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Partial Replacement of Coarse Aggregate with Waste Glass in Concrete Production

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Abstract: *A modern lifestyle, alongside the advancement of technology has led to an increase in the amount and type of waste being generated, leading to a waste disposal crisis. This study tackles the problem of the waste that is generated from construction fields, such as demolished concrete, glass, and plastic. In order to dispose of or at least reduce the accumulation of certain kinds of waste, it has been suggested to reuse some of these waste materials to substitute a percentage of the primary materials used in the ordinary Portland cement (OPC) concrete.*
The waste materials considered to be recycled in this study is flat glass (Aluminium window). Glass was used to replace up to 35% of coarse aggregates in concrete mixes. To evaluate these replacements on the properties of the OPC mixes, a number of laboratory tests were carried out. These tests included particle size distribution test on fine aggregate, aggregate impact value test, workability and compressive strength. The main findings of this investigation revealed that the waste material could be reused successfully as partial substitutes for coarse aggregates in concrete production and the optimum strength of the concrete was observed at 25% of waste glass against 75% of granite for coarse aggregate, whereby the compressive strength of the concrete cube at 28 days of curing is 15.78N/mm^2
Keywords: *Waste glass, coarse aggregates, Fine aggregate, workability, aggregate impact value, Compressive strength.*

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I. Introduction

Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas.

However, approximately 20% of the building construction waste consists of glass, plastic, and concrete. Therefore, introducing another means of disposal by recycling is nationally required. Large quantities of this waste cannot be eliminated. However, the environmental impact can be reduced by making more sustainable use of this waste. This is known as the ''Waste Hierarchy''. Its aim is to reduce, reuse, or recycle waste, the latter being the preferred option of waste disposal.

Researches into new and innovative uses of waste materials are continuously advancing. These research efforts try to match society's need for safe and economic disposal of waste materials. The use of recycled aggregates saves natural resources and dumping spaces, and helps to maintain a clean environment. It is well known that addition of these wastes in concrete as

a supplement of cement generally reduces the construction cost and more or less maintains the properties of concrete. In addition, waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications (Parviz, 2012)

This current study concentrates on those waste materials, specifically glass waste to be used as substitutes for conventional materials, mainly coarse aggregates, in ordinary Portland cement concrete (OPC) mixes. Recycling concrete as aggregate offers a solution to the problems encountered with the quarrying of natural aggregates and the disposal of old concrete. As these substitutes require extensive studies about their effect on the properties of concrete, a number of research studies were performed. The use of plastic materials and glass in a number of civil engineering applications has been investigated through a large number of research studies. These have been conducted to examine the possibility of using plastics and glass in various civil engineering projects in the construction field (Caijun, 2017, Serniabat et al,2014, Tamanna et al, 2013, Shayan et al., 2004,Chanbane et al, 1999, Rindl, 1998).

This study focuses on the use of waste glass as partial replacement for coarse aggregate in concrete production. Waste glass is some of the waste product that cause hazard and waste disposal problems as they are non-decaying waste. So it will be of great help and solution to the problem of disposing these wastes if they can be actually recycled and use for construction purpose, which is going to serve economic improvement and sanitary purposes by reducing the amount of environmental pollution caused by these wastes.

Towards this end, experiments were carried out in the laboratory which includes particle size distribution test on fine aggregate, aggregate impact value test, workability and compressive strength.

II. Methodology

2.1 Material used

The materials (fine aggregates, coarse aggregate, cement and water) used for this research were locally sourced. Ordinary Portland cement (OPC) conforming to British standard code BS 12 and graded river sand was used. The waste glasses and granite as coarse aggregate were obtained from the waste glasses dumping ground of an aluminum window/door fabricating company within Ede town and rock quarry along Ara road, Osun state respectively. The waste glasses were crushed into smaller sizes of an average of 19mm and 12mm manually and with the use of hard wooden rod in an enclosed area . The granite used is also of varying sizes of 19 and 12 mm diameters.

2.2 Mix proportions and casting of concrete cubes

The batching of the materials was done by weight. The mix proportions used were 1:2:4 and water-cement ratio of 0.5 was maintained for all mixes. The equivalent weights of the materials were: Cement (64.80kg), Fine aggregates (129.60kg), Coarse aggregates (259.201kg) and water (35.63kg), the summary of the material used, mixed proportion for each mix and description of the mixes are shown in table 2.1, 2.2 and 2.3. Concrete cube with 0% of waste glass serve as control experiment.

The combination of waste glass and granite were used as coarse aggregate at 0%, 10%, 15%, 20%, 25%, 30% and 35% . The mixing was done on a dry, clean and hard surface. The fresh mixture was cast in cube moulds of size 150mm x 150mm x 150mm in two layers and each layer was tamped for 25 times. Immediately after the casting, the concrete cubes were covered with a polyethylene sheet for 24 hours to avoid escape of moisture. For each of the mix proportions, two concrete cubes were cast and therefore, a total of fifty-six (56) cubes were produced for testing. At the end of 24 hours, the concrete cubes were removed from the moulds and later kept in storage curing tank measuring 2.0m x 6.0m filled with tap water only for periods of 7, 14, 21 and 28 days respectively.

Table1: Summary of Materials Used

Quantities	Cement	Fine Agg.(kg)	Coarse Agg.(kg)	Water(kg)
Per m^3 of Concrete	64.80	129.60	259.201	35.63

Table 2: Summary of Mix Proportions for Each Mix

Mix No	Mix ID	Water(kg)	Cement(kg)	F.A(kg)	Waste glass(kg)	Granite(kg)	W/C
1	M	5.09	9.257	18.51	-	37.027	0.5
2	I	5.09	9.257	18.51	3.703	33.326	0.5
3	G	5.09	9.257	18.51	5.554	31.474	0.5
4	F	5.09	9.257	18.51	7.406	29.623	0.5
5	2	5.09	9.257	18.51	9.257	27.771	0.5
6	N	5.09	9.257	18.51	11.109	25.920	0.5
7	M	5.09	9.257	18.51	13.015	24.012	0.5

Table 3: Description of Mixes

Mix NO	Mix ID	Description
1	M	0% waste glass
2	I	10% waste glass & 90% granite
3	G	15% waste glass & 85% granite
4	F	20% waste glass & 80% granite
5	2	25% waste glass& 75% granite
6	N	30% waste glass & 70% granite
7	M	35% waste glass & 75% granite

2.3.Testing

2.3.1 Aggregate Impact Value Test for Crushed Granite and waste glass

Aggregate impact value test was done on both the crushed granite and waste glass to check the toughness of the coarse aggregate to resist their disintegration due to impact. The aggregate impact is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

2.3.2 Slump test

Slump test was carried out on fresh concrete to determine the workability of the concrete as shown in Fig 4. The measured slump must be within a set range, or tolerance, from the target slump. Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It can also be defined as the relative plasticity of freshly mixed concrete as indicative of its workability.

2.3.3 Compressive strength of Concrete

The compressive strengths of the concrete cubes were determined after 7, 14, 21 and 28 days of moist curing by testing two concrete cubes from each mix.

III. Results and Discussion

3.1 Aggregate Impact Value Test for Crushed Granite and waste glass

Table 4 shows the impact values of both waste glass and granite as 33.85 and 30.42 respectively, which fall between the ranges of 30-35, whereby the classification for this range is satisfactory for use according to BS 812-112: 1992. Therefore, both aggregates are satisfactory for use as coarse aggregate for concrete

Table 4: Aggregate Impact Value Test for Crushed Granite and waste glass

Net weight of sample in the mould(g)		**Weight of sample retained on 2.36mm IS sieve**		**Weight of sample that passed through 2.36mm IS sieve**		**Impact value(%)**		**Average**	
C.G	C.W	C.G	C.W	C.G	C.W	C.G	C.W	C.G	C.W
306.10	306.10	213.30	205.20	92.80	100.9	30.31	32.96	30.42	33.85
305.50	305.50	215.40	210.30	90.10	95.80	29.49	31.36		
295.60	295.60	202.60	195.50	93.00	110.06	31.46	37.23		

C.G- Crushed granite   C.W- Crushed waste glass

3.2 Slump Test

From Table 5, the slump value of the wet concrete decreased with increasing percentage content of the waste glass which is in line with the work of Awogboro et al (2016) and was deduced from the research that this was due to angular edged grain size of coarse waste glass, This implies that increased waste glass replacement for coarse aggregate reduces the workability

Table 5: Slump Test Result

Sample identification with mix ratio 1:2:4	Height of cone (mm)	Height of concrete (mm)	Slump value (mm)	Type of slump	Degree of workability
M	300	210	67.00	SS	High
I	300	214	60.00	TS	High
G	300	220	55.00	TS	High
F	300	225	52.00	TS	High
2	300	228	46.00	TS	Medium
N	300	233	40.00	TS	Medium
M	300	240	37.00	TS	Medium

TS = True Slump   SS = Shear Slump

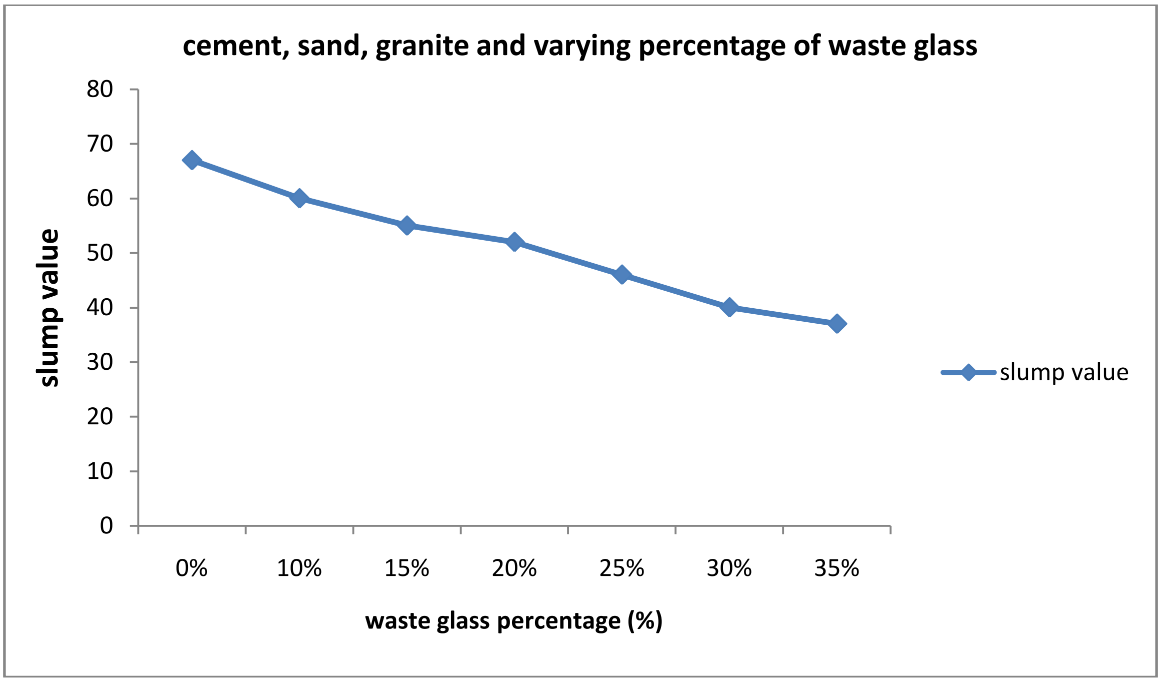

Figure1: Slump Test

3.3Compressive strength

The compressive strength of concrete with varying percentages of coarse aggregate increased as the age of curing increased, whereby the highest compressive strength throughout the varying percentages of coarse aggregate was observed at the 28days of curing.

The results also indicated that the compressive strength of concrete for any curing period increased with increase waste glass content up to25% as having the highest compressive strength values of 11.89. 13.56, 15.00, 15.76 (N/mm^2) for 7, 17, 21, 28 days respectively and reduced appreciablyfrom 25% - 35%. The 35% waste glass content had the lowest compressive strength values of 9.22,11.00, 13.11 and 13.56 (N/mm^2) for 7, 14, 21, 28 days respectivelycompared to other percentages. This is contrary to the previous findings that the compressive strength of the specimen reduced with increased waste glass content for all the curing period examined, (Iqbalet al, 2013 and Awogboro et al, 2016). This implies that the best effect on the mechanical properties of the concrete was observed at 25% replacement of coarse aggregate with waste glass and this is contrary to previous findings that 10% waste glass as coarse aggregate content in concrete are comparable to control specimen having similar compressive strength values and therefore be used for structural concretes, (Awogboro et al, 2016).

Table 6: Summary of the Compressive Strength Test Result for all Percentage of Waste Glass Replacement for Various Age of Curing

Percentage of waste glass / Granite constituent in concrete	Compressive strength(N/mm²) with increasing age of curing			
	7days	14days	21days	28days
M	10.23	11.67	13.11	14.11
I	10.67	12.22	13.67	14.45
G	11.00	12.67	14.00	14.67
F	11.23	13.11	14.67	15.45
2	11.89	13.56	15.00	15.76
N	9.56	11.34	13.45	14.33
M	9.22	11.00	13.11	13.56

Compressive strength (N/mm²) = $\frac{crushimg\ \ load\ \ (N)}{surface\ \ Area\,(mm^2)}$

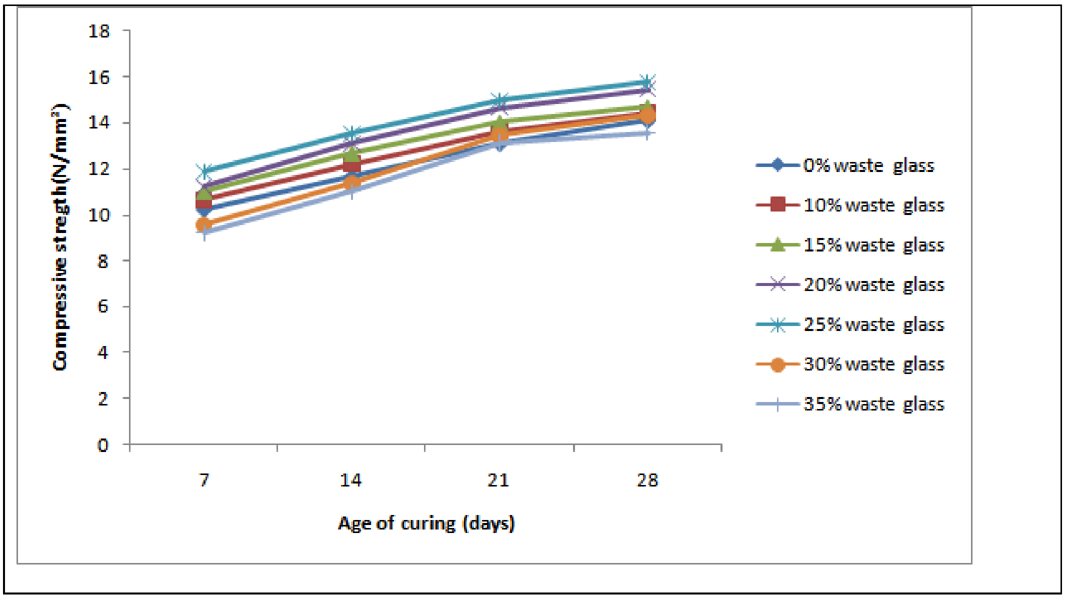

Figure 2: Summary of Compressive Strength Test Result

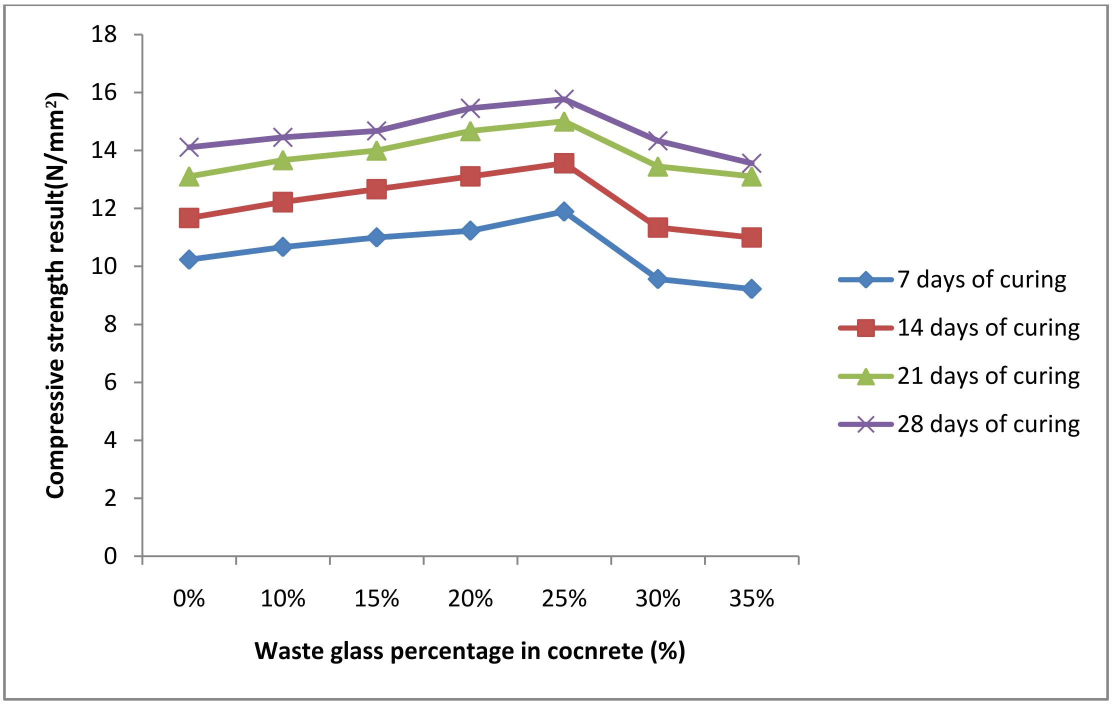

Figure 3: Summary of Compressive Strength Test Result

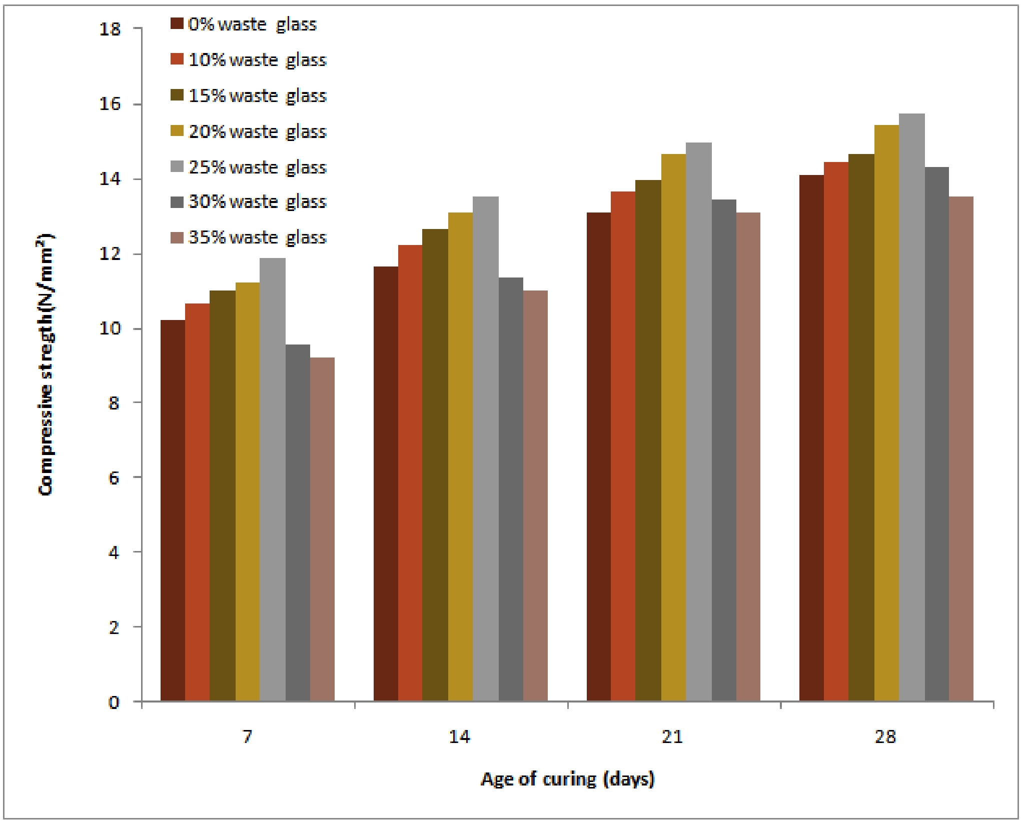

Figure 4: Histogram for the Summary of Compressive strength test result

IV. Conclusion

Waste glass was used as a partial replacement of coarse aggregate, and from the observation gotten from the results of various experimental works carried out, the following conclusions were drawn.

1. The impact values of both waste glass and granite are 33.85 and 30.42 respectively, which falls between the ranges of 30-35 whereby the classification for this range is satisfactory for use. Therefore, both aggregates are satisfactory for use as coarse aggregate for concrete.
2. The slump of the wet concrete decreased with increasing percentage content of the waste glass as partial replacement for coarse aggregate, which was deduced from research that this was due to angular edged grain size of coarse waste glass.
3. The best effect on the mechanical properties of the concrete was observed at 25% replacement of coarse aggregate with waste glass. Whereby the compressive strength of the concrete at 28days of curing for this percentage was 15.78N/mm²
4. The result obtained from this study help to draw the general conclusion that, using recycled waste glass as a partial replacement of coarse aggregate in concrete production gives a dual economical effect. That is, it helps to get rid of accumulated quantities of waste glass in our environment and at the same time, enhances the mechanical properties of concrete.

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