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A Study of Performance of Compressed Earth Brick Incorporation with Waste Fire Clay Brick as a Filler

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Abstract: This study examines the use of waste fire clay brick as a filler in compressed earth brick production. The purpose of this study is to determine the compressive strength and water absorption of the compressed earth brick incorporation with waste fire clay brick as a filler. The optimum amount of waste fire clay to utilize as a filler is also being studied. A total of 72 compressed earth bricks were produced with the brick size of 125 mm x 250 mm x 100 mm which consist of a mix of sand, soil and cement with mix proportion of 1:4:4. A few tests were conducted which are compressive strength test and water absorption test. The waste fire clay bricks were utilized in this study and replace by volume fraction percentage of 10%, 20%, 30%, 40% and 50% while 0% is set as the control. The findings obtained show that the compressive strength of the bricks was increasing. The percentage of water absorption were decreasing along with the increases of percentage of waste fire clay brick as a filler.

Keywords: Compressed earth brick, waste fire clay brick, filler, sustainable brick

1. Introduction

Brick is frequently used in construction, especially when creating infrastructure and structures. In attempt to find ways to make bricks stronger while simultaneously making them more affordable to produce, numerous experiments have been carried out. Utilizing waste as a component of the bricks' creation was one method used to lower manufacturing costs. A quicker, easier, more cost-effective, high-strength, and ecologically friendly approach is provided by compressed earth bricks (CEBs). It does not require the use of expert staff for installation, it is cost-effective. Walls, roofs, gates, and other structures have all been built with CEBs, a sustainable building material (Oti, Kinuthia & Bai, 2021). Bricks made by the compression technique are known as compressed earth bricks. The burning process can be substituted by autoclaving and mechanical compression techniques (Han et al., 2020). While autoclaving uses steam pressure to start a reaction in sand-lime bricks, mechanical compression relies on hydraulic power to create pressure to physically compress the mixture (Hany et al., 2021; Han et al., 2020)

Waste fire clay bricks were referred to as solid waste created during building or building structure demolition as a result of modernization (Aliabdo et al., 2014; Cheng, 2016). Utilizing discarded fire clay brick as a filler in compressed earth brick has both benefits and drawbacks (Christine, 2004). The utilisation of discarded fire clay brick offers the benefit of encouraging environmentally friendly building (Naceri & Hamina, 2009). However, using waste clay brick demands a thorough product observation because of the study's limitations. Waste fire clay bricks can still be used as a

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filler in compressed earth brick, according to tests on density, compression, and water absorption. Previous study had discovered the potential of using waste materials as partial or full replacement of the mix which give significant effect on enhancing its compressive strength (Kasinikota & Tripura, 2021; Hany et al., 2021).

The purpose of this study is to ascertain the compressive earth brick's strength and water absorption capacity when combined with waste fire clay brick. Additionally, the ideal proportion of waste fire clay brick was used as a filler in the compressed earth brick. Recycling waste is only possible if the newly created products' characteristics and environmental practices are assessed against the necessary environmental standards (Al-Fakih et al., 2018; Al-Fakih et al.,2019; Muntohar, 2011). In order to be employed as a creative strategy for creating a new building material that can be used in the industry, the compressive strength and the percentage of water absorption of the fresh product should be acceptable and meet with the standard requirement given

2. Materials

Portland cement that complies with the standard requirement studied in Ishak, Ikhwat & Lai (2019), soil, sand and water were the material used in this study (Ali et al., 2016; Ali et al., 2016). The soil would be replaced by waste fire clay brick by percentage. The waste fire clay bricks were collected from the brick manufacturing factory, Hoe Guan Brickworks Sdn. Bhd. located in Ayer Hitam, Johor. The fire clay bricks were crushed before mixed with other materials. The wastes were further crushed again in a crusher machine to get a finer size of the waste fire clay bricks as shown in Figure 1. Figure 2 shows the laterite soil which was used in this study. The soil also needs to undergo the crushing process to ensure that the size of the soil meets the grading requirement (Abdullah et al., 2021). Figure 3 shows the local white colour of natural river sand used.

Fig. 1 - Fire clay brick powder

Fig. 2 - Laterite soil

Fig. 3 - Sand

3. Method and Laboratory Testing

The design of the brick size was 125 mm x 250 mm x 100 mm. The overall volume was replaced by the waste fire clay bricks by volume fraction percentage such as 10%, 20%, 30%, 40% and 50%. The volume fraction percentage of 0% was set as the control. The minimum number of bricks produced were expected about 72 bricks where 36 bricks were used for compression test and 36 bricks were used for water absorption test. The design mix ratio is 1:4:4 which were (cement: soil: sand). Table 1 shows the bricks produced in this study.

Table 1 - Brick samples

Brick type	Control brick	Waste fire clay brick					Total no. of sample
Percentage of filler (%)	0	10	20	30	40	50	
Number of samples at 7 days	6	6	6	6	6	6	
Number of samples at 28 days	6	6	6	6	6	6	72

The materials were prepared and weighted according to the calculated designed mix proportion for each material as shown in Table 2. Then, all the materials were mixed in the mixer machine. The mix then moved onto the conveyor to get into the Compressed Stabilized Earth Block Machine as shown in Figure 4. After the brick manufactured, the bricks undergo dry curing for 7 days and 28 days as shown in Figure 5. The bricks took advantage of the humidity in the air to allow for quick piling following compression, but with time the strength improved (Riza, Rahman & Zaidi, 2010). Then, laboratory tests would be conducted on the sample. The bricks then were tested for density test. The bricks were measured by its width, length and thickness using measuring tape. The bricks then were dried in the oven for 24 hours and weighted after. Next, the bricks were immersed in water tank for 24 hours and weighted on weighting scale. The bricks were also weighted while immerse in water using immersed weight measurement apparatus. Another brick samples would be tested for compression test. The load was applied on the brick with a speed of 7 kN/s on the surface area of the brick which is 27388 mm^2 after deducted with the hollow surface area on the brick. All the tests were conducted according to the requirement in ASTM C140 (American Society for Testing and Materials, 2019).

Table 2 - Design mix proportion

Percentage of filler (%)	Cement (kg)	Sand (kg)	Soil (kg)	Waste fire clay brick (kg)
0	11.1	50.75	44.40	0
10	11.1	50.75	41.31	6.35
20	11.1	50.75	36.72	12.70
30	11.1	50.75	32.13	19.05
40	11.1	50.75	27.54	25.40
50	11.1	50.75	22.95	31.75

Fig. 4 - Compressed stabilized earth block machine

Fig. 5 - CEBs undergo dry curing for 7 days and 28 days

4. Result and Discussion

In the present study, data analysis's main goal was to systematically examine if it was possible to incorporate waste products into building materials. To do this, a thorough review and test findings collected from various observations and tests were carefully analysed. Finding the ideal percentage of waste fire clay bricks that could be successfully used as a filler in construction materials was one of the main objectives in which we were particularly interested. For the purpose of future development and application of these waste materials in the construction industry, this proportion would be an important point of reference. Hence, our data analysis not only highlighted the potential of waste materials in building but also offered valuable information that can support environmentally friendly and sustainable construction methods

4.1 Compression Test

Figure 6 shows the percentage increment of brick's strength after 7 days and 28 days of curing duration based on control brick with 0% waste fire clay brick. According to the results of the 7-day brick curing process, the compressive strengths are higher than the standard CEB strength. The CEB, which utilizes 20%, 40%, and 50% waste fire clay brick as filler, has the greatest strength value. Meanwhile, it is found that the CEB with 30% filler has a 0.1 N/mm^2 reduction in strength. The 28-day brick curing result further indicates that, with no waste fire clay brick filler, the compressive strengths are also increasing and exceeding the typical CEB strength. The highest strength of compressive strength is on the CEB with 50% waste fire clay brick filler. This analysis shows that the brick incorporation with waste fire clay brick enhances the compressive strength. This observation agrees with the previous study which said that the incorporation of crushed brick waste improves the compressive strength significantly compared to the control sample (Kasinikota & Tripura, 2021; Chen et al., 2017).

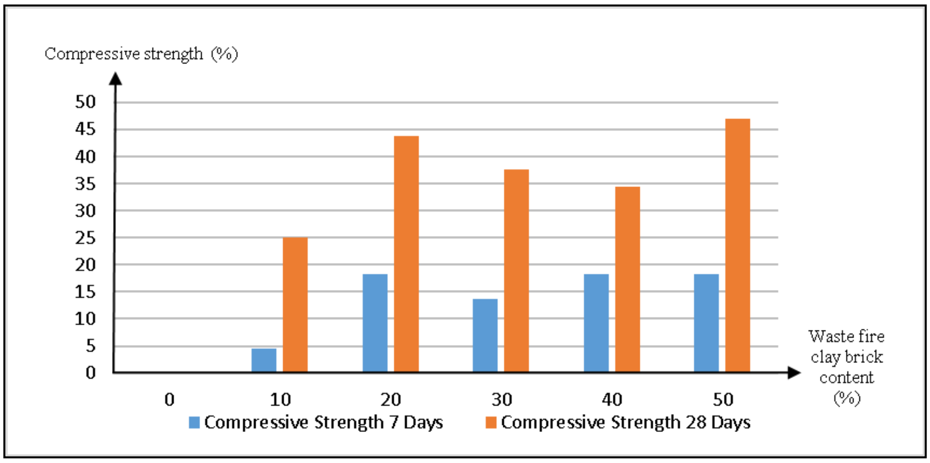

Fig. 6 - Increment of compressive strength of brick at 7 and 28 days

4.2 Water Absorption Test

The percentage of water absorption of the CEB was calculated using a formula that complies with ASTM C140 (American Society for Testing and Materials, 2019). The data which the weight of oven-dry, saturated, and immersed bricks was used to analyse the result. Figure 7 shows the increment and reduction percentage of water absorption. The percentage of water absorption for 7 days of curing bricks is increases and is found to be greater than the rate of water absorption for control bricks. Based on the graph, the optimum was obtained with a brick containing 20% waste fire clay brick filler. On the other hand, water absorption for curing bricks decreased over time and was lower than the values for control brick. The brick containing 50% waste fire clay brick had the lowest water absorption value. This observation of brick after 7 days of curing agrees with the previous study by Kasinikota & Tripura (2021) however it is contradictory with study conducted by Aliabdo et al., (2014). Meanwhile, the water absorption of bricks after 28 days of curing was decreasing as the percentage of waste fire clay brick as a filler was increasing. The acceptable water absorption for a normal clay brick should be between 12% to 20%.

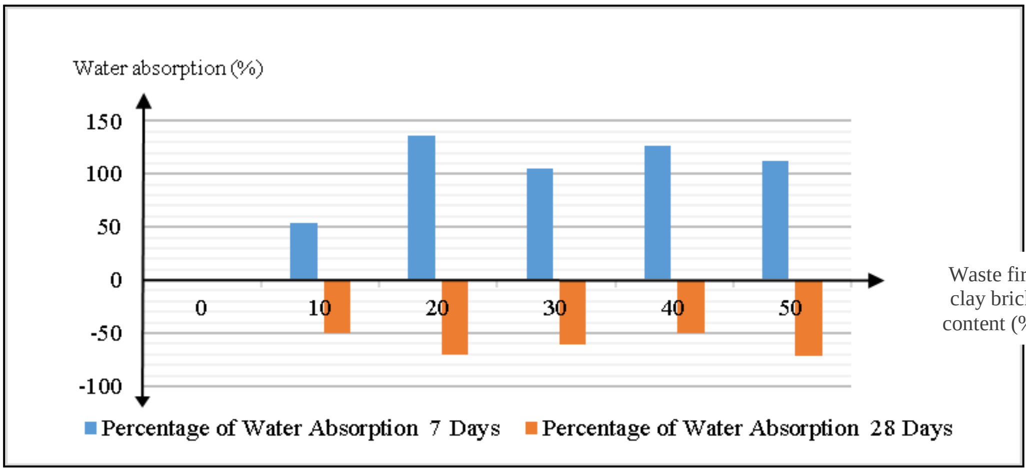

Fig. 7 - Increment and reduction of water absorption of brick at 7 and 28 days

4.3 Density Test

The density of 7 days curing bricks were decreasing compared with the value of control brick's density. The highest density value is on the brick with 10% waste fire clay brick as a filler. On the other hand, the density of 28 days curing bricks were increasing compared with the density value of control brick with 0% waste fire clay brick as a filler. However, the highest value of density for 28 days curing bricks is on the brick with 50% waste fire clay brick as a filler. Figure 8 shows the percentage of density increment and reduction for both 7 days and 28 days of curing duration.

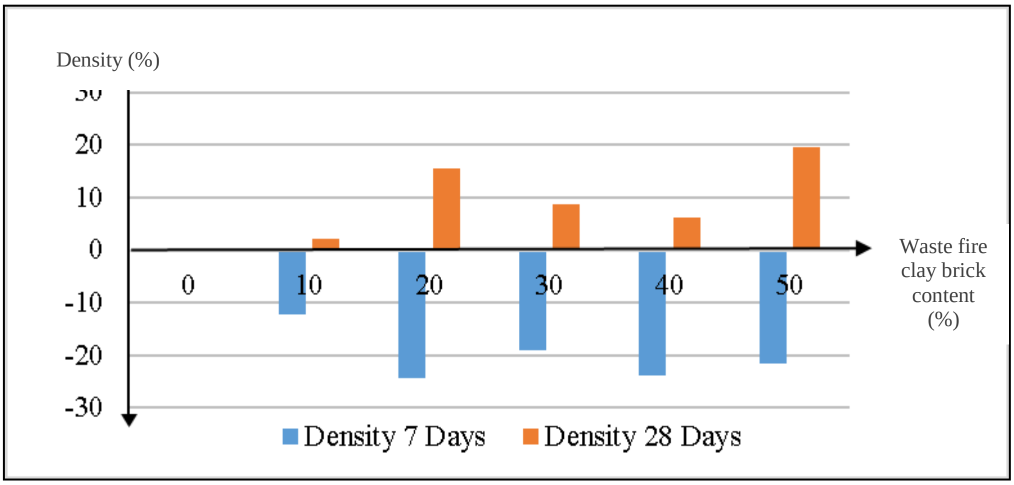

Fig. 8 - Increment and reduction of density of brick at 7 and 28 days

4.4 Relationship between Compressive Strength and Density

Based on Figure 9, it shows that the increases of density contribute to the increase value of compressive strength. The brick's strength qualities are significantly improved as a result of the decrease of voids within it. Less voids suggest a more tightly packed structure, which results in a brick that can take larger compressive loads, which helps to explain the phenomena. The green line shows the minimum requirement value of compressive strength of brick based on MS 76: 1972 which is 2.8N/mm^2 (Jabatan Kerja Raya Malaysia, 2020). In a nutshell, Figure 9 offers insightful empirical evidence that clarifies the relationship between density and compressive strength and emphasizes the significance of adhering to industry standards to guarantee the dependability and safety of construction materials.

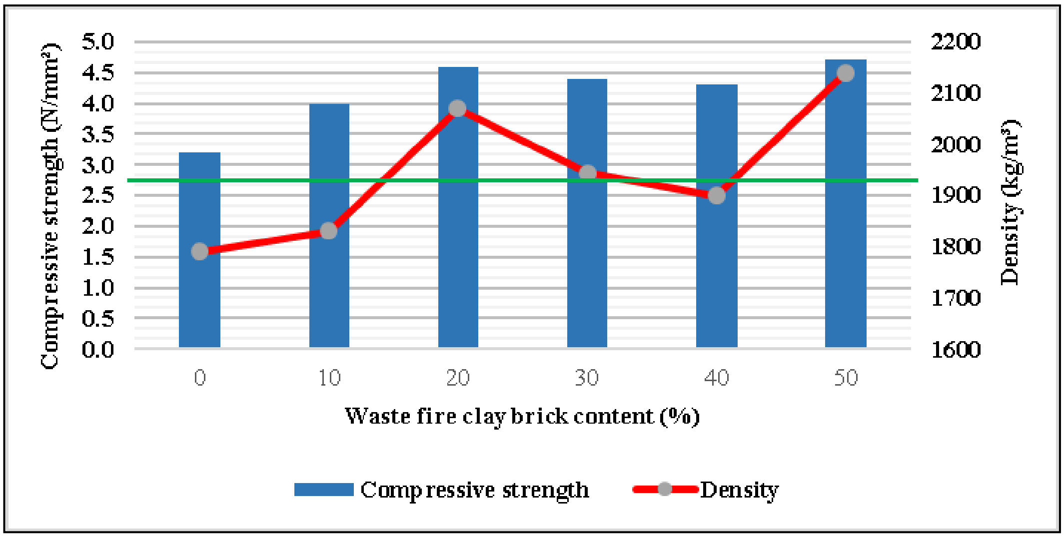

Fig. 9 - Relationship between compressive strength and density

4.5 Relationship between Percentage of Water Absorption and Density

As seen in Figure 10, the amount of water absorption decreased as the amount of waste fire clay bricks increased. Reduced water absorption would result from density increases. From thorough study and observations, it clearly shows that 50% is the ideal amount of waste fire clay bricks to use as a filler in crushed earth bricks since it has the maximum compressive strength when compared to other waste filler percentages.

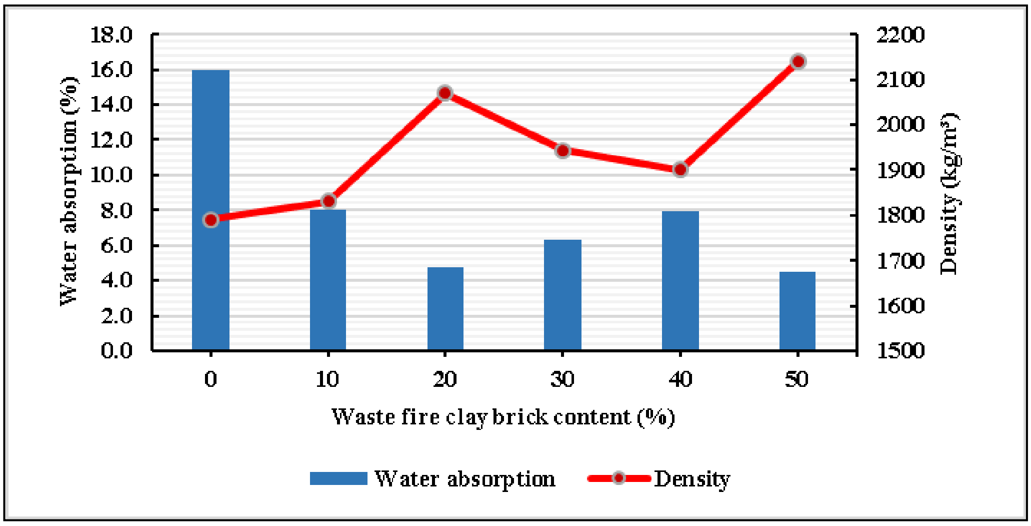

Fig. 10 - Relationship between percentage of water absorption and density

5. Conclusion

The utilization of waste fire clay brick as a filler in a compressed earth brick is one of an approach in order to reduce the improper disposal of waste fire clay bricks in the environment. This approach can be developed towards sustainable product in construction industries

The minimum strength achieved by the brick is at 4.0 kN/m^2 which follow the minimum permissible average compressive strength of 2.8N/mm^2 for hollow blocks as stated in the Jabatan Kerja Raya Standard Specification for Building Works (2020) for wall system section which is also comply with MS 76: 1972 (Malaysia: Standard & Industry Research Institute of Malaysia, 1972) for non-load bearing bricks. The replacement of soil with fine waste fire clay brick as a filler may be reducing the pores and voids in the brick which give a slower reaction for the water to absorb into the brick. If the value of the water absorption was lower than 12%, it might affect the bonding performance between the mortar and the bricks in construction.

The density result also shows the relation with the compressive strength of the brick. The higher the density, the higher the value of compressive strength. The higher the density, the lower the percentage of water absorption. The percentage of compressive strength increment was not increasing consistently, and the reduction of water absorption percentage was not decreasing consistently along with the increases of waste fire clay brick as a filler. The factor of the inconsistency of graph pattern was due to the error of mixing materials during the brick manufacturing process and the low quality of the materials which might affect the physical properties of the bricks.

Overall, it can be concluded that the waste fire clay brick has the potential to be used incorporated in compressed earth brick as it played an important role in the creation of construction materials. The 50% of waste fire clay brick content as a filler in the compressed earth brick was decided as the optimum percentage of waste fire clay brick content. The aims of this study were achieved. In the building industry, the usage of waste fired clay brick can provide sustainable resources.

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