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Mechanical Properties of lightweight Concrete Produced using Pottery Waste as Aggregate

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***Abstract**: Structures built using lightweight concrete have feature of the lower own weight than that of the conventional concrete, where this property contributes to reducing the construction cost. This paper study recycling of pottery waste (PW) to use it as aggregate to develop structural lightweight concrete. To achieve this aim, six concrete mixtures were prepared. Five mixes developed using PW of 20%, 40 %, 60%, 80%, and 100% as a partially and wholly replacement of normal weight aggregate, while the control mix produced using normal weight aggregate of dolomite. The properties; consistency, dry density, water absorption, compressive, tensile and flexural strengths were studied and compared with the same properties of the control mix. Experimental results indicate that using 40, 60, 80, and 100% of PW as dolomite replacement can produce lightweight concrete, also all concrete mixtures containing PW aggregate can classified as structural concrete where their compressive strengths are more than 17 Mpa.*

Keywords: pottery, Lightweight Concrete, Dolomite, Density, Compressive Strength, Absorption.

I. INTRODUCTION

In present time recycling of waste materials is an environmental and economic necessity. Utilization of these materials to develop concrete contributes to their disposal and environment preservation. For approximately seven thousand years, Egyptian craftsmen continue to create copious amounts of pottery for various applications; such pottery remains an important part of modem Egyptian, a large proportion of pottery products are converted to waste during and after the manufacturing process, this percentage may reach 25% of the production. This research studies the utilization of pottery waste (PW) as aggregate to produce lightweight concrete. Lightweight concrete has dry density between 800 and 2000 kg/m^3[1] and has been used since the early Roman Empire in several structures includes the Coliseum and Cosa Port. Lightweight concrete can be obtained in three different types; no-fines concrete (concrete does not contain fine aggregate), aerated concrete, and cconcrete produced by using lightweight aggregate. The various kinds of lightweight aggregate will not always produce equal compressive strengths for concrete of similar cement content and slump. Structural lightweight concrete is a concrete has a minimum 28-day compressive strength of 17 MPa [2].

Several researches have been conducted to study the properties of lightweight concrete; some of these researches were covered.

Piyaphanuwat and Asavapisit [3] studied the possibility of using ceramic tiles wastes as a coarse and fine aggregate in lightweight aggregate concrete.

The results showed that increasing the levels of ceramic wastes decreased density and compressive strength but increased the water adsorption. Also, they reported that the optimum ratio of ceramic waste was 50 %. Yasar et al. [4] study suggested use of scoria aggregate and fly ash to develop structural lightweight concrete (SLWC). The slump, fresh density, compressive and flexural tensile strengths were measured. Hossain et al. [5] studied the applicability of using pumice as a replacement material of cement with percentage of 0% to 25% and as coarse aggregate to produce lightweight concrete. The properties were evaluated by conducting tests of workability, drying shrinkage, strength, and permeability. The results indicated that pumice has suitable strength and density to be accepted as structural lightweight concrete. Effect of curing on lightweight concrete properties has been studied by Haque et al. [6].They were used a high strength structural lightweight concrete of 1800 kg/m^3 and compressive strength of 50 MPa. The specimens initially cured as; 1day curing, 3 day curing and 7 day curing. According to test results the compressive strengths of SLWC is less sensitive to lack of curing than normal weight concrete. Fahrizal et al. [7] stated that Lightweight concrete is typically 25 % to 35% lighter normal weight concrete. Also, structural lightweight concrete has design flexibility and improved seismic response better than conventional concrete. Khonsari et al. [8] stated that the Lightweight concrete is applicable for structural purposes, because of their improved properties such as the workability, strength, and less own weight. Arunachalam et al. [9] Studied the compressive and tensile strengths of lightweight concrete (LWC) of density 1700 kg/m^3 to 1800 kg/m3 with 0.2% to 0.8% aluminum powder . The strength tests were conducted on concrete at the age of 7 days and 28 days. Results showed that 1:6 mix proportions gives strength more than the other mixes in both the cases with quarry dust and sand. However, compared with quarry dust mixes, sand mixes gave more strength. Hamad et.al. [10] Reported that features of light weight, concrete are higher strength to weight ratio compared to conventional concrete, enhanced in thermal and sound insulation in the structure and minimize the steel reinforcement. This research conducted to evaluate utilization of the waste produced from pottery industry to develop lightweight concrete mix with mechanical properties suitable for structural purpose.

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II. MATERIAL PROPERTIES

A. *Aggregate:* Two types of aggregate were used here as coarse aggregate:

- *Normal weight aggregate* of dolomite that meets the requirements of ASTM C 33/C33-M [11] was used in control mix as coarse aggregate.

-*Crushed pottery waste (PW)* shown in Fig.1, and meets ASTM C 33/C33-M [12] was used in the other concrete mixtures as coarse and fine aggregate.

-*Natural sand* was used as fine aggregate in the control mixture only. Grading and physical properties of aggregates are shown in Table I and Table II respectively.

Fig. 1. Crushed Pottery Waste (PW)

Table-I: Grading of Aggregates

Sieve Size (mm)	Dolomite	Pottery Waste	Natural sand
19	100	100	-
12.5	100	100	-
9.5	78.3	98.6	-
4.75	6.26	84.55	100
2.36	0	47.55	96
1.18	0	14.75	78
0.6	0	6.15	47.5
0.3	0	3.5	8
0.15	0	3.2	1
0.075	0	0	0

B. *Cement:* Ordinary Portland cement (OPC) CEMI-42.5N that meets the ASTM C150/C150-M requirements [13] was used.

C. *Water*: Potable tap water that compatible with the ASTM C1602/C1602M-18 requirements [14] has been used in mixing and curing concrete.

D. *Sikament-163M* high range water reducer (HRWR) complies with ASTM C494 type F [15] was used as with percentage of 1% of cement weight.

III. MIX PROPORTION

The mix proportions were calculated according to Procedures outlined in the guide for Structural Lightweight-Aggregate Concrete ACI 213R-14[2], mix proportions of concrete mixtures given in Table III.

Table-III: Mix Proportions of concrete Mixtures

Mix	Cement	Fine Agg.		Coarse Agg.		W/C
		Sand	PW	Dolomite	PW	
CM	1	1.65	0	2.9	0	0.48
P20	1	0	1.65	2.32	0.58	0.48
P40	1	0	1.65	1.74	1.16	0.48
P60	1	0	1.65	1.16	1.74	0.48
P80	1	0	1.65	0.58	2.32	0.48
P100	1	0	1.65	0	2.9	0.48

IV. EXPERIMENTAL INVESTIGATION & RESULTS.

Mixing was carried out in a revolving electric mixer of pan drum type. Then concrete was cast into steel moulds immediately after mixing. Specimens were removed from moulds after 24 hours and cured in clean water until test at ages 7, 28, and 56 days in according with ASTM C39-15 [16] and ACI 213R-14 [2]. Cube specimens of 15 cm side length were used for compressive strength test, while cylindrical specimens of 15x30 cm were used for split tensile strength test. Six prisms of dimensions 10 x 10 x 50 cm were cast for the determination of flexural strength at 28 days. Also, density and water absorption of concrete mixtures at 28 days were tested in according with ASTM C642-13 [17].The 15 × 15 × 15 cm cube specimens were used for the testing of water absorption.

Table-II: Physical Properties of used aggregate

Physical Property	Dolomite	Pottery Waste	Sand
S. G.of oven dry	2.65	2.1	2.56
Dry R.weight (kg / m^3)	1650	1020	1670
N.M.Size (mm)	12.5	9.5	-
Absorption %	1.93	7	3

V. RESULT AND DISCUSSION

A. *Consistency*

Fig.2 shows the results of slump test for all concrete mixes. The slump test results show that concrete mixtures containing pottery waste (PW) have lower slump values than that of the normal weight concrete (control mix). The slump value of the concrete mixture contains 20% PW decreased by 10% than that of control mix, while the concrete mixtures containing 40%,60%,80% and 100% PW have slump values decreased by 20%,28.6%,34.3% and 44.3% respectively. This may be attributed to the porosity of PW aggregates and their high absorption compared to the dolomite. Mehta et al. [19] stated that concretes with at least slump value of 50 mm could attain a suitable workability.

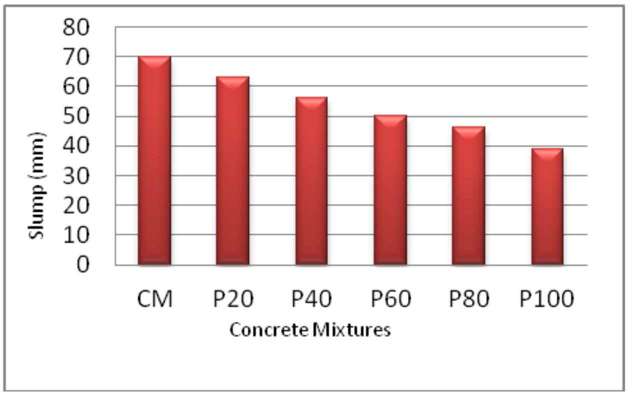

Fig. 2. Slump of Concrete Mixes

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B. *Density*

Fig.3 shows that blending of PW aggregate and normal weight aggregate (dolomite) reduce the concrete density compared with the control mix contains normal weight aggregate only. As shown in Fig.3 the densities of concrete mixtures containing 20,40,60,80 and 100% of PW aggregate were lower than that of control mix with 16.1, 23, 30, 36, and 45% respectively. This occurs because PW aggregate have pores more than dolomite, consequently it is lighter than dolomite aggregate. British Standard EN 206-1 [1] reported that dry density of lightweight concrete ranging between 800kg/m^{3}and 2000kg/m^3.Therefore, the concrete mixes P40,P60, P80, and P100 are considered lightweight concrete.

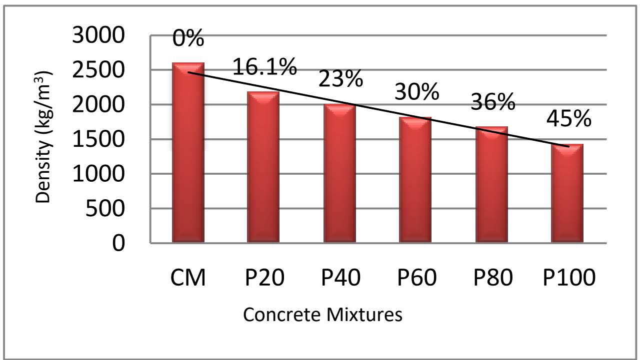

Fig.3. Density of Concrete Mixtures

C. *Water Absorption*

Results showed in Fig.4 illustrate the absorption percentage of concrete mixtures. These results indicate that the water absorption increase as the level of PW increased where the absorption percentage increased linearly from 6.7% for concrete mixture contains 20% PW aggregate up to 13.1% for concrete mixture contains 100% PW aggregate. In general, the absorption of concrete mixtures containing PW aggregate were higher than that of control mix with 4.5% at least (case of 20% PW aggregate).This results corresponds to the results reported by Grabiec et al. [20] .This property is due to porosity of PW aggregate that relatively higher than that of dolomite increase of the lightweight aggregate increased the void and the percentage of pore area in the LWAC that was caused increase of waster adsorption.

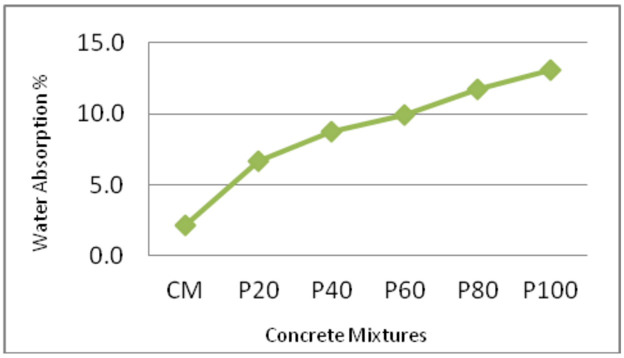

Fig.4. Water Absorption Percentage for Concrete Mixtures

D. *Compressive Strength*

Fig.5 shows the test results of compression test at different curing time of 7, 28 and 56 days. These results indicate that increasing the level of PW aggregate in concrete mixtures; result in decrease in compressive strength at all curing times. Also, the results demonstrate that the compressive strength of all concrete mixtures at age of 28 days were higher than 173.35kg/cm^2(17Map),this mean that these mixtures classified as structural lightweight concrete [2].Fig.6 show the compressive strengths of concrete mixtures containing different levels of PW relative to compressive strength of the control mix. The results show that as the percentage of PW increase in the concrete mix, the reduction of compressive strength increase where reach up to 44%, 53% and 57 % for 100% PW at curing times 7,28,and 56 days respectively. Also, these results indicate that the reduction in compressive strength due to use of PW aggregate are slightly more than the corresponding reduction in the density, for example at replacement level of 60% (i.e.P60) the reduction in density was 30% while the reduction of compressive strength at 28 days was 39%.

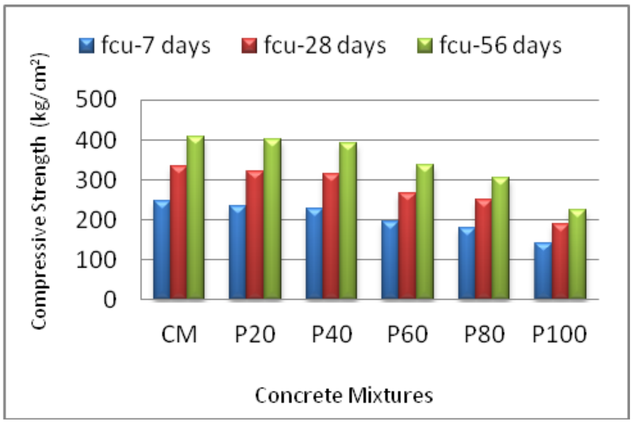

Fig.5. Compressive Strength at ages of 7,28 and 56 days

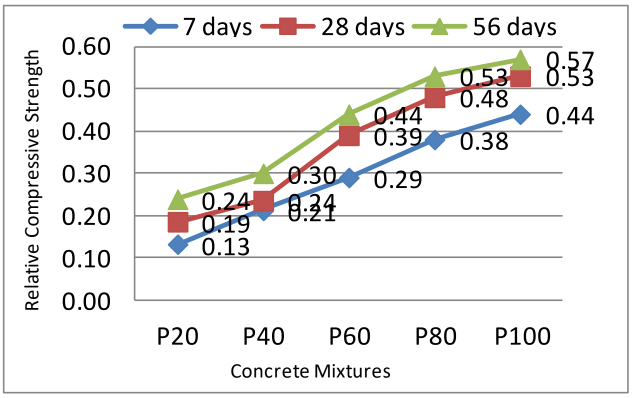

Fig.6. Compressive Strength Relative to Strength of Control Mix

E. *Tensile Strength*

Fig.7 shows the results of split tensile test for concrete mixtures at ages of 7, 28 and 56 days. These results indicate that use aggregate of PW result in decrease in tensile strength than that of control mix (i.e. dolomite concrete mix).In general, Fig.6 indicate that tensile strength of PW concrete mixtures have tensile strength changed gradually from 12.4 kg/cm^2 to 17.4 kg/cm^2 at curing time of 7 days, while the same mixtures have tensile strength ranging between 20.6 and 31.3 kg /cm^2 at 28 days and ranging between 27.5 and 45 kg/cm^2 at age of 56 days.

The results in Fig.8 show the reduction in tensile strength of concrete mixtures relative to tensile strength of control mix at age of 7, 28 and 56 days due to the increase of PW aggregate level. These results indicate that use of PW aggregate result in strength reduction ranged between 1% and 36% at age of 7 days and 16% to 45% at age of 28 days. Also, results indicate that maximum reduction strength of PW concretes 51% considering the results at curing time of 56 days.

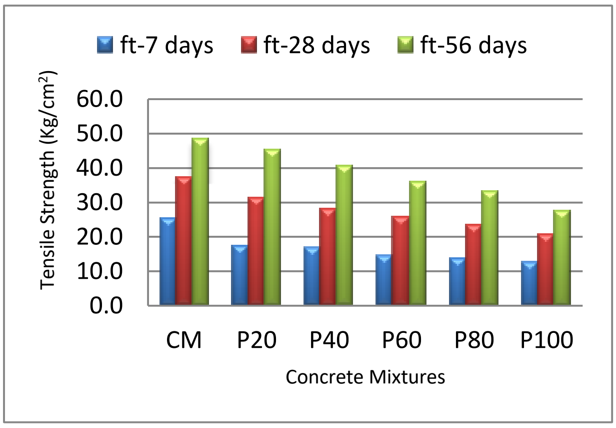

Fig.7. Tensile Strength at ages of 7, 28 and 56 days

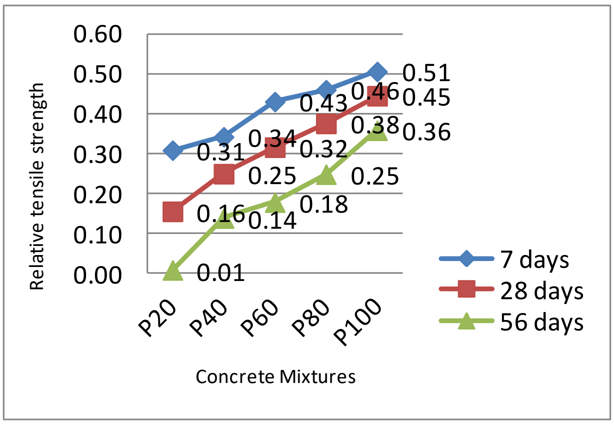

Fig. 8.Tensile Strength Relative to Tensile Strength of Control Mix

F. *Flexural Strength*

The results in Fig.9 indicate that the flexural strength of PW concrete mixtures were lower than that of the control mix. The experimental results show that the flexural strength decrease as the percentage of PW aggregate increase in the concrete mix, where the flexural strengths of 20,40,60,80 and 100% PW aggregate less than that of control mix with 27.8, 38.4, 42.98, 46.4, 50.1 % respectively. The higher flexural strength of control mix than that of concretes containing PW is due to the aggregate strength contribute to the higher flexural strength observed for concrete containing dolomite.

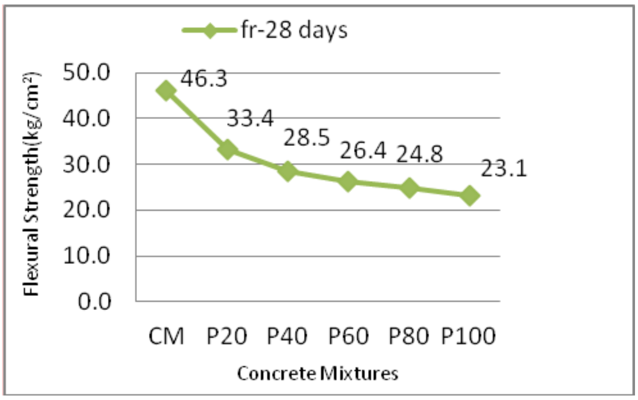

Fig. 9. Flexural Strength at age of 28 days

VI. CONCLUSION

According to the experimental results, the following conclusions can be drawn:

-The slump, bulk density, compressive strength, tensile and flexural strengths of concrete mixtures containing PW aggregate were less than that of control mixture, but the absorption increased as the level of PW increased.

- Concrete mixtures containing PW aggregate with percentage of 40%,60%, 80%,and 100% have dry densities of 1984,1795,1650,and 1410 kg/m3 respectively ,these densities are lower than that of control mix (2570 kg/m^3).

- Mixtures produced using PW with percentage of 20%, 40%,60%, 80%,and 100% have compressive strength of 320,315,267,250,and 188.86 kg/cm2 respectively ,these strengths are lower than that of control mix (335kg/cm^2).

–According to structural lightweight concrete conditions, the concrete mixtures P40, P60, P80, and P100 are classified as structural lightweight concrete where, these mixtures have compressive strengths more than 17 MPa (173.35 kg/cm^2) [2] and dry densities less than 2000 Kg/m^3 [1], i.e. all these mixes are suitable to use as structural concrete.

REFERENCES

1. BSI Document,"European Draft Standard Specification for lightweight aggregates."CEN/TC154/SC5 (1992).
2. American Concrete Institute,“Guide for structural lightweight Aggregate concrete,” ACI Manual of Concrete Practice, Part 1:Materials and General Properties of Concrete." ACI 213R-14(2014),Farmington Hill, MI.
3. R.Piyaphanuwat and S.Asvapizite"Utilization Ceramic Wastes from Porcelain Ceramic Industry in Lightweight Aggregate Concrete," International Journal of Environmental Science and Development, Vol. 8,2017,pp.342-346.
4. E.Yasar, C. D. Atis, A. Kilic and H.Gulsen,"Strength properties of lightweight concrete made with basaltic pumice and fly ash," Materials Letters. Vol.57, 2003, pp.2267–2270.
5. K.Hossain,"Properties of volcanic pumice based cement and lightweight concrete," Cement and Concrete Research,vol. 34(2),2004,pp.283–291.
6. M.N.Haque, H.Al-Khaiat, and O.Kayali," Strength and durability of lightweight concrete,"Cement & Concrete Composites,"vol. 26(4), 2004, pp.307–314.
7. F.zulkarnain and M.Ramli,"Durability of Light Weight Aggregate Concrete for Housing Construction,"2nd International Conference on Built Environment In Develpoing Countries, 2008, pp.541-551.
8. V.Khonsari, E.Eslami, and A.Anvari," Effects of expanded perlite aggregate on the mechanical behavior of light weight concrete," Proceedings of Fracture Mechanics of Concrete and Concrete Structures 2010,pp.1354-1361.

9. N.Arunachalam,V.Mahesh, and V.Sounder," Development of Innovative Building Blocks,"IOSR Journal of Mechanical and Civil Engineering, 2012,1-7.
10. J. Hamad and A. J. Hamad, " A Classification of Lightweight Concrete: Materials, Properties And Application Review,"International Journal of Advanced Engineering Applications,vol. 7(1),214,pp. 52-57.
11. American Society of Testing Materials, "Standard Specification for Concrete Aggregates." ASTM C33 / C33M-18(2018).
12. American Society of Testing Materials, "Standard Specification for Lightweight Aggregates for Structural Concrete." ASTM C330 C330M-17(2017).
13. American Society of Testing Materials, "Standard Specification for Portland cement." ASTM C150 / C150M-19a (2019).
14. American Society of Testing Materials, "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete." ASTM C1602 / C1602M-06(2006).
15. American Society of Testing Materials, "Standard Specification for Chemical Admixtures for Concrete."ASTM C494 / C494M-15(2015).
16. American Society of Testing Materials, "Standard test method for Compressive strength of concrete."ASTM C39-15(2015).
17. American Society of Testing Materials, "Standard test method for density, absorption and void of hardened concrete."ASTM C642-13(2013).
18. American Society of Testing Materials, "Standard test method for density, absorption, and voids in hardened concrete."ASTM C642-13 (2013).
19. P.K. Mehta and P.J.M. Monteiro,"Concrete: Microstructure, Properties and Materials," USA, New York, McGraw-Hill, 2006.
20. M.,Grabiec, D. Zawal, and J.Szulc, "Influence of type and maximum aggregate size on some properties of high-strength concrete made of pozzolana cement in respect of binder and carbon dioxide intensity indexes," Construction and Building Materials, Vol. 98,2015, pp. 17-24.

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