Al-Nahrain Journal for Engineering Sciences **NJES** 22(1)14-17, 2019
http://doi.org/10.29194/NJES.22010014

Effectiveness of Glass Wastes as Powder on Some Hardened Properties of Concrete

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Paper History:

Received: 7th Nov. 2018

Revised: 2nd Jan. 2019

Accepted: 30th Jan. 2019

Abstract

This paper present glass waste material reusing in concrete as partial replacement of cement. Some hardened properties like compressive and flexural strengths, modulus of elasticity and % absorption was made. The effect of glass powder on these properties was examined compared to reference specimens without glass powder. Five percentage was tested: 0%(reference), 10%, 15%, 20% and 25%. From tests results one can conclude that replacing cement partially by glass powder enhanced strengths of concrete (compression and flexural) up to 20% replacing level Using glass powder as partial replacement of cement improved strengths and modulus of elasticity of concrete. The %absorption decrease with increasing of glass powder content. The results show that utilization of waste glass as powder in concrete can reduce amount of cement which save cost besides its environmental benefits.

Keywords: Hardened Properties, Glass Powder, Strength Gain, Flexural Strength, Absorption.

1. Introduction

In current years, the interest for utilization glass wastes in concrete is rising because the glass waste which existing from empty bottles, waste windows glass and containers have been increased. Glass can be shaped in many forms like packaging of container (bottles, jars), flat glasses (windows, windscreens), lamp glass (light globes), cathode ray tube glass (TV screens, monitors, etc.). The reusing of these wastes would considerably reduce glass waste's disposal. Shayan and Xu found that incorporation glass powder into concrete up to 30% as a pozzolanic material prevent the alkali silica reaction (ASR). The results found that max. increasing in compressive strength occurred for the concrete mix with 20% glass wastes as fine aggregate and 30% as a pozzolanic material [1]. Meena and Singh [2] used glass wastes as a partial replacement of cement. The results showed that 30% of glass powder of size ≤100µm can be used without any unfavorable effect.

Hama used a companion of glass powder plus plastic fiber and study their effects on properties of lightweight aggregate concrete. The results showed that using 1%plastic fibers with 20% percentage of glass powder improve clearly the lightweight concrete properties [3]. Vasudevan and Pillay found that utilization of glass powder has ability to improve both the workability of and the compressive strength of concrete. while density is decreased with compare to reference concrete without glass powder [4]. Omoniyi et. al. study utilization of glass wastes powder replaced partially the cement by: 0% (reference), 5%, 10%, 15%, 20%, 25%, and 30% in saw dust composite brick to study its effects on the properties of this composite. He found that glass powder with particle size ≤100µm can be utilized as cement replacement up to 30% (by weight) to prevent ASR and also can be utilized in the manufacture of non-load bearing sand concrete block without any harmful effect [5].

2. Materials, Mix Proportions and Tests

Type I Portland cement from mass factory with specific gravity of 3.16 was used in casting of the specimens for the experimental work. Chemical oxides compositions of the cement which are recorded in Table (1) show that using cement is conformed to the Iraqi specification No.5/1984. [6]

Table (1): Chemical oxide composition and components of cement

Chemical Compounds	By weight%	Iraqi specifications Limits
CaO	61.6	-
SiO_2	21.4	-
Al_2O_3	5.28	-
Fe_2O_3	3.4	-
SO_3	1.11	≤ 5%
MgO	1.8	≤ 2.8%
Main compounds (Bogues eq.)	By weight of cement%	
C3S	46.95	

C2S	24.52
C3A	8.05
C4A	10.39

Waste broken windows glass, was collected and crushed to powder before adding in the concrete. Table 2 show sieve analysis of resulting glass powder. The strength activity index of utilizing glass powder in this work was 102% which is compiled with the strength activity index requirements of ASTM C311–05 [7]. X-ray fluorescence spectrometry (XRF) of glass powder as shown in Figure 1.

Table (2): glass powder sieve analysis

Sieve NO.	% passing
300μm (No.50)	100%
150μm (NO.200)	24%
75μm (NO.200)	73%
< 75μm (NO.200)	73%

Fine aggregate with a max. size of 4.75 mm and specific gravities of 2.60 was used. The coarse aggregate was gravel with a nominal max. size of 10 mm with SG. 2.82. The sieve analysis results of the using fine and coarse aggregates are shown in Table 3 which are compiled to the Iraqi specification No. 45 [8]. High-performance superplasticiser (Sika ViscoCrete-5930) type G and F was used to improve mixes workability without increase w/c ratio. The superplasticiser meet the ASTM C 494 requirement [9].

Table (3): sieve analysis of both coarse and fine aggregate

Sieve size (mm).	% passing for coarse aggregate	Iraqi specification limits	% passing for fine aggregate	Iraqi specification limits
10	100	100	100	100
4.75	95.77	85-100	100	90-100
2.36	75.57	0-25	85	75-100
1.18	65.2	0-5	56	55-90
0.6	29	-	30	35-59
0.3	10	-	13	8-30
0.15	6	-	3	0-10

Concrete mixes were designed with a constant w/b ratio of 0.32 and 1:1.5:3 cement: sand: gravel. The glass powder was used as a 0%, 10%, 15%, 20% and 25% of total binder content by weight. 1% superplasticiser (by the weight of cement) was used. Compressive strength (at 28 and 90 days ages), flexural strengths, modulus of elasticity and absorption tests were carried out with respect to ASTM C39-05 [10], ASTM C78 – 02 [11], ASTM: C469–02 [12] and ASTM: C642–06 [13], respectively.

3. Results and Discussions

3.1 Compressive strength

Figure 1 clarify the results of replacing glass powder (GP). One can see the improvement in the strength of concrete compared with reference on without glass powder for glass powder content up to 20%. The percentage difference in the compressive strength of concrete due to replacing of glass powder compared to reference mix at 28-day age are 25.92%, 44.34%, 55.72%, and -14.65% for 10%, 15%, 20% and 25% GP, respectively. The percentage difference in the compressive strength of concrete due to replacing of glass powder compared to reference mix at 90-day age are 13.95%, 38.04%, 15.21%, and -22.59% for 10%, 15%, 20% and 25% GP, respectively. The 20% GP gave the higher compressive strength at 28-day age while 15% gave the higher compressive strength at 90-day age. While at 25% GP the concrete compressive strength decreased in both age.

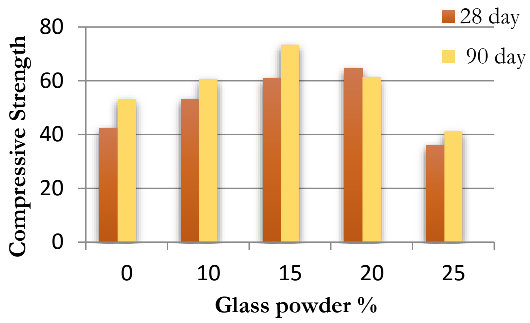

Figure (1): Strength gain with time and % glass powder

Figure 2 shows the shape of cylinder specimens under compressive loads before and after failure.

Figure (2): Shape of the specimens under compressive loads before and after failure.

3.2 Flexural tensile strength

Figure 3 shows flexural tensile strength test results. The percentage difference in flexural tensile strength of glass powder concrete compared to reference mix are 18.64%, 33.36%, 20.64%, and -9.80% for 10%, 15%, 20% and 25% GP replacement, respectively. Figure 4 clarify the specimens under two-point flexural loads before and after failure.

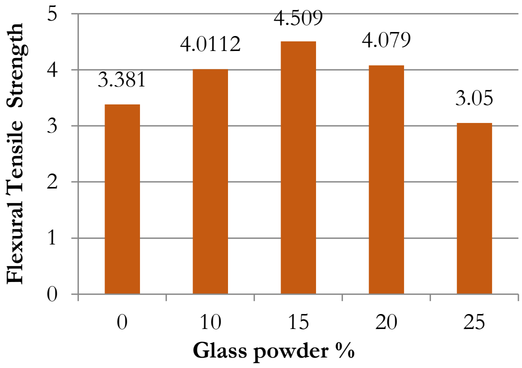

Figure (3) : Varaition of flexural tensile strenth with % glass powder

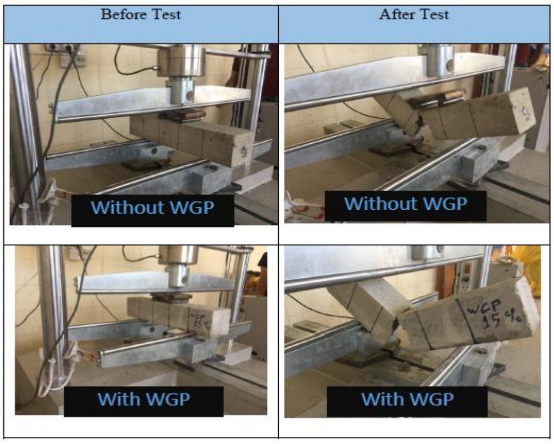

Figure (4): Specimens under two-point flexural loads before and after failure.

3.3 Modulus of elasticity

Figure 5 shows shape of failure in stress-strain test under compressive loads for determination of modulus of elasticity.

Figure 6 shows modulus of elasticity test results. The percentage difference in modulus of elasticity of concrete due to glass powder replacing compared to reference mix are 4.42%, 3.28%, -0.52% and 1.4% for 10%, 15%, 20% and 25% GP replacement, respectively.

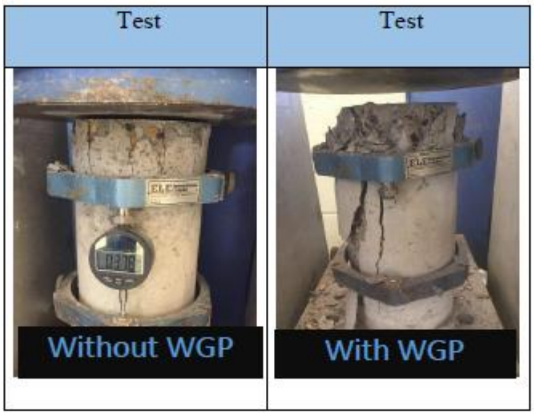

Figure (5): Shape of failure in stress-strain test under compressive loads for determination of modulus of elasticity.

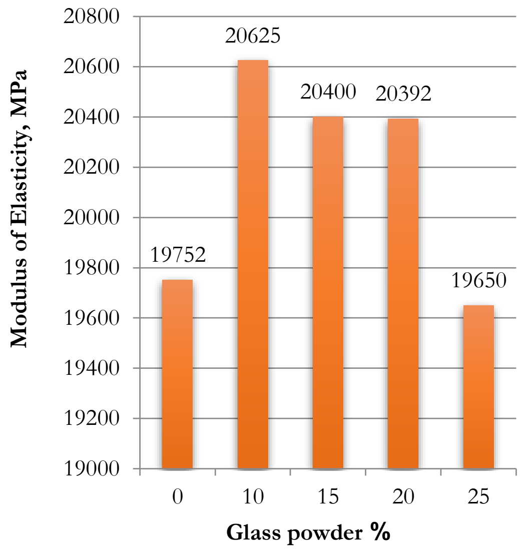

Figure (6) : Varation of modulus of elasticity with % glass powder content

3.4 Absorption test

Figure 7 shows the %absorption verse glass powder content. The results show that all GP mixes gave lower absorption percentages compared to reference one. The percentage decreasing in %absorption was:15.47%, 26.58%, 30.44% and 35.27% for 10%, 15%, 20% and 25% GP replacement, respectively.

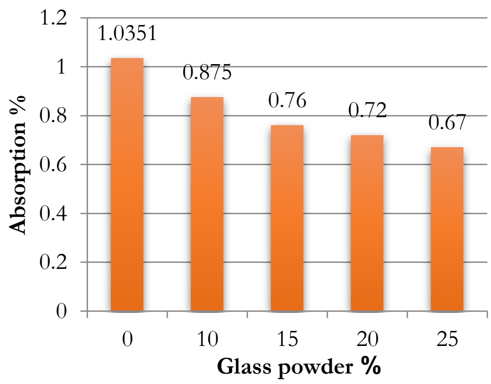

Figure (7): Varation of concrete a bsorption with glass powder %

4. Discussion of Results

Glass powder are rich of silica. Silicates interact with an alkali medium which is produced during the hydration of cement which result in a component similar to that produced during the hydration of cement. This will lead to less porous and an enhancing in hardened properties was notice especially for glass powder percentages up to 20% GP.

5. Conclusions

Glass powder replaced partially the cement in concrete at these levels: 10%, 15%, 20% and 25%. Based on the comparison with reference mixes without glass powder the following conclusions are made:

1. Using glass powder as partial replacement of cement improved strengths of concrete (compression and flexural) for glass powder content up to 20%. This applies to the modulus of elasticity
2. The %absorption decrease with increasing of glass powder content
3. From the results above, it seems that using waste glass as powder in concrete has an environmental benefit besides improving concrete properties.

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