shape was prepared for tensile strength (TS) test. For CS test, the straws had to be laminated in cylindrical shape (after Standard of Compression Strength Test for Concrete). Lamination in cylindrical shape was conducted first since CS test is run at first stage.

Prior to lamination, critical characteristic of paddy-straw was scrutinized. This study indicated when straws are dry; the panels are very fragile, because the usage of

adhesive (i.e. cement or gypsum) might not fully-attached to the straw. It also indicated that when adhesive is in emulsion matter (blended with a proportion of water), the constructed panel is much too heavy. This will cause difficulty when being attached to the main wall and produces cracks afterward. Finally, the experiment delivered information on the best characteristic of individual element to produce the best mixture for lamination, i.e. the straws should be slightly moisturized (within particular water composition as presented in Table 1), the adhesive powder should also be in particular composition to the straws (presented in Table 1), which then be sprayed on to the moisturized straws. Once the mixture is even, it is poured into cylindrical casing or lamination tray for 2 x 24 hours and dried under direct sunlight (approximately 14 days to be fully dried and ready for use). A full dryness is important to minimize the presence of fungus that will decompose straws and decrease panel performance. Drying the panel out of direct sunlight is also important to avoid sudden drying that will cause fragileness.

## EXPERIMENTAL STAGES

### Structural Experiment

The main experiment of paddy-straw lamination for structural test was conducted

after the pre-experiments. There are fix and flexible variables determined in this experiment. The fix variable is the characteristic of straws, which is only straw from cross-fertilization paddy being used.

Whilst, the flexible are:

- Straw length, i.e. as it is in natural conditions (approx. 40 cm), cut in 30 length cm and 20 cm length.
- Adhesive substance, i.e. Portland cement powder and gypsum powder + alcasit. Alcasit is an additive substance to improve adhesive capability of gypsum. It is taken into account due to low adhesive capability of gypsum.
- Element proportion or ratio of volume among straw: adhesive substance: water, i.e. 3:1:1.5 / 3:1:2 / 3:1:2.5

Each mixture was laminated three times to produce sufficient specimen for the accuracy of structural test. As shown on Table 1, 81 combination specimens were tested. They were laminated in cylindrical shape of 10 cm diameter and 20 cm height to comply with National Standard of Compression Strength Test for Concrete (*Standar Pengujian Kuat Tekan/Desak Beton SK SNI M-62-1990-03*) and be tested in Bahan Konstruksi Teknik (BKT) Lab of Atma Jaya Yogyakarta University.



Figure 3. A cylindrical specimen went through compression strength (CS) test, using Universal Testing Machine for Load Factor (Shimadzu UMH-30).  
Source: Private collections

Table 1. Result of Compression Strength (CS) Test

Sample Number	Mixture Composition	Diameter (cm)	Height (cm)	Load (kgf)	Compression (N/mm <sup>2</sup> )	Averages (N/mm <sup>2</sup> )
1a	Natural straw, cement powder, water Volume ratio 3:1:1.5	10.5	20	14700	16.60	14.82
1b		10.5	20	0	0.00	
1c		10.5	20	11500	13.04	
2a	Natural straw, cement powder, water Volume ratio 3:1:2	10.4	20.3	7750	8.95	9.86
2b		10.4	19.8	0	0.00	
2c		10.5	19.9	9500	10.77	
3a	Natural straw, cement powder, water Volume ratio 3:1:2.5	10.5	20	8525	9.66	10.24
3b		10.5	20.2	9125	10.34	
3c		10.5	19.3	9450	10.71	
4a	Straw cut in 20 cm length, cement powder, water Volume ratio 3:1:1.5	10.6	20	4870	5.42	9.48
4b		10.7	20	8600	9.38	
4c		10.6	20	12275	13.65	
5a	Straw cut in 20 cm length, cement powder, water Volume ratio 3:1:2	10.4	19.9	4900	5.66	6.67
5b		10.2	20.7	7150	8.59	
5c		10.2	20.3	4800	5.77	
6a	Straw cut in 20 cm length, cement powder, water Volume ratio 3:1:2.5	10.3	20.3	3100	3.65	2.91
6b		10.6	20.6	2250	2.50	
6c		10.1	20.6	2100	2.57	
7a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:1.5	10.5	20	9975	11.31	10.06
7b		10.5	20	8350	9.29	
7c		10.6	20	8625	9.59	
8a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:2	10.5	20.4	440	0.50	3.81
8b		10.6	20.6	4620	5.14	
8c		10.7	20.6	5300	5.79	
9a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:2.5	10.7	20.8	4610	5.23	5.46
9b		10.4	20.8	4740	5.48	
9c		10.5	20.8	5000	5.67	
10a	Natural straw, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:1.5	10.3	20.5	5050	5.95	6.96
10b		10.5	20.5	8050	9.12	
10c		10.4	20.5	5025	5.81	
11a	Natural straw, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2	10.4	20.5	4950	5.72	5.29
11b		10.5	20.5	4900	5.55	
11c		10.5	21	4050	4.60	
12a	Natural straw, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2.5	10.1	20.1	400	0.49	0.45
12b		10.1	19.8	350	0.43	
12c		10	20.1	340	0.42	
13a	Straw cut in 20 cm length, gypsum powder, water Volume ratio 3:1:1.5	10.3	20.7	4800	5.65	5.28
13b		10.6	20.5	4890	5.44	
13c		10.3	20.3	4040	4.76	
14a	Straw cut in 20 cm length, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2	10.2	20.4	1240	1.49	1.56
14b		10.2	19.9	1340	1.61	
14c		10.5	20.6	1400	1.59	
15a	Straw cut in 20 cm length, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2.5	10.5	20.5	320	0.36	0.30
15b		10.2	21	220	0.26	
15c		10	20.5	230	0.29	
16a	Straw cut in 30 cm length, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:1.5	10.5	19.8	920	1.04	0.99
16b		10.1	20.7	940	1.15	
16c		10.6	20.5	710	0.79	
17a	Straw cut in 30 cm length, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2	10.4	21.4	310	0.36	0.44
17b		10.2	21.1	520	0.62	
17c		10.6	21.6	300	0.33	
18a	Straw cut in 30 cm length, gypsum powder, water (+alcahit 2.5 ml). Volume ratio 3:1:2.5	10.3	21.5	300	0.35	0.28
18b		10.3	20.7	310	0.36	
18c		10.2	21.7	120	0.14	

19a	Natural straw, gypsum powder, water (+alcasit 5 ml).	10.5	19.5	4600	5.21	5.99
19b	Volume ratio 3:1:1.5	10.5	19.7	4950	5.61	
19c		9.9	20.5	5600	7.14	
20a	Natural straw, gypsum powder, water (+alcasit 5 ml).	10.4	20.5	4560	5.27	5.18
20b	Volume ratio 3:1:2	10.3	20.3	4720	5.56	
20c		10.4	20.2	4060	4.70	
21a	Natural straw, gypsum powder, water + air (+alcasit 5 ml).	10.3	20.3	4620	5.44	5.60
21b	Volume ratio 3:1:2.5	10.4	21.2	4940	5.71	
21c		10.1	21.1	4600	5.64	
22a	Straw cut in 20 cm length, gypsum powder, water (+alcasit 5 ml).	10.2	20.4	4600	5.53	5.20
22b	Volume ratio 3:1:1.5	10.4	20.5	4150	4.80	
22c		10.4	20.5	4560	5.27	
23a	Straw cut in 20 cm length, gypsum powder, water (+alcasit 5 ml).	10.5	20.6	1170	1.33	1.36
23b	Volume ratio 3:1:2	10.6	20.5	1230	1.37	
23c		10.5	20.2	1120	1.38	
24a	Straw cut in 20 cm length, gypsum powder, water (+alcasit 5 ml).	10.6	20.8	430	0.48	0.46
24b	Volume ratio 3:1:2.5	10.3	20.5	300	0.35	
24c		10	20.7	440	0.55	
25a	Straw cut in 30 cm length, gypsum powder, water (+alcasit 5 ml).	10.4	21.4	4100	4.74	4.73
25b	Volume ratio 3:1:1.5	10.4	21.4	4210	4.86	
25c		10.3	21.8	3900	4.59	
26a	Straw cut in 30 cm length, gypsum powder, water (+alcasit 5 ml).	10.5	21.4	120	0.14	0.18
26b	Volume ratio 3:1:2	10.5	20.9	210	0.24	
26c		10.7	21	150	0.16	
27a	Straw cut in 30 cm length, gypsum powder, water (+alcasit 5 ml).	10.2	20.9	90	0.11	0.12
27b	Volume ratio 3:1:2.5	10.4	20.5	120	0.14	
27c		10.7	20.2	100	0.11	

Source: BKT lab test No. 76/L.BKT/ FT UAJY/IX/2006

### Result and Discussion of Structural Experiment

In Table 1, the compression strength (CS) is calculated using equation below:

$$CS = \frac{load \times 9,81N}{diameter} \dots\dots\dots(1)$$

As an example, we take sample 1a:

$$CS = \frac{14700 \times 9,81}{(5,25)^2 \times 3,14} = \frac{144207}{86,5.10^2} = 16,60 \text{ N/mm}^2$$

By studying Table 1, narrowed to adhesive substance point of view, there is indication that mixtures of paddy-straw and Portland cement generally produce better CS than those by gypsum. Narrowed to water proportion point of view, there is also indication that mixtures of less water produce greater CS than those by more water. However, it was investigated that there is no

CS closed to the standard of ordinary walling material used in Indonesia, i.e. grey bricks (less dense concretes, locally named *batako*) 20 N/mm<sup>2</sup> and red bricks (less dense compared to those used in developed countries) 25 N/mm<sup>2</sup>. The greatest CS from this test is approximately 15 N/mm<sup>2</sup> which is considered significant for non-structural elements (again, standard of grey bricks and red bricks are for structural elements). From this experiment, there is no conclusion could be made by the CS test. Therefore, other test was conducted to support the inconclusive, i.e. tensile strength (TS) test. Unfortunately, there is no such standard of TS for both structural and non structural elements. The TS test was carried out merely to seek the best mixture, which could not be fully concluded by CS test. Sample chosen for TS test is number 1, 4, 7 for specimen with Portland cement adhesive and number 19, 22,

25 for gypsum adhesive (after Table 1). This six best specimens are sufficient to represent different types of adhesives. All the six specimens are laminated three times to produce valid TS test. Detailed composition of panels to go for TS is presented in Table 2. Dimension of panels for TS test is 30 cm x 60 cm with thickness of 2 cm.

In Table 2, TS is calculated as follows:

$$TS = \frac{m.y}{I} \dots\dots\dots(2)$$

Where,  $m = \frac{1}{4} PL$

- P = load x 9.81 N
- L = distance between supporting beam used during test (i.e. 380 mm)
- y =  $\frac{1}{2}$  panel thickness, cm
- I =  $\frac{1}{12} bh^3$
- b = panel width, cm
- h = panel height, cm

As an example, we take sample 1a, as follows.:

$$P = 3.89 \text{ kgf} \times 9.81 \text{ N} = 38.161$$

$$L = 40 \text{ cm}$$

$$Y = 10 \text{ mm}$$

$$I = \frac{1}{12} \times 300 \times 20^3 = 200,000 \text{ mm}^2$$

$$m = \frac{1}{4} \times 38.161 \times 380 = 3625.295 \text{ N}$$

$$TS = \frac{3625.295 \times 10}{200,000} = 0.181 \text{ N/mm}^2$$

Table 2 indicates that in general, mixture of paddy-straw with Portland cement

produces greater TS compared to that of gypsum. However, the indication is not clear enough since TS values are varies. Considering this result, further experiment to produce more valid result is of importance. Third test was held to once again see TS values, but at this stage, the experiment would only limited to mixtures with Portland cement, whilst mixtures of with gypsum is temporarily neglected since they generally produce lower CS and TS. In the third test, the panel was also laminated in different thickness, i.e. 2 cm and 3 cm. Two centimeters were considered as the minimum and 3 cm as the maximum thickness. Thinner and thicker panels may fail to maintain its own weight when attached to the wall.

Detail specification of the third test is presented in Table 3, with TS is calculated using equation (2). From Table 3, it can be studied that there is no significant difference in TS between natural straws and cutting straws of 30 cm length. This gives benefit that straws can be used as it is which will reduce the production cost. Laminated panels which produced from natural straws, Portland cement and water in volume ratio of 3:1:1.5 showed to be the most effective panels with highest result of the whole structural test. This type of mixtures was then re-laminated for acoustic test.

Table 2. Result of Tensile Strength (TS) Test Part I

Sample Number	Mixture Composition	Length (cm)	Width (cm)	Thickness (cm)	Load (kgf)	TS (N/mm <sup>2</sup> )	Averages (N/mm <sup>2</sup> )
1a	Natural straw, cement powder, water Volume ratio 3:1:1.5	60	30	2	3.89	0.181	0.18
1b		60	30	2	3.63	0.169	
1c		60	30	2	0	0.000	
2a	Straw cut in 20 cm length, cement powder, water Volume ratio 3:1:1.5	60	30	2	2.3	0.107	0.11
2b		60	30	2	2.12	0.099	
2c		60	30	2	2.88	0.134	
3a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:1.5	60	30	2	8.63	0.402	0.33
3b		60	30	2	5.4	0.252	
3c		60	30	2	6.99	0.326	
4a	Natural straw, gypsum powder, water (+alcasit 5 ml). Volume ratio 3:1:1.5.	60	30	2	2.12	0.099	0.11
4b		60	30	2	2.43	0.113	
4c		60	30	2	2.39	0.111	
5a	Straw cut in 20 cm length, gypsum powder, water (+alcasit 5 ml). Volume ratio 3:1:1.5.	60	30	2	1.15	0.054	0.05
5b		60	30	2	0.97	0.045	
5c		60	30	2	0.97	0.045	
6a	Straw cut in 30 cm length, gypsum powder, water (+alcasit 5 ml). Volume ratio 3:1:1.5.	60	30	2	3.41	0.159	0.21
6b		60	30	2	3.32	0.155	
6c		60	30	2	6.95	0.324	

Source: BKT lab test No. 76/L.BKT/ FT UAJY/IX/2006

Table 3. Result of Tensile Strength Test Part II

Sample Number	Mixture Composition	Length (cm)	Width (cm)	Thickness (cm)	Load (kgf)	TS (N/mm <sup>2</sup> )	Averages (N/mm <sup>2</sup> )
1a	Natural straw, cement powder, water Volume ratio 3:1:1.5	60	30	3	7.3	0.340	0.56
1b		60	30	3	10.4	0.485	
1c		60	30	3	18.38	0.857	
2a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:1.5	60	30	3	12.35	0.576	0.78
2b		60	30	3	22.33	1.041	
2c		60	30	3	15.67	0.730	
3a	Natural straw, cement powder, water Volume ratio 3:1:1.5	60	30	2	8.19	0.382	0.47
3b		60	30	2	10.58	0.493	
3c		60	30	2	11.64	0.543	
4a	Straw cut in 30 cm length, cement powder, water Volume ratio 3:1:1.5	60	30	2	11.73	0.547	0.43
4b		60	30	2	7.61	0.355	
4c		60	30	2	8.23	0.384	

Source: BKT lab test No. 76/L.BKT/ FT UAJY/IX/2006

### Acoustic Experiment Result and Discussion

Final test was a test to investigate acoustic properties of the panels, i.e. insulation capability or Transmission Loss (TL) test. This was carried out after the completion of structural test, which indicates the best mixture of the panels. The experiment was conducted in Acoustic and Vibration Lab of Gadjah Mada University, considering the availability of testing equipments (Fig 4). Panels with composition specified in Table 3 are referred for the

acoustic test. The test result is presented in Table 4 and Fig. 5.

Centered band frequency of 500 Hz is used as reference for other frequency [5] and TL of 10 dB is a minimal to create quieter environment [6]. From Table 4, we found that the panels were capable to increase TL properties of main wall by 10 dB as the lowest (2 cm panel thickness) up to 16 dB as the highest (3 cm panel thickness). The insulation value gradually increases along with the increase of the sound frequency, with exception in frequency of 250 Hz.

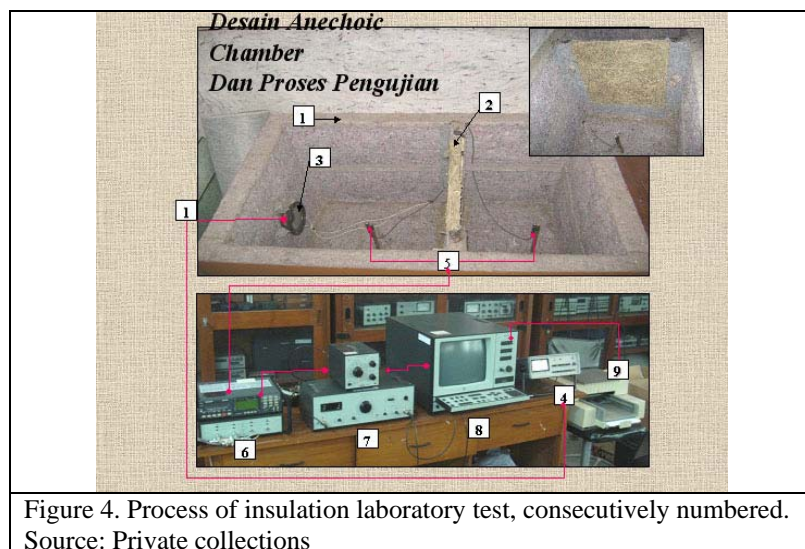


Figure 4. Process of insulation laboratory test, consecutively numbered.  
Source: Private collections



Table 4. Result of Transmission Loss (TL) test

Frequency (Hz)	TL of panels with 2 cm thickness ( dB)	TL of panels with 3 cm thickness ( dB)
63	1.42	2.4
125	11.62	11.62
250	3.16	3.72
500	10.4	16.4
1000	20.1	21.66
2000	29.6	31.26
4000	32.42	35.22
8000	28.56	31.04

Source: Lab test results

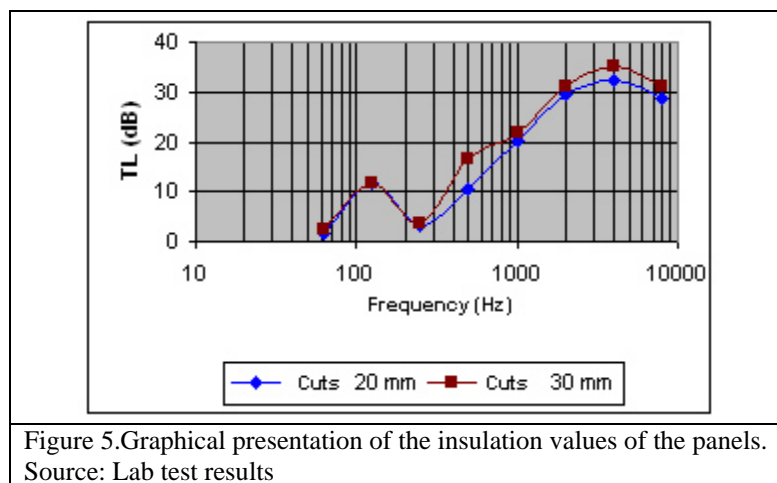


Figure 5. Graphical presentation of the insulation values of the panels.  
Source: Lab test results

## CONCLUSION AND RECOMMENDATION

The study to see the potency in using paddy-straw as main material for wall panels indicates a great possibility in utilizing this disposal material. From structural test, the panels showed CS of up to 15 N/mm<sup>2</sup>, which is considered significant for a non-structural material, whilst from acoustic properties, the panels also showed a significant value of minimum TL of 10 dB. These values are produced by wall panel constructed from paddy-straw mixed with Portland cement powder and water in volume ratio of 3: 1: 1.5, regardless straws in natural condition or cut in 30 cm length. This means that straw can be utilized in its natural condition, which will reduce the production cost.

Further research to produce more qualified panels is recommended, such as a study to seek possibility in using fungicide (to kill germ and fungus that will lower panel

durability) without distracting its CS value. During the experiment, it is found that fungus is easily present when the proportion of water is more than 1.5 and when the drying process is incomplete. Further research to conduct more accurate laboratory test both structural and acoustic is also recommended.

## ACKNOWLEDGEMENT

The author is in great debt to DIKTI, Indonesia, which had provided full funding for this research to be conducted using Hibah Bersaing 2006-2007 Scheme. The author would also express a deep gratitude to Architecture Technology and BKT Laboratories of Atma Jaya Yogyakarta University, and Acoustic and Vibration Laboratory of Gadjah Mada University, which had given full access for the author to use their facilities.

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