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Research TTEA

Study of Evaluating the Feasibility of Banana Stem Fibers and Sugarcane Husk as a Sustainable Additive in Pervious Concrete for Urban Pavements

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Abstract

This study explores the integration of eco-friendly materials: banana stem fibers and sugarcane husk, into pervious concrete to enhance its mechanical properties while maintaining high permeability. The research addresses environmental concerns related to agricultural waste disposal and the resource-intensive nature of traditional construction materials. Banana stem fibers, known for their tensile strength and durability, and sugarcane husk, rich in lignin and cellulose, were selected as reinforcements. The fibers were extracted, cleaned, and processed into uniform sizes, while the sugarcane husk was dried and processed into small particles. Various mix proportions incorporating different percentages of these materials were developed and compared against a control mix with no added fibers or husk. The experimental phase involved testing the mechanical and hydrological properties of the modified pervious concrete, including compressive strength, permeability, and water absorption test using standard testing methods. Results indicated that the addition of banana stem fibers improved tensile and flexural strengths by 15–20%, enhancing resistance to cracking and bending. The effect BSF composition on the composites' properties enhanced the study report. The sugarcane husk reduced the concrete's density, contributing to its lightweight nature without compromising permeability. The modified concrete maintained a high infiltration rate, essential for effective stormwater management.

Keywords: Pervious concrete, eco-friendly materials, pervious pavement block, environmental sustainability, laboratory testing

INTRODUCTION

Pervious concrete, a specialized type of concrete, allows water to percolate through it, reducing surface runoff and promoting groundwater recharge [1]. This unique property makes it an ideal material for sustainable infrastructure in urban areas prone to flooding and waterlogging [2]. Recent advancements in material science have explored the incorporation of eco-friendly and locally available materials, such as agricultural byproducts, to improve the sustainability and performance of pervious concrete [2]. The use of pervious concrete can help mitigate the negative environmental impacts of rapid urbanization, such as erosion, floods, groundwater depletion, and pollution of rivers, lakes, and coastal waters [3]. Additionally, pervious concrete can help reduce the urban heat island effect, and improve air [4]. Furthermore, the incorporation of sustainable materials in pervious concrete can help to reduce greenhouse gas emissions, conservation of natural resources, and promotion of waste reduction and recycling [5].

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In recent years, there has been a growing interest in the use of natural fibers, such as banana stem fibers and sugarcane husk, as sustainable reinforcements in concrete [6]. These natural fibers have been shown to improve the mechanical properties and durability of concrete, while also reducing its environmental impact [7].

The increasing demand for sustainable and eco-friendly construction materials has led to a growing interest in the use of agricultural waste materials in concrete production. Pervious concrete, in particular, has gained attention due to its ability to reduce stormwater runoff and improve water quality [8]. Recent studies have explored the use of various agricultural waste materials, such as banana leaf ash [9], sugarcane bagasse ash [10], and banana fibers [11], as sustainable alternatives to traditional concrete materials. These innovative approaches aim to reduce the environmental impacts associated with traditional concrete production, such as greenhouse gas emissions and resource depletion [12]. Furthermore, the use of agricultural waste materials in concrete production can also contribute to waste reduction and recycling [13, 14].

OBJECTIVES

1. To evaluate the feasibility of pervious concrete using banana stem fibers and sugarcane husk.
2. To determine the sustainability and suitability of pervious concrete in urban areas using pavement blocks.
3. Assessing the viability of banana stem fibers and sugarcane husk as a sustainable additive in pervious concrete through laboratory testing (Figures 1–4).

MODEL WORK

Material Preparation

1. *Banana stem fibers:* Extracted, cleaned, and processed to uniform dimensions for incorporation.
2. *Sugarcane husk:* Dried, ground into fine particles.

Mix Design

Volume of One Cube

The volume of a 150 mm×150 mm×150 mm cube:
Volume of Cube (V)=L×B×H
$V=0.15\text{ m}\times 0.15\text{ m}\times 0.15\text{ m}=0.003375\text{ m}^3$

Material Proportions

The mix ratio used is 1:3 (cement: aggregate) with a water-cement ratio (W/C) of 0.45.

Calculation of Material Quantities for One Cube

Water-Content

Using the water-cement ratio: W= Cement Content × W/C Ratio
For-calculations:
Assume Cement =450 kg/m³

For typical Design mix:
$W=450\text{ kg/m}^3\times 0.45=202.5\text{ kg/m}^3$ (or liters)

For the cube volume:
$W=202.5\text{ kg/m}^3\times 0.003375=0.683$ l.

Cement Content

For 1 part cement, proportion of cement:
C= Volume of cube/sum of mix ratios × cement proportion × density of cement (1440 kg/m^3)
$=0.003375/4\times 1\times 1\times 1400=1.215$ kg

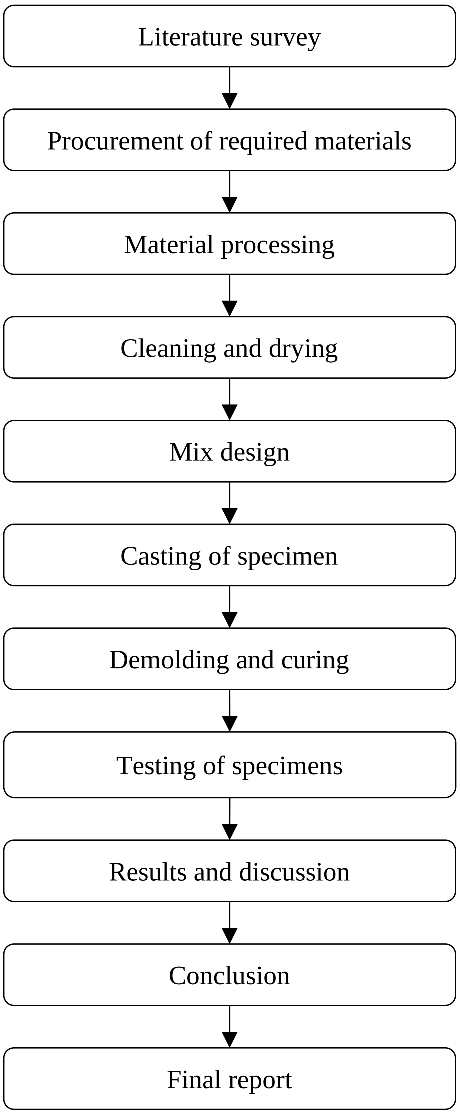

Figure 1. Work model.

Figure 2. Sugarcane husk/ bagasse.

Figure 3. Banana stem fiber.

Figure 4. Mold casting.

Aggregate Content

For 3-parts aggregate:

A= Volume of Cube/Sum of Mix Ratios×3×Density of Aggregate (2700 kg/m^3)

=40.00337/5×3×2700=6.835 kg

Banana Fibers and Sugarcane Husk (5–7% of Aggregate)

Taking 4% of aggregate weight:
Additive Weight =0.04×6.835=0.2734 kg (273.4 gm)
The total is distributed as:
Banana fibers: 0.5×0.2734=0.1367 kg (136.7 gm), and
Sugarcane husk: 0.5×0.2734=0.1367 kg (136.7 gm).

TESTS AND DISCUSSION

1. Compressive test
2. Permeability test
3. Water absorption test

Compressive Test

Compressive strength testing is a crucial assessment of concrete's performance under various environmental conditions and over time. As concrete plays a vital role in ensuring structural integrity, a well-defined compressive strength is essential. In this study, we utilized 43-grade Portland Pozzolana Cement (PPC) and prepared concrete cubes with varying material proportions to evaluate their compressive strength (Table 1, and Figures 5 and 6).

Permeability Test

Permeability testing is a vital assessment of pervious concrete's performance, particularly in sustainable applications incorporating eco-friendly materials such as banana stem fibers and sugarcane husk. This test evaluates the concrete's ability to allow water to pass through, ensuring optimal drainage and hydrological balance for environmentally friendly infrastructure.

Table 1. Compressive strength of specimen cubes and pavements blocks.

S.N.	Strength in days	Concrete cube specimen (150×150×150) mm		Pervious pavement block (250×130) mm	
		Concrete cube (kN/m^2)	***Pervious cube (kN/m^2)***	***Standard pavement block (kN/m^2)***	***Pervious pavement block (kN/m^2)***
1.	7 days	131.8	98.3	443.6	273.5
2.	14 days	262.6	186.7	613.8	326.8
3.	21 days	394.3	280.2	703..3	353.5
4.	28 days	525.3	373.3	754.2	388.5

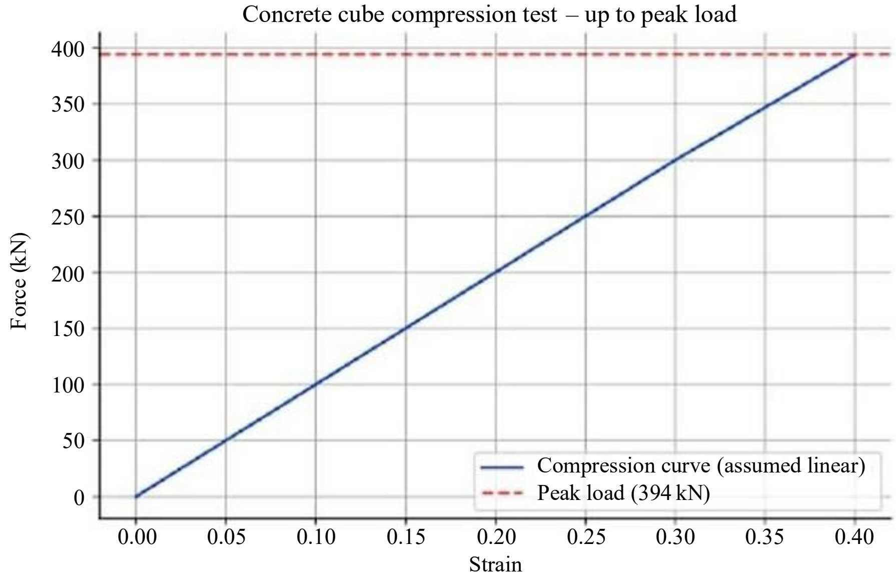

Figure 5. CTM peak load.

Figure 6. Specimen under failure in CTM.

Permeability Test Discussion

The permeability of specimen is calculated as follows:

Q=KIA

Where,

Q = discharge rate (cm^3/min),

K= hydraulic conductivity (cm/min),

I = hydraulic gradient, and

A= Cross Section Area(cm^2).

Above formula can be arranged as (I=H/L) K=(Q×L)/(A×H×/\T)

=336.46×25/325×7×20

K=0.18 cm/min

Hence, the hydraulic conductivity of specimen is *0.18 cm/min*.

Water Absorption Test

The water absorption test quantifies the amount of water absorbed by the pores of a pervious concrete specimen, providing valuable insights into its durability and performance in wet conditions. This critical property assessment is essential for evaluating the suitability of pervious concrete for various applications, particularly those exposed to moisture.

Water Absorption (%)=*((W2–W1)/W1)×100*

Where,

W1= initial weight of the dried sample, and

W2= weight of the sample after submersion in water.

Calculation: Initial weight (W1)=4940 g

Weight after submersion (W2)=5020 g

Water Absorption (%)=((5020–4940)/1000)×100=*8% pm*

The result indicates that the material absorbed *8%* of its dry weight in water.

COMPARATIVE ANALYSIS

- Incorporating banana stem fibers and sugarcane husks into the concrete mixture slightly decreased its compressive strength due to increased porosity. Nevertheless, this combination optimized permeability, striking an appropriate balance for environmentally friendly pervious concrete.

- The concrete demonstrated an 8% water absorption rate, indicating its ability to withstand wet conditions without significant deterioration, thus meeting durability standards.
- The utilization of renewable resources such as banana fibers and sugarcane husk provides comparable performance.
- The economic assessment reveals that the Pavement Block appears to be more cost-effective than conventional block pricing, with standard blocks at Rs. 18/each and pervious blocks at Rs. 12/each.

CONCLUSION

Studies on the utilization of banana stem fibers and sugarcane husk as eco-friendly materials in pervious concrete demonstrate their potential to enhance sustainability in construction while maintaining functional performance. The incorporation of these agricultural byproducts addresses two significant challenges: the environmental burden of agricultural waste and the necessity for more sustainable construction solutions. Experimental findings reveal that the inclusion of banana fibers and sugarcane husk improves the mechanical properties, such as compressive strength and tensile capacity, while retaining adequate permeability for stormwater management. The utilization of these materials also contributes to reduced reliance on conventional aggregates and cement, thereby lowering carbon emissions and promoting circular economy principles.

Furthermore, the research underscores the versatility of pervious concrete as a material that can integrate non-conventional additives without compromising its primary function of water infiltration. The results suggest that fibers and husks, when used in optimal proportions, not only enhance the durability of the concrete but also align with global objectives of sustainable development. Future research could explore scaling these methods for larger projects, optimizing mix designs for varied environmental conditions, and evaluating long-term performance. This study establishes a foundation for environmentally conscious innovations in civil engineering, fostering a balance between environmental conservation and infrastructure advancement.

FUTURE SCOPES

1. Integrating pervious concrete with smart sensors to monitor water infiltration rates and structural performance can create intelligent infrastructure solutions. This integration can also aid in assessing the real-time efficiency of eco-friendly materials in stormwater management.
2. Beyond banana fibers and sugarcane husk, other agricultural wastes, such as rice husk ash, coconut coir, or corn stalks, can be examined for their potential in enhancing concrete properties. Comparative studies can help identify the most effective materials for specific applications.
3. Research into the cost-effectiveness and market viability of utilizing agricultural waste materials in concrete production can promote commercialization and create new economic opportunities for farmers and industries handling agro-waste.

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