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Glass-Polymer- Concrete Composite and Its Mechanical, Chemical and Thermal Properties

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors BGM and AAF managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In this research, the production of glass-polymer-concrete (GPC) composite and comparing of its mechanical, chemical and thermal properties with the reference concrete have been investigated. The present work deals with study of ternary blended concrete with glass waste and polymer as reinforcement and binder. New product is designed for compressive strength of 52 MPa and other mechanical and thermal properties were improved. As well as the results revealed remarkable improvements in chemical resistance against harsh acidic environment; and decrease the absorption of moisture by 14%. Beside benefits for this research is to disposal amassed glass waste that increasing day after day. Statistical ANOVA and Box Welson techniques are used to lessen the trial and error tests (not shown).

Keywords: Composite; polymer concrete; glass concrete; water adsorption; compressive strength.

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1. INTRODUCTION

Concrete is the most widely used in construction material and has most desirable properties such as compressive strength, stiffness and durability under natural environmental. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. In our study, these properties can be improved by the use of waste glass in the concrete after crashing them to fine grains and adding a different ratio of polymer (type of PU). It has been revealed that concrete reinforced with optimum size and ratio of fine crashed glass and optimum ratio of polymer acquires better mechanical and chemical properties.

The properties of polymer concrete differ greatly depending on the conditions of preparation. For a given type of polymer concrete, the properties are dependent upon binder content, aggregate size distribution, nature and content of the microfiller, curing conditions, and so forth [1]. Lot of research has been carried out in last few decades to develop promising applications of polymer concrete, that is, its use in machine tool structures [2-9].

Berardi and Mancusi studied the time-dependent behavior of polymer concrete columns reinforced with different bar types using a mechanical model developed by them [10]. They have concluded that the stiffness and strength of beams made from reinforced polymer concrete can change considerably over time due to viscous phenomena. Georgiopoulos P et al. [11] have investigated the short-time creep behavior at tensile and single cantilever mode of deformation for a series of biodegradable composites. The benefits of their research is to study the effect of stress, temperature and wood fiber type on the material's creep response. A mechanical model for predicting the long term behavior of reinforced polymer concretes was studied by Berardi et al. [12].

Barros et al. [13] investigated the tensile behavior of reinforcement concrete specimens at 28 days of age. It was observed that fracture energy of cement based materials is significantly increased by adding glass fiber to the mix composition. Raman et al. [14] studied the mechanical properties of polymer concrete and reported that the addition of glass fibers improves the behavior of polymer concrete. Martinez et al. [15] studied the special characteristics of polymer concretes (PC) as well as the role of how additives and processing can enhance their properties. Tomas and Ganiron [16] stated that polymer fiber being added to the cement as an admixture gave efficient characteristic on the performance of the concrete with respect to its properties as to better strength, durability, elasticity and shrinkage.

2. EXPERIMENTAL WORK

Cement used in this research was Yemeni ordinary Portland cement available in local market. The chemical properties of cement were analyzed using Pul Verizing mill HSM type HERZOG and the results obtained in weight percentage are 22.6% SiO_2, 5.8% Al_2O_3, 3.5% Fe_2O_3, 61.3% CaO, 1.8% MgO, 1.7% SO_3, 0.8% Alkalis, 1.5% free lime, 0.5% insoluble residue.

The sieving used ranging from 2.36 mm to 600 µm. Its grading conformed to ASTM – C33-87.

Coarse aggregate used in this research was natural crushed gravel obtained from Al-Hagar area. According to ASTM –C 33-87, the sieving used ranging from 12.5 mm to 4.75 mm. But we did not study the effect of aggregate in this investigation.

Glass waste used in this investigation is fine grading in different size. It is used instead of cement with size of 600 µm, however the glass waste used instead of fine aggregate is 1.2 mm in size.

Polymer polyurethane can be formed when two liquid chemicals an isocynate and polyol react in the presence of suitable catalysts and additives.

The cube and cylinder specimens were prepared by mixing different ratio of glass, polymer and cement, and different size of glass. ASTM-C 1585 and ASTM – C 267 are used as test method for water absorption and thermal conductivity respectively. Compressive testing machine 3000 kN capacity to test rectangular blocks up to 500×300 mm, cubes up to 300 mm and cylinders up to diameter of 160×320 mm (Figs. 2.1 and 2.2). Mixture machine, flexural machine, jolting machine and failure mode are shown in (Figs. 2.3, 2.4, 2.5 and 2.6) respectively.

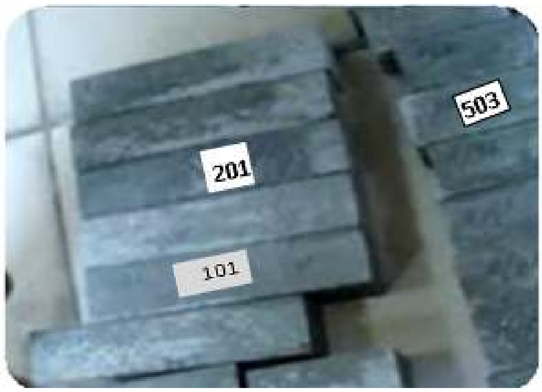

Fig. 2.1. Fabricated specimens

Fig. 2.2. Compressive machine

Fig. 2.3. Mortar mixture machine

Fig. 2.4. Flexural test machine

Fig. 2.5. Jolting machine

Fig. 2.6. Failure mode

3. RESULTS AND DISCUSSION

3.1 Compressive Strength

Fig. 3.1 shows the effect of glass and polymer compositions on compressive strength of GPC specimens. The optimum value of compressive strength tests at different ages of concrete cubes in presence of different ratio of G/P/C was 52.43 MPa comparing with conventional concrete (32.5 MPa). It is shown that beyond the optimum results, there is no significant of additives. This improvement is due to the presence of polymer as binder and particles of glass waste as an reinforcement fillers which decrease the brittle of concrete.

3.2 Splitting Tensile Strength

Fig. 3.2 shows the results obtained from splitting tensile strength test. It is observed that with increase in glass waste, the splitting strength also increases with age as beyond the optimum value no significance. From the Table 3.1, at the age of 28 days with optimum of 10% of glass waste and 8% of polymer, the splitting is 22.6% in excess over the strength of the reference one, For 56 days the percentage of splitting strength increase at the same ratios is found to be 26.5%.

3.3 Flexural Strength

Results of flexural strength test are depicted in Fig. 3.3. The obtained values for this experiment showed that these glass polymer concrete composite reached to great flexural strength. This is because the polymer is flexible and glass waste particles is hard and form a new material in the concrete posses good characteristic.

The highest value for flexural strength was 6.8 MPa which was greater than the flexural strength of conventional concrete (3.52 MPa). Mechanical properties results at different ratios of glass powder and polymer at different time are incorporated in Table 3.1.

3.4 Chemical Resistance

Three optimum specimens were exposed as a one face and bulk to harsh chemical environments such as dilute solution of 3% by weight H_2SO_4 and 5% HNO_3 as acidic rain solution (pH is 5.5-6.5) for 28 days per ASTM – C- 267. The experiments carried out showed that the acidic resistance of the three optimum specimens was significant improvement comparing to that normal concrete due to increase the siliceous as glass and decrease the porosities by the additives of glass particles and polymer.

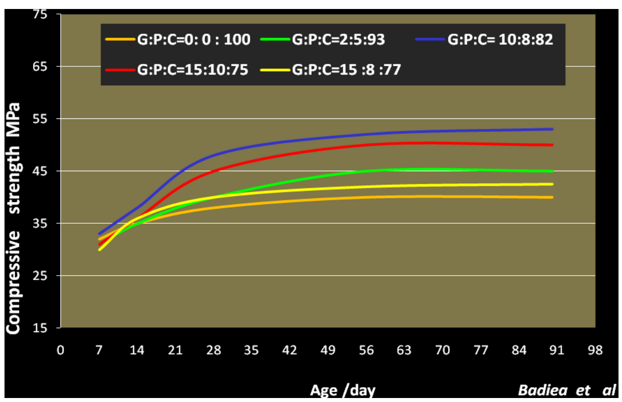

Fig. 3.1. Compressive strength at different composition relating to ages

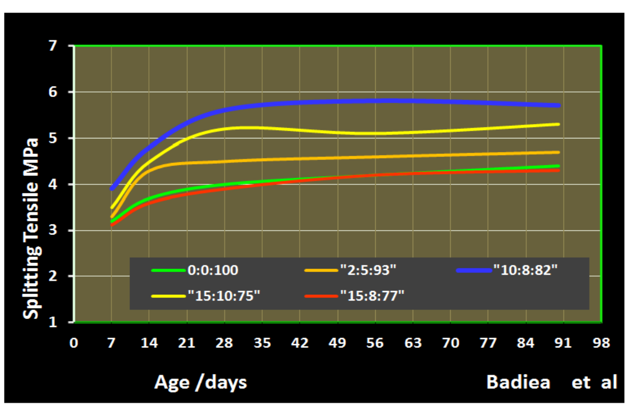

Fig. 3.2. Splitting tensile strength at different composition relating to ages

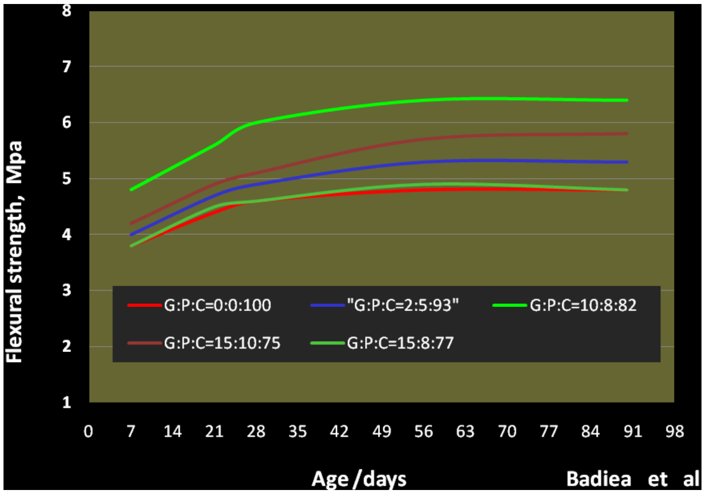

Fig. 3.3. Flexural strength at different composition of glass waste and polymer relating to ages

3.5 Water Absorption Test

The test is carried out under ASTM- C 1585. As shown in Fig. 3.4, the absorption is taken for the three optimum specimen at different time in hours depending on the equation:

$$Ab\% = \frac{(W_2 - W_1)}{W_1} \times 100 \tag{1}$$

where Ab % is percentage absorption, W_2 and W_1 are the weight of the specimens before and after emersion in the water. The average value of the three optimum specimens was 0.0365 and is very reasonable to that of conventional concrete which is 0.043, this is due to the presence of small particle size of glass and polymer in the voids instead of gases.

3.6 Thermal Conductivity

Thermal conductivity k as indicator for quality of the product can be evaluated using the following Eq.

$$Q = k\,A\,\frac{\Delta T}{x} \tag{2}$$

where Q (W) is the heat transfer through the specimen, k (W/m.K) is thermal conductivity for the specimen, A (m^2) is the surface area of the specimen, x (m) is the thickness of the specimen and ΔT (K) is the gradient temperature from the hotter to the colder face. The apparatus used is guarded hot plate which is made locally. Three optimum specimen were made to fit the guarded hot plate and tested according to

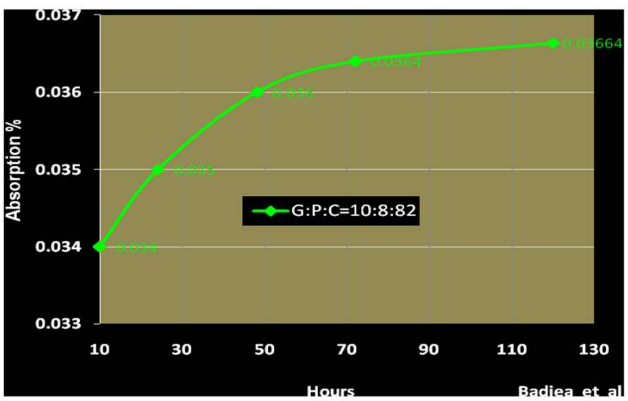

Fig. 3.4. Water absorption of specimen against immersion time

ASTM –C 177. The results obtained of thermal conductivity for the average three optimum specimen was 0.73 W/m.K comparing to the conventional one (1.2 W/m.K). The summarized results for all properties are depicted in Table 3.2.

Table 3.1. Mechanical properties of fabricated GPC at different ratio and different days for 110 µm particle size of glass waste

Test period, day	Sample ID	Ratio of glass, polymer and concrete (% wt)			Compressive strength, Mpa	Flextural compressive, Mpa	Splitting strength, Mpa
	100	Blank	Blank	100			
	101	Blank	10	90			
	102	2	5	93			
7	103	10	10	80		Not shown	
	104	10	5	85			
	105	10	8	82			
	106	15	8	77			
	107	15	10	75			
	200	Blank	Blank	100			
	201	Blank	10	90			
	202	2	5	93			
14	203	10	10	80		Not shown	
	204	10	5	85			
	205	10	8	82			
	206	15	8	77			
	207	15	10	75			
	300	Blank	Blank	100	28.08	4.89	4.40
	301	Blank	10	90	30.12	4.88	4.39
	302	2	5	93	40.09	5.19	4.52
28	303	10	10	80	40.56	5.42	4.86
	304	10	5	85	39.89	5.89	4.56
	305	10	8	82	48.67	6.09	5.43
	306	15	8	77	36.45	4.78	4.24
	307	15	10	75	45.97	5.54	5.15
	400	Blank	Blank	100	33.48	4.95	4.60
	401	Blank	10	90	34.00	4.43	4.45
	402	2	5	93	45.58	5.49	4.51
	403	10	10	80	45.18	6.08	5.12
56	404	10	5	85	45.14	6.50	5.74
	405	10	8	82	52.43	6.83	5.82
	406	15	8	77	43.45	5.08	4.47
	407	15	10	75	48.42	5.88	5.20
	500	Blank	Blank	100	32.87	4.93	4.41
	501	Blank	10	90	30.57	4.11	4.47
	502	2	5	93	45.40	5.82	4.64
	503	10	10	80	45.73	6.00	5.10
90	504	10	5	85	49.87	5.87	5.42
	505	10	8	82	52.00	6.80	5.81
	506	15	8	77	44.78	5.88	4.45
	507	15	10	75	47.47	5.91	5.22

Table 3.2. Summarize of mechanical, thermal, chemical and physical properties of the optimum specimen

Properties	Units	Value
Density	kg/m^3	1680
Linear shrinkage	%	0.006
Compressive strength	Mpa	52.43
Flexural strength	Mpa	6.83
Splitting tensile strength	Mpa	5.78
Modulus of elasticity (compression)	Gpa	30
Brinell hardness	Mpa	260
Poisson ratio	%	0.31
Thermal expansion coefficient	$K \times 10^{-6}$	12
Water absorption	%	3.65
Thermal conductivity	W/m.K	0.73
3% H_2SO_4	Weight loss, g	0.94
5% HNO_3	Weight loss, g	1.05

4. CONCLUSION

GPC ternary blend showed improvement of mechanical, chemical and thermal properties of concrete whereas this properties had been found to decrease with increase the ratio of glass powder and polymer in concrete up to optimization values. The results gave strong reliability to use the new products for construction and others utilizes.

Compressive strength increased up to maximum values which was 52.43 Mpa at the ratio of 10% and 8% by mass of glass powder and polymer, respectively. More additives of glass powder and polymer for example beyond 15% and 12% of glass and polymer led to negative results in concrete due to increasing in the porosity which made a permeability rating up to the specimen when exposure to the surrounding environment. As well as there was good improvement in the flexural tensile strength, modulus elasticity and splitting strength which were 6.8 Mpa, 30 Gpa and 5.8 Mpa respectively at the same ratio. Maximum resistance to harsh environment which was represented by dilute sulphric acid (3%) and nitric acid (5%) were remarkably recoded as improvement of 32% and 37% in the term of mass loss, respectively, relative to conventional one. Other characterization of the new product are thermal conductivity and water permeability were 0.73 W/m.K and 3.65%. This product with these characterization enable us to use it with high reliability in our life.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kirlikovali E. Polymer concrete composites. J. Polymer Engineering & Science. 1981; 21(8):507–509.
2. Bignozzi MC, Saccani A, Sandrolini F. New polymer mortars containing polymeric wastes- part 2: Dynamic mechanical and dielectric behavior. J. Composites A. 2002; 33(2):205–211.
3. Bruni C, Forcellese A, Gabrielli F, Simoncini M. Hard turning of an alloy steel on a machine tool with a polymer concrete bed. Journal of Materials Processing Technology. 2008;202(3):493–499.
4. Bruni C, Forcellese A, Gabrielli F, Simoncini M. Effect of the lubrication-cooling technique. insert technology and machine bed material on the workpart surface finish and tool wear in finish turning of AISI 420B. International Journal of Machine Tools and Manufacture. 2006; 46(12):1547–1554.
5. Cortés F, Castillo G. Comparison between the dynamical properties of polymer concrete and grey cast iron for machine tool applications. J. Materials & Design. 2007;28(5):1461–1466.
6. Orak S. Investigation of vibration damping on polymer concrete with polyester resin. Cement and Concrete Research. 2000;30(2):171–174.
7. Tanabe I, Takada K. Thermal deformation of machine tool structures using resin concrete. JSME International Journal C. 1994;37(2):384–389.
8. Tanabe I. Development of ceramic resin concrete for precision machine tool

structure. JSME International Journal C. 1993;36(4):494-498.

9. Vrtanoski G, Dukovski V. Design of polymer concrete main spindle housing for cnc lathe. In Proceedings of 13th International Scientific Conference on Achievements of Mechanical and Materials Engineering. Gliwice, Poland. 2005;696–698.
10. Berardi VP, Mancusin G. Time-dependent behavior of reinforced polymer concrete columns under eccentric axial loading. Materials Journal. 2012;5:2342-2352.
11. Georgiopoulos P, Evagelia K, Aggelos C. Short-term creep behavior of a biodegradable polymer reinforced with wood-fibers. Composites part B. 2015;80: 134-144.
12. Berardi VP, Mancusi G. A mechanical model for predicting the long term behavior of reinforced polymer concretes. Mechanics Research Communications. 2013;50:1–7.
13. Barros J, Taheri M, Salehian H, Mendes. A design model for fibre reinforced concrete beams pre-stressed with steel and FRP bars. J. Composite Structures. 2012; 3(7):2494-2512.
14. Raman B, Chandra R, Singh SP. Mechanical properties of polymer concrete. Journal of Composites. 2013;51:1-12.
15. Martínez G, Vigueras E, Gencel O, Hagg H E. Polymer concretes: A description and methods for modification and improvement. Journal of Materials Education. 2011;33(1-2):37-52.
16. Tomas U, Ganiron Jr. Influence of polymer fiber on strength of concrete. International Journal of Advanced Science and Technology. 2013;55:53-66.

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