The Use of Calcined Waste Glass Powder as a Pozzolanic Material

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Abstract—The amounts of waste glass in the Bayelsa State metropolis have been growing noticeably without being reutilized increasing the danger to public well-being because of the shortage of land area. This rising challenge of waste glass in the Bayelsa State metropolis can be improved if new dumping possibilities other than landfill can be discovered. This study is geared toward the better use of waste glass material as admixture in concrete as a means to improve the concrete compressive strength. To achieve research objectives, the broken waste glasses were obtained from aluminum fabrication workshop in Amassoma, Bayelsa State Nigeria, the glasses were then milled to a fine powder smaller than 0.075mm and burnt at a controlled temperature of 200, 400, and 600°C respectively. A total of 156 concrete cubes of 150mm x 150mm x 150mm were produced employing different contents of calcined or burnt waste glass powder as admixture. The quantity of calcined waste glass powder used as admixture was varied from 0-20% at step of 5% for three different temperatures, 200°C, 400°C and 600°C. The samples were cured for 7, 14, 21 and 28days and tested in the laboratory for compressive strength. Results obtained from the study showed that the best addition dosage of calcined waste glass powder at 200°C, 400°C and 600°C are 20%, 5% and 5%. A 20% addition of Calcined waste glass powder at 200°C exhibited about 23% increase in compressive strength than the control. Base on the findings, it is recommended that the use of calcined waste glass powder as pozzolanic material should be embraced for production of concrete and can be utilized in concrete production as admixture with 5% - 20% for 200°C 400°C and 600°C respectively.

Index Terms—Waste Glass Powder, Admixture, Concrete Strength, Calcination.

I. INTRODUCTION

Wastes are materials caused by the frequent human activities that have to be discarded. Waste substances generally comprise medical, domestic and industrial wastes. Especially, construction solid waste is the produce result of building and demolition, reintegration, external strengthening, and installations. This discarded material is comprised of wood, fine and coarse aggregates, tiles, glass, aluminum, plastic, plumbing and electric pipes, and asbestos. One of the key environmental worries concerning the landfills in the Bayelsa State metropolis is the limited area accessible in both their present and future expected amount of waste. The amounts of waste glass in the Bayelsa State metropolis have been growing noticeably without being reutilized increasing the danger to public well-being because of the shortage of land area. This rising challenge of waste glass in the Bayelsa State metropolis can be improved if new dumping possibilities other than landfill can be discovered. Solid waste in Bayelsa State metropolis mostly consists of domestic wastes, building remains, agricultural wastes, medical wastes, workshops wastes. Commonly, clear, green or brown bottles arising from juice, soft drinks, glass jars and clear pure glass originating from construction and renovation processes are amongst the sources of waste glass materials in Bayelsa State metropolis.

The practice of reutilized materials in construction is very pleasing, because considerable number of such materials can be consequently consumed. Shao et al., [10] shown that ground glass having a particle size finer than 38μm did demonstrate a pozzolanic behavior. Shayan and Xu [1] examined the use of waste glass in concrete and revealed that both fine glass powder of < 10μm particle size, and crushed glass aggregate could be utilized in concrete together without harmful effects on concrete durability. Finely pulverized glass powders showed very high pozzolanic activity. The finer the milled glass powder is, the higher its pozzolanic reactivity is. The rapid mortar bar expansion test (ASTM C1260) outcomes show that the replacement of Portland cement with milled glass powder reduces the expansion as a result of alkali-aggregate reactions [9].

Kou and Poon, [6] examined the effects of reused glass cullet on fresh and hardened properties of self-compacting concrete. Recycled glass was used to replace river sand (in proportions of 10%, 20% and 30%), and 10 mm granite (5%, 10% and 15%) in making the self-compacting concrete mixes. The study showed that the slump flow and air content of the recycled glass self-compacting concrete mixes increased with increasing recycled glass content.

Milling of glass to powder form, for improving the reactions amongst glass and cement hydrates brings environmental and economic benefits when cement is replaced partially with waste glass powder for production of concrete [8].

Arthanari et al. [2] defined Pozzolans as siliceous material, which by itself possesses no cementitious properties but in processed form and finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitious properties.

Glass originates as an equal mixture from three core raw natural resources: sand, silica, and limestone. The glass recycling method yields a crushed glass produce called "cullet", which mixed with virgin glass substance to yield new end products. Table IV lists some of approximate
chemical compositions. The recyclability of calcined glass powder as a pozzolan material is evaluated. The purpose of this research is to clarify the strength of calcined waste glass as admixture while it is alkaline-activated, and to examine its hydration products.

II. MATERIALS AND METHODS

A. Materials

Concrete is made by mixing different constituents like cement, fine aggregate, coarse aggregate water, which are efficiently obtainable. Portland limestone cement of 42.5 grade conforming to EN 197-1 [3] was used all through the study. The fine aggregate employed in this study was clean river sand conforming to BS 882: [4]. Crushed stone angular in shape was used as coarse aggregate.

1) Waste glass

The broken waste glass was obtained from aluminum fabrication workshop in Amassoma, Bayelsa State. The broken waste glass was cleaned and crushed to produce “cullet; and then further milled into powder form.

2) Mix proportion

A mix ratio of 1:2:4 (cement: fines: coarse aggregate) by weight was adopted in this investigation with water/cement ratio of 0.55. The concrete mould of (150x150x150mm) was considered for the production of concrete cubes. The mould was coupled and properly oiled prior to mixing.

B. Method

1) Calcination of Milled Glass

The milled waste glass (powder form) was burnt in a furnace under a controlled temperature of 200, 400 and 600°C. After calcination, it was observed that the molecules of the calcined samples at 400 and 600°C were bonded together, so further pulverization was done to achieve the finest. The ash was sieved through 75µmm British Standard (BS). The calcined glass powder was used as admixture (5 - 20% addition by weight of cement).

2) Fresh Concrete Test

Slump was investigated to determine the workability of fresh concrete both control and concrete containing calcined waste glass powder.

3) Compressive Strength Test

A total of 156 concrete cubes of 150mm x 150mm x 150mm were produced for this investigation, twelve of which were used as control (0% Calcined glass powder) and twelve for each percentage addition (5%, 10%, 15% and 20% by weight of the cement) per calcined temperature (200°C, 400°C and 600°C) respectively. A vibrator was used to ensure even distribution of the fresh concrete in the concrete mould and also to avoid voids. The concrete cube samples were allowed to set for a minimum of 24 hours before demolding and then stored in water to cure in order to increase the strength of concrete, eliminate shrinkage and absorb heat of hydration. Cured concrete cubes were tested for their compressive strength at 7, 14, 21 and 28-days.

III. RESULTS AND DISCUSSION

A. Results

| TABLE I: COMpressive STRENGTH OF CALCined GLASS POWDER ADDITION FOR 200°C AT 7, 14, 21 AND 28 DAYS |
|----------------------------------------|--------|--------|--------|--------|
| % Addition | 7-Days (N/mm²) | 14-Days (N/mm²) | 21-Days (N/mm²) | 28-Days (N/mm²) |
| 0% | 16.00 | 18.89 | 20.44 | 23.83 |
| 5% | 19.85 | 20.89 | 24.59 | 25.48 |
| 10% | 24.52 | 25.04 | 26.16 | 27.70 |
| 15% | 15.71 | 15.63 | 18.52 | 19.33 |
| 20% | 23.56 | 19.70 | 23.36 | 30.67 |

| TABLE II: COMpressive STRENGTH OF CALCined GLASS POWDER ADDITION FOR 400°C AT 7, 14, 21 AND 28 DAYS |
|----------------------------------------|--------|--------|--------|--------|
| % Addition | 7-Days (N/mm²) | 14-Days (N/mm²) | 21-Days (N/mm²) | 28-Days (N/mm²) |
| 0% | 16.00 | 18.89 | 20.44 | 23.83 |
| 5% | 16.59 | 21.18 | 20.44 | 22.74 |
| 10% | 16.14 | 19.03 | 21.18 | 20.88 |
| 15% | 17.48 | 17.33 | 14.07 | 20.51 |
| 20% | 22.51 | 22.67 | 22.37 | 20.74 |

| TABLE III: COMpressive STRENGTH OF CALCined GLASS POWDER ADDITION FOR 600°C AT 7, 14, 21 AND 28 DAYS |
|----------------------------------------|--------|--------|--------|--------|
| % Addition | 7-Days (N/mm²) | 14-Days (N/mm²) | 21-Days (N/mm²) | 28-Days (N/mm²) |
| 0% | 16.00 | 18.89 | 20.44 | 23.85 |
| 5% | 18.31 | 25.18 | 20.74 | 27.85 |
| 10% | 20.37 | 20.14 | 24.00 | 25.40 |
| 15% | 20.44 | 22.51 | 19.18 | 23.70 |
| 20% | 22.51 | 19.11 | 22.67 | 25.92 |

Fig. 1. Compressive Strength against days for 0%, 5%, 10%, 15%, and 20% of calcined waste glass powder relative to cement weight at 200°C

Fig. 2. Compressive Strength against days for 0%, 5%, 10%, 15%, and 20% of calcined waste glass powder relative to cement weight at 400°C

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IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

This study was performed to examine the use of calcined waste glass powder as a pozzolanic material. The following conclusions drawn are based on the research results of the study:

i. Calcined waste glass powder at 200°C, 400°C and 600°C calcination temperature can effectively be used as admixture in concrete.

ii. Calcined waste glass powder can be used as a pozzolanic material.

iii. 20% addition of Calcined waste glass powder at 200°C exhibited about 23% increase in compressive strength.

iv. The workability of the concrete increases with an increase in calcined waste glass powder content.

v. The best addition dosage of Calcined waste glass powder at 200°C is 20%

vi. The best addition dosage of Calcined waste glass powder at 400°C is 5%

vii. The best addition dosage of Calcined waste glass powder at 600°C is 5%

B. Recommendation

Based on the conclusions from this investigation, the following recommendations are made:

i. The use of calcined waste glass powder as pozzolanic material should be embraced for production of concrete.

ii. The calcined waste glass powder can be utilized in concrete production as admixture with 5% - 20% for 200°C 400°C and 600°C respectively.

APPENDIX

TABLE IV: CHEMICAL COMPOSITION OF GLASS POWDER AND CEMENT [5]

| S/N | Compositions (%) | Waste Glass Powder | Cement |
|-----|------------------|---------------------|--------|
| 1   | SiO₂             | 70.22               | 23.71  |
| 2   | CaO              | 11.13               | 57.27  |
| 3   | MgO              | -                   | 3.85   |
| 4   | Al₂O₃            | 1.64                | 4.51   |
| 5   | Fe₂O₃            | 0.52                | 4.83   |
| 6   | SO₃              | -                   | 2.73   |
| 7   | Na₂O             | 15.29               |        |
| 8   | K₂O              | -                   | 0.37   |
| 9   | Cl               | -                   | 0.0068 |
| 10  | Loss on ignition | 0.8                 | 7.24   |

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REFERENCES

[1] A. Shayan, A. Xu. (2004) Value-added utilization of waste glass in concrete, Cement Concrete Res. 34 81- 89.

[2] Arthanari, S. Augustine, A.G., Dayanithi, P., Ramaswamy, S., Sethuratham. A., and Thanikachalam, V. (1981) BuildingTechnology and Valorization. Tata McGraw-hill, New Delhi,

[3] British Standard Institution (2001) Composition, specification and conformity criteria for common cements, BS EN 197: Part1, BSI, London.
[4] BS 882: (1992) Specification for aggregate from normal sources for concrete

[5] Dhanaraj Mohan Patil and Dr. Keshav k. Sangle, (2013) Experimental Investigation of Waste Glass Powder as Partial Replacement of Cement in Concrete. International Journal of Advanced Technology in Civil Engineering, ISSN: 2223 - 5721, Volume-2, Issue-1.

[6] Kou, S. and Poon, C., (2009) “Properties of self-compacting concrete prepared with recycled glass aggregate”, Cement and Concrete Composites Journal, Vol. 31, pp. 107 – 113.

[7] Nathan Schwarz, Hieu Cam and Narayanan Neithalath, (2008) “Influence of a fine glass powder on the durability characteristics of concrete and its comparison to fly ash” Cement & Concrete Composites, Vol.30, p.p.486–496

[8] Rashed, A.M., (2014). Recycled waste glass as fine aggregate replacement in cementitious materials based on Portland cement Constr. Build. Mater. 72, 340–357

[9] Shi C., Wu Y., Riefler C., and. Wang H. (2005) Characteristics and pozzolanic reactivity of glass powders, Cement Concrete Res. 35 987–993.

[10] Y. Shao, T. Lefort, S. Moras, D. Rodriguez, (2000) Studies on concrete containing ground waste glass”, Cement Concrete Res. Vol.40, no.1, pp. 91–100.