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Investigation of Sugarcane Bagasse Ash (SBA)-Based Engineered Geopolymer Mortar Reinforced with Coconut Fibre for Engineered Geopolymer Composites

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Abstract:- In recent years, there have been growing demand for fibre-reinforced cementitious composites using materials wastes to reduce cost and cement usage in concrete production. Therefore, this study aims to prepare sugarcane bagasse ash (SBA)-based geopolymer reinforced with coconut fibre as a material suitability evaluation for engineered geopolymer composites. The sugarcane baggase ash was characterised for its physical and chemical properties using scanning electron microscopy (SEM), Energy dispersive X-ray spectroscopy (EDS), X-ray powder diffraction (XRD). The coconut fibres was added at 0%, 1%, 2%, and 3%, while the plain cement mortar was used as the control mix. Both destructive (compressive and tensile strength) and non-destructive test (water absorption, and ultrasonic pulse velocity test) were conducted on the resulting geopolymer mortar. The result of the SBA characterisation showed that the SBA met the ASTM C618 requirement for a pozzolanic material. The addition of 1% fibre to the geopolymer composite resulted in enhanced durability property than the plain cement mortar. The ultrasonic pulse velocity test demonstrated that bagasse ash-based geopolymer composites can be classified as a excellent cementitious material. The study also found the engineered cementitious composite showed better compressive and tensile strength than the plain concrete mortar, while the addition of fibre provided a denser microstructure for additional strength. The optimum fibre content was found at 1% for improved water absorption performance, UPV, and compressive strength. The study concludes that SBA composite reinforced with coconut fibre can provide better alternatives to achieve sustainability in engineered geopolymer concrete applications.

Keywords:- *Sugarcane Bagasse Ash; Coconut Fibre; Geopolymer Mortar; Engineered Cementitious Composites; Compressive Strength, Tensile Strength.*

I. INTRODUCTION

Concrete made from portland cement is one of the most widely used manmade construction materials (Akbar et al., 2021). The portland cement is an essential cohesive agent in concrete that has been tested and verified by past research findings. As the world grows in the construction of the built environment, the cement industry contributes about 6-9% of the world's carbon emission (World Economic Forum, 2022). The production process involves the use of massive raw materials and energy consumption, leading to a rise in CO_2 emission (He et al., 2019). In addition to increasing cost of cement production, the method of production also contributes to environmental degradation. Given these, it is imperative to minimize energy consumption and reduce CO2 emissions throughout the cement production phase in a manner that is both secure and environmentally sustainable.

Over the past few decades, the surge in agricultural expansion has called for an effective handling of agricultrual waste materials, given that a large portion of these wastes are disposed in landfills, leading to reduction of green land areas, and contamination of the environment. As a result, research attention shifted to the use of agricultural wastes for both binary and tenary replacement of cement in concrete production (Thomas, et al., 2017). Several agricultural residue has been found significant as cement replacement, however, the resulting bottom ash (BA) or fine waste got the attention of most researchers showing that they can be used as supplementary cementitious materials (Khan & Ali, 2019). For instance, materials such as elephant grass ash (EGA) (Nakanishi, et al., 2016), palm oil fuel ash (POFA) (Thomas, et al., 2017), paper mill ash (PMA) (Fava, et al., 2010), corn cob ash (CCA) (Adesanya & Raheem, 2009), and sugarcane bagasse ash (SBA) (Cordeiro and Kurtis, 2019; Sales and Lima, 2010) have been found positive and useful in the development of engineered cementous supplements in concrete production. The findings across these research suggest that the addition of bottom ash (BA) from agricultural wastes can improve mechanical properties of concrete, whie reducing greenhouse gas (GHG) emissions in the process.

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Sugarcane bagasse is one the agricultural wastes employed more valuably in modern concrete and geotechnical research. Sugarcane bagasse (SCB) is the waste bye-product of juice extraction from sugarcane. It is estimated that about 280 kg wet bagasse is produced from one tons of cane processed in major cities in India (Joshaghani, 2017). The calcination of sugarcane bagasse has a high silica content, which is about 53.1% w/w (Norsuraya, Fazlena, & Norhasyimi, 2016). Some researchers are of the submission that it is possible to produce silica from SCBA using simple methods, and that this produced silica with purity above 98%. The amorphous nature of silica in sugarcane bagasse makes it extractable at a lower temperature range. Thermal degradation and pyrolysis of sugarcane bagasse followed by the combustion of the char results in a highly porous and amorphous silica with a varying percentage of unburnt carbon (Ghosh & Ghosh, 2012). Practical application of the ash produced from the pyrolysis of sugarcane bagasse, has initiated the progress of geopolymer production (Faisal & Muhammad, 2016), phillipsite zeolite synthesis (Patcharin, et al., 2012), mesoporous silica as a catalyst (Rahman, et al., 2015), and sodium water glass (SWG) (Tchakouté, et al., 2017), among others. Within these applications, the SiO2 composition of SBA gave rise to the several research exploration of SBA application in cement production. The research focused greatly on using bagasse ash in cement-based materials to improve their ability to bind and reduce carbon emission (Fairbairn, et al., 2010; Chusilp, et al., 2009). The bagasse ash has been found to have pozzolanic properties where the reaction between amorphous silica and calcium hydroxide increases the binding capacity.

To contribute to the growing knowledge on SBA application, this study presents an analysis of the effect of SBA geopolymer with coconut fibres (Coir) to enhance its cementitious property. The result from this study emphasise the significance of integrating bagasse ash to improve the performance of cement mortar by the addition of coir fibre. The coir fibres apart from its resistance to microorganisms and weathering, it is lighter than other fibres, with appreciable durability properties and water absorption capacity (Celica, et al., 2013). In Southwest Nigeria, coir fibres are agricultural wastes found on landfill. Therefore, the study adopts coir fibre based on its availability, cost impact on the project, and its environmental advantage.

In addition, this study adds to the current knowledge that a cost and eco-friendly coir-fibre-SBA geopolymer can replace conventional cement in concrete production in the near future. As a result, the study aims to:

- Analyse the physical and chemical properties of SBA for its suitability as a geopolymer mortar.
- Assess the properties of bagasse ash in both the fresh and hardened state as a constituent of the geopolymer composite.
- Comparatively evaluate the behaviour of the geopolymer cementitious composite with and without the addition of coconut fibres.
- Determine the optimal percentage of coconut fibres that will result in the highest compressive strength improvement.

II. MATERIALS AND METHODS

A. Materials for Geopolymer Mortar

➢ *Sugarcane Bagasse Ash (SBA)*

The sugarcane bagasse (SCB) was obtained from local sugarcane distributors in Ilorin, Kwara State, Nigeria. The SCB was cut into uniform sizes and sun-dried for 48 hours before burning. The burning process, conducted at the Department of Civil Engineering, Kwara State Polytechnic, involved heating a blast furnace to 700°C, then turning it off. The SCB was placed in the furnace for 30 minutes and allowed to cool at 25°C for another 30 minutes, as per Abdulkadir et al. (2014). This process was repeated twice to obtain white amorphous bagasse ash.

The ash was weighed and subjected to sieve analysis using a 300 mm sieve, following Rukzon and Chindaprasirt (2014). The sieved bagasse ash was then treated with hydrochloric acid (HCl) to remove aluminum and iron content. Five grams of SBA were stirred with 50 ml of 1M HCl for 2 hours at room temperature, based on the method described by Norsuraya et al. (2016). The mixture was filtered using Whatman No. 41 ashless filter paper, and the residue was washed with 20 ml of distilled water to remove metallic ions. The final residue was air-dried for 24 hours.

The chemical composition of the final SBA was analyzed using X-ray fluorescence (See Table 1). The combined SiO2, Al2O3, and Fe2O3 content was 80.71%, exceeding the 70% requirement for natural pozzolans according to ASTM C618 (2001). SiO2 was the predominant element at 66.94%.

Fig 1 Image of the SBA during the Seiving Process

Table 1 Chemical Characteristics of Sugarcane Bagasse Ash (SBA)

Element	Content	Detection limit	Error
Al2O3(%)	12.5091	0.0000	0.3776
SiO2(%)	66.9364	0.0000	0.3849
P2O5(%)	0.6927	0.0000	0.0075
SO3(%)	0.2020	0.0000	0.0018
K2O(%)	3.8510	0.0000	0.1714
CaO(%)	2.9137	0.0000	0.0868
TiO2(%)	0.1535	0.0000	0.0078
MnO(%)	0.0652	0.0000	0.0025
Fe2O3(%)	1.2615	0.0000	0.0093
CuO(%)	0.0050	0.0000	0.0002
ZnO(%)	0.1044	0.0000	0.0017
SrO(%)	0.0227	0.0000	0.0003
ZrO2(%)	0.0179	0.0000	0.0001
Nb2O5(%)	0.0132	0.0000	0.0001
Ag2O(%)	0.0005	0.0000	0.0000
PbO(%)	0.0072	0.0000	0.0003

To identify the elemental contents and energy ranges of minerals in the SBA, Energy Dispersive X-ray Spectrometry Analysis (EDAX) was conducted, as shown in Figure 2. Most significant elements in the SBA were detected at energy levels below 12 keV, except for zinc, niobium, and strontium, which appeared above 12 keV. Overall, 99% of elements exhibited energy levels below 24 keV. The presence of aluminum (Al) and silicon (Si) with oxygen at energies below 3 keV resulted in the lowest peaks, indicating that most minerals are within the lower energy range. These peaks are associated with the emission of k-shell X-rays.

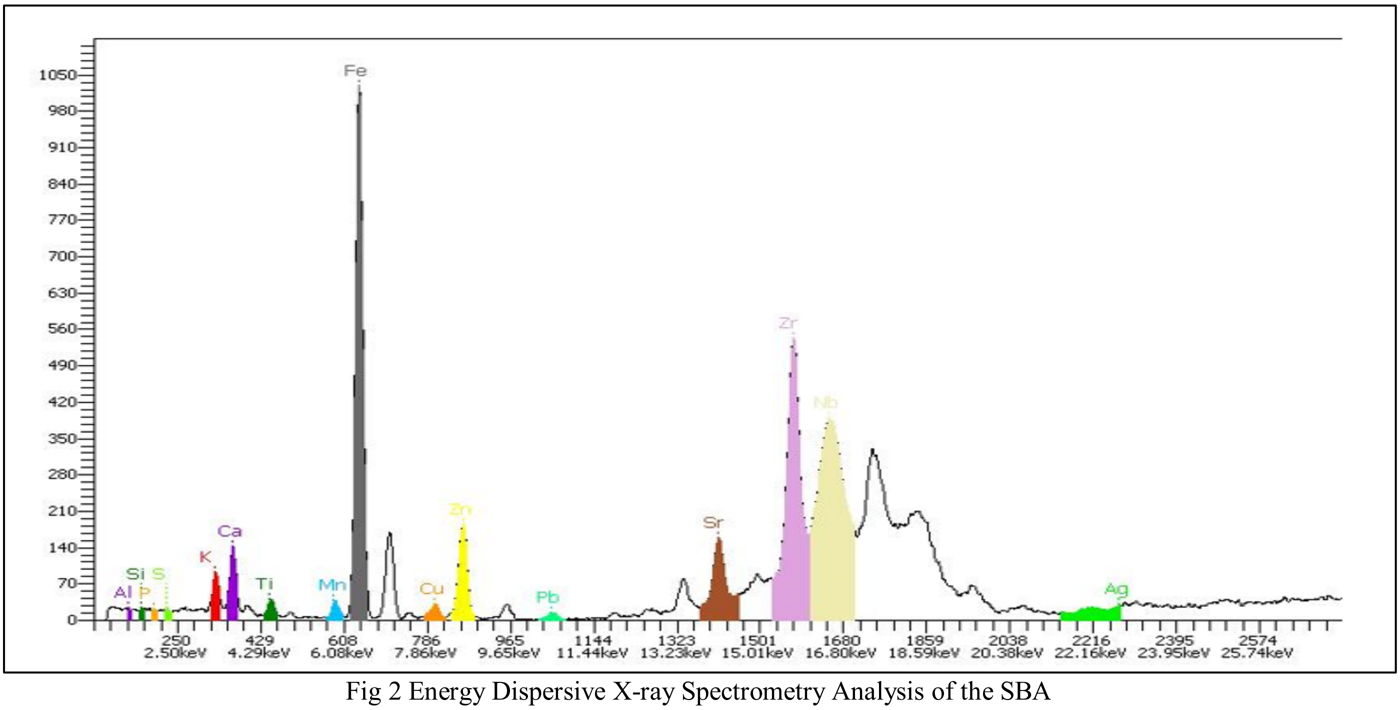

Fig 2 Energy Dispersive X-ray Spectrometry Analysis of the SBA

The EDAX analysis of SCBA reveals the presence of low atomic number minerals such as Al, K, Mn, and P, indicating a low energy range. A higher peak at 6.08 keV confirms the presence of iron, supported by the chemical analysis results shown in Table 1. The analysis also indicates that 66.94% of the SCBA is silica, alongside Al, Fe, Mn, and K, with a high concentration of oxygen elements, suggesting sufficient pozzolanic minerals in the SCBA.

To verify the amorphous nature of the silica in SCBA, X-Ray Diffraction (XRD) analysis was performed. The XRD results, shown in Figure 3, display continuous intensity changes and shifts in the two-theta values, indicating alterations in the internal atomic arrangement. The XRD pattern reveals significant humps at 25°θ and 38°θ, indicating the presence of amorphous silica, quartz, and cristobalite. This suggests that some silica in SCBA exists as elongated spheres, primarily consisting of a silica structure with minor quartz crystal phases.

The microstructural analysis using Scanning Electron Microscopy (SEM) at 100 µm and 200 µm, presented in Figure 4, shows a layered and columnar fibrous structure of SCBA. At 100 microns, the material exhibits small holes and irregular surface features, indicating a porous structure. This detailed characterization supports the suitability of SCBA as a pozzolanic material with significant potential for use in geopolymer composites.

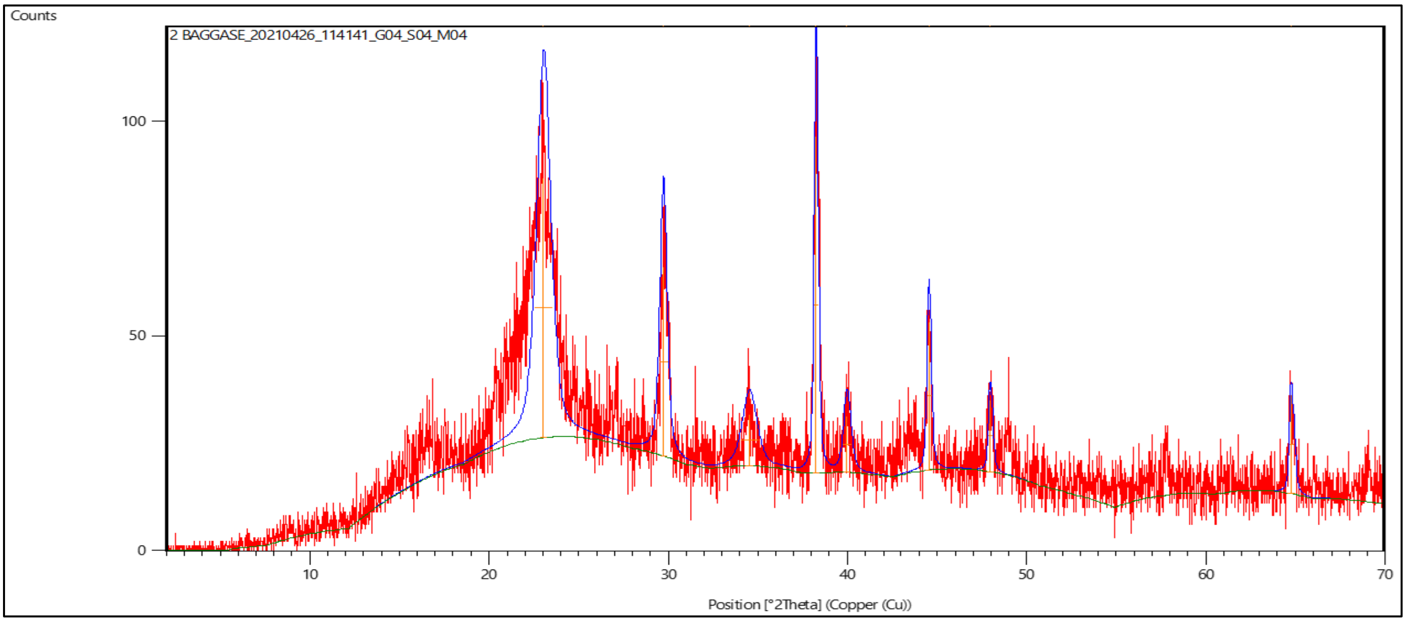

Fig 3 X-ray Diffraction Analysis of the Sugarcane Bagasse Ash (SBA).

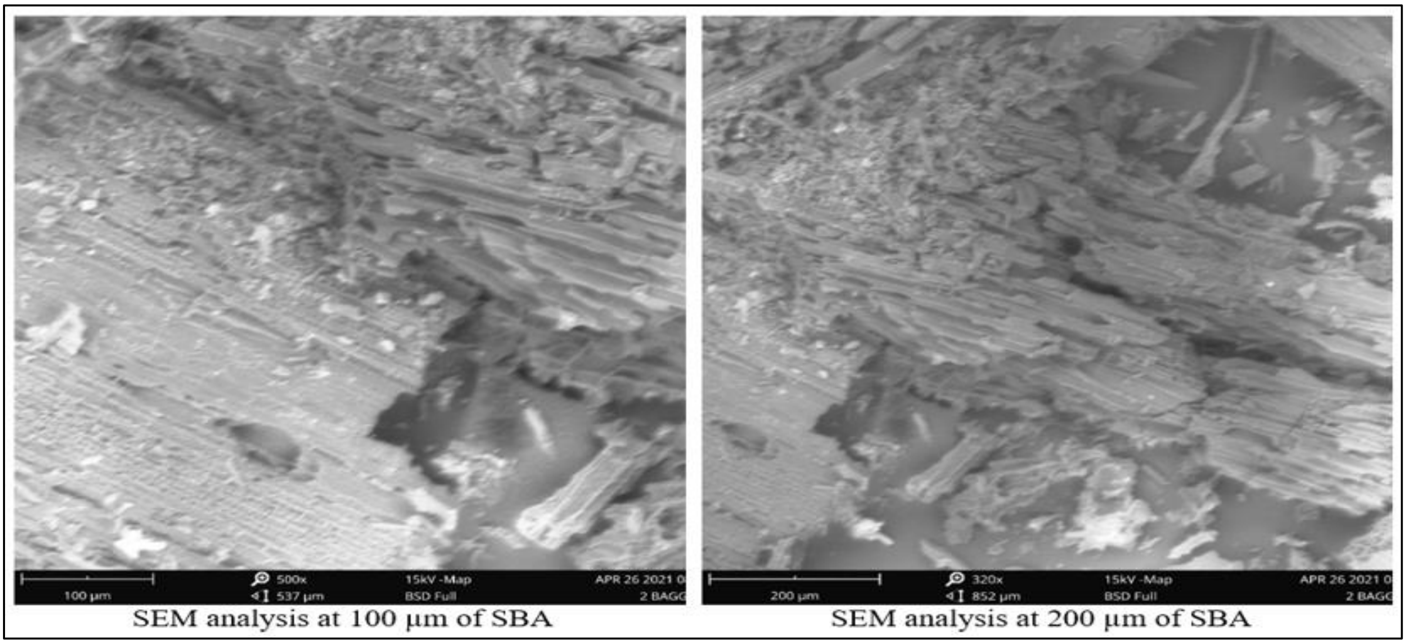

Fig 4 SEM analysis at 100 and 200 µm of the SBA

➢ *Alkaline Activator*

This study employs a two-stage process for producing geopolymer mortar using an alkaline activator. Typically, three activators are used in geopolymer concrete: sodium silicate, sodium hydroxide, potassium hydroxide, or their mixtures. Research by Shoaei et al. (2019) shows that sodium hydroxide (NaOH), alone or combined with sodium silicate (Si), enhances strength properties and accelerates geopolymer processing. The concentration of the alkaline activator affects both the fresh and hardened properties of geopolymer mortar (Hanjitsuwan et al., 2014). For this study, the activator solution was prepared at the University of Ilorin's Chemistry Department, comprising sodium hydroxide and sodium silicate with concentrations of 10% Na_2O and 30% SiO_2.

➢ *Coconut Fibres (Coir)*

The coconut fibres were extracted from coconut wastes found at Badagry area of Lagos State, Nigeria. The extracted fibres were carefully removed, sundried, cut into smaller length at 10mm (Aguwa, 2013), and tested for physical properties in Table 2.

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Table 2 Physical Characteristics of the Coir Fibre

Physical Properties	
Specific Surface Area	210 m^2/kg
Fibre Diameter	20 µm
Density	1.35 g/cc
Fibre Length	10 mm
Tenacity	13.85
Specific Gravity	0.95 kg/Lt
Purity	100%
Swelling in water	88.35 %

➢ *Superplasticizer*

To mitigate the high viscosity of the alkaline activator solution and counteract the workability reduction due to the coir fibre mixture, Conplast SP 430 was chosen as a water reducing agent. This agent, containing sulphonated naphthalene polymers, was selected in accordance with ASTM C-494 (2020) standards to enhance workability and reduce slump retention in the geopolymer mortar.

➢ *Fine Aggregates*

Natural river sand obtained from vendors in Ilorin was used as fine aggregates. Sieve analysis was performed according to ASTM C136 (2015), and the particle size distribution is shown in Figure 5. The specific gravity and water absorption of the fine aggregate were tested following ASTM C128 (2022), yielding values of 2.65 and 3.8%, respectively.

Table 3 Sieve Analysis Result

Sieve Size	Weight Retained (g)	% Weight Retained	% Cummulative Weight Retained	% Passing
4.75 mm	10	2.00	2.00	98.00
1.0 mm	35	17.00	19.00	81.00
0.5 mm	245	49.00	68.00	32.00
0.3 mm	122	24.40	92.40	7.60
0.25 mm	17	3.40	95.80	4.20
Pan	21	4.20	100.80	0.00

Fineness Modulus = 378/100 = 3.78

From the sieve analysis result of the soil sample, it could be inferred that with a fineness modulus of 3.78, the soil is fine enough to form a workable mix with the sugarcane bagasse ash.

B. Mix Proportions

The mix proportions included one control mix (CC) using cement instead of SBA, and four engineered geopolymer composite (EGC) mixes to evaluate the effect of geopolymer mortar. The CC mix was prepared at a ratio of 1 part cement to 1.5 parts similar to Akbar et al. (2021). The EGC mixes were prepared with 0%, 1%, 2%, and 3% fibre content. Details of the mix proportions for CC and EGC mixes are presented in Table 4.

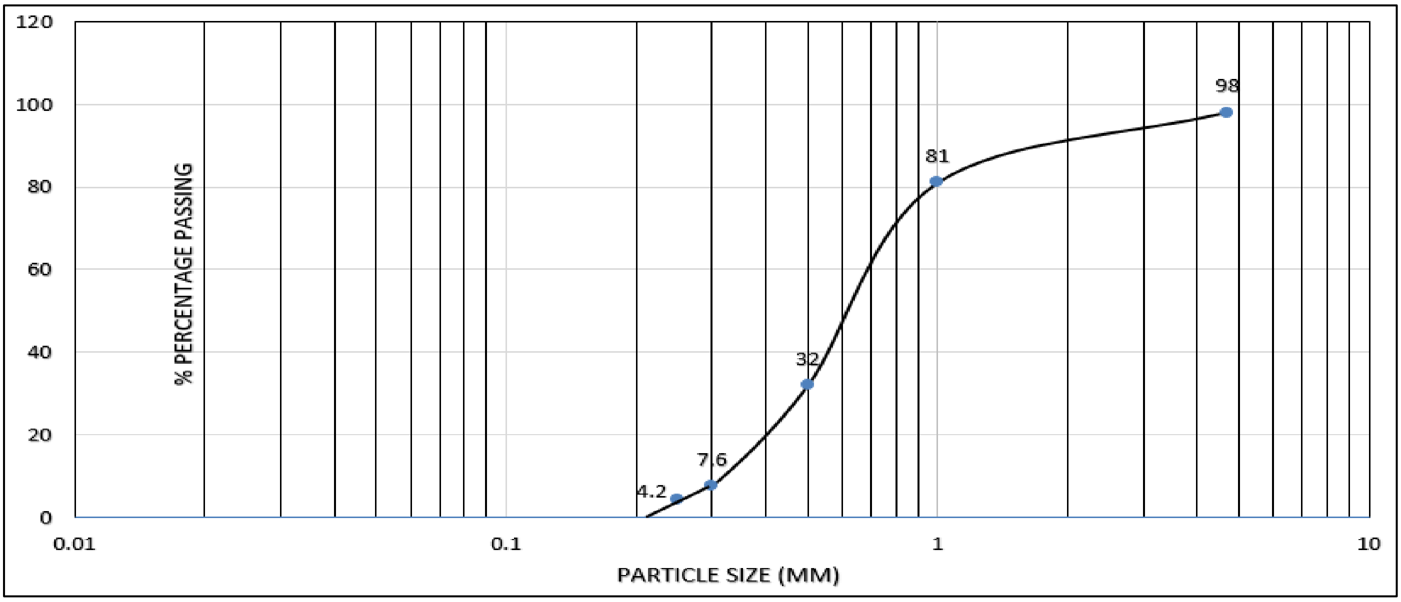

Fig 5 Particle Size Distribution of the Fine Aggregates

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Table 4 Mix Proportions in Terms of Weight ratio of the CC and EGC Mixes

Mixes	Sand/SBA	Alkaline Sol/SBA	W/GP Solid	$Na_2SiO_3/NaOH$	SP/SBA	Coconut Fibre (% Vol)
CC	1.5	-	0.20	-	0.01	0
0CF-EGC	1.5	0.38	0.20	2.5	0.01	0
1CF-EGC	1.5	0.38	0.20	2.5	0.01	1
2CF-EGC	1.5	0.38	0.20	2.5	0.01	2
3CF-EGC	1.5	0.38	0.20	2.5	0.01	3

C. Mixing, Casting, and Curing

➢ *Mixing*

The mixing procedure was conducted in the Civil Engineering Department's concrete laboratory under controlled environmental conditions at 25°C to minimize temperature fluctuations. Initially, a 10 M NaOH and Na2SiO3 alkaline solution was prepared and left to stand for 24 hours. Following this, the EGC samples were mixed with the specified volume of coconut fibres using the alkaline activator solution. Dry ingredients were first mixed in a Hobart mixer at 145 revolutions per minute for 60 seconds. Then, the alkaline activator solution was added while mixing continued for another 60 seconds. Water and superplasticizer were subsequently introduced, and the mixture was stirred for 7 minutes. After a brief 30-second pause for bowl cleaning, coconut fibres (if included) were added and mixed slowly for 60 seconds. Finally, rapid mixing was performed at 285 revolutions per minute for 120 seconds.

➢ *Casting*

After mixing, the freshly prepared geopolymer mortar was poured into 50 mm × 50 mm × 50 mm moulds. Once the mortar cubes had sufficiently hardened to maintain their shape, typically after a few hours, the moulds were removed. The cubes were then cured on a clean, debris-free surface to achieve the desired strength before testing.

➢ *Curing*

After casting, the samples underwent initial heat curing in a drying oven at 60°C for 24 hours. Subsequently, they were transferred to an environmental control chamber set at 25°C and 50% relative humidity until testing on days 7, 14, and 28.

Fig 6 Process of Casting of Geopolymer Mortar in the Laboratory

D. Testing of Samples

The concrete samples were tested at days 7, 14, and 28 in their hardened state using both destructive (DT) and non-destructive testing (NDT). DT involved compressive and testing strength testing following ASTM C39-20 (2020) and ASTM C496 (1996) respectively. NDT included water absorption testing according to ASTM D5229-04 (2004) and ultrasonic pulse velocity testing as per ASTM C597-09 (2009).

III. RESULT AND DISCUSSIONS

A. Non Destructive Testing

➢ *Ultrasonic Pulse Velocity (UPV) Test*

The ultrasonic pulse velocity (UPV) test revealed significant insights into the internal structure of the geopolymer matrix across various formulations. Samples from both the conventional cement (CC) and engineered geopolymer composite (EGC) mixes were tested, with results showing an average UPV value presented in Figure 7, with an error bar of ±5% indicating consistency. The UPV results indicated that the geopolymer matrix containing sugarcane bagasse ash (SBA) exhibited a denser and more robust internal structure, facilitating efficient transmission of ultrasonic waves.

Specifically, the UPV was higher in the geopolymer without coconut fibres, attributed to the uniform and compact bonding characteristic of geopolymerization. However, with the addition of coir fibres, the permeability of the geopolymer increased, leading to a reduction in its density and subsequently a decrease in UPV. This trend suggests that as the percentage of coir fibres in the mix increased, there was a corresponding decrease in the velocity of ultrasonic waves passing through the material.

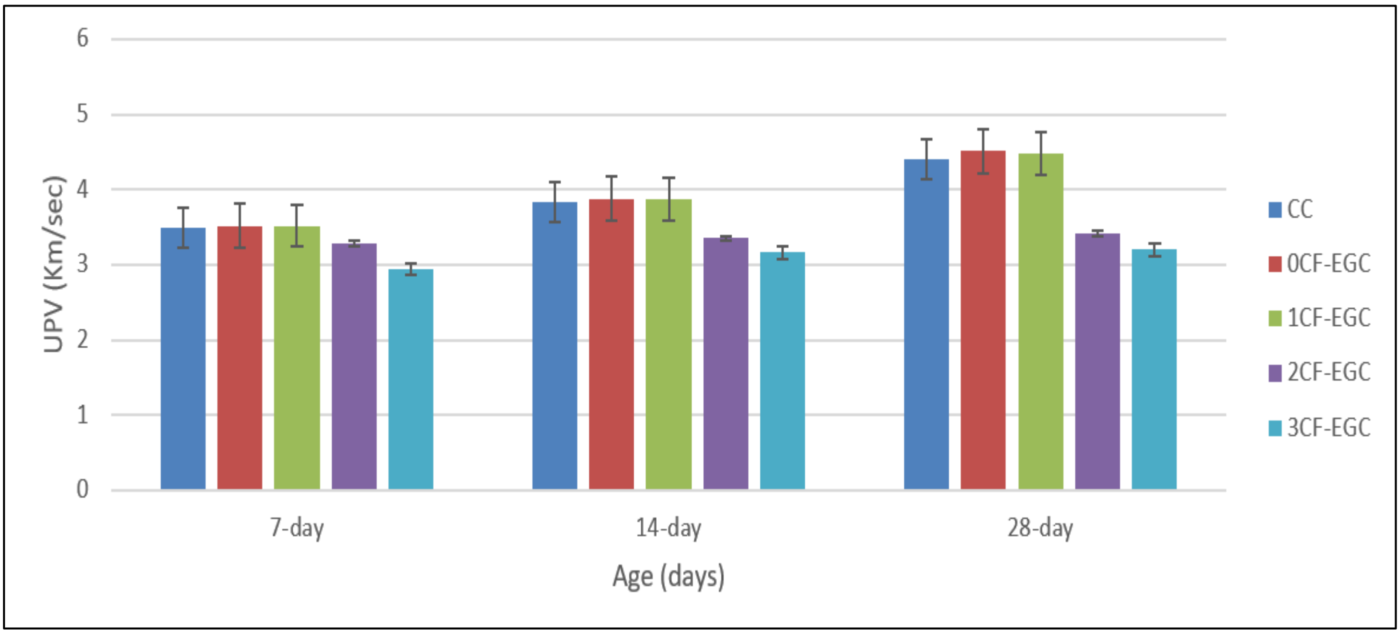

Fig 7 The Average UPV values of the CC and EGC Concrete Mortars

The ultrasonic pulse velocity (UPV) measurements showed that all formulations exhibited increasing values with curing time, indicating progressive internal structure development. After 7 days, the geopolymer composite without coir fibres had the highest UPV at 3.520 km/s, a 0.56% increase compared to plain cement mortar. However, the addition of 1% coir fibres slightly increased UPV by 0.57% compared to plain cement mortar, suggesting slower hydration.

Conversely, 1% coir fibre reduced UPV by 0.57% compared to coir-free geopolymer, indicating increased internal pores. UPV decreased further with 2% and 3% coir fibres due to reduced density and more internal pores. By day 28, coir-free geopolymer showed the highest UPV at 4.513 km/s, a 2.22% increase over plain cement mortar, while 3% coir fibre reduced UPV by 22.27%.

Based on these findings, 1% coir fibre was optimal, balancing internal structure, density, and flexural properties. According to BS 1881-203 (1983), geopolymer without coir fibre and with 1% coir fibre met excellent quality standards, whereas 2% and 3% coir fibre formulations achieved satisfactory to medium quality grades.

In all, SBA geopolymer mortar with 1% coir fibre offers a sustainable alternative to cement, reducing environmental impact and enhancing performance.

Table 5 Quality Assessment of the UPV Result from CC and EGC Samples

Age	Average UPV (Km/s)				
	CC	**0CF-EGC**	**1CF-EGC**	**2CF-EGC**	**3CF-EGC**
28-day	4.47	4.61	4.52	3.48	3.29
Quality	Excellent	Excellent	Excellent	Satisfactory	Satisfactory

➢ *Water Absorption Property*

The water absorption capacity of both CC and EGC mortar samples was assessed to understand how geopolymerisation affects the pore structure of the SBA-based geopolymer matrix. Samples from each formulation were tested after 7, 14, and 28 days of air curing, and the results are summarized in Table 6 and illustrated in Figure 8.

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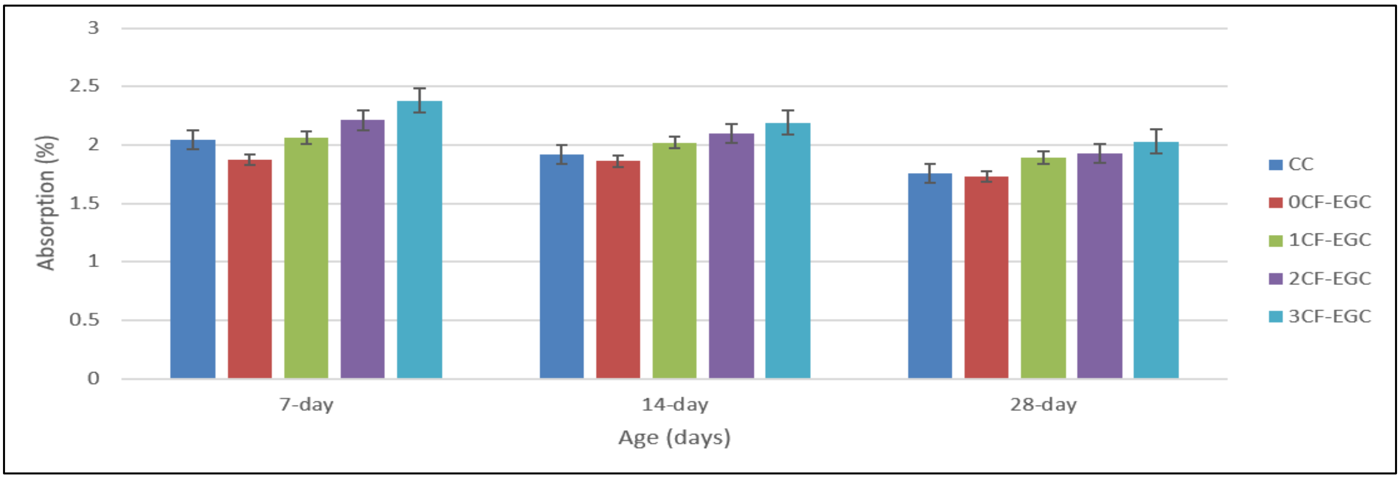

Fig 8 Average values of Water Absorption of CC and EGC Samples at Curing Age

Table 6 Average values of Water Absorption of CC and EGC Samples

Mix	**Water Absorption (%)**		
	7-day	**14-day**	**28-day**
CC	2.04	1.92	1.75
0CF-EGC	1.87	1.86	1.73
1CF-EGC	2.06	2.02	1.89
2CF-EGC	2.21	2.1	1.93
3CF-EGC	2.38	2.19	2.03

The control geopolymer matrix without coconut fibers exhibited the lowest water absorption due to the substitution of bagasse ash and the chain geo-polymerization reaction, which creates a compact linkage structure that prevents water absorption. The fine particle size of bagasse ash enhances the microstructure, reducing water absorption. SEM images show varied shapes and sizes of bagasse ash particles, leading to a compact arrangement and fewer linked pores in the matrix. High concentrations of sodium hydroxide and alkali activators improve polymerization and hydration, enhancing water resistance in the geopolymer matrix (Ghosh & Ghosh, 2012).

Water absorption increases with higher coconut fiber concentrations, as coir expands pore volume in the surrounding area. After 28 days of air curing, adding 3% coir increased water absorption from 1.75% to 2.03% (Aulia, 2002). Table 6 shows that adding 1%, 2%, and 3% coconut fiber to the bagasse ash-based geopolymer mixture increased water absorption by approximately 9%, 15.4%, and 21.4% respectively after 7 days of air curing. Over time, water absorption decreases as the geopolymer matrix forms and reduces internal pores. After 28 days, water absorption decreased to 14.7% with 3% coir addition, indicating improved matrix microstructure.

Comparing portland cement (CC) with geopolymer mortar without coconut fibers (0CF-EGC), the water absorption difference decreased from 8.33% to 1.70% after 7 and 28 days of air curing, respectively. The geopolymer matrix showed faster microstructure development and hydration due to heat curing and alkali activators. The 0CF-EGC material absorbed less water than CC at the same age (7 days), indicating accelerated hydration kinetics and reduced pores, resulting in lower water absorption.

B. Destructive Testing

➢ *Compressive Strength*

The compressive strength of CC and EGC mortar samples was evaluated, with results shown in Table 7 and Figure 9. All EGC formulations exhibited higher strength than plain cement mortar (CC), highlighting superior geo-polymerization and crack resistance from coconut fibers. The 0CF-EGC showed a 4.1% strength increase at 7 days compared to CC. Adding 1% coconut fibers (1CF-EGC) further enhanced compressive strength by 12.72% after 7 days. Geopolymer matrices with 2% and 3% coir had compressive strengths 3.27% and 2.30% higher than CC, respectively, but were 0.87% and 1.86% lower than the control geopolymer matrix without fibers.

Table 7 Average Compressive Strength of CC and EGC Samples

Mix	**Compressive Strength (MPa)**		
	7-day	14-day	28-day
CC	16.54	20.16	23.82
0CF-EGC	17.25	22.14	25
1CF-EGC	19.12	24.21	25.85
2CF-EGC	17.10	21.82	24.73
3CF-EGC	16.93	21.1	24.28

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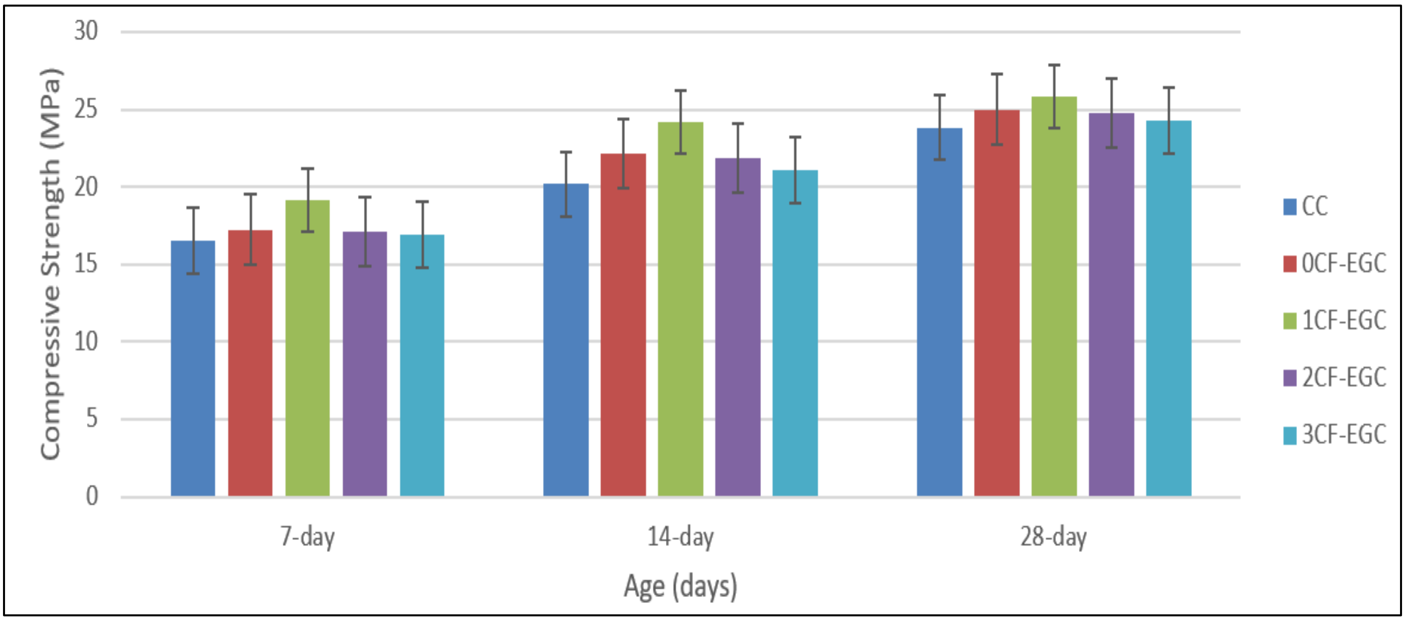

Fig 9 Average Compressive Strength of CC and EGC Mortar Samples at Curing Age

All geopolymer formulations showed improved compressive strength after 28 days of air curing compared to control cement (CC). The bagasse ash geopolymer without fibers (0CF-EGC) had a 4.72% strength increase over CC. Adding 1% coconut fibers (1CF-EGC) boosted compressive strength by 7.85% due to a denser microstructure from finer bagasse ash particles and polymerization. While higher fiber content (2% and 3%) decreased strength compared to 1CF-EGC, it still outperformed plain cement mortar, with increases of 3.6% and 1.89%, respectively.

The bagasse ash geopolymer (0CF-EGC) achieved 74.7% of its maximum strength in the first 7 days, compared to 69.3% for plain cement mortar, indicating faster early-age hydration. The 1CF-EGC also showed rapid strength development, reaching 75.2% of its maximum strength in 7 days, similar to 0CF-EGC. However, formulations with 2% and 3% coconut fibers showed slightly lower early strength gains of 72.5% and 71.6%, respectively, compared to 0CF-EGC. This suggests that higher coconut fiber content slows early strength development but still provides significant improvements over plain cement.

➢ *Tensile Strength*

Table 8 and Figure 10 present the tensile strength of CC and EGC samples. EGC formulations with coconut fibers showed significant tensile strength improvement over plain cement and geopolymer mortar without fibers. Plain cement mortar had tensile strengths of 0.847 MPa and 1.327 MPa after 7 and 28 days, respectively. The EGC without coir had tensile strengths of 0.958 MPa and 1.398 MPa after the same periods, a 5.08% increase over plain cement after 28 days.

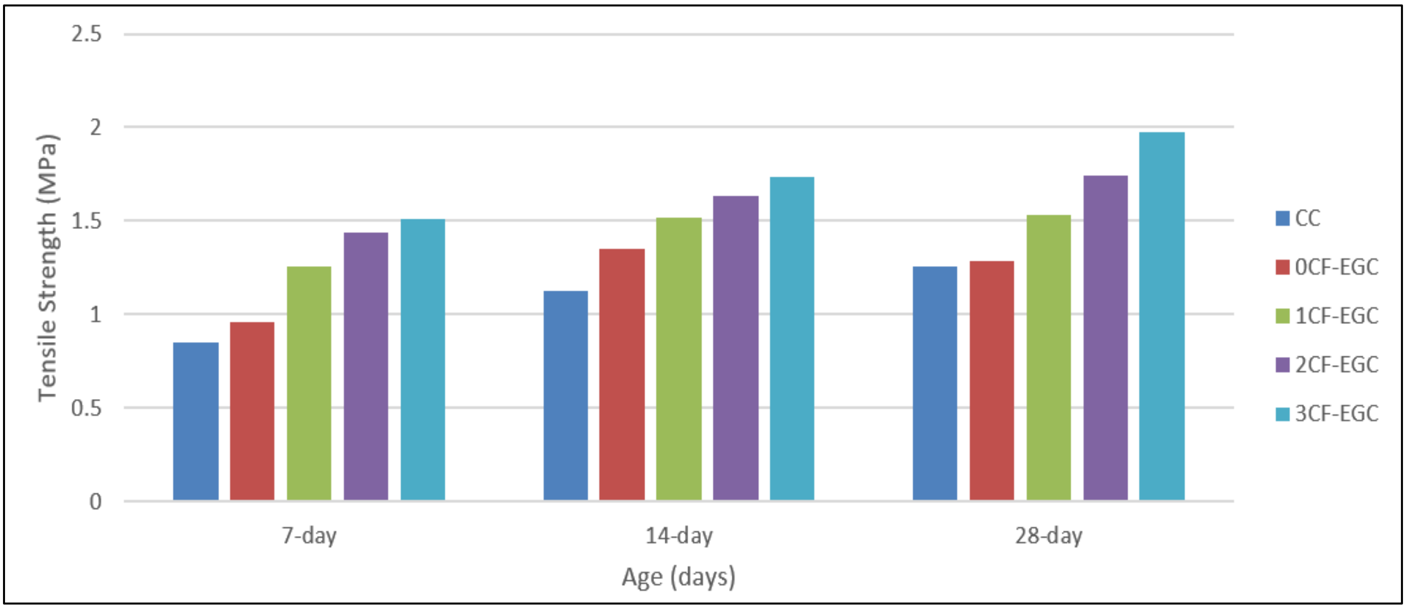

Fig 10 Average Tensile Strength of CC and EGC Samples

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Table 8 Average Tensile Strength of CC and EGC Samples

Mix	Tensile Strength (MPa)		
	7-day	14-day	28-day
CC	0.847	1.128	1.253
0CF-EGC	0.958	1.354	1.289
1CF-EGC	1.256	1.52	1.534
2CF-EGC	1.438	1.631	1.74
3CF-EGC	1.513	1.734	1.974

The study showed a direct correlation between tensile strength and fiber content in EGC samples. Adding 1% coconut fibers increased tensile strength by 32.6% after 7 days compared to fiberless geopolymer and plain cement mortar. After 28 days, 1CF-EGC exhibited tensile strengths 16% and 18.31% higher than fiberless geopolymer and plain cement, respectively. With 2% and 3% coconut fibers, tensile strengths reached 1.740 MPa and 1.974 MPa, improving by 26% and 34.7% over the fiberless geopolymer, and by 28% and 36.5% over plain cement. The dense microstructure of the bagasse ash geopolymer efficiently transmitted stress to the fibers and prevented crack propagation, enhancing tensile strength.

IV. CONCLUSION

➢ *From the Result of the Analysis Presented, the Following Conclusions can be drawn from the Study Findings:*

- Bagasse ash, when finely ground, contains amorphous silicates that can react with alkali activators at a high temperature of around 60°C. This reaction results in the formation of well-structured geopolymer composites.
- Bagasse ash-based geopolymer mortar exhibits accelerated hydration even when a larger amount of superplasticizer is added, resulting in a strength of around 60%. This strength is attained by a 24-hour heat curing process, followed by 6 days of air curing at room temperature.
- The ultrasonic pulse velocity test demonstrated that bagasse ash-based geopolymer composites can be classified as a excellent cementitious material.
- The compressive strength of the geopolymer mortar peaks with 1% coconut fiber, showing a 7.85% increase over traditional cement mortar.
- The tensile strength of the coconut fibre geopolymer composite was found to increase gradually with an increase in coconut fibre addition, with 3% fibre content exhibiting a 36.5% increase compared to the plain cement mortar.
- The optimal performance of bagasse ash-based geopolymer mortar, considering water absorption, ultrasonic pulse velocity, and compressive strength, is achieved with 1% coconut fiber content.

These findings highlight the superior performance and structural integrity of bagasse ash-based geopolymer composites, particularly with the inclusion of coconut fibers, making them a highly effective alternative to traditional cement mortars.

RECOMMENDATIONS

This study demonstrates that coconut fiber effectively reinforces engineered cementitious composites. However, future research should focus on the tensile ductility of these composites and explore the use of other fibers, such as polypropylene (PP), polyethylene (PE), and oil-coated fibers, in developing sugarcane bagasse ash-based lightweight geopolymer concrete.

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