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Material Characterization of Jute Fibre and Ground Waste Glass and Their Effect on the Workability of Concrete

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ABSTRACT

This study investigates the preliminary characterization of locally sourced jute fibre and ground waste glass (GWG) and evaluates their influence on the workability of concrete. Characterization tests included tensile strength, water absorption, density, X-ray fluorescence (XRF), X-ray diffraction (XRD), and thermal properties. The slump cone test was used to assess the workability of concrete mixes incorporating jute fibre (0–1.5% by cement volume) and GWG (0–15% cement replacement). Results showed that treated jute fibres contained high cellulose (67–72%) and moderate hemicellulose (12–16%) with reduced lignin content after treatment, while GWG exhibited a high silica composition suitable for pozzolanic reactivity. Concrete slump decreased with higher fibre content due to increased surface area and absorption, but improved marginally with GWG replacement up to 10% before declining at 15%. The findings suggest that the combination of treated jute fibre and GWG can contribute to sustainable concrete development with acceptable workability and enhanced material performance.

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INTRODUCTION

Concrete remains the most widely used construction material globally, yet its heavy dependence on Portland cement results in significant carbon dioxide emissions. At the same time, the improper disposal of waste glass contributes to environmental pollution. Recent research has sought to incorporate natural fibres and supplementary cementitious materials into concrete to enhance sustainability. Among these, jute fibre and ground waste glass (GWG) are promising options. A biological engineering material, jute fibres have the potential to be both economical and environmentally friendly for building (Islam and Ju Ahmed 2018; Kim et al. 2012; Zakaria et al. 2016). Natural fibre reinforced polymer composites suffer from weak interfacial adhesion between matrix and fibre. In contrast, significant interfacial adhesion between matrix and fibre in composites is essential for appropriate load transfer from matrix to fibre.

Surface modifications of fibres are required to improve surface properties such as adhesion between fibres and matrix, fibre wetting, porosity, and so on. To increase the interfacial adhesion between the polymer matrix and the fibres, several chemical treatments such as alkaline treatment (NaOH), silane treatment (SiH_4), acetylation, permanganate, acrylation, maleated coupling agents and others are used. It also alters the surface of the fibre to lower the moisture absorption tendency of the composite, hence increasing its mechanical qualities. Gupta et,al (2015). This study aims to characterize the physical and chemical properties of jute fibre and GWG, and to assess their influence on the workability of fresh concrete through slump testing.

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MATERIALS AND METHODS

Materials

The materials used in this research include Ordinary Portland Cement (OPC), fine aggregate (river sand), coarse aggregate (crushed granite), ground waste glass (obtained from Fanteka Market Kaduna) sieved through 75 µm, and locally sourced jute fibre (obtained from Zangon Afaka Village,Igabi local Government, Kaduna) treated with ammonia after retting. Potable tap water was used for mixing and curing.

Table 1: Chemical Composition of Treated Jute Fibre

Component	Content (%)
Cellulose	67–72
Hemicellulose	12–16
Lignin	Reduced after treatment

Characterization Tests

Jute fibre was subjected to tensile strength, water absorption, and density tests, as well as chemical composition analysis. XRF and XRD were conducted on both jute fibre and GWG to determine their oxide compositions and crystalline phases. Thermal conductivity and diffusivity were measured for GWG.

Table 2: Mechanical and Physical Properties of Treated Jute Fibre

Property	Value
Tensile strength	393–773 MPa
Density	1.46 g/cm³
Water absorption	Reduced after treatment

Workability Test

Concrete mix proportions were designed using the Response Surface Methodology (RSM) with variables: jute fibre (0%, 0.75%, and 1.5% by volume of cement) and GWG (0%, 7.5%, and 15% by cement replacement). Workability was measured using the slump cone test in accordance with BS EN standards.

RESULTS

Jute Fibre Characterization

Jute fibre showed cellulose content of approximately 67–72%, hemicellulose of 12–16%, and lignin reduction after treatment. The fibres exhibited tensile strength in the range of 393–773 MPa and a density of 1.46 g/cm³. Treated fibres demonstrated reduced water absorption, improving potential bonding with cementitious matrices.

Ground Waste Glass Characterization

XRF analysis revealed that GWG consisted primarily of SiO_2 (72%), CaO (11.25%), and Na_2O (12.85%), confirming its potential as a pozzolanic material. XRD indicated amorphous silica phases, and thermal tests suggested favourable durability characteristics.

Table 3. Oxide Composition of Ground Waste Glass (XRF Results)

Oxide	Content (%)
SiO_2	72.00
CaO	11.25
Na_2O	12.85

Slump Test Results

Slump values decreased with increasing fibre content due to reduced workability from fibre surface area and absorption. GWG improved slump slightly at 7.5–10% replacement due to its filler effect, but workability declined when GWG replacement reached 15%. The combination of moderate jute fibre (0.75%) and GWG (7.5%) produced an optimal balance between workability and sustainability.

Table 4. Slump Test Results of Concrete with Jute Fibre and Ground Waste Glass

Mix ID	Jute Fibre (% by cement volume)	GWG (% cement replacement)	Slump (mm)	Workability Observation
M1	0.00	0.0	120	Control mix (high slump)
M2	0.75	0.0	~60	Moderate reduction
M3	1.50	0.0	15	Very low workability
M4	0.00	7.5	125	Slight improvement

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Mix ID	Jute Fibre (% by cement volume)	GWG (% cement replacement)	Slump (mm)	Workability Observation
M5	0.00	15.0	130	Highest slump
M6	0.75	7.5	~65	Balanced workability
M7	1.50	7.5	20	Very low workability
M8	0.75	15.0	70	Acceptable
M9	1.50	15.0	25	Poor workability

Discussion

The treatment of jute fibre enhanced its cellulose content and reduced lignin, which improves fibre–matrix interaction in concrete. High silica content in GWG promotes pozzolanic reactivity, though excessive replacement levels negatively impact workability. The slump reduction observed with fibre inclusion aligns with other studies on natural fibre reinforced concrete. Overall, combining treated jute fibre with GWG demonstrates promise for sustainable concrete with acceptable workability.

CONCLUSION

This study demonstrates that locally sourced jute fibre and ground waste glass possess favourable material properties for use in concrete. Treated jute fibre contained high cellulose and low lignin, while GWG exhibited high silica content suitable for pozzolanic reactions. Concrete workability decreased with fibre addition but improved slightly with moderate GWG replacement. An optimal mix of 0.75% jute fibre and 7.5% GWG provided adequate slump and material sustainability. These findings highlight the potential of combining agricultural and industrial waste products for greener construction practices.

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