International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(2) 2026 pp. 1613-1626
https://doi.org/10.70917/ijcisim-2026-4604
Article

A PERFORMANCE INVESTIGATION ON BAGASSE ASH –BASED GEOPOLYMER CONCRETE FOR DIFFERENT CURING REGIME

Varsha V. Yewale[1]*, Sachin B. Mulay [2]

[1*]Department of Civil Engineering, Sandip University, Nashik (MS), India
[2]Department of Civil Engineering, Sandip University, Nashik (MS), India
[1]varsha.yewale@ymail.com and [2]sachin.mulay@sandipuniversity.edu.in
Corresponding author: Varsha V. Yewale
varsha.yewale@ymail.com

Abstract: In this rapid growing development of country, there is demand for sustainability. Most important part of development is infrastructure because its increase GDP of the country and help economically and financially. As the demand for infrastructure increases there is increase in demand of cement which is one of the most and necessary material for the construction of infrastructure. Cement is a material which acts as binder and main ingredient in the concrete. The cement is also one of the materials, which is responsible for contribution to pollution because it emits tonnes of CO2 during manufacturing. This construction material is manufactured by using raw material which is quarried. To gain this sustainability, there is need to have a green concrete which will not contain a material that will affect our environment. So there is need to have a material which will be used instead of cement but not affect the environment. This paper investigates about the behaviour of geopolymer concrete for the replacement of the fly ash by sugarcane bagasse ash by 10-30% for different type of curing. Alkaline activators are used, NaOH and Na2SiO3 with 2.5 ratio. Compressive strength test had been done on different percentage replacement of fly ash by bagasse ash at different curing temperature and curing time for oven curing, room temperature and water curing for 7 days. As per the research work finding maximum strength at 15% replacement of Fly ash by Bagasse ash at 100°C for 18hrs gives maximum strength up to 43.42Mpa.
Keywords: Geopolymer concrete, Fly ash, Bagasse ash, alkaline activators, Curing type, Curing temperature, Curing Hours.

1. INTRODUCTION

In this fast growing technology, demand for sustainable infrastructure has become one of the key priorities. It is important to note that infrastructure development for national growth directly contributes to economic progress, especially in terms of GDP growth. Similarly, with the rise in demand for infrastructure, cement demand increases too, simply because cement is one of the major binding materials in concrete. Apart from this, the production of cement is considered one of the major sources of environmental pollution as it releases a huge amount of CO_2 during its production process [10-22-23]. Moreover, raw material consumption for cement requires huge quarrying, which again affects the environment. The demand for eco-friendly or "green" concrete, which does not require materials causing harm to the environment for sustainable development, is evolving. Therefore, alternative binder materials should be found that can work effectively instead of cement with minimum environmental degradation. From an ecological approach, this material should be such that it will not negatively impact the environment but enables to overcome from the waste material which cannot be dispose and negatively impacting the environment [2-15]. The usage of the material which have pozzolanic properties obtained from the agricultural and industrial material waste such as fly ash, sugarcane bagasse ash, rice rusk ash, and blast furnace slag which cannot be dispose of or destroyed easily [2]. These materials can be used as replacement of cement so that CO2 emission can be reduced to a limit. Therefore, to replace cement an eco-friendly concrete is introduced which is called as geopolymer concrete [24]. Geopolymer concrete is more sustainable and durable material for the construction purposes when compared with the conventional concrete [13]. Geopolymer is a new concept which was introduced by sir Joseph Davidoits [17]. Davidoits introduced a geopolymer technology which was used for the Geopolymer concrete by using Geopolymerization reaction so as to decrease CO2 emission by cement manufacturing industries as it contributes to global warming [3].

Geopolymer concrete has emerged as a sustainable alternative to ordinary Portland cement due to its ability to utilize industrial by-products and reduce carbon emissions [1-13]. As per the studies, Fly ash and industrial by product has been widely accepted as an additional cementitious material because of its alumina silicate composition, compatibility with alkaline activators and demonstrated effectiveness in geopolymer concrete. Under ideal curing and activator conditions, alkali-activated fly ash concrete shows good mechanical strength, decrease permeability, and improved resistance to chemical deterioration [1]. However increasing restrictions on coal based power generation have reduced fly ash availability creating an urgent need for alternative binders to ensure material sustainability and long term supply stability [5]. Sugarcane Bagasse Ash (SCBA), agriculture by product from burning bagasse in sugar mill cogeneration systems, is one such new material [21]. As one of the global largest producer of sugarcane, India generates millions of tons of Sugarcane Bagasse Ash annually [21]. Approximately 8 to 10% of burned bagasse turns into ash, resulting in growing abundant but underutilized waste products [4]. Disposing SCBA in landfills is hazardous for environment as the material contaminates the air, soil gets more alkaline, and consumes more space for disposal purpose [4]. As the studies show that, SCBA have high content of amorphous silica, which makes it a good alternative for binder replacement material if we heated and ground in a controlled way [4-26]. The reviewed paper confirms that Sugarcane Bagasse Ash (SCBA) possesses significant potential as a sustainable binder material due to its high reactive silica content and favourable pozzolanic behaviour [7]. The study also emphasizes that introducing SCBA into the alkali activated can reduce permeability, refine pore structure, and also promote long term structural stability but provided the replacement level of SCBA [7].

The primary environmental advantages associated with the usage of SCBA include not only reduce CO2 but also waste management and low reliance on the industrial by- product like fly ash [19]. Therefore it also enhances its role as low carbon alternative in green construction materials [6].Therefore, the development of eco-efficient materials such as fly-ash and biomass-derived waste like Sugarcane Bagasse Ash (SCBA) has become a research priority to achieve carbon-reduced concrete solutions without compromising performance [9]. According to Mohammed Ali M. Rihan et.al. study, SCBA participates in Geopolymerization under alkaline activation and helps to form C–S–H/N–A–S–H gels when SCBA used as partial replacement to the Fly ash, improving strength development within desired mix proportions [8]. The findings of the experiment showed that higher NaOH molarity accelerated matrix formation and improved the dissolution of alumino-silicate particles, with 16M concentration offering better compressive strength than lower molarity mixes. [8] Their study investigated SCBA as a partial replacement for binder materials at varying proportions and demonstrated that optimum performance was achieved near 30% replacement, beyond which compressive, tensile, and flexural strengths showed a reduction [11].

The authors further observed that workability tends to decrease with higher SCBA content due to its finer particle structure and increased water absorption, although the use of super plasticizers can improve flow ability when required [11]. The research establishes that SCBA has strong potential as a sustainable binder in geopolymer concrete, especially when used within optimized limits and activated under controlled alkali concentrations, making it a relevant material for green construction development.[11]

2. MATERIAL USED

2.1 Material

The material used is fly Ash, bagasse ash, sand, coarse aggregate, alkaline solution containing Na OH and Na2SiO3. Fly Ash processed to low calcium class F, supplied as POZZOCRETE 60 by Dirk India Private Limited. Fly ash used has a specific gravity of 2.26. The fly ash has a fineness 360 m2/kg as per Blaine's method.

Fig 1. Fly ash

Sugarcane bagasse ash (SCBA) is an agro-industrial waste generated after the combustion of sugarcane bagasse in cogeneration plant. This bagasse is produced in sugar industry in millions of tonnes annually, mainly in the sugar producing countries. Disposal of this ash is an environmental challenge; however, its high silica content and pozzolanic potential make it a valuable precursor for sustainable cementitious and geopolymer materials [16]**.**Sugarcane bagasse ash can be used as partial replacement of flyAsh geopolymer concrete by proper thermal and mechanical processing [18]**.**Sugarcane bagasse ash was acquired from Mula Sakar Karkana, Sonai, Ahilyanagar, Maharashtra in India. Sugarcane ash was sieved through 500µm sieve to eliminate the residue and collect the fine SCBA [12]. After the collection of fine SCBA it is calcinsed at temperature 700°C for 2hrs for promoting pozzolanic reactivity and the specific gravity of Bagasse ash is 2.56 [12-15]. Then, this calcinsed SCBA is used to replace the fly ash in Fly ash Geopolymer concrete by 5%,10%, 15%, 20%, 25% and 30% at different curing temperature for different time at 7days.

Fig. 2 Untreated Bagasse ash collected from Mula Sakar Karkana, Sonai, Ahilyanagar, and Maharashtra in India

Fig. 3 Treated Bagasse ash

As geopolymer concrete is prepared with the alkaline solution, Sodium silicate and sodium hydroxide solution is used as alkaline liquid. Molarity of the NaOH solution 16 M is used [8]. Coarse aggregate of 12.5 and 20 mm with specific gravity 2.7 and river sand having specific gravity 2.4 is used as fine aggregate.

Fig. 4 NaOH in pellets form

Fig.5 Na2SiO3 in gel Form

2.2 Mixing, Casting and Curing

In Bagasse ash Geopolymer concrete, mixing of all the ingredients is done in concrete mixer as per the conventional concrete [20]. For casting bagasse ash geopolymer concrete, 16M NaOH is prepare a day prior of casting. The need to prepare NaOH a day before is as it liberates heat when added to water for 16 Molarity and hence this liberated heat will not allow to bind the other material properly. Due to this, compressive strength will decrease. Bagasse ash geopolymer concrete is prepared by replacement of fly ash by 5%, 10%, 15%, 20%, 25%, 30% with the concentration of alkaline solution for 16M Na OH and ratio of NaOH/Na2SiO3 is 2.5.[8] Bagasse Ash geopolymer concrete cubes are cast for replacement of fly ash by 5%, 10%, 15%, 20%, 25%, 30% and oven curing of the cubes are done for 60°C, 80°C, 100°C curing temperature at 6hrs, 12hrs, 18hrs and 24hrs curing hours and test the compressive strength for 7days Similarly, cubes are test for room temperature and water curing for 7 days.

Fig. 6 Mixing of material in concrete Mixer

Fig. 7 De-moulded Samples

2.3. Test Conducted

Compressive Strength testing of concrete is done as per IS516:1959. A compression testing machine with a 2000KN capacity was used to test sample. For every replacement of the fly ash by bagasse ash 03 cubes of sample were tested for each curing type, curing temperature and curing hours. Flexural and split tensile test were conducted on the optimum percentage replacement of fly ash by bagasse ash, curing type, curing temperature and curing hours for 28 days according to IS516:1959.

3. RESULT AND DISCUSSION

3.1 Workability

In this, workability of fresh concrete for replacement of fly ash by 5%, 10%, 15%, 20%, 25%, 30% by bagasse ash had been done. As per the following graph, as slump value for each percentage of replacement of fly ash by bagasse ash had been decreasing. It is also graphically represented in fig 8 for each percentage of replacement of fly ash by bagasse ash.

Table 3.1 Slump Test Result

Mix ID	%FA	%SCBA	Slump Value
95F5B	95%	5%	95
90F10B	90%	10%	86
85F15B	85%	15%	75
80F20B	80%	20%	69
75F25B	75%	25%	50
70F30B	70%	30%	38

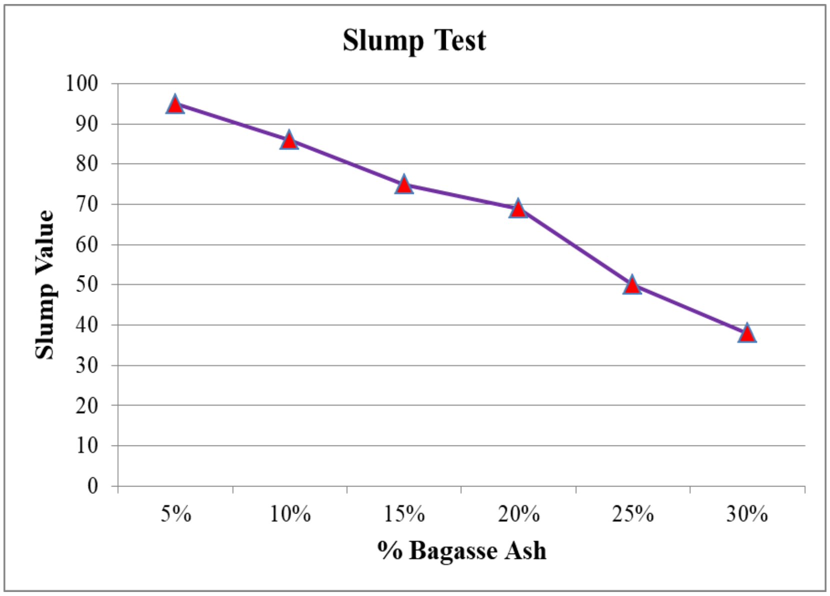

Fig.8 Slump Test

As per the Fig 8, it is observed that slump value is decreasing as we are increasing the percentage replacement of bagasse ash in Fly ash Geopolymer Concrete.

3.2 Compressive Strength

3.2.1 Oven Curing

The compressive strength of cube for oven curing at different temperature and different curing hours for 7 days by replacement of the fly ash by bagasse ash for different percentage is done. In oven curing, optimum percentage replacement, temperature and curing hours are determined. To determine the optimum percentage of replacement of Fly ash by the bagasse ash compressive strength is evaluate at different curing hours and different temperature.

Fig. 9 Oven for oven curing

Fig. 10 Samples kept for Oven Curing

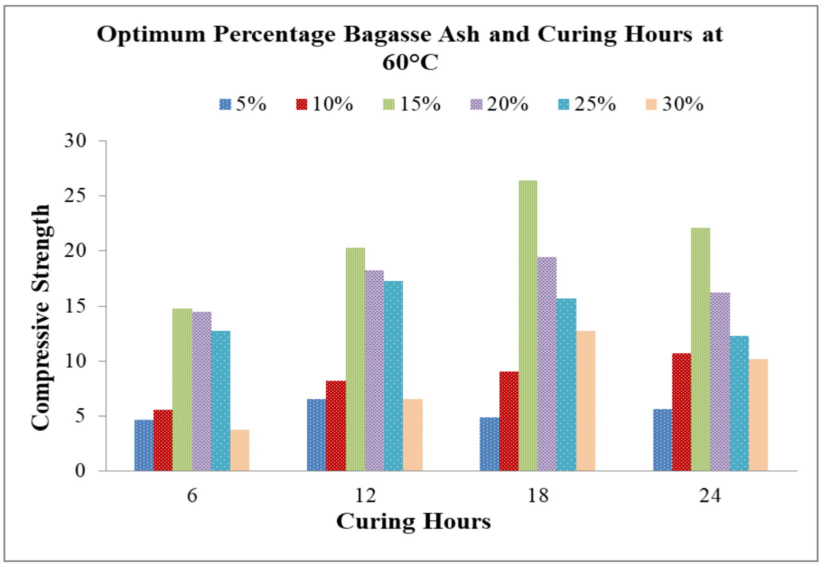

Fig.11 Optimum Percentage Bagasse Ash and Curing Hours at 60°C

At 60°C temperature, bagasse ash is replaced by 5%, 10%, 15%, 20%, 25%and 30% and cured for 6hrs, 12hrs, 18hrs, and 24hrs in oven. As the curing hours and percentage replacement of fly ash by bagasse ash is replacing the compressive strength is increase up to 15% replacement of bagasse ash for 18hrs of curing of bagasse ash concrete.

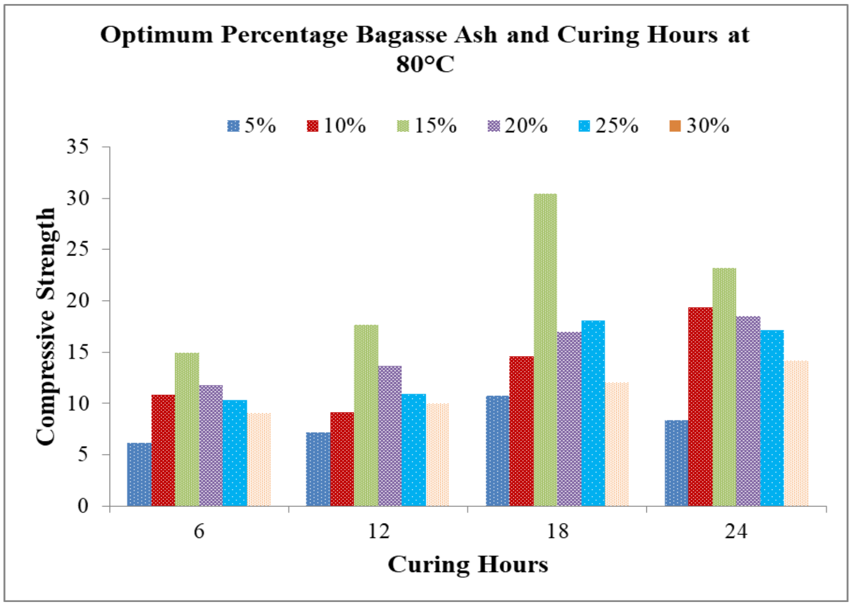

Fig.12 Optimum Percentage Bagasse Ash and Curing Hours at 80°C

At 80°C temperature, bagasse ash is replaced by 5%, 10%, 15%, 20%, 25%and 30% and cured for 6hrs, 12hrs, 18hrs, and 24hrs in oven. As the curing hours and percentage replacement of fly ash by bagasse ash is replacing the compressive strength is increase up to 15% replacement of bagasse ash for 18hrs of curing of bagasse ash concrete.

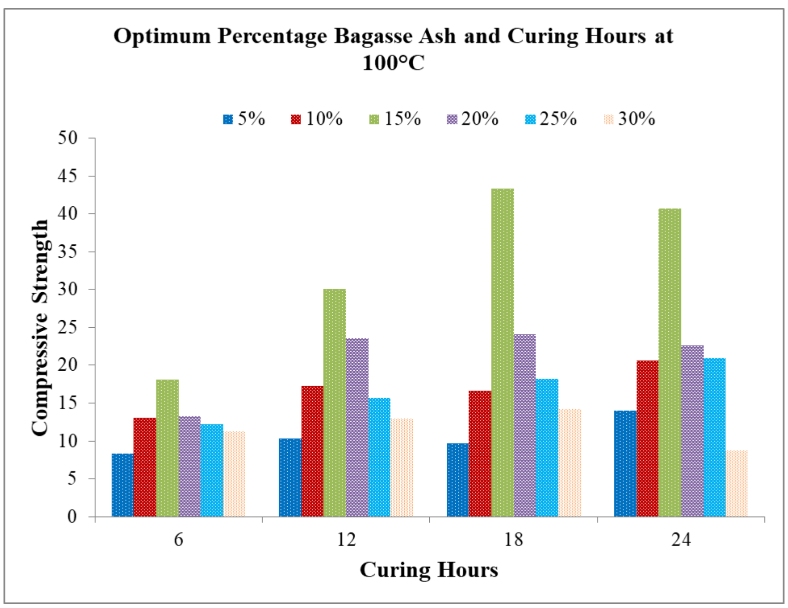

Fig.13 Optimum Percentage Bagasse Ash and Curing Hours at 100°C

At 100°C temperature, bagasse ash is replaced by 5%, 10%, 15%, 20%, 25%and 30% and cured for 6hrs, 12hrs, 18hrs, and 24hrs in oven. As the curing hours and percentage replacement of fly ash by bagasse ash is replacing, the compressive strength is increase up to 15% replacement of bagasse ash for 18hrs of curing of bagasse ash concrete.

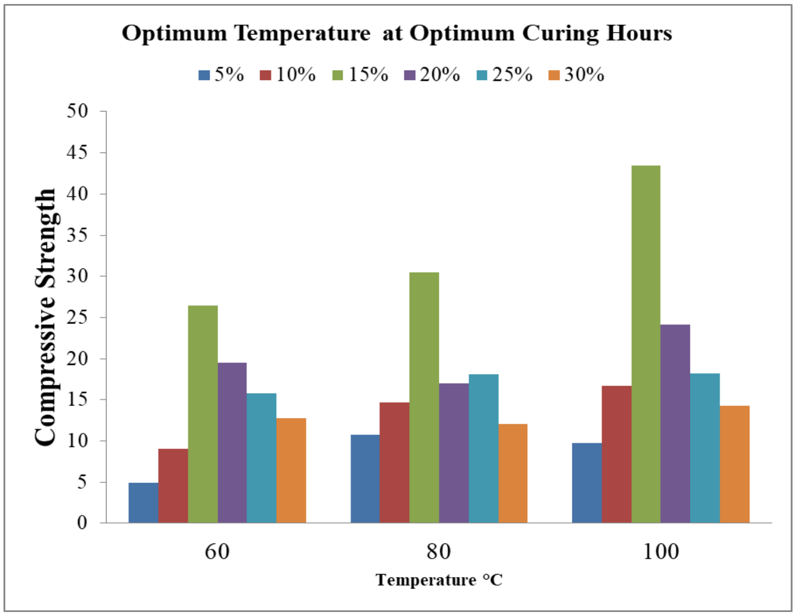

Fig.14 Optimum Temperature at optimum Curing Hours

As Fig 14 shows, as the temperature increases from 60°C to 100°C there is an increment in the compressive strength of bagasse ash geopolymer concrete in optimum curing hours.

Fig.15 Testing of Compressive Strength using 2000KN compression testing Machine

3.2.2 Room and Water Curing

The compressive strength of cube for room and water curing for different percentage replacement of the fly ash by bagasse ash for is done. In oven curing, optimum temperature and curing hours are determined for each percentage of replacement of fly ash by bagasse ash. In the fig.6, as the percentage of bagasse ash replacement increase there is increase in the compressive strength but after 15% replacement of bagasse ash, compressive strength is decreased but again there is increment in the strength for 30% replacement.

Fig.16 Water cured Samples

Fig. 17 Samples at Room temperature

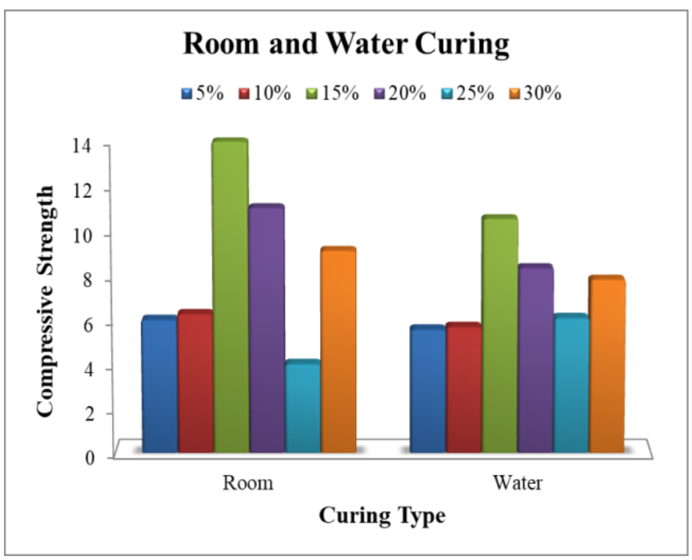

Fig.18 Room and Water Curing

3.2.3 Flexural Strength

For the optimum percentage replacement of bagasse ash, curing type, curing temperature and curing hour's flexural strength of the bagasse ash geopolymer is test for 28 days according to IS516:1959. Flexural Strength is evaluated at 15% replacement of fly ash by bagasse ash by oven curing at 100°C for 18hrs, for the sample of beam having size 100x100x500mm at 28days. In fig 20, there is an average of 3 sample at optimum is 4.22MPa.

Fig. 19 Sample test on Flexural Strength test apparatus

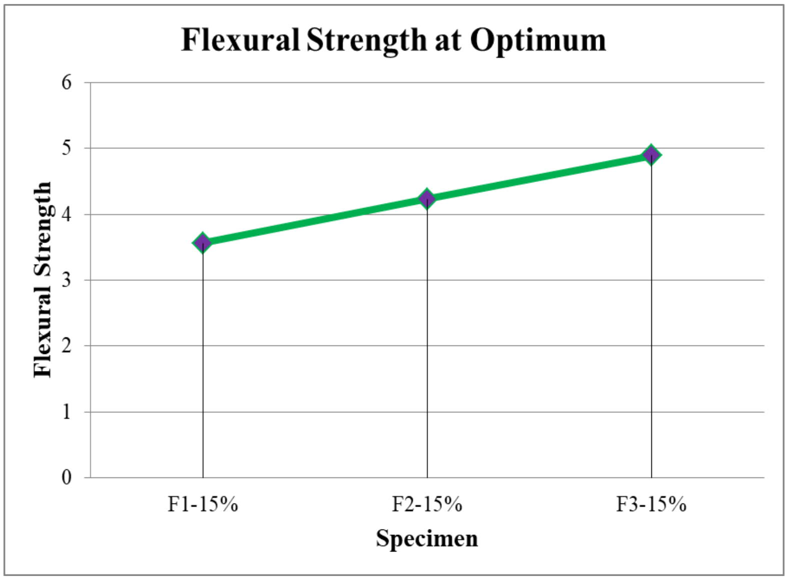

Fig.20 Flexural Strength at Optimum Condition

3.2.4 Split Tensile Strength

For the optimum percentage replacement of bagasse ash, curing type, curing temperature and curing hour's Split tensile strength of the bagasse ash geopolymer is test for 28 days according to IS516:1959. Split tensile Strength is evaluated at 15% replacement of fly ash by bagasse ash by oven curing at 100°C for 18hrs, for the sample of Cylinder having size 150x300mm at 28days.

Fig. 21 Sample test on Split tensile test apparatus

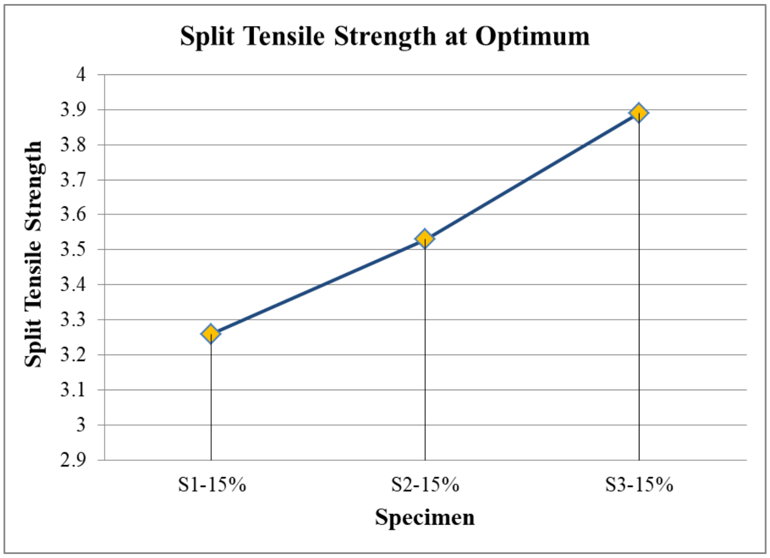

Fig. 22 Split Tensile Strength at Optimum Condition

In fig 22, there is an average of 3 sample are tested for split tensile Strength at optimum is 3.02MPa.

4. CONCLUSION

In this study, the impact of different curing hours at different curing temperature for different percentage of replacement of fly ash by bagasse ash had been explored. Based on the above experimental work carried out, curing hours play a vital role in compressive strength of bagasse ash geopolymer concrete sample. From the above experimental work following can be concluded:

1. The workability of the bagasse ash geopolymer concrete decreases as we increase the percentage replacement of the fly ash by bagasse ash primarily may be due to its larger specific surface area. As the larger specific surface area which will increase the demand for alkaline activator solution for the proper mixing.

2. The experimental results demonstrated that oven curing is showing effective result as we compare with the room and water curing. At room temperature curing is not producing sufficient heat so that Geopolymerization reaction will complete. As the water curing is also showing less effective results. Therefore oven curing is optimum type of curing for the bagasse ash geopolymer concrete.

3. In this study, an increase in the percentage replacement of the fly ash by bagasse ash for Oven curing at 60°C, 80°C, and 100°C temperature for 6hrs, 12hrs, 18hrs and 24hrs shows an increment in the compressive strength for 15% replacement of bagasse ash at 100°C temperature for 18hrs of curing hours at 7days.

4. The bagasse ash geopolymer concrete containing 15% bagasse ash cured at 100°C temperature for 18hrs of curing hours exhibit the optimum flexural and split tensile strength at 28 days.

The experimental work finding proves that bagasse ash can be used as supplementary alumni silicate material in the Fly ash geopolymer concrete but when used at optimum percentage replacement, optimum curing type, curing hours and curing temperature.

ACKNOWLEDGEMENT

The author would like to express its gratitude towards the Mula Sakhari Sakhar Karkhana, Sonai, Ahilyanagar, Maharashtra, India for supplying raw Sugarcane bagasse ash for this experimental work. The author also thankful to the Civil Engineering Department of Sandip University, Nashik, Maharashtra and Shri Chhatrapati Shivaji Maharaj College of Engineering, Nepti, Ahilyanagar, Maharashtra for providing the facilities for the experimental work.

DECLARATIONS OF CONFLICT INTEREST

The author declares that there is no conflict of interest

DECLARATIONS OF FUNDING

This research work not received any financial funding.

References

1. I. G. Ishwarya, B. Singh, S. Deshwal, and S. K. Bhattacharyya, "Effect of sodium carbonate/sodium silicate activator on the rheology, geopolymerization and strength of fly ash/slag geopolymer pastes," Cement and Concrete Composites, vol. 97, pp. 226–238, 2019. doi:10.1016/j.cemconcomp.2018.12.007.
2. M. A. M. Rihan, R. O. Onchiri, N. Gathimba, and B. Sabuni, "Mechanical and microstructural properties of geopolymer concrete containing fly ash and sugarcane bagasse ash," Civil Engineering Journal, vol. 10, no. 4, pp. 1292–1314, Apr. 2024. doi:10.28991/CEJ-2024-010-04-018.
3. B. V. Rangan, Fly Ash-Based Geopolymer Concrete, Research Report GC 4, Engineering Faculty, Curtin University of Technology, Perth, Australia, 2008.
4. A. Bahurudeen, K. S. Vaisakh, and M. Santhanam, "Availability of sugarcane bagasse ash and potential for use as a supplementary cementitious material in concrete," Indian Concrete Journal, vol. 89, no. 7, pp. 31–41, Jul. 2015.
5. S. N. Minnu, A. Bahurudeen, and G. Athira, "Comparison of sugarcane bagasse ash with fly ash and slag: An approach towards industrial acceptance of sugar industry waste in cleaner production of cement," Journal of Cleaner Production, vol. 285, p. 124836, 2021. doi:10.1016/j.jclepro.2020.124836.
6. A. Gupta, N. Gupta, and K. K. Saxena, "Mechanical and durability characteristics assessment of geopolymer composite (GPC) at varying silica fume content," Journal of Composites Science, vol. 5, no. 9, p. 237, 2021. doi:10.3390/jcs5090237.
7. W. E. Farrant, A. J. Babafemi, J. T. Kolawole, and B. Panda, "Influence of sugarcane bagasse ash and silica fume on the mechanical and durability properties of concrete," Materials, vol. 15, no. 9, p. 3018, 2022. doi:10.3390/ma15093018.
8. M. A. M. Rihan, T. S. Alahmari, R. O. Onchiri, N. Gathimba, and B. Sabuni, "Impact of alkaline concentration on the mechanical properties of geopolymer concrete made up of fly ash and sugarcane bagasse ash," Sustainability, vol. 16, no. 7, p. 2841, 2024. doi:10.3390/su16072841.
9. B. C. McLellan, R. P. Williams, J. Lay, A. van Riessen, and G. D. Corder, "Costs and carbon emissions for geopolymer pastes in comparison to ordinary Portland cement," Journal of Cleaner Production, vol. 19, no. 9–10, pp. 1080–1090, 2011. doi:10.1016/j.jclepro.2011.02.010.
10. N. Elawadly and S. A. Sanad, "Sustainable concrete incorporating sugarcane bagasse ash: A study on workability, mechanical behavior, and microstructure," Innovative Infrastructure Solutions, vol. 10, p. 401, 2025. doi:10.1007/s41062-025-02177-6.
11. D. Srinivas, N. Suresh, and L. N. H., "Experimental Investigation on Bagasse Ash Based Geopolymer Concrete Subjected to Elevated Temperature," IOP Conference Series: Earth and Environmental Science, vol. 796, no. 1, p. 012028, 2021. doi:10.1088/1755-1315/796/1/012028.
12. Jondhale, S. B. Mulay, and P. K. Kolase, "Transforming Biowaste into Sustainable Pozzolanic Binder: Effects of Calcination and Mechanical Activation on the Properties of Sugarcane Bagasse Ash," Journal of Applied Bioanalysis, vol. 11, no. 8, pp. 296–308, 2025. doi:10.53555/jab.v11i8.1875.
13. T. S. Alahmari, T. A. Abdalla, and M. A. M. Rihan, "Review of Recent Developments Regarding the Durability Performance of Eco-Friendly Geopolymer Concrete," Buildings, vol. 13, no. 12, p. 3033, 2023. doi:10.3390/buildings13123033.
14. T. A. Abdalla, D. O. Koteng, S. M. Shitote, and M. Matallah, "Mechanical and Durability Properties of Concrete Incorporating Silica Fume and a High Volume of Sugarcane Bagasse Ash," Results in Engineering, vol. 16, p. 100666, 2022. doi:10.1016/j.rineng.2022.100666.

15. A. Bahurudeen and M. Santhanam, "Influence of Different Processing Methods on the Pozzolanic Performance of Sugarcane Bagasse Ash," Cement and Concrete Composites, vol. 56, pp. 32–45, 2015. doi:10.1016/j.cemconcomp.2014.11.002.
16. N. Chusilp, C. Jaturapitakkul, and K. Kiattikomol, "Utilization of Bagasse Ash as a Pozzolanic Material in Concrete," Construction and Building Materials, vol. 23, no. 11, pp. 3352–3358, 2009. doi:10.1016/j.conbuildmat.2009.06.030.
17. D. Hardjito, Studies on Fly Ash-Based Geopolymer Concrete, Ph.D. Thesis, Department of Civil Engineering, Curtin University of Technology, Perth, Australia, Nov. 2005.
18. S. Rukzon and P. Chindaprasirt, "Utilization of Bagasse Ash in High-Strength Concrete," Materials and Design, vol. 34, pp. 45–50, 2012. doi:10.1016/j.matdes.2011.07.045.
19. U. Kashyap, A. R. Nirala, and R. N. Khare, "Sugarcane Bagasse Ash (SCBA)-Blended Geopolymer Concrete – A Comprehensive Review," International Journal of Engineering Research & Technology (IJERT), vol. 14, no. 12, Dec. 2025.
20. M. A. M. Rihan, R. O. Onchiri, N. Gathimba, and B. Sabuni, "Effect of Sugarcane Bagasse Ash Addition and Curing Temperature on the Mechanical Properties and Microstructure of Fly Ash-Based Geopolymer Concrete," Open Ceramics, vol. 19, p. 100616, 2024. doi:10.1016/j.oceram.2024.100616.
21. T. A. Abdalla, A. A. E. Hussein, Y. H. Ahmed, and O. Semmana, "Strength, Durability, and Microstructure Properties of Concrete Containing Bagasse Ash – A Review of 15 Years of Perspectives, Progress and Future Insights," Results in Engineering, vol. 21, p. 101764, 2024. doi:10.1016/j.rineng.2024.101764.
22. T.-V. Vo, V. T.-A. Phan, and D.-H. Le, "Sustainable Use of Sugarcane Bagasse Ash in Fly Ash-Based Geopolymers: Implications for Compressive Strength and Shrinkage," Periodica Polytechnica Civil Engineering, vol. 69, no. 3, pp. 869–883, 2025. doi:10.3311/PPci.40532.
23. E. Aprianti, P. Shafigh, S. Bahri, and J. N. Farahani, "Supplementary Cementitious Materials Origin from Agricultural Wastes – A Review," Construction and Building Materials, vol. 74, pp. 176–187, 2015. doi:10.1016/j.conbuildmat.2014.10.010.
24. N. Thoudam, T. Lairikyengbam, and S. Thokchom, "Effect of Sugarcane Bagasse Ash in GGBS Geopolymer Composites," ASPS Conference Proceedings, vol. 1, pp. 143–146, 2022. doi:10.38208/acp.v1.486.
25. N. B. Singh and B. Middendorf, "Geopolymers as an Alternative to Portland Cement: An Overview," Construction and Building Materials, vol. 237, p. 117455, 2020. doi:10.1016/j.conbuildmat.2019.117455.
26. U. Khalid, Z. ur Rehman, I. Ullah, K. Khan, and W. I. Kayani, "Efficacy of Geopolymerization for Integrated Bagasse Ash and Quarry Dust in Comparison to Fly Ash as an Admixture: A Comparative Study," Journal of Engineering Research, 2023. doi:10.1016/j.jer.2023.08.010.