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The Effect Waste Ceramic Tile as Partial Material Replacement of Sand for Sand Cement Brick

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Abstract: The production of sand cement bricks is now focused on the use of waste materials as a substitute for some of the materials in bricks especially sand. The application of recycled materials in the construction industry is essential for the sustainable development of the country. Waste ceramic tiles are used as a semi-sand substitute material in sand cement bricks because 30% of the daily production of the ceramic industry is estimated to be wasted. In this study, the performance of bricks was investigated based on mechanical and physical tests. The percentage of residual replacement of ceramic tiles in sand cement bricks is 0%, 10%, 20%, and 30%. From the analysis, the ceramic tile residue contributes to the improvement of the mechanical and physical properties of the brick. Significant findings from this test, it can be seen that among the samples, bricks with 30% substitution had the greatest strength of 61N/mm on the 28th day which is directly proportional to the brick density from the test conducted. From the water absorption test, the brick is classified as a first-class brick because the average water absorption obtained is below 15%. These bricks are categorized as hard bricks because no trace is left on the surface of the brick when conducting the hardness test as well as not breaking after the impact test is carried out.

Keywords: Sand Cement Brick, Ceramic Tile Waste, Testing

1. Introduction

Construction materials consisting various elements, one of the most important material is brick. Brick is widely used in many constructions work such as the construction of the retaining wall in any sizes of brick, floor and wall of the building. Then, one of the most common brick uses in building construction is sand cement brick. There are various advantages of cement brick can serve into the building construction such as mature production technology. This is due to high pressure is apply during

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the forming brick process, so it caused the product to have high density, low water absorption, high strength and good freezing resistance. Thus, it is widely used as it gives a lot of advantages in building construction.

Generally, the composition of the sand cement brick consists of three main material which including of the cement, water and sand [1]. The replacement of raw materials has been considered with another recycle product to produce the new composition of brick. Therefore, the recycle waste ceramic tile is propose as partial replacement of sand in the sand cement brick. The recycle ceramic tile is obtain from the demolition waste and processing construction that has been produce increasingly.

Ceramic is known as inorganic and non-metallic solids that consists of highly crystalline, semi crystalline, vitrified or completely amorphous [2]. The ceramic tile is made with the clay with the mixing of the sand on it. The ceramic tile product is low water absorption and height mechanical strength. This is result due to the low porosity. According to [2], the low porosity is affected by processing conditions during the high degree milling of the raw materials, high force of compaction and sintering temperature. Then, due to the potential of raw material to turns into the liquid phase during the sintering which can affect the properties of the ceramic tile product.

The aim of this study is assessing the properties of the sand cement brick that containing the waste ceramic tile as partial replacement material of sand. So, the observation is including on the influence of the of waste material in sand cement brick. Therefore, the evaluation is determines based on the laboratory testing that contain of physical properties, and mechanical properties of the bricks.

2. Materials and Methods

The materials used in the preparation of brick sample were Ordinary Portland Cement, natural sand, water and ceramic tile waste (CTW) obtained from landfill site area at Parit Samijan, Batu Pahat, Johor. The CTW used is involved the crushing process using the Los Angeles Machine Testing until the size distribution of CTW turned into fine aggregate size as shown in **Figure 1**. In this study, 0%, 10%, 20% and 30% CTW was used as sand replacement in the brick sample. **Table 1** shows the mass of material to produce the 18 brick sample. For each percent replacement, a total of 18 brick sample were prepared where 6 brick sample for compression strength test, 6 brick sample for flexural strength test and another 6 brick sample for physical test. For each test, 3 sample brick were tested at 7 day of curing while another 3 brick sample were tested at 28 day of curing. The size of the sample of brick is designed based on the BS 5628-3-2005 which is 215mm (length) x 103mm (width) and 65mm (depth). **Figure 2** and **Figure 3** shows the process of brick production.

Figure 1: CTW used in this study.

Table 1: Mass of material.

Material	Mass (kg)			
	0%	10%	20%	30%
Cement	12.83	12.83	12.83	12.83
Sand	38.47	34.62	30.78	26.93
Water	7.72	7.72	7.72	7.72
Ceramic Tile Waste	0	3.85	7.69	11.54

Figure 2: Brick sample production.

Figure 3: Compaction of brick.

The brick was left for 24 hours in mould and then take out for the water curing. They were placed in curing tank for 7 and 28 days of water curing as shown in **Figure 4**. Then, the brick sample were then tested to determine the compression strength, flexural strength, density, water absorption, hardness and impact testing.

Figure 4: Water curing of brick sample.

2.2 Equations

In this study, there were formula used to calculated the density and water absorption of the sample brick. The formula used for density as Equation 1 and water absorption as Equation 2:

$$Density = \frac{Mass}{Volume} \ Eq.1$$

$$Water\ absorption = \frac{M1 - M2}{M2} \times 100\% \ Eq.2$$

Where, M1 = Weight after immersed in water 24 hours

M2 = Weight after dry oven 24 hours

3. Results and Discussion

3.1 Compressive Strength

Table 2 shows the average result of compressive strength of the sand cement brick with partial replacement of sand with definite percentage which are 0%, 10%, 20% and 30%. The procedure of the compression strength is based on the BS 1881: Part 115: 1986 “Specification for Compression Testing Machine for Concrete”. The testing equipment involved Compressive Strength Test Machine. Then, the graph is plotted as shown in **Figure 5**. The graph is representing the average compression strength of the brick sample for 7 day and 28 day of curing period.

Table 2: Average result of compression strength at 7 day and 28 day of curing period

Percent Replacement of CTW (%)	Average of compression strength at 7 day	Average of compression strength at 28 day
0	36.4	43.8
10	34.0	49.8
20	49.0	60.5
30	46.5	61.2

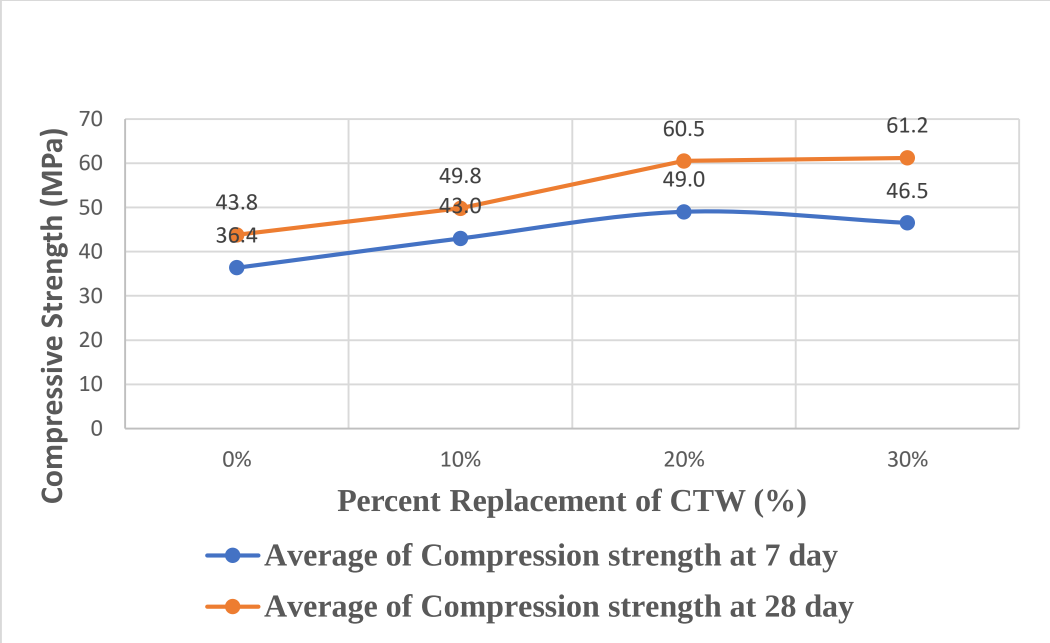

Figure 5: The compressive strength of sand cement brick with partial replacement of sand with ceramic tile waste.

Generally, t can be seen that the compressive strength of the brick sample for 0%, 10%, 20% and 30% of replacement material is increase from day 7 to day 28 of curing period. The compressive strength for 0% of replacement at 7 day is 36.4 MPa and 43.8 MPa at 28 day curing age. For 10% is 43.0 MPa at 7 day and 49.8 MPa at 28 day, for 20 % is 49.0 MPa at 7 day and 60.5 MPa at 28 day, lastly 30% of replacement of sand compressive strength is 46.5 MPa at 7 day and 61.2 MPa at 28 day of curing age. Thus, replacement of sand with ceramic tile can contribute to the increases of cement brick strength.

The significant finding from this test, it can be seen that among the samples, brick with 30% replacement having the greatest strength of 61N/mm at 28^{th} day. However, the sample having low strength compared to brick with 20% replacement as can be observed on day 7. This indicated that the sample 30% of replacement gained more strength at the later stage. This can be causes by lack of compaction during the mixing process. The brick is not well compacted using the rod which can cause the honeycomb. Honeycomb is happened when the compaction not having been adequate to cause the mix to fill the voids between the material. To be conclude, the presence of ceramic tile waste in the brick can increase the strength of brick to retain more load. These increases of the brick strength can be influenced by many factors. According to [3], sand is the raw material that contributed to increase the strength of mortar by used as filler to mortar. So, replacement of raw material into waste material which is ceramic tile waste successfully to increase the strength as the CTW can turn the brick into more compact condition.

3.2 Flexural Strength

Flexural strength was analyzed to identified the deflection of the brick when loading is applied on the brick. The flexural testing is conducted on the 3 samples of the brick on each percent replacement 0%, 10%, 20% and lastly 30% of CTW in sand cement brick. The average of flexural strength is shown in **Table 3** and being plotted on graph as shown **Figure 6**. The result is being compared between the percent replacement of CTW and curing age at 7 day and 28 day.

Table 3: Average result of flexural strength at 7 day and 28 day of curing period.

Percent Replacement of CTW (%)	Average of deflection at 7 day	Average of deflection at 28 day
0	1.0	1.0
10	1.3	2.0
20	1.0	1.0
30	1.7	1.7

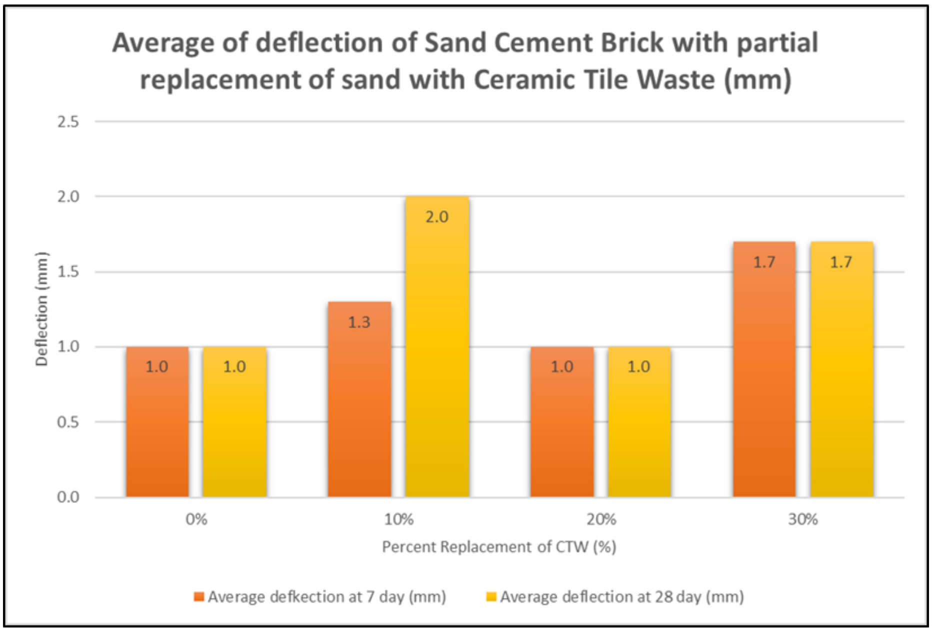

Figure 6: The flexural strength of sand cement brick with partial replacement of sand with ceramic tile waste.

Based on the graph it can be seen that the deflection at day 7 is lower than 28 day of curing age. The deflection value of 7 day of curing age is similar for 0% and 30% of replacement which is 1.0mm. At 7 day of curing age, the value of deflection at 10% and 30% of replacement which are 1.3 mm and 1.7 mm respectively. However, the deflection value at day 28 of curing age are 1.0 mm with 0%, and 20% of percent replacement, while 2.0 mm at 10% and 1.7 mm at 30% of percent replacement of CTW. This result shows that the brick achieved more strength after day 7 of curing.

Furthermore, the brick sample can apply more loading before the deflection occurred. Based on the result, it can be be conclude that 30% of percent replacement of CTW can retained more maximum load compared to other sample brick with percent replacement. Besides, the value of deflection on 30% is higher compared to 0%, 10% and 20% of percent replacement which shows that the brick sample is high strength to retained load.

3.3 Density

The density of brick is measured based on the weight of brick sample per volume of the brick. Generally, the weight of brick sample is ranged between 2.8-3.0 kg. The standard weight of brick is not exceeded 3.0kg. Then, volume of brick is calculated based on the size of the brick which is 215 mm x 103mm and 65mm which is $1.439\ x\ 10^{-3}\ mm^{3}$. The density results of brick sample are shown in **Table 4.**

Table 4: Average density of the brick sample at 7 day and 28 day of curing period.

	Average density at 7 day			Average density at 28 day		
Percent replacement of CTW (%)	Compression strength (Brick)	Flexural strength (Brick)	Physical test (Brick)	Compression strength (Brick)	Flexural strength (Brick)	Physical test (Brick)
0	2082	2027	2064	2101	2087	2094
10	2092	2069	2062	2062	2096	2080
20	2080	2094	2094	2071	2099	2101
20	2036	2059	2089	2069	2117	2085

From **Table 4**, the density of the brick by percent is not fixed. Generally, the density of brick sample is decrease when the percent replacement in cement brick is increase. However, the density for 30% replacement is increase from day 7 to day 28 of curing age. The density of brick is depending on the raw material and mixing process. Referring to [3], the density of cement bricks affected by the raw material and the manufacturing process. On the mixing process, the brick is not compacted at same pressure which can affect the weight of the brick. Then, the low pressure of compaction using the rod the is caused to give the lower the weight of the brick. During the mixing, the brick is applied three layers of pouring and being compacted 25 blows at every layer using the rod. Thus, the different pressure can lead into difference of density of the brick. In addition, the density of brick can influence the strength of brick. From this testing result, the strength of brick is increase directly proportional to density at 30% of replacement.

3.4 Water absorption

Water absorption testing is important in order to determine the quality of the brick produce. Water absorption is closely related to the porosity of the brick. The high-water permeability can affect the strength of the brick to decrease. The average of the water absorption is being summarize in **Table 5** and result is being compared based on the graph plotted on **Figure 7**. The water absorption testing is used as an indicator on the durability properties. The durability properties can be identified other than quality properties which are degree of burning, and behavior of the brick in weathering. However, in this study, the main focus is to identify the quality of the brick

Table 5: Average result of water absorption at 7 day and 28 day of curing period.

Percent Replacement of CTW (%)	Average of water absorption at 7 day	Average of water absorption at 28 day
0	10.9	6.20
10	7.47	5.78
20	6.63	5.28
30	8.00	8.90

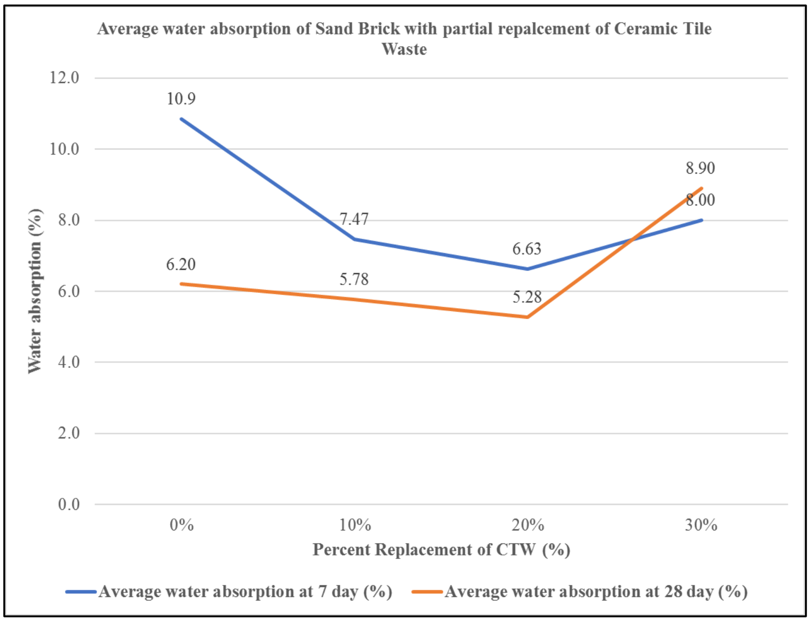

Figure 7: Average water absorption of Sand Cement Brick with partial replacement of CTW.

Based on the graph plotted, it can be seen the water absorption of the brick is decrease directly proportional to 10% and 20% replacement. Then, the water absorption of brick increase when the replacement of sand with ceramic tile waste at 30% compared to 10% and 20% of replacement. However, the water absorption result is below than 15% of water absorption which the brick can be considered as first-class brick which can influence the strength and durability of the brick. Furthermore, the optimum water absorption of the brick is at 20% of percent replacement with CTW compared to the measure control of the brick. This can be caused of the decreases of porosity in the brick. Referring to Ali et al., (2018), the water absorption rate of a unit brick is closely related to the porosity. Thus, it also can be related to compressive strength of brick which the result is increase in both curing age.

3.5 Hardness

The hardness testing is conducted to observe the resistance of the brick to scratch. The brick sample is being scratched with a sharp tool which is a nail. Based on the test conducted, the brick is considered as hard brick due to no impression leave behind on the brick surface. The **Figure 8** below shows the condition on the brick surface after the scratch.

Figure 8: The surface condition of the brick after the scratch.

3.6 Impact

Impact testing is conducted to identify the quality of the brick. Based on the **Figure 9** below, it shows the condition of the brick after being drop at one meter of height. The brick is considered as in a good quality due to condition of the brick is not break at all.

Figure 9: The condition of the brick after drop.

4. Conclusion

Throughout the whole process of testing, it can be concluded, the replacement of sand with ceramic tile waste were influence the performance of the sand cement brick. It shows the strength of the brick increase respectively when the percentage of ceramic tile waste replacement on the brick increase. Furthermore, the physical properties of the sand cement brick also affected with the presence of the CTW in sand cement brick. Overall, the physical properties were showing the increasing on the the durability of the brick to perform as good building material.

In order to enhance the study of using CTW in cement brick, there are several recommendations that is suggested to be investigated/ the recommendation includes:

i. Percentage of replacement can be varied to get more range of data.
ii. Consider to study the effect of different mix design.
iii. Other type of testing for example thermal testing.

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References

[1] E. Science, “Performance of composite sand cement brick containing recycle concrete aggregate and waste polyethylene terephthalate with different mix design ratio Performance of composite sand cement brick containing recycle concrete aggregate and waste polyethylene t,” 2018.

[2] C. Kanali and E. Ronoh, “Physical and Chemical Properties of Crushed Ceramic and Porcelain Clay Tile Physical and Chemical Properties of Crushed Ceramic and Porcelain Clay Tile Powder,” no. July 2018, 2019.

[3] N. Ali, N. F. Mohd Yusup, F. Sheikh Khalid, S. Shahidan, and S. R. Abdullah, “The Effect of Water Cement Ratio on Cement Brick Containing High Density Polyethylene (HDPE) as Sand Replacement,” *MATEC Web Conf.*, vol. 150, pp. 4–8, 2018, doi: 10.1051/matecconf/201815003010.