Enhancement of Bituminous Concrete Performance Using Bamboo Fiber as an Additive and Palm Kernel Shell as Partial Aggregate Replacement

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Abstract— Flexible pavements are highly susceptible to rutting, cracking, and deformation under heavy traffic loading and environmental conditions. The present study investigates the enhancement of bituminous concrete performance using bamboo fiber as an additive and palm kernel shell as partial aggregate replacement. Marshall Stability tests were conducted to evaluate the performance characteristics of conventional and modified bituminous mixes. The study revealed that optimum addition of bamboo fiber and palm kernel shell improved Marshall Stability, flow value, density, and durability characteristics. The utilization of agricultural waste materials in pavement construction contributes toward sustainable and eco-friendly infrastructure.

Index Terms— Bituminous Concrete, Bamboo Fiber, Marshall Stability, Palm Kernel Shell, Sustainable Pavements.

I. INTRODUCTION

Flexible pavements are widely used due to their smooth riding quality, ease of construction, and economical maintenance. However, increasing traffic intensity and axle loads cause premature failures such as rutting, fatigue cracking, potholes, and stripping. Therefore, improvement of bituminous mix characteristics has become an important area of research in pavement engineering.

In recent years, the utilization of waste materials and natural fibers in pavement construction has gained significant importance because of environmental concerns and depletion of natural resources. Palm kernel shell is an agricultural waste material that can be effectively used as partial replacement for coarse aggregates. Bamboo fiber acts as a natural reinforcing material which improves tensile strength and bonding properties within the bituminous mix.

II. LITERATURE REVIEW

Several researchers have studied the application of natural fibers and waste materials in bituminous pavements. Sisal fiber, coconut fiber, and bamboo fiber were reported to improve Marshall Stability and fatigue resistance of bituminous mixes. Studies also demonstrated that agricultural wastes such as palm kernel shell can partially replace aggregates without reducing the engineering performance of pavements.

Previous investigations indicated that optimum fiber content enhances stability, flow value, and resistance to deformation. The use of sustainable materials also minimizes environmental pollution and reduces dependence on natural aggregates.

III. MATERIALS AND METHODOLOGY

The materials used in the present study include VG-30 bitumen, coarse aggregates, fine aggregates, mineral filler, bamboo fiber, and palm kernel shell. The physical properties of aggregates were determined through impact test, abrasion test, crushing test, specific gravity test, and water absorption test.

Marshall mix design method was adopted to prepare and test the specimens. Palm kernel shell was used as partial replacement for coarse aggregate, while bamboo fiber was added in varying percentages to evaluate its effect on Marshall properties.

TABLE I: PROPERTIES OF MATERIALS

Property	Aggregate	Palm Kernel Shell	Bamboo Fiber
Specific Gravity	2.72	1.35	-
Water Absorption (%)	0.5	10.59	-
Impact Value (%)	18.2	22.4	-
Tensile Strength	-	-	2.33 cN/dtex

IV. EXPERIMENTAL RESULTS

Marshall Stability tests were conducted for various bitumen contents and bamboo fiber percentages. The results indicated that the modified bituminous mix exhibited improved engineering characteristics compared to conventional mixes.

The optimum bitumen content was observed at 5.5%, which produced maximum stability and density values. The addition of bamboo fiber improved resistance against deformation and crack propagation.

TABLE II: MARSHALL TEST RESULTS

Bitumen (%)	Stability (kN)	Flow (mm)	Density	Air Voids (%)
4.5	9.5	2.6	2.18	5.2
5.0	11.8	2.9	2.24	4.5
5.5	14.2	3.3	2.31	3.9
6.0	13.4	3.1	2.28	4.2
6.5	12.1	2.8	2.22	4.8

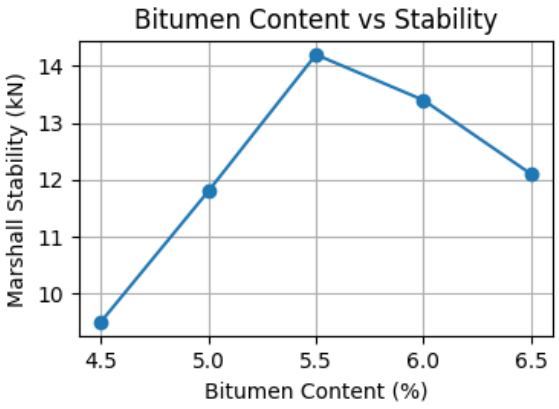

Fig.1 Bitumen Content vs Marshall Stability

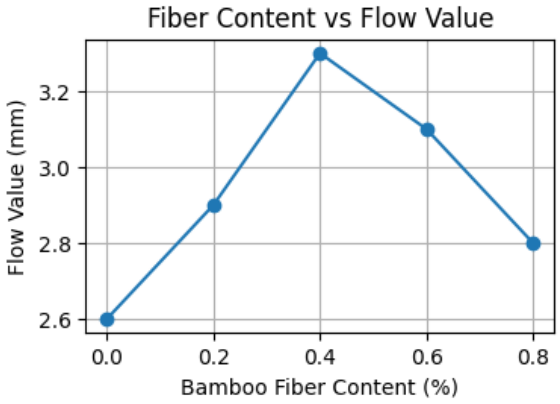

Fig.2 Bamboo Fiber Content vs Flow Value

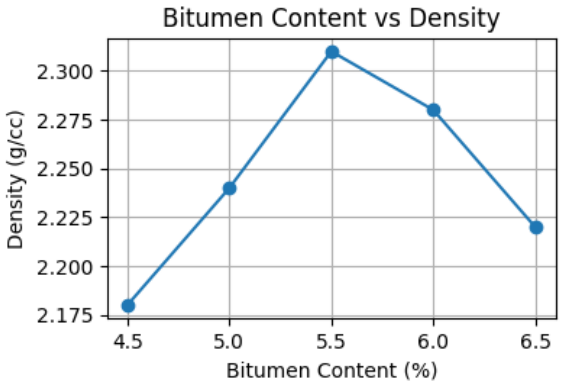

Fig.3 Bitumen Content vs Density

V. DISCUSSION

The modified mix containing bamboo fiber and palm kernel shell showed superior performance compared to conventional bituminous concrete. The increase in Marshall Stability was attributed to better interlocking and improved bonding characteristics. Bamboo fibers acted as reinforcing elements that reduced crack propagation and improved load distribution.

Palm kernel shell reduced the dependency on natural aggregates and provided environmental benefits through effective utilization of agricultural waste. The modified mix also exhibited satisfactory flow values and air void characteristics within IRC permissible limits.

VI. CONCLUSION

The present investigation concludes that bamboo fiber and palm kernel shell can be effectively utilized in bituminous concrete mixes for improving pavement performance. The modified mixes demonstrated higher Marshall Stability, better resistance to deformation, and improved durability compared to conventional mixes. The study also highlights the significance of sustainable construction materials in modern pavement engineering.

Future studies may focus on long-term field performance and fatigue behavior of modified pavements.

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