
Production of Steel Fibre Reinforced Concrete Using Waste Glass Powder as Partial Replacement for Cement

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ABSTRACT

Waste glass is one of the wastes generated in the environment and because it is a non-biodegradable material, it tends to pollute the environment. As a result, the reduction of this waste becomes imperative. The thrust of this paper is to utilize waste glass as partial replacement for concrete in the production of steel fiber reinforced concrete. In this research, waste glass was used to replace cement at 0%, 10%, 20%, 30% and 40% respectively to produce a grade 20 concrete using 1:2:4 mix ratio. A total of 15 cubes of 100 x 100 x 100 mm and 15 concrete beams of 750 x 150 mm were casted and subjected to compressive strength, flexural test and scanning electron microscopy (SEM) after 28 days curing period. The result showed that concrete cubes with 0%, 10%, 20%, 30% and 40% had compressive strength of 20 N/mm², 17 N/mm², 14 N/mm², 11 N/mm² and 9 N/mm² respectively. The flexural strength for the steel fiber reinforced concrete beam with the same percentage replacement of waste glass are 1.16 N/mm², 0.93 N/mm², 0.71 N/mm², 0.78 N/mm² and 0.62 N/mm² respectively. For the SEM, only the 0% replacement had complete hydration reaction. From the results, 10% cement replacement is ideal for fiber steel reinforcement concrete as it had a compressive strength of 17 N/mm² which conform to the minimum requirement of ASTM A820/A820M standard.

Keywords: Waste glass, Steel fibre reinforced concrete

INTRODUCTION

Concrete containing hydraulic cement, water, fine or fine and coarse aggregate and discontinuous discrete fibers is called steel fiber-reinforced concrete. It contains short discrete fibers that are uniformly distributed and randomly oriented. These fibers are of high strength and are added to concrete to improve the concrete properties particularly tensile and flexural strength. The extent of improvement in the mechanical properties achieved with SFRC over those of plain concrete depends

on several factors, such as shape, size, volume, percentage and distribution of bars (Mohammad *et al.*, 2016; Mythili, Vidhya and Balaraman 2017; The Constructor, 2017).

Concrete is an artificial material which has wider application in the construction industry. The basic ingredients of concrete are cement, sand, coarse aggregate and water. Mohammad, Chavan and Sonali (2016), opines that since cement which is one of the main constituent of concrete is among carbondioxide (CO₂) emitting sources besides deforestation and

burning of fossils fuels, it is therefore necessary to research for other sources that could either replace cement partially or completely in concrete production be developed. Manufacturing of cement currently exceed 2.6 billion tonnes per year worldwide and it increases at 5% rate each year thereby generating nearly 7% of atmospheric carbon-dioxide (CO₂) which contributes largely to the global warming (Jindal 2015). This prompted researchers to develop supplementary cementitious materials like waste glass to replace cement so as to eliminate the issues associated with its manufacturing and usage.

Waste glass is one of the wastes generated in the environment and because it is a non- biodegradable material, it tends to pollute the environment. Waste glass is generated from broken doors, windows, car windscreens, tablewares, bottles, fluorescent lamps and light bulbs. They can either be added as cullet to the batch in furnace to make new bottles or used for decoration (in form of cullet) to make glass mosaic or use cullet as raw material in paint (Garkida, 2007; WRAP, 2010; Adejo, 2016). Besides using waste glass as cullet, efforts have been made to by researchers to crush waste glass into powder and use it as partial or complete replacement in concrete since the demand in concrete production continue to increase day by day (Bajad, Modhera and Desai 2011; Gautam 2012; Mohammad *et al.*, 2016; Oluwarotimi, Julius, Anthony and Colin 2017; Mythili, Vidhya and Balaraman 2017). Despite all effort to recycle this waste glass as partial replacement of cement for concrete production, Sadiqul and Nayem (2016), explain that million tonnes of waste glass is being generated all over the world. This paper therefore gives report for the

production of steel fiber reinforced concrete using waste glass powder as partial replacement for cement.

METHODOLOGY

The materials used in this research include: Waste glass sourced within Zaria metropolis. The waste glass was beneficiated by soaking and washing them and after drying, they were broken into smaller sizes and then fed into a dual purpose glass crushing machine at the Department of Glass and Silicate Technology, Ahmadu Bello University, Zaria. The waste glass was crushed into 2mm particle sieve size before pounding before pounding to obtain 0.75µmm particle which was used to replace the cement. Dangote brand of Ordinary Portland Cement (OPC) was used for this research as and it satisfies the minimum requirement as provided by BS 12 (1996). River sand locally sourced within Zaria was used as fine aggregate for this research. The coarse aggregate was also obtained within Zaria. Both fine and coarse aggregates were used in Saturated Surface Dry (SSD) condition. Portable water fit for drinking was used for beneficiating, mixing the concrete mix and for curing the concrete in this research.

Grade 20 concrete was designed for the concrete produced in this research using a mix ratio of 1:2:4. Cement and powdered waste glass (WG) were first mixed together followed by the aggregate (fine and coarse). Water was then added and mixed thoroughly. The replacement of proportion of cement with powdered waste glass was varied between 0% (no powdered glass), 10%, 20%, 30% and 40%. The variation in the percentages replacement of WG was done so that any change in trend could be

determined. After mixing, fresh waste glass concrete (WGC) was produced. Some of the samples were cast into 100mm X 100mm X 100mm mould in 2 layers and each layer compacted by giving 25 blows with a tapping rod while some sample was cast into 750mm x 150 mm moulds embedded with 4Y10mm diameter steel reinforcing bar (rebar) of 700mm length. A total of fifteen (15) 100mm X 100mm X 100mm cubes and fifteen (15) 750mm x 150mm beams were for WGC. The specimen was demoulded after 24 hrs and immersed in a curing tank for 28 days so as to allow for effective curing.

The compressive and flexural strength tests were carried out according to ASTM A820/A820M. The analytical technique carried out to know the micro-structure morphology of the reinforced

concrete was scanning electron microscopy (SEM).

RESULTS AND DISCUSSION

Figure 1 presents the average compressive strength of WGC cubes specimens containing 0%, 20%, 30% and 40% replacement of powdered waste glass cured at 28days. The compressive strength obtained were 20N/mm², 17 N/mm², 14 N/mm², 11 N/mm² and 9 N/mm² respectively. From the result, there is continuous decrease in compressive strength as the replacement of WG continues to increase. As replacement of cement increased, the compressive strength decreased as complete hydration reaction is faster in complete cement concrete than in partial replacement. Complete hydration reaction takes place in cement first before reaction with waste glass.

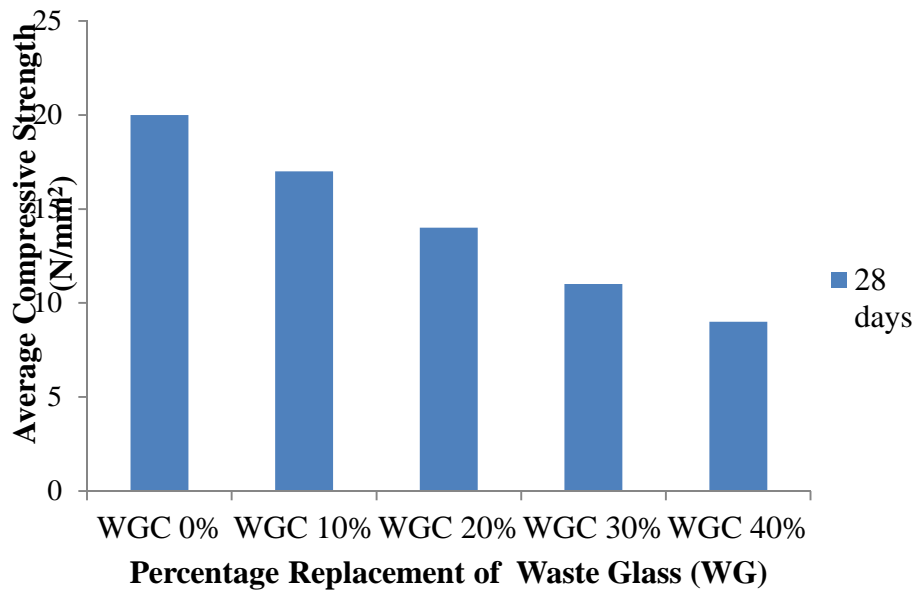


Figure 1: Compressive Strength of Cubes with Increase in Waste Glass

Flexural Strength Test

The results of the flexural strength test from Figure 2 shows that the samples

with 0%, 10%, 20%, 30% and 40% have their flexural strengths of 1.16 N/mm², 0.93 N/mm², 0.71 N/mm², 0.78 N/mm² and 0.62

N/mm² respectively. As replacement of cement increased, the flexural strength decrease as complete hydration reaction is

faster in complete cement concrete than in partial replacement.

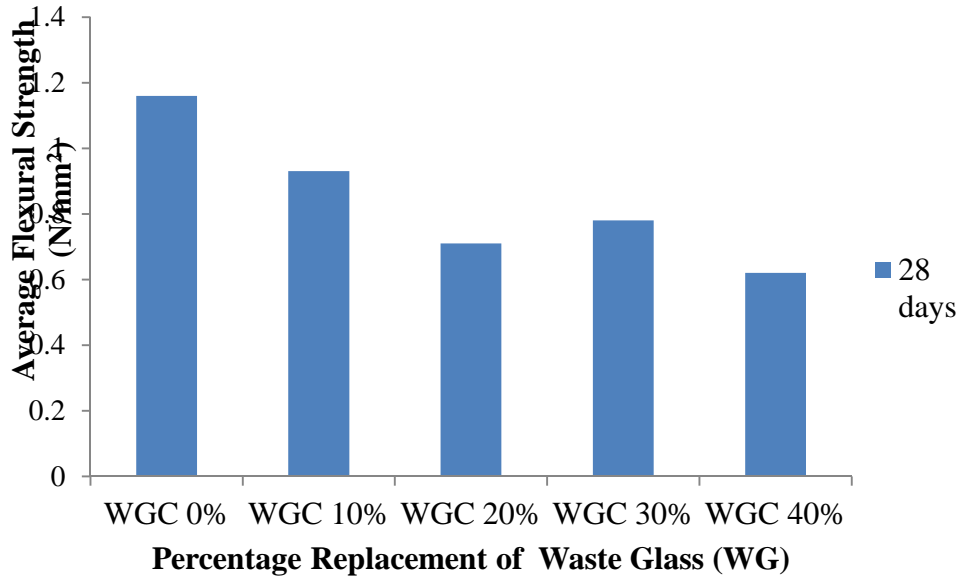


Figure 2: Flexural Strength of Beams with Increase in Waste Glass

Scanning electron microscopy of hardened concrete (ASTM C1723-16, 2016)

Plates 1, 2 and 3 show the microstructure morphology of concrete with 0%, 10% and 40% respectively. From the result, plate 1, showed complete hydration

reaction of 0% due to absence of WG. While Plate 2 and 3 shows some pores which could be as a result of the presence of powdered waste glass resulting to breaking down of the bonds in the network structure of glass.

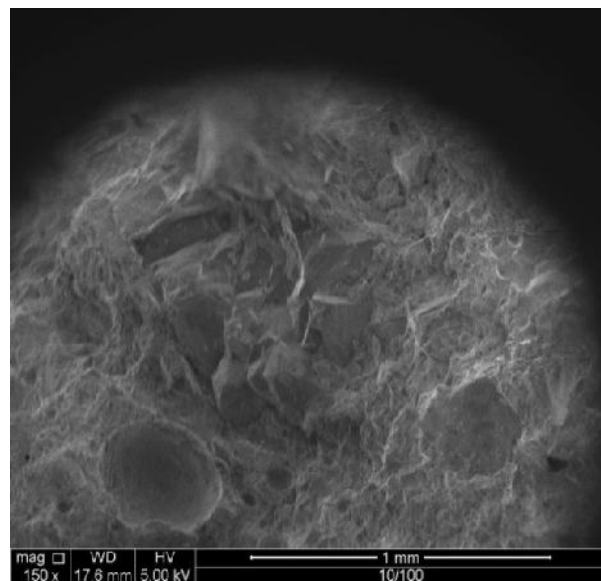
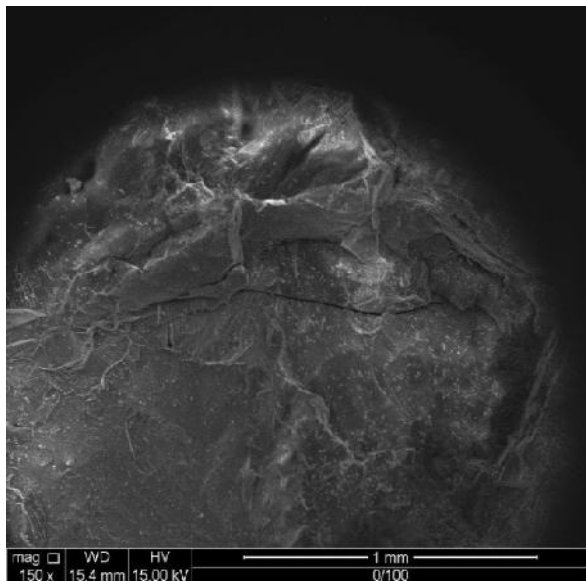


Plate 1: SEM of Concrete with 0% Replacement. Magnified at 150x

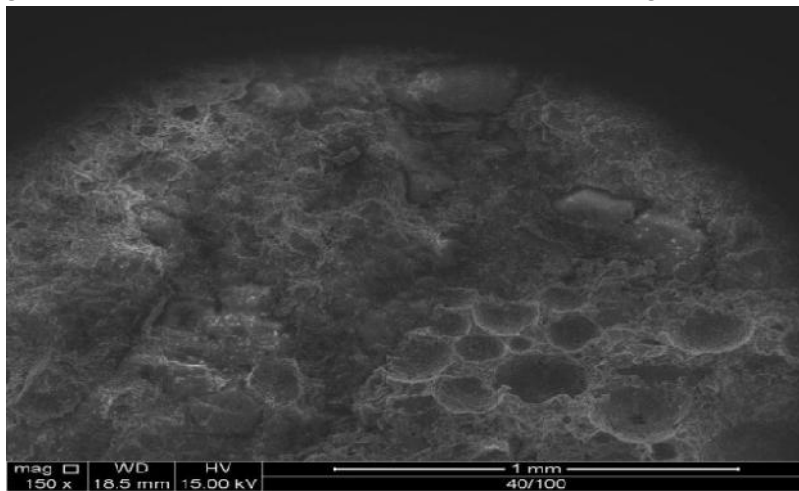


Plate 2: SEM of Concrete with 10% Replacement. Magnified at 150x

Plate 3: SEM of Concrete with 40% Replacement. Magnified at 150x

CONCLUSION

From the results of this study, up to 10% cement replacement is ideal for fiber steel reinforcement concrete as it had a compressive strength of 17 N/mm² which is the minimum requirement of ASTM A820/A820M. Therefore, further increase of cement replacement will yield a decrease in the compressive strength of fiber steel reinforcement concrete which in turn affects the integrity of the concrete.

REFERENCES

- Adejo, A. O. (2016). Utilization of Glass Cullet for the Production of Paint for Buildings. An Unpublished Post Graduate Dissertation Submitted to Department of Industrial Design, Ahmadu Bello University, Zaria, Nigeria.
- Garkida, A. D. (2007). Glass Recycling in Waste Management. A Published PhD Dissertation Submitted to Department of Industrial Design, Ahmadu Bello University, Zaria.
- Jindal, B. B. and Kamal, K. (2015). Geopolymer Concrete - A Review. *SSRG International Journal of Civil Engineering*. 96-99.
- Kuriakose, E. B. and Paul, M. M. (2017). Experimental Investigation on Performance of Steel Fiber Reinforced Self Compacting Concrete by Partial Replacement of Cement with Lime Sludge. *International Journal of Science Technology and Engineering* 3 (10) 541
- Luhar, S. and Gourav, S. (2015). A Review Paper on Self Healing Concrete. *Journal of Civil Engineering Research* 5(3) 53-58
- Mohammad, S. S., Chavan, F. I. and Sonali, P. (2016). Suitability of Waste Glass Powder as a Partial Replacement of Cement in Fibre Reinforced Concrete. *International Journal of*

- Innovative Research in Science, Engineering and Technology*. 5(7) 13554
- Mythili, T., Vidhya, T. and Balaraman, R. (2017). Study on the Strength Characteristics of Waste Glass Powder and Steel Fibre in Concrete. *International Journal of Civil Engineering and Technology (IJCIET)*. 8(8) 121- 128
- Oluwarotimi, M. O., Julius, M. N., Anthony N. E. and Colin, B. (2017). Application of Waste Glass Powder as a Partial Cement Substitute towards more Sustainable Concrete Production 77-93
- The Constructor (2007). “Steel Fibre Reinforced Concrete” Retrieved August 18, 2015 from <http://theconstructor.org/concrete/steel-fibre-reinforced-concrete/4771>
- The Constructor (2018). “Composition of Portland Cement” Retrieved July 30, 2018 from <http://theconstructor.org/building/composition-of-portland-cement/5725>
- WRAP (2010). Can you recycle your Flat Glass Waste? The Potential for Recycling Flat Glass Waste in the Domestic Replacement Window Sector, Banbury, WRAP, Retrieved August 3, 2016, from <http://www.wrap.org.uk/downloads/FlatGlassWaste1.c48b676f.55.pdf>.