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REPLACEMENT EFFECT OF COARSE AGGREGATE BY CRUSHED TILES ON HARDENED CONCRETE PERFORMANCE

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ABSTRACT

The goal of sustainable construction is to reduce the environmental impact of a constructed facility over its lifetime. Concrete is the main material used in construction in Oman. Therefore, it makes economic and environmental sense to use recycled materials in the making of new concrete for different applications. The objective of this study is to investigate the effects of using the crushed tiles (CT) as a coarse aggregate in the concrete mix. The general properties, such as the specific gravity, water absorption and water content, abrasion of the natural crushed aggregate and the CT aggregate were tested and compared with natural aggregate. Three different replacement percentages of CT aggregates (0%, 50% and 100%) were used in the concrete mix, in each replacement percentage; W/C and G/S were changed as a parametric study to investigate their effects on slump and compressive strength. Three beams casted with different crushed building waste material replacement contents varying from 0%, 50%, and 100%. All the beams are simply supported and subjected to one concentrated loads at mid-span of the beam. It has found that the plain cement concrete specimen has shown a typical crack propagation pattern which leaded into splitting of beam. The load carrying capacity were compared with theoretical values calculated using BS8110 (Design Manual). In general, the results confirm that increasing the W/C will cause to decrease the compressive strength of the concrete mix that with CT aggregate.

Key Words: Recycled aggregate, crushed tiles, physical properties, concrete mix, compressive strength, flexural behavior.

1. INTRODUCTION

The amount of tile waste on earth is enough for use as an aggregate in concrete. Tile is produced from natural materials sintered at high temperatures. There are no harmful chemicals in tile. Waste tiles cause only the apparition of pollution. However some parts of tiles are used as flooring and also flooring in tennis courts, walkways, cycling paths and gardens as a ground material. Therefore waste tiles are stored in factory fields because of their economic value. Nevertheless, each year approximately 250,000 tons of tiles are worn out, while 100 million tiles are used for repairs. These waste materials can be recycled to save money. Crushed tile aggregate, CTA, is a material especially proposed for the buildings constructed in hot climates.

The unit weight of concrete is decreased with use of the CTA compared to the control concrete. The use of CTA decreases costs and it also supports environmental health. Both the compressive and tensile strengths of the CTA added concrete were higher, but the drying shrinkage was lower. The inclination of the curve in the ascending part of the strain deformation diagrams was smaller and also deformation was higher compared to the normal concrete due to compressive strength. It was observed that CTA was 33 % lighter in weight. Besides, porosity and resistance to abrasion of CTA were smaller. The 28-day relative compressive strength, tensile strength and flexural strength of CTA concrete were 0.93, 1.02 and 1.15, respectively [1]. The technology of concrete recycling is well established in the U.S. Recycling of Portland cement concrete, as well as asphaltic concrete, has been shown to be a cost-effective alternative for new road, street, and highway construction. As early as 1987, more than 1000 lane miles of Portland cement concrete pavement had been recycled into new pavement. Concrete recycling to produce structural grade concrete for non-pavement uses is technically feasible, with certain precautions. For example, it is generally accepted that when natural sand is used, up to 30 % of natural crushed aggregate can be replaced with coarse recycled aggregate without significantly affecting any of the mechanical properties of the concrete [2].

Fung, (2005)[3] discovered that the maximum content of recycled coarse aggregates could be raised to 50% from a current practice of 20% for Grade 30 concrete and below, and to 30% for Grade 35 to Grade 45 concretes. Lower replacement levels are suggested for recycled aggregates of lower quality. Similarly other properties of recycled aggregate concrete have also found satisfactory and its use in Hong Kong for structural application is now gradually increasing.

Topçu et al.(2007) [1] replaced crushed stone by CTA to produce concrete specimens. Thereafter, the strength of the concrete was examined by conducting mechanical and physical tests.

Dunster (2007)[4] described the use of both natural stone waste and production waste as coarse aggregates in concrete landscaping products. Many of these concrete products routinely include industrial by products and recycled/secondary aggregates. Example includes mainly recycled concrete aggregates (from crushed production waste), furnace bottom ash, ground granulated blast furnace slag, pulverized fuel ash. Increasingly, manufacturers of landscaping products crush this material into recycled concrete aggregate at the manufacturing site and recycle into new production as a partial replacement for primary aggregates.

Wadhah M Tawfeeq et al, (2016)[5] investigated the possible use of crushed pavement blocks as coarse aggregate for the production of new concrete. The concrete specimens were prepared by 100% natural coarse aggregate; which would then be replaced by crushed pavement blocks at various percentages (50 and 100%). The mechanical and physical properties of crushed pavement block aggregates such as specific gravity, clay percent, grading, water content and water absorption were tested. Experimental results indicated that absorption of coarse crushed pavement blocks aggregate were about 221% higher than that of natural aggregate. The compressive strength of 28 days by using crushed pavement blocks aggregate showed an increment of nearly 8% when it fully replaced the natural aggregate in concrete mixes.

2. MATERIALS

2.1 Fine Aggregate

Natural sand from AL-Braimi region Sultanate of Oman is used. Its grading fits within the limits set out in B.S. 882, 1992 [6]. Also average of three samples was taken to evaluate the bulk specific gravity, water absorption, water content and clay percentage, the values were 2.64, 2%, 11% and 2.87% respectively.

2.2 Coarse Aggregate

2.2.1 Crushed Natural Aggregate

Crushed natural aggregate (gravel) of maximum aggregate size 20 mm from AL-Braimi region Sultanate of Oman is used. Which fits within the limits set out in B.S. 882, 1992[6]. Also average of three samples was taken to find each of bulk specific gravity, water absorption, abrasion and water content, the values were 2.7, 1.62%, 1.8% and 0.66% respectively.

2.2.2 Crushed Tiles Aggregate

Waste tiles are obtained from Sohar Tiles factory Sohar, Sultanate of Oman was graded in the laboratory. Its grading fits within the limits set out in B.S. 882,1992[6]. The average of three samples was taken to find each of bulk specific gravity, water absorption, abrasion and water content, the values were 2.435, 7.8%, 21.7% and 0.6% respectively.

2.3 Cement

The Cement used in this study is Raysoot-Sultanat of Oman ordinary Portland Cement type (I) according to British Standard Specification BS EN 197-1:2000[7]

2.4 Water

Tap water is used in concrete trial mixes and in curing. Sulfate content, hardness and PH of water were 250 mg/l, 120-150 ppm, 6.5-8, respectively.

3. PREPARATION OF SPECIMENS

In this study, ninety concrete cubes with different mix design were prepared and tested in the concrete laboratory of Sohar University-Sultanate of Oman. Different percentages of crushed tiles aggregates were used with 0%, 50% and 100% replacement of natural crushed aggregate. Three gravel/sand (G/S) ratios were used 1, 1.1 and1.2. Also, three different water/cement (W/C) ratios were used 0.55, 0.6 and 0.65. Also three simply supported beams were casted and tested with three bending points. The cement quantity for all mixes was constant 400 kg/m^3. The bench marking trial mix was 400:835.2:904.8/0.6.

For each trial mix, six (150×150×150mm) cubes were casted on three layers each layer compacted 25 times by compacting bar then finishing the cube surface was made, in the second day the cubes mold opened, designated and put it in curing tank with water temperature 25^{o}C. After 7 days three cubes were tested by using standard 2000 kN compression machine from ELE company to determine the compressive strength of concrete. After 28 days the remaining three cubes tested. The tests are accomplished according to BS 812-2:1995[6] and BS EN 1097-3:1998[8]

3.1 Design of Simply Supported Beam

According to BS8110-1997[9], the ultimate moment of resistance of singly-reinforced rectangular beams can be determined in terms of concrete capacity and the steel capacity. The maximum compressive force which can be resisted by the concrete corresponds to the maximum depth permitted for the neutral axis. If the maximum neutral axis depth is limited to 0.5d the steel stress will reach its design strength of 0.95fy. The maximum ultimate moment of resistance of a singly-reinforced beam in which the dimensions b and d and the area of reinforcing steel A_s are known is given by the lesser of the following equations:

Based on the concrete strength

$$M_{ult}\text{, concrete} = 0.156bd^2f_{cu}$$

Based on the steel strength where $z = 0.775d$

$$M_{ult}\text{, steel} = 0.95f_yA_s\, z$$

In this study 10 mm bar diameter was used, the concrete cover is equal to 25mm, height of mold (H)=200 mm and breadth (b) of the mould=100mm. as shown in Figures 1-3.

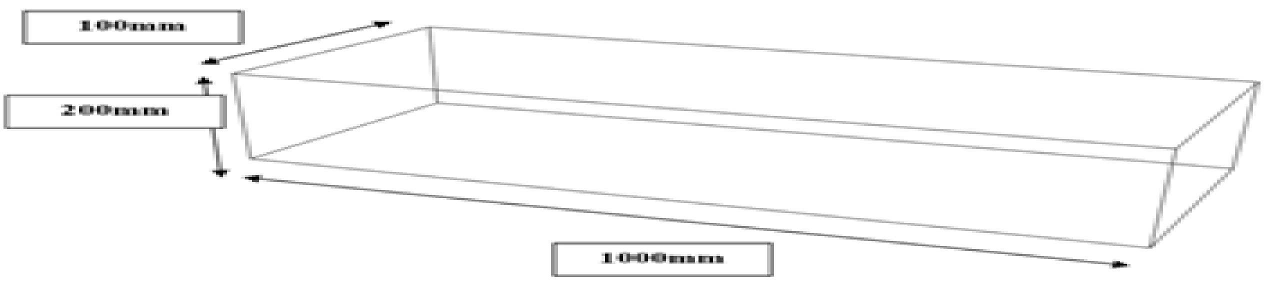

Figure 1 Slump VS w/c Ratio

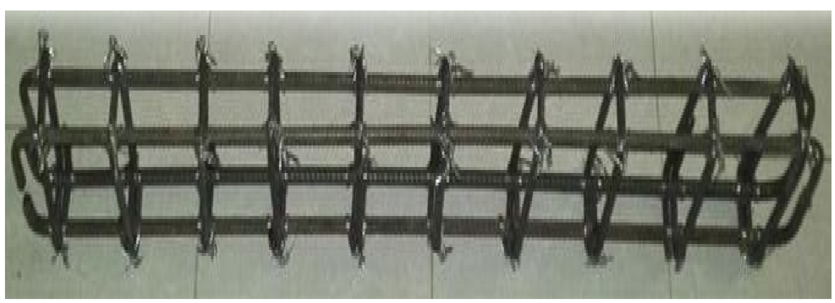

Figure 2 Beam Steel Reinforcement

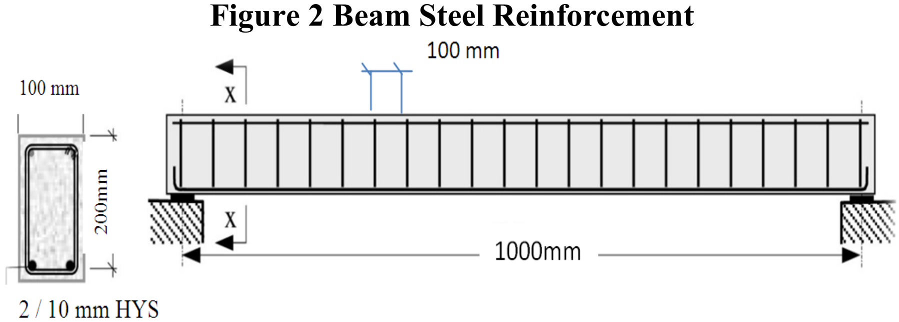

Figure 3 Adopted Simply Supported Beam Details

4. RESULTS & DISCUSSIONS

4.1 Compressive Strength

The concrete compressive strength is measured at 7 and 28 days. Figure 4 shows that the compressive strength decreases as crushed tiles replacement percentage is increases. Also the optimum compressive strength of 7 days age concrete is achieved when the G/S ratio is 1.1. This is matching the British method to design the trial concrete mix. When G/S=1.1 & W/C=0.6 difference in strength between the 0% and 100% replacement is 28.56%.

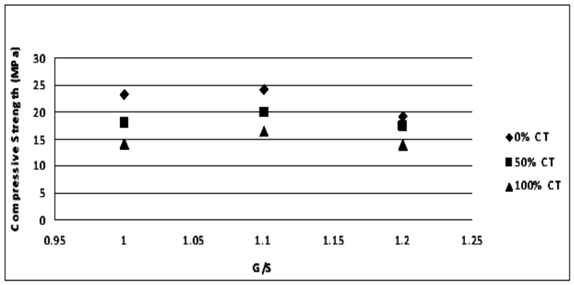

Figure 4 Seven days Compressive Strength vs G/S relationships for various CT% and W/C=0.6.

Figure 5 shows that the three different mixes having the same trend, they go down as W/C ratio increasing and the strength for the three mixes are maximum when the W/C is 0.55 and minimum when the W/C is 0.65. Also the compressive strength decreases as the crushed tiles replacement percent increases. For example, the concrete mix with G/S=1.1 and W/C=0.65 the strength was decreased about 18.5% when 50% of natural aggregate replaced with CT, then this reduction increased up to 32.27% when replaced all the natural aggregate with CT (100% replacement).

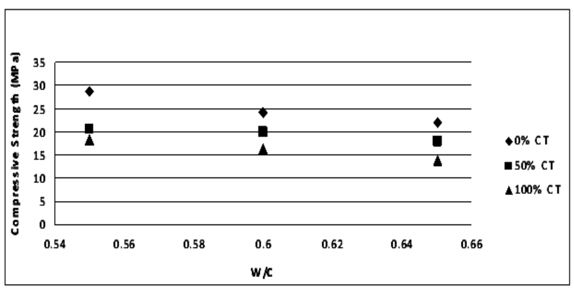

Figure 5 Seven days Compressive Strength vs W/C relationships for various CT% and G/S=1.1.

Figure 6 shows that 28 days age compressive strength of concrete decrease as the crushed tiles replacement percent increase. Also same as 7 days compressive strength of concrete the optimum compressive strength can be gotten when the G/S ratio is 1.1. In this study, the benchmark of concrete mix when G/S ratio is 1.1 and W/C is 0.6. It is clear that the compressive strength of concrete with 0% crushed tiles replacement is higher than 50% and 100%.Overall the compressive strength for both natural and crushed tiles is increased about 45% at the age of 28 days more than at age of 7 days.

Figure 7 shows a decrease in compressive strength of concrete as W/C ratio increase. The highest compressive strength was at W/C=0.55 and the lowest at W/C=0.65. For

G/S=1.1 & W/C=0.65 it was about 17.46% difference between 0 and 50% and about 15.77% between 50% and 100% replaced crushed tiles aggregate.

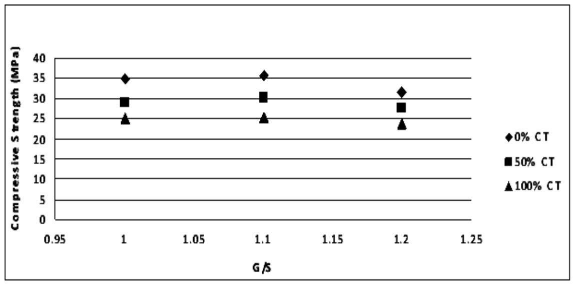

Figure 6 Twenty Eight Days Compressive Strength vs G/S relationships for various CT% and for W/C=0.6.

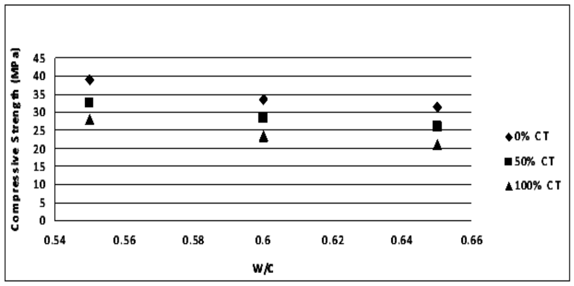

Figure 7 Twenty Eight Days Compressive Strength vs W/C relationships for various CT% and for G/S=1.1.

4.2 Beam Flexural Behavior

This paragraph describes the test result in this study. The failure modes and deformed shape at failure were presented. The behaviour and performance during the flexural beam test are also detailed in this paragraph. The discussion is based on ultimate capacity, and concrete crushing strength. The design calculation of and ultimate load are also conducted and discussed in compared to the experimental results. Pressing machine with 150 Ton capacity, load cell with 600kN Max capacity, and Electronic Dial gauge with 25.4mm capacity where used.

Beam B1 (Bench Mark)

This beam has 0% recycled aggregate, with dimension as all other test specimens and tensile strength was 2.69 MPa and prism flexural strength was 4.5 MPa. The specimen procedure testing was identical as detailed in the test setup shown in Figure 8. By the starting of the loading, till the first crack was observed the specimen behaved linearly. After that, the displacement increased significantly, and the width of crakes increased until complete failure occurred. We can see that the cracks were observed under the position of the load and expended through the beam depth and at the region were the maximum bending moment concentrated. Figure 9 shows the failure mode prophesies at the end of the test. The failure mode was mainly by flexural bending and reinforcement bars reach to the maximum stress region at the position of the load were the maximum bending moment concentrated. However, continuing loading combined flexural bending and concrete crushing occurred. 94.757 kN was the maximum failure load measured in the test. The relation between the load applied to the specimens and the displacement are shown in the Figure 10.

Figure 8 Beam B1Test Set-Up

Figure 9 Beam B1 after Failure

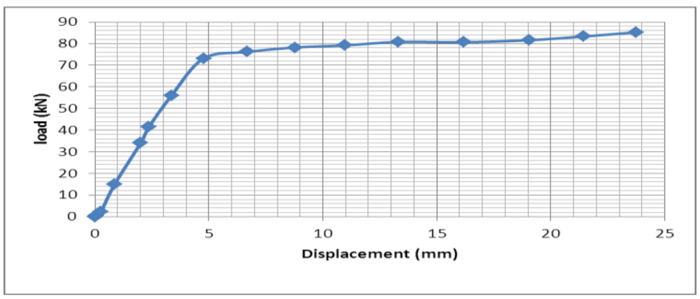

Figure 10 Load-Displacements for B1

Beam B2 (50% crushed tiles)

This beam contains 50% of crushed tiles, with dimension as all other test specimens and tensile strength was 2.65 MPa and prism flexural strength was 5 MPa. By the starting of the loading, till the first crack was observed the specimen behaved linearly. After that, the displacement increased significantly, and the width of crakes increased until complete failure occurred. We can see that the cracks were observed under the position of the load and expended through the beam depth and at the region were the maximum bending moment concentrated. The failure mode was mainly by flexural bending and reinforcement bars reach to the maximum stress region at the position of the load were the maximum bending moment concentrated. However, continuing loading combined flexural bending and concrete crushing occurred. 94.757kN was the maximum failure load measured in the test. The relation between the load applied to the specimens and the displacement are shown in the Figure 11.

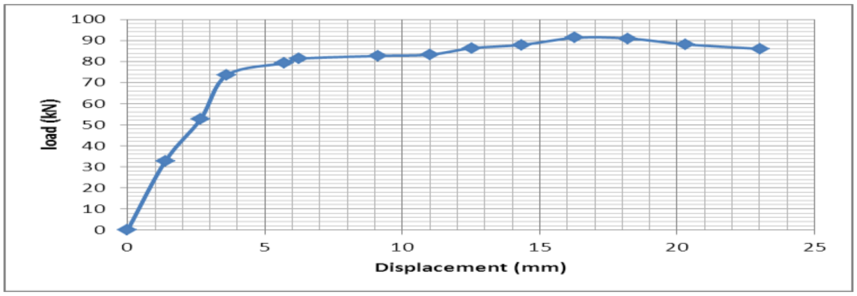

Figure 11 Load-Displacements for B2

Beam B8 (100% crushed tiles)

This beam contains 100% of crushed tiles, with dimension as all other test specimens and tensile strength was 2.72 MPa and prism flexural strength was 5 MPa. By the starting of the loading, till the first crack was observed the specimen behaved linearly. After that, the displacement increased significantly, and the width of crakes increased until complete failure occurred. We can see that the cracks were observed under the position of the load and expended through the beam depth and at the region were the maximum bending moment concentrated. The failure mode was mainly by flexural bending and reinforcement bars reach to the maximum stress region at the position of the load were the maximum bending moment concentrated. However, continuing loading combined flexural bending and concrete crushing occurred 94.757kN was the maximum failure load measured in the test. The relation between the load applied to the specimens and the displacement are shown in the Figure 12.

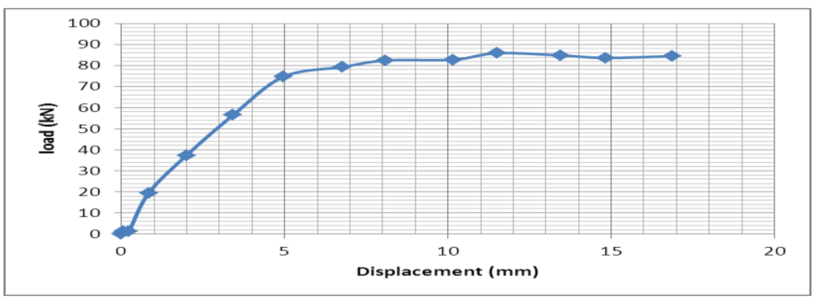

Figure 12 Load-Displacements for B3

5. CONCLUSION

In conclusion, the percentage of replacement and the water absorption of the recycled aggregate in concrete mix change its properties and affect its compressive strength and flexural behavior.

1- The compressive strength increases as W/C decreases. The average compressive strength was more than the benchmark (mixes with G/S=1.1 & W/C=0.6) for mixes with G/S=1.1 and W/C=0.55 and it was lower for mixes with G/S=1.1 and W/C=0.65. It was observed that the compressive strength decreased by 13% when the W/C increased to 0.65, on the other hand it increased by 9% when the W/C decreased to 0.55.

2- In general the remaining compressive strength is about 83% of the control concrete when the replacement was 50% crushed tiles and about 72% of the compressive strength remained when it replaced fully with crushed tiles.

3- The flexural strength for the beams is approximately different considerably by the recycled materials replacement percentage.
4- For all the beams the experimental maximum load of failure was 94.757 kN because the failure happened in steel reinforcement.
5- There is no significant effect of replacement percentage on the concrete tensile strength (splitting test for cylinder 150×300 mm) and for the concrete flexural strength (prism 500×100×100 mm)

REFERENCES

1- I. B. Topcu and M. Canbaz, “Utlization of Crushed Tiles as Aggregate in Concrete”, Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 31, No. B5, pp561-565.(2007).
2- Recycling Portland Cement Concrete, DP-47-85. Demonstration Project Program, Federal Highway Administration, Washington, D. C., (1985).
3- Fung, W. K, “The Use of Recycled Concrete in Construction”. Doctoral Thesis, The University of Hong Kong (Pokfulam, Hong Kong), HKU Thesis Online (HKUTO) http://hub.hku.hk/bib/B30517643. (2005).
4- Dunster, A M., "Crushed Waste Stone and Production Waste in Concrete Landscaping Products", Case Study, Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material, October 2007.
5- Wadhah M. Tawfeeq, Othman AlShareedah, and Taimoor Hossain," Properties of Concrete Mix with Crushed Pavement Blocks as Coarse Aggregate ", International Journal Of Scientific & Engineering Research, Volume 7, Issue 7, July-(2016).
6- BS 882:1992,"Aggregates from Natural Sources for Concrete"1992.
7- BS EN 197-1:2000,"Cement. Composition, Specifications and Conformity Criteria for Common Cements”.
8- BS EN 1097-3:1998," Tests for mechanical and physical properties of aggregates”.
9- BS8110-1997 (Structural Use of Concrete –Code of Practice for Design and Construction).