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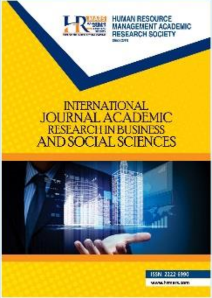

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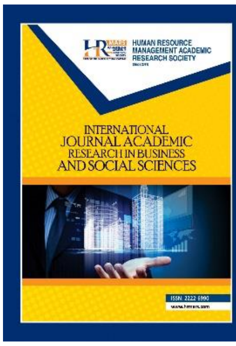

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Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi MARA Perak Branch, Seri Iskandar Campus, Seri Iskandar 32610, Perak, Malaysia

Abstract

Malaysia's building sector undertaking a transformation from old techniques to the Industrial Building System. Nevertheless, thermal comfort must be addressed with the usage of typical concrete that has great heat conductivity. Despite that, the major purpose of this research was to investigate the cooling influence of Eco-waste concrete wall panels utilizing a hybrid fruit waste binder. The growth of the idea of creative goods is towards ecologically friendly which waste is employed in the manufacturing of products. A literature review is a strategy used to find flaws and difficulties in current wall panels. Further, the study approach was quantitative, where the data are acquired through laboratory experiments and fieldwork. Additionally, data gathering techniques concentrate on document analysis, observation, experimentation, and prototype to address the research questions and attain research goals. The data gathered demonstrates that the innovative product effectively delivers thermal comfort to the occupants. With the findings produced the innovative product has marketability potential.

Introduction

In the construction and design industries, structures that develop are walls which are described as vertical structures that connect, separate, and protect the space in a building. In addition, the wall structure which is the greatest structural element that can be categorized into two that are exterior and inner walls. The outside wall aids in giving security and seclusion while the inner wall divides the area into rooms preferred by the owner (Krishna, 2019). However, the true objective of a wall construction is to support the roof, floor and ceiling where the living load on the roof will be transmitted to the wall or column and distributed on the foundation supported by the earth underneath it. In 2 typical approaches, the wall structure is constructed using bricks with cement mortar although the usage of this method is less successful in obtaining high quality. Besides, it leads to protracted building periods, high construction expenses owing to spending on manpower, raw materials, transportation, and prolonged construction time (Thomas et al., 1994).

Subsequently, the most important consideration for the occupant in building design is thermal comfort as it guarantees increased morale, productivity, health and safety. Here, the selection of building materials are the 3 major and prime controls in maintaining the thermal comfort of occupants other than selection of site, orientation of building, vegetation, choice of thermal mass or thermal insulation for the particular climate. In line with Malaysia's dependence on concrete materials in the construction of buildings, the performance of concrete in terms of properties and sustainability requires the implementation of new ideas to lower the thermal conductivity of concrete and reduce global industrial carbon dioxide (CO2) emissions. Alternatively, the US Portland Cement Association recommended the use of supplementary cementitious materials (SCMs) as a cost-effective way to reduce carbon dioxide emissions from concrete production (Portland Cement Association, 2004). Nevertheless, the problem of inadequate waste management system causes a large amount of solid waste material generated by the agricultural industry cannot be processed properly and become a burden to the environment and health issues. Therefore, to address the problem, this waste material can be incorporated into concrete in order to help reduce the environmental impact as well as be a substitute for cement.

Recently, in improving the properties of concrete and cement mortar researchers have focused on the use of agricultural waste as a partial replacement for cement mixes (Mukhtar et al., 2018). In this study, the agricultural waste will be used as a partial replacement for Ordinary Portland Cement 4 (OPC) to observe the effect in terms of the cooling properties, compressive strength and durability. The energy savings of the building can be minimized by using materials with low and moderate thermal conductivity. Hence, this paper explores and reviews the cooling impact of eco waste on concrete wall panel using hybrid fruit waste binder.

Literature Review

Global warming is a never-ending issue that continues to pose a threat to the planet resulting in a variety of severe environmental impacts. The cause of this warming is greenhouse gas (GHG) emissions, especially carbon dioxide (CO2) emissions (Majid et al., 2017). On a global scale, buildings contribute 30-40 % of primary energy to maintain a comfortable indoor climate (Diaz et al., 2013). Here, to provide comfortable indoor climates, the use of air conditioner and fans is an alternative way for occupants where all of this consume electrical energy (International Energy Agency, 2002). Thus, increased energy demand leads to increased greenhouse gas emissions, which contributes to increased global warming and energy costs (Majid et al., 2017). In order to reduce the consumption of electrical energy in the building, the researchers used an environmentally friendly passive cooling system to solve the thermal problem. Based on a case study in Burkina Faso, Coulibaly that wanted to apply buildings without air conditioning and a mechanical ventilation system, a bioclimatic approach was taken to reduce thermal discomfort by using high heat capacity building materials such as clay bricks, mud bricks, concrete blocks or compressed earth blocks (CEB) which absorb heat from solar radiation at a slower rate and make these materials ideal for preventing rapid heat transfer (Hema et al., 2020). However, this research contradicts to the researchers who stated that the insulation material showed better performance on the thermal performance of the building in a hot-dry climate especially placing the insulation layer outside of the building envelope. Further, the phase change materials (PCM) were introduced as one of the building temperature control methods in the daily life cycle where the material will store and release heat through latent heat within 24 hours then change and discharged into heat (Majid et al., 2017). Typically the PCM used to build cooling or heating is a solid-liquid variety (Sun et al., 2016). Although PCM is a method of controlling building temperature, PCM has drawbacks in terms of cost, lack of thermophysical investigations for commercial applications, and chemical and thermal instability (Nazir et al., 2019). Furthermore, the application of PCM in building materials faces segregation problems due to leakage and difficulties in moisture transfer across the enclosure (Pasupathy et al., 2008). After all, the recommendations encourage the use of biopolymers to promote sustainability such as cellulose or nanocellulose that are environmentally friendly and readily available (Sivanathan et al., 2020).

Global fruit production exceeded one billion tonnes in 2017, resulting in a large amount of waste and by-products (Food and Agriculture Organization of the United Nations, 2021). Regard, the rapid economic growth in Malaysia is the source of the cultivation of various types of vegetables and fruits, however, the result of fruit waste due to high consumption and industrial processing such as the production of canned fruit, fruit juice, and flavouring, result on excessive peels and seeds that are not used to be waste (Ibrahim et al., 2016).

Here, fruit waste is not suitable for incineration because of the moisture content, and high organic components produce seepage solution in layers or landfills leading to serious environmental pollution (Viturtia et al., 1989). Thereby, fruit waste is converted into treasure and resource utilization in an effort to develop sustainable building materials, and improve environmental pollution (add up commercial). Previously, fruit peels which are a waste were used as food packaging in producing sustainable and environmentally friendly packaging. Llignocellulose wastes from the agroindustry Prunus avium are applied in the manufacture of particle boards because the hardness of the pit is similar to wood sawdust particles, and the fiber of the peduncle is similar to wood lignocellulosic fibre (Hernández et al., 2020). In brief, the increase in fruit waste and its properties is believed to create an innovation of eco waste concrete wall panels using hybrid fruit waste that can reduce the thermal conductivity of concrete and increase thermal comfort in the building. Moreover, fruit waste has added value in terms of increased strength and durability of concrete which results in the eco-waste concrete wall panels produced having a good overall quality of the finished product which reduces maintenance and repair.

In particular, the selection of fruit waste is based on a study of relevant literature along with the type of fruit and the application of fruit waste in the industry. Previous studies have mostly focused on fruit waste as a replacement for cement, the reason cement production uses 12-15% of the world’s total energy and contributes 7% of CO2 emissions due to the process of decomposition of carbonates into oxides during cement production which leads to global warming (Ali et al., 2011). The replacement of cement with organic waste or more specifically fruit waste must go through a chemical reaction decomposition process that later will form a powder to be used as a building material (Izquierdo et al., 2018). Obviously, past studies have applied orange peel in the green building sector as a new sustainable product. In the study by (Raciti et al., 2020), orange peel waste is used as insulation to minimize heat loss in winter and provide maximum cooling in summer which results in significant energy savings by lowering heating and cooling costs. Further, the use of orange peel waste as insulation has a high possibility according to the analysis because of the chemical and physical properties of orange peel waste as shown in table 2.5. Apart from insulation, the orange peel has been processed to produce boards with good thermal insulation and high sound absorption. The study examined by Vitale et al (2021), stated that the collected orange peel has the characteristics of 200- 300 kg/m³ _for bulk density, varied water content, and two different layers causing the boards to show high results for thermal conductivity compared to commercial boards. Indeed, the result obtained in the production of boards is contributed by the chemical composition of the orange peel which consists of cellulose, pectin, sugar, acids, lipids, mineral elements, essential oil, and vitamins (Bampidis et al., 2006; Llano et al., 2008; Satari et al., 2018; Zema et al., 2018; Vincenzo et al., 2019). In regard to chemical and physical properties of orange peels, there are several types of fruit that have been shown through research to have similar properties to orange peels. Here, fruits such as mango, banana, citrus, papaya and lime that are formed with peels that cannot be digested or absorbed in human intestine will be converted into fiber based on the main composition of the peels which is non-starch polysaccharides and lignin (Wanlapa et al., 2015). Moreover, the peel of the fruit mentioned has main components such as pectic polysaccharides, gums, cellulose, lignin, and hemicellulose. As recommended by Mattos in the study, materials containing cellulose or lignocellulose have good potential as filler or reinforcements, not only having an advantage of being lightweight, low cost, easily recyclable, being non-abrasive to machinery, having non-brittle fracture yet cellulose and lignocellulose materials have low thermal expansion (Mattos et al., 2014).

In whole, orange, mango, and papaya are the fruits selected to be employed in the study because of their cellulose composite combined with chemical and physical qualities as discussed above that create cooling when used as construction materials. The combination of the three varieties of fruit in this research will minimize the considerable quantity of organic waste in landfills and provide green construction materials that reduce CO2 emissions to the environment.

Here, the use of agro-waste in the production of building materials is less developed yet conventional building materials that have issues with global warming are the cause of the development of alternative materials. Tea waste has been mentioned in studies used in the production of particleboard but not on a large scale. It was found that the addition of 5% PWT into bricks has illustrated effectiveness with an increase in strength properties along with an increase in porosity and bulk density to unfired and fired bricks. According to Cao et al. (2021), the success in improving the thermal insulation properties is due to the porous structure and high absorption capacity of tea waste resulting in a material suitable for controlling hydration and high internal temperatures.

Additionally, tea waste is used in high-strength mortars (HSMs) and high-strength concretes (HSCs) to slow down hydration which affects early age shrinkage (Jakhrani et al., 2019). Early age shrinkage causes exceptional brittleness, low tensile strength, and high cracking thus limiting the application of HSMs and HSCs in mega construction projects (Pacheco et al., 2019). The result of the study for the measurement of interior temperature and hydration for five mixes using the semi-adiabatic method for 40 hours showed that the peak maximum temperature for the maximum of tea waste was slightly lower than the control mix or the conventional mix. The delay in hydration occurs due to the increased need for water when tea waste is added where the water contained in the HSCs and HSMs will be released from the pores of the tea waste during the hydration process to form complete hydration (Gupta et al., 2015). Overall, tea waste or processed waste tea has the potential to provide thermal comfort and slow hydration through its porous structure, water content, and absorption.

Methodology

In making the new product Eco-Waste Concrete Wall Panel, the experimental work employs materials such as cement, coarse and fine aggregate, water, silica fume (SF), fruit waste (mango, papaya, and orange peel), waste tea bag, and superplasticizer (SP).

Cement, coarse and fine aggregate, water, silica, and SP are the main ingredients in concrete. The ordinary Portland cement (OPC) type I conforming to MS: EN 197-1:2007, coarse aggregate with a size of ¾ or 0.75 inches, and natural river sand as fine aggregates were used in the experimental work. Next, SF with ASTM C1240-20 specification was used to help reduce bleeding and improve bonding between the main ingredients, fruit waste, and teabag waste. All the materials are available in the laboratory and used in the same way as in construction. Meanwhile, Conplast SP2000 Type G which complies with BS 5075, BS: EN 934-2, and ASTM C494 is a liquid mixture used to produce high-strength concrete for workability retention at low water content. This SP is obtained through an authorized supplier on an online platform in small quantities. As for mixing and curing of concrete, supplied tap water was used.

The fruit skin will undergo a burning process which will be placed in the oven for 45 minutes to 55 minutes depending on the thickness of the skin at a constant temperature of 200°C. This process aims to get rid of the moisture content in the fruit skin. The skin of the fruit will change from its original colour to dark after going through the burning process. After that, the crusty fruit skin is ground into powder form and sieved to obtain the desired size. The waste tea bags will then be separated to get the tea fiber in the bag before being dried. The tea fiber is dried in an oven at a temperature of 100°C for 20 minutes to remove moisture content and change the appearance of the tea fiber to ash. The ash will be cooled to ambient temperature and then sieved to remove coarse particles.

The concrete samples were designed with a ratio of 1:0.75:1.5 by mass of cement: sand: coarse aggregate, fruit waste, waste tea bag, and silica fume (SF) were used as a partial replacement for cement at 0% (control), and 5% of cement. Table 1 shows the mix proportion for concrete samples by weight (kg). In order to obtain a strong concrete bond with a compressive strength that meets the standard, several trial mix proportions were performed. Subsequently, the SP: cement ratio was 1.7% and the amount of SP allowed in the mixture according to the Fosroc guidelines is between 0.5% to 3%. The quantity of SP to be used is calculated from the weight of the cement. Additionally, SF replaces 5% of the total amount of cement as well as fruit waste and waste tea bag.

Table 1
Mix proportions of studied specimens

Mix Design	Waste Tea Bag (kg)	Fruit Waste Powder (kg)	Cement (kg)	Fine Aggregate (kg)	Water (kg)	SP (kg)	SF (kg)
Control	-	-	1.429	1.126	2.251	0.735	0.015
5%	0.075	0.075	1.279	1.126	2.251	0.735	0.015

Thereafter, the obtained mixed design was used to produce four sample cubes with plastic mold size of 100 x 100 x 100 mm. Concrete is mixed by hand with trowel equipment. Start by mixing dry materials such as cement, sand, SF, fruit waste, waste tea bags, and coarse aggregate until the colour is even. Then, pour 50% of the total water into the dry mixture and followed by the remaining water mixed with SP. This is to ensure that the SP can function properly. Followed by putting the concrete mixture into a mold that has been greased with oil. The concrete mix must be placed into the mold in three layers with each layer vibrating for 30 seconds. Upon completion of vibrating the concrete surface on the mold should be levelled. For this experiment, the concrete takes more than 24 hours to harden, unlike normal concrete. An addition of 6 hours is required and after that, the concrete cube is removed from the mold to be submerged in water for the curing process.

There are three tests namely compressive strength, water absorption, and density. The priority of the test is on compressive strength which determines the quantity of fruit waste and waste tea bags in the concrete that influenced the structural behavior. Additionally, water absorption to test the durability of concrete with the existence of fruit waste and waste tea bags as a partial replacement of cement.

Four specimens with the size 100 mm x 100 mm x 100 mm were prepared and tested on the 7th and 28th day of water curing to obtain a significant increase in strength, as per ASTM C192 and C39. Subsequently, this test used a Universal Testing Machine (UTM) to obtain a maximum load (kN) and compressive strength (MPa) of concrete. The density of hardened concrete is determined using either simple dimensional checks, weighing, and calculation, or weight in air or water buoyancy methods (ELE International, 2019). The first step in water absorption test, a 100m^3 _specimen cured for 28 days was dried in an oven at 110°C for 24 hours (Plate 3.12). The purpose is to dry all the water contained in the specimen to obtain a net weight (Plate 3.13). After 24 hours, the specimen was weighed and the weight was recorded. Then, immerse the specimen in a water tank for 35 minutes to obtain the weight of the specimen that has permeated the water. Thereafter, the specimen was weighed and recorded to obtain the difference in weight value. Tests against temperature, relative humidity, and wind speed aim to achieve the second objective and prove the effectiveness of innovative products through built prototypes. This test uses three units of 4 in 1 meter to obtain external environmental data and internal data for normal concrete and eco-waste concrete in an open area for 1 hour starting at 1100 am to 1200 noon with a reading gap of 10 minutes in a 90° position. The test is conducted to obtain temperature, relative humidity, and wind speed data for exterior and interior was done simultaneously.

Analysis

Laboratory tests present the results of compressive strength, density, and water absorption on the specimens whereas field tests comparing two types of prototypes give results for thermal comfort focusing on temperature. Graphs and charts of data were generated for analysis followed by discussion. Through the results of both tests, the performance of the innovation product is proposed for the purpose of marketability.

The tables show the result of the investigation conducted on normal concrete and eco-waste concrete related to air temperature, relative humidity and wind speed along with maximum, minimum and average values. Along with the laboratory result of compressive strength, density and water absorption.

Table 2
Result of the investigation outdoor

Time	Air Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)
1100	30.4	69.8	0.0
1110	30.8	69.4	0.0
1120	31.1	67.9	0.0
1130	30.9	67.5	0.0
1140	31.4	64.4	0.8
1150	31.4	67.1	0.0
1200	31.5	65.1	0.8
Minimum value	30.4	64.4	0.0
Maximum value	31.5	69.4	0.8
Average value	31.07	67.31	0.2

Table 3
Result of the investigation indoor normal concrete

	Normal Concrete			Eco-Waste Concrete		
Time	Air Temp (°C)	Relative Humidity (%)	Wind Speed (m/s)	Air Temp (°C)	Relative Humidity (%)	Wind Speed (m/s)
1100	29.8	76.3	0.0	29.9	73.4	0.0
1110	30.4	75.5	0.0	30.1	74.0	0.0
1120	30.7	72.6	0.0	30.3	72.5	0.0
1130	31.1	74.1	0.0	30.3	71.7	0.0
1140	31.5	74.5	0.0	30.3	69.4	0.0
1150	31.8	74.6	0.0	30.5	71.5	0.0
1200	32.0	73.3	0.0	30.6	71.5	0.0
Minimum value	29.8	72.6	0.0	29.9	69.4	0.0
Maximum value	32.0	76.3	0.0	30.6	74.0	0.0
Average value	31.0	74.4	0.0	30.3	72.0	0.0

Table 4
Result of Compressive Strength Test

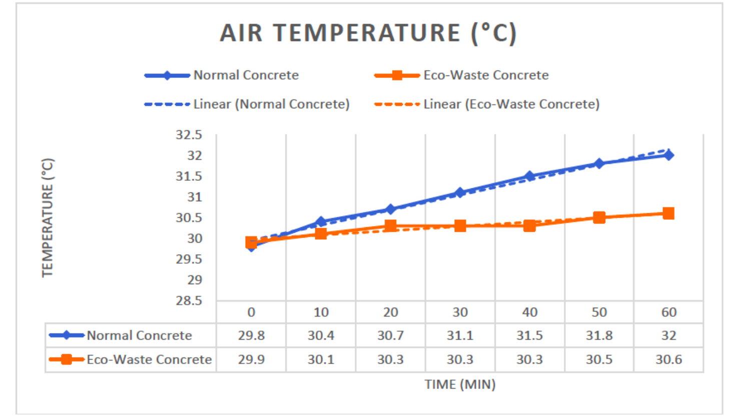
Mix Design	Replacement %	Compressive Strength (MPa)	
		7 days	28 days
Control	0	19.0	31.7
M - 1	5	11.7	23.8

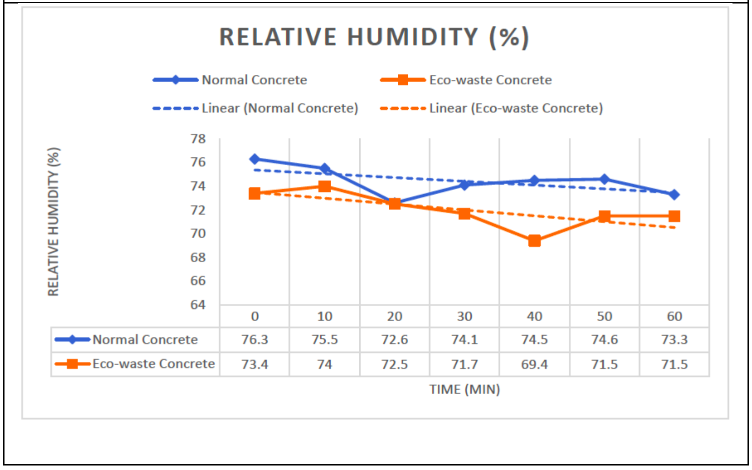
Table 5
Result of Water Absorption Test

Mix Design	Replacement %	Dry weight (kg)	Weight after immersion (kg)	Absorption value (%)
Control	0	2.151	2.193	1.95
M - 1	5	2.062	2.210	7.18

Table 6
Result of Density Test

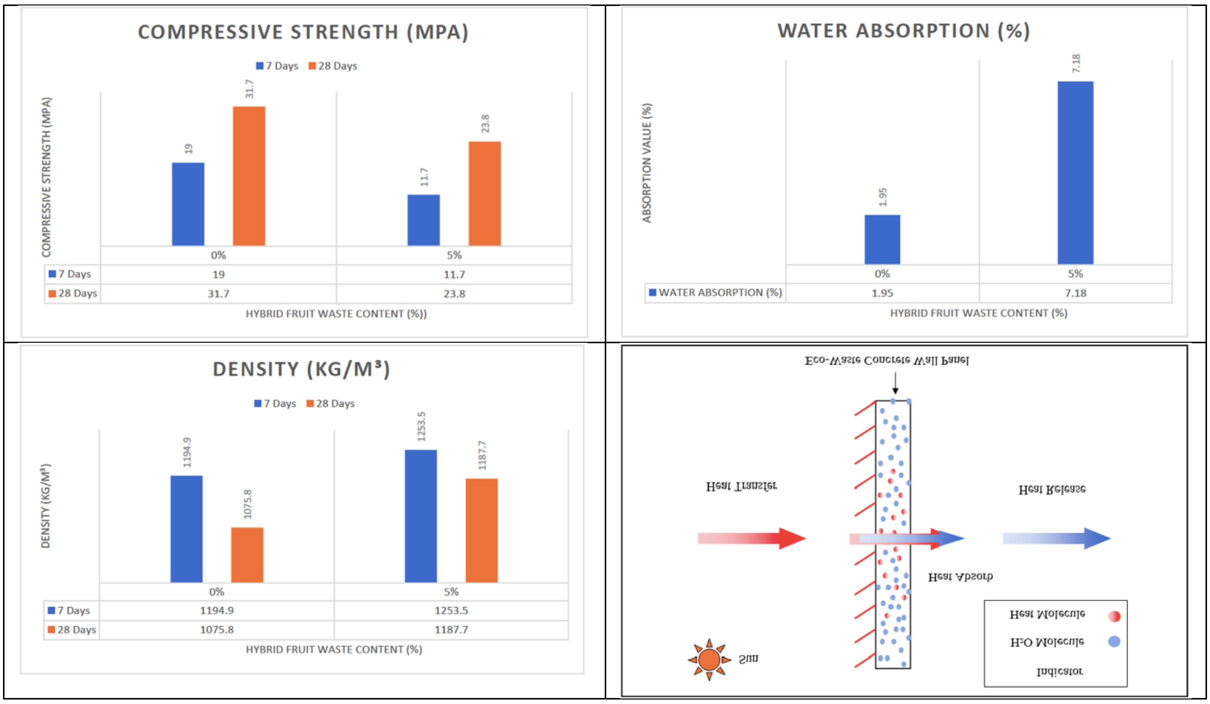
Mix Design	Replacement %	Density (kg/m3)	
		7 days	28 days
Control	0	1194.9	1075.8
M - 1	5	1253.5	1187.7





The level of relative humidity achieved is at a comfortable level and is capable of reducing heat directly to humans. Nevertheless, relative humidity decreases slowly, and in short relative humidity decreases as the temperature increases. In addition, the presence of wind affects the humidity where the flowing air will evaporate the amount of vapor in the air. It was proved that the presence of air at 40 and 60 minutes lowered the relative humidity to a low level. The average obtained exceeds the average exterior relative humidity of 74.4%. Although the temperature continues to rise it does not affect the relative humidity because the interior air speed plays an important role in obtaining high relative humidity.

In contrast to Eco-waste concrete, the interior temperature is remarkably consistent where it is slow to respond to the outdoor climate. Partial replacement of cement in concrete mixes is a major reason. As much as 10% cement replacement is done where 5% is fruit waste and 5% is a waste of tea bags. Obtained the average interior temperature of Eco-waste concrete is 30.3 and the maximum value is 30.6. The maximum value for the internal temperature of Eco-waste concrete has a large gap with normal concrete of 1.4. This value is to some extent able to affect the comfort of the occupants. Subsequently, the relative humidity for Eco-waste concrete obtained an average of 72 which is the acceptable level. Nonetheless normal concrete has a high relative humidity of 2.4% but the high relative humidity rate can cause issues with the growth of mold and cause symptoms for those with asthma and allergies. Then, the wind speed obtained is similar to normal concrete which is 0 m/s. This is because the Eco-waste concrete is similarly designed to the normal concrete without an opening.



On the 28th day, the compressive strength of the control concrete and 5% HFW experienced a significant increase of 31.7 and 23.8. Through the findings, the control concrete has no trouble in obtaining the value of compressive strength in accordance with the grade utilised for the mix. However, the compressive strength of 5%HFW does not reach the set grade standard of more than 30 MPa yet the minimum compressive strength for concrete structure applications, SNI 2847-2019, was met which is 21 MPa. The filler effect and pozzolanic reaction of HFW after 28 days of curing became the cause of the compressive strength unattainable by 5%HFW. Another possible explanation for the decrease in compressive strength was the increase in air voids due to the fresh mixture's lack of plasticity when concrete is replaced with HFW.

Water absorption of normal concrete and Eco-waste concrete was conducted on the 28th day with a time period of 35 minutes immersed in water. Here, the weight difference between the two concrete is 0.017 kg. This proves that foreign materials in concrete affect absorption in which normal concrete only absorbs less water compared to Eco-waste concrete in a period of 30 minutes. Clearly through the calculation of the absorption value, control concrete only absorbs 1.95% whereas Eco-waste concrete absorbs 7.18%. A percentage difference of 5.23% states that Eco-waste concrete is characterized as porous which allows high water absorption due to high porosity. In general, high-water absorption and porosity will reduce the compressive strength of concrete.

Discussion

The Eco-waste concrete wall panel is designed with a simple concept through the partial replacement of cement to reduce the temperature of the interior. Basically, concrete is known to have a high potential for absorbing heat from direct sunlight due to the presence of materials such as cement and aggregate. The stored heat will be released gradually and the capacity of the concrete, in this case, is called the thermal mass. Therefore, theoretically, the total percentage of water absorption in Eco-waste concrete wall panels is able to reduce the temperature because the heat absorbed from sunlight must pass through water molecules and bonds before it can be released into the interior. Thus, it will stabilize the internal temperature to a minimum to achieve thermal comfort. This can be related to the term heat sink which applies a fluid medium that is liquid and air to dissipate heat from a device so the device remains at the allowable temperature.

The green building concept focuses on the development of innovative green materials which provide an opportunity for a growing and competitive market. In construction, wall structures play an important role in providing protection, security, and privacy. Despite the function, the wall surface receives a lot of direct sunlight which is then converted to heat. Generally, heat absorption stems from building materials. Afterward, the absorbed heat will be released into the building space which becomes the major cause of the dependence on mechanical ventilation which are fans and air conditioning. In addition, Malaysia’s hot and humid weather throughout the year makes mechanical ventilation a necessity in buildings, especially for those living in major cities. The issue of non-environmentally friendly building materials and dependence on mechanical ventilation in building led to the innovation of green materials in the precast concrete wall. The innovative product of Eco-Waste Concrete Wall Panel focuses on the main material of concrete which is cement. Partial replacement of cement in the mix proportion helps in lowering the heat absorbed and stabilizing the temperature in the building. As a result, thermal comfort is achieved by consumers where the building space is neither hot nor too cold.

Conclusion

The problem of worldwide energy expenditure and overall energy consumption in buildings is the greatest concern notably in the construction business. The extensive use of concrete in construction is a key driver in the growth of the interior temperature of buildings. Hence, this research focused on the cooling influence of Eco-waste concrete wall panels employing a hybrid fruit waste binder. The innovation was made to solve the problem of thermal comfort, particularly in Malaysia which endures hot and humid throughout the year. The use of fruit waste and waste tea bags in the concrete mix may maintain the temperature in the room and with porous features can boost the rate of air movement in the structure. This is shown by fieldwork and laboratory studies on six specimens and prototypes. Through field study done the temperature for Eco-waste concrete wall panels is constant and not influenced by the external temperature.

Motivation and Contribution

Based on the study and findings, this research may give a contribution to the society and to the world in conserving natural resources, reusing a sustainable materials and following with the globally spread trend of sustainability, the modern 4R concept of waste management promotes: reducing waste at the source, reusing elements and their parts, recycling to produce raw materials, and recovering embodied energy. Reuse and recycling also reduce the amount of waste material produced and the demand for limited landfill space, as well as the extraction of new natural resources and the negative impact of their exploitation.

Corresponding Author

Muhammad Naim Mahyuddin
Department of Built Environment Studies and Technology, College of Built Environment,
Universiti Teknologi MARA Perak Branch, Malaysia
Email: naim7917@uitm.edu.my

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