RESEARCH ARTICLE OPEN ACCESS

Experimental Investigation of Using Ultra-Fine Glass Powder in Concrete

*Doha Mothefer Abdul-Razzaq Al Saffar
Al-Mansour University College/Civil Engineering Department
Corresponding Author: Doha Mothefer Abdul-Razzaq Al Saffar

ABSTRACT
The Ultra- Fine Glass Powder (UFGP) smaller than 0.075 mm (No. 200) produced from grinding and polishing edges on flat glass of different size and thickness, has been used instead of sand in different proportions which are 15%, 30%, 45%, 60%, 75%, 90% and 100%. It was found that there was a slight decrease in workability when the percentage of replacement decreased.The effects of UFGP on properties ofhardened concrete which includedry density, water absorption compressive strength and thermal conductivity are analyzed. The results of this study show that UFGP is determined to have a significant effect on increasing its compressive strength at 15%, 30%, and 45% , and there is a reductionindry density atup to ~ 45% . As for cost analysis and thermal conductivity test, this investigation is an environmental one by taking into consideration the fact that UFGP could be used to produce lightweight aggregate concrete without the need for high cost or energyloss.
***Keywords*:** Ultra-fine aggregate, glass powder, waste glass, thermal conductivity.

Date of Submission: 16-09-2017 Date of acceptance: 29-09-2017

I. INTRODUCTION

Fine aggregates (smaller than 4.75mm, No.4 mesh) play a very important role in controlling the properties of fresh concrete. They help to improve the cohesiveness and workability of the fresh concrete, and prevent segregation. A key factor to increase workability of concrete is the contribution of fines to the cohesiveness of the fresh concrete mixture. Thus, one may conclude that a large amount of fines can also be used in normal slump concrete [1]. On the other hand, another work recently tested the effect of addition of fines to concrete. It was found that the addition of a small amount of fines (~55kg/m^3) led to a significant reduction in the workability of the fresh concrete and to some increase in its compressive strength. However, the composition (size distribution and mineralogy) of the fines tested in the study is not clear; therefore, the affecting parameter could not be identified [2].

II. RESEARCH SIGNIFICANCE

The objective of the present work is to systematically study the effect of UFGP on the most widely manufactured normal concrete with slump 100 mm, prepared under normal conditions. Positive results of this study will enable the use of larger amounts of fines in the manufactured sand, reducing the environmental impact and direct costs involved in its removal from the sand.

III. EXPERIMENTAL PROGRAM

Experiment was conducted on concreteprepared by partial replacement of natural sand by wasteglass powder of particle size 90. UFGP was replaced by 15%, 30%, 45%, 60%, 75%, 90% and100% of the natural sand.

The effect of UFGP on early age and later age has been evaluated. The early age study included workability, and a slump test, whereas the hardened (late age) concrete properties studied were density, water absorption,compressive strength, and thermal conductivity.

IV. MATERIALS

4.1 Cement

The cement used in the concrete mixtures is ordinary Portland cement, a product of Iraqi cement produced by Al Kubaisa Cement Factory. The Physical and chemical properties indicate that the adopted cement conforms to the Iraqi specification No. 5/1984 [3].

4.2 Sand

The fine aggregate used is natural sand, whose fineness modulus is 2.67. Its gradation lies in zone (3). Results indicatethat the fine aggregate grading are within the requirements of the Iraqi specification No.45/1984 [4], as shown in Table 1 and plotted in Fig. 1

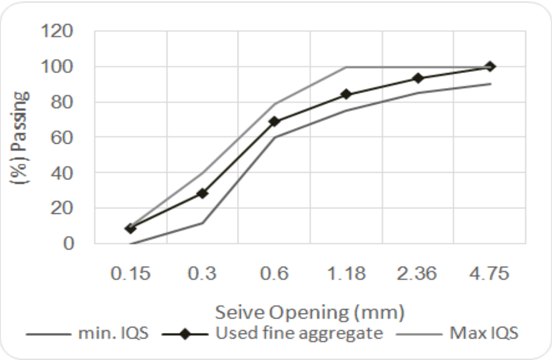

Fig. 1. Grading curve for fine aggregate

Table 1. Grading of fine aggregate and requirements

Sieve Size (mm)	Accumulative % Passing	% Accumulative Passing according to limits of I.O.S No. 45/1984
4.75	100	90-100
2.36	93.43	85-100
1.18	84.48	75-100
0.60	69.13	60-79
0.30	28.68	12-40
0.15	8.98	0-10
Fineness Modulus = 2.67		

4.3Glass Powder

Ultra-fine glass powder as shown in Fig. 2 broughtfrom DEKAR Glass Companywas used as a partial replacement of sand. It is produced from grinding and polishing edges on flat glass of different size and thickness as shown in Fig. 3.its aggregate size is less than 150 µm. The chemical composition of UFGP is shown in Table 2.

Table 2. Chemical composition of waste glass

Compound	%by Weight
SiO_2	68
Al_2O_3	7
Fe_2O_3	1
CaO	11
MgO	1
K_2O	1
Na_2O	12
SO_3	0.4

Fig. 2. Ultra-fine glass powder

Fig. 3. Grinding and polishing edges on flat glass machine

4.4 Coarse Aggregate

Natural crushed stone brought from Al Sulaimania governorate has been used throughout the work. Its max size is (10 mm). The grading of crushed coarse aggregate is shown in Table 3and plotted in Fig. 4. Grading of this aggregate conformed to the Iraqispecification No. 45/1984 [4]. The specific gravity & absorption are (2.68) & (0.08%) respectively.

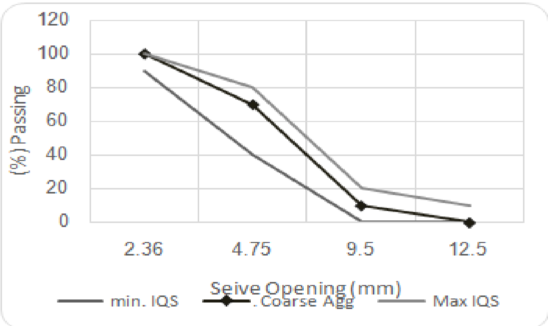

Fig. 4. Grading curve for coarse aggregate

Table 3. Grading for coarse stone aggregate

Sieve size (mm)	Selected %passing	% passing ASTM C330-87
12.5	100	90-100
9.5	70	40-80
4.75	10	0-20
2.36	0	0-10

4.5 Water
Potable water of Al-Risafa, Baghdad, was used throughout this investigation for mixing and curing.

V. CONCRETE MIX PROPORTION AND PREPARATION

Trial mix design was conducted to obtain the target strength of 30MPa at 28 days with a workability of 80–100 mm as perB.S.1881: Part 116:1989 [6]. The UFGP replacement with naturalsandis varied (0-100%). Mix proportion of concrete is shown in Table 4. Firstly, coarse stone and sand were dry mixed for a minute. Appropriate quantity of UFGP was blended with cement in a separate panthen the required quantity was added, and the mixing continued for 3 minutes at which a good homogenous mix was produced. The water – cement ratio (w/c) in all the mixtures was kept constant at 0.42. Workability of the fresh mixtures for all test was adjusted to a slump value of 100 ± 5mm. One control mixture, containing no UFGP.

Table 4.Mixture composition of all experiment series

Mix	Slump (mm)	Materials Content (kg /m^3) Concrete mix proportion (cement: fine agg. : coarse agg.) Constant at (1:1.5:3)				
		Cement	Sand*	UFGP	Coarse Aggregate*	Water
MR	98	360	540	-	1080	151
M15	97	360	459	81	1080	151
M30	93	360	378	162	1080	151
M45	90	360	297	243	1080	151
M60	86	360	216	324	1080	151
M75	85	360	135	405	1080	151
M90	83	360	54	486	1080	151
M100	83	360	-	540	1080	151

*Aggregates in SSD condition, water quantities were adjusted before mixing.

VI. TEST MIXTURES

6.1 Slump Test
Generally, concrete slump value is used to find the workabilityas shown in Fig. 5, which indicates water-cement ratio.The amount of slump measurement according to ASTM is C143/C143M [7].

Fig. 5Slump Test of reference Concrete mix

6.2 Dry Density The dry density test was determined from the dried weight (105 ˚C for 24 hrs.) and the measured volume by a ruler. Three 150mm cubes were measured in each tested sample. The density was found by weighing the specimens and dividing the weight by the measured volume of the specimens. The dry density is tested at age (28) days.

6.3 Water Absorption
The test was carried out according to ASTM C642-97[8]
on 150 mm cubic specimens. The specimens were tested for 28 days of curing.

6.4 Compressive Strength
The compressive strength test was carried out on 150mm cube according to B.S.1881: Part 116:1989 [6]. The specimens were tested for 28 days of curing.

6.5 Thermal Conductivity
This test was carried out on prismatic specimens of (200 ×100 × 50) mm. An unsteady state condition method was adopted according to the B.S. 874:1973 [9], Fig. 6.

Fig. 6. Thermal Conductivity Test.

VII. RESULTS AND DISCUSSION

7.1 Slump Test

The effect of adding UFGP on the workability of fresh concrete is presented in Fig.7. The initial slump for reference mix was adjusted to 100 ± 5 mm, and the results show that no significant differences exist for15%, and 30% replacement of UFGP. A reduction in workability was seen at higher levels of UFGP 90, and 100% replacement, the amount of reduction was 16.3%, and 17.3% respectively. This behavior may be due to the fact thatfiner particles require more water to wet their larger specific surface, whilst the irregular shape and rougher texture of an angular aggregate demand more water [10].

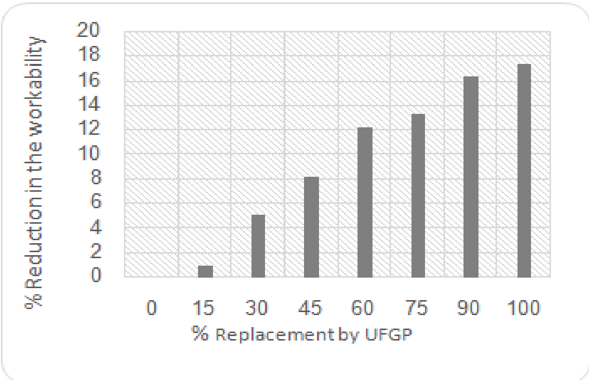

Fig.7. Reduction in the workability for various mixtures

7.2 Dry Density

The dry densities for all mixes are plotted in Fig. 8 and 9. The test results indicated that there is no significant reduction in dry density especially at 15% replacement. However, it is important to notice that concrete sample containing especially 30% replacement of UFGP leads to steep decline in weight of concrete.The results also show that the maximum reduction in density at 100% replacement of UFGP was 14.3%. This is perhaps attributed to the lower specific gravity of glass aggregate as compared with sand.

7.3 Water Absorption

The results obtained from measurement of water absorption at 28 days are plotted in Fig. 10 and 11. The test results indicate that the water absorption increases with the increase of % replacement of UFGP by up to ~ 45%, with most of the change occurring as a result of the increase in UFGP % of up to 60%. This behavior may be due to the fact that the UFGP grains led to the formation of lumps. Fig. 12 presents an examples of lumps in mixtures. If present in large quantities (over 45 per cent of the mass of the aggregate) these particles may lead to increases in the water absorption [11].

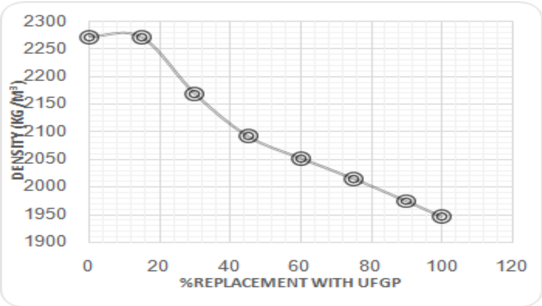

Fig. 8. Effect of UFGP content on the dry density

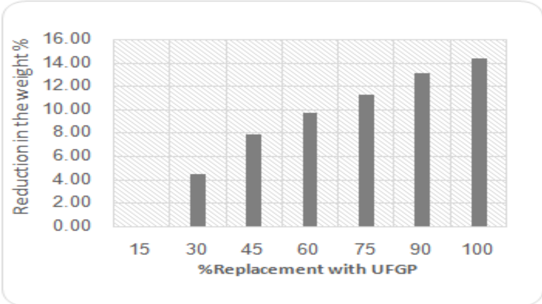

Fig. 9. The reduction in the dry density of concrete %

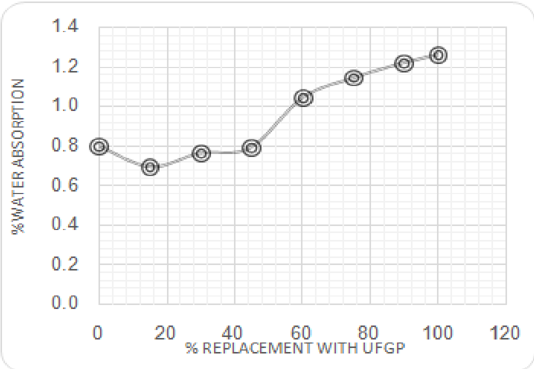

Fig. 10. Effect of UFGP content on water absorption

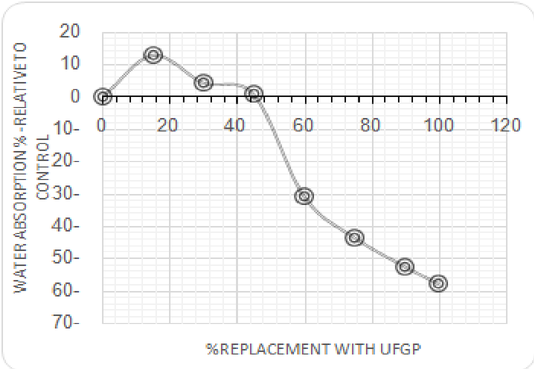

Fig. 11. Water absorption at 28 days relative to control

7.4 Compressive Strength

The mixtures exhibited an increase as the UFGP content increased up to 30% in their compressive strength as a result of the addition of ultra-fine aggregate Fig. 13, and 14. Some improvement was seen for the addition of a small content of UFGP from 15 to 25 %, and this improvement decreased with the increase of the amount of UFGP content. Maximum improvement was seen at 15% of UFGP, the percentage of increment was 32%. Fig. 13 presents the compressive strength at 28 days relative to control mixture. This behavior may probably lead to better packing of the mixtures, which, together with additional nucleation site for the hydration products, led to the formation of a denser matrix and to improved strength [12].

In the other side, the mixtures exhibited a strength reduction as the UFGP increased beyond 60 %. This adversely affects the strength of concrete may be due to the cumulative effect of the UFGP lumps.

Porosity is the primary factor affecting the strength of concrete. It will be shown as a source of weakness. Other sources of weakness arise from the presence of the aggregate, which itself may contain flaws in addition to being the cause of micro cracking at the interface with the cement paste [10]. Fig 14 plotted the relationship between porosity and compressive strength. This indicates that the optimum percentage of replacement by UFGP was 15% for compressive strength concrete.

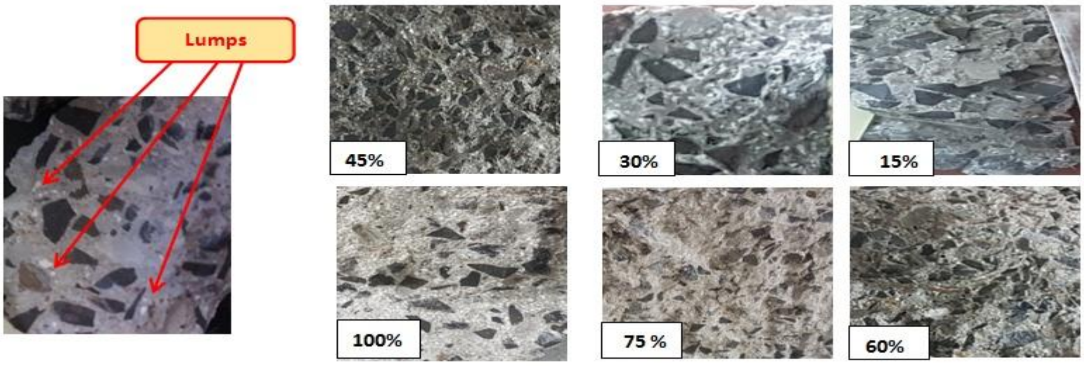

Fig. 12Some examples of UFGP lumps in mixtures

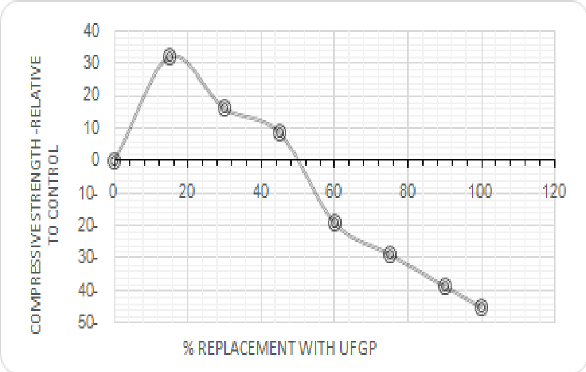

Fig. 13. Compressive strength at 28 days relative to control

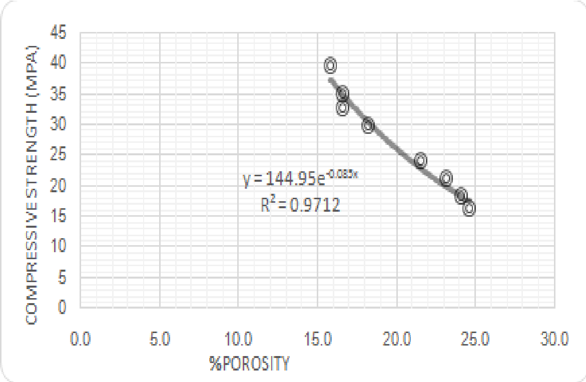

Fig. 14. Effect of UFGP on compressive strength at 28 days relative to control

7.5 Thermal Conductivity

The normal concrete as a complex mixture of varying composition can exhibit a wide range of thermal conductivity depending on the density, aggregate used , moisture condition and method of testing(9).From the test results for concrete mixes with different densities shown in Fig.15, it is indicated that the values of thermal conductivity for UFGP mixtures are approximately comparable. 100% with UFGP replacement mix concrete which has the lowest density has consequently the lowest thermal conductivity of other mixes.The value of thermal conductivity with 28 days age was 0.79W/m.°C. This is because its comparatively low density, specific gravity and porous structure of the cement matrix.

Normal concrete with normal aggregate mix exhibited a higher thermal conductivity 1.19 W/m.°C at 28 days. This is because normal aggregate density is the highest and there is a lack in the presence of voids within the cement matrix.

VIII. COST ANALYSIS

The produced concrete cost analysis in based on unit weight cost is compared with local prices in Iraq (2016). The costs of materials are calculated as shown in Table 5 below.According to the cost analysis shown, there is a decrease in the cost of 1m3 of concrete with 100% replacement with UFGP by 18.5 % from the plain concrete

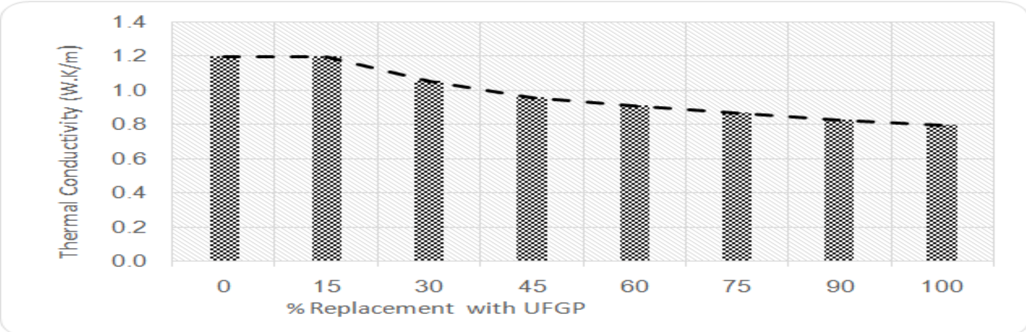

Fig. 15. Thermal conductivity for various replacement with UFGP at 28 days

Table 5. Cost analysis of replacement with UFGP

Building material	Cement (OPC)	River sand	Gravel	Water	Glass powder (UFGP)*	Total	Reduction in cost (%)
Price of materials $/m³&transportation	40	14	9	2.5	2		
Cost of m³ plain concrete	40	14	9	2.5	-	65.5	-
Cost of m³ with 15% UFGP	40	11.9	9	2.5	0.3	63.7	3
Cost of m³ with 30% UFGP	40	9.8	9	2.5	0.6	61.9	5.5
Cost of m³ with 45% UFGP	40	7.7	9	2.5	0.9	60.1	8.2
Cost of m³ with 100% UFGP	40	-	9	2.5	2	53.5	18.5

*The cost of UFGP is free, and the cost of transportation, is only 3$.

IX. CONCLUSIONS

Based on the results of the experimental work carried out it was found that:

1. When compared at a constant w/c, the addition of UFGP did not have significant effect on workability.
2. It is possible to produce lightweight aggregate concrete with the addition of high percentage of UFGP.
3. This study supports the idea that UFGP aggregates, as used within the specified ranges, improve their compressive strengths, and the maximum improvement was seen at 15%.
4. According to the cost analysis shown there is a decrease in the cost of $1m^3$ of 8.2, 5.5, and 3% at 45, 30, and 15% replacement with UFGP but did not otherwise adversely affect the compressive strength of concrete.

REFERENCES

[1]. Mindess, S.;Young,J. F.; and Darwin, D., 2002,Concrete, Prentice Hall, 644 pp.
[2]. Abou-Zaid, M. N., and Fakhry, M. M., "Short-Term Impact of High Aggregate Fines Content on Concrete Incorporating Water- Reducing Admixture,2003, " ACI Materials Journal, V.100, No. 4, July-August, pp.280-285.
[3]. I.Q.S. No. 5, 1984," Portland Cement", Central Organization for Standardization and Quality Control. PP. 8.
[4]. ASTM C29,1989, " Standard test method for unit weight and voids in aggregate", Annual Book of ASTM Standards, Vol.04-02, PP.1-4.
[5]. Iraqi Specification No. 45, "Natural Sources for Gravel that is used in Concrete and Construction", Baghdad, 1984.
[6]. B.S. 1881, Part 116, 1989, "Method for Determination of Compressive Strength of Concrete Cubes", British Standards Institution, 1881; PP. 3
[7]. ASTM C143/C143M, 2003, "Standard Test Methods for Slump of Hydraulic–Cement Concrete", Vol. 04.02, pp. 95–98.
[8]. 9- ASTM C642-97,1997, "Standard Test Method of Specific Gravity, Absorption and Voids in Hardened Concrete", ASTM Standards, Vol. 04-02.
[9]. B.S.874,"Determining thermal insulating properties, with definition of thermal insulation terms", British Standards Institutions, 1973, PP38.
[10]. Neville A.M.,2010, "Properties of Concrete", Longman Group, Ltd., UK. , Second Edition, pp. 339-35.
[11]. 11. Roz-Ud-Din and Nassar, ParvizSoroushian, 2012, "Strength and Durability of Recycled Aggregate Concrete Containing Milled Glass as Partial Replacement for Cement," Construction and Building Materials 29.
[12]. 12. PatilDhanraj Mohan and Dr.SangleKeshav K,2013, "Experimental Investigation of Waste Glass Powder as Partial Replacement of Cement in Concrete,". International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, V. 2, Issue-1.

Doha Mothefer Abdul-Razzaq Al Saffar. "Experimental Investigation of Using Ultra-Fine Glass Powder in Concrete." International Journal of Engineering Research and Applications (IJERA) , vol. 7, no. 9, 2017, pp. 33–39.