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Use of recycled plastic water bottles in concrete blocks

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Abstract

The purpose of this study is to examine the possibility of using plastic bottles in concrete block. The plastic bottles were used to create voids at equal distance between them in the masonry units. Concrete was placed around each bottle to encase it in the masonry units. The study utilized 500-mL plastic bottles placed inside concrete masonry units and analyzed the compressive strength. The testing for compressive strength was determined according to the ASTM C140 standard. Results from this study were deemed reasonable due to the testing of concrete cylinders as a control of compressive strength for the concrete blocks from Oman's market. This study shows 57% difference in the strength by using plastic bottles compared to local concrete blocks. This proves the necessity for further research regarding concrete mix design, amount of cement and properties of local concrete blocks as well as other technical and non-technical aspects to determine the appropriate mix design and feasibility in the production industry.

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Keywords: concrete blocks, plastic bottles, recycled materials

1. Introduction

Concrete masonry unit or concrete block is an important and common member in building construction in Oman. Usage of plastic water bottles are increasing rapidly in Oman and this country is facing the challenge of overflowing of landfills and impacts of disposal of plastic water bottles. Moreover the plastic bottles can provide thermal insulation that can reduce the consumption of electricity for cooling which is highly important since Oman has

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subtropical dry hot desert climate. This research intends to study the possibility of using recycled plastic water bottles within the local concrete blocks for the purpose of building construction with the focus of verifying the compressive strength. Hollow concrete block is a significant kind of masonry units existing for the builders and its application for masonry construction is increasing continuously. (Ahmad et al, 2014) Hollow concrete blocks may be used, as alternatives to bricks and traditional stones in construction and buildings. Due to its smaller weight and ease of transfer compared to bricks. Moreover it provides an advantage of uniform quality as well as speeding in construction and the largest durability. On one hand economically, they are less expensive, and consume less cement and less involvement of laborers. In addition, they can be used, in different places. Such as the interior walls, exterior walls bearing, and columns, the compound walls, and retaining walls etc. (Maroliya, 2012) several researches completed particularly to study the compressive behavior of concrete blocks mixed with other materials, commencing with 'High-Performance Concrete Masonry-Block Mix Design' by Amiri et al. This research was conducted on concrete block masonry design in 1994. This study looked at 41 different kinds of concrete mix designs and assessed the compressive strength of concrete with different types of aggregates. Amiri et al study determined that use of a minimum void gradation and a maximum aggregate size 1/4 inch (6.4 mm) allow a high-performance of lightweight to reduce the cost of concrete masonry block . Chandrakeerthy investigated on four test methods concerning properties of cement blocks to study the relationship of variables and properties with compressive strength at 1991. Chandrakeethy's study suggests the implementation of one part cement to one part sand capping with plywood packing. Compressive behavior of concrete with vitrified soil aggregate was tested by Palmquist et al through examination of 10 batches at four different coarse aggregate volume fractions with three different combinations of vitrified and natural coarse aggregates. Results show that compressive strength decreases when volume fraction of vitrified soil aggregate increases. (2001). Researches by Ahmad et al (2014) to compare masonry hollow concrete block and masonry brick and Maroliya (2012) on load carrying capacity of hollow concrete block masonry wall confirmed that the strength of hollow concrete block masonry wall is lower than brick masonry wall but the cost of construction of hollow concrete masonry wall is less. Stahl et al (2002) used recycled wood aggregate to prepare lightweight concrete masonry blocks and control the outcome to meet the conditions of ASTM C129.Trial cylinders and blocks were tested and found to be complying with the standard in terms of weight, compressive strength and durability. However economic performance was not studied.

The idea of using plastic bottles in concrete building construction was originated by Andreas Froses in Eco-Tec in 2001 where PET bottles are installed within the walls along with mortars to shape a structure (Froese, 2014). The Engineers without Borders at Kansas State University have worked on a method to use plastic bottles in wall construction of concrete walls. These plastic bottles were installed horizontally with concrete as mortar between them and also in the sides. Further tests were conducted to examine the compressive strength of concrete masonry units with plastic bottle cores. Results of the tests according to ASTM C140 showed that compressive strength is reasonable however further studies suggested to confirm the validity incase used in developing countries (Wonderlich et al, 2014)

Oman is facing challenges with regards to solid waste management and recycling. Since potable water mains do not exist in Oman consuming bottled water is greatly common and therefore waste plastic bottles management is a major challenge. Moreover hollow concrete blocks are vastly used in building construction in and thermal insulation of walls is another challenge that is faced in the hot dry climate of Oman. Using plastic bottles inside hollow concrete blocks may be a solution to some of the stated challenges. This study attempts to verify this method within the local concrete block products with the focus of testing the compressive strength for the purpose of initial validation of this method in Oman.

2. Methodology

The method of study designed for this research included tests for eight concrete blocks, seven concrete cylinders and six hollow concrete blocks from Oman's market. In Each block eight plastic bottles (500ml) was positioned. Main purpose is to control the concrete masonry to meet the ASTM C140 requirements. The compressive strength test was conducted for three times. First test was after 7days, the second time after 14 days and the last after 28 days. Further on the compressive strength of cylinders, bottle blocks and hollow concrete markets were demonstrated.

2.1. Test Plan

Three concrete batches were prepared and two, two and three concrete cylinders were made from them in order to determine the compressive strength of concrete blocks bottles after 7, 14, and 28 days.

Sample Code	Number
CY-7 D	2
CY-14 D	2
CY-28 D	3

Table 1. Number of specimens and coding

2.1.1. Concrete Mix Design

Concrete cylinders were tested to determine the compressive strength and then for comparing of compressive strength with concrete blocks. The testing followed the *ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens* and for concrete design mix was followed *BS standard* as it shows in this table.

Materials for concrete mix design	Value
F_c	20 N/mm^2
Cement	Portland Cement
Defective	5%
Slump	50 mm
Fine aggregate size	0-5 mm
Coarse aggregate size	5-10 mm
W/C	0.65

Table 2 concrete mix design.

2.1.2. Concrete blocks with plastic bottles

The size of concrete block with plastic bottles that is using in this study is 200mm wide by 200mm high by 400mm long. The plastic bottles will create the voids in the brick around eight bottles horizontal (500 ml). This study followed the ASTM C140 *Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units* for doing the procedures of the test. The compressive strength test of the concrete blocks with plastic bottles was tested after one week, the second will be after 14 days and the last one will be after 28 days. Each concrete blocks had eight bottles and a space between each bottle was positioned. This makes sure that concrete will cover each bottle to give more strength. Also, wires were used within the arrangement to ensure that bottles will not change their positions during concreting process.

Sample Code	Number of Specimen	Number of plastic bottle(500 ml)
CB - 7 D	3	8
CB – 14 D	2	8
CB – 28 D	3	8

Table 3. Number of specimens and coding

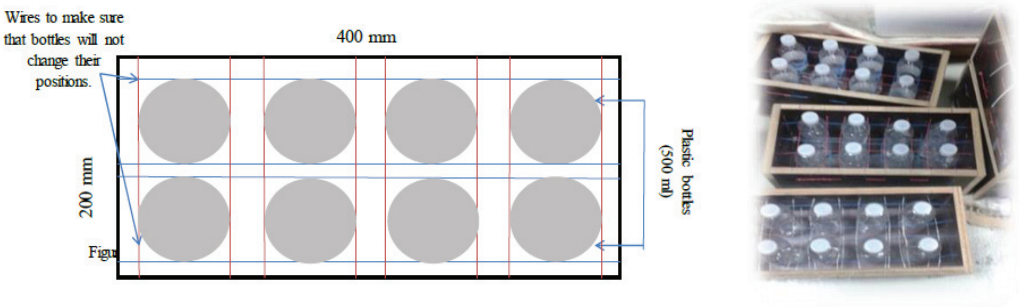

Figure 1 and 2.design of Concrete block with 8 plastic bottles (500ml)

2.1.3. Hollow Concrete Blocks from Oman's Construction market

The sizes of Hollow Concrete Block which is available in Oman's construction market (product of Oriental Insulated Block CO.L.L.C) Hollow Block is 200 X 200 X 400 with 20kg weight and eight specimen was used in the test to compare the compressive strength.

2.2. Compressive Strength test procedures

This test procedure was based on the ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units procedure. For this procedure there are two loads that were needed to be determined. The ultimate / load, Pu, is and the estimated load, Pest.

3. Results

3.1. Compressive strength comparison

Test of Cylinder Strength				
Sample Code	Diameter(mm)	Area(mm^2)	Maximum Load(N)	Compressive Strength (Mpa)
CY-7D(1)	150	17671.459	185012	10.469
CY-7D(2)	150	17671.459	217554	12.311
CY-14D(1)	150	17671.459	432822	24.493
CY-14D(2)	150	17671.459	436630	24.708
CY-28D(1)	150	17671.459	459988	26.030
CY-28D(2)	150	17671.459	449915	25.460
CY-28D(3)	150	17671.459	455994	25.804

Table 4. Test Results from Cylinder Tests

Table 4 shows the results from the cylinder testing. The first batch was tested after 7 days for CY-7D (1) and CY-7D (2). The second batch tested after 14 days for CY-14D (1), CY-14D (2) and CY-14D (3). The last batch was tested after 28 days for CY-28D (1) and CY-28D (2). By measuring the diameter of the cylinder on the top surface or bottom surfaces determined the diameter which used to calculate the area for each cylinder. Maximum load is given by the Mastest (Compressive strength test Machine) for the ultimate load at which failure occurs. Maximum load is given with an accuracy of ± 1%. The compressive strength of each cylinder is determined by taking the

maximum load of the cylinder and dividing it by the area of the cylinder. This compressive strength is then used to determine the estimated load of failure for the concrete masonry units. The compressive strength of cylinders between the 7 days and 14 days increase around 13 Mpa and the difference of compressive strength of cylinders between 14 days and 28 days around 1.2 Mpa.

Test of Concrete Block Strength			
Sample Code	Gross Area (mm^2)	Maximum Load (KN)	Gross Compressive Strength (Mpa)
CB-7D(1)	76000	458736	6.036
CB-7D(2)	76000	552520	7.270
CB-7D(3)	76000	584744	7.694
CB-14D(1)	76000	688138	9.054
CB-14D(2)	76000	748976	9.855
CB-28D(1)	76000	752400	9.900
CB-28D(2)	76000	760000	10.00
CB-28D(3)	76000	775200	10.20

Table 5. the results from the concrete masonry unit testing with plastic bottle cores.

The 8 specimens are used in 3 batches and each batch had different time. The first batch was after 7 days for CB-7D (1), CB-7D (2) and CB-7D (3). The second batch was tested after 14 days for CB-14D (1), CB-14D (2) and CB-14D (3). The last batch was tested after 28 days for CB-28D (1) and CB-28D (2). The gross area of the concrete block was determined in accordance with ASTM C140 standard. The dimension measurements were width and length of each specimen was used to determine the gross area. Maximum load for each block was determined from the same machine that used for cylinder testing. The maximum load is given with an accuracy of ± 1%. The compressive strength is determined by taking the maximum load of each block and dividing it by the area of each concrete block.

The above table reveals the difference between compressive strength of concrete block between 7 days and 14 days is about 2.5 Mpa, while the difference of compressive strength of concrete block between 14 days and 28 days is around 0.57 Mpa. There difference between the values of compressive strength of cylinder and values of compressive strength of concrete block id due to the different of gross area between the cylinder and concrete block.

Test Hollow Concrete Block from Oman's Market			
Sample Code	Gross Area (mm^2)	Maximum Load(KN)	Gross Compressive Strength(Mpa)
HCB-28(1)	74100	472410	6.375
HCB-28(2)	74100	523212	7.061
HCB-28(3)	74100	441870	5.963
HCB-28(4)	74100	385751	5.206
HCB-28(5)	74100	480027	6.478
HCB-28(6)	74100	535212	7.223

Table 6. Test results from Hollow Concrete Block

Table 6 shows the test results of hollow concrete blocks from the Oman's market. There were 6 specimens for one batch which was considered as after 28 days. The specimens labelled HCB-28(1) to HCB-28(6). The gross Area is determined by measuring the length and width of the block. The reading of maximum load is determined by the machine and its diagram that draw during the test. Gross compressive strength is determined by taking the maximum load value and dividing it by the gross Area.

Regarding the results above the difference between plastic bottled block after 28 days and the hollow concrete blocks which are from the market is about 3.64 Mpa.

3.2. Density comparison

Weight of cylinder after 14 days	Value (Kg)
CY-14D (1)	12.492
Cy-14D (2)	12.964

Table 7: The weight of the cylinder test after 14 days.

The average weight of two cylinders = $\frac{12.492+12.964}{2}$ = 12.728 Kg

The volume of the cylinder = $\frac{\pi \times 0.15^2 \times 0.3}{4}$ = 0.0053 m^3

Density = $\frac{12.728 \times 9.81}{0.0053} = 23558.81\ N/m^3$

Weight of cylinder after 28 days	Value (Kg)
CY-28D (1)	12.518
CY-28D (2)	12.534
CY-28D (3)	12.520

Table 8: The weight of the cylinder test after 28 days

The average weight of two cylinders = $\frac{12.518+12.534+12.520}{3} = 12.524\ Kg$

Density = $\frac{12.524 \times 9.81}{0.0053}$ = 23181.21 N /m^3

Density of Concrete mix design = 23936.4 Kg/m^3

As shown above the difference between the value of density of cylinder after 14 days and after 28 days is around 0.4 KN/ m^3 . Also, when compare between the values of density of cylinder and value of density of mix design is very small difference about 0.6 KN/ m^3.

Weight of concrete block after 14 days	Value (Kg)
CB-14D (1)	25.010
CB-14D (2)	24.924
CB-14D (3)	23.022

Table 9: The weight of concrete block test after 14 days

The average weight of blocks = $\frac{25.010+24.924+23.022}{3}$ = 24.318 Kg

Volume of block = 0.4× 0.19 × 0.19 = 0.0144 m^3

Density of bottle Concrete block = $\frac{24.318 \times 9.81}{0.0144}$ = 16566.6 N/ m^3

Weight of concrete block after 28 days	Value (Kg)
CB-14D (1)	25.122
CB-14D (2)	25.280
CB-14D (3)	24.154

Table 10: The weight of concrete block test after 28 days

The average weight of blocks = $\frac{25.122+25.280+24.154}{3}$ = 24.852 Kg

Density of bottle Concrete block = $\frac{24.852 \times 9.81}{0.0144}$ = 16930.425 N/m^3

Weight of Hollow concrete block after 28 days	Value (Kg)
HCB- 28D (1)	20.008
HCB- 28D (2)	20.030
HCB- 28D (3)	20.048
HCB-28D (4)	19.704
HCB-28D (5)	20.682
HCB-28D (6)	20.012

Table 11: The weight of concrete block test after 14 days

The average weight of Hollow Concrete Block = $\frac{20.008+20.030+20.048+19.704+20.682+20.012}{6}$ = 20.081 Kg

Volume of Hollow Concrete Block = 0.39× 0.19 × 0.19 = 0.0141 m^3

Density of Hollow Concrete Block = $\frac{20.08 \times 9.81}{0.0141}$ =13991.4 N/m^3

From the results above, we can see the difference between the density of concrete blocks after 14 days and 28 days is very small, while the difference between the density of concrete block and the density of hollow concrete block is about 2.75 kN/m^3 and that regarding to the size of the openings in hollow concrete block, however the size of block is the same size of our concrete blocks.

Conclusion

This study verifies the compressive study of plastic bottled concrete blocks used with local materials. The proximity of compressive strength and density between cylinder, bottled concrete blocks and hollow concrete blocks are acceptable. Moreover in comparison to Omani hollow concrete blocks the concrete blocks with plastic bottles shown 57% higher compressive strength. Further research on the other properties, economics and environmental benefits can be conducted to confirm the practice of using water bottles inside concrete blocks.

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Appendix A. Photos of the specimens

Figure 3, 4, 5 and 6 : The Cylinder after the test.

Figure 7, 8, 9 and 10 : The Concrete Blocks after the test.

Figure 11, 12 and 13 : The Hollow Concrete Blocks after the test.

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