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Strength and Durability Assessment of Low Water Absorption Glasscrete Blocks for Zero-Spalling Effect in Buildings

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Abstract: Glass waste produced around the world is disposed of carefreely, creating huge piles in landfills and increasing environmental pollution because it is non-biodegradable. This study was conducted to assess the strength and durability of waste glass as a partial replacement for a mortal mix of sharp sand and stone dust. The glasscrete block samples were produced in a 6" metal block mould with 0%, 25% and 50% partial replacement of stone dust and sharp sand respectively. The compressive strength and water absorption tests were conducted after the samples were cured for 7, 28 and 56 days in a laboratory. The highest compressive strengths of 102.333kN and 100.667kN were observed in 50% waste glass partial replacement with sharp sand and 50% waste glass combination with 25% sharp sand and 25% stone dust respectively. The least compressive strength was seen in the control samples of sand and stone dust with no replacement of waste glass. This shows that the addition of waste glass increased the compressive strength of the block samples. The least rate of water absorption was recorded in 50% waste glass, 25% sharp sand and 25% stone dust. It should be noted that the replacement of the waste glass with stone dust performed poorly unlike that of sharp sand. Therefore, it is recommended that 50% waste glass, 25% sharp sand and 25% stone dust should be adopted for the production of glasscrete blocks for a zero-spalling effect in buildings with varying mix ratios. Glasscrete blocks can therefore be used in the waterlogged environment and areas prone to the spalling condition.

Keywords: *Spalling, Glasscrete Blocks, Sustainability, Durability, Construction, Civil Engineering.*

I. INTRODUCTION

Far back in the 18th century, the concept of glass being used as a major constituent in concrete blocks has not yet been idealized. Concrete blocks (consisting of cement, sand and water) were of high importance as they became a suitable alternative to fired clay bricks. Glass was only seen in building construction as a prominent element in the world of aesthetics because of its vitreous glazing appearance and illumination potential at night [1]–[3]. An in-depth investigation regarding the relationship between glass and concrete was undertaken in the year 1904 to explore the possible usefulness of glass in building construction [4]. Joachim, a French architect, building the first cupola of concrete and glass prompted Fredrick Keppler in 1907 to apply for a grant of ownership for the concept of solid glass blocks of 4 to 6.5cm to be fitted at support structures of reinforced concrete. This led to the development of hollow glass blocks for vertical structures which were concluded to be more advantageous in terms of noise and thermal isolation in comparison to solid blocks[5]. Subsequent years later, the advancement of glass instigated prominent researchers in the study of glass for paving stones as well as the partial replacement for fine aggregates, hence the name Glasscrete[6]. The success of this research recognizes glass aggregate as a formidable substitute. Despite the explorative progression of glasscrete over concrete, the issue of spalling for glasscrete blocks in buildings was left undiscussed.

According to [7], spalling is defined as those fragments or pieces or chips of concrete, brick or limestone which gradually come off over time. This defect occurs as the concrete is subject to corrosion, biological weathering and most especially, excess moisture that usually occurs through leakages in conduit pipes. Not only because spalling give an unsightly appearance on walls and paints, but it also causes structural damage if left untreated. Much research has been done on the introduction of various alternative materials in concrete for various positives on its properties but none has looked into the possibility of glass solving the problem of spalling in sandcrete blocks [8]–[15]. In this study, the water absorption property of glass is of significant interest in achieving the no-spalling effect of glasscrete blocks in building construction. Glasscrete blocks are masonry units (usually precast), consisting of cement and waste glass used as both fine and coarse aggregates with admixtures. These stated constituents are thoroughly mixed with water as its binder in the appropriate mix ratios [16]. Glasscrete materials are highly recognized for pavement and interlocking structures, but can also be used for both interior and exterior wall construction [17]. According to [18], solid and hollow blocks are the conventional classification of blocks. Therefore, the above classes can also be made with glasscrete materials. These categories of blocks are either produced by hand or by concrete mixer [19]. [20] reported that the shape and size of blocks can be determined by the moulds used. According to the Nigeria Industrial Standard, the moulds used for block production are fabricated using the millimetre or inches metric system of measurement. [21] proposed the sizes of blocks as 450mm x 225mm x 100mm, 450mm x 225mm x 150mm and 450mm x 225mm x 225mm. Remnants of glass materials produced around the world are usually creating huge piles on landfills [22]. Glass waste as a non-biodegradable material has contributed immensely to environmental pollution. Many researchers [23], [24] studied the productive use of waste glass. These investigations yielded positive results as waste glasses could be used as aggregates in concrete block production.

II MATERIALS AND METHODS

The waste glass was cleaned with water to remove residue, dirt and other contamination, before grinding into powdered form as a replacement for sharp sand and stone dust. A 9" metal block mould (450mm x 225mm x 150mm) was used in the production of the glasscrete block with mix ratios as presented in Table 1.

Table 1. Mass of Aggregates and their Mix Proportions

Sample ID	Waste Glass (%)	Sharp sand (%)	Stone Dust (%)
$WG_0SS_{100}SD_0$	0	100	0
$WG_{25}SS_{75}SD_0$	25	75	0
$WG_{50}SS_{50}SD_0$	50	50	0
$WG_0SS_0SD_{100}$	0	0	100
$WG_{25}SS_0SD_{75}$	25	0	75
$WG_{50}SS_0SD_{50}$	50	0	50
$WG_{50}SS_{25}SD_{25}$	50	25	25

The water-cement ratio of 0.8 was used and seven (7) comparisons were carried out during production varying the quantity of Fine aggregate (Sharp sand and Stone Dust) with blocks produced for each variation as shown in Table 2. Three (3) categories of variations concerning the quantity of waste glass were done, which are 0% waste glass, 25% waste glass and 50% waste glass. Batching of materials was done properly. All blocks were placed on cellophane bags and cured for 7, 28 and 56 days using the water sprinkling method.

Table 2. Description of Block Sets and their Groupings

Mix	Waste Glass (*Kg*)	Sharp Sand (*Kg*)	Stone Dust (Kg)	Cement (*Kg*)	Water – Cement Ratio (Kg)
$WG_0SS_{100}SD_0$	0	213.88	-	32.91	29.62
$WG_{25}SS_{75}SD_0$	55.55	160.42	-	32.91	29.62
$WG_{50}SS_{50}SD_0$	111.09	106.95	-	32.91	29.62
$WG_0SS_0SD_{100}$	0	-	230.34	32.91	29.62
$WG_{25}SS_0SD_{75}$	55.55	-	172.76	32.91	29.62
$WG_{50}SS_0SD_{50}$	111.09	-	115.17	32.91	29.62
$WG_{50}SS_{25}SD_{25}$	111.09	53.47	57.59	32.91	29.62

III RESULT AND DISCUSSIONS

Compressive Strength

Table 3 reveals the average compressive strength of each block against their curing periods. The curing periods were directly proportional to the compressive strength of the blocks. The 50% glass content glasscrete blocks gave the highest strength compared to 25% and 0%. Samples made from sharp sand on average showed better strength compared to samples made from stone dust. The $WG_{50}SS_{50}SD_0$ the sample gave the highest compressive strength of 102.333kN/m^2 in all. In all, it is observed that an increase in the quantity of waste glass increases the strength of the blocks. Therefore, it is safe to say that there is a faster rate of strength development for block sets with the increased replacement of crushed glass and a slower, sometimes reduction in strength for block sets with higher replacement of stone dust as compared to the controlled sets. It can be seen that a concrete mix of waste glass, sharp sand and stone dust produces a higher compressive strength.

Table 3 Compressive Strength Test Result of Block Sets at different curing ages.

Sample ID	7 Days (KN)	28 Days (KN)	56 Days (KN)
$WG_0SS_{100}SD_0$	67.333	80.000	84.333
$WG_{25}SS_{75}SD_0$	76.333	97.000	97.333
$WG_{50}SS_{50}SD_0$	71.000	86.333	102.333
$WG_0SS_0SD_{100}$	73.333	78.333	93.000
$WG_{25}SS_0SD_{75}$	72.667	83.000	85.667
$WG_{50}SS_0SD_{50}$	69.667	78.667	93.000
$WG_{50}SS_{25}SD_{25}$	78.333	90.333	100.667

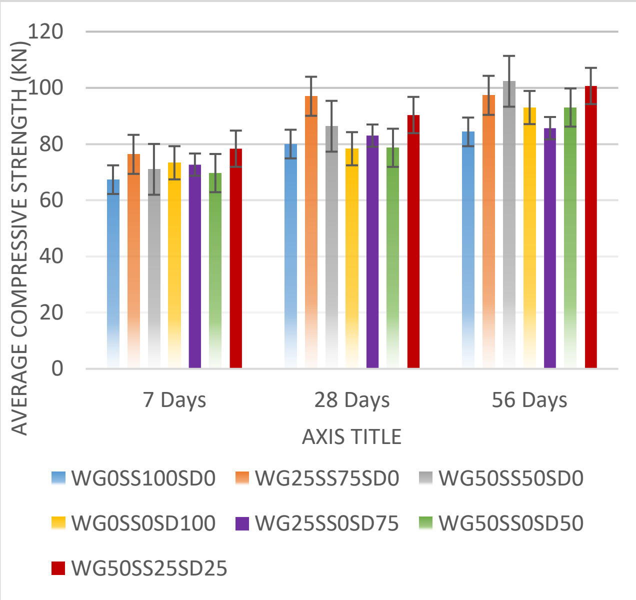

Figure 1. Compressive Strength of Block sets against different curing days

Water Absorption

The trend observes a reduction in water absorption rate with the introduction of waste glass to the mix. Samples with waste glass and sharp sand gave better water absorption properties compared to samples with stone dust. Though the block sets with partial replacement of crushed glass correspond to an improvement in water absorption rate, a 25% replacement of waste glass against 75% replacement of sharp sand and 50% replacement of waste glass against 25% each of sharp sand and stone dust both displayed consistent significant performance. The most favourable is the combination of waste glass, stone dust and sharp sand in different percentages as it improves water absorption greatly.

Table 2. Water Absorption for block sets at different times

Sample ID	2Hrs	4Hrs	6Hrs	24Hrs
$WG_0SS_{100}SD_0$	0.744	1.250	1.786	2.381
$WG_{25}SS_{75}SD_0$	0.236	0.377	0.472	0.472
$WG_{50}SS_{50}SD_0$	0.550	0.750	0.750	0.850
$WG_0SS_0SD_{100}$	0.246	0.590	0.688	0.737
$WG_{25}SS_0SD_{75}$	0.198	0.198	0.396	0.644
$WG_{50}SS_0SD_{50}$	0.749	0.891	1.238	1.840
$WG_{50}SS_{25}SD_{25}$	0.049	0.099	0.296	0.485

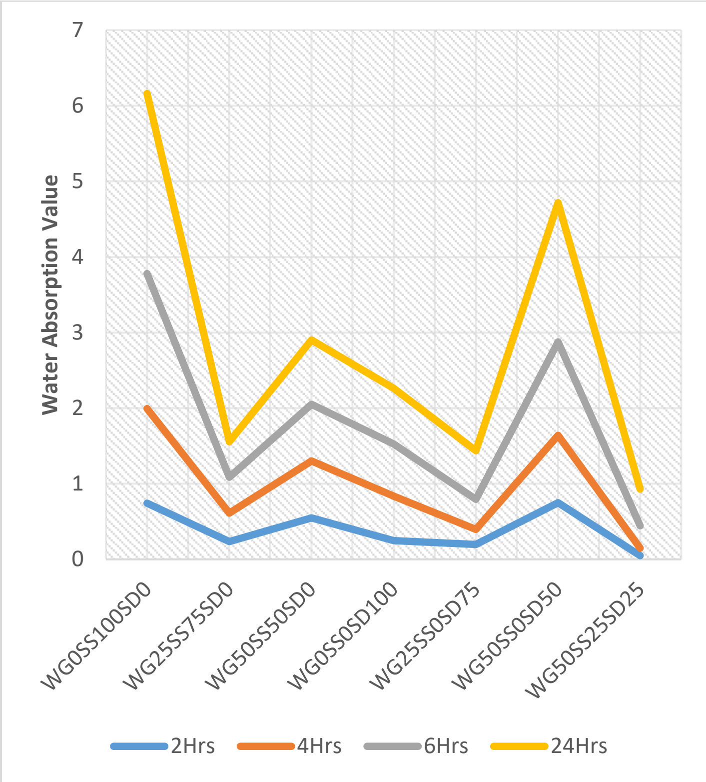

Figure 2: Water Absorption values of glasscrete blocks

IV CONCLUSION

This research was executed to determine the strength and zero-spalling effect of blocks containing crushed waste glass. From all the collated results, the conclusions drawn are:

- An increase in crushed waste glass content corresponds to an increase in the compressive strength of glasscrete blocks for a water-cement ratio of 0.8 compared to the conventional sandcrete blocks.
- A water-cement ratio of 0.8 displays a better performance of water absorption for 25% replacement of the crushed glass with stone dust or sharp sand.
- A mix of waste glass and sharp sand only produces higher compressive strength and better water absorption than Waste glass – Stone dust mix.
- Glasscrete blocks can be used in a waterlogged environment.
- Recycling waste glass into aggregates reduces environmental pollution, thus saving landfill space.
- The replacement of waste glass in concrete between 10% - 30% should be researched for further detailed analysis.

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