

Research Article

Effects of Waste Glass Powder as Pozzolanic Material in Saw Dust Cement Brick

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Abstract: This work examines the possibility of using Waste Glass Powder (WGP) as a partial replacement of cement in saw dust composite brick to assess its pozzolanic activity and its effect on the properties of the composite. WGP was used to partially replace cement at 0%, 5%, 10%, 15%, 20%, 25%, and 30% in the production of test samples of 100x100x100mm at binder sand mixing ratio of 1:6. After casting the cubes, they were tested for compressive strength, water absorption, capillary water absorption and volume porosity. The results indicated that WGP can be used as cement replacement material up to 30% at particle size less than 100µm to prevent alkali silica reaction and this can be utilized in the manufacture of non-load bearing sandcrete block without any unfavourable effect. The study further revealed that waste glass, if ground finer than 100µm shows a pozzolanic behaviour because it reacts with lime at early stage of hydration forming extra CSH gel thereby forming denser cement matrix. The early consumption of alkalis by glass particles mitigate alkali-silica reaction by increasing durability of composite brick which is manifested in the result of volume porosity, water absorption, capillary absorption as well as in the results of sample densities.

Keywords: Waste Glass Powder (WGP), Cement, Saw dust, Compressive Strength.

INTRODUCTION

The rapid urbanisation is creating a shortfall of conventional building construction materials due to limited availability of natural resources. On the other hand energy consumed for the production of conventional building construction materials pollutes air, water and land. In order to meet the ever increasing demand for the energy efficient building construction materials there is a need to adopt cost effective, environmentally appropriate technologies and upgrade traditional techniques with available local materials. Million of tonnes of controlled waste from household, commercial and industrial are disposed of in landfill sites in the most developing and developed countries causing a rise in landfill costs and environmental problems. Recycling of construction waste helps saving the landfill space and save waste disposal costs. The energy required to reuse the recyclable material is less than that of virgin materials [1]. The waste glass constitutes a problem for solid waste disposal in several municipalities. The current practice is still to landfill most of the non-recyclable glass. Since glass is a nonbiodegradable material, these landfills do not constitute an environmental solution [2]. Glass is a common product that can be found in different forms: bottles, jars, windows and windshields, bulbs, cathode ray tubes, etc. These products have a limited lifetime and must be recycled in order to avoid environmental

problems related to their stockpiling or land filling. Several recycling channels already exist for glass recovery [3]. A lot of researches have been conducted on the use of glass powder as pozzolans for construction purposes, Ahmad and Aimin [4] investigated the performance of GLP in concrete under field conditions, a field trial was conducted using a 40 MPa concrete mixture, incorporating various proportions of GLP (0%, 20%, and 30%) as cement replacement, the result showed a satisfactory performance of the glass powder in concrete. Ankur and Randheer [5] compared its performance with other pozzolanic materials like silica fume and fly ash, they observed that waste glass when ground finer than 100µm shows a pozzolanic behaviour and forms a denser cement matrix after mixing homogeneously. On the other hand, another material is sawdust which also constitute an environmental challenge when disposed in landfills has found use in the construction industry. Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes [6]. Obam [7] developed a composite ceiling board by converting saw-dust, waste paper and starch into its production. Ettu *et al.* [8] investigated the compressive strength of blended cement sandcrete containing rice husk ash with (RHA) and sawdust ash (SDA), their observation showed that that very high sandcrete strength values could be obtained with OPC-

RHA-SDA ternary blended cement with richer mixes, high quality control, and longer days of hydration. Usman *et al.* [9] experimented with sawdust and palm kernel shell as possible substitutes for fine and coarse aggregate in concrete and stated that water absorption capacity in both sawdust and palm kernel shells would need to be modified in order to improve its compressive strength and durability. Hence the need to investigate the effect of Waste Glass Powder on the property of Cement- Waste Glass Powder bonded Composites and the feasibility of producing Cement bonded Sawdust Hollow Blocks for non load bearing wall.

MATERIALS AND METHODS

Fresh Ordinary Portland Cement of 43% grade conforming to IS: 269 1976 was used in this research work and it was purchased from Bodija market, Ibadan, Oyo state. Sawdust was collected at University of Ibadan saw mill (Plate 1). The sawdust particles were between 2.5-3.5 mm in diameter. Prior to brick

formation, particles were soaked in water for 24 hours to reduce the amount of water-soluble sugars and tannins and were finally air-dried to approximately 5% moisture content. The sand used was clean, sharp river sand free from clay and silt gotten from river behind Nnamdi Azikwe Male Hostel, University of Ibadan. The waste glasses (11kg) were collected from dump sites at Independence Hall, University of Ibadan which comprised of broken louvre panes (Plate 2). After cleaning, they were first hammer milled at Mechanical Department of Faculty of Technology, University of Ibadan to reduce their sizes (10.5kg) for ease of grinding (Plate 3), and were finally grounded to powder of particle size less than 100microns with 9.5kg of glass powder recovered at Bodija Market, Ibadan. Water is an essential ingredient of concrete as it help in the chemical reaction between all other composite compositions (hydration of cement). The water used was potable, fresh, colourless, odourless and tasteless water that is free from organic matter of any type.



Plate 1: Sawdust



Plate 2: Broken Glasses



Plate 3: Glass Powder

Sawdust-Cement Composite particles were mixed with cement by mass for seven different mixing ratios and six replicate for each. The mixtures were placed in a forming mould of 50 mm x 50 mm x 50 mm and pressed to provide the required compaction. The specimens were cured under shade at room temperature for 28 days after removal from the mould for complete setting of the cement before testing (Plate 4). A nominal mix of concrete proportion 1:6 was adopted for the production of the samples for Sand Cement Composite with Partial replacement of Cement with Waste Glass Powder (WGP) (Plate 5) and a total number of six partial replacements of cement were used to produce test samples with cement composition at 100% serving as control sample. A standard mould of

100mmX100mmX100mm was used in casting cubes with 15 replicate for each mix proportion. Batching of the composite composition was by mass. Cement and the river sand were mixed to homogenous mix. Water was then added gradually and mixed with shovel to give a homogenous workable paste at Water-Cement ratio of 0.5. The moulds were (the moulds lubricated and allowed to dry before used for ease of removal of cubes) now filled, rammmed and vibrated to remove air spaces in the form work. The cast were demoulded after 24 hours and cured in water. For the subsequent sets of cubes that had various ratio of WGP and Cement, the above procedure follows except that river sand and cement were first mixed and the WGP was then added and the whole composition were mixed to homogeneity.



Plate 4: Test samples



Plate 5: WGP-Sawdust brick

Testing of Samples

Compressive Strength of Sand Cement/WGP Pozzollan Composite brick was done after crushing at 7, 14, 21, and 28th day at Civil Engineering Department Laboratory, Faculty of Technology, University of Ibadan with their Compressive Strength Testing Machine. Density of the bricks was calculated from mass and volume of the bricks which is mass per unit volume in kg/m³. The capillary absorption coefficient (k) was calculated using the formula:

$$n = \frac{Q}{A} * \sqrt{t}$$

where Q= amount of water absorbed, A = cross sectional area in contact with water , t = time (seconds).

The Volume Porosity was determined by direct measurement of the weight gained on saturation with water of initially dry samples after evacuation to remove air from the pore network. The water absorption was then converted to volume porosity by using the following relationship:

$$n = \frac{WA * D}{100 * w}$$

where n=volume fraction porosity, D=dry sample density(kg/m³), WA=water absorption(%).

RESULTS AND DISCUSSION

Compressive Strength

Variation of Compressive Strength with increasing Replacement of Cement with WGP

From Fig. 1, it could be seen that the Compressive Strength reduced with respect to increasing percentage of Waste Glass Powder in each of the test samples with sample G having a minimum value of 2.3N/mm². But with this, the minimum value of 2.3N/mm² for 30% replacement level is found suitable for building construction having attained a 28-day compressive strength which is more than 2.0N/mm² required by the Nigeria National Building Code (2006) for non-load bearing walls.

Variation of Compressive Strength with Curing Day

Fig. 2 shows that samples of composites having 100% cement composition(sample A) has attained almost the peak of their compressive strength at the end of the 14th day of curing, while samples B,C,D,E,F and G with partial replacement of cement with WGP have gradually increased with an increasing number of curing days. This may be due to the silicious an aluminous nature of the WGP compound in a finely divided form reacting with Calcium hydroxide to form highly stable, cementitious substances of complex composition involving Calcium, Silica and Water. The pozzolanic reaction is slow and thus, the production of heat of hydration and development of Strength is also low which explains the gradual increase in strength. This continued strength development clearly indicates the beneficial pozzolanic relation of WGP in composites.

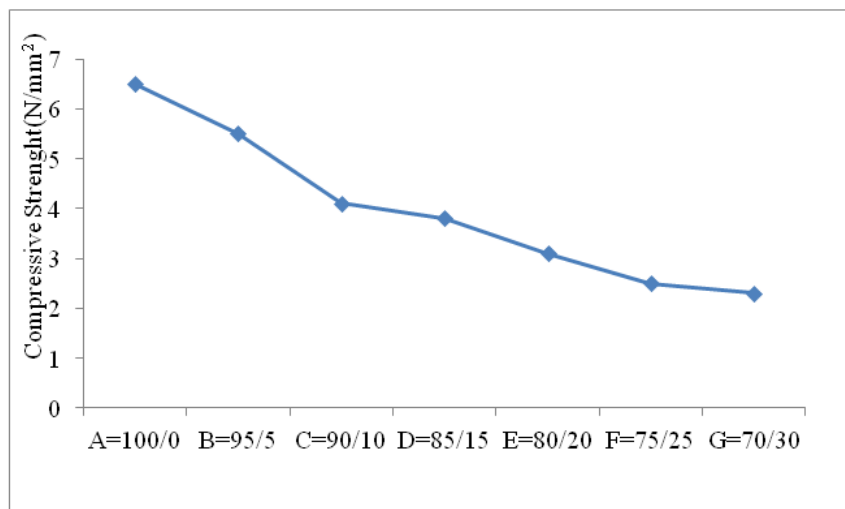


Fig. 1: Effect of WGP on Compressive Strength

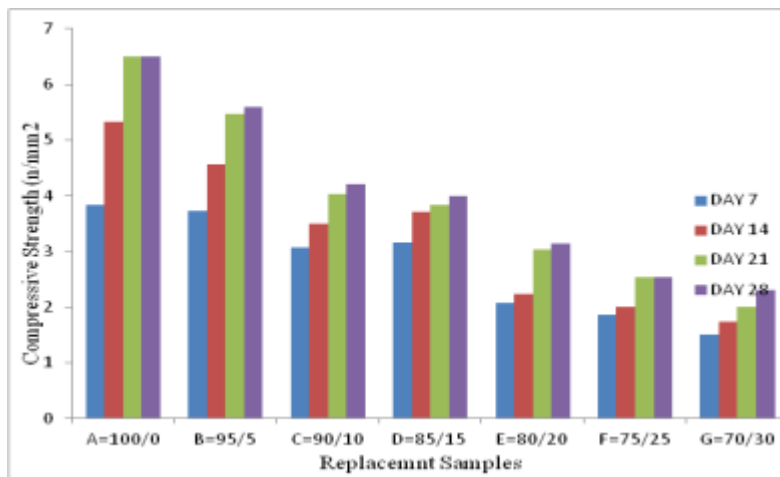


Fig. 2: Effect of Curing Day on the Compressive of Cement/WGP Composite

Capillary Water Absorption

The capillary absorption reduces due to addition of WGP because they act like fillers and the pozzolanic reactions form extra gel which makes cement matrix denser (Fig. 3). The reaction involves the consumption of Ca(OH)_3 and thus there is no production of Ca(OH)_3 . The reduction of Ca(OH)_3

increases the durability of cement paste by making the cement paste dense and impervious. Therefore, k value is lowest for sample G because of its 70%/30% cement to WGP replacement. Sample A has highest k value probably due to bond failure because of alkali-silica reaction as a result of its 100% cement composition.

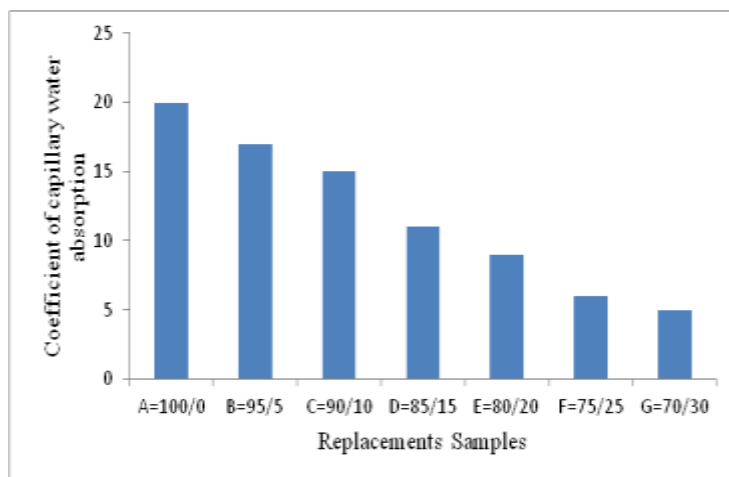


Fig. 3: Coefficient of capillary water absorption for Cement/WGP Composite

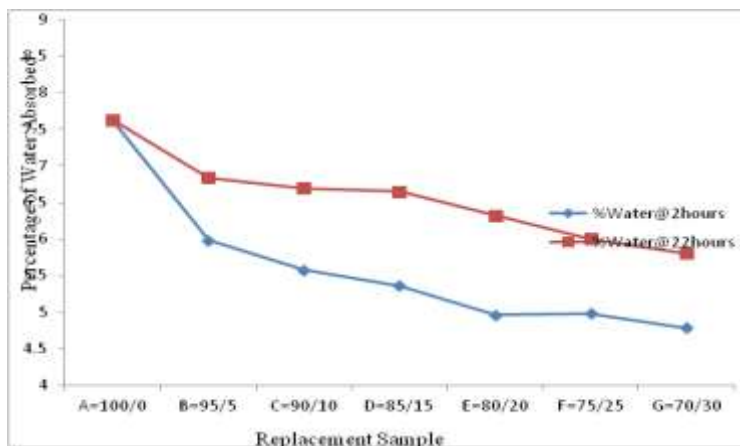


Fig. 4: Water Absorption Test of Cement/WGP Composite

Water Absorption

Sample A without WGP has the highest values of water absorption with little or no difference in the 2hours and the later 2hours. Although, samples B,C,D,E,F and G have low water absorption (Fig. 4) , there are significant differences in their initial and final water absorption. Water absorption of composite is an important factor in classifying its durability. Generally, composites of low water absorption will afford better protection to reinforcement within it. However the values obtained from this study suggest the performance seems to depend on the form and fineness of the waste-glass powder used.

Effect of WGP on Density

There is a significant relationship between density and the degree of Cement replacement with Waste Glass Powder and a noticeable difference in the average density of sample A (which serve as control sample i.e 100% Cement/0% WGP) when compared with all other samples with certain percentage of WGP (Fig. 5). This could be attributed to the dense texture developed as a result of better particle parking during curing.

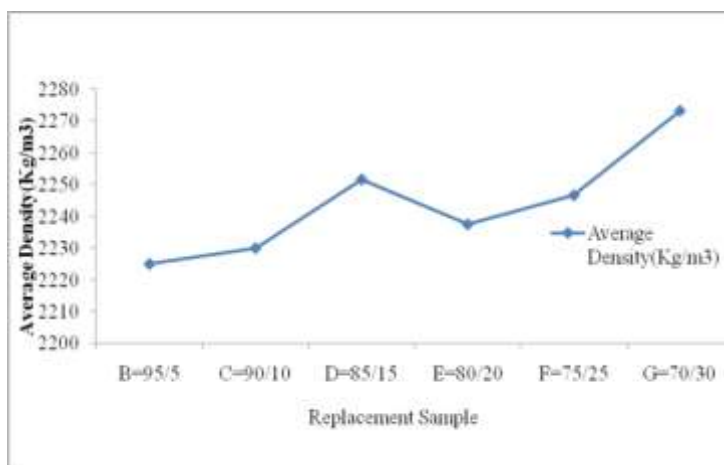


Fig. 5: Relationship between Density and the Quantity of WGP in the Composite

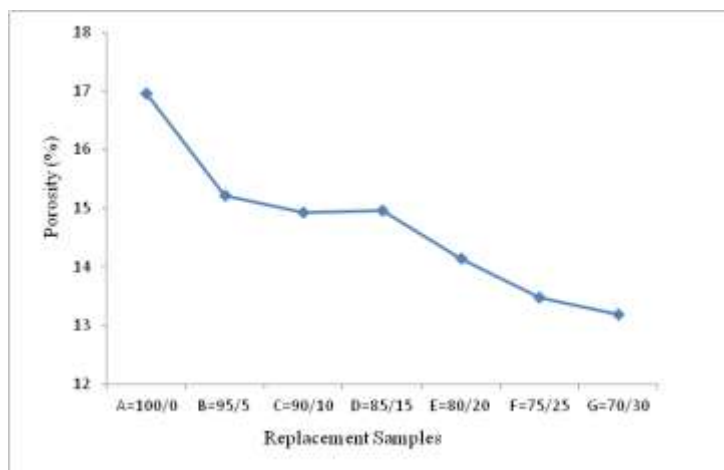


Fig. 6: Effect of WGP replacement of Cement on Porosity

Volume Porosity

The porosity of Cement/WGP composite samples decreased with increasing Cement replacement with Waste Glass Powder (Figure 6). Sample G has a minimum porosity of approximately 13% which is low volume porosity as established by Keralli [10] who stated that materials with volume porosity above 30% are considered to be of high porosity. The low porosity was explained by Al Khadimi *et al.* [11] who showed that re-alkalization actually improved the properties of composite, reducing porosity and permeability,

increasing strength and modulus and not apparently causing any difficulties.

CONCLUSION

On addition of WGP the initial strength was low but at 28th day it met required design strength. Hence, 30% of waste glass powder of size less than 100µm could be included as cement replacement in mortal mix of binder sand ratio of 1:6 in the production of non-load bearing sandcrete hollow blocks without any unfavourable effect.

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