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Thermal Insulation Improvement in Wall using Recycled Cellulose as An Alternative and its Physical Properties

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ABSTRACT

Nowadays, the construction of building industry has evolved its innovation towards the use of materials with regards to sustainability. The innovation is needed in order to ensure cost effective and environmental friendly materials. In ensuring sustainability in construction, renewable resources and less energy consumption are important aspect to be focused in producing eco-friendly materials. In relation to that, recycled cellulose fibre thermal insulation is an eco-friendly thermal insulation material made from recycled fibres available in our surroundings. The paper present the production of four types of recycle materials to be made as thermal insulation products namely as cardboard, newspaper, eggs tray and waste paper. Then, the recycled cellulose thermal insulation will be tested in phase of density, water absorption and thermal properties. According to the experiment result, it showed that newspaper is the most suitable material as main component of recycle cellulose fibre for thermal insulation followed by waste paper. In conclusion, the best recycled cellulose for thermal insulation at wall is newspaper and suitable to be as an alternative for thermal insulation improvement in future.

Keywords:
Thermal insulation; recycled cellulose; green materials; wall insulation

1. Introduction

Thermal insulation is between components of the building, which can decrease heat losses, heat transmitted into building and make building cooler to more energy efficiency [1]. Nowadays, the earth's climate has changed by increase the global mean temperature since the mid-20th century [2]. The increase of global mean temperature is causes by the increases in usage of mechanical appliances for air conditioning because of the comfortable needed with good indoor climate. Hence the energy consumption used will also increase in order to support the comfortable environment indoor of the building. The increase in energy consumption used will then leads to the greenhouse gases emission increase eventually, this repeated cycle action will become more serious if the problem is not be solved [3]. Based on the research at Europe, they found that the most energy saving method and reduce CO_2 emission is install good insulation at building [4].

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The use of thermal insulation to solve problem increase of 7.5% energy consumption in 2012 and rise 6-8% in following year at Malaysia [5]. Besides that, the growth of economic and population causes the increases of textile products. Those processes were bringing impacts of rise the CO_2 emission and toxic pollution. So that, to reduce the impacts of production to environment, the ways is reuse and recycle [6]. In current market, there are exist many types of thermal insulation, which are Extruded Polystyrene (XPS), Extruded Polyethylene (XPE), Polyurethane (PUR) and Polyisocyanurate (PIR), glass wool insulation, cellulose insulation and others [7].

Cellulose is increasing in popularity due to its eco-friendly nature and favorable thermal and acoustic properties. Cellulose fiber insulation is mostly made by ground paper fibers and adds with inorganic additives which improve the thermal insulation function of fire retardants and mould growth inhibitors. [8] Beside that, additional of borate salts, magnesium suplhate and ammonium phosptate also can be added in order to make it more resistance to fire, moulds and fungi. [9] Thus, this research is producing thermal insulation at wall by using recycles cellulose materials, newspaper, cardboard, egg trays and waste paper for the purpose of identify the best cellulose materials for thermal insulation improvement.

2. Materials and Methodology

2.1 Materials and Procedure

Materials collection is carry out to collect the raw materials for recycle cellulose thermal insulation, which are old newspaper, waste paper, cardboards and egg tray. The raw materials then were submerged into water bucket for about 1 hour at first. Then, the materials are stir until its turn into pulp condition. After that, saw dust and flour are added into the pulpy liquids to absorb the water of cellulose and also works as binding agent. The pulp condition cellulose materials then are move into mould to compress into square shape and also to remove the excess water. Lastly the wet square cellulose materials are put into the oven for 2 hours to dry out the water. **Fig 1** below explains the flowchart of the production process of the recycle cellulose.

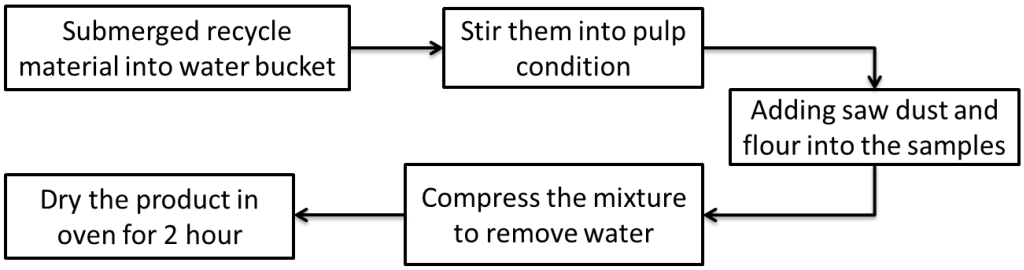

Fig. 1. Manufacturing process for recycle cellulose

2.2 Testing

Density of thermal insulations is determined by using electronic balance with the density formula [10] which is mass divide volume of thermal insulation which is 2.25×10^{-4}.

$$\rho = \frac{m}{v} \text{ kg} \quad (1)$$

Water absorption is refer ASTM C209 Sec. 14 [11], water absorption, 2 hour; Board (cellulosic fiber), this standard requires the thermal insulation to be immersed in water 2 hours, and drained for 10 minutes before weighing for water absorption. Then, water absorption of thermal insulation is calculated by using the formula:

$$\text{Percentage of water absorption} = \frac{|W1-W2|}{W1} \times 100\% \quad (2)$$

The experiment damping temperature a fluctuation using multiple-layered walls is carried out to record the change temperature depends on daytime and night-time and to compare heat transfer between different types of thermal insulation. Thermal insulation is installed at middle phase of the apparatus.

3. Results

3.1 Density

The density of recycled cellulose thermal insulation are out of the range 27 kg/m^3 to 65 kg/m^3 based on ICE Database [12]. This is because the compaction of thermal insulation materials during manufacture process reduced the voids in between the materials. The compaction forces the cellulose materials more close in cell materials and leads to high density of the product. Density of glass wool and polystyrene are in the standard range. The lower is the density of the material; the lower is the thermal conductivity [13]. Thus, the thermal conductivity of thermal insulation will be affect by higher density. The density for each type of thermal insulation is shown at Table 1.

Table 1
Dry Density of Thermal Insulation

Type of thermal insulation	Dry Density of Thermal Insulation (kg/m^3)			
	1	2	3	Average
Cardboard	203.333	239.467	228.089	223.630
Waste paper	174.667	178.578	179.467	177.570
Newspaper	169.600	148.622	156.800	158.341
Egg tray	154.978	155.867	154.178	155.007

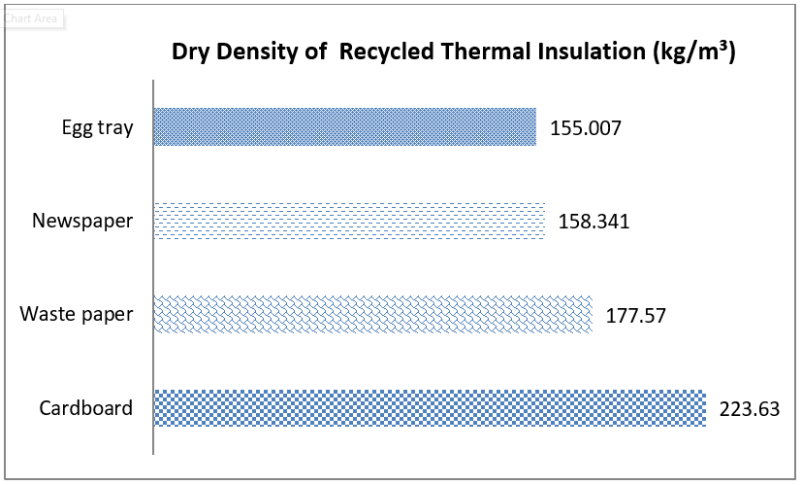

Fig. 2. Average for Dry Density of Recycled Thermal Insulation

3.2 Water Absorption

Water absorption of thermal insulations is showed in Table 2. Water absorption of cellulose thermal insulations is higher than polystyrene insulation and lower than glass wool insulation. The higher the water absorption means that the wall of building will be gain moisture as high water absorption inside the walls. Based on research Bulletin, Absorption, Performance, Plastic, & Insulation, 2011 [11], unless the building insulation is highly resistant to water absorption, moisture can degrade insulation R-value, structural integrity, and provide an essential ingredient to support mould growth. Whether it is a home, a commercial retail building, a school building, or an office, absorbed moisture is to be avoided to achieve sustainable quality construction. Fig. 2. showed that the water absorption of the recycled thermal insulation.

Table 2
Water Absorption of Thermal Insulation by weight (%)

	Moisture Content of Thermal Insulation by Weight (%)			Average (%)
Cardboard	310.667	291.685	302.065	301.473
Waste paper	328.753	322.847	315.255	322.285
Newspaper	323.742	377.691	364.144	355.193
Egg tray	**380.212**	**385.172**	**377.140**	**380.842**

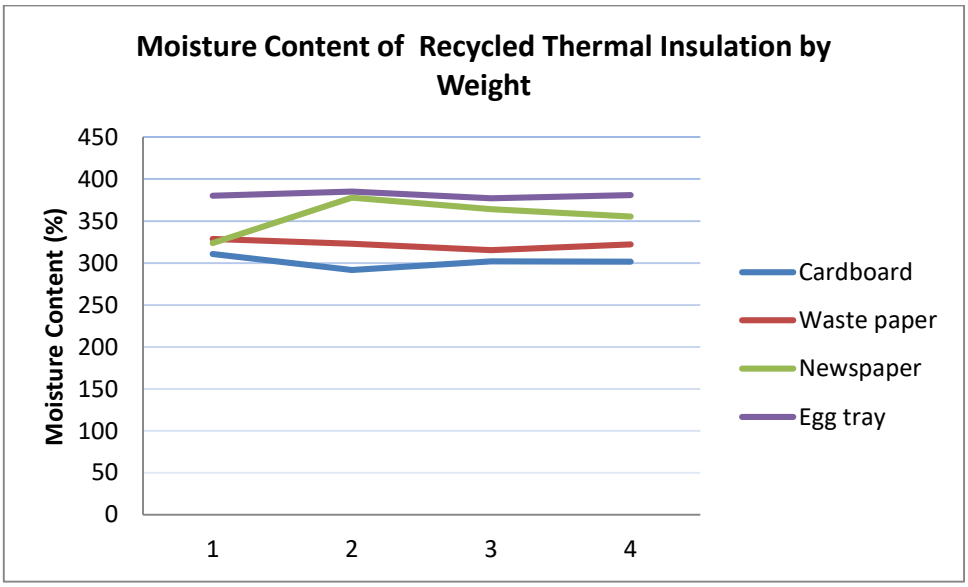

Fig. 3. Water Absorption of Recycled Thermal Insulation by Weight

3.2 Thermal Properties

When illuminated, the outside temperature (outer phase, θ_{A11}) quickly rises while the temperature between the buildings panels (middle phase,θ_{B11}) and the temperature inside (inner phase, θ_{A12}) the calorimetric chamber changes slowly. After turning off the lamps, temperature on the outside (outer phase) falls off quickly. While the temperature of middle phase and inner phase were decrease slowly. There are six different graph and data for 60 minutes testing. Then, to compare between the thermal insulation easily, the table and graph of average value of each phase of thermal insulations is tabulated.

Table 3
Average Value of Each Phase of Thermal Insulation

Average Value of Each Phase of Thermal Insulations				
Types of thermal insulation	outer phase (θ_{A11}) (˚C)	middle phase (θ_{B11}) (˚C)	inner phase (θ_{A12}) (˚C)	Temperature Difference Between Outer and Inner Phase (˚C)
Cardboard	27.841	28.169	26.743	1.098
Waste paper	28.525	27.889	26.085	2.439
Newspaper	**29.310**	**27.946**	**26.385**	**2.925**
Egg tray	28.639	28.298	27.361	1.279

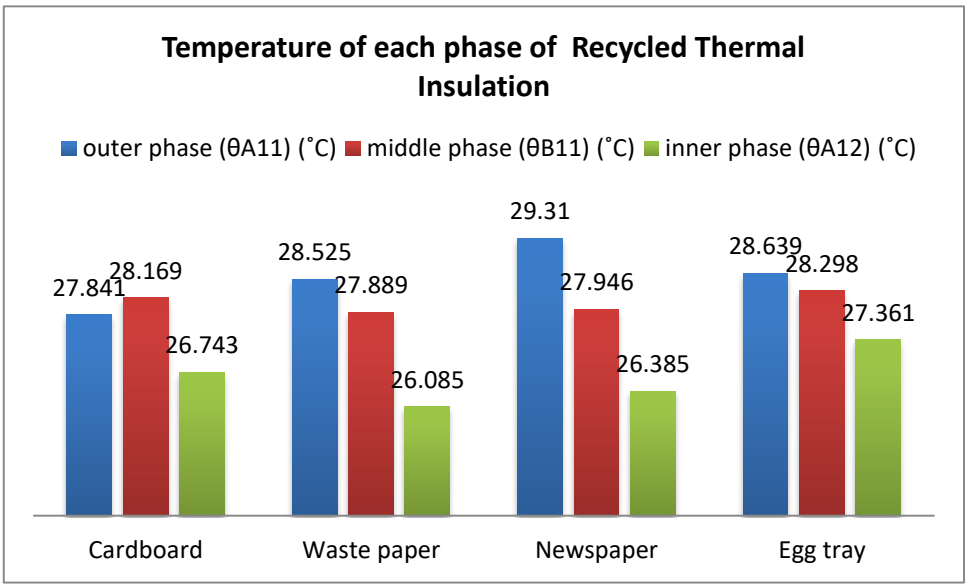

Fig. 4. Average Temperature of Each Phase of Recycled Thermal Insulation

From Table 3 and Fig. 4, the highest temperature difference between outer phase (θ_{A11}) and inner phase (θ_{A12}) is the thermal insulation manufactured by newspaper which is 2.925˚C. While the lowest temperature difference between outer phase (θ_{A11}) and inner phase (θ_{A12}) is the thermal insulation which manufactured by newspaper (1.098˚C) only. Therefore, newspaper is the most suitable material for made recycle cellulose thermal insulation [14]. Research by Hurtado., *et al*., [15] showed that newspaper cellulose fiber insulation thermal properties value is the lowest. However, its properties and performance are depending on manufacturing and method of installation and can be vary slightly.

4. Conclusions

Based form the above data, the best temperature insulated is 2.925˚C, newspaper is the most suitable material to produce as recycle cellulose thermal insulation. However the density and water absorption of recycle cellulose thermal insulation made by newspaper is not very good. Hurtado *et al*., [15] did mentioned that, some improvement and further research need to be explore before optimization of the newspaper into cellulose fiber due to different composition of paper from suppliers for newsprint.

This recycled thermal insulation helps to insulate the heat from outside the building and let the temperature of inner building becomes lower. Hence, the energy used by HVAC can be reduced and the purpose of sustainability in energy efficiency of daily life can be achieved. The recycle cellulose thermal insulation made by newspaper had function of temperature for average 2.9°C. The function of recycled cellulose thermal insulation which insulated temperature can contribute to provide a cooler and more comfortable inner building condition. In relation, less power consumptions used energy efficiency in building can be met. Thus, global temperature can be control and the sustainability aims will eventually also met.

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