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Mechanical and Rheological Properties of Concrete with Ceramic Tile Waste as Partial Replacement of Fine Aggregate

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Abstract. The rapidly increasing in population has led to the higher of construction, repairing and renovation activity that lead to produce large amount of construction material waste. The disposal of broken ceramic tiles during construction is one of the factors which contribute to this matter and can lead to land pollution. On the other hand, the natural resource in construction such as fine aggregate also facing depletion in order to cater the current and future demand. Therefore, this paper explores the properties of concrete with ceramic tile waste used as a partial replacement for fine aggregate. About 45 cube samples, 30 prism samples and 15 control samples were casted. Various percentage of ceramic tile waste has been introduced as partial replacement for fine aggregate with proportion of 10%, 15%, 20% and 30%. Tests for mechanical and rheological properties which have been done to identify the concrete performance are compressive strength, flexural, water absorption and slump test. From the results obtained, the sample of concrete contain of 15% ceramic tile waste as fine aggregate replacement has reached the optimum strength in both compressive strength and flexural strength. However, by using 20% of ceramic tile waste as fine aggregate replacement does show higher workability and water absorption.

1. Introduction

Construction activity such as renovation, demolition and repairing work have increased the amount of solid waste. Construction waste contribute the highest percentage of solid waste in the world with various of ceramic materials such as ceramic tile, brick tile, roof tile and the other ceramic products. Malaysia has recorded an approximately 8 million ton of construction waste per year which stated by Solid Waste and Public Cleansing Management Corporation [1].

It is crucial for a developing country to has a growing construction industry with a good waste management system so that the rapid development will not affect the environment. Another option is to reduce the waste from construction industry by reuse or recycling the waste. In this study, the focus is to reuse the ceramic tiles waste obtained from the construction site as a partial replacement for fine aggregate in concrete in terms of its mechanical and rheological properties performance.

Improper management of ceramic tiles waste will not only give impact to land pollution but also to human health if ceramic tiles waste were disposed in ash form. It can affect the lung function, cardiovascular disease and chronic abnormal [1].



Furthermore, with this study, it also contributes to less use of fine aggregate which cater the issue of insufficient of natural resources. The problem arose from continuously mining the sand which effect the ecosystem and cause the degradation of the river, as well as affect the water quality [1] can be reduce.

2. Literature Review

Previously, a study on ceramic tiles as a replacement for both fine and coarse aggregate in concrete mixture has been done [2]. About 10% of ceramic tile used as fine aggregate replacement while for coarse aggregate replacement contain of three percentage which are 30%, 60% and 100%. The mix concrete is for M30 grade and from the results obtained, with 10% of ceramic tiles as fine aggregate replacement and 30% of ceramic tiles replace as coarse aggregate, the compressive strength has achieved 31.70N/mm². The compressive strength increased to 34.61N/mm² when the percentage of ceramic tiles as coarse aggregate replacement increased to 60%. However, with the used of 100% ceramic tiles as coarse aggregate has shown the decrease in compressive strength value which it only reaches until 28.34N/mm².

Another study shows replacement of both fine and coarse aggregate with amount of 22.1% will increase the compressive strength value [3]. On the other hand, 20% replacement of tile ceramic waste and ceramic sanitary for natural limestone aggregate and fine aggregate also achieved higher value of compressive strength compared to the conventional concrete [4].

The study of ceramic aggregate as alternative material in replacing fine aggregate show the flexural strength has increased with the increment of ceramic aggregate percentage from 25% to 75% content [5]. Other than that, one study shows that the flexural strength in M30 concrete at 28 days are higher with the increment content of crushed ceramic tiles as fine aggregate replacement due to the reaction of the crushed ceramic tiles with the Portland-pozzolana cement grade 43 which used in the mix design [6].

In terms of workability, previous study shows that the slump test is similar with the control sample if the ceramic tile was replaced as coarse aggregate and it shows higher value compared to control sample if the ceramic tile waste is replaced as fine aggregate [7]. The optimum content which was obtained from the study is 20% ceramic tile for fine aggregate replacement. Another study on influence of water absorption using ceramic tiles as aggregate replacement shows the higher value of water absorption compare to the normal sample [8].

3. Experimental Procedure

Experimental procedure is done starting from the preparation of raw material, mixing and conducting related testing on the samples prepared.

3.1. Raw Material

Type of ceramic tile waste used in this study as raw material is porcelain tile which has been collected from the construction site area. This raw material is first having to be cleaned from any other substance or mud. It then will be break into small pieces before crushed in order to get the 4.75mm size aggregate. Then, it will be dry for 24 hours in oven. The procedure stated is shown in Figure 1.

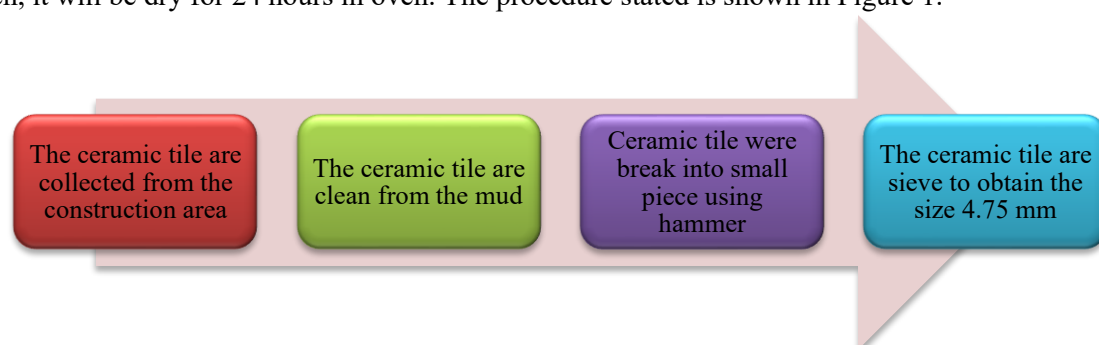


Figure 1. Preparation of ceramic tile waste as raw material.

3.1.1. Mix Design and Process.

Mix design of concrete grade 25 for control samples (CS) and samples with ceramic tile waste (CTWC) are as shown in Table 1. Ordinary Portland Cement (OPC) grade 42.5 has been used in this study with 0.5 ratio of water-cement content. The coarse aggregate with the range size of 16mm to 10mm will be mixed with fine aggregate with the range size are 4.75mm to 1.18mm. Four different proportion of CTWC are used to replace fine aggregate which are from 10%, 15%, 20% and 30% of ceramic tile fine aggregate will be replaced with fine aggregate. The mix design is then will placed into cube and beam size samples. The samples will be cured in the water before testing for 7 and 28 days.

Table 1. Design concrete mix.

Percentage replacement of fine ceramic tile (%)	W/C ratio	Cement content (kg/m ³)	Water (kg/m ³)	Fine aggregate (kg/m ³)	Coarse aggregate (kg/m ³)	Ceramic tile waste (kg/m ³)
0% (CS)	0.5	380	190	558	1302	NA
10% (CTWC-10)	0.5	380	190	502.2	1302	55.8
15% (CTWC-15)	0.5	380	190	474.3	1302	83.7
20% (CTWC-20)	0.5	380	190	446.4	1302	111.6
30% (CTWC-30)	0.5	380	190	390.6	1302	167.4

3.2. Testing and Analysing

Testing made to identify the performance of concrete with CTW replacement for fine aggregate in terms of mechanical and rheological properties. For mechanical properties, compressive and flexural strength test has been done to the samples. The compressive strength test of concrete was carried out according to BS 1881: Part 116: 1983 while flexural strength test of concrete was carried out in accordance with BS 1881: Part 118: 1983. Rheological properties for this study focused on the workability of the concrete samples by the standard slump test according to the BS 1881 Part 102: 1983 and the water absorption test according to BS 1881-122. Figure 2 shown the process for water absorption which involved water curing process, oven dry process and weight.



Figure 2. Water absorption test process.

4. Results and Discussion

4.1. Compressive Strength

The compressive strength test done on the cube samples after 7 and 28 days. Based on Figure 3, compressive strength for CS at 7 days has reached 37.1MPa and 33.4MPa at 28 days. On the other hand, the compressive strength value for CTWC-10 and CTWC-15 samples has reached higher compared to CS samples with value of 42.3 MPa and 44.5MPa each at 7 days while at 28 days the value are 36.9MPa and 40.5MPa each. For CTWC-20 and CTWC-30samples at 7 days, the values are lower than CS samples but still higher than the design of normal strength concrete in this study which is 25MPa. However, the values are higher compared to CS samples at 28 days which are 35.4MPa and 33.9MPa each. The positive results by replacing fine aggregate with ceramic tile waste in concrete may due to the

pozzolanic activity of ceramic micro particle when combined with cement compound. Other than that, the type of fine aggregate used in these samples that are very fine may cause the increase of compressive strength value.

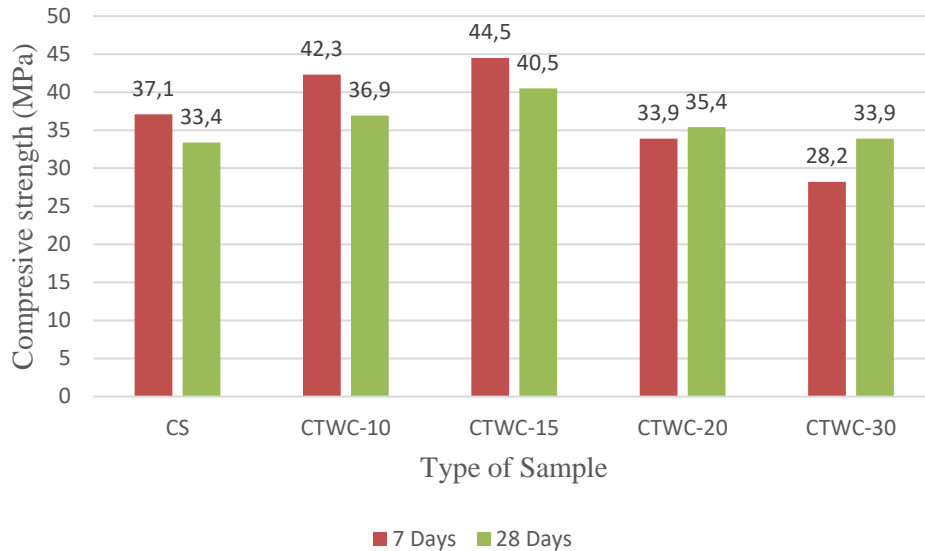


Figure 3. Compressive Strength Test.

4.2. Flexural Strength

The flexural strength test done on the prism samples shows that flexural strength for CS at 7 days has reached 4.1MPa and 5.1MPa at 28 days. On the other hand, the flexural strength value for CTWC-10 and CTWC-15 samples has increment value compared to CS samples with value of 4.6MPa and 4.8MPa each at 7 days while at 28 days the value are 5.6MPa and 5.8MPa each. For CTWC-20 and CTWC-30 samples at 7 and 28 days, the values are lower than CS samples. The reduction of flexural strength in replacement of ceramic tile as fine aggregate may be due to the ceramic material did not have good adhesion between the cement paste and the aggregate surface. In this study, the ceramic tile surface that been used are smooth on both top and bottom surface of ceramic tile that can affect the low cohesion between cement paste and ceramic tile fine aggregate accounts the reduce of flexural strength.

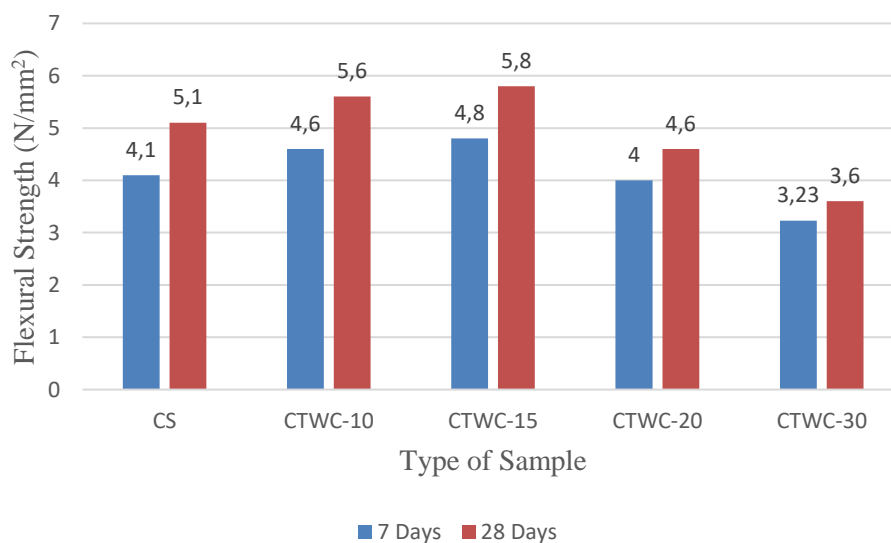


Figure 4. Flexural strength test.

4.3. Workability of Concrete

Figure 5 show the result of slump test. There is similar result for CS, CTWC-10, CTWC-15 and CTWC-20 samples which is 30mm. Meanwhile, CTWC-30 samples shown result of decreasing value which is 20mm. This is in line with previous study which stated that the replacement of fine aggregate with ceramic tile in the concrete inhibit to the decrement of slump test [6]. This finding can be explained as when the surface of ceramic tile is smooth, it might reduce the workability of concrete. Other than that, the finer particle requires more water to wet their larger surface, whilst the irregular shape and rougher texture of an angular demand more water [3].

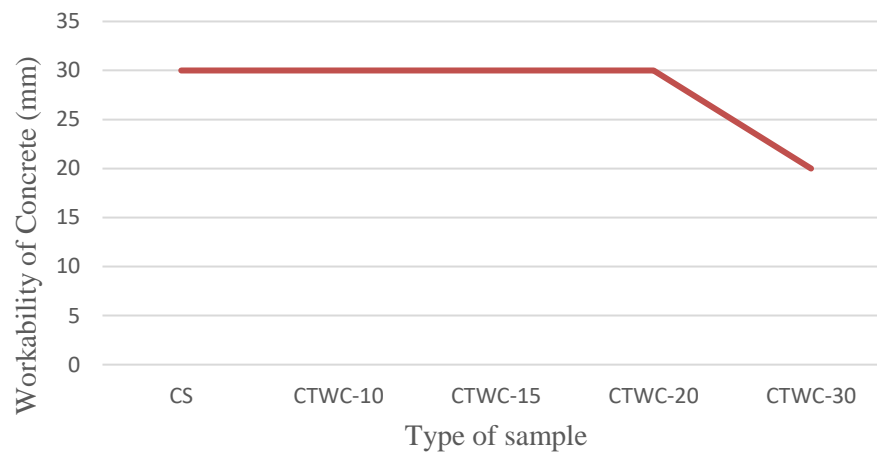


Figure 5. Workability of concrete.

4.4. Water Absorption of Concrete

Based on the Figure 6, it shows that the percentage of water absorption is increase with the increase of ceramic tile waste content used as fine aggregate replacement. The percentage of improvement for water absorption is from 8.76% for CTWC-10 up until 15.65% for CTWC-30. This result is similar with previous study which stated that the ceramic waste has water absorption is 0.18% compare with natural aggregate [8]. The higher percentage of ceramic tile used; the higher porosity of the concrete preserved in the air. Other than that, the surface area, pore structure and clay content play important role on the higher of water absorption. However, the higher of water absorption give the effect of reduction of compressive strength of concrete since it can give the improper bonding in the interfacial transition zone [4].

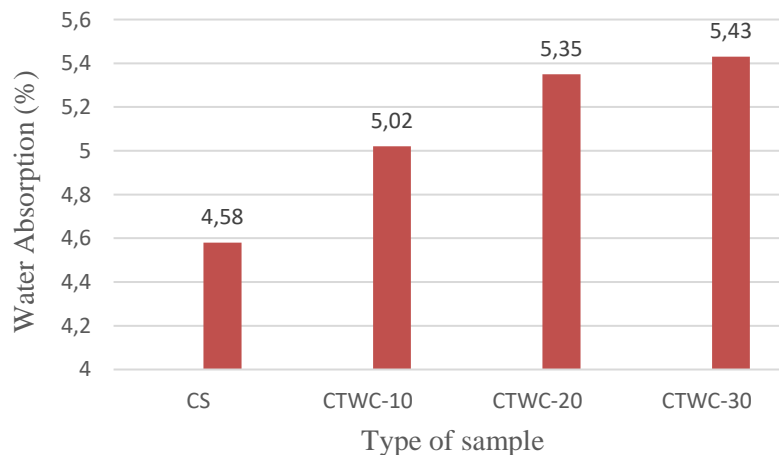


Figure 6. Water absorption of CS and CTWC.

Table 2. Results of water absorption and percentage of improvement.

Type of mixture	Water absorption (%)	Percentage of improvement on water absorption (%)
CS	4.58	-
CTWC-10	5.02	8.76
CTWC-15	5.12	10.55
CTWC-20	5.35	14.39
CTWC-30	5.43	15.65

5. Conclusion

This study focusses on the mechanical and rheological properties of concrete by partial replaced of fine aggregate with ceramic tile waste. From the results obtained, the sample of concrete contain of 15% ceramic tile waste as fine aggregate replacement has reached the optimum strength in both compressive strength and flexural strength. However, by using 20% of ceramic tile waste as fine aggregate replacement does show higher workability and water absorption.

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