International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

Experimental Investigation on the Performance of Thin White Topping Concrete Incorporating Metakaolin and Jute Fiber

Manjima M, Anusree Suresh
Final Year B.Tech Student, Department of Civil Engineering, College of Engineering Vadakara, India

Sreelakshmi VS
Assistant Professor, Department of Civil Engineering, College of Engineering Vadakara, India

Abstract - Concrete is the primary material used in the construction and rehabilitation of infrastructure worldwide. Due to the rapid deterioration of flexible pavements under heavy axle loads, Thin White Topping (TWT) has emerged as a sustainable alternative. This paper investigates the mechanical properties of M50 grade concrete modified with Metakaolin and Jute fibers for TWT applications. Metakaolin was employed as a partial replacement for cement at levels of 0%, 5%, 10%, and 15%. Additionally, alkali-treated Jute fibers were introduced at dosages of 0.5%, 0.75%, and 1.0% by volume. The experimental results indicate that the incorporation of Metakaolin at a specific percentage significantly refines the micro-structure, leading to better mechanical performance compared to conventional concrete. Furthermore, the hybrid combination of Metakaolin and Jute fiber at optimal dosages provides superior flexural and tensile strength, making it highly suitable for thin pavement overlays. The study concludes that these sustainable additives offer a high-performance solution for durable pavement rehabilitation.

Keywords: Thin White Topping, Metakaolin, Jute Fiber, M50 Concrete, Pavement Rehabilitation, Sustainable Construction.

1. INTRODUCTION

The construction industry is under constant pressure to develop materials that are both structurally superior and environmentally sustainable. Flexible pavements, which constitute a majority of the road network, often suffer from rutting, cracking, and fatigue due to escalating traffic volumes and varying climatic conditions. Thin White Topping (TWT) is a rehabilitation technique where a thin layer (typically 100mm to 200mm) of high-strength concrete is placed over existing distressed asphalt. This creates a composite pavement structure that leverages the flexibility of the asphalt and the rigidity of the concrete.

To enhance the performance of TWT, supplementary cementitious materials (SCMs) are often utilized. Metakaolin (MK), produced by the calcination of kaolinite clay, is a highly reactive pozzolan. When added to concrete, it reacts with calcium hydroxide—a byproduct of cement hydration—to form additional calcium silicate hydrate (C-S-H) gel. This densifies the transition zone between the cement paste and aggregates, leading to higher early strength and reduced permeability.

However, high-strength concrete is inherently brittle. To mitigate this, natural fibers like Jute are gaining popularity. Jute is an abundant, biodegradable, and cost-effective material. When treated with alkaline solutions, Jute fibers develop a rougher surface texture, ensuring a strong bond with the concrete matrix. This reinforcement helps in bridging micro-cracks, improving the modulus of rupture, and enhancing the post-cracking energy absorption capacity of the pavement. This study focuses on the synergistic effect of MK and Jute fibers in M50 grade concrete to meet the rigorous demands of TWT.

2. MATERIALS AND PROPERTIES

2.1 Cement

Ordinary Portland Cement (OPC) of 53 Grade conforming to IS 12269 was used. The specific gravity was found to be 3.15, with an initial setting time of 32 minutes.

2.2 Aggregates

Fine Aggregate: Locally available river sand passing through a 4.75mm sieve, conforming to Zone II of IS 383, was used. The specific gravity was 2.64.

Coarse Aggregate: Crushed angular granite stones of 20mm nominal size were used. The specific gravity was 2.74, and the water absorption was limited to 0.5% to ensure mix stability.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

2.3 Metakaolin

The Metakaolin used in this study was a fine white powder with a specific gravity of 2.3. It acts as a micro-filler and a pozzolanic catalyst, significantly improving the chemical resistance of the concrete.

2.4 Jute Fiber

Raw Jute fibers were cut to a uniform length of 20mm-30mm. To prevent organic degradation and improve mechanical bonding, the fibers were treated with a 5% NaOH solution for 24 hours, followed by washing and air-drying.

3. EXPERIMENTAL METHODOLOGY

The experimental program was designed to evaluate the strength characteristics of concrete through a two-phase approach. In the first phase, the optimum percentage of Metakaolin was determined. In the second phase, Jute fibers were added to the optimized Metakaolin-concrete mix.

3.1 Mix Proportioning

A control mix of M50 grade was designed as per IRC 44:2017. The water-cement (w/c) ratio was kept constant at 0.30. A polycarboxylate-based superplasticizer was added to maintain a slump of 75-100mm, ensuring adequate workability for the fiber-reinforced mixes.

3.2 Casting and Curing

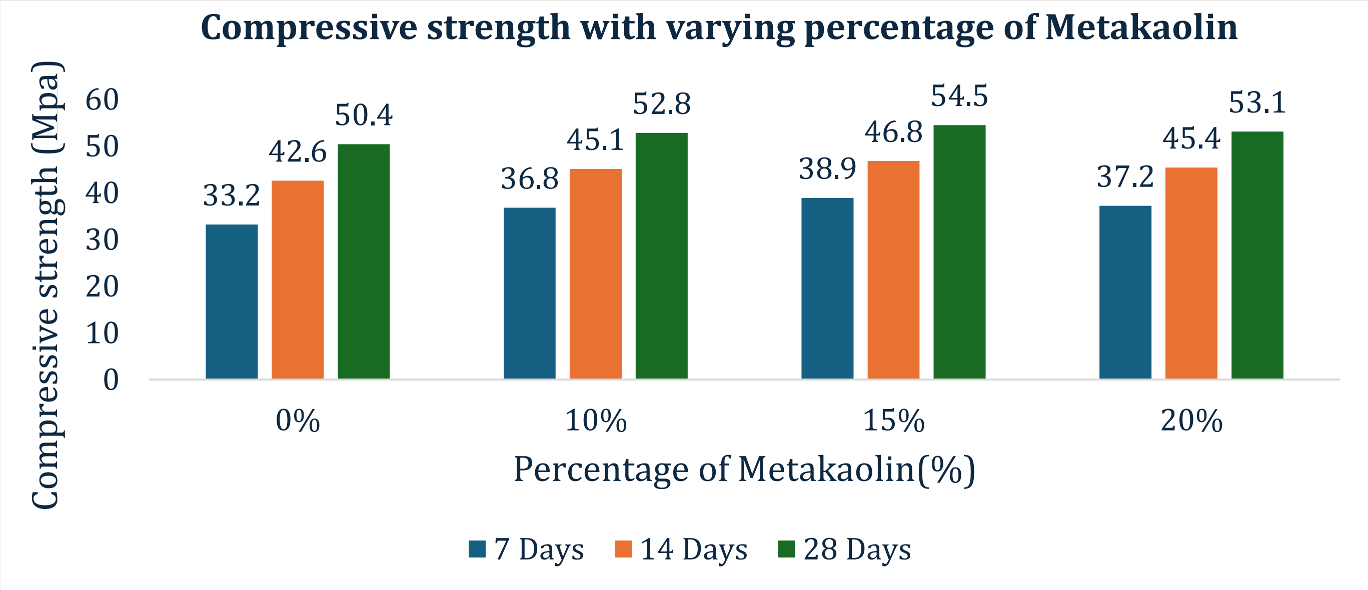
Standard cubes (150*150*150 mm), cylinders (300*150mm), and beams (100*100*500mm) were cast. The specimens were demolded after 24 hours and submerged in a clean water curing tank until the day of testing (7 ,14and 28 days).

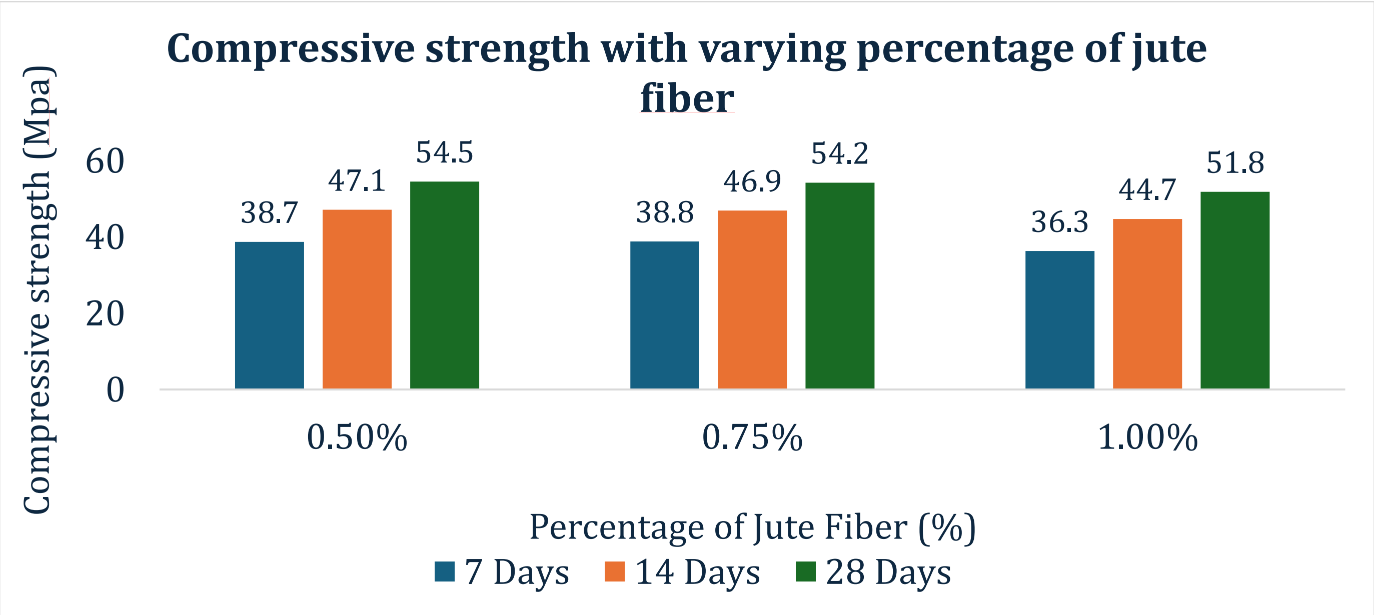
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

4. RESULTS AND DISCUSSION

4.1 Compressive Strength

The test results showed a progressive increase in compressive strength as the Metakaolin replacement level increased up to 15%. This is attributed to the pore-filling effect and the accelerated secondary hydration. While the addition of Jute fiber slightly impacted workability, the compressive strength remained well above the target mean strength for M50 grade.

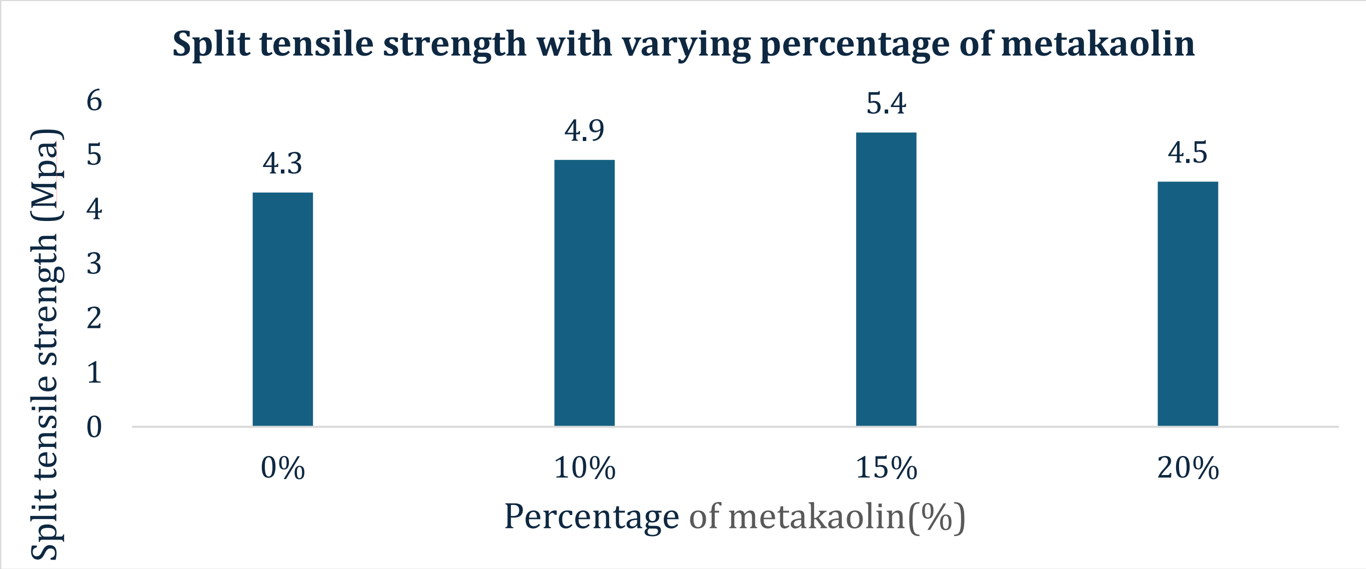


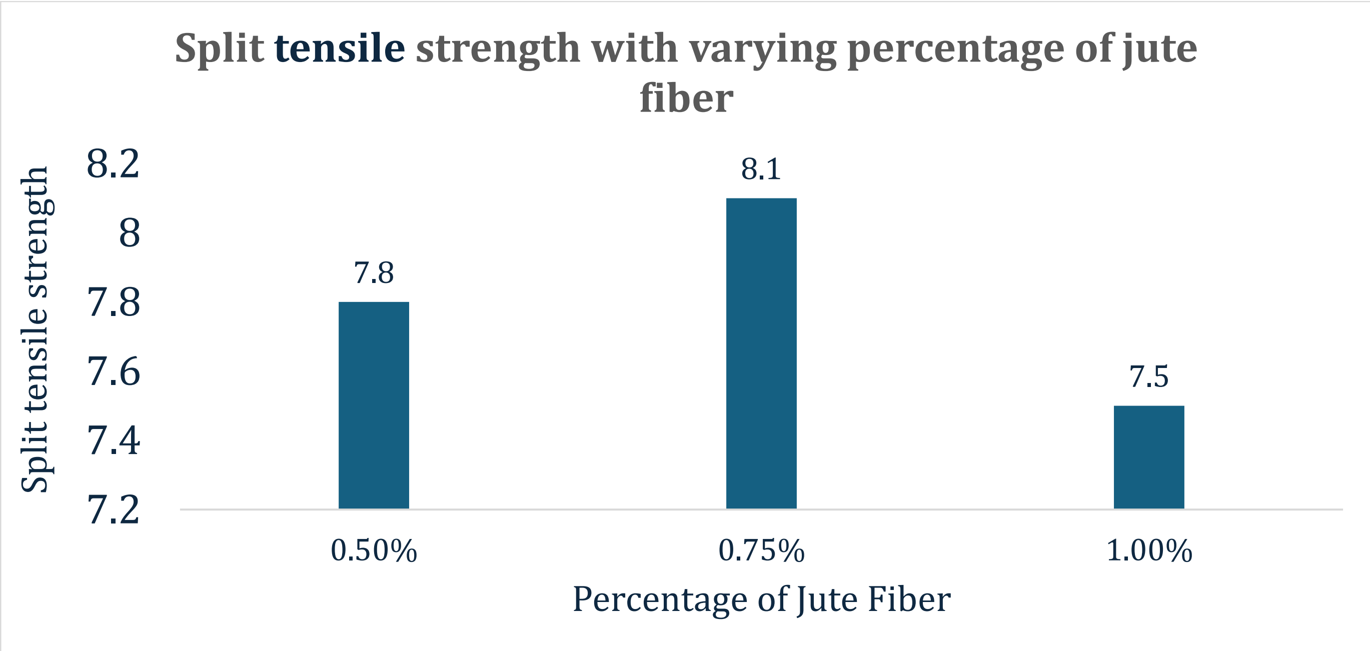


4.2 Split Tensile Strength

The split tensile strength is a critical parameter for TWT, as it indicates the material’s ability to resist cracking under wheel loads. The introduction of 0.75% Jute fiber to the 15% MK mix showed a significant improvement. The fibers act as "bridges" across the cracks, preventing sudden failure.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

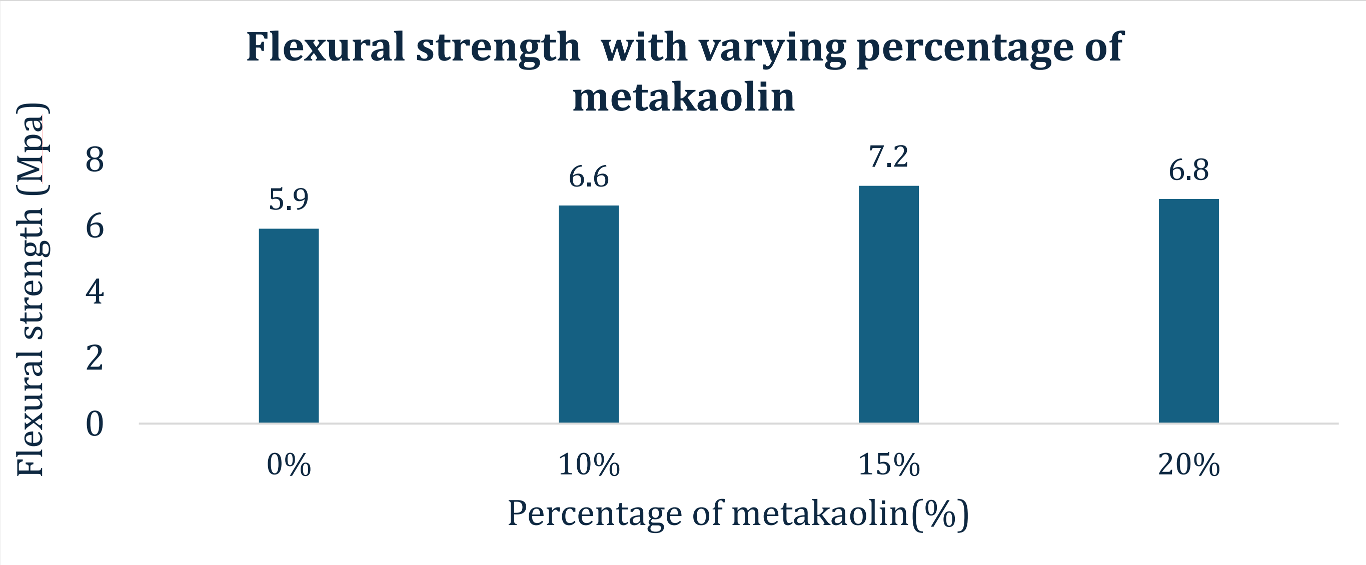


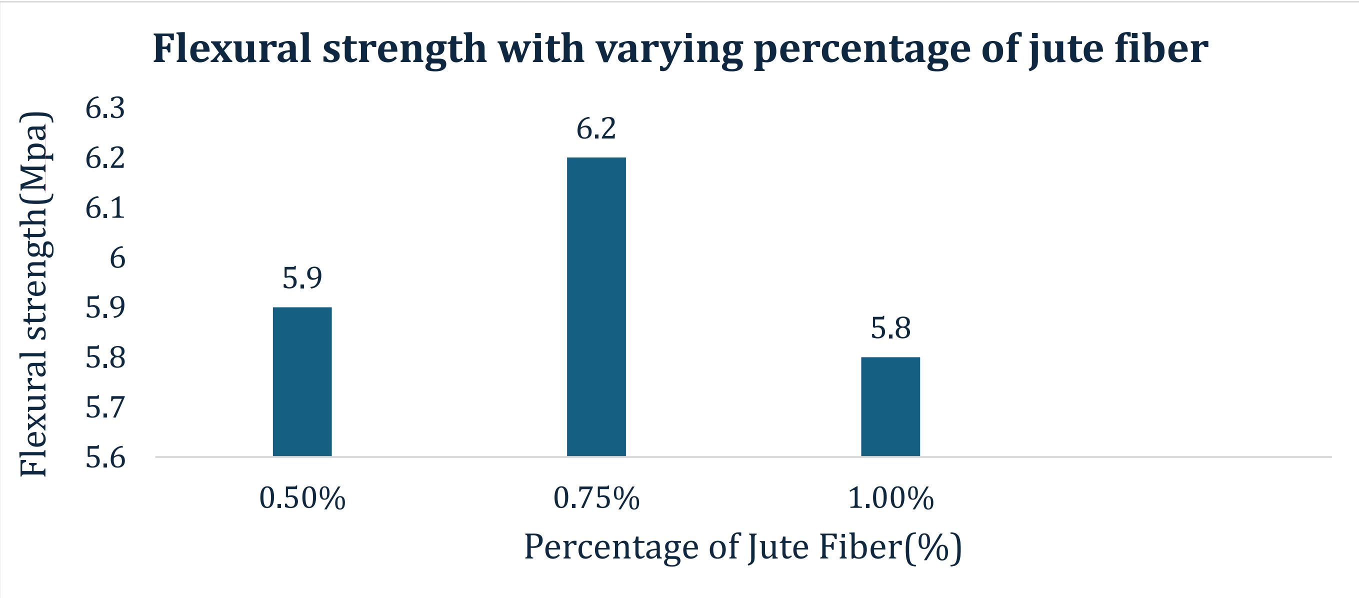


4.3 Flexural Strength

The flexural strength (Modulus of Rupture) showed the most substantial improvement. The hybrid mix of 15% Metakaolin and 0.75% Jute fiber demonstrated a better result compared to the control mix. This enhancement is vital for thin topping applications where slab curling and edge loading are primary concerns.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026





5. CONCLUSION

Based on the experimental investigation conducted on M50 concrete modified with Metakaolin and Jute fibers, the following conclusions are drawn:

Metakaolin is an effective SCM that enhances the mechanical properties of high-performance concrete. A 15% replacement level is found to be the optimum for maximizing strength.

Alkali treatment of Jute fibers is essential for improving the interface between the fiber and the cement matrix.

The addition of 0.75% Jute fiber significantly improves the tensile and flexural capacity of the concrete, providing the ductility required for Thin White Topping.

The combination of 15% MK and 0.75% Jute fiber provides a better result than conventional M50 concrete, offering a sustainable and durable solution for modern road infrastructure.

ACKNOWLEDGMENT

I express my sincere gratitude to the Almighty for the grace and strength provided throughout the course of this research. I am deeply thankful to my professor and co-author for the invaluable guidance and mentorship during our experimental study on Metakaolin and jute fibers. I also thank the College of Engineering, Vadakara , and the Department of Civil Engineering for providing the laboratory facilities and technical support necessary for this work.

REFERENCES

[1] Suresh, S., Karthik, R., & Selvakumar, A. (2018). Effect of Metakaolin on Strength and Durability of Concrete Pavements. *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, Vol.6 Issue 8.

[2] Patel, M. R., Desai, A. S., & Patel, B. (2019). Performance Evaluation of Metakaolin Blended Concrete in Thin White Topping Overlays. *International Journal of Civil Engineering and Technology (IJCIET)*.

[3] Ghosh, K., Mukherjee, A., & Roy, S. (2020). Influence of Jute Fibre on Mechanical Properties of Concrete. *Journal of Materials in Civil Engineering*, ASCE.

[4] Sharma, R., Singh, P., & Bansal, V. (2021). Effect of Jute Fibre Reinforcement on Pavement Quality Concrete. *Construction and Building Materials*, Elsevier.

[5] Prasad, T., Srinivasan, L., & Mehta, R. (2019). Comparative Study on Metakaolin, Silica Fume, and Fly Ash as Cement Replacements in Concrete. *International Journal of Engineering Research & Technology (IJERT)*.

[6] IRC 44-2017 – Guidelines for Cement Concrete Mix Design for Pavements.

[7] IS 516:1989 – Methods of Tests for Strength of Concrete.