Investigating the Influence of Bagasse Ash as a Partial Cement Replacement in Geopolymer Concrete Production

Gururaj M. H. [1], Naresh Kumar B. G. [2]
[1] Assistant Professor, Department of Civil Engineering, Maharaja Institute of Technology Mysore, Mandya, Visvesvaraya Technological University Belagavi-590018, Karnataka, India.
[2] Professor, Department of Civil Engineering, Maharaja Institute of Technology Mysore, Mandya, Visvesvaraya Technological University Belagavi-590018, Karnataka, India.

Abstract: The production of cement by the industry causes pollution to the environment; geopolymer concrete is an alternative construction material that has comparable mechanical properties to that of OPC and PPC consisting of aluminosilicates and alkali solutions Bagasse ash-based geopolymer concrete hardens through a process of geopolymerization. The hardening process requires heat activation at steam curing temperatures. Thus, Bagasse ash-based Geopolymer concrete will be an adequate construction material for in situ casting as heat curing will be uneconomical. The test is performed by replacing the cementitious material with Bagasse ash for different percentages (5%, 10%, 15%, and 20%). Alkaline liquids (Sodium Hydroxide and Sodium, Silicate solution) mixed with proper ratio (Ratio of Na_2SiO_3 to NaOH is 2.0). A sodium hydroxide solution was made by dissolving NaOH solid in water. Sodium hydroxide solutions were prepared for 12 molar solid mass depending on the solution concentration. For 12 molar solutions, 480gm of NaOH pellet was mixed in 1000 ml of water.

Key Words: Bagasse ash, geopolymer concrete, alkaline liquid, sodium hydroxide, sodium silicate.

1. Introduction

Concrete is a widely used construction material that solidifies over time and consists of cement, fine aggregates (such as sand), and coarse aggregates mixed with water. Portland cement is the most commonly utilized type of cement in concrete production. It finds extensive application in the construction of foundations, columns, beams, slabs, and other load-bearing elements in buildings. The paste used in concrete typically comprises Portland cement, water, and may incorporate supplementary cementing materials like slag cement and admixtures. However, conventional concrete has some limitations. Its tensile strength is relatively low compared to other building materials, and it exhibits less ductility [8]. Additionally, concrete is heavy in relation to its strength and may contain soluble salts that cause efflorescence. Structures subjected to sustained loads can develop creep, and construction joints are incorporated to prevent cracks due to drying shrinkage and moisture expansion. Moreover, the use of Portland cement contributes to increased CO2 emissions, leading to global warming. To address these issues, industrial by-products such as bagasse ash can be employed to enhance the fresh and hardened properties of concrete. This research aims to investigate the impact of using bagasse ash as a partial replacement for Ordinary Portland Cement (OPC)[22]. Strength improvement in concrete can be achieved through ambient curing instead of water curing. Various mix combinations of materials have been tested to determine the ultimate compressive strength, flexural strength, and splitting tensile strength of hardened concrete, comparing these values with those of conventional concrete [3]. The purpose of this investigation is to raise awareness among practicing Civil Engineers about the advantages of these new concrete mixes. To overcome the limitations of conventional concrete, an experimental study on alkali-activated cement, known as Geopolymer concrete [17], with partial replacement by bagasse ash has been conducted. Geopolymer concrete is recognized for its resistance to acid, mechanical properties, and fire resistance, making it a potential alternative construction material with comparable properties to OPC concrete. Geopolymers emit approximately 80% less CO2 than OPC during production, making them more environmentally friendly. Geopolymer concrete typically requires heat curing and is already used in the precast industry where heat curing facilities are available. The goal is to advance geopolymer concrete to a stage where it can be cast in-situ, replacing conventional construction methods. To achieve this, geopolymer concrete must be capable of curing at ambient temperatures, which was investigated in this study. Previous studies in this field have suggested that the addition of slag in the matrix accelerates the curing process and enables ambient temperature curing[18]. Hence, a bagasse ash-based geopolymer concrete was studied in this research. Low calcium-based geopolymer concrete undergoes a process called geopolymerization to harden. The binder, consisting mainly of silica, ferric oxide, and aluminum, undergoes a dissolution process where silica and aluminum ions are released. When slag or ash is added to the geopolymer matrix, Calcium Silicate Hydrates (CSH) are formed alongside the geopolymeric gel. The formation of CSI-I improves both the setting time and compressive strength of bagasse ash-based geopolymer concrete when cured at ambient temperatures.

Objectives:

- To find the suitableness of Sugar Cane Bagasse Ash (SCBA) as partial replacement in concrete mix of M20 grade.
- To study the influence of hardened properties of GPC by varying the percentage of bagasse ash with constant ratio of sodium silicate to sodium hydroxide solution.
- To identify the factors influencing mechanical properties of geopolymer concrete.
- To assess the microstructural characteristics of geopolymer concrete with varying levels of bagasse ash using Scanning Electron Microscopy (SEM).
- To analyze the phase composition and crystallographic properties of geopolymer concrete samples incorporating different proportions of bagasse ash using X-ray Diffraction (XRD)

2. MATERIALS & METHODS

2.1 Bagasse ash

Fly-ash used in this study was from Pandavapura sugar factory near Mandya district. Bagasse ash is a source of silica and aluminium.

- Specific gravity : 1.93

Fig -1: Bagasse ash

2.2 Aggregates.

Locally available aggregates were used comprising of 20mm, 12mm and 6mm and fine-aggregate passing through 4.75 mm all aggregates were in saturated surface dry condition. The course aggregates were crushed granite type and the fine-aggregate used in this study was manufactured sand.

Table -1: Physical characteristics of course-aggregate

Sl. No.	Specific gravity	Fineness modulus	Flakiness index	Density kg/m^3	
				loose	Rodded
1	2.65	6.961	17.56%	1228	1504

Fig -2: Coarse aggregate

Fig -3: Fine aggregate

Table -2: Physical characteristics of fine aggregate

Sl. No.	Specific gravity	Fineness modulus	Density kg/m^3	
			loose	Rodded
1	2.66	2.72	1350	1617

2.3 Alkali Activator

In the alkaline activator substances of Silica are dissolved in strong alkaline conditions with high P^H. During the dissolution of the silica and aluminum the alkaline solution is active and plays a main role in the condensation process (Lindgård et al. 2012). Sodium hydroxide, potassium hydroxide, sodium silicate and potassium silicate are the common activators used for geopolymer. Alkaline liquid was framed by mixing sodium-hydroxide (NaOH) solution and sodium-silicate (Na_2SiO_3) solution. Sodium hydroxide solution was made by dissolving NaOH solid in water. Sodium hydroxide solutions were prepared for 12 molar mass of solid depends on the concentration of solution. For 12 molar solution 480gm of NaOH pellet mixed in 1000 ml of water. Where 1M = 40gm of solid in 1000 ml water, during the development of mixing lot of heat get liberated when dissolving NaOH pellet in water. Therefore solution is kept for cool for 24 hour; this duration is required for polymerization process of alkaline liquids.

2.3.1 Sodium- Hydroxide (NaOH)

Caustic soda is the other name to Sodium hydroxide, which is manufactured by the electrolysis of sodium chloride brine in a membrane or diaphragm electrolytic cell (Occidental Chemical Corporation 2000). Paper industry and manufacturers that need an alkaline based material are the largest users and buyers of caustic soda. Sodium hydroxide (NaOH) is accessible in four varieties: beads, flakes, compounders and solid castings. All the forms have the same chemical composition.

Fig.4. Sodium- Hydroxide flakes

2.3.2 Sodium- Silicate Solution (Na_2SiO_3)

Alkali silicates Solutions are also termed as "water glass". Na_2SiO_3Solution can be produced in two ways one by dissolving alkali silicate pellets in hot water or second way is hydrothermally dissolving a reactive silica source, mainly silica sand, into the respective alkali hydroxide solution (PQ Europe 2004).

Fig.5. Sodium- Silicate Solution

2.4 Super plasticizer

- In order to enhance the ease of handling and shaping fresh concrete, a high-range water-reducing superplasticizer called Conplast SP

430, which is naphthalene-based, is incorporated. This superplasticizer significantly improves the workability of the concrete.

- Conplast SP-430 is based on sulphonated naphthalene polymer.
- It is brown in color and instantly disperses in water.
- Conplast SP-430 has a minimum 12 month of durability when stored in normal temperature.

Fig.6. Conplast SP-430

3. GEOPOLYMER CONCRETE MIX PROPORTION

3.1 Mixing

Fine-aggregates and coarse-aggregates were mixed together dry in 80 liters capacity pan mixer for around 2 to 3 minutes. For Saturated surface dried aggregates are used in the mix . Get ready with alkaline liquid and super plasticizer, and the extra water if required to be added depends upon the workability of concrete [12]. The liquid component alkaline liquid slowly added to the pan with continuous mix with the dry material, this mixing should be again continued up to 2 minutes. Then the addition of liquid in the pan mixer is done and mixed for 1 to 2 more minutes the same procedure were repeated for different percentage replacement of bagasse ash for 5%,10%,15%,20% . Then the prepared fresh-concrete is poured in the workability mould and check the consistency of the concrete. If the GPC doesn't achieve required slump (80 to 100), discard the sample and prepare the fresh mix once again by repeating the same procedure with different mix proportions, then pour the concrete to the moulds prepared which are already oiled or greased and tamped as same as the conventional concrete.

Table -3: Quantity of materials as per the Mix design

Materials	Mass, kg/m^3		
Coarse aggregate	15%	20mm	277
	20%	12mm	370
	35%	6mm	647
Fine aggregate (30%)	554		
Fly ash	394.28		
Na_2SiO_3	112.66		
NaOH	45.06		
Super plasticizer	2.0 %		
Extra water	5 %		

Fig.7. Fresh Geopolymer Concrete mix

3.2 Curing of geopolymer concrete

After the preparation of fresh concrete the concrete is filled in the moulds and leave them 24 hours in the room temperature and then it is demoulded and kept in oven for curing at the temperature of 60^0 C for 24 hours [15]. The curing temperature will also influence the concrete strength. The chemical reaction occurs in the GPC, the process of polymerization takes place in the curing period. Later the specimens were allowed to ambient curing. Some researches noticed that even curing these specimens in oven for extended duration with constant temperature may increase the strength properties of the geopolymer-concrete.

Fig.8. Oven curing of Geopolymer-Concrete specimens

4. TEST RESULTS & DISCUSSIONS

4.1 Compressive-Strength on GPC

Concrete is primarily employed for structural applications, including foundations, columns, beams, and floors, and as such, it must possess the capacity to withstand the anticipated loads. To evaluate its suitability for these purposes, a concrete cube test is conducted, which determines the compressive strength of the concrete and directly correlates to the designated design strength [9]. Compressive strength, in turn, plays a significant role in ensuring durability, as higher compressive strength typically leads to improved durability.

Relevant Indian Standards: **As per code IS: 516-1959**

Compressive strength = [P/A] N/mm^2

Cross sectional area of cube = $0.0225 m^2$,

Table -4: Compressive-strength test results

compressive strength (MPa)			
% of Bagasse ash	7Days	14Days	28Days
5%	18.59	21.1	25.63
10%	22.65	28.63	31.42
15%	20.79	22.72	24.87
20%	13.05	19.74	21.23

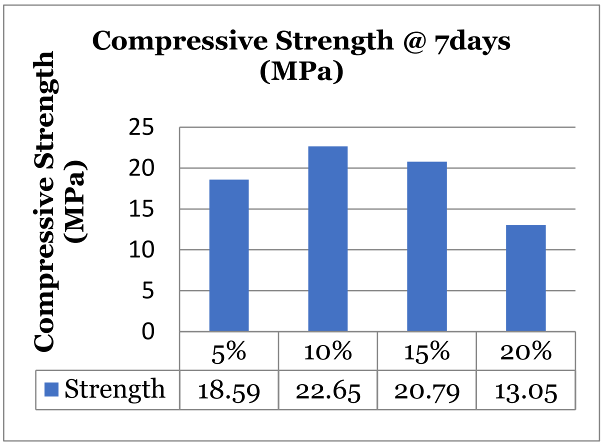

Chart -1: Compressive strength @ 7 days

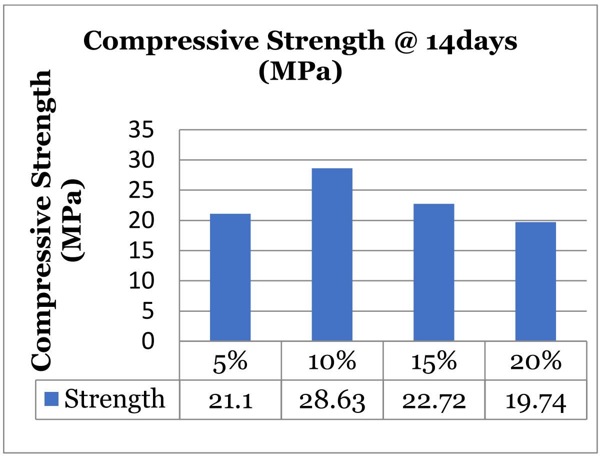

Chart -2: Compressive strength @ 14 days

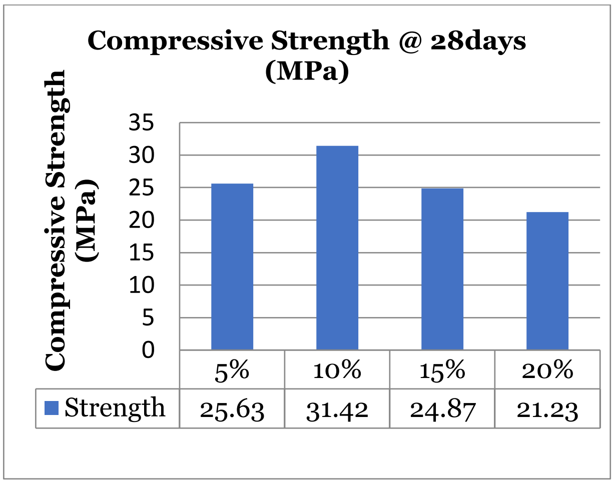

Chart -3: Compressive strength @ 28 days

4.2 Split-Tensile Strength on GPC

Tensile strength is a fundamental and crucial property of concrete. Due to its relatively low tensile strength and brittle characteristics, concrete is not typically relied upon to withstand direct tension. Nevertheless, it is essential to determine the tensile strength of concrete in order to assess the point at which it may develop cracks. Cracks in concrete are a manifestation of tension or flexural failure [9].

Cross sectional area of cylinder = [(2xP) / (πxdxL)] N/mm^2

Table -5: Split-Tensile strength test results

Split Tensile strength (MPa)			
%of Bagasse ash	7Days	14Days	28Days
5%	1.546	1.694	2.078
10%	1.693	2.264	2.641
15%	1.428	2.081	2.327
20%	1.278	1.912	2.112

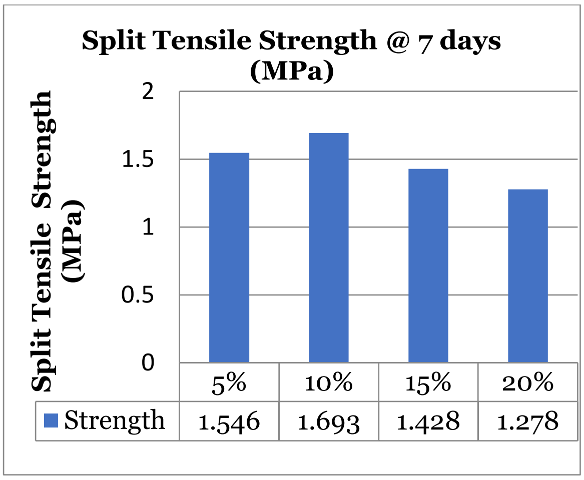

Chart -4: Split-tensile strength @ 7 days

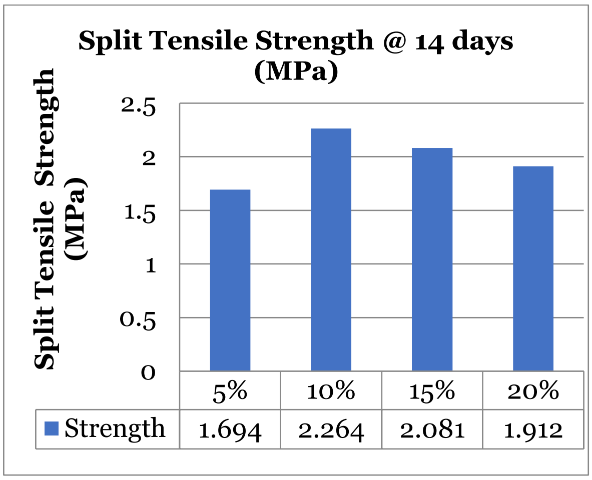

Chart -5: Split- tensile strength @ 14 days

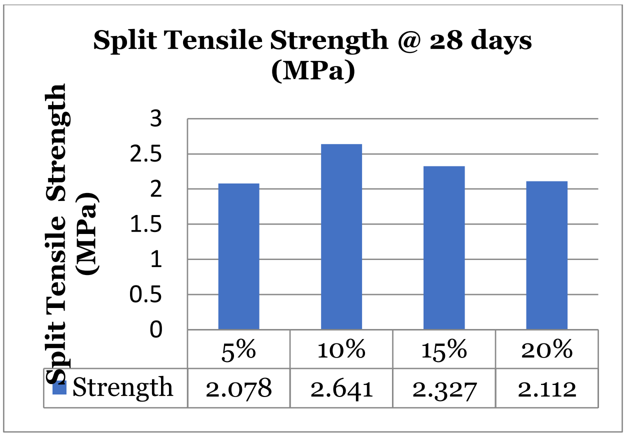

Chart -6: Split tensile strength @ 28 days

4.3 Scanning Electron Microscopy (SEM) analyses

4.3.1 SEM Analysis

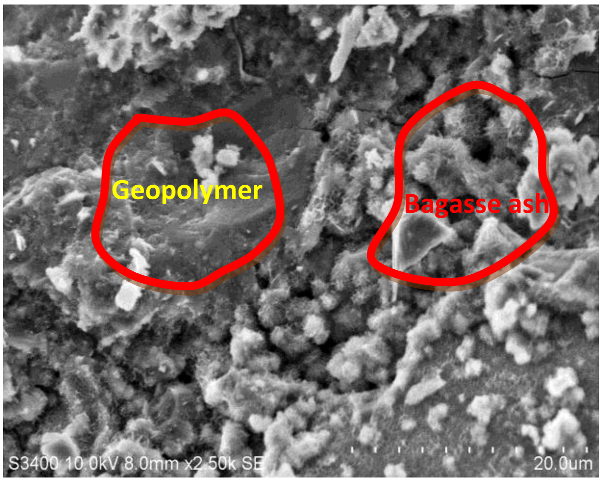

Fig.9: SEM image of 10% Bagasse ash based GPC

Observation:

- As per the SEM analyses of 10% replacement of bagasse ash from the above **Figure.9**, the complete C-S-H formation appears in the image and also it clearly appears that in the right side portion of the image Bagasse ash particle with fibrous particles on the surface of the Bagasse ash.

- Homogeneous distribution of C-S-H formation: The SEM analysis reveals a uniform and complete C-S-H (Calcium Silicate Hydrate) formation throughout the image. The presence of C-S-H indicates that the chemical reaction between bagasse ash and the surrounding cementitious materials was successful in producing the desired hydration products. The homogeneous distribution of C-S-H suggests that the bagasse ash is capable of contributing to the cementitious matrix uniformly, potentially enhancing the overall strength and durability of the concrete.
- Larger fibrous particles on the right side of the bagasse ash particle: The SEM analysis shows that on the right side portion of the image, there are larger fibrous particles attached to the surface of the bagasse ash particle. These fibrous particles might have formed due to the specific characteristics of the bagasse ash or could be a result of the hydration process during the interaction with cementitious materials. The presence of larger fibrous particles indicates some heterogeneity in the bagasse ash sample and may have implications for its mechanical properties or reactivity when incorporated into concrete.
- In conclusion, the SEM analysis confirms the presence of complete C-S-H formation throughout the image, signifying the successful reactivity of bagasse ash with cementitious materials. Additionally, the presence of larger fibrous particles on the right side of the bagasse ash particle suggests some degree of heterogeneity, which could be relevant to its performance as a supplementary cementitious material in concrete applications. Further investigations are needed to understand the influence of these fibrous particles on the overall behavior of the bagasse ash in concrete mixes.

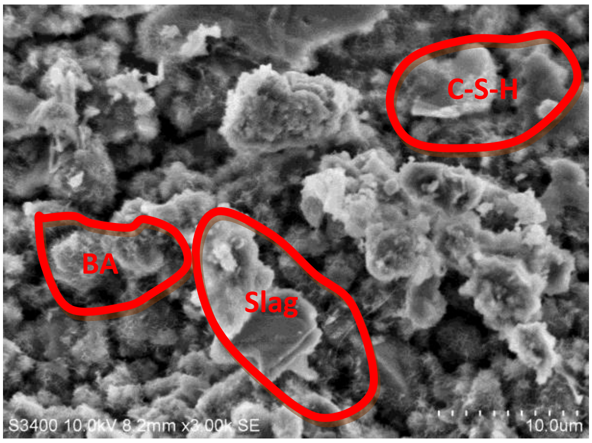

Fig.10: SEM image of 15% Bagasse ash based GPC

Observation:

- According to the SEM analyses of 15% replacement of bagasse ash from the above **Figure.10**, the slag appears perfect in this dosage and bagasse ash appears with fibrous particle on the surface, which shows the perfect blend of Geopolymer concrete.
- Perfect blend of Geopolymer concrete: The SEM analysis indicates that the combination of 15% replacement of bagasse ash with slag results in a "perfect blend" of Geopolymer concrete. This suggests that the incorporation of 15% bagasse ash as a replacement material, along with slag, has led to a desirable microstructure and morphology in the concrete. The perfect blend of Geopolymer concrete implies that the mixture has achieved the desired properties, such as strength, durability, and overall performance, making it suitable for practical applications.
- Presence of fibrous particles on the surface of bagasse ash: The SEM analysis reveals the presence of fibrous particles on the surface of bagasse ash particles. These fibrous particles might be a characteristic feature of bagasse ash or could have formed during the interaction with other components in the Geopolymer concrete. The presence of fibrous particles may have implications for the mechanical properties and reactivity of the concrete mix, but in this context, they are deemed as contributing to the "perfect blend" of the Geopolymer concrete.
- Finally, the SEM analysis shows that the 15% replacement of bagasse ash in combination with slag has resulted in a Geopolymer concrete with

a "perfect blend." The presence of fibrous particles on the surface of bagasse ash is likely contributing to the desired microstructure and overall performance of the concrete. This suggests that the chosen blend of materials is well-suited for producing high-quality Geopolymer concrete with potentially improved properties compared to traditional cement-based concrete mixes.

4.4 X Ray Diffraction (XRD) analyses

4.3.2 XRD Analysis

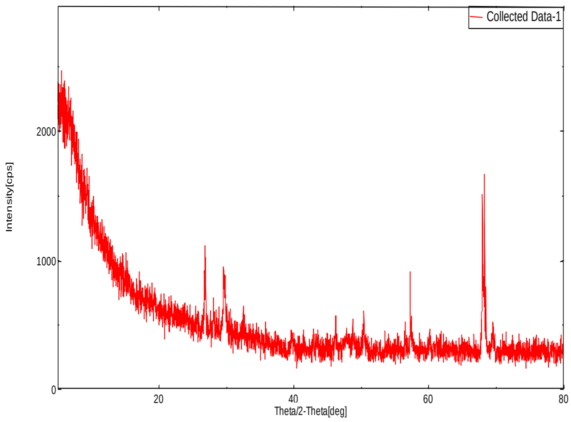

Fig.11: X – Ray Diffraction pattern of GPC with 10% Bagasse ash

Observation:

- According to the XRD analysis pattern of BA of 10% replacement from the above **Figure.11**, the bagasse ash was mainly amorphous silica as indicated by the small hump around 25 to 30° θ/2 with small amount of quartz. And later at 70° θ/2 good indication of quartz appears with sudden increase in the intensity.
- Gradual transition from amorphous silica to quartz: The XRD analysis pattern indicates a gradual transition from amorphous silica to quartz as the angle (θ/2) increases. At angles around 25 to 30 degrees θ/2, a small hump is observed, which corresponds to the presence of amorphous silica. However, at 70 degrees θ/2, a significant increase in the intensity of the quartz peak is evident, suggesting the transformation from the amorphous phase to the crystalline phase of silica.
- Increased quartz content at 70 degrees θ/2: The XRD analysis shows a notable increase in the intensity of the quartz peak at 70 degrees θ/2. This indicates a higher concentration of quartz in the bagasse ash sample at this specific angle. The higher quartz content might have implications for the material's properties and behavior, as quartz is a crystalline phase known for its hardness and durability.
- As per the above statements, the XRD analysis provides evidence of a gradual transformation from amorphous silica to quartz as the angle increases. The sudden increase in quartz intensity at 70 degrees θ/2 suggests a higher concentration of quartz at that angle, indicating potential changes in the material's characteristics and properties.

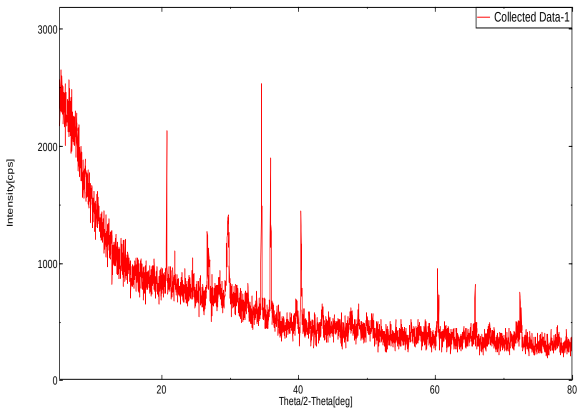

Fig.12: X – Ray Diffraction pattern of GPC with 15% Bagasse ash

Observation:

- According to the XRD analysis pattern of BA of 15% replacement from the **Figure.12**, the bagasse ash was mainly amorphous silica as indicated by the variations around 25 to 30° θ/2 with considerable hump. At later increase in the θ value, no such observation appears. Around 38° θ/2 a considerable increase in the quartz indicates in the 15% replacement of BA based GPC.
- Amorphous silica dominance with a significant hump: The XRD analysis pattern shows that the bagasse ash with 15% replacement is mainly composed of amorphous silica. This is indicated by the variations observed around 25 to 30 degrees θ/2 with a considerable hump. The presence of a hump in this region is a characteristic feature of amorphous materials, indicating the absence of long-range crystalline order.

- Absence of significant observations at later θ values: As the θ value increases beyond the range of 25 to 30 degrees θ/2, the XRD analysis does not show any significant observations or variations. This suggests that at higher angles, there are no distinct peaks or patterns indicating the presence of other crystalline phases. The absence of peaks beyond this range indicates that the dominant phase in the bagasse ash at 15% replacement is amorphous silica, and there is no other crystalline phases present in notable quantities.
- In summary, the XRD analysis confirms the presence of predominantly amorphous silica in the bagasse ash with 15% replacement. The considerable hump observed around 25 to 30 degrees θ/2 signifies the dominance of the amorphous phase. Additionally, at higher angles, no other significant peaks or observations are evident, indicating the absence of other crystalline phases in considerable amounts.

5. Conclusions:

1. As comparing to the fresh properties of the bagasse ash based geo polymer concrete at 15% replacement of bagasse ash a slump of 80 mm is obtained, which was very good in workability,

2. Bagasse ash based GPC has a very good earlier strength at 10% of bagasse ash than the later age strength, because of variation in ambient temperature.

3. The compressive- strength of geopolymer concrete with 10% of bagasse ash increases by 18.42% than the GPC with 5% of bagasse ash and the compressive-strength of GPC with 15% of bagasse ash is increased to 20.85% than GPC with 10% of bagasse ash. Further 20% replacement of Bagasse ash showed decreasing in the strength. This concludes that optimum dosage of BA with cement is 10% by weight of cement.

4. The Split tensile strength of GPC with 10% Bagasse ash increases by 21.32% than the GPC with 5% Bagasse ash and tensile strength of GPC with 15% of bagasse ash is decreased by 11.89% than the strength of GPC with 10% of bagasse ash. This concludes the optimum dosage of Bagasse ash is 10% of the weight of the cement.

5. The XRD analysis indicated that the bagasse ash primarily consisted of amorphous silica, with a small amount of quartz present. The sudden increase in quartz intensity at 70 degrees θ/2 may be an indication of a specific phase or concentration change in the sample at that angle.

6. Bagasse ash showed a predominantly amorphous silica phase: The XRD analysis revealed a small hump around 25 to 30 degrees θ/2, which indicates that the majority of the bagasse ash consisted of amorphous silica. Amorphous silica refers to a non-crystalline form of silica, which lacks long-range order in its atomic structure.

7. Complete C-S-H (Calcium Silicate Hydrate) formation: The SEM analysis revealed the presence of complete C-S-H formation in the image. C-S-H is a crucial cementitious phase that contributes to the strength and durability of concrete. Its presence suggests that the reaction between bagasse ash and the surrounding cementitious materials was successful, leading to the formation of the desired hydration products.

REFERENCES

[1] Davidovits, J. (1994), "High-Alkali Cements for 21st Century Concretes". ACI Special Publication, P.N-144.

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

[3] Akram T, Memon S A, Obaid H (2009), "Production of low-cost self compacting concrete using bagasse ash", Construction and Building Materials, 23(2), pp.703-712.

[4] Sales, S. A. Lima (2010), “Use of Brazilian sugarcane bagasse ash in concrete as a sand

replacement". Waste Manag. 30 (2010) 1114 – 1122.

[5] JE Oh, PJM Monteiro, SS Jun, S Cho (2010), "The evolution of strength and crystalline phases for alkali-activated ground blast furnace slag and fly-ash based geopolymers", Cement & Concrete, Elsevier.

[6] R. Zhao (2011). "Geopolymer and Portland cement concretes in simulated fire", Magazine of Concrete Research, 63(3), 163–173.

[7] A Bhowmick, S Ghosh (2012), "Effect of synthesizing parameters on workability and compressive strength of fly ash based geopolymer mortar", International Journal of Civil & Structural, indianjournals.com.

[8] 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.

[9] Badami Bhavin (2013), "Geopolymer Concrete and Its Feasibility in India", Proceedings of National Conference CRDCE13, P.No.20-21.

[10] 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.

[11] 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.

[12] U.R. Kawade (2014), "Fly Ash-Based Geopolymer Concrete", International Journal of Innovative Research in Science, Engineering and Technology Volume 3, Special Issue 4, April 2014.

[13] K Ramujee (2014), "Development of low calcium fly ash based geopolymer concrete ", International Journal of Engineering and Technology, researchgate.net.

[14] 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.

[15] Tony Suman Kantha 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.

[16] 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.

[17] G Gorhan, G Kurklu (2015), "The influence of the NaOH solution on the properties of the fly ash-based geopolymer mortar cured at different temperatures", Composites Part B: Engineering, Elsevier.

[18] Sujay Chetan Nanavati (2017), "A Review on Fly Ash-based Geopolymer Concrete & quote", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 14, Issue 4 Ver. VII, PP 12-16.

[19] G. C. Cordeiro, K. E. Kurtis (2017), "Effect of mechanical processing on sugarcane bagasse ash pozzolanicity". Cement Concrete Res. 97 (2017) 41 – 49.

[20] S. Deepika, G. Anand, A. Bahurudeen, M. Santhanam (2017), "Construction products with sugarcane bagasse ash binder". J. Mater. Civ. Eng. 29 (2017) 4017189.

[21] M S Padmanaban, Sreerambabu J (2018), "Geopolymer concrete with GGBS", International journal of engineering sciences & research Technology, pp 2277-9655.

[22] M. Khan, M. Ali (2019), "Improvement in concrete behavior with fly ash, silica-fume, and coconut fibers". Construct. Build. Mater.

[23] H. Sasanipour, F. Aslani, J. Taherinezhad (2019), "Effect of silica-fume on the durability of self - compacting concrete made with waste recycled concrete aggregates". Construct. Build. Mater. 227-116598.

[24] H. Chol, J. Lee, B. Lee, J. Nam (2019), "Shrinkage properties of concretes using blast furnace slag and frost-resistant accelerator". Construct. Build. Mater. 220 (2019) 1– 9.

[25] X. Li, J. Liu, J. Qin, Y. Liu, Y. Qu, R. Zhang (2019), "Dissolution behavior of a novel composite fiber made from blast furnace

slag". Construct. Build. Mater. 206 (2019) 442 – 448.

[26] J. Rissanen, C. Giosué, K. Ohenoja, P. Kinnunen, M. Marcellini, M. L. Ruello, F. Tittarelli, M. Illikainen (2019), "The effect of peat and wood fly ash on the porosity of mortar". Construct. Build. Mater. 223 (2019) 421 – 430.

[27] G. P. Lyra, V. dos Santos, B. C. De Santis, R. R. Rivaben, C. Fischer, E. M. de J. A. Pallone, J. A. Rossignolo (2019), "Reuse of sugarcane bagasse ash to produce a lightweight aggregate using microwave oven sintering". Construction and Building Materials, Volume 222, 20 October 2019, Pages 222-228.

[28] Parthiban Kathirvel, Murali Gunasekaran, Sreenath Sreekumaran, Arathi Krishna (2020), "Effect of partial replacement of Ground granulated blast furnace slag with sugarcane bagasse ash as source material in the production of geopolymer concrete". Materials Science, Vol.26, No-04, P.No:477-481.

[29] Muhammad Nasir Amin, Muhammad Ashraf, Rabinder Kumar, Kaffayatulla Khan, Daniyal Saqib, Syed Sajid Ali, Sajidullah khan (2020), "Role of sugarcane bagasse ash in developing sustainable engineered cementitious composites", Frontiers in Materials, Vol.7, Article:65, 2020.

[30] Deepa G Devadig, K.Subrahmanya Bhat, GT Mahesha (2020), "Sugarcane bagasse fiber reinforced composites:Recent advances and applications", Cogent Engineering, Vol.7, P.No:1-12.

[31] Arun Kumar Parashar, Ankur Gupta (2020), "Investigation of the effect of bagasse ash, hooked steel fiber and glass fiber on the mechanical properties of the concrete", Materials Today: Preceedings, Elsevier.

[32] Muhammad Jahanzabib Khalil, Muhammad Aslam, Sajjad Ahmad (2020), "Utilization of sugarcane bagasse ash as cement replacement for the production of sustainable concrete – A review", Construction and Building materials, Elsevier.

[33] Edyta Pawluczuk, Katarzyna Kalinowaska, Jose Ramon Jimenez, Jose Maria Fernandez Rodriguez, David Suescum Morales (2021), "Geopolymer concrete with treated recycled aggregates: Macro and micro structural behavior", Journal fo Building Engineering, Elsevier, Vol.44.

[34] Athika Wongkvanklom, patcharapol Posi, Arpichit Kampala, Traitot kaewngao, Prinya Chindaprasirt (2021), "Beneficial utilization of recycled ashphaltic concrete aggregate in high calcium fly ash geopolymer concrete", Case studies in Construction materials, Elsevier, Vol.15.

[35] Akshit Lamba, Swati Agrawal, Abhinav Dubay (2021), "Analysis of use of sugarcane bagasse ash for the production of geopolymer concrete", International Research Journal of Modernization in Engineering technology and Science, Vol.03, Issue-05/may/2021.

[36] Ahmad L Almutairi, Bassam A tayeh, Adeyemi Adesina, Haytham F isleem, Abdullah M Zeyad (2021), "Potential applications of geopolymer concrete in construction: A review", Case studies in Construction Materials, Elsevier, Vol.15.P.No.1-20.

[37] K. Ramakrishnan, V. Ganesh, G. Vignesh, M. V ignesh, V. Shriram, R. Suryaprakash (2021), "Mechanical and durability properties of concrete with partial replacement of fine aggregate by sugarcane bagasse ash (SCBA)", Materials Today: Proceedings, Volume 42, Part 2, 2021, Pages 1070-1076.

[38] Zhihang Wang, Erlei Bai, He Huang, Chaolia Liu, Tengjiao Wang (2022), "Dynamic mechanical properties of carbon fiber reinforced geopolymer concrete at different ages", Ceramics International, Elsevier, Vol.49, P.No-834-846.

[39] Yang Li, Jiaqi Chai, Ruijun Wang, Xu Zhang, Zh eng Si (2022), "Utilization of sugarcane bagasse ash (SCBA) in construction technology: A state-of-the-art review", Journal of Building Engineering, Elsevier, Volume 56, 15 September 2022, 104774.

[40] G. Anusha, R. Dinesh kumar (2022), "Study on paver blocks using waste plastics and sugarcane bagasse ash", Materials Today: Proceedings, Volume 68, Part 6, 2022, Pages 2088-2092.