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Mechanical Properties of Fiber Reinforced Roller Compacted Concrete with Partial Replacement of Cement by Bagasse Ash

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Abstract: *This project explores the incorporation of bagasse ash, a by-product of sugarcane processing, as a supplementary cementitious material in roller-compacted concrete (ROCC) for rural road construction. This study examines the effects of replacing 15%, 30%, and 45% of cement with bagasse ash, combined with the addition of synthetic fibers at 0.25%,0.50% and 0.75% by volume. The aim is to enhance both the sustainability and performance of ROCC.*

Bagasse ash contributes to the sustainability of the concrete by recycling agricultural waste, reducing the need for cement, and lowering carbon emissions. It also improves the mechanical properties of the concrete, such as its compressive strength and durability. Synthetic fibers enhance the tensile strength and crack resistance of the ROCC, providing greater flexibility and toughness compared to normal concrete. To evaluate the performance of the developed mixes, we conducted tests on compressive strength, flexural strength, and split tensile strength. A consistent water-cement ratio of 0.39 was maintained to achieve zero slump concrete, appropriate for roller- compaction. The fine aggregate to coarse aggregate ratio was adjusted between 0.45 and 0.55 to find the optimal balance for workability and strength. The results demonstrated that using bagasse ash significantly benefits the environment and enhances the mechanical properties of ROCC. The inclusion of synthetic fibers further improved tensile strength and crack resistance. These enhancements make the ROCC mixes more durable and cost-effective for rural roads compared to normal concrete roads, which typically lack such improvements in tensile strength and sustainability.This research highlights the potential of utilizing eco-friendly materials in construction, promoting resource efficiency, and long-term durability in rural road development.

Keywords: Bagasse Ash, Synthetic Fibers, Concrete Mix design

I. INTRODUCTION

This investigates the mechanical properties of fiber-reinforced roller-compacted concrete (ROCC) with the partial replacement of cement by bagasse ash for rural road construction. The primary objective is to enhance the sustainability and performance of ROCC by integrating industrial by-products and synthetic fibers. This research aims to contribute to the development of more durable, cost-effective, and environmentally friendly construction materials for rural infrastructure.

Roller-compacted concrete (ROCC) is widely used for constructing roads and pavements due to its high strength, durability, and cost-efficiency. Unlike conventional concrete, ROCC is placed using asphalt paving equipment and compacted by rollers, making it suitable for large-scale applications where traditional paving methods might be impractical. However, traditional ROCC can be further improved by incorporating supplementary materials and fibers to address specific performance requirements.

1.1 Bagasse Ash as a Supplementary Cementitious Material

Bagasse ash is a by-product of sugarcane processing, generated from the combustion of bagasse in sugar mills. This ash, rich in silica, can be used as a supplementary cementitious material (SCM) to partially replace cement in concrete. The use of bagasse ash not only reduces the environmental impact of cement production but also recycles agricultural waste that would otherwise be discarded. In this study, we explore the effects of replacing 15%, 30%, and 45% of cement with bagasse ash in ROCC.

1.1.1 The incorporation of bagasse ash in concrete has several potential benefits:

• Environmental Sustainability: Reducing the amount of cement used in concrete helps lower greenhouse gas emissions associated with cement production. Additionally, utilizing bagasse ash addresses waste management issues related to the disposal of agricultural by-products.

• Improved Mechanical Properties: Bagasse ash can enhance certain mechanical properties of concrete, such as compressive strength and durability, due to its pozzolanic reaction, which contributes to the formation of additional calcium silicate hydrate (C-S-H) gel, thereby improving the concrete's microstructure.

• Cost Efficiency: By replacing a portion of cement with bagasse ash, the overall cost of concrete production can be reduced, making it an economically viable option for large-scale construction projects.

II. ROLE OF SYNTHETIC FIBERS IN ROCC

Synthetic fibers, such as polypropylene fibers, are added to ROCC to improve its mechanical properties, particularly its tensile strength and crack resistance. The inclusion of fibers helps distribute loads more evenly within the concrete matrix and prevents the propagation of cracks, enhancing the durability and lifespan of the concrete. This study examines the effects of adding synthetic fibers at 0.25%, 0.50%, and 0.75% by volume.

2.1 The benefits of incorporating synthetic fibers in ROCC include:

• Enhanced Tensile Strength: Fibers improve the tensile properties of concrete, making it more resistant to cracking and deformation under load.

• Increased Flexural Strength: The presence of fibers in the concrete matrix helps resist bending forces, thereby increasing the flexural strength of ROCC.

• Improved Durability: By controlling crack propagation and enhancing tensile strength, fibers contribute to the overall durability of ROCC, making it more suitable for long-term use in rural road construction.

III EXPERIMENTAL PROGRAM

• Specimens to be casted-Cubes, cylinders & Beams for different proportions as mentioned in table.
• 7 &14 Days strength is to be assessed.
• Use of Plasticizer- 0.15% by wt. of cement

Table No. 3.1: Experimental Program:

BA \ FIBERS ⇨	0.25 %	0.50 %	0.75 %
15 %	3	3	3
30 %	3	3	3
45 %	3	3	3

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3.2 Concrete Mix design:

3.2.1 As per IRC SP 68

- Design of Roller Compacted concrete mix for Pavement.
- Roller Compacted Concrete Pavement are used in low volume roads with average daily traffic less than 4.5 commercial vehicles per day.
- forest roads, Parking areas & shoulders of Pavements.
- Final Finished surface is not smooth- max permissible values of roughness of Reciprocal Should be 3200mm/km.
- The minimum characteristic strength = 30 MPa with minimum flexural strength = 3.8 MPa at 28 days.
- The Subgrade CBR will not be less than 5%. The thickness of subgrade will be minimum 300 mm.

3.3 Calculation of Material for 1 m³ of concrete

1. Cement Content:
Cementitious material content: 380 kg/m³

2. Water Content:
Water content = Cementitious material content * w/c
= 380 kg/m³ * 0.39
= 148.2 kg/m³

3. Fine Aggregate (FA) and Coarse Aggregate (CA):
Total aggregate content = 1000 kg/m³ - (Cementitious material content + Water content)
= 1000 kg/m³ - (380 kg/m³ + 148.2 kg/m³)
= 471.8 kg/m³

4. Ratio of FA to CA = 0.45 to 0.55
Let's assume the ratio as 0.5 for this calculation.

5. Fine aggregate (FA) content = Total aggregate content * 0.5
= 471.8 kg/m³ * 0.5
= 235.9 kg/m³

6. Coarse aggregate (CA) content = Total aggregate content - Fine aggregate content
= 471.8 kg/m³ - 235.9 kg/m³
= 235.9 kg/m³

Table No. 3.3.1: Mix Proportions for 1 m³ Concrete

Material	Weight in Kg/m3
Cement	380
Fine Aggregate	235.9
Coarse Aggregate	235.9
Water	148.2

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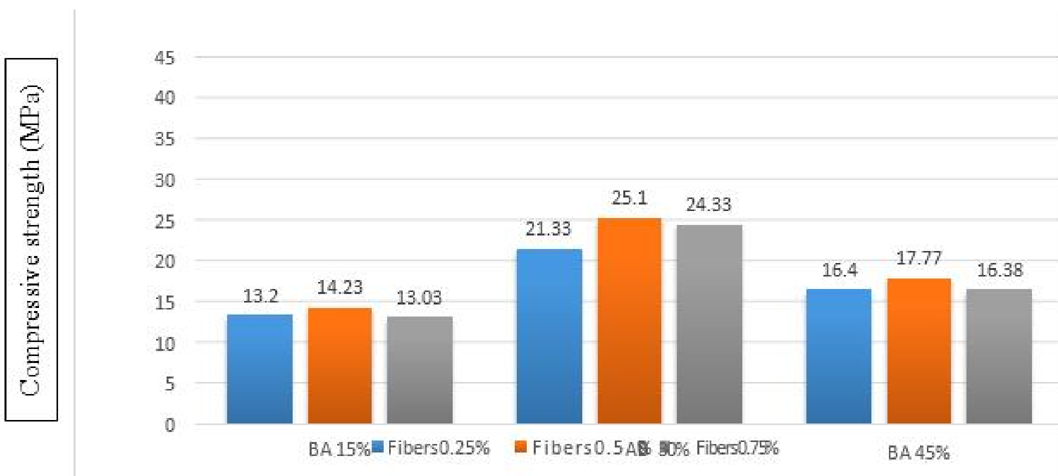
IV RESULTS AND DISCUSSION

4.1 Compressive Strength of ROCC

4.1.1 Compressive strength at 7 days

Table No. 4.1.1: Compressive Strength for 7days

Fibers % ⇨ / BA % ⇩	0.25	0.50	0.75
15	13.20	14.23	13.03
30	21.33	25.10	24.33
45	16.40	17.77	16.38



Graph 4.1.1. Compressive strength for 7days

Table No. 4.1.2: Compressive Strength for 14 days

Fibers % ⇨ / BA % ⇩	0.25	0.50	0.75
15	17.58	18.20	17.49
30	29.61	35.32	32.50
45	29.2	31.91	29.09

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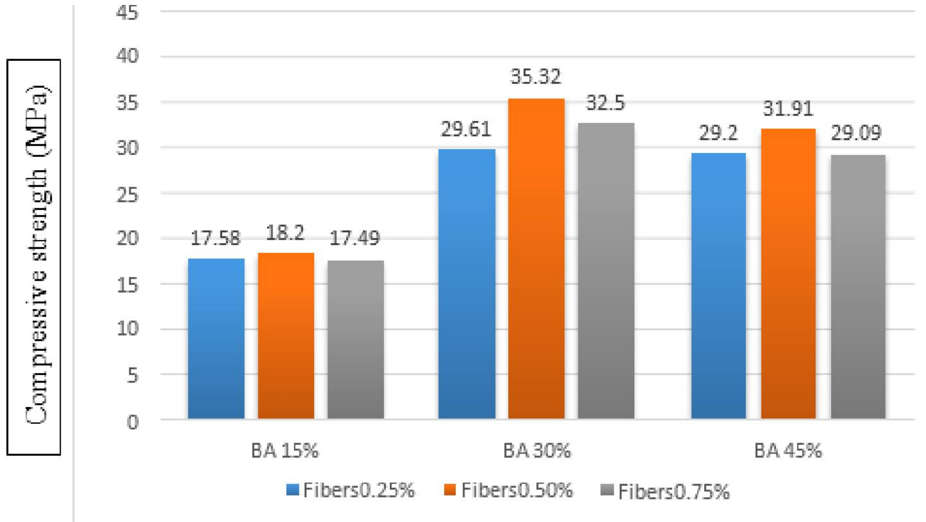
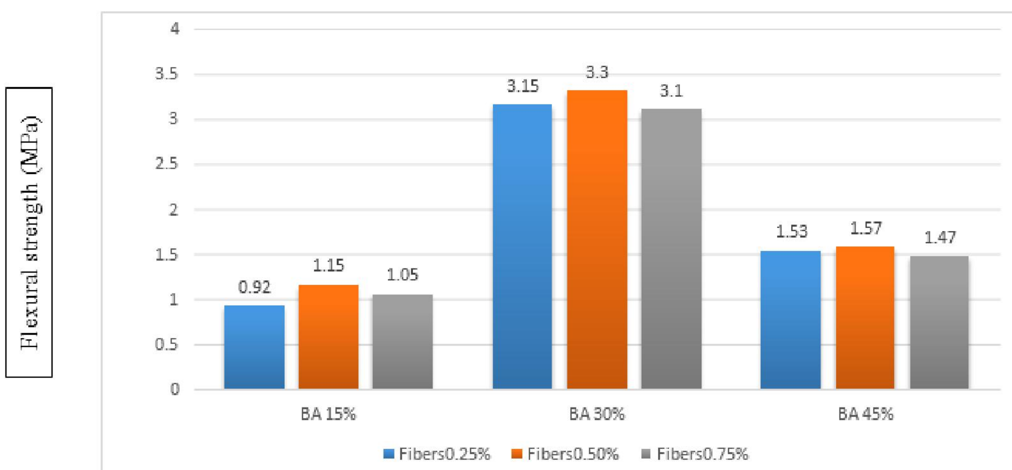


Graph 3. Compressive strength for 14 days

4.2 Flexural Strength of ROCC

Table No. 4.2.1: Flexural strength test for 7 days

% ⇨ Fibers / ⇩ BA %	0.25	0.50	0.75
15	0.92	1.15	1.05
30	3.15	3.30	3.10



Graph 4.2.1 Flexural strength test for 7 days

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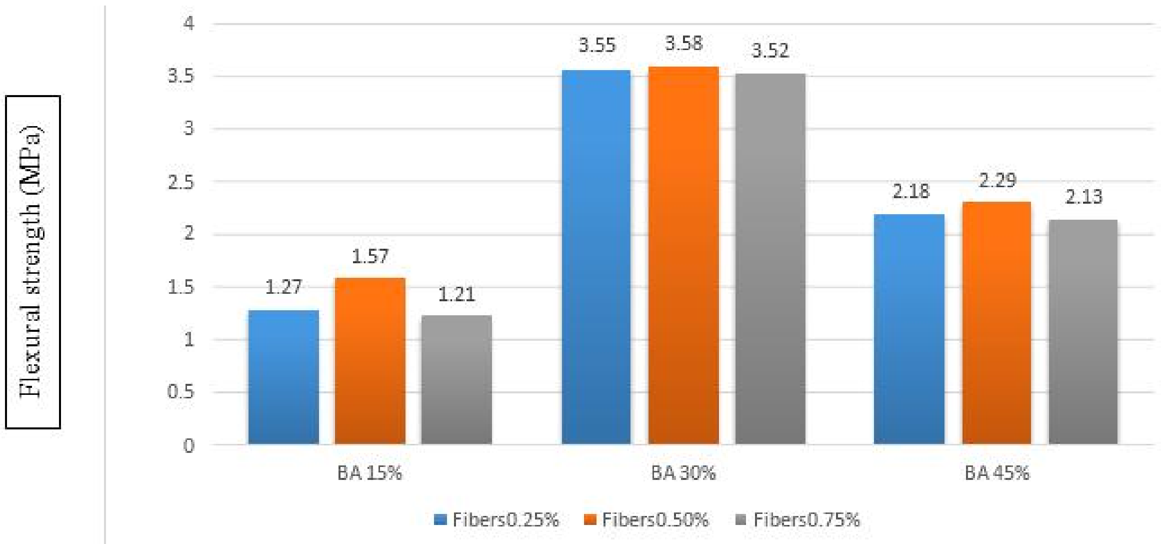
Table No. 4.2.2: Flexural strength test for 14 days

Fibers ⇨ / % ⇩ BA %	0.25	0.50	0.75
15	1.27	1.57	1.21
30	3.55	3.58	3.52
45	2.18	2.29	2.13



Graph 4.2.2. Flexural strength test for 14 days

4.3 Split Tensile Strength of ROCC

Fibers ⇨ / % ⇩ BA %	0.25	0.50	0.75
15	0.94	1.30	0.91
30	1.96	2.16	1.93
45	0.83	0.93	0.82

Table No. 4.3.1: Split tensile strength test for 7 days

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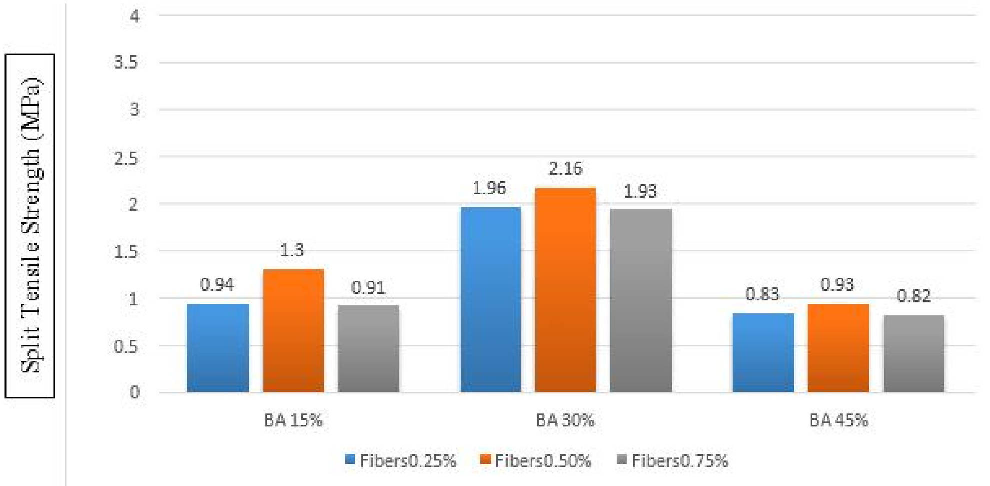
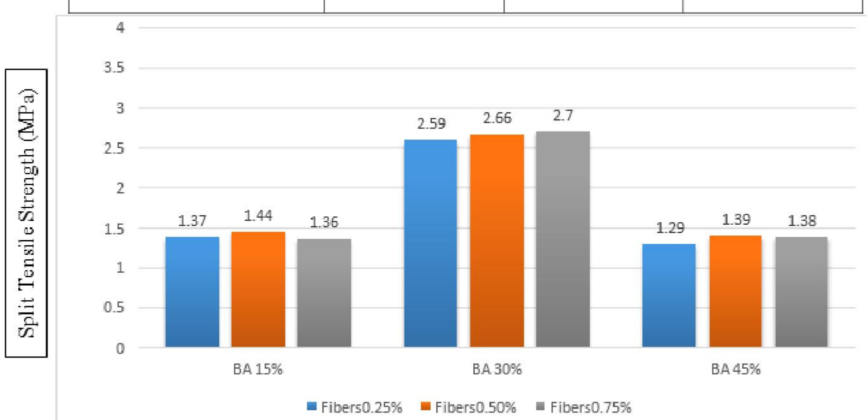


Graph 4.3.1. Split tensile strength test for 7 days

Table No. 4.3.2: Split tensile strength test for 14 days

Fibers % / BA %	0.25	0.50	0.75
15	1.37	1.44	1.36
30	2.59	2.66	2.70
45	1.29	1.39	1.38



Graph 4.3.2. Split tensile strength test for 14 days

V. CONCLUSION

5.1 Compressive Strength:

• The compressive strength of the concrete generally increases with increasing fiber content and moderate levels of bagasse ash replacement.

• At 7 days, the highest compressive strength was observed with 30% bagasse ash and 0.50% fibers, indicating the effectiveness of moderate replacement levels and fiber reinforcement in enhancing early- age strength.
• However, at 45% bagasse ash replacement, there is a slight reduction in compressive strength compared to lower replacement levels, suggesting that excessively high levels of bagasse ash may have a detrimental effect on early-age compressive strength.
• At 14 days, similar trends are observed, with the highest compressive strength achieved with 30% bagasse ash and 0.50% fibers, indicating sustained strength development over time.
• From this experimental study it is concluded that processed bagasse ash shows better performance in the concrete properties.

5.2 Flexural Strength:
• The flexural strength of the concrete also shows improvement with increasing fiber content and moderate levels of bagasse ash replacement.
• The highest flexural strength is observed at 30% bagasse ash and 0.50% fibers at both 7 and 14 days, suggesting that this combination provides optimal reinforcement for resisting bending forces.
• Flexural strength tends to decrease at 45% bagasse ash replacement, indicating that higher replacement levels may compromise the ability of the concrete to withstand bending stresses.

5.3 Split Tensile Strength:
• Similar to compressive and flexural strength, split tensile strength exhibits an increase with increasing fiber content and moderate levels of bagasse ash replacement.
• The highest split tensile strength is achieved at 30% bagasse ash and 0.50% fibers at both 7 and 14 days, indicating enhanced resistance to tensile stresses.
• Split tensile strength shows a slight decrease at 45% bagasse ash replacement, suggesting that higher replacement levels may negatively impact the concrete's ability to resist tensile forces.

5.4 Optimal Mix Proportion:
• Considering the balance of mechanical properties, the optimal mix proportion appears to be 30% bagasse ash replacement with 0.50% fibers. This combination consistently demonstrates improved compressive, flexural, and split tensile strengths at both early and later ages.
• Higher replacement levels of bagasse ash (45%) may lead to reduced strength, indicating the importance of maintaining moderate replacement levels for optimal performance.

5.5 Sustainability and Practical Implications:
• The use of bagasse ash as a partial replacement for cement offers sustainability benefits by utilizing industrial by-products and reducing carbon emissions associated with cement production.
• Incorporating polypropylene fibers further enhances the mechanical properties of the concrete, making it a suitable and durable material for rural road construction.
• Overall, the study demonstrates the potential of fiber-reinforced roller compacted concrete with partial replacement of cement by bagasse ash for sustainable infrastructure development in rural areas.

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