Preliminary Investigation on Tiger Grass Pollen as an Alternative Insulation Board Material

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Abstract

Tiger Grass (Thysanolaena maxima) pollen is disregarded as a valuable agricultural waste; thus this study investigates its potential and beneficial uses as an alternative building insulation material with arrowroot starch as binder. Samples were prepared with the following mix proportions. Mixture A: 250 grams - tiger grass pollen and 100 grams - arrowroot starch which is equivalent to 40% of the tiger grass pollen weight. Mixture B: 250 grams - tiger grass pollen and 125 grams - arrowroot starch which is equivalent to 50% of the tiger grass pollen weight. Mixture C: 250 grams - tiger grass pollen with 150 grams - arrowroot starch which is equivalent to 60% of the tiger grass pollen weight. The samples were air-dried for 10 days. The thickness of the particleboards ranges from 8 mm to 10 mm. Based on the tests conducted for acoustic properties, thickness swelling, water absorption, and thermal conductivity, Mixtures B and C demonstrated acceptable results having met the allowable limit values.

Keywords: Tiger Grass pollen, insulation material, particle board, arrowroot starch, building insulation

Introduction

Tiger grass (*Thysanolaena Maxima*) is one of the most commonly cultivated grasses locally grown in the Philippines and it looks similar to bamboo and sugarcane. Tiger grass has a variety of uses and it plays a valuable role as the main material for broom production. The bamboo-like stalks make strong handles and the dried flower panicles are tied together to make the broom parts. The fibers (panicles) of this plant are already proved its importance and life span because it is being used in handicraft production that is why this fiber performs certain strength that could resist loads applied into it.

One of the most important challenges of future buildings is the reduction of energy consumptions in all their life phases - from construction to demolition. Through that, building insulations were developed and commonly realized using materials obtained from petrochemicals (mainly polystyrene) or from natural sources processed with high energy consumptions (glass and rock wools). These materials cause significant detrimental effects on the environment mainly due to the production stage like use of non-renewable materials and fossil energy consumption, and to the disposal stage like problems in reusing or recycling the products at the end of their lives.

Due to other problems brought about by climate change, the use of thermal insulation materials sustain the comfortable temperatures in living environments or in building which became rampant in recent years. The use of thermal insulation is regarded as one of the most energy-efficient improvements and means of energy conservation in buildings. As the largest building component, it plays an important role in achieving buildings' energy efficiency. This will result in decreasing the cost of cooling as well as decreasing the pollution of the environment. Talking about energy consumption, both commercial and residential buildings spent almost half of primary energy resources and trend to increase in the future.

Review of Related Literature

Particleboards are relatively new type of engineered wood product that are made from gluing together small chips, sawdust, saw shavings, recycled wood, agricultural residue, etc. Particleboard is a wood-based composite that is used for many applications such as furniture, flooring, panels and the likes (Khosravi, 2011). Particleboards consist of wood particles glued together at high temperature and pressure. The particles are separated based on size after they have been dried, the sizes of the particles are of great importance and will influence the properties of the final product. Normally, particleboards have three layers namely (a) core layer with coarser particles and a lower density, and (b) two surface layers with finer particles and higher densities. The Australian Standard (AS/NZS 1859) gives limit values for certain mechanical and physical properties (EWPAA, 2008). Table 1 shows the typical values of these properties (rather than limit values) presented in 3 thickness classes.

Table 1. Typical Property Values for Standard Particleboard (Source: EWPAA, 2008)

Property	**Units**	**Thickness Class - mm**		
		<=12	**13 - 22**	**>23**
Density	kg/m^3	660 - 700	660 - 680	600 - 660
Bending Strength (MOR)	MPa	18	15	14
Bending Stiffness (MOE)	MPa	2800	2600	2400
Internal Bond Strength	MPa	0.6	0.45	0.40
Surface Soundness	MPa	1.25	1.30	1.30
Screw Holding - Face	N	-	600	700
Screw Holding - Edge	N	-	700	750
Thickness Swell (24 Hr)	%	15	12	8
Formaldehyde E1 (Desiccator Method)*	mg/l	1.0 –1.5	1.0 –1.5	1.0 –1.5

Related Studies

Many research studies have experimented various alternative materials from agricultural wastes with emphasis on finding new materials for acoustic component panels and insulation particleboards (Faustino et al, 2012; Paiva et al, Charoenvai et al, 2013; Asrubali, D'Alessandro & Schiavoni, 2015; Acol et al, 2015; Tangjuank & Kumfu, 2011; Aguila et al, 2015; Suleiman et al, 2013; and Ismail, 2012). These new alternative sustainable sound insulation building products have been at the center of society's concerns. For example, sound insulation products processed with natural materials such as cotton, cellulose, hemp, wool, clay, jute, sisal, kenaf, feather and coco or processed with recycles materials like wood, canvas, foam, bottle, jeans, rubber, polyester, acrylic, fiberglass, carpet and cork are some solutions already established for sound insulation. Some other residual wastes such as newspaper, honeycomb, are polymeric waste were also tested to determine their technical potential. Thus, these green products or eco-products intend to be sustainable alternative to the traditional ones like glass or rock wool (Faustino et al, 2012). Particleboards made of agricultural wastes such as bagasse, cereal, straw, corn stalk, corn cobs, cotton stalks, rice husk, straws, sunflower hulls and leaves oil were also tested for thermal insulation performance (Paiva et al, 2012). The main goal of using these agricultural wastes, aside from meeting the challenges of disposing such wastes, is to identify energy-saving building materials with low thermal conductivity so as to reduce heat transfer into the building (Charoenvai, 2013). In addition, previous studies compared these unconventional and recycled insulation materials based on several properties such as density, thermal conductivity, specific heat, fire classification, and water vapor diffusion (Asrubali, D'Alessandro & Schiavoni, 2015). Moreover, other properties such as acoustic absorption, acoustic insulation, including thickness were evaluated. Tests were also carried out to determine the physical properties (moisture content, thickness swelling and water absorption) and fire resistance of these alternative waste materials [(Tangjuank et al, 2011). Previous studies also evaluated not only the composition of the main alternative waste materials but also the type of binding ingredient or adhesive used Charoenvai et al, 2013; Acol et al, 2015; Tangjuank & Kumfu, 2011; Suleiman et al, 2013; Mouburik et al, 2010; Sulaiman et al, 2013; Elbadawi et al, 2015; and Abayomi et al, 2015). The type of bonding materials, particularly biodegradable and environmentally-friendly binders are important to produce structurally strong, stable, and durable particleboards.

Objectives

This study was conducted to be able to produce an economical and profit-oriented product. This study also aimed to produce durable particleboard as insulation materials for structural applications from locally source materials by using tiger grass pollen in conjunction with different natural binders. This is in effort to reduce the rate of importation of synthetic fibers and make locally made building materials available at a cheaper rate.

Materials and Method

Mix Proportion

Table 2 shows the three mix proportions used in the study. Every sample mixture has three samples indicating the amount (in grams) of the Tiger Grass pollen, arrowroot starch as binder, and water as the main ingredients for the mix.

Table 2. Mixing Proportion of the Particleboard

Mixture	No. of Sample	Amount of the Tiger Grass Pollen(g)	Amount of Arrowroot Starch(g)	Amount of Water Used for Binder
Mixture A	Sample 1	250	100	1 ½ cup
	Sample 2	250	100	1 ½ cup
	Sample 3	250	100	1 ½ cup
Mixture B	Sample 1	250	125	1 ¾ cup
	Sample 2	250	125	1 ¾ cup
	Sample 3	250	125	1 ¾ cup
Mixture C	Sample 1	250	150	2 cups
	Sample 2	250	150	2 cups
	Sample 3	250	150	2 cups

Testing of Acoustical Properties

a. Fabrication of Testing Chamber - The dimension of the testing chamber is 0.7m x 0.6m for the base and 1.0m for its height with a volume of $0.42m^3$ to accord with the specimen area of $0.09m^2$. The chamber is an enclosed space made of plywood and studs.
b. Placement of Specimen in the Testing Chamber - Install the specimen for each mixture occupying the three faces of the chamber, three specimens for each face.

Determination of Peak Amplitude

Loud speaker is outside the chamber at fixed point for all types of mixture with varying frequency and intensity of sound having the microphone probe inside the chamber. The microphone probe is connected to a magnetic tape recorder for data storage and future measurement or reference. The software used in determining the peak amplitude was Cool Edit Pro which the data are recorded, analyzed and summarized.

Determination of Thickness Swelling, Water Absorption and Thermal Conductivity

The determination of 2-hour water absorption (WA) and thickness swelling (TS) tests were performed according to ASTM D-1037. After 2 hours, the uncoated/natural and coated samples with paint were taken out from the water and reweighed and re-measured for its thickness. The water absorption of each specimen was calculated by the weight difference. The water absorption and thickness swelling of each specimen were prepared with a surface dimension of 0.15m x 0.15m and calculated using Equations 1 and 2.

$$\textbf{Thickness Swelling}(\textbf{TS}) = \frac{t_f - t_i}{t_i} x100\% \qquad (1)$$

Where:

$\mathbf{t_i}$ = initial thickness of the sample

$\mathbf{t_f}$= final thickness of the sample

$$\textbf{Water Absorption }(\textbf{WA}) = \frac{w_f - w_i}{w_i} x100\% \qquad (2)$$

Where:

$\mathbf{w_i}$ = initial weight (dry) of the sample

$\mathbf{w_f}$= final weight (wet) of the sample

The test for thermal conductivity was done in terms of moisture content (MC) and dry density of the samples. To calculate the thermal conductivity of each sample, the formula derived by Siau (1983) was applied (TenWolde et al, 1988). Thermal conductivity is being computed to determine how much electric current or amount of heat the sample can receive before it yields following Equations 3, 4 and 5:

a. Get the moisture content of the sample (MC) with a formula of:

$$MC = \frac{Ww - Wd}{Ww} \text{ x } 100\% \qquad (3)$$

b. Get the dry density of the sample (ρ) with a formula of:

$$\rho = \frac{W_{dry}}{V} \qquad (4)$$

c. Solve for the thermal conductivity (k) with a formula of:

$$\mathbf{k} = 0.509547 - 0.471983(a) \qquad (5)$$

Where:

k = thermal conductivity of the sample

a = Porosity = $\sqrt{(1 - 0.000667D - 0.00001MD}$

M = moisture content of the sample

D = dry density of the sample (kg/m^3)

Results and Discussion

Peak Amplitude Results

Table 3 shows the results of the peak amplitude per mixture. Comparing the result of the three mixtures, Mixture C has the lowest peak amplitude of -15.68 dB which means the intensity of sound being absorbed is low while Mixture A recorded the highest peak amplitude of -14.01 dB which means there's no effect in the intensity of sound being absorbed as it compares to the peak amplitude recorded by the empty room which is -14.08 dB. Mixture B recorded peak amplitude of -15.31 dB.

Table 3. Comparison of Results using Different Mixture

Amplitude Value	Empty Room		Mixture C		Mixture B		Mixture A	
	Left	Right	Left	Right	Left	Right	Left	Right
Min Sample Value:	-7513	-6401	-6336	-5389	-5537	-4713	-7332	-6261
Max Sample Value:	7630	6481	6154	5244	6571	5621	7674	6528
Peak Amplitude (dB)	-12.66	-14.08	-14.27	-15.68	-13.96	-15.31	-12.61	-14.01
Minimum RMS Power dB)	-32.79	-34.19	-33.83	-35.2	-34.89	-36.27	-35.03	-36.39
Maximum RMS Power (dB)	-15.74	-17.13	-21.62	-23.01	-21.51	-22.9	-20.51	-21.9
Average RMS Power (dB)	-24.71	-26.1	-29.4	-30.78	-29.92	-31.3	-28.91	-30.29
Total RMS Power (dB)	-24.26	-25.65	-29.12	-30.5	-29.75	-31.13	-28.59	-29.97
Actual Bit Depth (Bit)	16	16	16	16	16	16	16	16

Thickness Swelling

The determination of two-hour thickness swelling (TS) test was performed according to ASTM D-1037. After two hours, the specimens which are uncoated/natural and coated with paint were taken out of the water for the measurement of its thickness. The thickness of each specimen was calculated by the thickness difference. The thickness swelling of each specimen was prepared with a surface dimension of 0.15m x 0.15m. Table 4 shows the results for the three mixtures, comparing uncoated or natural and coated with paint before and after soaking.

Table 4. Thickness Swelling (TS) of the Uncoated/Natural and Coated with Paint

Thickness Swelling (TS) in Percentage (%)					
Mixture	No. of Samples	Uncoated/ Natural	Coated with Paint	Average	
				Uncoated/ Natural	Coated with Paint
Mixture A	Sample 1	13	38	12	25
	Sample 2	11	33		
	Sample 3	11	0		
Mixture B	Sample 1	11	11	11	11
	Sample 2	11	11		
	Sample 3	11	11		
Mixture C	Sample 1	0	22	3	17
	Sample 2	0	10		
	Sample 3	10	20		

The thickness of the samples that ranges from 8mm to 10 mm subjected for testing were considered as thin particleboard according to Australian Standard (AS/NZS 1859). The thickness of the particleboard under thin category ranges from 0 to 12mm thick. Table 4 shows the thickness swelling of the uncoated/natural and coated with paint samples. The percentage of thickness swelling of the uncoated/natural samples attained a value which ranges from 0% to 13% and did not exceed the maximum percentage of thickness swelling which is 15% according to Australian Standard (AS/NZS 1859). On the other hand, coated with paint samples revealed that only Mixture B samples acquired a percentage of 11% which did not exceed the standard maximum value of thickness swelling.

Water Absorption

The determination of two-hour water absorption (WA) test was performed according to ASTM D-1037. After two hours, the specimens which are uncoated/natural and coated with paint were taken out from the water and reweighed them. The water absorption of each specimen was calculated by the weight difference. The water absorption of each specimen was prepared with a surface dimension of 0.15m x 0.15m.

Table 5. Water Absorption (WA) of the Uncoated/Natural and Coated with Paint

Water Absorption (WA) in Percentage (%)					
Mixture	No. of Samples	Uncoated/ Natural	Coated with Paint	Average	
				Uncoated/ Natural	Coated with Paint
Mixture A	Sample 1	220	153	204	148
	Sample 2	200	122		
	Sample 3	191	169		
Mixture B	Sample 1	100	133	111	119
	Sample 2	100	88		
	Sample 3	133	135		
Mixture C	Sample 1	146	88	140	107
	Sample 2	160	144		
	Sample 3	113	90		

The percentages of water absorption of uncoated/natural and coated with paint samples are shown in Table 5. For uncoated/natural sample, Mixture A showed the highest water absorption of 220% and Mixture B revealed the lowest water absorption of 100%. For samples coated with paint, Mixture A still got the highest water absorption of 169% and Mixture C attained the lowest water absorption of 88%. By getting the average percentages of water absorption for uncoated/natural and coated with paint sample, Mixture B showed the lowest value water absorption of 115% and it is considered as good particleboard.

Thermal Conductivity

The test was done in terms of moisture content (MC) and dry density of the samples. The surface dimension of the sample used was 0.15m x 0.15m. Thermal conductivity is being computed to determine how much electric current or amount of heat the sample can receive before it yields. As shown in Table 6, the calculated value for Mixture C fairly met the AS/NZC 1859 standards (0.075 W/m-K).

Table 6**.** Thermal Conductivity of the Samples

Mixture	No. of Sample	Weight Wet (g)	Weight Dry (g)	Dry Density Kg/m^3	Moisture Content %	Porosity (a)	Thermal Conductivity W/m-K
Mixture A	Sample 1	125	50	277.78	60	0.9026	0.078
	Sample 2	300	75	370.37	75	0.8351	0.111
	Sample 3	137.5	68.75	339.51	50	0.8986	0.080
Mixture B	Sample 1	187.5	75	370.37	60	0.7285	0.1626
	Sample 2	150	75	370.37	50	0.7535	0.1505
	Sample 3	150	75	370.37	50	0.7535	0.1505
Mixture C	Sample 1	150	81.25	401.23	45.83	0.8884	0.085
	Sample 2	137.5	75	333.33	45.45	0.9089	0.075
	Sample 3	162.5	93.75	416.67	42.31	0.8921	0.083

Conclusion and Recommendation

This preliminary investigation was conducted to establish the potentials of Tiger Grass pollen as an alternative building insulation material. Based on the findings, Tiger Grass pollen can replace the synthetic fiber in the production of particleboards. With the tests carried out for acoustic properties, thickness swelling, water absorption, and thermal conductivity, Mixtures B and C, having the proportion of 250g of Tiger Grass pollen and 125g of arrowroot starch as binder, and 250g of Tiger Grass pollen and 150g of arrowroot starch, respectively, showed favorable properties compared with standard particleboard. Thus, it proved that this disregarded agricultural waste combined with arrowroot starch has a promising potential as an environmentally- and eco-friendly substitute for thermal insulation product. To improve its durability and resistance to external factors such heat/fire and fungal, it is recommended to conduct more tests to address these issues before a widespread use of Tiger Grass pollen as the primary ingredient in particleboard production.

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