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# THE EFFECT OF OIL PALM SHELLS ON THE MECHANICAL AND PHYSICAL PROPERTIES OF COMPOSITE BRICK

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## ABSTRACT

Horticultural modern wastes of separating palm oil from palm organic products known as oil palm shell (OPS) are accessible in extensive amounts in Malaysia, Indonesia and other tropical nations. This massive production of palm oil has produced a high amount of waste, which may lead to environmental problems. This study aims to investigate the effects of OPS as a coarse aggregate replacement in bricks. The density and compressive strength performances of bricks incorporated with OPS as a coarse aggregate replacement were investigated. The investigation also analyzed the optimum percentage of OPS added in bricks made by various levels of OPS substitution, from 10% to 40% at intervals of 10%, and compared it with the control brick at 0% OPS. The result showed the advantage of OPS when the density of brick decreased significantly from 2502 kg/m$^3$ at 0% OPS to 2021 kg/m$^3$ at 40% OPS. OPS bricks showed a reduction of 19.2% in weight compared to control bricks. Furthermore, the compressive strength exhibited an optimum of 30% OPS with 506.3 kN, which increased by 7.9% compared to the control brick strength. However, the effect of OPS towards bricks showed a slight decrease compared to control bricks. This shows the workability of OPS as the coarse aggregate replacement has the potential to produce lightweight bricks, improve bricks' strength, and help reduce environmental problems.

**Keywords:** *coarse aggregate, composites brick, compressive strength, lightweight brick, oil palm shell*

## INTRODUCTION

Malaysia was the second largest palm oil producer in the world in 2006 (43%) after Indonesia (44%), which involved 4.4 million hectares and is expected to increase every year [1]. The palm oil industry of Malaysia generates approximately 80 million tons of solid waste biomass annually, including empty fruit bunch, trunk, frond, mesocarp fiber, and oil palm shell [2]. The main products produced by palm oil mills consist of crude palm oil and oil palm kernel, as well as huge quantities of residues such as oil palm fibre, shell, and empty fruit bunches [1]. Generally, the oil palm industry in Malaysia generates an abundant amount of OPS of approximately 4 million tons per year [3]. OPS was a solid waste material that contributed 5.5% to the overall solid waste of the oil palm manufacturing process.

Using oil palm shells (OPS) as filler materials to manufacture biocomposites can solve the agriculture disposal problem in an environmentally friendly manner [4]. OPS are used as thermal insulators, concrete ingredients in the building industry, carbon activation for water purification, fuel for heat generation, and automobile disk brake pads [5]. OPS has traditionally been used as solid fuels for steam boilers to run electricity turbines and cover the surface of the roads in the plantation area. It was also densified into briquettes, converted to bio-oil through a pyrolysis process for biomass energy, and used to produce charcoal and activated carbon [4]. For more than 20 years, researchers have investigated the potential of OPS as a structural lightweight aggregate [6]. The natural advantage of the OPS is its high porosity content, which produces low thermal conductivity aggregate, similar to other lightweight aggregates such as pumice, expanded vermiculite, expanded slate and expanded clay [7]. Thus, it is suitable for use as coarse aggregate in lightweight aggregate concrete for thermal insulation material in building construction [8]. Previous studies have found that lightweight aggregate can be good thermal insulation in lightweight concrete [9].

Brick is one of the oldest manufactured building materials in the world and the most important components in the construction industry. Bricks are common building materials actively applied in most construction works. Because of their remarkable features, such as high strength, low production costs, and durability, bricks have played an important role in construction for thousands of years [10]. As cement was introduced as a concrete binder, clay brick was also innovatively developed into cement brick to reduce the consumption of heating energy that is used to produce clay bricks. Both clay and cement bricks are used in the current construction industry [11]. The building and demolition industry accounts for 40% of global energy consumption and one-third of greenhouse gas emissions [12]. According to reports, as the need for building materials increased, so did raw materials and energy use, particularly during the extraction, processing, and material

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transit phases [13]. Natural resource shortages and the formation of solid waste without effective disposal are global concerns [14]. In the meantime, the demand for brick using many natural resources harvested from nature has been increasing throughout the years. The conventional production of brick has brought some shortcomings and caused damage to the environment due to the continued exploration and depletion of natural resources. Most source materials are mined from riverbeds and hillsides, leaving the mining area unreclaimed. Due to this situation, much research has been done to investigate the potential materials that can be used in the construction industry. Many researchers have lately worked to have the privilege of using recycled waste in the construction industry [15]. Continuous research in brick material has produced many types of brick known by various names with unique characteristics that fulfil the current construction industry demand.

In many developed countries, due to the increasing cost of raw materials and the continuous reduction of natural resources, the use of waste materials is a potential alternative in the construction industry. When properly processed, waste materials are effective as construction materials and readily meet the design specifications [16]. This will have the double advantages of reducing the cost of construction materials and also being a means of disposing of waste. For constructing environmentally sustainable structures, the possibility of using OPS as coarse aggregate for bricks will be highly desirable and have economic advantages [17].

Therefore, this research aims to utilise the OPS as a replacement for coarse aggregate in cement bricks. The utilization of OPS in bricks is in intervals of 10% from 0% to 40%. The investigation of brick properties using the proposed mix was by compressive strength and density, which, to date, no study has found.

## EXPERIMENTAL

### Preparation of Oil Palm Shell

OPS were collected from oil palm shell mills in Kuala Selangor, Selangor, Malaysia as shown in Figure 1. OPS was obtained from the process of solving the oil palm fresh fruit to produce oil palm shells. Once the fruits were placed in the machine, the shells were separated by mechanical removal. Shell was isolated from fibre and coconut palm to get the perfect quality shell. The OPS samples were washed with tap water a few times to remove impurities such as dust, sand and debris. Then, the cleaned OPS were left under the shed for three days for drying. After that, the dried OPS was crushed using a metal hammer and then sieved using a siever with a size range between 5 mm and 10 mm, which complied with ASTM C33M for coarse aggregate replacement [18]. The primary goal of the sieve study was to identify the particle size distribution for each material used to cast concrete in accordance with the standard. The OPS were then kept in a container to maintain dryness for further use.

**Figure 1** Collection of oil palm shells

### Preparation of Brick Moulding

The brick mould was designed using Catia V3, and the sketch was presented in Figure 2. Then, the brick mould was prepared using plywood. The plywood was obtained from a local store. The plywood was cut and trimmed using a cutter machine into four pieces according to the measurement. The length, width and height of the mould prepared were 251 mm, 90 mm and 73 mm. Then, finally, the pieces were nailed to form the mould (Figure 3).

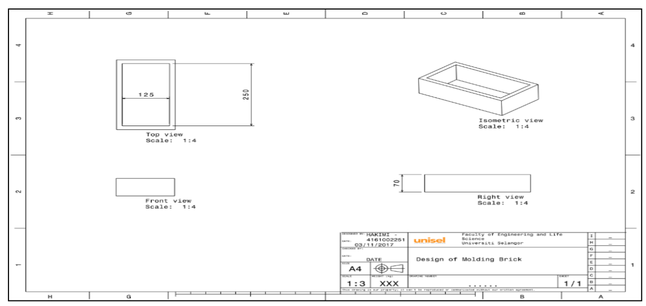



**Figure 2** Sketch design of moulding brick


**Figure 3** Preparation of brick mould (a) plywood measurement, (b) plywood cutting, (c) nailing the mould, (d) brick mould

### Preparation of Brick

Bricks were produced by mixing the fine aggregates, coarse aggregates, Portland cement and water in the brick mould. The Portland cement was obtained from local stores that complied with MS EN 197-1 and ASTM C150. The fine aggregates and coarse aggregates were obtained from a hardware store located in the local area. The use of OPS in the brick mixture has the following composition of 0%, 10%, 20%, 30% and 40% according to [4]. Control bricks consist of 0% OPS. In this study, the OPS were used to replace the coarse aggregates. This percentage is the most effective percentage of the cement type used [4]. The brick composition of the mixture design is tabulated in Table 1.

OPS bricks and controls were manually mixed in the laboratory based on the ratio mix in Table 1. Each ingredient was weighed and mixed evenly in a tray using a spatula. Water was added gradually until the mortar paste reached the desired level of workmanship. The mixture was then put into the mould and then the compaction was made on each layer manually at the uniform rate for each sample. The mould was then left to dry at room temperature for 24-48 hours.

**Table 1** Mix design concrete for w/c ratio at 0.50 [4]

| % OPS | Cement (kg) | Water (kg) | Fine Aggregate (kg) | Coarse Aggregate (kg) | OPS (kg) |
|---|---|---|---|---|---|
| 0 ( control) | 6.44 | 3.22 | 9.02 | 13.94 | 0 |
| 10 | 6.44 | 3.22 | 9.02 | 12.55 | 1.39 |
| 20 | 6.44 | 3.22 | 9.02 | 11.16 | 2.79 |
| 30 | 6.44 | 3.22 | 9.02 | 9.76 | 4.18 |
| 40 | 6.44 | 3.22 | 9.02 | 4.18 | 5.58 |

### Brick Test

In this section, the tests conducted to characterize the bricks are described. The bricks were conducted to determine the density and compressive strength of the produced bricks. Three samples of bricks were selected to carry out this determination for density measurement. The selected samples were dried again at room temperature within a minimum of 24 hours. Each sample was then weighed and recorded its value. The volume of the brick was calculated by multiplying its length, height, and width. The density of the bricks was calculated using Equation 1.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad (1)$$

A compression strength test was performed by using machine ADR 2000 to obtain the strength of the brick samples. This test was based on BS 5628: Part 1: 1992 complied with ASTM C496 [19], and the testing machine is shown in Figure 4. Before laying the brick on the platform, the rig was cleaned first to ensure no impurities such as the impact of breaking the calf. The load were gradually applied to the opposite side of the bricks till the bricks failed and automatically stopped. The maximum load were then recorded. This test was performed at 7 days age of bricks in air curing.

## RESULTS AND DISCUSSION

This section presents the results and discussion of the test carried out on bricks. The average density difference between all the bricks studied is shown in Figure 5. The density of the bricks decreased relatively with the addition of OPS in the bricks. On average, the bricks produced have the highest density of 0% OPS of 2502 kg/m$^3$. The lowest density of OPS brick is 40%, which is 2021 kg/m$^3$. OPS density generally varies from 1170 to 1370 kg/m$^3$, and their 24-h absorption capacity ranges from 21% to 33% [20]. OPS has a low specific gravity thus these properties of OPS played the main reason for the decreasing brick density whilst the percentage of OPS increased [4]. The OPS can be used to obtain concrete with a density ranging from 1725 to 2050 kg/m$^3$, which corresponds to a 15–25% reduction in density compared to ordinary concrete [4]. In this study, the brick showed a density reduction of 19.2% compared to the control brick. This will eventually help reduce the transportation cost of materials and fulfil the supporting members' dimension needs [11]. Our results demonstrate that the density of OPS brick composites dropped linearly with an increase in OPS, satisfying the manufacturer's demand for application in the automotive and construction industries. Based on the results, OPS bricks can be classified as lightweight bricks.

OPS is known as biomass, which has high porosity and high water absorption [1]. The high porosity of the brick also allowed it to dry fast. Thus, the water leaves more quickly and in greater quantities through the system of pores [20]. The workability of a mixture of bricks also plays a role in determining the density of the bricks. A brick with good workability will encourage high-density brick production. This factor explains the density differences occurring among all the bricks studied. Density difference analysis shows that the use of OPS in bricks affects workability, as proved by different density records, especially with control specimens. This indicates that the use of OPS in the brick dough interferes with the workability of its blend, thus prompting a decrease in density. According to

**Figure 4** Compression strength machine for brick testing

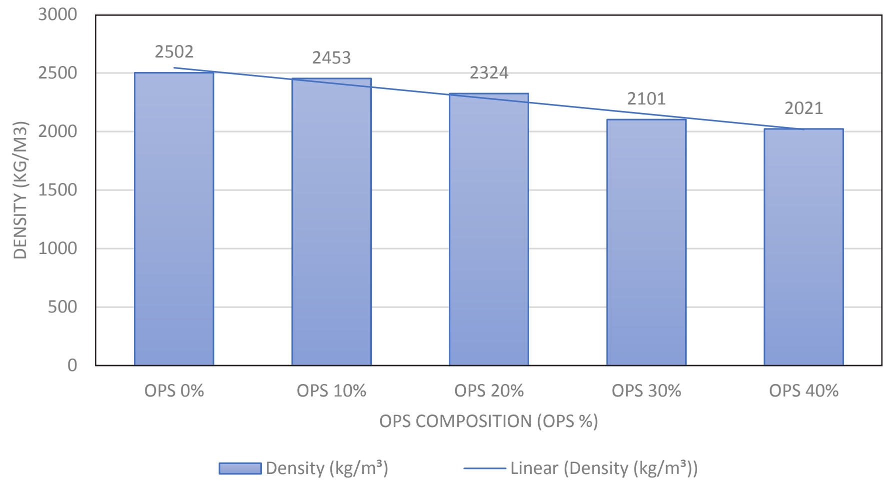


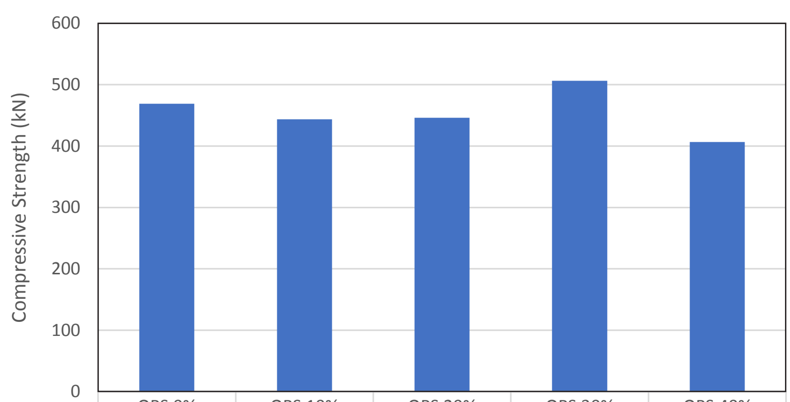

**Figure 5** The average density of bricks

Elnaz et al. [21], sustainable lightweight pervious concrete by substituting common coarse aggregate sized 6.30–9.50 mm with 4.75–6.30 mm and 6.30–9.50 mm OPS.

Compression strength is an important aspect in assessing the ability of a brick to bear. From Figure 6, the average compressive strength of the control brick was 468.9 kN. The strength decreased slightly with 443.4 kN for 10% OPS but increased again to 446 kN for 20% and was 506.3 kN at 30% OPS. The strength was then decreased again to 406.6 kN at 40% OPS. The brick with 30% OPS showed the highest compressive strength with 506.3 kN. The lowest compressive strength was the brick, which had 40% OPS and 406.6 kN. The result shows that the content of coarse aggregate in brick is not a dominant factor in determining the level of its pardon strength. This condition can be observed in brick samples. Due to the low specific gravity of OPS, the design mixes tended to separate, potentially reducing their compressive strength. Compressive strength grew with the increase in cement content and based on the kind of aggregate used for a given workability. Therefore, the development of compressive strength of OPS concrete was lower than normal concrete [22]. In spite of the fact that the surface texture of the concave and convex faces of OPS is completely smooth, the broken edges are rough and spiny [23], which creates a sturdy physical bond between the aggregate and the hydrated cement paste. The low compressive strength is also influenced by weak bonding between OPS's flat-concave and convex surfaces [24]. The air vacancy trapped in those surfaces weakens the bricks' bonding as cement and aggregates do not fill the empty spaces and thus can not act as binders in bricks.

## Bricks

All bricks produced in this study were not exposed to water curing. All oil palm shell concrete (OPSC) samples exposed to water curing recorded higher compressive strength compared to the specimens cured in air curing. The water curing regime simplified the continual hydration of the binder, while the insufficiency of moisture for hydration in the samples exposed to air curing caused compressive strength reduction in the concretes [22]. Possibly, it could pass through if OPS aggregates were treated with a lime solution before mixing [12]. Normal-weight concrete has a constant w/c ratio, but lightweight aggregate requires a lot of water due to its high absorption capacity.




| | OPS 0% | OPS 10% | OPS 20% | OPS 30% | OPS 40% |
|---|---|---|---|---|---|
| Strength (kN) | 468.9 | 443.4 | 446 | 506.3 | 406.6 |

**Figure 6** Result average from compressive strength of the bricks

## CONCLUSION

The study found, the replacement of coarse aggregate by 10%, 20%, 30% and 40% of OPS has made the changes to compressive strength and density of bricks respectively. The results showed the optimum compressive strength was at 30% OPS with a 7.9% increased strength compared to control. The percentage of strength is considered low compared to normal bricks strength range but it is still within the theoretical workability. However, the OPS bricks are significantly lighter than control bricks when increasing OPS with a density reduction of 19.2%. and can be used as lightweight bricks. In conclusion, it shows that OPS have a high potential to be used as coarse aggregate replacement.

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