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An Innovative Prototype of Insulated Lightweight Wall Panel

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Abstract
The construction industry's growth significantly affected the environment. Since global warming occurred, the drastic change in the weather has threatened the lives of living things. As a result, the effort to reduce the impact of global warming and construction work on the environment must be taken. This research introduced an innovative prototype proposed as an insulated lightweight wall panel. This research aims to produce an innovative product using sugarcane fibre as the insulation material. This research was conducted by assembling the prototype to test the prototype's performance. The result obtained by the experiment that was carried out meets the objective of this research. Finally, with the excellent performance shown by the product, this product has the potential to be introduced in the current market.
Keywords: Insulated, Lightweight, Wall Panel

Introduction

Environmental pollution is a global problem that continues to hit people worldwide. Of late, many efforts have been suggested to deal with the situation. Green House Gas (GHG) emission was one of the environmental pollutions caused by energy usage, vehicle movement, solid waste creation, and disposal and electricity generation (Aziz et al., 2012). The impact of the GHG emission was climate change, mainly global warming, which has made many people worry due to this harmful impact. Moreover, GHG emissions significantly affect the composition of the Earth's atmosphere. Therefore, a large amount of investment is needed to reduce the emission rate in the atmosphere. Hence, there is a growing need for high-quality environmental sustainability to adapt to the harmful effects of unavoidable climate change.

The development of lightweight, industrialized and sustainable building components is a need to this day. The present precast wall panel that is usually used in the construction industry focus on the use of cement as load-bearing walls are heavy. This problem involving the weight of the component will have another impact, such as difficulty handling the component and a significant risk to the workers during the work. The ability of the wall to resist heat from sunlight is considered for the prototype to see whether this proposed innovation will give an advantage in the construction materials.

Literature Review

Since the world faces global warming, the innovative product of precast wall panels has become more popular to support the implementation of the Industrialized Building System (IBS). A precast wall panel is a product of an industrialized building system (IBS) that provides the minimal working process at the construction site. For example, there was a sandwich wall panel, a lightweight wall panel, and an insulated wall panel. Although these products are produced to improve the quality of the thermal comfort in the building, the mass of these products is high due to the use of concrete (Naito et al., 2010). When the wall component is high in mass, it risks the workers responsible for handling and installing the part during the construction process that led to the accident.

Furthermore, the usage of the existing precast wall panel provides a high cost for the small-scale project because of the price of each component. The high cost of purchasing the component is due to the high labour cost during manufacturing (NAAMAN, 2006). For example, a Ferro-cement wall panel contains wire mesh. It needs the proper skill to pour concrete into the mould because improper pouring work prevents concrete segregation. Hence, the manual repairing work will cause the time taken to produce that product to be longer, so the cost will be higher. Then, the addition of work done after the component is brought out from the mould will affect the strength of the element and the bonding between the insulation materials with the concrete.

Thermal Insulating Concrete Wall Panel

The thermal insulating concrete wall panel is a sandwich of concrete and gypsum wall that is built for economical and able to achieve better thermal insulation performance of building envelopes. The sandwich concrete and gypsum wall panel are designed by adding the gypsum in the middle between the inner and outer layers of concrete. This wall panel uses gypsum as the insulating material because, compared to other polymer materials, gypsum provides an excellent thermal mass, and the thermal mass of the overall wall panel has increased. Furthermore, gypsum is one of the green materials that did not affect
The environment provides dependable thermal performance. Moreover, the extruded polystyrene concrete sandwich panel is also used in the existing industry, where two concrete layers sandwich extruded polystyrene. The proposed sandwich concrete and gypsum wall panel are designed for residential buildings, especially low-rise housing. Hence, the strategy implemented in this new wall is to save the amount of energy usage that can affect the environment (D'Agostino et al., 2019)
Implementing this sandwich of concrete and gypsum wall panel provides consumers with many benefits. Firstly, the shape and dimensions of this precast sandwich wall panel unit can be standardized to support mass production for the faster construction process, which means that this sandwich wall panel is economical. With these benefits provided, it has been adopted worldwide, and it is expected that precast concrete panels' thermal insulating performance will further increase precast units' popularity in building construction. Secondly, the advantages of this sandwich wall panel coming from the gypsum material are applied because the gypsum is very broad in the construction industry due to its low cost, and it is

easy to get due to its high availability. Moreover, gypsum is very popular with its environmentally friendly characteristic of low embodied energy (Vimmrová et al., 2011).

Novel Insulated Concrete Wall Panel Reinforced with Glass-Fiber Reinforced Polymer Shear Grids

Insulated concrete wall panels generally come out with two layers of concrete for the outer and inner layers. Many types of insulated concrete wall panels have been introduced in the construction industry, but there are still for the same reason, which is for thermal and structural efficiency. In this product, the Expanded Polystyrene Foams (EPS) are applied as the inner layer of the insulated concrete wall panel because it has high thermal performance and workability. Moreover, the energy-saving effects are higher than those of fibreglass under the same environmental conditions (Ekici et al., 2012). The insulated concrete wall panel is categorized as the non-composite wall panel. The inner and outer concrete layers behave independently. The inner and outer concrete wall panels are interlinked with various shear connectors made from concrete, steel, or fibre-reinforced plastic (FRP), including carbon, glass, and aramid fibre composites.

This product's insulated wall panel is reinforced with glass-fibre-reinforced polymer shear grids (GFRP). The role of the GFRP is to enhance the composite action and reduce the energy loss by the thermal bridge. The advantage of applying the GFRP is that this shear connector shows higher strength and stiffness than the other polypropylene. Hence, there was an experimental test on four-point bending about this shear connector. The result shows that the flexural strength of the panel was 80% of the theoretical power of the fully composite panel (Tomlinson et al., 2014).

Furthermore, instead of installing the shear connector in the sandwich wall panel to provide strength, it also has another advantage: low conductivity, lightweight, and anti-corrosive. The thermal conductivity of GFRP is only 1/200 that of steel, which prevents the occurrence of a thermal bridge or condensation in the existing system by a steel stud penetrating the insulation layer. However, although the GFRP provides advantages to the sandwich wall panel, it still has its disadvantage. The bonding between concrete and insulation needs to be improved when applying the GFRP because when there is a problem with its bonding, it can affect the strength of the sandwich wall panel.

Lightweight Ferro-Cement Wall

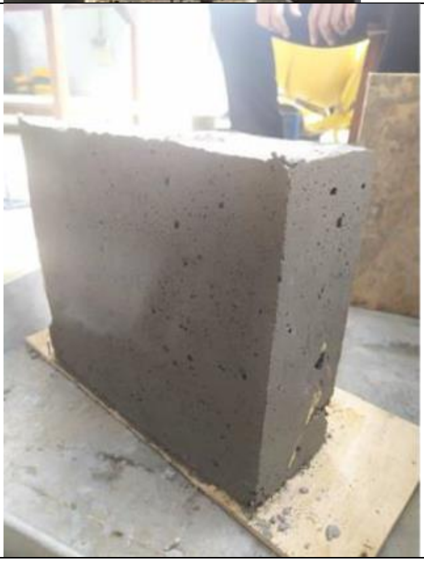
Ferro-cement is a construction material that is a relatively new cementitious composite. Hence, it was a thin-walled reinforced concrete often made from cement mortar and tightly spaced layers of continuous fine wire mesh (Rashid et al., 2019). Ferro-cement reinforcement is precisely spaced and consistently distributed, transforming the ordinarily brittle material into a better ductile composite. As a function, Ferro-cement has considered an elastic building material with unique strength and serviceability features. No other thin building material can match its advantages in terms of strength, toughness, water tightness, lightweight, durability, fire resistance, and environmental stability (NAAMAN, 2006). Hence, Ferro-cement is a promising composite material in the construction industry (Suresh, 2004). The lightweight Ferro-cement wall aims to solve the thermal problem in the building due to the weather change and to solve the issue according to the heavy construction component.

The Ferro-cement provided several advantages. Firstly, the Ferro-cement has an excellent tensile strength property. Moreover, Ferro-cement can be fractured, but the cracks in Ferro-cement under service loads are tiny and better than the reinforced concrete (Arif et al., 1999). Next, the advantage of the Ferro-cement is its strength. It has a good strength that can carry more loads. Ferro-cement is adequate to resist the impact due to its higher ability to absorb impact energy than conventional reinforced concrete.
According to Abdullah and Takiguchi (2002), the strength enhancement of Ferro-cement confinement achieved up to 20% to 30. However, the Ferro-cement also has its disadvantage, which is less economical due to the higher cost. The high cost of implementing Ferro-cement products is because of the labour-intensive nature (Yardim, 2018). Since the thickness of the Ferro-cement ranges between 10mm and 30mm and contains the wire mesh, this often results in reinforcement congestion and poor concrete quality in the end product if the elements are produced by the method of pouring. Hence, this brings the standard method applied in the construction of Ferro-cement is by manually plastering the wire mesh with cement mortar in three stages that not only affect the cost but also the time in production work is longer.

Experimental Materials and Method
Two materials are used in fabricating specimens: concrete and sugarcane bagasse as the insulation material. A recent experimental study, which investigated the thermal conductivities of different materials used in construction, showed that concrete possesses the worst thermal resistance compared with masonry brick and red clay brick (Zhou et al., 2014). Although precast concrete is not the best for thermal insulation, it is still one of the most extensively used construction materials in practice because of the following advantages (Vizcayno et al., 2010).
The test specimen for this research is a sandwich concrete/sugarcane bagasse wall panel. The panel contains a sugarcane bagasse layer inside the precast concrete.

Table 1
The Procedure for producing the innovative product.

No	Description	Figure
1	Dry sugarcane bagasse compacted into the shape of an innovative product (200mm x 20mm x 200mm)	

2	Preparation of the formwork for the test specimens prepared.	
3	Preparation of the concrete mixture to be poured into the formwork.	
4	The concrete was poured into the formwork.	
5	Prototype of precast concrete wall panel	

6	The prototype is placed under the sun at 8.00 am. The temperature of the prototype is recorded every two hours until 8.00 pm.	
7	Every two hours, the temperature of the prototype is recorded, and the data is saved.	

To determine the thermal insulation performance of the innovative prototype and conventional concrete wall, a series of heat transfer tests was performed to measure the temperature variation across the wall thickness over time in different specimens.

Findings and Discussion

The analysis of this research was conducted based on the concrete test and thermal analysis.

Table 2
Weight of material for each type of wall panel

Type	Normal Concrete Precast Wall Panel	Cocopeat Precast Wall Panel	Insulated Lightweight Wall Panel
Weight (kg)	14.32	13.71	13.66

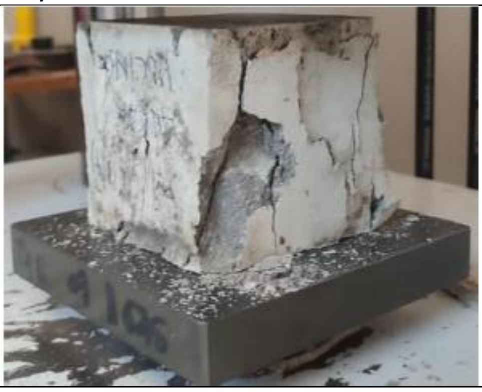
Table 2 shows the weight of the wall panel prototype, standard concrete precast wall panel, cocopeat precast wall panel, and insulated lightweight wall panel. The differences in the weight of 14.32kg, 13.71kg, and 13.66kg, respectively, are due to the composition of the material, whereby sugarcane bagasse and the insulated lightweight wall panel differed from the solid concrete wall panel.

Table 3
Concrete Test Result day 14 and 28

Specimen	Elastic Modulus	Maximum Load (kN)	Compressive Strength (MPa)	Deformation/Fracture (mm)
1	4567.9	411.23	41.1	2.60
2	3423.5	370.26	37.0	2.52
Average	3845.7	390.75	39.05	2.56
3	3130.8	366.98	36.7	3.31
4	3582.0	375.38	37.5	2.59
Average	3356.4	371.18	37.1	2.95

Two specimens were prepared for testing on day 14 and day 28. Each collection of specimens is ready with two model samples to see the average data obtained. The cube's dimension is 100 mm X 100 mm X 100 mm. Based on table 2, the result of the compressive strength on day 14 and day 28 shows that cube 1 is 41.1 MPa while cube 2 is 37.0 MPa. There was a difference between cubes 1 and 2, although it is the same concrete mixture. The difference is that there may be many coarse aggregates in specimen one compared to specimen two. The compressive strength of cube 1 is higher than cube 2. Meanwhile, on day 28, the compressive strength test for cube 3 is 36.7 MPa, and cube 4 is 37.5 MPa. Hence, the average reading for the compressive strength test of cubes 3 and 4 was 37.1 MPa.

Table 4
Cube concrete

Day 14	Day 28
	

Thermal Performance

The thermal test was conducted for each panel which is the standard concrete, cocopeat, and insulated lightweight wall panel. The thermal test aims to measure how much the temperature will pass through the precast panel, and the temperature of all the precast panels is recorded every two hours.

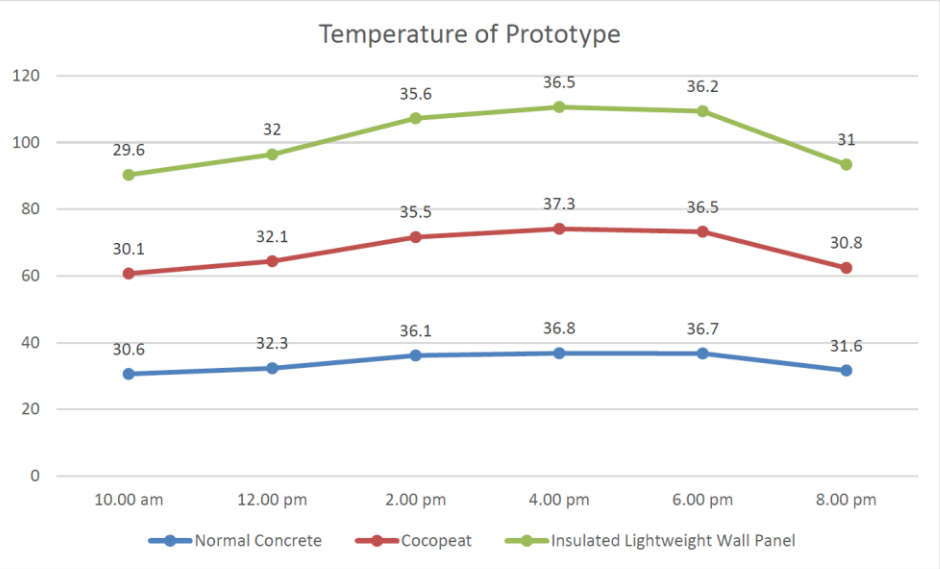


Figure 1: Temperature of each prototype

Figure 1 shows the temperature of each prototype. The thermal test was conducted on a sunny day. The graph pattern shows an increasing way from 10.00 am until 4.00 pm and a decreasing pattern from 6.00 pm to 8.00 pm. This indicates that the prototype gains heat during the day and starts to release the heat at night. The result shows that the insulated lightweight wall panel temperature was the lowest at 10.00 am, which is 29.6 °C compared to 30.1°C for the cocopeat precast wall panel and 30.6 °C for standard concrete precast wall panel. Hence, the highest temperature recorded after 2 hours of the panel being dry under the sun is for normal concrete. Next, at noon, there was no significant difference in the temperature. In contrast, the insulated lightweight wall panel is 32.0 °C, the cocopeat precast wall panel temperature is 32.1, and the standard concrete precast wall panel is 32.3.
Next, the highest temperature recorded for all the prototypes was at 4.00 pm, which was 36.5 °C for the insulated lightweight wall panel, 37.3 °C for the cocopeat precast wall panel, and 36.8 °C for the typical concrete precast wall panel. However, from all the prototypes that had been tested, the cocopeat precast wall panel shows the highest heat gain compared to others. Besides, although the heat gain of the cocopeat precast wall panel is highest at 4.00 pm at 8.00 pm, the cocopeat precast wall panel has the lowest temperature compared to others. On the other hand, this shows that the cocopeat precast wall panel is suitable for releasing heat. Finally, the insulated lightweight wall panel's ability to resist the sun's heat during the day was reasonable compared to the cocopeat precast wall panel and typical precast wall panel.

Conclusion

Based on the analysis gathered from data collection and analysis, it can be concluded that:
The insulated lightweight wall panel is 0.06 kg lighter than the standard concrete precast wall panel. Moreover, the insulated lightweight wall panel that is being proposed can resist the high heat gain at the wall during the day. However, in further study, it is recommended to

measure the life span of the sugarcane bagasse as the thermal material because since it is a natural fibre, it can decay.

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