Performance Evaluation of Bitumen Mixtures Reinforced with Coir and Carbon Fiber in Road Pavements

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***Abstract*—This experimental study investigates the feasibility and performance implications of incorporating coir and carbon fibers into bitumen for road construction. The research explores the potential benefits of these fibers in enhancing the mechanical properties, durability, and environmental sustainability of bitumen-based road materials. Through a series of controlled experiments, the study aims to provide insights into the optimal proportions of coir and carbon fibers for achieving improved road performance, laying the groundwork for environmentally friendly and resilient road construction practices.**

***Index Terms*—Coir fiber, Carbon fiber, Bitumen Durability, Optimal proportions**

I. INTRODUCTION

1.1 INTRODUCTION

Fast increment of urban populace in India with quick ascent in industrialization needs appeal of vehicles. Street divisions are significant for the development of economy, vocations and strengthening of a nation. India's street connects with almost 55 lakh Km Street length is second biggest street arrange on the planet. About 98% streets are adaptable in nature and rest 2% are unbending asphalts. Around 40% streets are unpaved of absolute street lengths. The normal bitumen shows disappointment and major issues during stormy seasons. The treatment and reinforcing of bitumen are required to keep the asphalt surface useful. So, Fiber materials a nano material as of late utilized as an added substance to reinforce the asphalt surface and to improve the properties like entrance, pliability and dampness harm of asphalt.

According to National Highway Authority of India there are 55 lakh km street lengths in India which is second biggest street arrange on the planet coming after USA. Out of which around 61% streets cleared and rest 39% are unpaved. Street systems are the fundamental component of transportation framework which goes about as a key component of economy of the nation. Streets ought to be competent to take overwhelming burdens and fulfills the need of street client with upgraded execution of asphalt. Scientists are constantly attempting to improve the asphalt with proper quality, better life time and solidness. Bituminous blends are most regularly utilized all over world in the development of asphalt. Due to quick increment in populace, modernization, urbanization and mechanical insurgency the quantity of vehicle with higher hub load which are answerable for putting high worries over constraining accessible streets causes more noteworthy misery bringing about diminishing usefulness and it legitimately expands the asset utilization and upkeep cost. So as to beat these issues the adjustment of fastener is a decision to fulfill the expanding traffic need with suitable asphalt quality.

1.2 Coir

Coir, also called coconut fiber, is a natural fiber extracted from the outer husk of coconut and used in products such as floor mats, doormats, brushes, and mattresses. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture. White coir, harvested from unripe coconuts, is used for making finer brushes, string, rope and fishing nets. It has the advantage of not sinking, so can be used in long lengths in deep water without the added weight dragging down boats and buoys.

Coir Fiber

1.3 CARBON FIBER

Carbon fiber (CF) is made of thin, strong crystalline filaments of carbon that is used to strengthen material. Carbon fiber can be thinner than a strand of human hair and gets its strength when twisted together like yarn. Carbon fiber, on top of being strong it is high in stiffness, high in tensile strength, is tolerant to temperature susceptibility and has a low in weight to strength ratio.

Chopped carbon fiber

2. LITERATURE STUDY REVIEW STUDY

M. K. Sayida et. All, in this paper, pavement proposed on soft subgrade (SG) that requires improvement is studied and reported. One of the methods of improvement is reinforcing SG with geotextile. Laboratory studies were conducted on both paved and unpaved sections, whereas field performance studies were conducted only on paved roads. Three types ofwoven and one type of nonwoven coir geotextiles were used as reinforcement in the laboratory study, out of which one woven geotextile was used in the field. Effects of reinforcements were studied by placing the geotextiles at different positions of the section in the lab model, and cyclic load tests were conducted and resistance to permanent deformation was reported. Field performances were evaluated by the Benkelman beam deflection (BBD) test, the dynamic cone penetration (DCP) test, and the field California bearing ratio (CBR) test. Test results indicate that the reinforced roads have less distress compared to the unreinforced one. Change in characteristic deflection, DCP indices, and about 50% improvement in field CBR values were obtained for the reinforced one.

Mohd. Adil SANI, et. All, In Malaysia, most of the pavement is made with hot mix asphalt (HMA) as this is one of the most economical materials available and it is also very suitable for the climate here. However, the HMA pavement normally required frequent maintenance and rehabilitation due to damages caused by excessive traffic loadings. Therefore, one of the alternatives to minimize the damages of pavement and to prolong the service life is to use modified asphalt pavement. HMA can be modified with filler, extender, rubber, plastic, rubber-plastic combinations, fibre, antioxidants, hydrocarbon, anti-stripping agents, waste materials and etc. This study demonstrates the properties of HMA added with coir fibre and kenaf fibre. The laboratory result reveals that both fibres are effective in increasing the Marshall stability of the ordinary HMA. The coir fibre and kenaf fibre increases the Marshall stability of the ordinary H

3 MATERIALS AND METHODOLOGY

3.1 Materials:

Required materials were gathered from the accessible sources and the essential properties of total and bitumen were checked. In the examination, the pre-owned totals were gotten from neighborhood sources in Tripura. Fastener utilized was ordinary folio VG-40. Coir fiber is a natural material which is proven natural material in resisting tensile loading which is successful in the concrete technology. The same principle using here in the road construction mixing it in the asphalt mix resulting in the holding the aggregate from failure due to vehicular loads. The mix of coir in the asphalt at its hot liquid mode can easily help in holding the bitumen along with aggregate after its cool down. Later, coming to carbon fiber

Aggregates

The Coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36mm sieve and shall be clean, hard, durable and cubical in shape. Where crushed gravel is proposed for use as coarse aggregate, not less than 90percent by weight of the crushed material retained on the 4.75mm sieve shall have at least two fractured faces. The Physical requirements for Coarse aggregate for Bituminous Concrete shall be as per Table 500-16 of MoRTH-V as given below.

S.no	Property	Test	Specification	Method of Test
1.	Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075mm sieve	IS:2386 Part I
2.	Particle shape	Combined flakiness and Elongation indices	Max 35%	IS:2386 Part I
3.	Aggregate Strength	Los Angeles Abrasion value or Aggregate Impact Value	Max 30% Max 24%	IS:2386 Part IV
4.	Durability	Soundness either Sodium sulphate or Magnesium sulphate	Max 12% Max 18%	IS:2386 Part V
5.	Polishing	Polished stone value	Min 55	BS:812-114
6.	Water Absorption	Water Absorption	Max 2%	IS:2386 Part III
7.	Stripping	Coating and Stripping of Bitumen Aggregate Mix	Min. retained Coating 95%	IS:6241
8.	Water Sensitivity	Retained tensile strength	Min. 80%	AASHTO 283

4. EXPERIMENTAL INVESTIGATIONS ON MATERIALS

4.1. TESTS PERFORMED ON COARSE AGGREGATES

A lot of tests have been carried out on Coarse aggregate, Bitumen and other relevant materials in total and the properties of total are considered:

1) Sieve Analysis (Gradation)
2) Aggregate Impact Test
3) Aggregate Crushing Test
4) Shape Test

a) Flakiness Index
b) Elongation Index

5) Los Angeles Abrasion Test
6) Specific gravity and Water absorption

4.1.1. Sieve Analysis

Objective: this test method covers the procedure for the determination of particle size distribution of coarse aggregate. The apparatus for the test shall be the sieves conforming to IS;460-1962 specification.

Hypothesis: The test is to be carried out to ensure the aggregate in conformity with the specification limits as specified in the relevant codes and to decide the aggregate proportions.

Mechanical Assembly: The sieve sizes of 50mm, 40mm, 26.5mm, 19mm, 13.2mm, 10mm, 4.75mm, 2.36mm and 0.3mm shall be used for coarse aggregate and Sive sizes of 2.36mm, 1.18mm,0.6mm,0.3mm,0.15mm and 0.075mm sieves for Fine aggregate.

4.1.2. Aggregate Impact Test

Objective: This strategy for test covers the methodology for deciding the total effect estimation of coarse total.

Hypothesis: The "total effect esteem" gives a general proportion of the opposition of a total toabrupt stun or effect, which in certain totals contrasts from its protection from a moderate compressive burden.

Mechanical assembly: An effect testing machine conforming to the accompanying:

1. A tube-shaped steel cup of inside measurements: Diameter 102 mm, Depth 50 mm and not than 6.3 mm thick
2. A metal mallet gauging 13.5 to 14.0 kg, the lower end of which will be round and hollow fit as a fiddle, 100.0 mm in distance across and 5 cm long, with a 2 mm chamfer at the lower edge, and unfeeling. The mallet will slide openly between vertical aides so orchestrated that the lower (round and hollow) some portion of the sledge is above and concentric with the cup.
3. Means for raising the sledge and permitting it to fall openly between the vertical aides from a stature of 380 mm on to the test in the cup, and means for modifying the tallness offall inside 5 mm. Strainers the IS Sieves of sizes 12.5, 10 and 2.36 mm, Tamping Rod, equalization of limit at the very least 500 gm, Oven and so forth.

Calculation:

The ratio of the weight of fines formed to the total sample weight in each test shall heexpressed as a percentage, the result being recorded to the first decimal place:

Aggregate Impact Value =

S. No	Details	Values
1.	Total weight of aggregate samplefilling in the cylinder=A	Empty cylinder=1797g Empty cylinder + aggregate=2131g Aggregate(A)=334g
2.	Weight of aggregate passing 2.36mm sieve after the test=B	Sample(B)= 56g $\frac{56}{334} * 100$ =16.77%
3.	Aggregate Impact value	

Result: The aggregate Impact value of given sample of coarse aggregate is **16.77%**

The aggregate impact value should not be more than 40 per cent for aggregate used for concrete other than for wearing surfaces, and 24 per cent for concrete used for wearing surfaces such a runways, roads and air field pavements.

4.2 TESTS PERFORMED ON BITUMEN (VG-30)

1. Specific Gravity
2. Absolute viscosity
3. Penetration at 25 ◦c
4. Softening point
5. Flash point
6. Ductility after TFOT

4.2.1 Specific gravity

The specific gravity of semi-solid bituminous material, asphalt cements, and soft tar pitches shall be expressed as the ratio of the mass of a given volume of the material at 25

°C to that of an equal volume of water at the same temperature. This test is done to determine the specific gravity of semi-solid bitumen road tars, creosote and anthracene oilas per IS: 1202 – 1978.

4.2.2 Absolute Viscosity (IS: 1206 Part-II)

Objective: To determine the absolute viscosity of Bitumen (VG-30) by capillary viscometer at any specified temperature having a viscosity range of 42 to 200,000 poise.

Hypothesis: Cannon-Manning vacuum viscometer made of borosilicate is used to determine the internal friction caused by tangential force acting on a planes of unit area produces unit tangential velocity.

Devices: 1. Viscometer

2. Thermometer
3. Water bath
4. Vacuum system
5. Stop watch Viscosity – 3227 poise.

4.2.3 Penetration at 25◦C (IS:1203)

Objective: Determination of penetration of bitumen VG-30 using a penetrometer.

Hypothesis: To determine the penetration of bituminous materials is the distance in lengths of a millimeter that a standard needle will penetrate vertically into a sample of the Bitumen material under standard conditions of temperature, load and time.

Table: 4.10. Penetration Test

Penetrometer dial	Initial mm	0	0	0
	Final mm	67	63	64
	Mean mm	64.7		

Penetration Value = 64.7mm

4.2.4 Softening point (IS:1205)

Objective: to determine the softening point of Bitumen using ring and ball method.

Hypothesis: determine the temperature at which the Bitumen attains a particular degree of softening under specified test conditions.

Table: 4.11. Softening Point Test

TEST PROPERTY	SAMPLE NUMBER		MEAN VALUE (℃)
	BALL NO.1	BALL NO.2	
Temperature(℃) at which sample to	50.2	50.8	50.5

Softening point – 50.5 ◦C

4.2.1 Ductility after TFOT (IS:1208)

Objective: To determine the ductility of Bitumen after thin film oven test (TFOT).

Hypothesis: The ductility of bituminous materials is measured by the distance in CM to which it will elongate before breaking when a briquette specimen of the material of the form at a specified speed and specified temperature.

5. FINALISATIONS OF AGGREGATE GRADATION AND JOB MIX FORMULA

The properties of the bituminous blend including the thickness and steadiness are a lot of reliant on the totals and their grain size appropriation. Degree profoundly affects blendexecution. It may be sensible to accept that the best degree is one that produces most extreme thickness.

6 PROPORTIONING OF AGGREGATES

In the wake of choosing the totals and their degree, proportioning of totals must be done andfollowing are the regular techniques for proportioning of totals:
1. Graphical Methods: Two graphical strategies in like manner use for proportioning oftotals are, Triangular outline strategy and Rothfutch's technique.
2. Experimentation method: The extent of materials is differed until the necessary total Degree is accomplished.

Fig.: 6.1. Marshall Test setup

Fig.6.2 Marshal Specimen

7. EXPERIMENTAL RESULTS

7.1 PROPORTION OF MATERIAL (BC GRADE - II)

Voids: The air void content of bituminous materials is an important control parameter for the quality of bitumen being laid and compacted. If the air void content is too high, it allows for intrusion of air and water. Moreover, it also increases the rate of hardening of binders which produce premature embrittlement of pavements. In addition, too high avoid content will also lead to differential compaction subject to traffic loads and result in formation of ruts and grooves along the wheel track.

Air Voids = (Gmm – Gmb)/Gmm * 100 Va = 2.438-2.341/2.438 * 100 = 3.99

8. CONCLUSIONS

1. The Bituminous Concrete mix design has been carried out with the given constituents using various bitumen Percentages viz. 4.5%,5.0%,5.5%,6.0% and 6.5% and determined the Optimum Bitumen content (OBC) at 5.7% with Density – 2.342 g/cc, Marshal stability value of 1330 kg and Flow value of 4.3 mm.
2. To the Optimum Bituminous mix when coir fiber is added at different percentages, it was observed that at 2% (by the weight of Bitumen) coir fiber the Marshal stability increased by a max. of 3% and Flow decreased by 20% and 2% is Optimum percentage of Coir fiber.
3. To the Optimum Bituminous mix when carbon fiber is added at different percentages, it was observed that at 0.4% (by the weight of Bitumen) carbon fiber the Marshal stability increased by a max. of 7% and Flow decreased by 51% and 0.4% is Optimum percentage of Carbon fiber.
4. The test results indicates that a significant increase in the amount of Coir fiber and Carbon fiber in the mixture causes a large surface area to be coated with the bitumen, as a result the aggregate particles and fiber particles are not sufficiently covered with the Bitumen resulting in a loose mixture consequently drop in stability and high Flow values are Observed.

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