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Experimental study for mechanical properties of concrete incorporating waste materials

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Abstract:
Recently, waste materials have been used in concrete manufacturing in order to get rid of these wastes that cause environmental problems, to reduce solid waste, and reuse it as much as possible. The aim of this research is to study the effect of partial replacement cement by waste materials (glass powder, recycled concrete and granite dust) on mechanical properties of concrete. Concrete specimens includes two partial replacement ratios (10%, 20%) of each type of these waste materials besides control mix (without replacement) were carried out. First, X-Ray Fluorescence (XRF) test for waste materials was performed. Tensile strength, flexural strength, heat resistance, and ultrasonic pulse velocity were performed at 28 days age of concrete specimens while compressive strength was performed at 7, and 28days ages. All specimens were cured by immerse in water until the test ages. Results showed that the highest compressive strength, tensile strength, flexural strength, heat resistance and lowest pulse time were obtained at 28 days age of concrete specimens with 20% recycled concrete to cement replacement ratio. Additionally, the compressive strength, flexural strength, and splitting tensile strength were decreased with the increasing of glass powder, and granite dust to cement replacement ratio at 28 days age.

***Key Word**: Glass powder; Recycled concrete; Granite dust; Mechanical properties; Concrete*

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I. Introduction

Concrete is based on a properly proportioned mixture of hydraulic cement, water, fine and coarse aggregates, and often, chemical, or mineral admixtures. The most important ingredient of concrete is cement but it is the most expensive constituent. During the production of cement, one of the greenhouse gasses namely carbon dioxide is emitted which is responsible for causing globe warming. So, in recent years there has been a search for materials have properties almost like cement characteristic such as fineness and ability to hydrate with water to get concrete hardness. pozzolans are used as cement replacements rather than cement additions preserves the mix proportions[1]. Pozzolans combine with the lime to produce additional calcium silicate hydrate, the material responsible for holding concrete together [2]. Pozzolanic materials are added to clinker during the production stage of cement or to cement for production of concrete [3]. The waste glasses studied could be used as pozzolanic materials. Glass is amorphous and high silica content, which is the primary requirement for a pozzolanic material [4]. In [5] investigated concrete included glass powder as partial replacement of cement. The results demonstrated that the compressive strength decreased with replacement ratios of 10% and 15% and the maximum compressive strength at 28 days achieved at 20% glass powder replacement ratio. Other research illustrated that the early compressive strength enhanced at 15 % replacement ratio but at 28 days' difference in strength reduced and the ideal replacement ratio is at 10 % [6].

In previous study, cement is replaced by marble dust Powder by different percentages of 0%,5%.10% and 20% and the result showed that the compressive strength increased up to 10% marble dust replacement [7]. In [8] noticed that the mechanical properties of concrete enhanced when replacing cement by 5-10% marble dust. Other study used crushed glass, crushed marble as partial replacements for cement on the compressive strength of concrete. The results showed a decrease in the compressive strength of concrete when the replacement ratio was increased from 10% to 30% for each waste material [9]. Granite powder waste materials used to replace sand with 5%, 10%, 15%, and 20% in concrete and the results showed that substitution of 10% of sand by weight with granite powder in concrete increased the compressive and flexural strength [10,11]. On the other hand, the experimental results showed that the substitution of 20 to 50% of cement by granite dust decreased significantly the mechanical properties (compressive strength and tensile strength) of concrete [12].

In this study, waste materials (glass powder, recycled concrete and granite dust) were investigated as a partial material for cement in concrete. Tests were carried out on concrete containing cementitious materials of waste materials with 0, 10, and 20% cement replacement ratios. Hardened concrete properties were examined. The paper proceeds as follows, the experiments for concrete are illustrated. Then, results and discussion in addition to the conclusion are introduced at the end of paper.

II. Material and Methods

Natural sand with fineness modulus and specific gravity of 2.62, and 2.7 respectively was used. Coarse aggregate with nominal maximum size of 25mm and specific gravity of 6.18 was tested. Cement used was ordinary Portland cement (CEM-42.5N). Waste materials (after passing through sieve #200) as shown in Figure 1 were added as a partial replacement of 0%, 10% and 20% by weight of cement. A summary of chemical composition for waste materials is presented in Table1.

Figure 1: Waste materials: *(a). granite dust, (b): recycled concrete, (c): glass powder*

Table 1: Chemical analysis of waste materials

Element	Si	Ca	Ti	Fe	Ni	Te	Ag	K	Mn
Glass powder	19.1	63.2	1.9	3.8	0.02	0.45	1.75	2.5	0.75
Recycled Concrete	1.7	90.8	-	3.9	0.08	0.84	2.5	-	-
Granite dust	43.4	17.7	2.2	21.3	0.13	-	-	9.2	0.25

Study Design:

We have three mixes, the first one was control concrete without replacement of waste materials, two mixes were with 10 and 20% for each waste materials used as partial replacement of cement. Table 2 shows quantities required to produce one-meter cube of concrete.

Table 2: Cement/ waste materials ratios of mixes used for concrete experiments

% Of replacement	Cement (kg/m^3)	Water (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Waste materials (kg/m^3)
0 %	361.1	195	1009.4	779.8	0
10%	325	195	1009.4	779.8	36.1
20%	288.8	195	1009.4	779.8	72.2

Procedure methodology

Four tests were performed as shown in the Figure 2: compression test, indirect tension test, flexural test, and heat resistance test. The compression test was executing at room temperature (20°C - 24°C) according to [13] using cubes 150 x 150 x 150 mm in size. Indirect tension test was proceed using cylinders of 150 mm diameter and 300 mm height. The flexural test was performed at room temperature by loading a simply supported prism beams of size 150 x 150 x 750 mm at their mid-spans according to [14]. For heat resistance test, the residual compressive strength was observed for specimens at elevated temperatures of 400°C according to [15]. Finally, the ultrasonic pulse velocity test was performed to assess the quality of concrete. Compression and flexural tests were performed on different mixes at specimen ages of 7, and 28-days. Heat resistance test was conducted on the same mixes at a specimen age of 28-days. It should be noted that, for all tests performed for concrete specimens, the obtained results represent the average results for three specimens.

Figure 2: *(a):* compression test, *(b): indirect tension test, (c): flexural test*

III. Result and Discussion

Compressive strength

The experimental results of the compressive strength at 7-days and 28-days for concrete specimens without replacement of cement and concrete specimens with replacement of 10%, and 20% of cement with glass powder, recycled concrete, and granite dust are illustrated in Table 3 and Figure 3.

Table 3: Experimental results of the compressive strength

	Compressive strength (MPa)					
% of replacement	0 %		10 %		20 %	
Waste material/ days	7days	28days	7days	28days	7days	28days
Glass powder	18.7	25.2	17.3	24.6	15.6	23.6
Recycled concrete	18.7	25.2	22.0	26.6	24.6	29.4
Granite dust	18.7	25.2	17.0	21.3	14.3	19.1

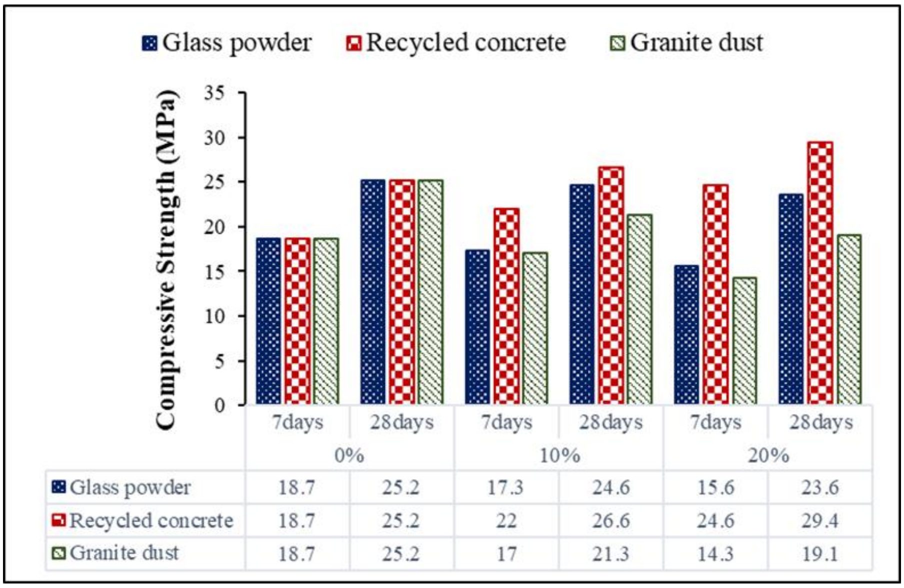

Figure 3: Experimental results of the compressive strength

Figure 3 shows that at 7 and 28 days ages, the concrete included recycled concrete as a partial replacement of cement has the highest compressive strength among different concrete mixtures. At 7 days age, compressive strength increased by 17.6, and 31.5% for 10, and 20% replacement ratios, respectively. Whereas, at 28 days age of specimen, compressive strength increased by 5.5, and 16.6% for 10, and 20% replacement ratios, respectively.

The glass powder has satisfactory results at 10% and 20% replacement, knowing that the compressive strength value was reduced in both percentage of replacement. But the 10% replacement is the closest to compressive strength value for the control specimens at 7 and 28 days ages. At 7 days age, the decrease in compressive strength for 10%. replacement was 7.4% and 16.5% for 20% replacement. Whereas, at 28 days age, the decrease in compressive strength for 10% replacement was 2.4% and 6.3% for 20% replacement. For 10%, and 20% replacement by granite dust, the value of the compressive strength decreased by 9.1%, and 23.5% respectively at 7 days age. While at 28 days age, the decrease in compressive strength for 10% replacement was 15.4% and 24.2% for 20% replacement. Decrease in compressive strength due to the presence of alkaline ions in cement decreases the solubility of calcium ions which retard the Pozzolanic reaction [16].

Tensile strength:
The experimental results of splitting tensile strength at 28-days as a partial replacement of cement with glass powder, recycled concrete, and granite dust are illustrated in Table 4 and Figure 4.

Table 4: Experimental results of the compressive strength

	Tensile strength at 28 days (MPa)		
% of replacement	0 %	10 %	20 %
Glass powder	2.27	2.21	2.10
Recycled concrete	2.27	2.73	3.62
Granite dust	2.27	2.20	1.39

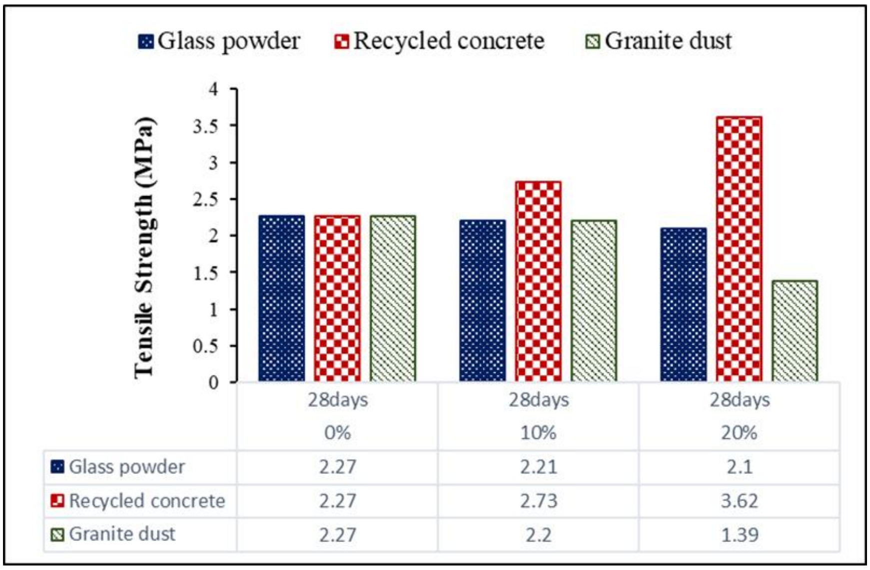

Figure 4: Experimental values of tensile strength

The maximum tensile strength obtained at 20% recycled concrete replacement, which increased by 59.5%. While, at 10% recycled concrete replacement, tensile strength increased by 20.3%. For 10%, and 20% glass powder replacement, the tensile strength reduced by 2.6% and 7.5% respectively. The minimum tensile strength obtained at 20% granite dust replacement, which decreased by 38.7%. While, at 10% granite dust replacement, tensile strength decreased by 3.1%.

Flexural strength
Flexural strengths of concrete for all partial replacement of cement by glass powder, recycled concrete, and granite dust at 28 days age are plotted in Table 5 and Figure 5. It can be seen from Table 5 and Figure 5. that, with increasing of recycled concrete by 10, and 20% replacement ratios, the flexural strength increased by 8.7, and 18.3% at 28 days age, respectively. For 10% of glass powder replacement, the flexural strength increased by 5.6% but for 20% replacement, the flexural strength decreased by15.2%. the flexural strength decreased by 19.7, and 28.2% for 10, and 20% replacement ratios of granite dust, respectively.

The reduction in mechanical properties of concrete (compressive, tensile, flexural strengths) as a result of using 10%, and 20 % of granite dust or glass powder as cement replacement may be due to the reduction in cement content. Whereas the recycled concrete improves the mechanical properties of concrete due to the presence of calcium carbonate $CaCO_3$ in large quantities in its chemical composition.

Table 5: Experimental results of the flexural strength

	Flexural strength at 28 days (MPa)		
% of replacement	0 %	10 %	20 %
Glass powder	3.55	3.75	3.01
Recycled concrete	3.55	3.86	4.2
Granite dust	3.55	2.85	2.55

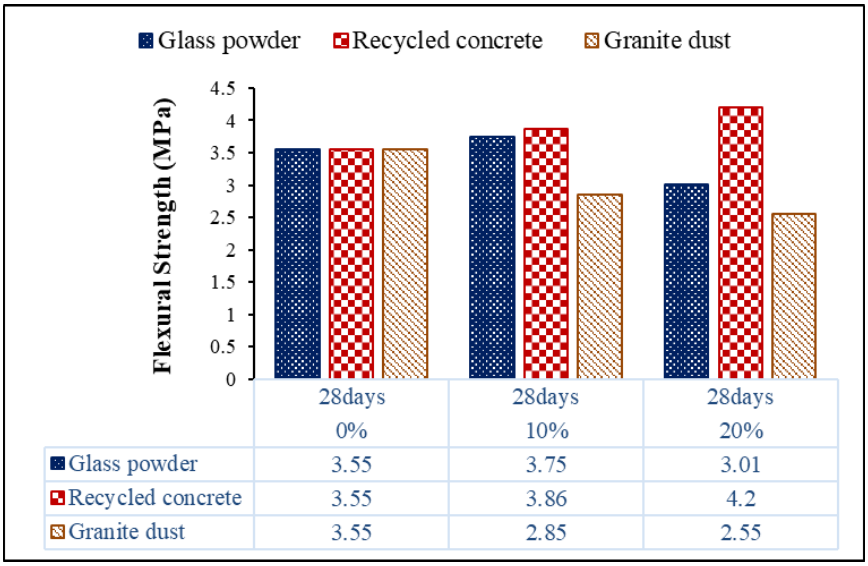

Figure 5: Experimental values of flexural strength

Heat resistance

Table 6 and Figure 6 shows the effect of elevated temperature (800°C) on the compressive strength of concrete specimens with 10, and 20% replacement ratios of glass powder, recycled concrete, and granite dust. It is clear the recycled concrete replacement specimens has heat resistance more than glass powder, and granite dust replacement. Maximum residual compressive strength achieved at 20% recycled concrete replacement. The residual compressive strength increased by 8.3%, and 17.2% for 10%, and 20% replacement by recycled concrete replacement respectively. Whereas the residual compressive strength decreased by 28.1%, 24.9%, 27.5%, and 33.3% for 10%, and 20% replacement by glass powder and granite replacement respectively

Table 6: Experimental results of heat resistance

	Residual compressive strength at 28 days (MPa)		
% of replacement	0 %	10 %	20 %
Glass powder	24.67	17.74	18.53
Recycled concrete	24.67	26.72	28.93
Granite dust	24.67	17.87	16.45

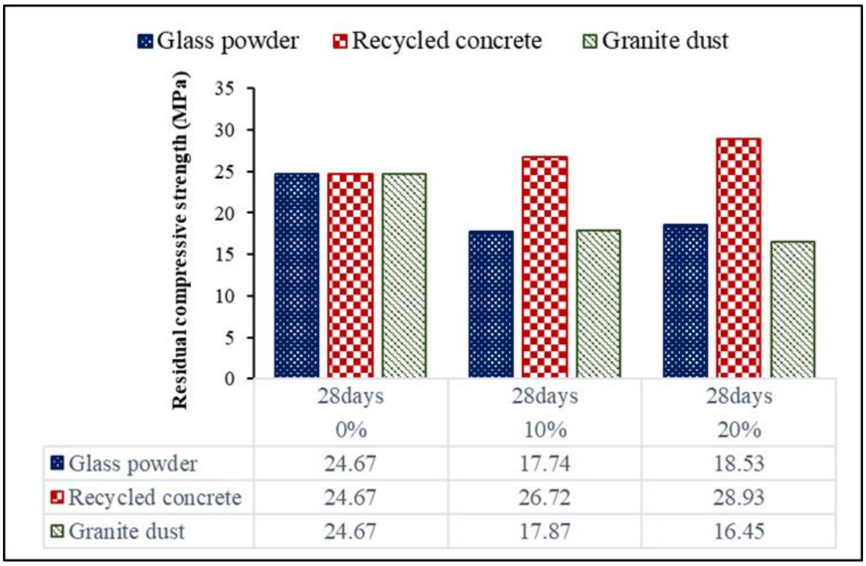

Figure 6: Experimental results of heat resistance

Ultrasonic Pulse Velocity

Table 7 and Figure 7 shows values of time (µs) determined for 28 days age versus glass powder, recycled concrete, and granite dust percentage as cement replacement. the time increased by 10.8, 18.2, 7.4, and 14.7% for 10, and 20% replacement ratios of glass powder and granite dust, respectively. Whereas, pulse time decreased by 8.2, and 10.3 % for 10, and 20% replacement ratios of recycled concrete respectively**.**

Table 7: Experimental results of ultrasonic pulse velocity test

	Time results of ultrasonic at 28 days (µs)		
% of replacement	0 %	10 %	20 %
Glass powder	23.1	25.6	27.3
Recycled concrete	23.1	21.2	20.7
Granite dust	23.1	24.8	26.5

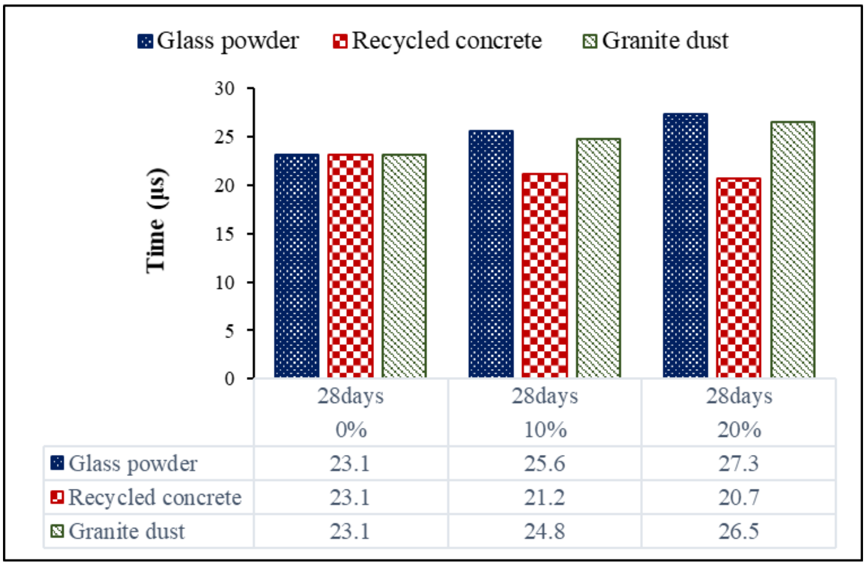

Figure 7: Experimental results of ultrasonic

The velocity was reduced when adding the glass powder to the concrete, so we achieve the lowest porosity by replacement. Minimum velocity achieved at 20% replacement while decrease by 15.4% and by 9.77% at 10% replacement.

IV. Conclusion

This research investigated the influence of substituting cement by 10, and 20% of glass powder, recycled concrete, and granite dust on properties of concrete at 7, and 28 days ages. Based on the experimental results, the concrete specimens with 20 % recycled concrete replacement ratio had the highest value of compressive strength. At 7 days age, the compressive strength increased significantly for 10, and 20% replacement ratios. Whereas, at 28 days age of specimen, the compressive strength increased slightly for both replacement ratios. In addition, the maximum flexural, residual compressive and splitting tensile strengths obtained at 20% recycled concrete replacement. Finally, glass powder, and granite dust have a negative effect on compressive, flexural, and splitting tensile strengths.

References

[1]. K Al-Chaar, G., Alkadi, M., & Asteris, P. G. Natural pozzolan as a partial substitute for cement in concrete. The Open Construction and Building Technology Journal,2013, 7(1).

[2]. Rodrıguez-Camacho, R. E., & Uribe-Afif, R. Importance of using the natural pozzolans on concrete durability. Cement and Concrete Research, 2002, 32(12), 1851-1858.

[3]. Messaoudene, R. Jauberthie, A. Rechache, A. Bounechada, Strength development of ternary blended cement with marble powder and natural pozzolana, Cement Wapno Beton 1, 2015, 32–37.

[4]. Khmiri, A., Samet, B., & Chaabouni, M. Assessment of the waste glass powder pozzolanic activity by different methods. International Journal of Research and Revies in Applied Sciences,2012, 10, 322-328

[5]. Vasudevan, G., & Pillay, S. G. K. Performance of using waste glass powder in concrete as replacement of cement. American Journal of Engineering Research, 2013, 2(12), 175-181.

[6]. Dhanaraj Mohan Patil and Dr. Keshav K. Sangle, "Experimental Investigation of Waste Glass Powder as Partial Replacement of Cement in Concrete", International Journal of Advanced Technology in Civil Engineering, 2013, Volume-2, Issue-1.

[7]. Subramani, T., & Ram, S. S. Experimental Study on Concrete Using Cement with GlassPowder. IOSR Journal of Engineering (IOSRJEN), 2015, Volume, 5(5).

[8]. Arel, H. Ş. Recyclability of waste marble in concrete production. Journal of Cleaner Production, 2016, 131, 179-188.

[9]. Tayeh, B. A. Effects of marble, timber, and glass powder as partial replacements for cement. Journal of Civil Engineering and Construction, 2018, 7(2), 63-71.

[10]. Ghannam, S., Najm, H., & Vasconez, R. Experimental study of concrete made with granite and iron powders as partial replacement of sand. Sustainable Materials and Technologies, 2016, 9, 1-9.

[11]. Kumar, Y. Y., Vardhan, C. V., & Anitha, A. Use of granite waste as partial substitute to cement in concrete. International Journal of Engineering Research and Application,2015, 5(4), 25-31.

[12]. Abukersh S.A, Fairfield C.A, "Recycled aggregate concrete produced with red granite dust as a partial cement replacement," Construction and Building materials, 2011, vol.540/32.

[13]. BS EN 12390-3:2019. Testing hardened concrete. Compressive strength of test specimens

[14]. BS EN 12390-5:2009. Testing hardened concrete. Flexural strength of test specimens

[15]. O. A. Al Bakri, A. M. Kamarudin, H. Nizar, I. K Abdulkareem. Fire resistance evaluation of lightweight geopolymer concrete system exposed to elevated temperatures of 100-800 C. Trans Tech Publications Ltd, 2014, 594, 427-432.

[16]. Gebremariam, A. T., Vahidi, A., Di Maio, F., Moreno-Juez, J., Vegas-Ramiro, I., Łagosz, A., ... & Rem, P. Comprehensive study on the most sustainable concrete design made of recycled concrete, glass and mineral wool from C&D wastes. Construction and Building Materials, 2021, 273, 121697.

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