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Recycled Waste Glass As A Partial Replacement Of sand in glass fiber Reinforce Dconcrete

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Abstract
With increasing environmental pressure to minimize solid wastes and to reuse it as much as possible, concrete making has selected some techniques to fulfill this aim. This job attempts to determine the effects of utilizing waste glass (WG) as a partial substitution of sand on ordinary concrete and also glass fibers (GF) reinforced concrete. The WG was used in concrete mixes as a partial substitution of sand (fine aggregate) at proportions 0, 10, 20, 30, 40, 50, 60, and 80%. Silica fume (SF) was added in concrete mixes as a partial substitution of the cement weight by 10%, and also GF added by1% ratio from the cement weight. In terms of all waste glass substitution ratios, some hardened and fresh concrete properties were evaluated in this research. The tensile strength and compressive strength of ordinary concrete at 20% WG replacement content increased by around 12% and 15%, respectively, related to the reference mixes.
Keywords*: crushed waste glass, compressive strength, silica fume,tensile strength, glass fibers*

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I. Introduction

Production of concrete requires many quantities of natural aggregates. Using the sand as a fine aggregate will lead to the exploitation of ordinary resources. If sand is replaced by a specific dosage of WG, it will decrease sand content and thus reducing the ill effects of sand, so making the concrete industry sustainable **[1].** The volume of WG produced has increased through recent years owing to the growing requirements of glass products. Glass is a transparentsubstance and used in manufactured products as sheet glass and container glass. It is a perfect material for recycling, and its use saves much energy. Glass aggregate is strong but brittle. It has an angular shape and a relatively smooth texture. It is low in shrinkage and water absorption, and it is high in resistance to abrasion. When WG is recycled in the concrete industry, the concrete cost will be decreased. Recycling of WG by transforming it to fine aggregate leads to saving landfill place and reduces the extraction request of natural raw materials for the building sector. One of its valued contributions is concrete production **[2-4].**Moreover, an earlier study has explained that recycled WG may be proper for usage in an extensive range of applications, including concrete, blocks, and road engineering projects **[5-8].**The use of WG causes the interaction between alkalis in cement and the silica in aggregates, which gives silica gel that may be swelled by absorbing water and, so the gel volume increases, this swelling generates internal stresses which introduce cracks. Because of the alkali-silica reaction (ASR), which causes a decrease in durability and also concrete strength, its application is still not common at present time. Studies in the region of WG in construction have confirmed that recycled WG during incorporated in concrete, either powder form or crushed as an aggregate, improved the concrete mechanical strength **[9,10-19].**It was observed a clear enhancement in the compressive strength of WG concrete mixes, but the workability decreased when the amount of WG increased. Also, incorporation of 30% WG powder could be prepared in concrete without any long term effects. It was found that the flexural, compressive, and tensile strengths of WG concrete had a decreasing tendency with increasing WG ratio **[10-19].** Although, some researches have decided that a mix of 10% and a scale of 15%, until 30% of WG included with concrete respectively as a sand [fine aggregates] or cement will possess no damaging result on the indirect tensile and compressive strength respectively **[12,14,17,19-30].** Because of the rarity of researches that studies the influence of using WG as the sand onconcretes containing silica fume and fibers, this work attempts to define this relationship.

II. Materials

In this job, the materials used are cement, sand [fine aggregate], dolomite [coarse aggregate], water, silica fume, glass fibers, and WG. The details of the materials utilized in this project are summarized as follows.

2.1 Cement

The cement used in this work was ordinary cement. The cement utilized in this work was locally sourced and conforming to the Egyptian Standard Specifications **[ESS] 2421/2005 [31].** The cement characteristics were defined by laboratory tests. These tests confirmed the suitability of cement for concrete works. The cement properties in this research are displayed in Table [1] and Table [2].

Table [1] Cement properties

Properties	Results
Soundness (Le Chatelier) [mm]	1.1
Initial setting time [min]	106
Finial setting time [min]	186
Compressive strength[(MPa)] 3days	21.2
Compressive strength[(MPa] 28days	46.5

Table [2] Cement chemical composition

Composition % by mass	% By mass
CaO	64.32
SiO2	21.15
Al2O3	5.79
Fe2O3	3.57
SO3	2.37
MgO	1.51
Loss of ignition	0.89
Insoluble residue	0.35

2.2 Aggregates

The fine aggregate utilized in this job is natural sand. In this job, dolomite of 19 mm maximum grain size is employed as a coarse aggregate. Aggregate properties [coarse and fine] were examined, as stated by the **ESS 1109/2002[32]**. The sand and dolomite characteristics are presented in Table [3].

Table [3] Sandand dolomite properties

Property	Dolomite	Sand
Specific weight	2.60	2.71
Density [t/m3]	1.52	1.72
Water absorption%	0.81	1.3
Value ofimpact %	33.50	-
Abrasion value %	29.20	-

2.3 Waste glass

WG was employed as sand [fine aggregate] in this study. It was brought from a glass factory and pulverized in apparatus of coarse aggregate abrasion [Los Angeles] and, then the sieves analysis test had performed on it. The WG used has a maximum size of 4.75mm. The WG properties are given in Tables [4-5].

Table [4] Waste glass properties

Property	Results
Specific Gravity	2.24
Particle Size	4.75 mm
Water absorption%	0.37
Bulk density (t/m3)	1.45

Table [5] Chemical composition of waste glass

Composition	% by mass
Silica (SiO2)	68.52
Alumina (Al2O3)	1.42
Magnesium oxide (MgO)	4.31
Iron oxide (Fe2O3)	0.31
Sodium oxide (Na2O)	10.75
Calcium oxide (CaO)	9.82
Sulphur trioxide (SO3)	---
Potassium oxide (K2O)	0.1

2.4 Water

In this experimental work, pure, fresh, and clean tap water is free from organic matter was used.

2.5Silica Fume

Silica fume is an industrial product result of thesilica and ferrosilicon alloys production. Table [6] presents the used silica fume properties.

Table [6]Silica fumeproperties

Properties	Item	Properties Item Value
Physical properties	Color	Light gray
	Specific weight	2.1
	Bulk density (kg/m3)	350
	Specific area	16.7
Chemical properties	SiO2	97
	Fe2O3	0.5
	CaO	0.20
	MgO	0.50
	K2O	0.5
	Na2O	0.20
	SO3	0.15
	Cl	0.01
	H2O	0.50
	Al2O3	0.20

2.6 Glass fibers

The glass fibers used were of elastic modulus72 Gpa, and length 12 mm.

2.7Superplasticizer

In this experimental work, Superplasticizer is used to get a steady water-cement ratio =0.5 and constant slump [5-11] cm. In concrete mixes, the superplasticizer is considered a high water decreasing factor. The superplasticizer used was from SIKA Company.

III. Experimental Procedure

3.1. Mixture proportions

In this experimental work, the concrete of water/cement ratio 0.5 was produced. An overall of 24 concrete mixes was made, including the reference mixes. The mixes proportions of sand substitution have been illustrated in Table [7]. The concrete mixing was performed in a mechanical mixer. The mixes were cast in all forms by compacting with a tamping rod. The samples were remolded after one day, cured for 28 days, and then tested. Different tests like compression, splitting tension, and slump, have been performed then the values of all tests were listed.

Table [7]: Concrete Mixes Proportion

Group No.	Mix No.	WG %	WG kg/m^3	SF %	SF kg/m^3	GF %	GF kg/m^3	C kg/m^3	W kg/m^3	D kg/m^3	S kg/m^3	SP kg/m^3
1	1	0	0	0%	0	0%	0	350	175	1261	630	3.5
	2	10	63					350	175	1261	567	3.5
	3	20	126					350	175	1261	504	3.5
	4	30	189					350	175	1261	441	3.5
	5	40	252					350	175	1261	378	3.5
	6	50	315					350	175	1261	315	3.5
	7	60	378					350	175	1261	252	3.5
	8	80	504					350	175	1261	126	3.5
2	9	0	0	10%	35	0%	0	315	175	1261	630	4.55
	10	10	63		35			315	175	1261	567	4.55
	11	20	126		35			315	175	1261	504	4.55
	12	30	189		35			315	175	1261	441	4.55
	13	40	252		35			315	175	1261	378	4.55
	14	50	315		35			315	175	1261	315	4.55
	15	60	378		35			315	175	1261	252	4.55
	16	80	504		35			315	175	1261	126	4.55
	17	0	0				3.5	350	175	1261	630	4.55
	18	10	63				3.5	350	175	1261	567	4.55
	19	20	126				3.5	350	175	1261	504	4.55

3	20	30	189	0%	0	1%	3.5	350	175	1261	441	4.55
	21	40	252				3.5	350	175	1261	378	4.55
	22	50	315				3.5	350	175	1261	315	4.55
	23	60	378				3.5	350	175	1261	252	4.55
	24	80	504				3.5	350	175	1261	126	4.55

WG= waste glass SF= silica fume GF=glass fiber D=dolomite S=sand
SP=superplasticizer C=cement W=water

3.2 Testing of specimens

The slump, dry density, and water absorption tests were accomplished by **BS 12350-2; 2009[33], BS EN-12390-7 (2009)[34],** and **ASTM C642 [35]** respectively, as the compressive and splitting tensile strengths were achieved, according to **ESS, 1658 /2006 [36].** From each concrete mix, 3cubes of size 15cm length and3cylinders [15cm diameter x 30cm depth] were made and tested at 28 days for estimating the values of compressive and splitting tensile strengths, respectively**.**

IV. Results and discussion

4.1. Slump test

The results of the slump tests of the 24 concrete mixes are summarized in Table [8]. It can be remarked from Table [8] that the reused glass mixes slump was higher than of control mixes. This performance attributed to the weaker adherence among the WG aggregates and the cement paste, owing to the smooth surface of WG particles. This result is similar to that of **Kou and Poon [37],** they announced that the slump of ordinary concrete was lower than that of concrete with recycled WG. It can be observed from Table [8] that the higher the slump values at the higher glass substitution ratios, and this may be due to the greater compactness of the concrete granular frame. Because the glass particles are more accurate than the sand, it can fulfill better the voids of the coarse aggregates and possesses a low water absorption and high smooth surface. From figure [1], the slump increased with increasing the WG content for all concrete mixes, and this agrees with a study by **Ali A. Aliabdo et al. [38], t**hey announced that with increasing the mixing ratio of WG, increased the concrete slump. From figure [1], the maximum slump values were at an 80% ratio replacement. The existence of SF and GF in concrete mixes reduced the slump values.

Table [8] Slump results

WG ratio %	**Slump cm**		
	Group 1 ordinary	**Group 2 10%SF**	**Group 3 1%GF**
0%	6.2	6	5.2
10%	6.8	6.4	5.5
20%	7	6.7	5.9
30%	7.4	7.1	6.4
40%	7.8	7.5	7
50%	8.2	8	7.5
60%	9	8.7	8
80%	9.8	9	8.4

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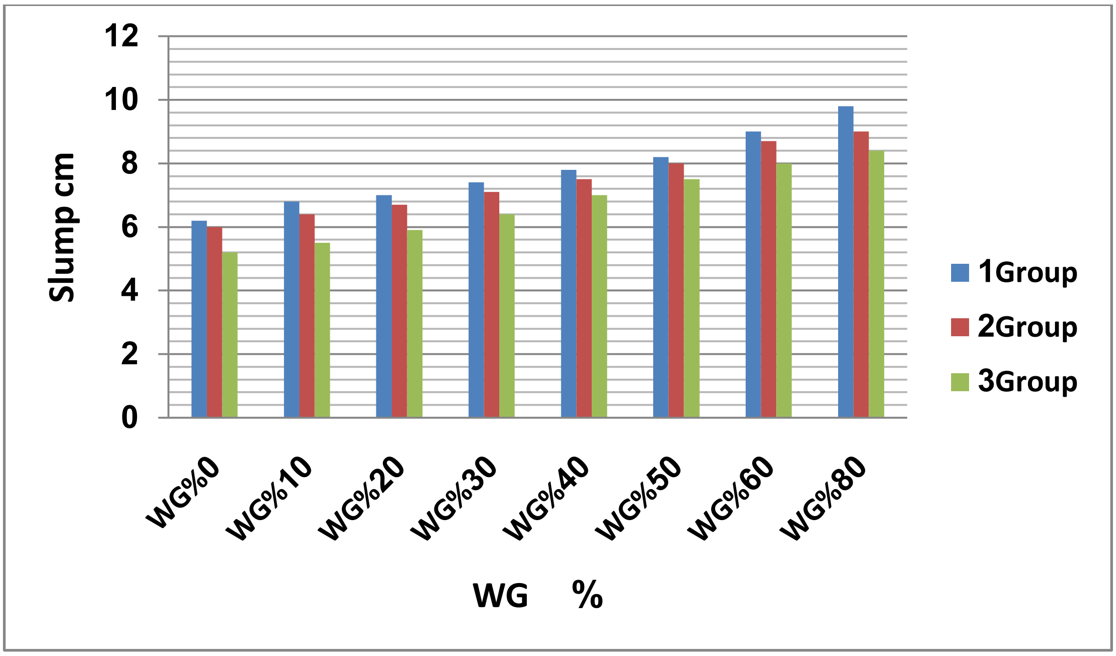

Figure [1] Values of the slump [cm]

4.2.Dry density test

Table [9] shows the dry density test values of all WG concrete mixes. The decreasing ratios in dry densities of specimens made of 10%, 20%, 30%, 40% ,50%, 60%,and 80% WG are [1.24%,2.15%,2.7%,3.73%,4.48%,5.23%, and 7.1%],[1.25%, 2.16%,2.58%,3.75%,4.45%, 5.29%,and 7.28%], and [0.45%,0.99%,1.94%,2.80%,3.17%, 3.71% , and 4.37%] for groups 1,2, and 3 respectively compared to control mixes [0%WG].From figure [2], it was realized that the densitydecreased with increasing the WG content for all concrete mixes. The decrease in the dry density of the WG concrete mixes can be attributed to the WG specific gravity, which is about 14.8% lesser than that of the sand **[39].** Similar results were informed by **Topcu and Canbaz[40].** They verify the conclusion that the unit weight of concrete with WG is lesser than that without waste glass. The presence of SF as partial substitution of cement reduced the density of concretes [group 2] slightly owing to the reduction of its unit weight compared to the cement. But the presence of glass fibers increased the density of concretes [group 3] because the glass fibers were as adding not replacement.

Table [9] Dry density results

WG ratio %	Dry density kg/m^3 and the %of decreasing					
	Group 1 ordinary		Group 2 10%SF		Group 3 1%GF	
0%	2410	control	2402	control	2428	control
10%	2380	1.24%	2372	1.25%	2417	0.45%
20%	2358	2.15%	2350	2.16%	2404	0.99%
30%	2345	2.70%	2340	2.58%	2381	1.94%
40%	2320	3.73%	2312	3.75%	2360	2.80%
50%	2302	4.48%	2295	4.45%	2351	3.17%
60%	2284	5.23%	2275	5.29%	2338	3.71%
80%	2239	7.1%	2227	7.28%	2322	4.37%

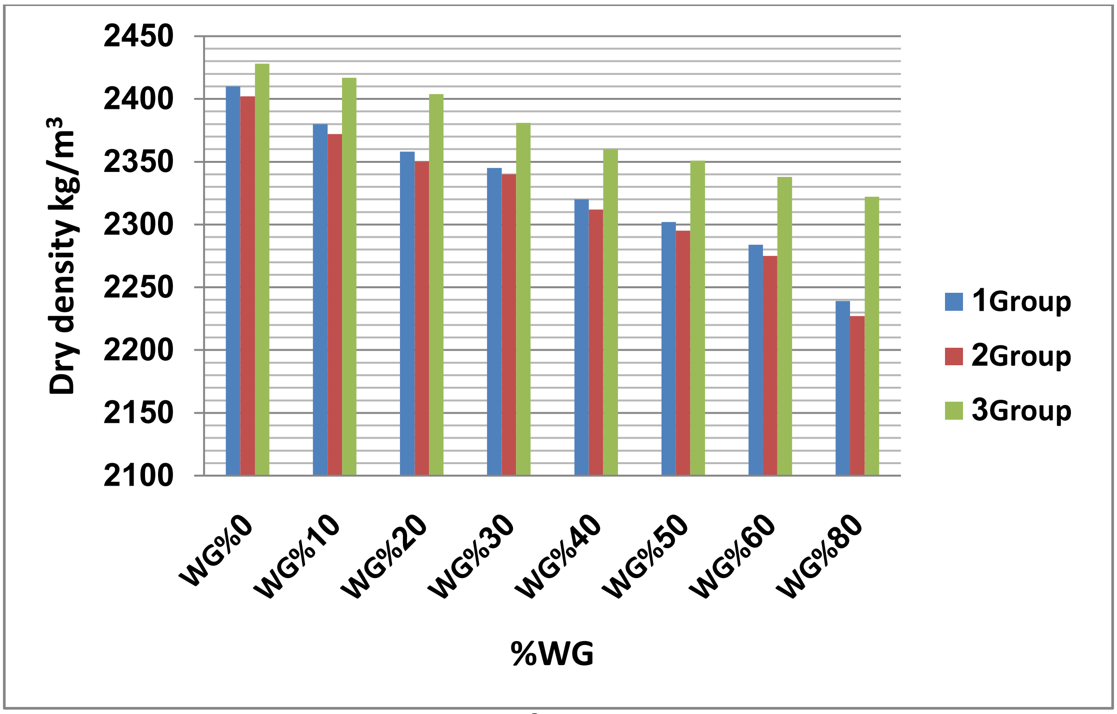

Figure [2] Values of the dry density [kg/m^3]

4.3. Water absorption test

One of the general significant points that relate to concrete durability is water absorption. For co-operation lifetime prediction and long-term performance of concrete, the water absorption test should be studied deeply**. Liu [41]** assumes that water absorption phenomena can be one of the most primary agents for predicting the deterioration of concrete exposed to freezing and thawing cycling and carbonation. Table [10] represents the level of absorption ratio for all mixes. Figure [3] shows that the percentage of water absorption decreased with WG content increase for all groups, and this is maybe because the glass water absorption percentage is about zero. The same results were stated by **MuzamilLiaqat et al [42], as** they verified that the WG concrete water absorption ratio is lower than of concrete without WG, also reported that with increasing WG aggregate ratio, the concrete water absorption ratio decreased. In this study, the lowest value of the water absorption ratio of all concrete mixes was reported at 80% WG ratio. Also, it can be noticed from Table [10] and Figure [3] that the existence of silica fume [group 2] reduced the water absorption ratio for all WG replacement ratios, and this may be due to its accurate particles which full the tiny voids in the concrete. But the existence of glass fibers [group 3] increased the water absorption ratio for all WG replacement ratios, and this may be owing to the formation of balling phenomena that increased the voids in concrete.

Table [10] Water absorption results

WG ratio %	%Water absorption		
	Group 1 ordinary	**Group 2 10%SF**	**Group 3 1%GF**
0%	1.85	1.8	2.01
10%	1.62	1.6	1.78
20%	1.45	1.4	1.65
30%	1.15	1.1	1.35
40%	1.02	0.97	1.22
50%	0.87	0.85	1.03
60%	0.69	0.62	0.81
80%	0.44	0.39	0.52

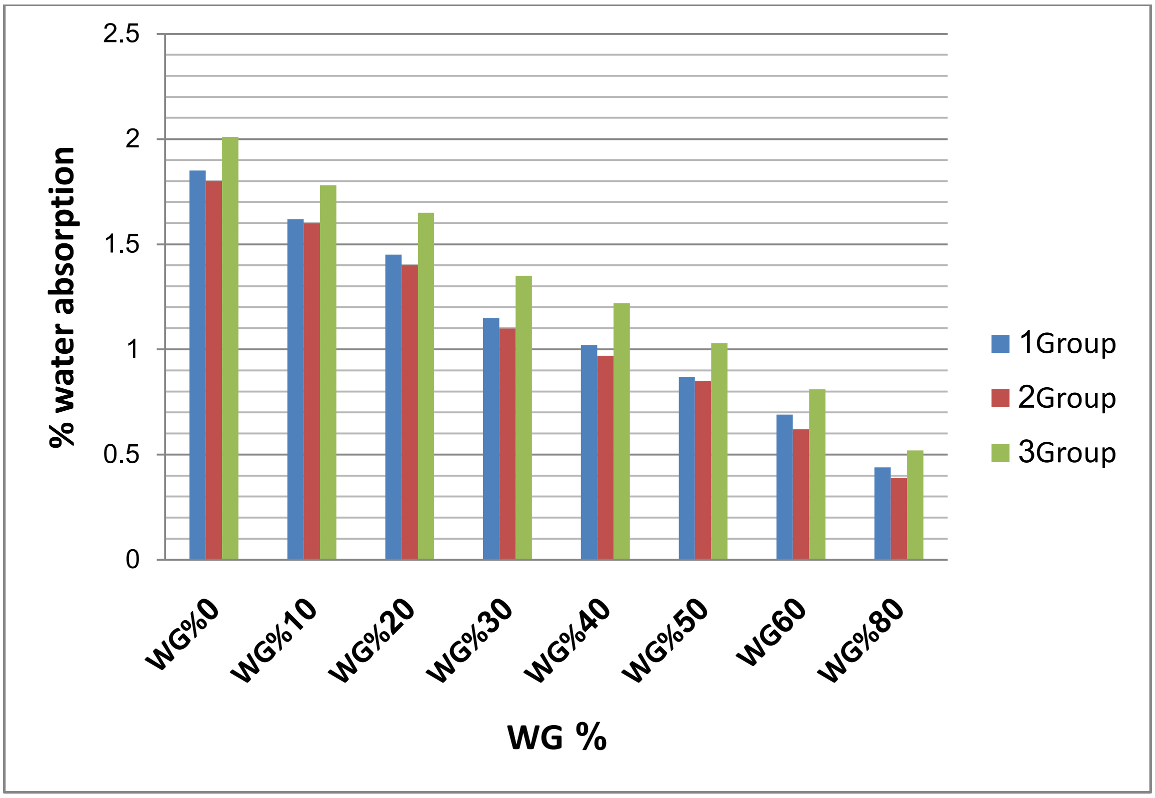

Figure [3] Values of water absorption

4.4Compressive strength

The test result values of the compressive strength of the control, recycled glass, silica fume, and glass fiber concrete mixes at 28 days are summarized in Table [11]. Each assignedvalue is the average of three measurements. It is apparent from Table [11] that the utilizationof recycled glass waste as a sand replacement until a 30% replacement ratio increases the compressive strength of the all-concrete mixes comparedto the control mixes. As presented in Table [11], the increase in 28 days compressive strength were [6.72%, 8.77%, 10.23%, 11.46%, 13.65%],[6.72%, 8.77%, 10.23%, 11.46%, 13.65%],and [6.72%, 8.77%, 10.23%, 11.46%, 13.65%] respectively. Also, it can be noticed from Figure [4] that as the WG content increases from 30% to 80%, the compressive strength decreased gradually, and The lessening of concrete compressive strength was [about 18%] at 80% ratio relatedto the control mixes. The same results were stated by Olomo Rachael.O. et al (2019) [43]. They announced that with increasing WG fine aggregate ratio until 20%, the concrete compressive strength improved then after, this value the compressive strength of concrete decreased.The existence of SF [group 2] and glass fibers [group 3] increased the compressive strength at all WG replacement ratios compared to group1 [ordinary concrete], as displayed in Figure [4].

Table [11] Compressive strength [Mpa] of concrete

WG ratio %	Compressive strength [Mpa]		
	Group 1 ordinary	Group 2 10%SF	Group 3 1%GF
0%	27.41	29.94	30.5
10%	29.08	32.53	32.52
20%	30.29	33.88	34.85
30%	31.8	34.16	35.21
40%	28.04	32.75	33.49
50%	24.83	27.91	29.18
60%	22.01	24.91	27.46
80%	21.03	24.06	25.14

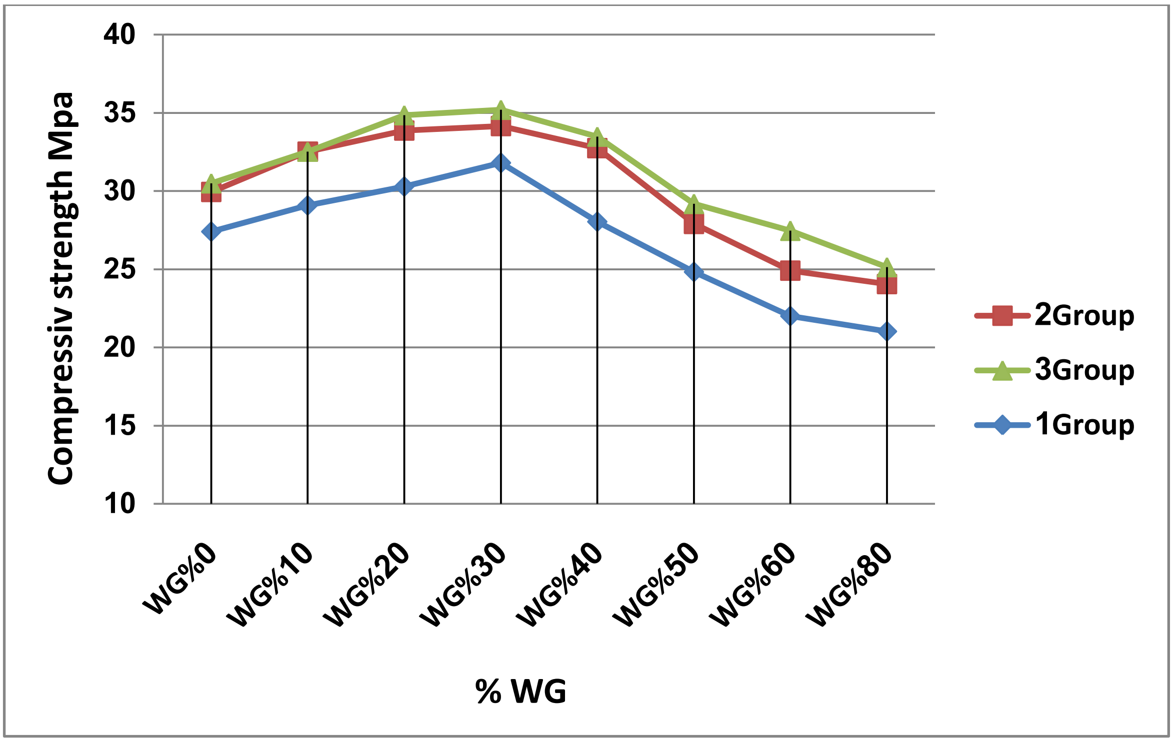

Figure [4] Variation of Compressive strength [[MPa]]

4.4Splitting tensile strength

The tensile strength test results of the control, recycled glass, silica fume, and glass fiber concrete mixes at 28 days are summarized in Table [12]. Each given value is the average of three measurements. It is evident from Table [12] that the utilization of recycled glass waste as a sand replacement until a 30% replacement ratio increases the tensilestrength of the all-concrete mixes related to the control mixes. The increase in 28 days tensile strength were [6.72%, 8.77%, 10.23%, 11.46%, 13.65%] ,[6.72%, 8.77%, 10.23%, 11.46%, 13.65%],and [6.72%, 8.77%, 10.23%, 11.46%, 13.65%] respectivelyrelated to the control mixes. Also, it can be noticed from Figure [5] that as the WG content increases from 30% to 80%, the tensile strength decreased gradually, and The reduction of concrete tensile strength was [about 18%] at 80% ratio compared with the control mixes. The same results were stated by **Olomo Rachael.O. et al (2019) [43].** They reported that with increasing WG fine aggregate ratio until 20%, the concrete tensile strength increased then after, this value the tensile strength of concrete decreased. The presence of SF [group 2] and glass fibers [group 3] increased the tensile strength at all WG replacement ratios compared to group1 [ordinary concrete], as shown in Figure [5].

Table [12] Splitting tensile strength [Mpa]of concrete

WG ratio %	Tensile strength [Mpa]		
	Group 1 ordinary	Group 2 10%SF	Group 3 1%GF
0%	1.85	2.02	2.18
10%	1.97	2.21	2.38
20%	2.18	2.37	2.53
30%	2.47	2.60	2.72
40%	1.99	2.46	2.58
50%	1.68	1.95	2.52
60%	1.55	1.85	2.32
80%	1.48	1.72	2.12

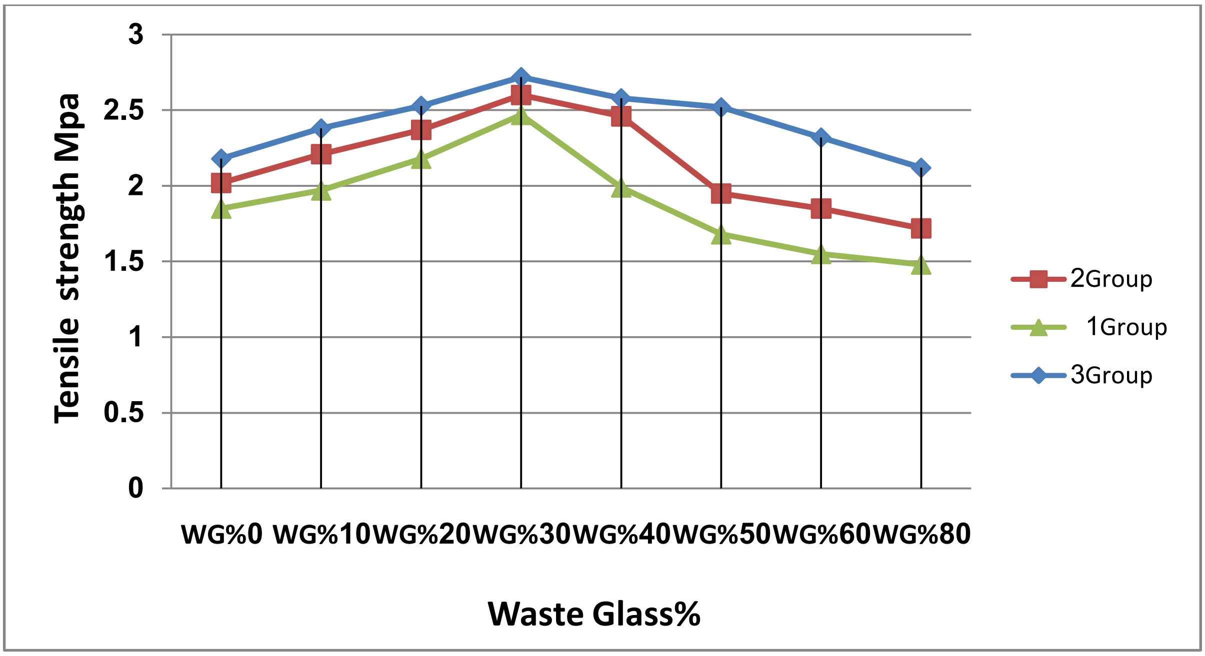

Figure [5] Variation of tensile strength [MPa]

V. Conclusion

1- When the sandwas replaced by the WG, the compressive and split tensile strengths of all concrete mixesincreased until 30% replacement.
2- For 30% substitution of sand by the crushed waste glass, the increase of compressive and split tensile strengthscompared to reference mixes is obvious.
3- When the cement was replaced, by 10% silica fume, compressive strength and tensile strength increased for all percentage of waste glass replacement.
4- The presence of GF, as adding, increased compressive and tensile strengths of concrete for all percentage of waste glass substitution.
5. Utility of WG in concrete can confirm to be cost-effective when it is not beneficial to waste and free of cost.
6. Utility of WG in concrete will eliminate the disposal problem of WG and verify to be environment friendly, thus paving the way for greener concrete.
7. Utilization of WG in concrete as partial substitution of sand will preserve natural resources and make the concrete construction industry sustainable.

There is no conflict of interest

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