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Slump and Compressive Strength of Concrete Mix with Crushed Concrete Blocks as Coarse Aggregate

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ABSTRACT

The problems of construction and demolition waste causes an environmental pollution, this waste comes from the development in Oman and rise in urbanization. Therefore, to solve these problems, construction and demolition waste can be reuse as raw material in concrete mix. The main purpose of this project is to study the possible use of crushed Concrete Hollow Blocks as coarse aggregate to produce a new concrete. Using construction and demolition waste as raw material will have a positive effect on the economy. The compressive strength of concrete at 7 & 28 days of age of concrete mix have been determined using natural coarse aggregate. The replacement of the coarse aggregate by crushed Concrete Hollow Blocks was at three different percentages (0 %, 50 %, and 100 %). The mechanical and physical properties of aggregate were investigated such as specific gravity, water absorption, water content, sieve analysis and clay percent.

Key Words: Recycled aggregate, crushed blocks, physical properties, concrete mix, compressive strength, slump

1. INTRODUCTION

The construction of highways, bridges and buildings has been increasing from the beginning of the past century, especially in areas of high population density. These facilities need to be repaired or replaced with the passing of time because their end of service life is reached or the original design no longer satisfies the needs due to the growth in population or traffic. These facts have generated two important issues. First, a growing demand for construction aggregates and, second, an increase in the amount of construction waste. "Two billion tons of aggregate are produced each year in the United States. Production is expected to increase to more than 2.5 billion tons per year by the year 2020. This has raised concerns about the availability of natural aggregates and where we will find new aggregate sources" [1].

On the other hand, the construction waste produced from building demolition alone is estimated to be 123 million tons per year. Historically, the most common method of managing this material has been through disposal in landfills. As cost, environmental regulations and land use policies for landfills become more restrictive, the need to seek alternative uses of the waste material increases. This situation has led state agencies and the aggregate industry to begin recycling concrete debris as an alternative aggregate. Commercial construction industry has been leading the reuse of this debris, but with the State Transportation Agencies (STA) recognizing the engineering, economical and 5 environmental benefits that can be achieved for using RCA, use for highway work is on the increase [1].

Environmental Council of Concrete Organizations (1999)[2] found that Old concrete and masonry that have reached the end of the road can be recycled and used not only as aggregate for new concrete but also for a number of other applications in construction. In the U.S. there are no longer any barriers to the use of recycled concrete as aggregate in new concrete. 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.

Pihl, K. A. et al, (2002) [3] found that from demolition of houses and constructions, two types of demolition by-products are commonly used in road construction. These are crushed concrete and crushed tiles and bricks.

How-Ji Chen et al, (2003) [4] described the use of rubble collected from demolished structures such as waste concrete, brick and tile. A series of experiments using recycled aggregates of various compositions from building rubble were conducted. The test results show that building rubble can be transformed into useful recycled aggregate through proper processing. When the recycled aggregate was washed, the negative effects on the recycled concrete were greatly reduced. This is especially meaningful for flexural strength. Recycled coarse aggregate is the weakest phase given a low water/cement ratio. This effect will dominate the mechanical properties of recycled concrete. On the contrary, using recycled aggregate in concrete has little effect on its mechanical properties if the water/cement ratio is high. This mechanism does not occur in recycled mortar. The quantity of recycled fine aggregate will govern the mortar strength reduction percentage. Although using brick and tile in concrete will affect its mechanical properties, the effect is limited.

Yong-Huang Lin et al, (2004) [5] show that Recycled concrete aggregate, sometimes referred to as crushed concrete, comes from the demolition of Portland cement concrete elements of buildings, roads, and other infrastructures. As a result of crushing, micro cracks will remain in recycled concrete aggregate such that much particular attention. Normally, a series of tests in which purposeful changes were made to the variables of the concrete mixture was then conducted, so that as conclusions can be obtained both slump and compressive strength of concrete indicates that the optimal alphanumeric series of designation of experiment is water/cement ratio of 0.5, volume ratio of coarse aggregate of 42.0%, 100% natural river sand, 0% crushed brick, and as-is recycled aggregate without water-washed aggregate. The resulting concrete has slump of 180 mm and a compressive strength of 30.17 MPa at 28 days, which is applicable for most concrete structures.

Mashitah, M.D. et al, (2008) [6] show that as the numbers of landfills are diminishing, there is dire need to recycle used building material. In the matter of industrial waste ceramic, compressive strength of produced concrete is unchanged when the waste was used to partially replace conventional crushed stone course aggregate. During construction activities, a lot of homogenous tiles are used for heavy duty usage, as they are much harder, durable and highly resistant to biological, chemical and physical degradation forces. However, development of tiles-based materials are less reported and let alone be exploited, though it could provide an enormous economic and environmental benefit to the society in general. This work is aimed at evaluating the possibility of reusing ceramic tiles from construction sites as aggregate for production of concrete block.

Derek Chisholm et al, (2011)[7] describe that in New Zealand 27% of the total waste generated is construction and demolition waste (C&DW), and of this concrete represents 25%, i.e. 7% of the total waste. Many countries have recycling schemes for C&DW to avoid dumping to landfill, as suitable landfill sites are becoming scarce particularly in heavily populated countries.

Akaninyene A.Umoh (2012)[8] found that from Construction and demolition waste generated by the construction industry and which posed an environmental challenge can only be minimized by the reuse and recycle of the waste it generates. Therefore, this study seeks to utilize sandcrete blocks from demolition waste as an alternative material to fine aggregate in concrete. A concrete with compressive strength of 30N/mm2 at 28 days hydration period was designed for normal mixture. The fine aggregate was replaced with crushed waste sandcrete block (CWSB) in various percentages starting from 10% to a maximum of 100%. The properties of the concrete were evaluated at 7, 14 and 28 days curing periods. Results showed that replacing 50% of CWSB aggregate after 28 days curing attained the designed compressive strength as the conventional concrete. Thus it is concluded that CWSB can be used as a supplementary aggregate material in concrete.

Wadhah M Tawfeeq et al, (2016)[9] 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.

Wadhah M Tawfeeq et al, (2016)[10] conducted an experimental investigation to study the flexural behavior of concrete beams with stone slurry as a fine aggregate. General properties of aggregate were studied such as specific gravity, water absorption and water content. Six beams

casted with different stone slurry replacement contents varying from 0%-50% by. All the beams were simply supported and subjected to one concentrated loads at mid-span of the beam, by using 600kN flexural and transverse frame. It has found that the plain cement concrete specimen has shown a typical crack propagation pattern which leaded into splitting of beam. But due to replacement of 5% stone slurry, cracks gets ceased which result into ductile behavior. The optimum percent of stone slurry to be used was found to be 5%. Also the compressive strength of concrete cubes is increased slightly by the replacement of 5% stone slurry. The load carrying capacity were com-pared with theoretical values calculated using BS8110 (Design Manual)
There is a different design of concrete mix available in the world. However, we need to test these mix designs by using Omani material. As one of the most development projects nowadays is the coastal road from Barka to Shinas, which affect about 9500 of the building, according to the municipality. This study describes the use of both natural crushed coarse aggregate and crushed concrete blocks as coarse aggregates in concrete. This study is useful to assess crushed concrete blocks aggregates in comparison with the natural crushed coarse aggregate. To achieve this comparison, aggregate characterization and compressive strengths are needed for the two cases. Also this study aims are to reduce the environmental problems generated from dumping the construction and demolition wastes. This aim can be achieved by recycling the construction and demolition wastes to produce concrete mixes for structural elements with high performance as natural aggregate.

2. MATERIALS

2.1 Fine Aggregate

The Natural Sand was brought from Al-Turki Crusher, Sohar (AL-O'hi). Sultanate of Oman. The aggregate have been graded to fit the limits set out in B.S. 882, 1992[11]. Also average of three samples was taken to find each of bulk specific gravity, water absorption, water content and clay percentage, the values were2.66, 3.87%, 5.83% and 2.73% respectively.

2.2 Coarse Aggregate

2.2.1 Crushed Natural Aggregate

Crushed gravel of maximum aggregate size 20 mm from AL-Braimi region Sultanate of Oman is used. The aggregate have been graded to fit the limits set out in B.S. 882, 1992[11]. Also average of three samples was taken to find each of bulk specific gravity, water absorption and water content, the values were 2.67, 0.79% and 0.89% respectively.

2.2.2 Crushed Concrete Block Aggregate

The crushed blocks were brought from Al-Batinah International factory in Sohar (AL-O'hi). Sultanate of Oman was graded in the laboratory. The crushed aggregate have been graded to fit the limits set out in B.S. 882,1992[11]. Also average of three samples was taken to find each of bulk specific gravity, water absorption and water content, the values were 2.39, 7.15% and 1.98% 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[12]

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, two types of coarse aggregate were used; natural crushed aggregate and crushed concrete blocks aggregates with 0%, 50% and 100% replacement of natural crushed aggregate. The natural sand was used, and the cement quantity for all mixes was constant 400 kg/m^3.Three (gravel/sand) ratios were used (1.22, 1.27 and 1.32) in different trial mixes. Also, three (water/cement) ratios were used (0.40, 0.45 and 0.50). For each trial mix the Slump cone test was performed for all concrete mixtures immediately after mixing to measure workability of concrete and 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 25ºC. 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[13] and BS EN 1097-3:1998[14]

4. RESULTS & DISCUSSIONS
4.1 Slump Test
To determine the workability of the concrete, the slump test was measured for each trial mix in this study. This gives indication how much water has been used in the mix. The relationship between slump and w/c ratio at G/S = 1.27 is shown in Figure 1.

The figure shows that, the highest slump test was found in 0% (Natural Coarse). However, the trial mix with 100% crushed block replacement has the lowest slump values. For all percentages of replacement (0%, 50% and 100%) when w/c ratio increase the slump will increase.

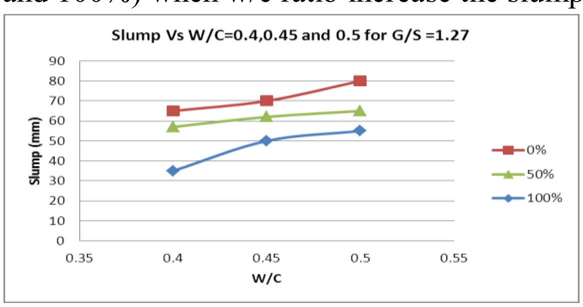

Figure 1 Slump VS w/c Ratio

Figure 2 shows different slump values for 0.45 w/c ratios with different percentage of replacement crushed block in trial mixes. When the percentage of replacement by crushed block is 0% in the trial mix, the slump is higher than the 100% by 28.6%. In addition, when the replacement by crushed block is 50%, the slump goes also lower than the 0% trial mix by 11.4%.

When the w/c ratio is reduced to 0.4, slump values follows the same trend again as illustrated in Figure 3.

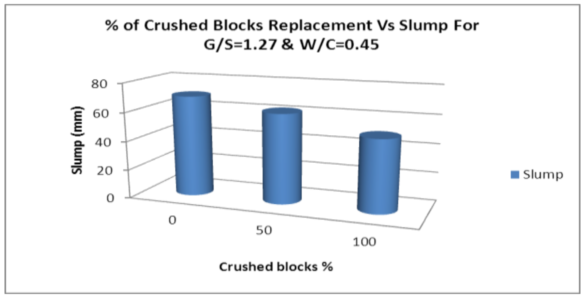

Figure 2 Replacement% VS Slump

The 0% crushed block has the highest slump of trial mixes with 14.3% higher than the 50% crushed block. Replacement by 100% crushed block showed a slump value higher than the 0% crushed block trial mix by 46.2%.

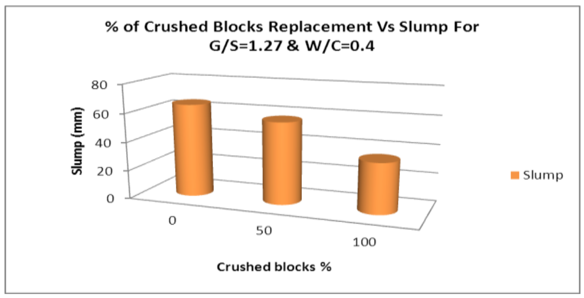

Figure 3 Replacement% VS Slump

Also Figure 4 shows that 0% crushed block has the highest slump of trial mixes with 18.75% higher than the 50% crushed block. Replacement by 100% crushed block showed a slump value higher than the 0% crushed block trial mix by 31.25%.

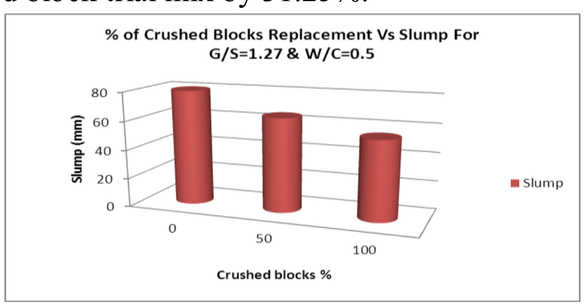

Figure 4 Replacement% VS Slump

As conclusion, the results of slump test have been discussed in the figures. The highest slump recorded with 0% crushed block replacement and the lowest slump was with 100% crushed block replacement. However, due to the high absorption capacity of the crushed block, water content in the concrete mix had to be increased so that there is enough water for hydration process. Therefore, trial mixes with 50% and 100% crushed block replacement recorded lower slump value than the 0% replacement trial mix. Because the shape of coarse aggregate is inconsistency in 50% trial mixes since it has 50% natural crushed aggregate and 50% crushed pavement block aggregate comparing with the trial mixes 100% and 0% crushed block replacement. So, the interaction between the aggregates will decrease and the result is high value of slump. Moreover, it is recommended to use concrete with high workability for sections with congested reinforcement and vibration is not suitable [15].

Reducing w/c ratio to 0.4 reduced the water content in the concrete mix. As a result, slump reduced in trial mixes with 0.4 w/c ratio. On the other hand, increasing w/c ratio increased the water content in the concrete mix and therefore, high workability is recorded for trial mixes with 0.5 w/c ratio.

Increasing fine aggregate in the concrete mix will obviously increase its workability. Consequently, trial mixes with G/S ratio of 1.22 recorded the highest slump values. On the other hand, a balance should be maintained in the ratio of coarse to fine aggregate. This is because, if the fine aggregate quantity is reduced, the overall interaction between the aggregates will reduce which will result in high slump value. Therefore, trial mixes with G/S ratio of 1.32 had higher slump values than the trial mixes with 1.27 G/S ratio, as shown in Figure 5.

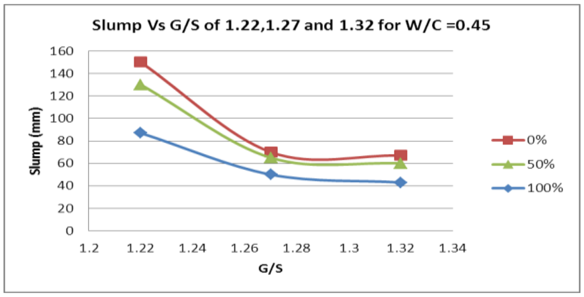

Figure 5 Slump VS G/S Ratio

4.2 Compressive Strength at 7 Days

It can be seen from Figure 6 that the compressive strength decreases as the replacement of crushed block instead of natural aggregate increased. In addition, the maximum compressive strength when the G/S=1.27 while for G/S 1.22 and 1.32 the compressive strength is almost in the same range and that prove the optimization for G/S ratio to get a good strength. For G/S=1.27 where the maximum strength occur the difference in strength between the natural aggregate and the full replacement of 100% is about 19.9%.

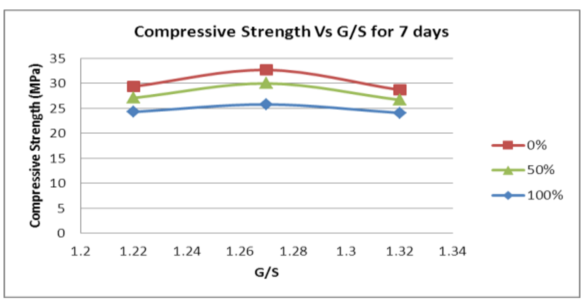

Figure 6 Compressive Strength VS G/S

Figure 7 clearly shows a decline in the general trend of 7 day compressive strengths with respect to their w/c ratios. Lower w/c ratio gave higher compressive strength and vice versa. The highest strength observed here is for the 0% crushed block replacement trial mix with w/c ratio of 0.4. The difference between the strengths of 0% and 50% crushed block is noticed to be minor; whereas the 0 % crushed block replacement high strength is seen to decline linearly. The 0 %

crushed block replacement trial mix with w/c = 0.4 is higher than the same trial mix with w/c = 0.5 by 13 %.

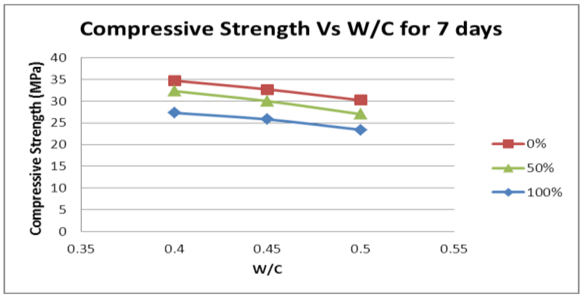

Figure 7 Compressive Strength VS w/c

Figure 8 shows the difference in compressive strengths of concrete with respect to crushed block replacement percentages in the 7 days. It can be seen that the peak strength was yielded with 0% crushed block replacement, while the 100% crushed block replacement trial mix have resulted in a strength of 25.8 MPa, which is about 21.1% lower than the 0% crushed block replacement trial mix. However, the strength of 50% crushed block replacement recorded was 30 MPa, which is lower than the 0% about 8.3%.

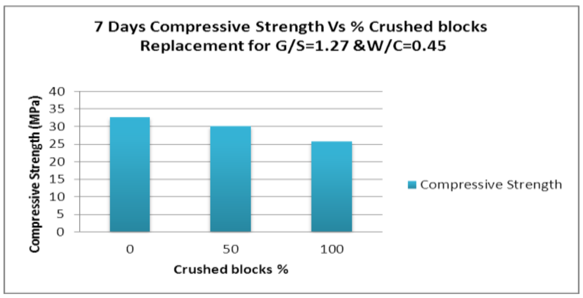

Figure 8 Compressive Strength VS Replacement%

Figure 9 also shows similar trend to that of the previous figure, where the highest compressive strength was obtained from the 0% crushed block replacement, i.e. 7 days compressive strength of 34.7 MPa. This strength is observed to be about 21.3% greater than the 100% crushed block replacement. An approximate difference in strength of 7% was noticed between the 0% mix and 50% crushed block replacement.

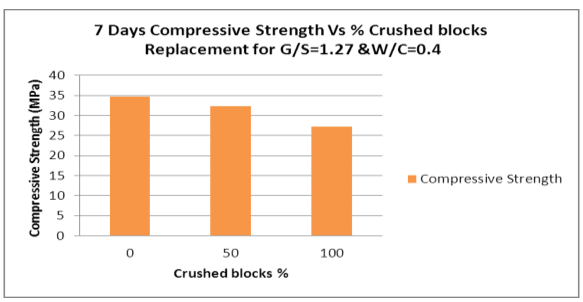

Figure 9 Compressive Strength VS Replacement%

Figure 10 represents the lowest results of compressive strengths compared to the trial mixes of w/c ratios of 0.4 & 0.45. Trial mix with 50% replacement resulted in a compressive strength of 28.6 MPa. Moreover, the trend seemed to be the same here, showing the highest strength in the group of w/c ratio being 0.5 with 0% crushed block replacement mix. The compressive strength gap observed between the 0% mix and the 100 % crushed block replacement was 22.5%.

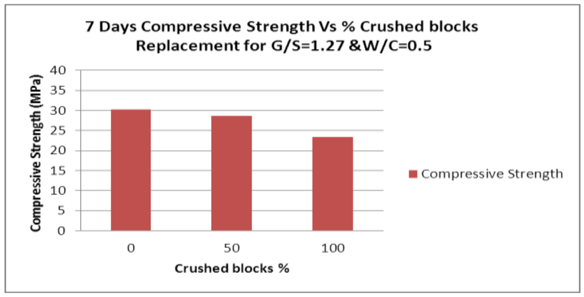

Figure 10 Compressive Strength VS Replacement%

Figure 11 shows the change in the G/S ratio = 1.22, the compressive strength of the three trial mixes was the lowest among the other G/S ratios. Furthermore, the strength produced by 0% crushed block replacement is noticed to be the highest of the other trial mixes of this G/S ratio. The strength for the 100% trial mix is observed to be about 16.2% lower than that of 0% crushed block replacement trial mix. The difference in strength of 6.6% was noticed between the 0% mix and 50% crushed block replacement.

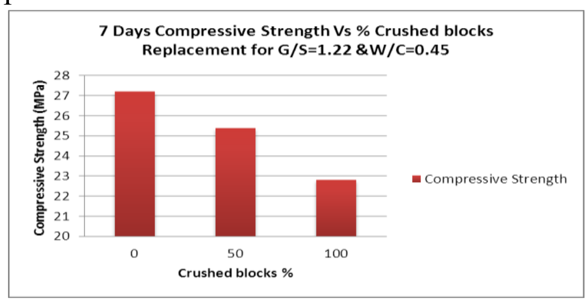

Figure 11 Compressive Strength VS Replacement%

Figure 12 shows an increase in the strength produced in comparison to the trial mixes with G/S= 1.22. Here the highest 7 day compressive strength is noticed to be of 0% crushed block replaced mix being 28.7MPa, which is ahead in the strength for 0% trial mix by 12.2%.

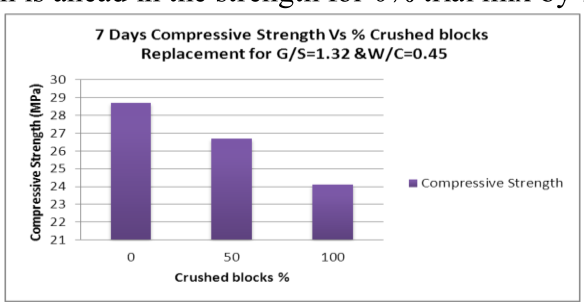

Figure 12 Compressive Strength VS Replacement%

4.3 Compressive Strength at 28 Days

Figure 13 indicate the 28 days compressive strength vs. G/S ratio. So, we can see that from this relationship for all % of replacement added the compressive strength of G/S 1.27 is the highest and it decrease as we increase and decrease G/S ratio. In our study, the benchmark of concrete mix for G/S ratio was 1.27.The increase in the value of G/S ratio to 1.32 which involved the reduction of fine aggregate and increased the coarse aggregate caused by decreasing the strength about 9% for 100% crashed blocks replacement. Moreover, the 50% crashed blocks replacement decrease about 12% and for 0% replacement (Natural aggregate) decrease about 16%. On other hand, when the G/S ratio decreased to 1.22 which mean an increase in the amount of fine aggregate and the compressive strength for all % of replacement decreased. To sum up, the design of G/S ratio was set to be 1.27. Reducing and increasing this ratio to 1.22 and 1.32 decrease the strength. So, G/S ratio at 1.27 was the best of those trail mixes.

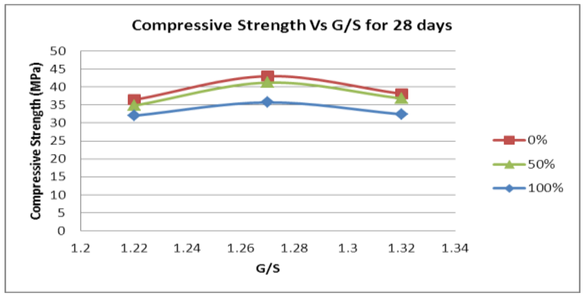

Figure 13 Compressive Strength VS G/S

The relationship between W/C ratio and compressive strength at 28 days at different % of replacement in Figure 14. However, the twenty eight days results did not change from the seven days results except that the compressive strength increase but the trend is same as before. As it is cleared the higher compressive strength was at W/C=0.4 and it is lower at W/C=0.5. Furthermore, the compressive strength of concrete was higher at age of 28 days by as much as approximately 40% at of 7 days, indicating that the higher water absorption capacity and replacement level of recycled coarse aggregate reduce the compressive strength of concrete mix. The compressive strength can also be significantly affected by the W/C ratio and curing condition.

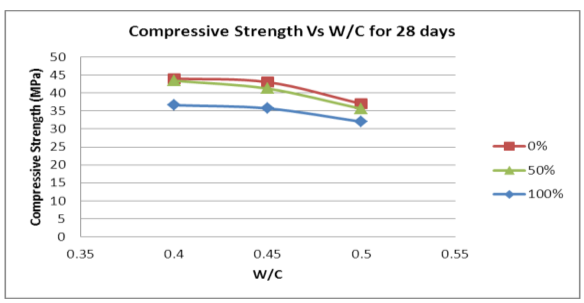

Figure 14 Compressive Strength VS w/c

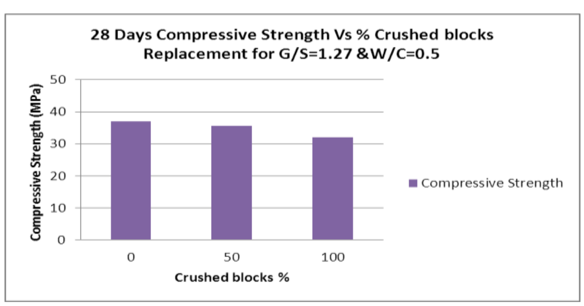

Figure 15 Compressive Strength VS Replacement%

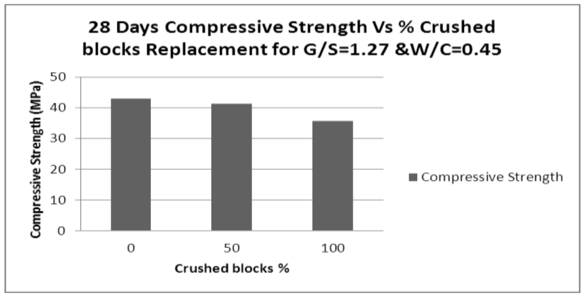

Figure 16 Compressive Strength VS Replacement%

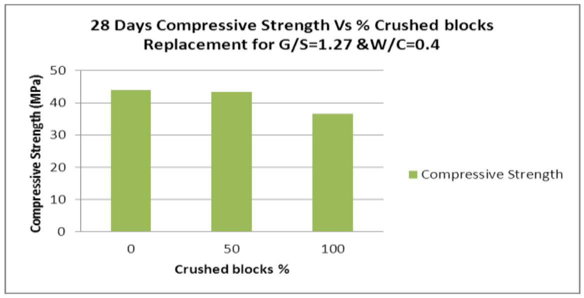

Figure 17 Compressive Strength VS Replacement%

Figure 15 presented the 28 days compressive strength for mixes with W/C 0.45 and G/S 1.27. It shows the same behavior of 7 days Compressive Strength and same trend except that the compressive strength was higher for all the three type of replacement and the percentage of decreasing in compressive strength was smaller. It was about 7% difference between 0 and 50% and about 13% between 50 and 100% replaced crushed blocks. The general decrement in the compressive strength was about 33% in comparison with 38% for figure for seven days compressive strength. The G/S ratio 1.27 indicates the highest compressive strength than G/S ratios 1.22 and 1.32 for all % of replacement.

The same trend is repeated here again for W/C 0.5 and G/S 1.27 in Figure 16. The maximum strength was yielded with 0% replacement. The difference was about 5% between 0 and 50% and about 8% between 50 and 100% replaced crushed crashed blocks, leaving a minor strength gap between them. However, the lowest strength was with 100% replacement of crashed blocks. The 0.5 W/C ratios have the lowest compressive strength as for 7 days compressive strength from other W/C ratio like 0.45 and 0.4.

In Figure 17 can be seen difference is almost similar for twenty eight days compressive strength comparing with seven days compressive strength. The peak 28 days compressive strength of 43 MPa was given by 0% replacement and there was very small difference between 0% and 50% replacement of crashed blocks about 2%.also, the deferent between 50% and 100% of crashed blocks is a little bet high about 14%. These W/C ratios represent the highest compressive strength from W/C ratios 0.45 and 0.5 for all % of replacement.

For Figure 18 as increase in G/S ratio to 1.32 there was about 15% decrement in the compressive strength as the replacement percent increased from 0% to 50% and about 24% when replacement percent changed from 0% to 100%. The maximum strength being 38 MPa, which belong to 0% replacement and 100% crashed blocks replacement has the lowest strength about 32 MPa.

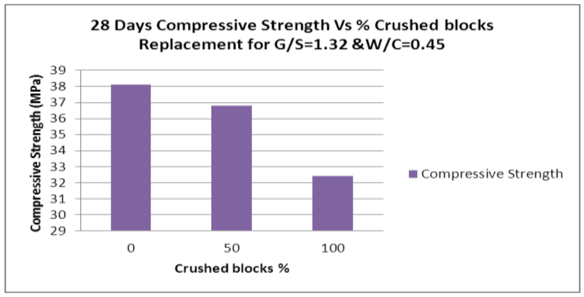

Figure 18 Compressive Strength VS Replacement%

Figure 19 represent the similar trend of concrete strength as decreasing G/S ratio to 1.22 it has shown a drop in the compressive strength by about 17% when the replacement was 100% and by about 10% when the replacement was 50%. Again, the 0% replacement is seen to be the highest and 0% replacement is the lowest about 34 MPa. The overall trend shows G/S ratio 1.22 still the lowest from the other G/S ratios as before in 7 days presented in Figure 11.

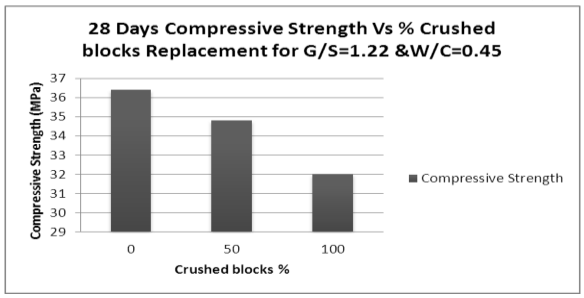

Figure 19 Compressive Strength VS Replacement%

5. CONCLUSION

1- The specific gravity of natural fine aggregate was 2.66, for coarse aggregate the natural was 2.67 and crushed concrete blocks was 2.39.

2- Water absorption of natural coarse aggregate was 0.79%, crushed concrete block aggregate was 7.15% and natural fine aggregate was 3.87%.

3- Replacement by 0 % of crushed block in trial mixes gave the highest slump values.

4- The highest slump values for all G/S ratios in 0% crushed block replacement trial mixes.

5- Trial mixes with G/S ratio of 1.32 had the lowest slump value and the highest slumps noticed was with G/S = 1.22.

6- The G/S ratio of 1.22 exhibited low strengths of concrete. While increasing the ratio of G/S to 1.32 resulted in higher compressive strength which did not exceed the strength results obtained from trial mixes with G/S = 1.27.

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