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THE ENHANCEMENT OF HEAT TRANSFER OF WOOD (*Neobalanocarpus Heimii, Shorea Sp, Instia Palembanica Miq*) OF BIO-COMPOSITE MATERIALS FOR GREEN BUILDING IN MALAYSIA

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ABSTRACT

In this study, heat transfer investigation is done in order to improve the cooling effect for green building without damaging the environment. This proposal is provoked by the desire to reduce the temperature for the green building and to sustain the environment and natural resources. The building industry is also a large consumer of non-renewable materials and this trend has increasing dramatically over the past century. To this end, we have been addressing sustainability concerns related to building construction materials through many research approach applied to building elements where we can collectively influence design, materials, construction, energy consumption and disposal. Bio-composites can best be used in the building industry today and what fundamental advancements are needed to facilitate more widespread application of these clean, energy-efficient and resource-rich construction materials. The use of heat insulation in the building envelope in hot and humid climate is investigated through computer simulation. Simulation of heat transfer in the aspect of reducing the temperature phenomenon inside the green building using FLUENT-GAMBIT. In this project work the simulation of heat transfer and the temperature curve in the traditional wood house and green building model is computed out using gambit and fluent software. The use of thermal insulation in the building envelope in hot and humid climate is investigated through computer simulation. Comparison of temperature profiles of the material in the traditional wood house and green building model using constant temperature heat source and linearly varying temperature of the heat source for unsteady state is done. Also the time for temperature to become steady is compared. The problem will be solved by using the software package FLUENT – GAMBIT. The parameters under analysis focused on changing the influence of exterior walls in the energy consumption for cooling the building.

Keywords: bio-composites, FLUENT, Heat Transfer, CFD.

INTRODUCTION

In this study, heat transfer investigation is done in order to improve the cooling effect for green building without damaging the environment. This proposal is provoked by the desire to reduce the temperature for the green building and to sustain the environment and natural resources. The building industry is also a large consumer of non-renewable materials and this trend has increasing dramatically over the past century. To this end, we have been addressing sustainability concerns related to building construction materials through many research approach applied to building elements where we can collectively influence design, materials, construction, energy consumption and disposal.

We will identify where bio-composites can best be used in the building industry today and what fundamental advancements are needed to facilitate more widespread application of these clean, energy-efficient and resource-rich construction materials. The use of heat insulation in the building envelope in hot and humid climate is investigated through computer simulation.

Simulation of heat transfer in the aspect of reducing the temperature phenomenon inside the green building using FLUENT-GAMBIT. In this project work the simulation of heat transfer and the temperature curve in the traditional wood house and green building model is computed out using gambit and fluent software. The use of thermal insulation in the building envelope in hot and humid climate is investigated through computer simulation (Fernando *et al.*, 2011).

Comparison of temperature profiles of the material in the traditional wood house and green building model using constant temperature heat source and linearly varying temperature of the heat source for unsteady state is done. Also the time for temperature to become steady is compared. The problem will be solved by using the software package FLUENT - GAMBIT. The parameters under analysis focused on changing the influence of exterior walls in the energy consumption for cooling the building.

Bio-composite Materials

Biocomposites are broadly defined as materials that are either partially or totally derived from bio-based or biodegradable materials. "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings (Sahoo, 2011). Bio-composites are the combination of natural fibers (biofibers) such as wood fibers (hard wood and soft wood) or nonwood fibers (e.g. rice straw, hemp, banana, pine apple, sugar cane, oil palm, jute, sisal and flax) with polymer matrices from both of the renewable and non-renewable resources (B.C Mitra, 2014).

Over the span of civilization, man has developed technology that utilizes natural resources as structural materials. One example of this is the progression from early civilization's use of grasses and straw in mud bricks, to straw bale housing, to fiber reinforcements in polymer matrix composites (Gillian *et.al*, 2008). Application developments of natural fibre composites as alternate building materials must be thoroughly studied for their durability, heat insulation and cost-effectiveness in order to obtain consistent product performance under service conditions (Singh and Gupta, 2005).

Bio-based composite materials are a new and innovative class of materials being developed today. They consist of environmentally friendly resins and natural fibers. They are made from annually grown renewable resources and therefore, do not deplete petroleum stock or timber reserves. The basic element for wood-based composites is the fiber, with larger particles composed of many fibers (Harry *et al*., 2008) Elements used in the production of wood-based composites can be made in a variety of sizes and shapes.

Properties of Bio-composites Materials

Bio-composites are prepared using natural fibers for the reinforcement phase and natural rubber or other natural polymer for the matrix. Natural fibers are abundantly available and cheap, and many have high strength and stiffness, as well as low cost and density. The properties of bio-composites are influenced by a number of factors such as fiber type, environmental conditions of preparation, processing method, as well as any modifications to the fiber through physical or chemical ways (Nair and Joseph, 2014). Wood fibres are the most abundantly used cellulose fibre. They have been extensively used in the modern composite industry due to their specific and unique characteristics.

Attributes of bio-composites

The numerous features of composite materials have led to the widespread adoption and use through many different industries. It is because of the unique feature of the composites that people benefit. Below are some of the important features of composites and benefits they provide;

a) Non-toxicity

Natural fibres are generally non-toxic , providing scope for manufacturing composites with no or heavily reduced, human health hazards and environmental damage throughout their life cycle (production, processing, use and disposal).(Dicker et al, 2014)

b) Light weight

Composites are incredibly light weight, especially in comparison to materials like concrete, metal and wood. Often a composite structure weigh is ¼ that of steel structure with same strength. That means a car made from composites can weigh ¼ that of carmade from steel. This equates to serious fuel saving. (Sahoo, 2011)

c) High strength

Composites materials are extremely strong especially per unit of weight. An example of this is high tenacity structural fibers used in composites such as amid and s-glass which are widely used in body amour and green buildings nowadays. (Sahoo, 2011).

Green Buildings

The purpose of green building materials is to save energy,minimize its impact on climate change and decrease the rate at which we are consuming natural resources. A green building material has little or no impact on the environment. (Katarina, 2011). Widely, it refers to attempt to consciously create buildings with an eye to how they interact with our planet's ecosystem (Snell *et al.,* 2009). In Malaysia, building surfaces such as windows, walls, and roofs are exposed to the sun can absorb heat from solar radiation, leading to an increase in the amount of energy needed for cooling purposes (Al-Tamimi and Fadzil, 2011).

The energy consumption in the building is affected by three factors that are technology, people, and outdoor climate. These three factors determine the total amount of energy usage of a building. Currently, the first factor, i.e. technology, receives the main attention in the construction sector. Minimizing transmission and ventilation heat losses, e.g. by using efficient insulation in the building envelope with high air tightness, or by using energy saving equipment such as a heat recovery system, variable air volume ventilation system, or a heat pump all result in improving the technical properties of the building (L. and Hesaraki, 2013).

Green building in Malaysia

The Malaysian building industry has over the years been developing and working towardsa more sustainable and green architecture. The needs for SBRS (Sustainable Building Rating System) become more apparent with the increasing demand from building end-user for Green rated building (Ar Zuhairuse MD Darus and Nor Atikah Hashim, 2013). Shafii and Othman (2005) reveal that one of the major barriers holding back the development of sustainable building in Southeast Asia is the lack of awareness of sustainability issues in related to profession. The survey conducted by Shari, Jaafar et al (2007) also reveals that the Malaysian building industry players have ‘little’ knowledge on sustainable building assessment, rating and labeling system.

Bio-based composite wall

A sandwich material containing cork, clay,and resin as natural materials was manufactured and tested in order to evaluate the thermal conductivity. As previously shown, the use of the eco-sandwich in building application is an innovative solution suitable for well insulated light-weight structures (La Rosa et. al,2014).Walls are a predominant fraction of a building envelope and are expected to provide thermal and acoustic comfort within a building, without compromising the aesthetics of the building.(Sadineni et al, 2011).

Conventionally, insulation is placed in one of three different locations: (i) internally towards the building’s interior; (ii) externally, on the outside of the building shell; or (iii) in between the building’s outer and inner layer known as cavity insulation. Less commonly, insulation may be located in multiple layers throughout a construction, or comprise the entirety of the construction, however these rarely used solutions will not be discussed here as they do not apply to earth wall construction techniques (Hopfe et al, 2012).

Energy Efficiency of buildings

The energy efficiency of a building is determined by the rate at which energy is lost through the physical structure of the building (the building envelope), and the rate at which energy is used to meet the energy needs and physical comfort of the occupants. These two factors are often closely interrelated, because the physical structure and design of a building, interacting with the local climate, strongly influence the choice of energy system and the associated efficiency of that system (UNEP, 2009).

Relationship between heat and building material with Malaysia’s climate

The main causes of climatic stress in Malaysia are high temperatures, solar radiation, humidity and glare. To achieve climatic comfort in the Malaysian home, these factors must be controlled besides the control of rain, floods and occasional strong winds. Direct solar radiation is the primary source of heat gain while the others are secondary sources, thus making the proper control of solar radiation most crucial for the achievement of thermal comfort. The other major source of heat gain lies in the type of building material used. In most modern buildings where high-thermal-capacity material such as bricks, concrete and zinc is used, the heat absorbed within the building fabric which is radiated to the interiors of the buildings causes great discomfort. From the above discussion, it is clear that to achieve thermal comfort in the warm humid Malaysian climate, solar heat gain by the building and human body must be minimised while heat dissipation from the body must be maximised by ventilation and evaporative cooling (Lim, 2014).

The good solar-radiation and glare controls in the Malay house are other examples of good climatic design which are applicable to modem housing.The orientation of modern houses must be carefully designed so as to minimize solar heat gain in the building. Roofs, being the most important element in the control of solar radiation, should be made from low-thermal-capacity materials (Lim, 2014). It is found that the comfort range according to other studies that have presented the variation of thermal comfort in Malaysia of about 24°C to 28°C (Abdul Malik and Rodzi-Ismail, 2006).

Wood-based Industry

Historically, Malaysia has been rich in timber resources, now declining somewhat.Given the abundance of natural resources, Malaysia’s potential comparative advantage in resource-based industries (RBIs) is readily obvious. The Malaysian wood industry was innovative and creative enough to find and develop the means to convert wastes into profitable business by putting the woods to good use for making a variety of products, including furniture, panelboards, flooring and walls (M.Ariff, 2005). Nowadays, in order to reduce the uses of the raw natural resources technological advances of the wood-based composites industry have been largely increase. Today the wood-based composites industry is highly automated and has achieved a high level of efficiency in the utilization of raw materials. (Kamke *et al*, 2004).

Types of wood

i. Chengal (*Neobalanocarpus Heimii*) produces a very durable and heavy timber, with an air-dry density of 915-980 kg/m3. The sapwood is pale-yellow,

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heartwood light-brown, darkening on exposure. The wood is moderately lustrous with prominent ripple marks. It is suitable for all forms of heavy construction, houses, walls and many other uses where great strength and durability are required (Orwa *et al*., 2009). Like teak, the timber contains preservative compounds that protect the heartwood and even under exposed conditions the timber can last about 100 years.

ii. In Peninsular Malaysia, H.odorata is well known in Langkawi, Perlis and Kedah, and the north of Perak, Kelantan and Terengganu. It is essentially a riparian species, rarely occurring far from streams. On the banks of the larger rivers large trees overhang the water. In Kuala Kangsar district in Perak, H odorata is the preferred timber and is also valued by the villagers in Perlis, Kedah and Terengganu. (Symington, 1941).

Heat transfer

Heat transfer related to the rate of heat transfer between different medium. The process always involves the transfer of energy as heat, from higher temperature bodies to lower temperature. Heat transfer stop once it reaches equilibrium state. Calculation of the heat loss from building surface to the surrounding can be done by determine the analysis of heat transfer. The comfort of occupants in a room also can be determined by a balance of heat transfer from the person to the surrounding air as well as transfer of heat from interior wall (Mazlan *et al*., 2013).

Modes of heat transfer

There are three modes for heat transfer, which are conduction, convection and radiation. Understanding of the fundamental of heat transfer will help to aware the processes that take place in a building and its influence to the external environment

Conduction

Thermal conduction is the process of heat transfer from one medium (high temperature) to another adjacent medium (lower temperature). The rate of heat conduction is depends on the geometry of the medium, thickness and the material of the medium. In the study by Cengel (2008), they concluded that the rate of heat conduction through a plane layer is proportional to the temperature difference across the layer and the heat transfer area, but is inversely proportional to the thickness of the layer. The process of heat conduction is illustrated in Figure-A1.

Rate of heat conduction is represented as Q. It can be calculated by the equation:

$$Q = kA\frac{T_1 - T_2}{L}$$

where: *k* is thermal conductivity of material
T_2 is outdoor temperature A is surface area
L is thickness of wall
T_1 is indoor temperature

Convection

Convection is energy transfer between a solid surface the contact with moving liquid or gas. In other word, it involves the combination of conduction and fluid motion. It is believes that the faster the fluid motion, the greater the convection heat transfers (Mazlan *et al*., 2014).

Heat convection can be calculated by the equation:

$$Q_{conv} = hA_s(T_s - T_\infty)$$

Where: *h* is convection heat transfer coefficient
A_s is surface area
T_s is surface temperature
T_∞ is temperature of fluid that contact with medium

Radiation

Radiation is the emission of energy in the form of electromagnetic waves (or photons) such as infrared or visible light, by matter as a result of the changes in the electronic configurations of the atoms or molecules. Different from conduction and convection, it does not require any medium for transmission (Cengal, 2008).

(Mazlan *et al*., 2014) stated in their studied on heat transfer in using three dimensional numerical analysis of heat and fluid flow in computer. 3D model of microprocessors is built using GAMBIT and simulated using FLUENT software. The study was made for two microprocessors arranged in line under different types of inlet velocities and package (chip) powers. from natural fibre and petroleum-derived non-biodegradable polymers like PP, PE and epoxies or biopolymer like PLA and PHAs. While composites materials are derived from biopolymer and synthetic fibres such as glass and carbon also comes from bio composites. Bio composites derived from plant-drive fibre (natural/ biofiber) and crop/bio derived plastic (biopolymer/ bioplastic) are more eco-friendly (Mohanty et al., 2005).

Simulation

Among the commercially available avalanche General definition of simulation is imitation of a system. According to Robinson (2004), a simulation is prediction of the performances of an operations system under a specific set of inputs. The purpose doing simulation is to obtaining a better understanding of or identifying improvement to a system (Robinson, 2004).

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More investigation can be made by using simulation model over thermal balance for specific thermal zones in the building models in order to seek a better understanding where the thermal insulation could result in higher benefits for thermal performance in hot and humid climate (Westphal, Yamakawa, and Castro, 2011). Computer modeling and simulation are used to assist in exploring the parameter space, thus reducing or eliminating subsequent physical experimentation (Kamke *et al.,* 2005).

FLUENT is a computational fluid dynamics (CFD) software package to simulate fluid problems. It uses the finite-volume method to solve the governing equations for a fluid. It provides the capability to use different physical models such as incompressible or compressible, in viscid or viscous, laminar or turbulent.Geometry and grid generation is done using GAMBIT which is the preprocessor bundled with FLUENT (Mazlan *et al*., 2013).

MATERIALS AND METHODS

Experimental method

The experiments were undertaken to investigate the performance of the heat transfer to the surrounding of wood house prototype. The heat loss through the house prototype must be minimized to obtain more accurate experimental results. The experiment will be repeated for three months to ensure the accuracy and precision of the results.

1. Bio-composite materials were prepared
2. Cut the choosen bio-composite materials and solid woods to a desire size and measurement
3. Laminate the bio-composite materials and solid woods by using resin into a sandwich panels.
4. A house prototype with different woods were build up to represent a wood house
5. Arrange the model with the same arrange like in simulation arrangement.
6. Run the experiment and collect the data for the temperature measurement.
7. Analysis and varify the data.

Preparation of biocomposite panels

Preparation of biocomposites differ according to the type of biocomposites. As for Bc 2 does not require any resin while Bc 1 require resin to glue and stacked the biocomposites together which involves several steps to complete the biocomposite panel.

(i) Bc 1 (Biocomposite 1)

Preparation of raw material

Raw materials that are baggase fiber, coconut fiber and sawdust were obtained from factory and stalls. Baggase fiber and coconut fiber were sieved to the size of 5mm. After the all the materials were prepared, the materials were being dried in the oven for 12 hours at 90 °C.

Preparation of board

The materials for Bc 1 (Sawdust with coconut fiber) were weighted before being blended manually due to the limitation of the equipments. The mixture of sawdust and coconut fiber was stirred manually in uniform rotation and the latex resin was added to mix and glued them together. Then the glued biocomposite material were pressed using manual compressor to fuse the particles into a rigid biocomposite pressure-formed material. and leave it for 5 hours. The ratios of the raw materials are based on some journals and try and error. The appropriate ratio to bind the raw material for sawdust is 1:1, while the ratio of sawdust to coconut husk to bind the materials together is 2:1:1:5. After that the biocomposite panel must be heated in the oven for 24 hour at 100 C to dry it.

(ii) Bc 2 (Biocomposite 2)

Clay was obtained from Sungai Jeli. The clay was placed in the oven for 4 hours at 70 C t reduce 20% the moisture content of the clay. Then the clay was kneaded while the coconut fiber was being added until the mixture attained a uniform consistency. The ratio used is based on some reference of the articles and journals and also based on try and error technique. The appropriate ratio for clay to coconut fiber is 3:2. Finally the clay was put in the mold and had been placed in the oven for drying purpose at 100℃ for 24 hour.

(iii) Measuring indoor and outdoor temperature

Due to lack of instruments as for instance thermostat or thermal sensor, the measurement of temperature indoor and outdoor environment were done manually by using thermometer. Three types of data were recorded which is by month, daily and hours.

Simulation method

1. Design the simulation model with the complete geometry and dimension using GAMBIT software.
2. Meshing the mesh of the model with suitable meshing type.
3. State the boundary condition of simulation model.
4. Input the data of the model like material properties, air inlet velocities and etc.
5. Run the simulation model using FLUENT software.

In this research the simulation of heat transfer and the temperature curve in the bio-composites materials combining with the solid wood panel will be compute out

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using gambit and fluent software. Comparison of temperature profiles of the material in the combined panel with the traditional solid wood panel using constant temperature heat source and linearly varying temperature of the heat source for unsteady state will be done. In the process of carrying out Numerical analysis, Grids are developed in GAMBIT with fine meshing and exported into FLUENT. Meshed models for the house prototypes inserts. The geometry used is very simple, similar to model that were built up for experimental analysis.

The problem will be solved by using the software package FLUENT - GAMBIT and the result from the simulation will be compare with the experimental result, as simulation method will will be not influence by any external factors while the experimental method will be influence by some external factors.

RESULTS AND DISCUSSIONS

Bio-composites structure

In this study, types of materials for bio-composites play an important role in reduction of indoor temperature. Based on Figure-1, shows bio-composite from coconut fiber and saw dust. The appearance of this bio-composite is similar to the commercial particle board and medium in weight. This bio-composite labeled as Bc 1. Figure-2 is a bio-composite from the mixture of clay and baggasse fiber. The texture of the bio-composites is rough and heavy. There are some sample were cracked. It may be because of wrong composition of clay and coconut fiber.

Figure-1. Bc 1 (Sawdust + Coconut fiber).

Figure-2. Bc 2 (Clay + Baggasse fiber).

Experimental result

As for the experimental result the data of temperature was collected for three months August, September and October. The data of temperature which is for indoor and outdoor temperature of the house prototype had been obtained manually which is by using thermometer due to limitation of the equipment. The temperature was measured two hours interval daily. The data were represented in the Figure-3 and Figure-4 that shows the comparison of indoor temperature of different types of biocomposite materials and different types of woods. Outdoor temperatures were taken into account in order to compare the outdoor and indoor temperature. Outdoor temperature means the surrounding temperature.

This study focused on hot weather and radiant heat load can be reduced by choosing inner and/or outer surface covering. There are two main problems in the hot weather which is indoor air temperature caused by high outdoor temperature and radiant heat load from the sun-heated roof (A. Ruus *et al*., 2014). As for our country, Malaysia only experience two distinct seasons which is dry season and rainy season.

In general, outdoor temperature is lower than indoor temperature for any types of wall material as we can see from Figure-3 and Figure-4. It cause by sun radiation that absorbed by the model and increase indoor gains energy that brings warm into the building, thus create indoor temperature higher than outdoor (Azzmi and Jamaludin, 2014; Karyono, 2010).

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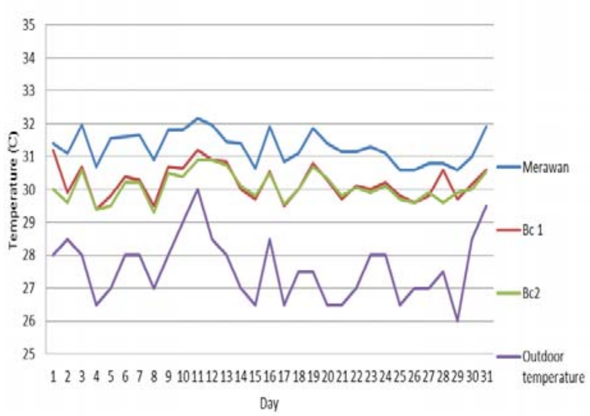

Figure-3. Comparison of indoor temperature for different types of biocomposite material and Merawan wood with outdoor temperature for August.

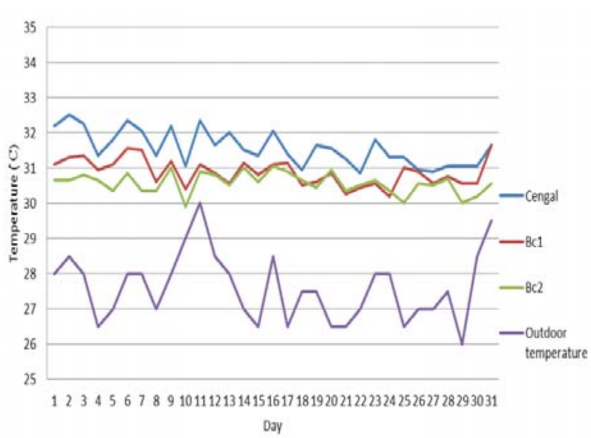

Figure-4. Comparison of indoor temperature for different types of biocomposite material and Cengal wood with outdoor temperature for August.

Comparison of indoor temperature with and without biocomposite laminating to wood panel

Based on the graph Figure 3 and Figure 4 shows that Merawan and Cengal wood panel without any lamination to it shows the highest temperature compared to wood panel that were laminate with the biocomposites panel followed by Bc 1 and finally Bc 2. Bc 2 recorded the lowest temperature among of these three types of panel.

The figure 3 and figure 4 shows the average temperature daily in August 2014. As mentioned on the above Bc 2 is the wood panel that had been laminate with the cob which is the combination of clay and bagasse fibre.

The highest indoor temperature recorded in August is 41 °C by Cengal wood which is on 2 August 2014 while the lowest temperature recorded in August is 23 °C on 17 August 2014 by Bc 1, While 29, and 11 August 2014 by Bc 2. It is probably due to the weather on that particular day as rainy day eventually will make the temperature become lower due to high humidity while if the weather is hot the temperature will increase due to low humidity.

As stated before M+Bc2 recorded the lowest temperature compared to other materials. Besides heat reduction between different types of biocomposites also has been compared. The Biocomposite 2 shows a significant reduction for indoor temperature for both type of woods which is 35.4 °C for Merawan and 36.3 °C for Cengal. Cob has the ability to absorb heat during hot day and keeping the house cool and it is because of its thermal properties, which is high specific heat capacity that lessens the thermal gradient of the house (Revuelta-Acosta *et al*., 2010).

Cob has thermal conductivity value that is much less than traditional Portland cement. This feature keeps thermal energy from entering the building when the environmental temperature exceeds the desired internal temperature of the building. Although the thermal conductivity of the straw bale is much less than cob and the density of straw bale are significantly smaller than the density of either Portland cement or cob. But the straw bale does not work for thermal energy storage. Hence it is the best to choose cob as a green building material in order to achieve the optimum temperature for the green building.

Table-1. Insulation properties of Building Materials (Amit Anad *et al*., 2013).

	Specific Heat Capacity J $kg^{-1}K^{-1}$	Density kg m^{-3}	Thermal Conductivity, W $m^{-1}K^{-1}$
Portland Cement	750	2320	0.29
Cob	800	1450	0.45
Straw Bale	600	60	0.067

Heat convection

One of modes of heat transfer is heat convection. Heat convection involves transfer of energy between a solid surface with adjacent gas or liquid in motion. This process occurs at the surfaces of walls, floor and roof. Temperature different between fluid and the contact surface, lead to variation of density in the fluid and resulting in buoyancy. This phenomenon cause heat exchange between solid surface and fluid. The mechanism of heat convection is shown by figure below.

Heat convection of the house prototype built up from Cengal and Merawan wood had been calculated by using the value from Figure-3 and Figure-4 and the results are shown in the Table-2.

Table-2. Heat convection on different types of materials.

Materials	Q conv (W)
Merawan	788.67
M+Bc 1	682.23
M+Bc 2	396.75
Cengal	1011.27
C+Bc1	929.01
C+Bc2	667.74

From Table 2 it is shown that Cengal has the highest value for the convection process of heat transfer (1011.27 W) compared to Merawan (788.67 W). This is one of the reasons that explains high indoor temperature of Cengal wood house prototype compared to Merawan wood house prototype. From Figure 3 and 4 the average for indoor temperature were determined for each type of wood house prototype. The house prototype that is made from Cengal recorded the highest average indoor temperature. From the Figure-4 it can be assumed that Cengal has low ability to transfer heat from indoor to outdoor by the heat conduction process since it cannot be proven clearly because of lack of data in order to determine the thermal conductivity of each bio-composite material.

When comparing heat convection between both types of wood with and without bicomposites, it is found that biocomposite reduce heat convection of wod especially Bc 2 biocomposites with the value of 396.75 W for Merawan and 667.74 W for Cengal as it is because of the difference of the thickness between the control wood house prototype (without biocomposite) and with biocomposites and this theory is supported by (Glicksman, 2010), as the board is thicker , heat transfer will penetrate further distance from the board surface. The thermal boundary layer thickens will increase and heat transfer coefficient will be smaller.

Simulation result

Simulation method used the same parameters that were being used in the experimental method which were thickness, area, density, thermal conductivity and weight. Simulation result were being analysed by using several types of colours that appeared on the contour of the wood house prototype in the CFD simulation which is basically red, orange, yellow ,green, light blue and dark blue. As for instance ,if more red colour appeared on the contour then it shows that the indoor temperature is not favourable which is very hot while if more green colour appeared on the contour hence it shows that the indoor temperature is at optimum condition. Different materials will provide different results in simulation. The simulation is design follows the design of the houses model that was used in experimental method.

Table-3. Bio-composites indicator.

Types of biocomposites combine with wood panel	Indicator
Sawdust + Coconut husk	Bc 1
Cob (Clay + Bagasse)	Bc2

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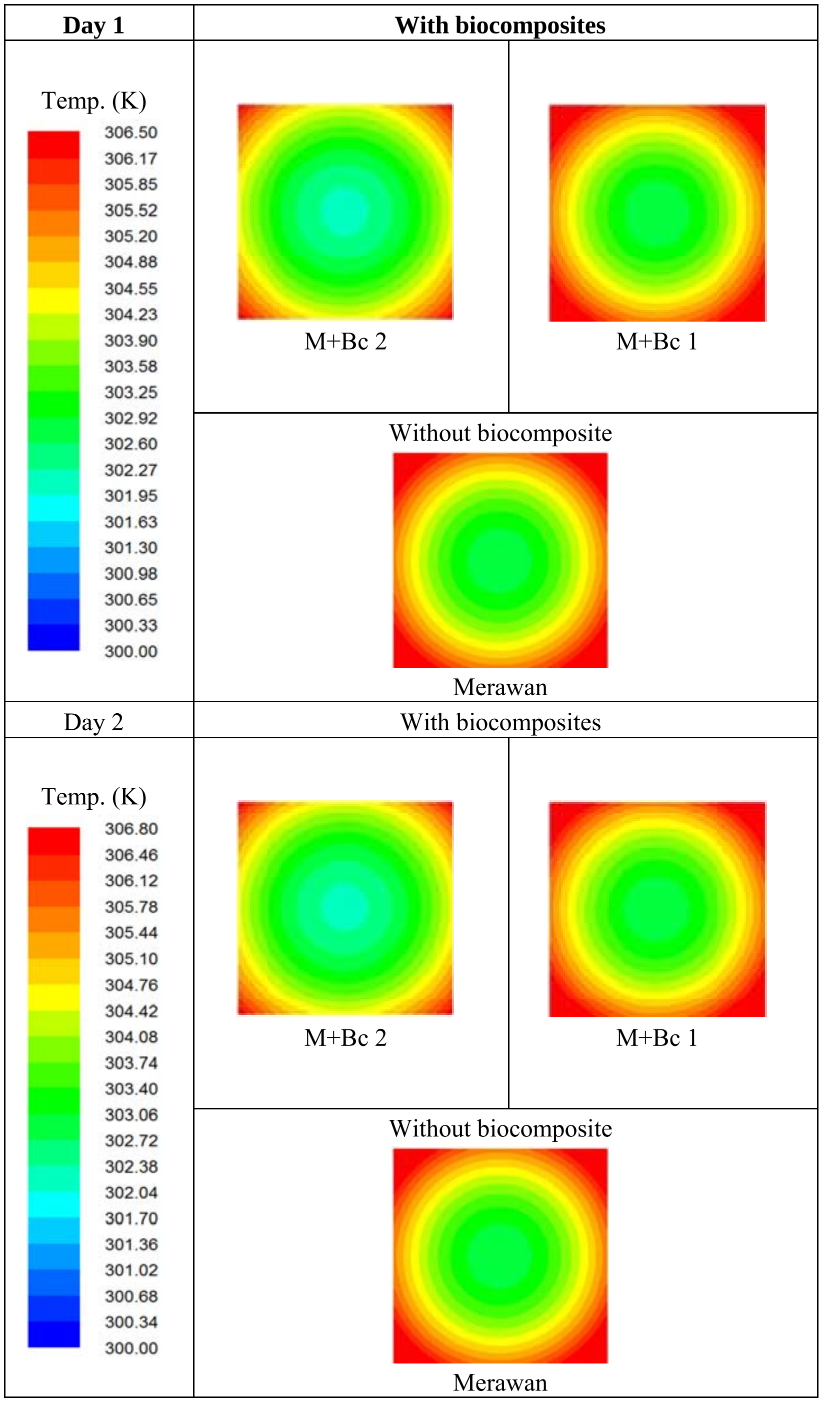

Figure-5. Merawan CFD simulation result daily average temperature with and without biocomposite.

Percentage of difference

Comparison between experimental and simulation results

In this sub-chapter, the comparison between experimental method and CFD simulation has been compared and analyzed. The experimental method demonstrates the use of the same dimension, parameter and data yielded from the comparison using CFD simulation on two types of different wood houses prototype. The results below show the differences between the experiment and simulation results in terms of indoor temperature.

Table-4. Percentage of differences between experimental and simulation.

	Percentage of difference (%)	
	Merawan	**Cengal**
Control house prototype	4.5095	4.2158
Bc1	4.6796	4.3709
Bc2	4.5415	3.8343

From the table above, we can see that the overall percentage of difference between experimental and simulation results is small which is in the range of 3.8-4.7 %. For Merawan, the maximum difference between the simulation and experimental result is Bc 1 which is 4.68 percentage differences whilst for Cengal the maximum percentage of difference was also shown by Bc 1 which is 4.37 percentage of difference.

Meanwhile for Controlled house prototype for Merawan is 4.51 % and for Bc 2 is 4.55%. For Cengal is 4.22 % and for Bc 2 is 3.83%. After comparing the result between experimental and simulation method it is found that the percentage of difference between these two methods is in a small range and below 5 % percentage of difference. Hence it is proven that the simulation result by using CFD simulation is excellent software to predict the effective thermal conductivity, thermal contour and distribution of the whole model.

Comparison between biocomposites

Table-5. Percentage of difference when using biocomposites.

	Merawan	Cengal
Bc 1	0.9712	0.7348
Bc 2	3.6232	3.1050

The percentage of difference for indoor temperature for Merawan and Cengal with two different types of biocomposites were calculated and shown in Table 5. For Merawan wood, when combining with biocomposite Bc 1 the percentage of indoor temperature reduced by 0.97 % which is only a little difference with solid wood Merawan. When Merawan wood is combine with the Bc 2, it shows that there is a greater difference in reduction of indoor temperature which is 3.62 %.

While for Cengal wood shows percentage of difference that are lower than the merawan percentage of difference value which is for Bc 1 only 0.73 % difference from the Cengal solid wood while fr Bc 2 with 3.11% of difference.

CONCLUSIONS

From the results above, it can be concluded that the indoor air temperature will reduce when biocomposite panel combine to the wood panel compared with wood panel without using biocomposite panel. The indoor air temperature of wood panel without using the biocomposite panel makes the indoor temperature becomes unfavourable. Different raw materials for biocomposites have different thermal properties which makes certain biocomposites to be preferable in different application.

Heat convection was calculated for each types of biocomposites materials which has shown the biocomposites reduce heat convection of indoor temperature of the traditional wood house. According to previous researcher explains that it is because of the thermal conductivity of certain bio-composite materials is high. Besides it is also proven that cob is one of the bio-composite materials that is good for the cooling effect for green building and it is supported by previous researcher that stated cob has a clear advantage over traditional cement in terms of the environmental impact. It is an order of magnitude better in embodied carbon released, and it does not cause harm to the local ecosystem.

Environmentally, Cob should be the material of choice. It is proven cob building is more environmental friendly, cheaper in production and maintenance cost and having positive social impact on both environment and its communities; hence, cob should be considered as an alternative building material for housing building material.

We found that biocomposites from clay has the most optimum temperature (cooling effect for indoor temperature). Both reading of clay biocomposites combining with Cengal and Merawan wood shows the lowest value than sawdust with coconut fiber composite. The significance of this research rests in the fact that it is able to optimize the performance and efficiency of the wood panel. Besides that, the use of material in the process to produce without having to waste any excessive material.

Besides , the simulations results also shows a positive finding which has been proven its accuracy with only a small range of percentage of difference with experimental results which is below than 5%. The images generated from the CFD simulations shows the result by indicating the temperature using the colour that appeared on the contour f the model. The colour of the contour will change according to the type of materials used. Intensity of the heat transfer was demonstrated clear.

After comparing the percentage of difference between the result of simulation and experimental it is proven that the CFD simulation is an effective tool to predict the thermal contour and distribution of materials that are being tested. Besides by using CFD simulation the time and the cost of experimental method can be reduce.

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