EXPERIMENTAL INVESTIGATION ON BAGASSE ASH BASED GEOPOLYMER CONCRETE SUBJECTED TO ELEVATED TEMPRETURE

Dilip Srinivas, Dr. N Suresh, Lakshmi N H
Research Scholar, National Institute of Engineering
Professor, Department of Civil Engineering, National Institute of Engineering
M.tech student structural Engineering, National Institute of Engineering
diipsrinivas1989@gmail.com,suresh61.nie@gmail.com,lakshmereddy0089@gmail.com

Abstract: Geopolymer in recent years is being deemed as a promising alternative to cement concrete, which has remained as backbone of the construction industry. Despite GPC having potential capability of reducing carbon footprint, still many of its characteristics and mechanism to be investigated. The present study represents the utilization of bagasse ash in the production of geopolymer concrete. In order to reduce the ecological imbalance by the emission of CO2 from cement production an attempt has been made to investigate the feasibility of utilizing sugar cane ash as one of the candidate in polymer concrete by maintaining different molar concentration of sodium based alkali activated solutions. Geopolymer concrete has been casted and assessed for the fresh and harden properties. In the present work sugar cane bagasse ash replacement was done partially from 10% to 100% to determine workability and strength parameters. The objective of the work is to find the maximum extent of bagasse ash by reducing GGBS & also to check the suitable silica content. GGBS has been used as a binder materials & to reduce the limitations of GPC with respect to workability, Aura mix super plasticizer has been used. While comparing the results with regular concrete after 28days sun curing shows the positive effect with maximum 30% bagasse ash further increment results in decrease in harden properties such as ultimate compressive strength, flexural strength and split tensile strength. specimens were subjected to the elevated temperature to study the properties of geopolymer concrete such as residual strength, mass loss.

Keywords: Sugarcane bagasse ash, Workability, Compressive strength and flexural strength.

1. Introduction

The contribution of Davidovits describes a new breed of alumino silicate binder popularly known as Geopolymer synthesized with kaolinite & alkali solution. Geopolymer concrete is an
ingenious and ecology friendly building material and it’s one of the ways to replace to the ordinary Portland cement concrete. The implementation of geopolymer concrete reduces the demand of the OPC which is responsible for "global warming”. Geopolymer was the name given way back in 1978 by the researcher J Davidovits to the material which is formed by the chains or ring structure or inorganic molecules or three-dimensional structure. Geopolymer concrete can be phrased as “A concrete without cement ”which is defined as “The concrete which consists of the source materials and the alkaline solution”. The alkaline solutions can be either sodium hydroxide and sodium silicate or potassium hydroxide and potassium silicate. Many research has been carried by NaOH or KOH as a supplementary material to cement. However use of geopolymer in construction is limited due to the problem which come across with workability. In order to understand the internal reactivity & also external factor such as strength and slump following investigation has been done. From the literature review it has been observed that various researches have been conducted on geopolymer concrete, hence there is dire need to make a comprehensive review of the progress made hitherto, in different directions with regards to GPC.

2. Literature Review

2.1 Vinicius N Castaldelli et.al, [1]2013 explain the concrete is necessary which is being used over 10 billion tonnes every year. Different types of bagasse samples were collected and studied the variation in the chemical composition and its feasibility in concrete. Different mixes such as 0%, 15%, 25%, 30% of sugarcane bagasse ash with BFS has taken further study the mechanical properties of the concrete. The chemical composition mainly silica of SCBA and BFS viz 31.41% and 30.19% respectively. The loss of ignition in the SCBA sample was 32.2% because of the wastewater in the sample and the mixing of the liquid from the scrubber. Sodium hydroxide and water glass mixture are preferred to activate the binders, 5M concentration of NaOH and the ratio of SiO2/Na2O molar ratio of 1.46 are the controlled factors for the study with the steam curing. The compressive strength of the mortar specimens at 3 days was 42 to 54MPa cured at 60 degrees, whereas the strength was good after 90 and 270 days which is 55 to 65 MPa which was cured at room temperature. This approach can help in using waste to produce concrete.
2.2 Erni Setyowati, [2] 2014 explains the world is facing global climate change due to the pollution caused by the industries mainly the cement production which alone causes 7 percent of the total emissions of CO2 viz 930 million tonnes per annum. Usage of Styrofoam and the bagasse ash in the concrete makes it aerated concrete which has sound insulation property. The silica content in the chemical composition of the bagasse ash sample is 71 percent. The strength of the concrete decreases after 15% replacement. The usage of waste material leads to the economic approach and improves the value of waste eliminating the problem of disposal. The structure can be earthquake resistant because of the reduction in weight which can help in the earthquake zones. The pores in the Styrofoam helps in additional special quality in the concrete which is sound insulation. Hence it solves the problem of waste disposal.

2.3 Tony Suman Kanth D et.al, [3]2015 explains the universe is facing the environment pollution due to the emission of pollutants from the industries to the atmosphere which one of them is cement production which contributes about 8% of total emissions of CO2 in the world. The 24 specimens cast for the study which are cubes, cylinders and the beams each of size 150mmx150mmx150mm, and 100mmx100mmx500mm respectively. The various controlled factors are taken care such as the heat curing at the rate of 60 degrees for 24 hours, the 12M concentration of NaOH, SSD basis aggregates with varying percentage of bagasse ash and rice husk ash. As the percentage of replacement increases the strength decreases which shows up to 10 percent replacement level the strength was good. The geopolymer concrete gives the early strength of 75% in 7 days which helps in the progress of the work in construction areas. This is preferable for the water shortage area.

3. MATERIALS

| Source materials | Specific gravity | Fineness(%) |
|------------------|-----------------|-------------|
| GGBS             | 2.92            | 6           |
| SCBA             | 0.41            | 54          |

| Alkaline liquids | Specific gravity | Density (kg/m³) |
|------------------|------------------|-----------------|
| NaOH             | 1.47             | 1470            |
| Na₂SiO₃          | 1.6              | 1600            |
### 1. METHODOLOGY

In the following investigation M25 grade of geopolymer is selected with the mixture of sodium silicate & sodium hydroxide solution throughout the work. Bagasse ash has been obtained from various sources and selected with maximum silica content. For the proportioning of ingredients Rangan guidelines were followed. For the obtained proportions cubes, cylinders and beams were casted. The specimens was removed from the mould after 24hrs and kept for air curing. At 7 & 28 days strength has been evaluated. The specimens were tested in 3000kN capacity compression testing machine. Flexure strength is also known as the modulus of rupture. A beam of dimension 100mmx100mx500mm was casted and the Flexural strength test at two point loading was conducted on test specimens at 28 days under the Universal testing machine at the load rate of 0.14 to 0.34 N/mm²/sec and the load at failure is noted as the ultimate load.

### 2. RESULTS AND DISCUSSIONS

The results obtained from the experimental study of GPC are discussed. Which represents the result of fresh concrete test like slump test and mechanical properties like compressive strength, split tensile strength, flexural strength of different geopolymer concrete mixes with variation in the percentage replacement of GGBS by BA. The variation in the mechanical properties with the variation of Bagasse ash source is discussed in this summery. Also microstructure analysis is also discussed.

| Aggregates      | Specific gravity | Bulk density (kg/m³) | Water absorption (%) | Sieve analysis                  |
|-----------------|-----------------|----------------------|----------------------|---------------------------------|
|                 |                 | Loose sample         | Compacted sample     |                                 |
| 20mm aggregates | 2.60            | 1264.19              | 1479.19              | 1.6                             |
|                 |                 |                      |                      | As per IS:383-1970              |
| 10mm aggregates | 2.62            | 1353                 | 1534.16              | 1.4                             |
|                 |                 |                      |                      | As per IS:383-1970              |
| M sand          | 2.51            | 1317.53              | 1572.96              | 1.25                            |
|                 |                 |                      |                      | As per IS:383-1970              |
5.1 Workability of Geopolymer Concrete

To study the effect of Bagasse ash in geopolymer concrete, on the fresh concrete, GPC is tested for slump. The workability for geopolymer concrete is tested as per IS1199-1959. Slump for different mixes are as shown in table.

![Workability of GPC mixes graph](image)

**Table 5.1.1: workability of GPC mixes**

| S1 no | Mix                  | Slump values |
|-------|----------------------|--------------|
| 1     | 5% BA + 95% GGBS     | 65           |
| 2     | 10% BA + 90% GGBS    | 76           |
| 3     | 15% BA + 85% GGBS    | 85           |
| 4     | 20% BA + 70% GGBS    | 91           |
| 5     | 25% BA + 75% GGBS    | 99           |
| 6     | 30% BA + 70% GGBS    | 105          |
| 7     | 40% BA + 60% GGBS    | 65           |
| 8     | 50% BA + 50% GGBS    | 35           |
| 9     | 100% GGBS            | 20           |

The workability of GPC decreases as the percentage inclusion of BA is increased in the mix because as the BA is added to the mix it absorbs water. Amount of extra water is kept constant for all the mixes.

5.2 HARDEDENED GEOPOLYMER CONCRETE PROPERTIES

5.2.1 COMPRESSIVE STRENGTH

To study the effect of partial replacement of GGBS by BA on the compressive strength of GPC, standard cube specimen of size 150mmX150mmX150mm were prepared and tested as per IS 516-1959. Two different Bagasse ash source is used for the study. A 5 molarity of NaOH solution is prepared. Specimens are cured in direct sunlight and tested after 7 and 28 days.
Compressive strength for different bagasse ash is tabulated in the following table. The average compressive strength of all the GPC mixes for different Bagasse ash source and their testing age is shown in the following graph.

| Bagasse Ash Source | Compressive Strength (MPa) |
|--------------------|-----------------------------|
| 5% BA | 42.10 | 41.09 | 29.19 | 42.10 | 29.19 |
| 10% BA | 53.74 | 53.74 | 54.84 | 55.67 | 55.67 |
| 15% BA | 55.56 | 55.56 | 56.01 | 55.81 | 55.81 |

Graph: 5.2.1 A comparative study of 7 days compressive strength

Graph: 5.2.2 A comparative study of 28 days compressive strength

From the Graph 5.2.1 and Graph 5.2.2 it is observed as the bagasse ash contents exceeds more than 30% the compressive strength of the GPC is reduced but as the molar concentration increases the hardened property of GPC is improved.

5.3 SPLIT TENSILE STRENGTH

The split tensile strength at the age of 28 days is presented on the first objective of the study. The cylinder dimension with the diameter as 150mm and length as of 300mm.
From graph it can be observed that the split tensile strength of the geopolymer concrete at the 28th day increases as the molarity of NaOH increases. Similar observations with regard to molarity of NaOH have been made by the investigators. For geopolymer concrete with 100% GGBS, the split tensile strength with 5M, 10M and 15M NaOH are 3.8 MPa, 4.08 MPa, and 4.94 MPa respectively. Similarly, for 75%, 50%, 25%, and 0% GGBS, the split tensile strength increases as the molarity of NaOH increases.

5.4 FLEXURAL STRENGTH

The Flexural strength of GPC estimated at the age of 28 days, the results are presented on the below graph:

![Graph 5.4.1: A comparative study of 28days Flexural Strength](image)
5.5 BEHAVIOR OF CONCRETE AFTER EXPOSURE TO ELEVATED TEMPERATURE

From the graph, it can be pragmatic that the average residual split tensile strength decreases as the temperature increases for an exposure of 2 hours. Parallel observations with respect to average residual strength have been through by other investigators. At ambient temperature, there is no change in the residual strength. At 200°C sustained elevated temperature it's understood that there is a decrease in average residual strength in cylinders and beams by 10.49% and 20.22% w.r.t ambient temperature but for cubes, the residual strength is increased by 1.05%. Similarly, at 400°C, 600°C, and 800°C the average residual split tensile strength decreases w.r.t ambient temperature respectively.

Graph 5.5.1 : A comparative study of Residual strength w.r.t Elevated temperature
5.5.2 A comparative study of Weight loss w.r.t Elevated temperature

From the graph, it can be detected that the average weight loss increases as the temperature increases for an exposure of 2 hours. Similar observations with regard to average weight loss have been made by other investigators. At ambient temperature, there is no change in the mass. At 200°C sustained elevated temperature it's understood that there is an increase in average weight loss in cubes, cylinders, and beams to 3.13%, 1.73%, 2.35% w.r.t ambient temperature. Likewise, at 400°C, 600°C, and 800°C the average weight loss in geopolymer concrete increases w.r.t ambient temperature respectively. The test specimens are self-governing of each other w.r.t weight loss.

3. CONCLUSION

Following important conclusions could be derived from based on the present study carried out:

- GPC mixes are more cohesive and stiff and the setting time of GPC is very quick as compared to OPC concrete. The addition of super plasticizers increases its workability with limited dosage.
- GPC mixes requires continuous rotation of the mixer in order to control fast setting.
- It was found that due to the use of GGBS there was early strength gain in GPC and very small difference was found in 7 and 28 days strength.
- The workability of GPC decrease with increase in percentage of bagasse ash.
➢ Addition of bagasse ash as a binder is applicable up to 30% without any retarding effect on compressive strength.

➢ Flexural strength of GPC is low in comparison with regular OPC based concrete.

➢ As the molarity increases workability of GPC will be more, further increment results in adverse effect on fresh properties of the mix.

➢ The weight loss in geopolymer concrete increases as the elevated temperature increases.

➢ The residual strength in geopolymer concrete decreases as the elevated temperature increases.

➢ The geopolymer concrete has a better resistance against surface cracking and spalling up to 600°C

Reference

1. Castaldelli, V. N. et al. (2013) ‘Use of slag/sugar cane bagasse ash (SCBA) blends in the production of alkali-activated materials’, *Materials*, 6(8), pp. 3108–3127. doi: 10.3390/ma6083108.

2. Setyowati, E. (2014) ‘Eco-building Material of Styrofoam Waste and Sugar Industry Fly-ash based on Nano-technology’, *Procedia Environmental Sciences*. Elsevier B.V., 20, pp. 245–253. doi: 10.1016/j.proenv.2014.03.031.

3. Tony SumanKanth D(2015). "Hardened Properties of Bagasse Ash GPC and Rice-husk Ash GPC", International Journal of Innovative Research in Science, Engineering and Technology Vol. 4, Issue 12, December 2015.

4. Badami Bhavin (2013). “Geopolymer Concrete and Its Feasibility in India”, Proceedings of National Conference CRDCE13, 20-21 December 2013, SVIT, Vasad.

5. P Topark-Ngarm, P Chindaprasirt - Journal of Materials in, 2015- ascelibrary.org

6. Xiaolu, Huishengs (2009) “Compressive strength and characteristics of class C Fly ash Geopolymer. Cement and Concrete Composites, 2010 – Elsevier

7. Buari T.A (2015). “Durability of Sugarcane Bagasse Ash Blended Cement Concrete Under Different Sulphate Concentration”, Department of Building Technology, Federal Polytechnic Ede, Osun State, Nigeria.
8. Sujay Chetan Nanavati (2017). & quot; A Review on Fly Ash-based Geopolymer Concrete & quot; IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 14, Issue 4 Ver. VII (Jul. - Aug. 2017), PP 12-16.

9. M S Padmanaban, Sreerambabu J, 2018, “Geo polymer concrete with GGBS (Ground Granulated Blast Furnace Slag)”, International journal of engineering sciences & research Technology, pp 2277-9655.

10. The evolution of strength and crystalline phases for alkali-activated ground blast furnace slag and fly ash-based geopolymers JE Oh, PJM Monteiro, SS Jun, S Cho - Cement and Concrete , 2010 – Elsevier.

11. Bennet Jose Mathew, Mr. M Sudhakar, Dr. C Natarajan, 2013, “Strength Economic and Sustainability Characteristics of Coal Ash-GGBS Based Geopolymer Concrete”, International Journal of Computational Engineering Research.

12. L Krishnan, S Karthikeyan, S Nathiya, K Suganya, 2014, “Geopolymer Concrete an eco-friendly construction material”, IJRET: International Journal of Research in Engineering and Technology, pp 2321-7308.

13. U.R. Kawade (2014). & quot; Fly Ash-Based Geopolymer Concrete & quot; International Journal of Innovative Research in Science, Engineering and Technology Volume 3, Special Issue 4, April 2014.

14. Development of low calcium fly ash based geopolymer concrete K Ramujee - International Journal of Engineering and Technology, 2014 - researchgate.net

15. Effect of synthesizing parameters on workability and compressive strength of fly ash based geopolymer mortar A Bhowmick, S Ghosh - International Journal of Civil & Structural , 2012 - indianjournals.com

16. The influence of the NaOH solution on the properties of the fly ash-based geopolymer mortar cured at different temperatures G Gorhan, G Kürklü - Composites part b: engineering, 2014 – Elsevier.

17. Effect of duration and temperature of curing on compressive strength of geopolymer concrete, V Patankar Subhash - International Journal of, 2012 idc-online.com

18. R. Zhao (2011). “Geopolymer and Portland cement concretes in simulated fire”, Magazine of Concrete Research, 2011, 63(3), 163–173.
19. Effects of elevated temperatures on the thermal behaviour and mechanical performance of fly ash geopolymer paste, mortar and lightweight concrete OA Abdulkareem, AMM Al Bakri, H Kamarudin and building materials, 2014 – Elsevier
20. Production of geopolymer mortar system containing high calcium biomass wood ash as a partial substitution to fly ash: An early age evaluation OA Abdulkareem, M Ramli, JC Matthews - Composites Part B: Engineering, 2019 – Elsevier

21. Davidovits J. From ancient concrete to geopolymer. Arts et Metiers Mag. 180, 8–16, 1993.
22. Djwantaro Hardjito, Steenie E Wallah, Dody M J, Sumajouw and B Vijaya Rangan .On the development of Fly ash-based Geopolymer Concrete, ACI Material Journal/November-December-2004.

23. Ganapati Naidu. P., A.S.S.N.Prasad., S.Adiseshu and P.V.V. Satyanarayana. A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S, International EXPERIMENTAL INVESTIGATION ON GEOPOLYMER CONCRETE Journal of Engineering Research and Development ISSN: 2278-067X, ISSN: 2278-800X, 4(2), 19-28, 2012.

24. IS 1903- 1999, Concrete Admixture, BIS New Delhi.
25. IS 5816- 1999, Split tensile strength of concrete, BIS New Delhi.
26. IS 456:2000, Plain and Reinforced Concrete, BIS New Delhi.
27. IS 516:1959, Methods of Test for Strength of Concrete, BIS New Delhi.
28. Mohd Mustafa Al Bakri, H., Mohammed H. Kamarudin, I. Khairul Niza and Y. Zarina. Research Vol. 3(1), 1-4, January, ISSN 2006-9790, 2011.