



APPLICATION OF PLASTIC BOTTLE AS A WALL STRUCTURE FOR GREEN HOUSE

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ABSTRACT

Wall structure plays important roles in supporting the superstructures, separates spaces in buildings into sections and delineates a space in open air. Most of the construction of house in Malaysia use bricks and mortar which consists of cement, aggregates and water as the materials to build the structure of wall. However, cement and bricks manufacturing process will contribute to a high emission of carbon dioxide (CO₂) which may lead to global warming. Therefore, objective of this paper is to find an alternative solution to reduce this environmental problem. The alternative way that can solve the problem is by replacing the use of bricks in building construction by plastic bottles filled with sand as we called it plastic bottle green house. Reuse of these non-biodegradable plastic bottles not only can solve the environmental problem, but it can also reduce the pollution. The main concern of this project is the strength of bottle bricks. Therefore, there were two types of experiments were used to evaluate the properties of bricks and plastic bottle filled with sand which are compression test and temperature test in indoor and outdoor of wall structure. The compression test is prepared for 1.5L bottle brick, 250ml bottle brick and common clay brick. As a results, the strength of 1.5L and 250ml bottle bricks is 3 and 4 times respectively stronger compare to common clay brick. The comparison of indoor and outdoor wall temperature, air humidity and wind velocity between the plastic bottle green house and normal brick house has indicate that plastic bottle has recorded highest reading for outdoor wall temperature with 36°C and lowest reading on outdoor humidity and outdoor wind velocity with 78% and 0.8 m/s respectively. From these result it can be concluded that plastic bottle green house have a potential as a wall construction material and further study on its other properties such as its lifespan and ratio between water, cement and sand usage as a mortar should be carried out.

Keywords: bottle bricks, strength, global warming, temperature, air humidity, wind velocity.

INTRODUCTION

Global warming refers to what is believed to be a trend where earth's temperature is increasing. This is believed to be primarily due to the emission of man-made pollutants that cause more of the sun's energy to be trapped in the atmosphere. These pollutants are referred to as-so called greenhouse gases [2]. Most of the pollutant also occur naturally in the environment in some form or another and while man-made emissions are often relatively small compared to those naturally occurring, they may affecting the natural balance in the environment. While it is estimated that it would take many years for there to be catastrophic consequences to the increase in green house gas emissions, it could be too late to reverse the trend if something is not done now.

Eco-house also known as green building is the creative buildings and supportive infrastructure that reduce the use of resources, create healthier living environments for people, and minimize negative impacts on local, regional, and global ecosystems [9]. Green building also has been studied at United State [8]; it shows that the annual impacts of building construction including 35% of carbon dioxide production which is a major contributor to global warming.

Strength of bottle bricks has been doubted by the public since they are made from plastic bottles. However, this doubt is solved because bottle bricks are stronger than common bricks and they are bullet proof. In a small village in Nigeria, a solution has been applied to not only

provide shelter in a poverty stricken country, but find a use for refuge [7]. Packing sand into plastic bottles is a technique that started nine years ago in India, South and Central America. Named "bottle brick" technology, the compacted sand inside the bottles is almost 20 times stronger than bricks. Adding to the appeal of the simple technology, the houses are ideal for the hot Nigerian climate because the bottle bricks buffer the house from the intense heat. Also, in a place known for violence, the houses are completely bullet proof [3].

Compressive Strength can be defined as the maximum compressive stress that a material is capable of withstanding without fracture. Structure of wall play an important role in supporting the load applied from roof. According to Public Work Department (PWD) Standard Specification for Building Works (2008), the minimum permissible average compressive strength shall be 5.2N/mm² for bricks and 2.8 N/mm² for hollow blocks per 10 samples taken at random from the Contractor's stock pile of 1000 or part thereof [5].

Thermal comfort is considered to be a principal requirement that is usually demanded of by occupants of accommodation units. A compatible indoor climate design is actually a modification of the external environmental system and is designed to provide comfort for occupants. There is a reciprocal relationship between climate and man in both indoor and outdoor areas. One of the significant objectives of designing buildings is to ensure the thermal comfort to occupants. This is because most people



generally spend 85-90% of their time indoors and thus providing a comfortable and healthy environment is imperative [1].

According to [4], thermal comfort might be determined by using the Predicted Mean Vote (PMV). This equation predicts the mean thermal comfort of people under various circumstances. Based on his finding the thermal comfort zone for Malaysia is 24.5°C to 26.5°C. Other studies done on comfort zone obtained almost the same results for the comfort zone in Malaysia, e.g. between 24 °C to 29 °C [6].

Combustion process in manufacturing cement and bricks will produce the pollutants gaseous such as carbon dioxide [2]. This situation will contribute the formation of global warming. Therefore, this paper will suggest an alternative way in construction industry that can reduce or replace the using of cement and bricks to ensure that the formation of global warming can be reduced in the future.

MATERIALS AND METHOD

Compression test (Figure-1) is carried out to test the compressive strength of 250ml bottle brick, 1.5L bottle brick and clay brick using compression testing machine. The area of clay brick is 0.021m² (0.22 m x 0.09 m). Since the area of contact of 250ml bottle brick and 1.5L bottle brick are not in regular shape like brick, their area are calculated by using irregular shape formula. The area obtained for 250ml bottle brick and 1.5L bottle brick are 0.002m² and 0.006m². From the testing, the maximum force applied on 250ml bottle, 1.5L bottle, and clay brick until failure.



Figure-1. Compression test on bottle brick.

A foundation slab is built to serve as the base of house prototype. Firstly, a formwork (Figure-2) is built with plywood in dimension of 1.2 m x 1m x 0.75m. Then reinforcement steel bars are placed inside. 34kg of cement, 68kg of sand, and 136kg of aggregates and 17kg of water are measured using electronic balance, and then mixed by concrete mixer for in a ratio of 1:2:4 and water cement ratio of 0.50.



Figure-2. A formwork of 1.2 m x 1m x 0.75m dimension.

A total of 308 bottles of 250 ml mineral water are used to produce bottle bricks. All the bottles are dried before proceed to the next step which is filling of sand. Filter funnel is used to ease the filling of sand into the bottle since the opening of bottle is undersized. Sand is wet partially so that it can be compacted easily and thus increasing the density of bottle bricks. Sand is compacted in three layers and each layer is compacted with 20 blows with tamping rod. In order to make sure all the bottles are completely compacted, quality check is carried out and those which are less compacted are improved.

Wall structure is constructed using mortar to bond the plastic bottles together after completed filling the sand into plastic bottles by. Cement, sand and water are mixed together according to mortar ratio 1:2 and water cement ratio 0.30 by using concrete mixer. Because of the water absorption of the clay bricks is different from plastic bottle, so the water cement ratio is modify from 0.50 to 0.30 to ensure the bottle bricks can bond between each other. After 15 minutes of mixing, mortar is used to paste the bottle bricks together to build up the wall.

The type of bond used is a stack bond because it is easier to arrange. As the name says, the stack bond has each course, made of stretchers, stacked right on top of the one below it. Made up of courses of stretchers where each stretcher is stacked directly above a stretcher and the joints align. In a stack bond as showed in Figure-3, the plastic bottles are literally stacked on top of each other and held by mortar.



Figure-3. Construction of wall with bottle in a stack bond.



Figure-4. Painted green house model with decoration.

After the completion of bottle brick wall, wall finishing is proceed which are plastering and painting. 28kg of plaster which comprises of cement (act as binder), carbonate powder (act as filler) and water soluble polymers (act as additives) is applied to cover up imperfection and act as wall coating. A coat of light blue color paint is applied on the walls to act as protection and decoration. Last but not least, the green house model is decorated with an artificial grass roof (king-post structure) made with plywood as well as some artificial flower pots and grass to accord with eco-friendly theme as showed in Figure-4.

In order to determine and compare the indoor temperature of both standard brick house and plastic bottle, a series of data related to factors affecting thermal comfort of a building e.g. air temperature, air humidity, and air velocity have been taken for the house model. Figure-5 shows the recording reading with anemometer apparatus.



Figure-5. Recording reading with anemometer.

RESULTS AND DISCUSSIONS

Compression test was conducted on 250ml and 1.5L bottle bricks as well as clay bricks to determine and compare the compressive strength between them. From this compression test, the maximum stress that can be achieved by 250ml and 1.5L plastic bottle is 38.34 N/mm² and 27.39 N/mm² respectively. The maximum stress for clay brick is 8.58 N/mm². According to PWD 20800 [5], the minimum permissible average compressive strength

shall be 5.2N/mm² for bricks and 2.8 N/mm² for hollow blocks per 10 samples taken at random from the Contractor's stock pile of 1000 or part thereof. Therefore, this can prove that both the 250ml and 1.5 L bottle bricks are qualified as wall materials to replace standard bricks as its compressive strength exceed the minimum permissible compressive strength. The clay brick used is also qualified as a build material as its compressive strength exceeding the JKR standard. As compared to the clay brick, the maximum stress for 250ml and 1.5 L bottle bricks is higher than the clay bricks for 4 and 3 times respectively. This proved that bottle bricks have the potential to replace standard bricks in building.

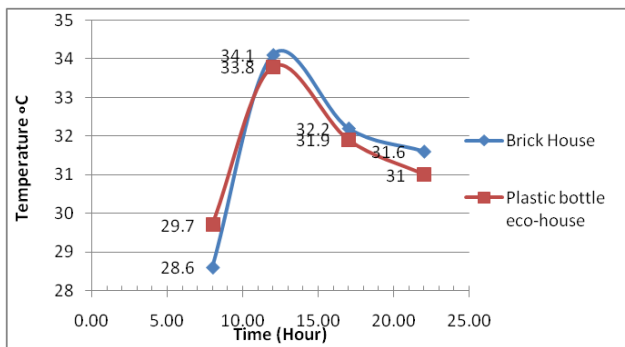
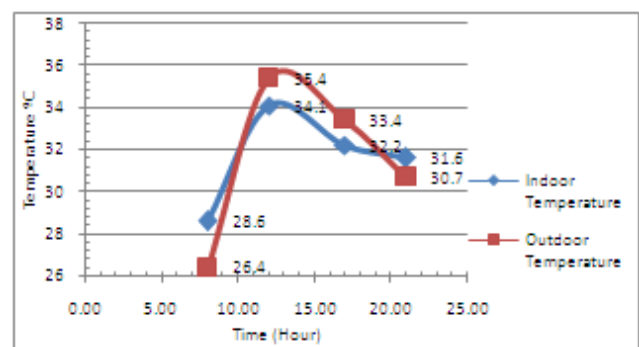
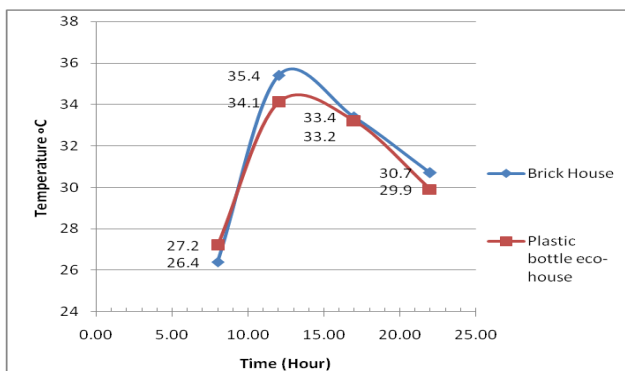
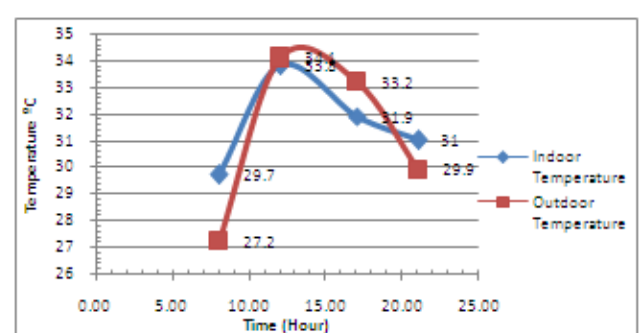
In order to determine and compare the indoor temperature of both standard brick house and plastic bottle eco-house, a series of data related to factors affecting thermal comfort of a building have been measured e.g. air temperature, air humidity, and air velocity. According to the test results (Table-1), the plastic bottle green house has not achieved the thermal comfort zone as its temperature range is 30°C to 34°C. Same goes to the normal brick house which range from 29°C to 34°C. Both of them share similar range of temperature. This could be caused by poor ventilation within the eco-house prototype as it only consist a small ventilation gap near the roof.

Furthermore for the housing area, the maximum outdoor temperature is between 34 °C and 36 °C while the minimum outdoor temperature is between 24 °C and 25 °C [6]. With a daytime ventilation strategy where the windows were open only during the day, the internal temperature dropped to 33 °C (only 1 °C lower than the maximum outdoor temperature). On the other hand, if night ventilation was applied (where the windows were open only at night), the indoor temperature dropped further to 28 °C.

By referring to Table-1, both standard brick house and plastic bottle green house (59% - 73%) have met the indoor air quality standard at the aspect of relative humidity which are 40% - 70%. While for the aspect of air velocity, both of the houses merely met the standards. These could be caused by poor ventilation of the houses. Most building in Malaysia are built with bricks which absorbs heat easily from the sun through the daytime. At night time the air outdoor cooled quickly, but the building fabric behaves differently where heat is released from the building mass to the surrounding air indoor and outdoor. By comparing with plastic bottle green house, it shows similar trends (refer to Figure-6-9) with standard brick house in term of changes of indoor and outdoor temperature over time in a day. This can be concluded that plastic bottle bricks have the capability to replace standard bricks in Malaysia's buildings in condition of thermal comfort.

**Table-1.** Thermal Comfort Parameters of Brick house and Plastic Bottles Filled with Sand.

Time Parameter	Brick house				Plastic bottle eco-house			
	8am	12pm	5pm	9pm	8am	12pm	5pm	9pm
Indoor temperature (°C)	28.6	34.1	32.2	31.6	29.7	33.8	31.9	31.0
Outdoor temperature (°C)	26.4	35.4	33.4	30.7	27.2	34.1	33.2	29.9
Difference (°C) = In-Out	2.2	-1.3	-1.2	0.9	2.5	-0.3	-1.3	1.1
Indoor humidity (%)	71.6	59.5	65.3	69.1	72.5	60.1	69.0	70.5
Outdoor humidity (%)	79.4	54.3	67.2	68.0	78.4	72.1	70.7	73.8
Outdoor wind velocity(m/s)	0.5	0.4	0.6	0.9	0.1	0.3	0.8	0.1

**Figure-6.** Indoor temperatures of brick house over the time.**Figure-8.** Indoor and outdoor temperatures of brick house over the time.**Figure-7.** Outdoor temperatures of plastic bottle eco-house over the time.**Figure-9.** Indoor and outdoor temperatures of plastic bottle eco-house over the time

CONCLUSIONS

As a conclusion, the application of plastic bottles filled with sand as wall structure to replace bricks in construction industry is acceptable as the strength is over the minimum permissible strength of PWD Standard and the plastic bottle bricks have the capability to replace standard bricks in Malaysia's buildings in condition of thermal comfort. However, this technique still needs some modification for a better result. For example, the using of cement can be further reduced by replace the mortar using



clay with adequate amount of water or any other suitable materials. The type of bond used is stack bond because it is easier to arrange. The ratio of cement and sand for bonding clay bricks is 1:2 and the water cement ratio is 0.50. However, because of the water absorption of the clay bricks are different from plastic bottle; the water cement ratio had been adjusted to 0.30 to ensure the bottle bricks bond enough between each other. Hence, a research on the optimum water cement for bottle bricks should be carried out.

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