Technical Paper

Experimental and Theoritical Analysis of Thermal Properties in Zephyr Bamboo Tali (Gigantochloa apus Kurz)

Eksperimental dan Teoritis Analisis Sifat Termal di Zephyr Bambu Tali (*Gigantochloa apus Kurz*)

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Abstract

Specific heat, thermal conductivity and thermal diffusivity of Bamboo panel are usable to support the Programming of Design and Planning in the Structure of the Agricultural Building Construction. The Specific heat of Bamboo's fiber, sheet and panel using the method of mixtures varied from 1.585-2.789 J/gr ^oC, with a mean value of 2.227 J/gr ^oC in the temperature difference range of 9 ± 0.1^oC . It was found it will increase linearly with an increase in the sample temperature. Thermal conductivity values of Bamboo's fiber based on the transient line heat source technique varied from 0.1035 x 10^{-3}-0.1322 x10^{-3} J/ cm^2 sec ^oC in the sample temperature 22 to 30 ^oC on thermal diffusivity of bamboo fiber in 22-30 ^oC was found to be 0.0823 x 10^{-3}J/cm sec^oC. The sorption Isotherm and the water activity in the bamboo's panel is depend on the chemical composition, glue laminated, additive and the porosity. There are related with the absorbing of the water into the bounded water and the diffusivity of the water in and out the panel. The moisture equilibrium range are 7.89 to 19.22% in the control of the circumstances and 11 to 75 % of the environment.relative humidity.

Keywords: *bamboo zephyr, thermal properties, sorption isothermal*

Abstrak

Kapasitas panas jenis, konduktivitas dan difusivitas ernal panel bambu dapat digunakan untuk mendukung Program Desain dan Perencanaan pada Struktur Bangunan dan Gedung dibidang pertanian. Kapasitas panas jenis, pada panel dan papan sera bambu dengan menggunakan metode campuran bervariasi 1,585-2,789 /gr J ^OC, dengan nilai rata-rata 2,227 J/gr ^OC pada rentang perbedaan suhu 9 ± 0.1 ^OC. Ditemukan akan serat bambu yang berbasis pada teknik pemanasan transient bervariasi dari 0,1035 x 10-3-0.1322 x 10-3 J/cm^2 ^OC det pada suhu sampel 22-30 ^OC pada difusivitas termal serat bambu di 22-30 ^OC ditemukan menjadi 0.0823 x 10^{-3} J/cm sec^OC. Penyerapan secara isotermis dan kegiatan aktifitas air pada panel bambu, tergantung pada komposisi kimia, bahan perekat laminasi, aditif dan porositas. Mempunyai kaitan dengan penyerapan air. ke dalam air terikat difusivitas air yang masuk dan keluar panel. Nilai rentang dari keseimbangan kelembaban adalah 7.89 sampai 19.22% dalam pengendalian kondisi lingkungan dari 11 sampai 75% dari kelembaban lingkungan.

Kata Kunci: Bambu angin sepoi-sepoi, sifat termal, Penyerapan Isotermal

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Introduction

Bamboo represent as an agriculture commodity to be used a raw material in the building construction all over in Indonesia. There are several variety of Bamboo to substitute of wood in the field, The famous one is bamboo Tali (Gigantochloa apus Kurz) which have lower prices so the farmer like to use its as several kinds of the bamboo household.

Bambang Sugiarto (2002), using the triplex sheet or "palupuh" bamboo to be a Zephyr board. The board consist of viscous bamboo fiber glued by phenol-formaldehyde or urea formaldehyde. This board are in the straight parallel fiber direction, diametrical moldable, curving and both of it. The advantage of zephyr bamboo panel can be compared to the wood intact log or board are curvature formable as long as needed. Panel made of a small fairish materials

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Table 1. The mechanical and physical board of bamboo Tali (*Gigantochloa apus* Kurz)

No	Item / Compression time (hour	Unit	0.5	1	1.5	2
1.	Improving the composite at zephyr	(%)	9.7	27.52	25.22	17.12
			24.08	33.79	28.6	20.20
2.	Water Infiltration rate at zephyr	Persen	45.43	47.54	53.17	44.37
		(%)	43.28	51.28	48.26	40.75
3.	Glue adhesion firmness	Kg/cm2	9.43	1.492	0.913	3.338
			1.263	0.995	1.54	2.36
4.	Strength firmness fiber //	Kg	29.31	35.48	31.6	30.99
			31.81	22.8	21.01	33.78
	Strength firmness of ⊥	Kg	37.45	38.13	34.44	54.86
			35.66	30.94	36.56	46.90
5.	Modulus of elasticity //	Kg/cm^2	16328	86488	28840	65438
			42412.	64483	27632	34671
	Modulus of elasticity ⊥	Kg/cm^2	7076	14937	6104	8148
			7234	8770	7368	8911
6.	Modulus of rupture //	Kg/cm^2	257.69	474.2	401.7	321.07
			175.98	666.6	247.4	284.9
	Modulus of rupture ⊥	Kg/cm^2	175.9	156.47	150.38	193.9
			149.6	115.95	167.94	203.7

cutting, according to the planning of the construction can be increased the strength and usage, to make an impression of good decorative appearance and. Even panel of zephyr bamboo have the power of equivalent with the class wood 1 and class 2. This matter of course adds the fascination of using the panel zephyr bamboo product.

To set up box machine to cool and refrigerate fresh fish will be influenced by choosing the wall of coagulation room. The important thing to consider is the thermal properties of the nature freezing wall (thermal conductivity and aqueous vapor diffusion of the materials, which is related to the heat conductivity. Thermal characteristic as an isolation, to prevent minimize the intrusion of the vapor into the box, environment to reach final temperature inside of the box. The effect of high vapor pressure differences among the environment and the panel cavity causing the vapor diffuse from environment through the wall. At the certain distance from wall in the cooling room, the aqueous vapor is going to freeze. Since during freezing the ice have volume specific characteristics bigger than water and the ice growth inside the panel by frozen aqueous vapor, can destroyed the panel. Coconut fiber as a ***waste product*** put in the middle of the panel layer to increase the thermal insulation.

The purpose of this research to find the thermal characteristics of bamboo panel zephyr consist of coconut fiber and calculated of heat transfer and mass transfer in the coiling box.

Bamboo

Bamboo is a part of the graminae species, growth in all over Indonesia archipelagos and anticipated to come from Burmese (Fauzi, 1995). Generally string bamboo grow in lowland and earn also grow better in mountain area until height 1.000 m. Bamboo Tali have the clump, its reed reach 10 - 20 m, bold green chromatic to yellowing-brass. Bamboo composition is in Table 1.

Moisture content of the each flatten shoot bamboo 54, 3% and 15, 1% in dried bamboo. Bamboo string have an interesting strength because of its fibrous structure, and also have the endurance (low durability).The bamboo string easy to slit and flammable. Several types of bamboo, grows in the high mountains of the tropics which produces

Table 2. Weight compositation of coconut*)

No	Item	Harvesting	Harvesting	Dried (laguna)	Hibrida
1	Age	7 month	1 year	1 year	1 year
2	Weight	1.9185 kg	1.2667 kg	> 1.0	>1.0
3	Husk and	62 %	56.3 %	41.7 %	43.4 %
4	Medium	7 %	17 %	28.4 %	21.4 %
5	White flesh	1 %	26.5 %	29.7 %	35.2 %
6	Milk	30 %	65 %		

both a culms and a string. Tropical bamboo is almost a "*clumping*" type, which tends to produce larger-diameter and thicker-walled culms. The above-ground vertical shoot and long horizontal underground shoots called rhizomes which are very short, so the bamboo plant stays more contained in culms. Bamboo flowers bloom and produce seeds annually. This blossoming occurs depending on the species. Bamboo is particularly fragile at this time, after the flowering occurs, all the existing culms die off, and the bamboo seed is only viable for six months. This can cause great problems for people or businesses dependent on a constant supply of culms. Different species of bamboo have different wall thickness, with natural composite. The walls are composed of "vascular bundles". The outside portion of the culms wall is dense, containing about 5% silica. It has an exterior waterproof film which occurs on the softer interior portion as well. Bamboo is particularly strong at the node, where there is an inner disc called the septum which connects the outside walls, strengthening the stalk and separating in into compartments. Bamboo can be used in the different things depend on ages, less than 30 days it is good for eating; 6-9 months for baskets; 2-3 years for bamboo boards or laminations; 3-6 years for construction; more than 6 years bamboo gradually loses strength up to 12 years old. Bamboo for construction is best cut right after new shoots have started to grow, as the plant will have given all its starch to the new culms. It is important to cut bamboo just above the node at the base. The age of the culms is very important to know in order to select culms with the greatest strength for bamboo construction. One-year-old bamboo is an emerald color with the sheaths just beginning to fall off. Bamboo 2-3 years old has white spots on the culms, indicating the beginning of lichens. At 5-6 years these lichens can be clearly seen. Branches also tell the age of a bamboo plant. Every year each culms of bamboo loses its branches which are replaced with new branches. Old bamboo is attacked by insects from the interior of the plant.

Laminated Bamboo

Many of the problems associated with bamboo can be alleviated by creating laminates of bamboo *strip*s. These are formed by simply dividing the length of the culms into individual strips which are then laminated together to create a number of products. Bamboo laminate products include the floor tile is the one type being particularly good for heavy floor traffic. The softer strips of bamboo from the interior of the culms can be safely used in the interior portion of "***glulam***" beams. There is really no limit to the uses of laminated bamboo. It can be used for chairs and other furniture, plates and utensils. In fact it can be used like laminated wood, with the advantage that bamboo laminates are much lighter in weight. To create the strips used for lamination, the interior soft part of the bamboo is removed with a plane, leaving the hard exterior for the lamination strip.Wirjomartono (1958) showed the string bamboo laminated should be formed a flimsy board and use the glue compiled with the parallel fiber direction, to be performed as diametrical board, to a curve forming or both. The preparation to made the laminate depend on the quality of bamboo-veneer to be glued, glue type, the way of ossifying it glue, the way of compression . The string excess laminate can compared by an intact log, to be made a long curvature, small fairish cutting wood, athwart and bigger length, and be planned to a "log-makes" with the bigger strength and glued lumber to impress the good decorative appearance (Brown et. al., 1952)

Bodig (1982), expressing that lamination of wood meant to yield the product by improving and repairing the nature of, its macroscopic properties, such as the dimension stability, defect select, wood handicap and nature of firmness to burden compared to intact log waste in the sawn timber mill and so do it's happened to Bamboo. Surjono.S (2001), had made some furniture using glued-bamboo.

Coconut Fiber as The Substitution of The Midlle Layer

According to laminated bamboo is needed the inner part, some using the other materials wood fiber, then in this experiment using the coconut fiber. Physical properties analysis of coconut fiber at laboratorium Departement of Technique Industry FATETA – IPB shows in Tabel 2.

Coconut fruits are large and nearly round. The husk is hard, medium brown, and has a rough, hairy surface. Three round depressions are found on one end of the fruit. The fruit is used for its husk, white flesh, and liquid in the fruit called "milk."

The coconut fiber is processed using the Hammer Mill, made by PT. Trikarya Teksindo Swadaya Jakarta and the capacity result 1500 to 4000 cernels /day. The moisture content of the coconut fiber in fresh 45.04 %, after drying 17.13 %,the color is yellow-green to brown. Physical characteristics of husk, weight of each kernels 433-670 gram, the length of fiber 0.27 to 0.40 m, with in the fiber diameter 0.011-0.05 mm.

Kermit Whitfield, (2007), DaimlerChrysler and its partner POEMA have developed a sustainable productive chain in Brazil that transforms locally grown coconuts into interior parts for DCX's Brazilian-made vehicles.

How they do it: 1) The process starts with coconuts harvested by small communities of farmers. After removing the fruit, the husk of the coconut, to become a part of a Mercedes. 2) Workers at local cooperatives use simple machines similar to wood chippers to separate the fibers of the husk. This use of "appropriate technology" is simple, cheap and can be located near the source of supply. Separated fibers are then dried, sorted and baled for transport. 3) The baled fibers are compressed to increase the density of the bales and treated with a conditioner to soften the fibers. 4) The bales are separated and fed into a machine that spins the fibers into long ropes. This twisting of the fibers increases their elasticity and helps to ensure that they have the proper cushioning qualities for their later life as seats and headrests. The ropes are treated under high heat and pressure in an autoclave and afterward unraveled and loaded into a machine that forms the fibers into two- meter-wide mats. The mats are cut into smaller pieces that are loaded into molds, pre-vulcanized with hot air, sprayed with latex, and finally pressed into their final shapes. Throughout the manufacturing process there is no material waste since all trimmings are re-used for new parts.

Materials and Methods

In agriculture building construction Zephyr bamboo panel will be applied in the natural condition and be used by farmer. The thermal circulation as

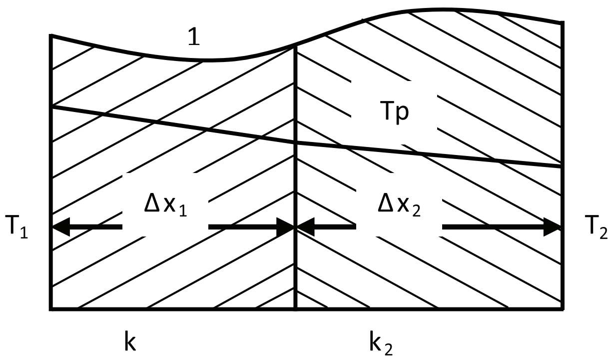


Fig 1. Heat flow inside the bamboo zephyr

a heat transfer to control the room temperature, to fulfill the requirement of the occupant, In order to feel balmy and comfortable so bamboo materials be used as the materials to avoid the influenced the environment (Sri Mudiastuti 1997).

The zehyr bamboo Tali panels are three layers, the first and the third layers made by bamboo sheet, and the second made by coconut fiber. The thickness of each layer are a.2-to 4 mm. The bamboo layers are made of the splitting bamboo shoot. The middle layer made by coconut fiber, then be glued using phenol-formaldehyde or urea-formal dehyde and be compressed at 120 ^oC. In the previous paper report in The Basic research (Pendas 2002)., sponsored by Department of Education and Culture, there is an alternative using the indoor wall, that is the bamboo laminating board which has special beautiful decorations.

The thermal properties will be formulated in this research, are k= heat conductivity, cp = heat capacities, hfg = coefficient of heat transfer of fluid emitting a stream, α = thermal diffusivities, g = specific gravity of air into the room and bamboo as a solid material. The calorie is passing as a combination process from solid materials conduction and air convection in the cavity. Assess the thermal properties from two pore isolator, this media which have different characteristic, will be expected to get the heat transfer phenomenon formulation inside of the material. Using the settling of the state, where temperature in each dot in the cross area of the bamboo panel have passed the heat energy to change by time, then assumed in remains to migratory amount of energy. The stream of heat energy per time depends on conduction passed the width and thickness of the wall. Tumescence, et al. 1977 and Bayazitoglu.Y., Necati O.1988, expressed as follows, when heat energy consistently passes a cross section of the different panel materials, to accelerate the heat transfer per width (m2), derivable expressed in alternately the value of wall heat conduction , k1, and k2 → kn, thickness x1 and x2, temperature surface T1 and T2 while Tp is the surface temperature touch both. At any dot there are symbolized the diffusivity α., temperature To and explained by coordinate x, y, (Tn), time (t).

$$T_1 - T_2 = q_{1-p}\left(\Delta x_1 / k_1\right) + q_{1-p}\left(\Delta x_2 / k_2\right) \rightarrow$$

$$q_{1-2} = \frac{T_1 - T_2}{\left(\Delta x_1 / k_1\right) + \left(\Delta x_2 / k_2\right)} \qquad (1)$$

$$Q_{1-2} = Q_{1-2}.\tau = Q = \frac{A\left(T_1 - T_2\right)\tau.10^{-3}}{3600\left\{\left(\Delta x_1/k_1\right) + \left(\Delta x_2/k_2\right) + ...+ \left(\Delta x_n/k_n\right)\right\}} \qquad (2)$$

$$\frac{\partial T}{\partial t} = \frac{k}{\rho Cp}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \qquad (3)$$

$$T_r,\tau = T_0 + (T_m - T_0)* G\oint\left(\frac{\Lambda}{2\sqrt{a\tau}}\right) \quad (4)$$

where $G\oint\left(\frac{\Lambda}{2\sqrt{a\tau}}\right)$ expressed in table at the appendix (4a)

$$Q_0,\tau = \int_0^\tau Q_0,\tau.d\tau \rightarrow = -\frac{k\Lambda(T_m - T_0)}{\sqrt{\pi.a}}\int_0^\tau \frac{1}{\sqrt{\tau}}d\tau \rightarrow \quad (4b)$$

$$= -2.k.A(T_m - T_0)\sqrt{\frac{\tau}{\pi.a}}$$

The temperature of a triple thick wall surface changing alters variedly, to be explain using the different equation. At the beginning temperature uniform equal to Tm, then decreased turned into nearly the environment. The temperature in wall will be change followed the equation and its value depend on evaluated arrest point, also a time gap among the moment at the starting point and when the temperature in the observation moment changing.

Difusivitas expressed:

$$\alpha = \frac{k}{\rho\ x\ Cp} \quad (5)$$

Temperature Transient at Slab:

$$\frac{\partial T}{\partial X} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \quad 0 < x < L, \text{for } t > 0 \quad (5a)$$

$$\frac{\partial T}{\partial x} \quad x = 0, \text{ for } t > 0 \quad (5b);$$

$$k\frac{\partial T}{\partial x} + hT = hT_\infty \quad x = L, \text{ for } t > 0 \quad (5c);$$

$$T = T_1 \quad t = 0, \text{ in } 0 \le x \le L \quad (5d);$$

$$\theta = \frac{T(x,t) - T_\infty}{T_i - T_\infty} \text{ temperature non dimension} \quad (5e);$$

$$X = \frac{x}{L} \text{ coordinate non dimension} \quad (5f)$$

$$Bi = \frac{hL}{k} \text{ Biot number} \quad (6)$$

$$\tau = \frac{\alpha\, t}{L^2} \text{ time non dimension} \quad (7)$$

Heat conduction:

$$\frac{\partial^2\theta}{\partial X^2} = \frac{\partial\theta}{\partial\tau} \rightarrow 0 < X < 1, \text{ for } \tau > 0 \quad (8a)$$

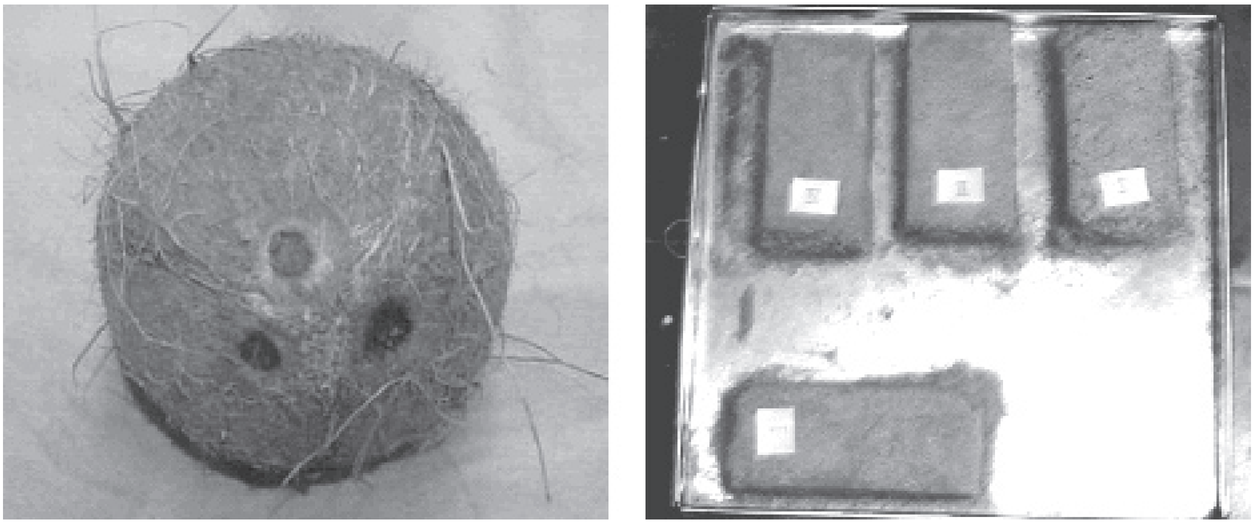


Fig 2. The laboratory of Bamboo panel board sample

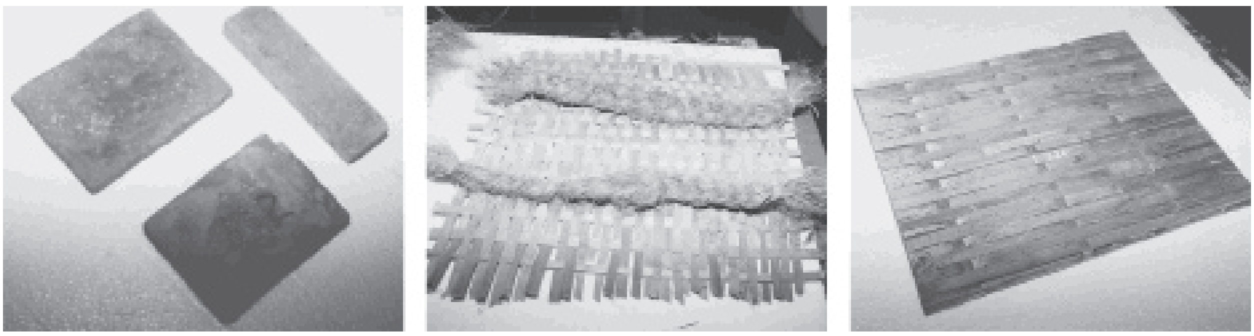


Fig 3. Concrete mixed of bamboo fiber. and b). layering cocoa fiber to bamboo sheet

$$\frac{\partial^2\theta}{\partial X} = 0 \qquad X = 0, \text{ for } \tau > 0 \tag{8b}$$

$$\frac{\partial\theta}{\partial X} + Bi\,\theta = 0 \qquad X = 1, \text{ for } \tau > 0 \tag{8c}$$

$$\theta = 1 \qquad 0 < X < 1, \text{ for } \tau = 0 \tag{8d}$$

$$\tau = \frac{\alpha t}{L^2} = \frac{k(1/L)L^2}{\rho c_p L^3/t} = \frac{(Average.of.thermal.conductivity.forL.in.Volume\ L^3, W/^0C)}{(Average.in.ternal.heat.in\ Volume\ L^3, W/^0C)} \tag{9}$$

Simplified Biot number at (8c)

$$Bi = \frac{hL}{k} = \frac{h}{k/L} = \frac{(Coefisien\ heat.transfer.at.solids.surface)}{(Conduk\ tan\,ce.at.solid.surface, L)} \tag{10}$$

energy quantity Q_0 for slab Volume Slab V = (2L) (depth).

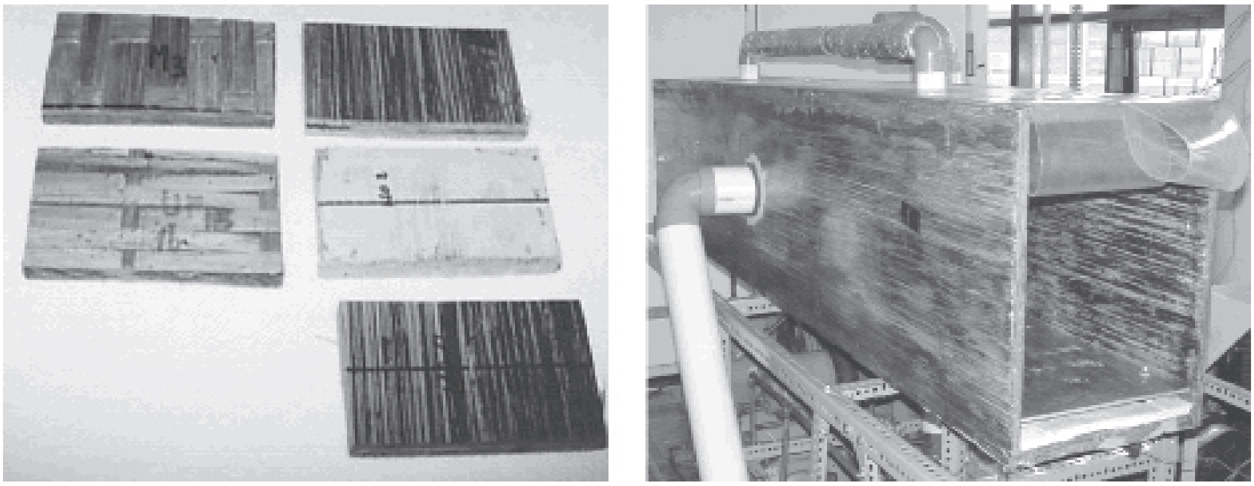
$$Q_0 = \rho c_p V(T_i - T_\infty)\ W.s \tag{11}$$

Changing of the internal energy related the value in the equation and by iteration to predict as numerical analysis, be compared to the phenomena into heat transfer inside the composit, then expressed into changing of the thermal properties and as usual physical and mechanical properties will following continue the differentation of he bamboo composit zephyr.

Results and Discussion

The bamboo tali panel has been done and showed at the Fig.1 and 2 and equlirium Moisture content of Zehyr bamboo panel.

The water activity using several equation in the Air blast cooling cavity made by Bamboo Tali and its usable to predicy how far the cavity will be damaged if the Air blast running.



a b

Fig 4. a) Triplex laminated Bamboo combined by coco-fiber, and bamboo Cooling panel b) Bamboo box at Cooling System

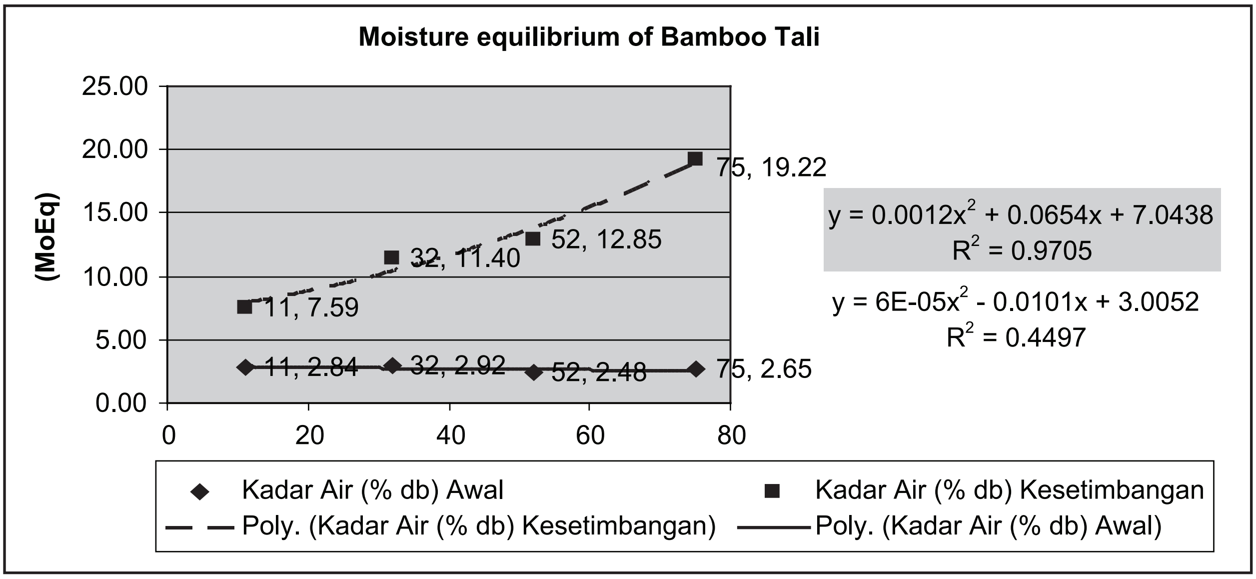
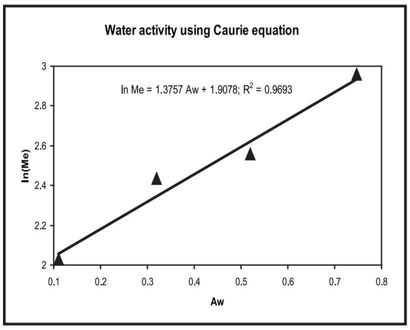
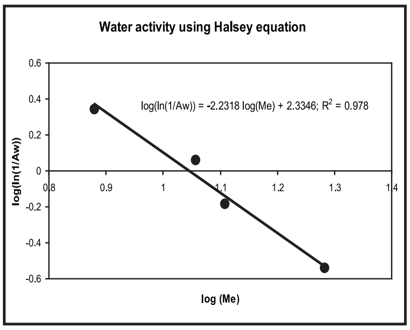


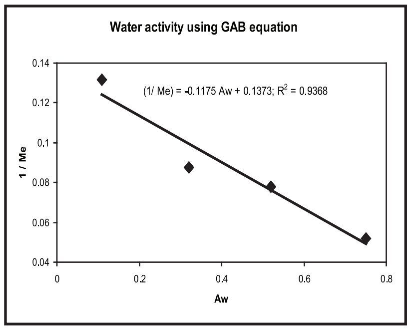
Fig 5. Moisture equilbrium of bamboo Tali



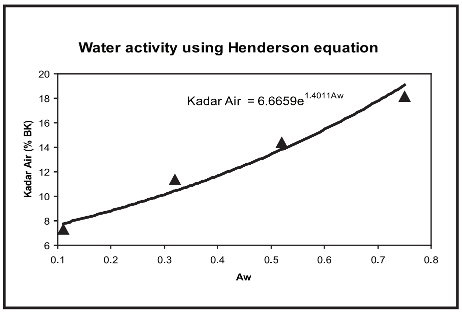
a) Caurie



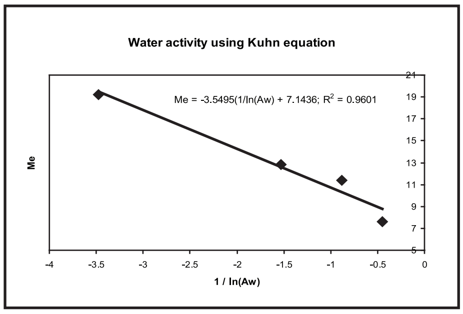
b) Halsey



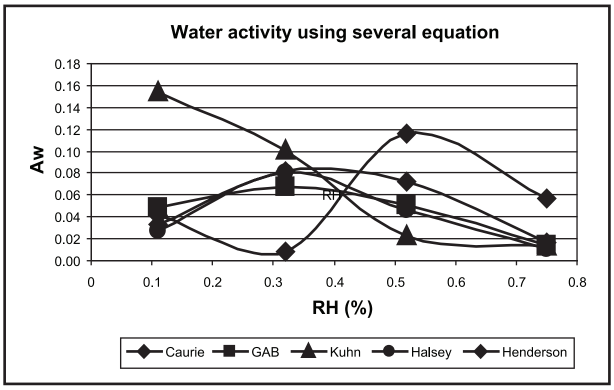
c) GAB equation



d) Henderson



e) Kuhn



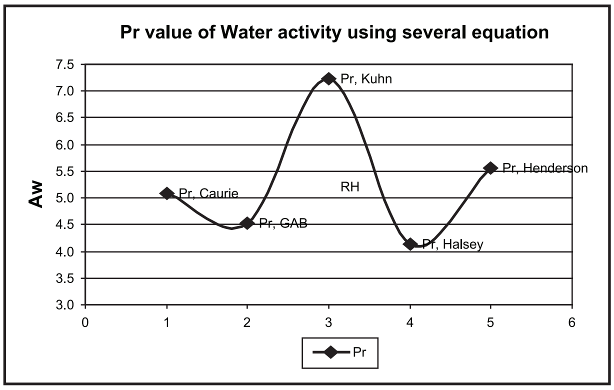


Fig 6 The water activity using several equation and PR

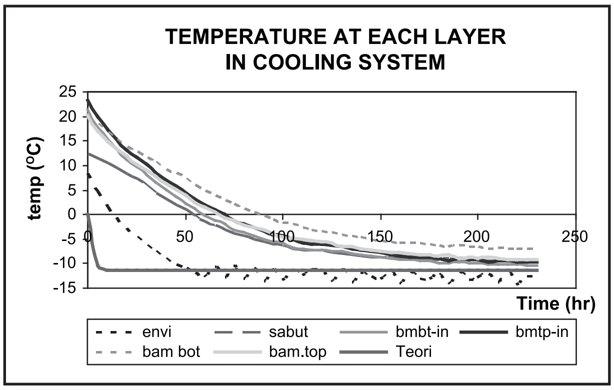


Fig 7. Temperature distribution in each the bamboo-fiber panel layer in cooling system

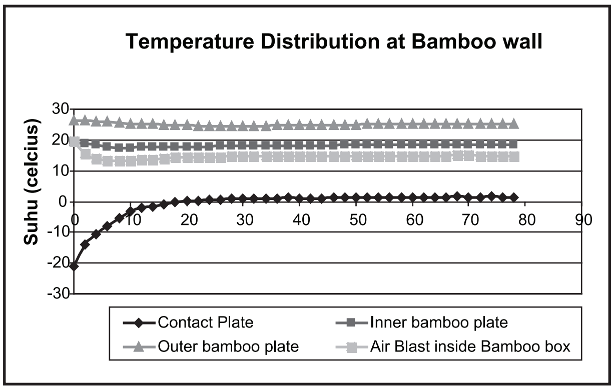


Fig 8 Temperature distribution in bamboo panel of the air blast cooling system

Table 3. The thermal properties of bamboo Zephyr of bamboo Tali

Moisture content m.c (% wb)	Density ρ (g/cm3)	Heat capacity Cp (J/g C)	Conductivity K (x E -3 J/cm dt C)	Diffusivity α = k/ρ.cp (x E3 J/cm dt C)
9.092798063	0.671	2.227137205	0.1194	0.082356425

According to the thermal properties in this study have been known the temperature distribution in the bamboo-zephyr, see Fig 5.

Conclusion

The small communities of farmers have a chance make another materials from the ***waste products***. Zephyr bamboo panel can be used as a good material for transfering heat to the circumstances in the area of the cooling system. Means hopefully coconuts can be useable to increase the farmer income. One suggestions that how to developed the bamboo panel can be distributed to the consumer, this is the next research.

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