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Research paper

Evaluation on the Mechanical Properties of Concrete Using Clay Brick as Sand Substitution

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Abstract

This paper investigates the mechanical properties of Clay Brick Powder Composites in the concrete design mix proportion in terms of compressive strength behavior. The Clay brick powder employed in this study is from the recycle brick waste of demolished house. The brick is being grinded by using Los Angeles Abrasion Machine. Three samples are being produced which contain the replacement of sand by substituting the first sample with 15% of brick powder, second sample with 20% of brick powder and third sample with 25% of brick powder. All the samples have been tested for compressive strength by using the Compression Testing Machine. The results show that the optimum proportion of clay brick powder as a fine aggregate replacement is 15 %, which recorded to have 58 MPa that is the highest compressive strength at the age of 28 days compare to the other proportion. Overall, in between of 15-25% of fine aggregate replacement, the strength can reach the highest performance at about 45-58 MPa of the compression. This can be concluded that the concrete clay brick has good and applicable compressive strength plus lighter than the normal concrete. This makes the concrete as one of the eco-friendly construction material.

Keywords: *brick powder; compressive strength; eco-friendly construction material; fine aggregate replacement; recycle brick waste.*

1. Introduction

In today's world, concrete is one of the most widely used material in building's construction. It is easily obtained, relatively cheap, strong and durable. However, the concrete industry has been addressed as one of the major consumers of the natural resources. It is reported that the annual concrete production is estimated as 11 billion metric tons, 70-75 % of the amount of aggregate; 15% is water and 10-15% is cementitious binder [1]. Therefore, it is great importance to develop advanced technologies in producing concrete. According to [2], quoted that large amount of waste is produced during reconstruction of old building. Most of these wastes are not reusable; their recycling contributes to wasting energy and pollution which in turn enhances the environmental problems. In conjunction with this, there is a need to develop strategy to achieve the both aims of reducing the waste material and improving the mechanical properties of concrete.

Previous studies have been documented on using construction waste materials as a substitution for aggregate in manufacturing concrete [3-4]. Construction wastes include concrete, bricks and blocks, glasses, roofing tiles, timber, steel and aluminum are generated increasingly from time to time as mention by [5]. One of the waste materials that are becoming effectively studied nowadays is clay brick. These wastes are commonly thrown away without any commercial value, can be further utilized by making more sustainable use of these wastes. In a study by [2], clay brick is produced in factories during and after the production process, inappropriate materials because of human mistakes, some others are during transportation and distribution stage and finally large volume of brick waste because of demolishing buildings. The volume of these materials has reached an unacceptable level from an environmental aspect, economic and social point of view as agreed in a study by [6].

In [7] investigated the performance of concrete grade 40 containing different amount of Recycled Concrete Aggregate (RCA) (30%, 22.5% and 15%) and Crushed Clay Brick (CCB) (10%, 15% and 20%) as partial replacement for coarse and fine aggregate respectively in concrete. It was depicted that the compressive strength of concrete specimen ranges from 24.22N/mm^2 to 27.78N/mm^2, 27.95N/mm^2 to 37.2N/mm^2 and from 25.15N/mm^2 to 32.48N/mm^2 at 7, 18 and 28 days respectively. Concrete made from RCA and CCB obtained compressive strength faster than Normal Concrete (NAC) at 7 days of curing, meanwhile the rate of strength becomes much slower than NAC at 18 and 28 days. These authors recommended that the compressive strength of concrete made from CCB will be at a maximum when the CCB content kept between 15% and 20%. This finding is in line with [2] who reported the optimum replacement of natural fine aggregate by crushed brick powder is found to be 20% at which the strength of concrete at 3, 7, 21 and 28 days are higher than those of concrete prepared without replacement of natural fine aggregate. Meanwhile, in [8] agreed that clay brick aggregate content should not exceed 25% of total aggregate content in concrete.

In [6] studied the effect of incorporating crushed red Clay Ceramic Bricks (CBAs) and Sanitary Ware (SWA) in manufacturing of concrete. They prepared different concrete mixes where the fine natural aggregate fraction was partially or fully replaced (20%, 50% and 100%, by volume) (C20CB, C50CB and C100CB) by each of these materials. The result revealed that fine CBA concrete demonstrated greater compressive strength gain when compared to SWA mixes. This result was attributed to the finer fraction of crushed clay bricks that may have high enough specific

surface area to allow pozzolanic reactions between the CBAs' high silica (SiO_2) and alumina (Al_2O_3) contents with the cement's hydrated products. Meanwhile, compressive strength values of mixes C100CB exhibited much lower compressive strength values than those of CC mixes. However, research by [8] showed that compressive strength of foamed concrete gradually decreased by increasing crushed clay brick aggregate content (0, 25, 50, 75 and 100% as sand replacement). The incorporation of 25% clay brick in concrete shows no significant effect on strength. This result was possible due to porous structure and relative lower specific gravity of the clay brick than that of sand. In contrast, in [9] revealed that lightweight concrete produced with 25% substitution of waste clay brick showed the highest strength of 25 MPa with density of 1647 kg/m^3. This finding is similar with the study conducted by [10].
Other studies on the effect of clay brick waste as partial of fine aggregate on rendering mortar performance have been reported by in [11]. The mortar aggregate was replaced by crushed brick waste in proportions of 33.33 %, 50 %, 66.67 % and 100 % by weight. According to the result gained, they proved that as the clay brick replacement level increases, the compressive strength of mortar decreases due to great water absorption of the clay brick. This high hygric characteristic is caused by the affinity of this brick to water as well as its porosity approximately 50%. In [12] also confirmed that compressive strength of concrete decreases as the porosity increases. The literature review presented above shows that there is lack of information regarding the influence of the incorporation of clay brick powder in terms of the mechanical behaviour of concrete. Therefore, this study intends to assess the influence of incorporating these materials on the mechanical performance of concrete.

2. Methodology

2.1. Material Preparation

The material used in the concrete mix proportion is cement, sand, aggregate and water. However, in this study, the sand is replaced with the clay brick powder as much as 15%, 20% and 25% of the normal composition. The type of cement used is the Ordinary Portland Cement (OPC). The coarse aggregate used is passing through 20mm sieve and retaining on 10mm sieve for the coarse aggregate size 20mm and passing through 10mm and retaining on 5mm for coarse aggregate size 10mm, while the fine aggregate was sieved passing into 5 mm size by using sieving machine.

In this study, the clay brick powder is obtained from construction brick waste. The clay brick was crushed into small particles by using Los Angeles Abrasion Machine with 100 rotations. The small particles used as sand replacement is the one that passes through 4.75-5 mm sieve and retain on 75-90 micron sieve. This is because, this clay brick powder appears similar as the size of the ordinary sand.

2.2. Mix Proportion

The mix concrete is designed to achieve the compressive strength of 35 N/mm^2 at 28 days. The free water/cement ratio is 0.51 with free water content of 190 kg/m^3 and cement content of 373 kg/m^3. The concrete density is 2430 kg/m^3, meanwhile the fine and coarse aggregate content used is 616 kg/m^3 and 1249 kg/m^3 respectively.
The total batch of concrete produced is four that consist of one batch of control concrete and three batch of substituted sand. The specimen is mould in the size of 100 x 100 x 100 mm for each trial mix. The water and cement used are 0.627kg and 1.328kg respectively. Meanwhile, the aggregate used is 1.368kg for 10mm size and 2.76kg for 20mm size. The sand used for control batch is 2.046kg and varies for the substituted batch namely Specimen 1 for 15% substitution of clay brick powder, Specimen 2 for 20% substitution of clay brick powder and Specimen 3 for 25% substitution of clay brick powder. Table 1 shows the weight of material used in the concrete mix proportion in this study.

2.3. Concrete Mixing

All materials were mixed into a standard concrete mixer machine. Firstly, the solid materials including the cement, aggregates and sand were placed into the mixer. The mixer is rotate around 1-2 minutes for mixing process. Next, water and clay brick powder were added slowly until fluidity and uniformity of concrete were achieved. This process is conducted about 4-5 minutes.

2.4. Concrete Casting

The surface of concrete mould was greased. The fresh concrete is poured into the mould and being compacted by using compactor machine. The concrete mix was left into water and were cured in the air condition at room temperature for 7days, 21 days and 28 days.

Table 1: Concrete mix proportion

Per Trial Mix of	Specimen	Weight (kg)					
		Water	Cement	Aggregate (10mm)	Aggregate (20mm)	Sand	Clay Brick Powder
0.0033	1 (15%)	0.627	1.238	1.386	2.760	1.739	0.307
	2 (20%)	0.627	1.238	1.386	2.760	1.637	0.409
	3 (25%)	0.627	1.238	1.386	2.760	1.535	0.512
	Control	0.627	1.238	1.386	2.760	2.046	-

2.5. Compressive Test Method

The specimen is being created with the size of 100mm x 100mm x 100mm cube of concrete for each category which is divided to control concrete and 15%, 20% and 25% brick replaced concrete. For each concrete mix, one repetitive cubic specimens of 50 x 50 x 50 mm were prepared and tested by using Compression Testing Machine. Figure 1 and Figure 2 show the test set-up for both experimental works. The concrete cubes were then tested into compression test by using compression machine for 7 days, 21 days and 28 days.

Fig 1: Compression test

Fig 2: Concrete mixer

3. Results and Discussion

3.1. Density

Density or unit weight is the mass per unit volume. The normal concrete density of hardened concrete is around 2400 – 2500 kg/m^3. From the finding, the weight of hardened concrete is decrease with the increase of the percentage of clay brick replacement with compared to natural fine aggregates as shown in Figure 3. The decreasing unit weight of Clay Brick Concrete will be resulted to the lightweight construction industry.

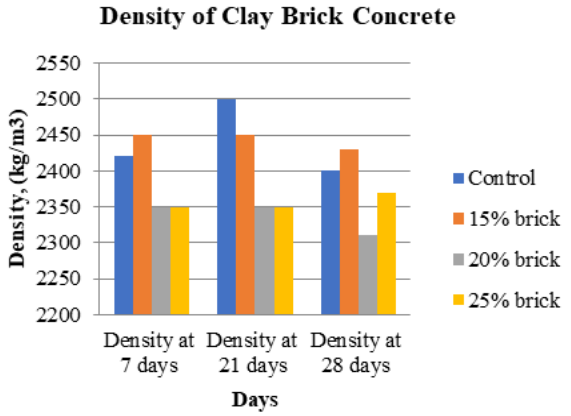

Fig 3: Density of hardened clay brick concrete

3.2. Compressive Strength

Compressive strength is the common and important test for the hardened concrete because most of the properties of concrete depend on the compressive strength. The compressive strength of concrete is conducted cubical or cylindrical sample based on ASTM C39/C39M-05. In this study, the compressive test is conducted to test each category of concrete cube specimens. The results for the compressive strength for all specimens at the age 7, 21 and 28 days are shown in Table 2.

Table 2: Compressive strength of Clay Brick Concrete

Specimen	Compressive strength at 7 days (MPa)	Compressive strength at 21 days (MPa)	Compressive strength at 28 days (MPa)
Control	44.0	30.6	56.2
15% brick	40.4	44.8	58.0
20% brick	36.5	58.0	48.0
25% brick	30.4	40.6	46.5

From the finding, the Clay Brick Concrete is weaker in compressive strength at the 7 days as compare to the control sample, but it is qualified that the result at 7 days musts should be two third from the target design mix with is grade M-35. At the age 21 days, it found that the compressive strength for Clay Brick Concrete is higher for all the replaced concrete than the control concrete. It shown that the replacement of 20% of clay brick to fine aggregates in the concrete has the highest compressive strength which is 58.0MPa. The important compressive strength of concrete is on 28 days of the ages of concrete should achieve 100% from the grade of the concrete and observed that the clay brick achieves the design mix grade even not higher than the concrete except 15% replacement of clay bricks.

The finding shows that the maximum compressive strength of the clay brick concrete is obtained at the 20% replacement ratio at 21 days, but it is decrease at 28 days. It is shown that the optimum proportion of clay brick as a fine aggregate replacement at 15 % as shown in Figure 4. Brick powder replacement in the concrete helps internal curing of the concrete compared to the case without the brick as fine aggregates. It is due to the higher absorption capacity of brick compared to the natural sands. However, the higher replacement of bricks, there will be a reduction of mechanical properties of concrete and weaken the strength of the concrete.

Overall, based on the finding, in the range of 15-25% of fine aggregate replacement, the strength of clay brick concrete can reach the highest performance at about 45-58MPa or N/mm^2 of the compression.

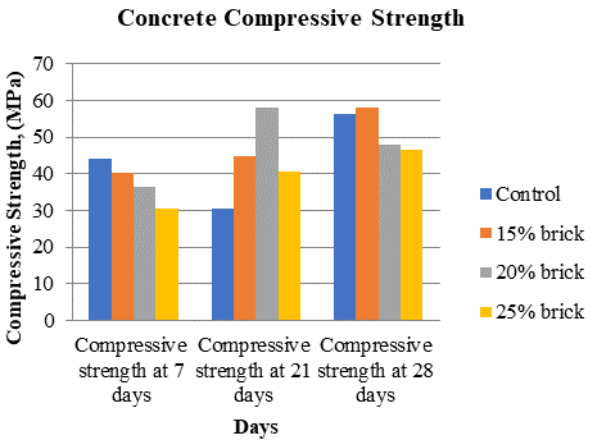

Fig. 4: The compressive strength

4. Conclusion

In general, the concrete with the clay brick powder composition as fine aggregate replacement have good and applicable compressive strength if compared with the control concrete which is produced without the composition of clay brick. Besides, the weight of the concrete clay brick also lighter than the control concrete. By reusing the brick waste as the replacement of fine aggregate in the concrete mix, it makes the concrete clay brick as one of the eco-friendly construction material. In line to reduce the wastage of bricks from the construction site, it makes the production of clay brick concrete more economic. This may be valuable due to the compressive strength of clay brick concrete is comparable as the control concrete.

In general, clay brick concrete can contribute in achieving the sustainable development. The clay brick concrete design creates opportunity for the construction companies to recycle the wasted bricks as a substitute material in producing the clay brick concrete. At the same time, this practice creates an opportunity towards profitable innovation since it uses wasted bricks as 15-35% of replacement to fine aggregate (sand) which reduces cost.

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