Investigating the Synergistic Impact of Coir and Carbon Fiber Additives on Bitumen for Enhanced Road Performance

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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.

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

1.2 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 HMA by 3.2% and 9.7% respectively. Therefore, coir fibre and kenaffibre has potential in modifying asphalt.

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 filler shall be free from organic impurities and have a plasticity index not greater than 4.

IS Sieve (mm)	Cum. % Passing by Weight of total aggregate
0.6	100
0.3	95-100
0.075	85-100

Bitumen binder VG-30

Bitumen is a sticky, black, highly viscous liquid or semi-solid form of petroleum. In the U.S.,it is commonly referred to as asphalt. It may be found in natural deposits or may be a refined product, and is classed as a pitch. Before the 20th century, the term asphaltum was also used. The word is derived from the ancient Greek. The largest natural deposit

of bitumen in the world, estimated to contain 10 million tons, is the Pitch Lake in southwest Trinidad.

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:

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.

4.1.1. *Aggregate Crushing Value Test:*

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

Hypothesis: The 'total smashing worth 'gives a general proportion of the obstruction of a totalto squashing under a step by step applied compressive burden. With total of 'total pounding value'30 or higher, the outcome might be odd, and in such cases the '10% fines esteem 'ought to be resolved.

Calculation: The proportion of the heaviness of fines framed to the all-out example weight in each test will be communicated as a rate, the outcome being recorded to the primary decimal spot:

Total pulverizing esteem =B/A*100 A=weight in g of immersed Dry example

B=weight in g of division going through suitable sifter

Total Crushing Value = 620/2746*100 = 22.57%

Result: The total squashing estimation of given example of coarse total is 29.86%. The total squashing worth ought not be more than 40 percent for total utilized for concrete other than for wearing surfaces, and 30 percent for concrete utilized for wearing surfacessuch a runways, streets and landing strip asphalts.

4.1.1. *Shape Tests:*

Objective: To assurance of Flakiness Index and Elongation Index of Course Aggregates.

Hypothesis: Particle shape and surface impact the properties of newly blended solid more than the properties of solidified cement. Harsh finished, precise, and prolonged particles require more water to deliver serviceable cement than smooth, adjusted minimized total. Subsequently, the concrete substance should likewise be expanded to keep up the water- concrete proportion. By and large, level and stretched particles are maintained a strategic distance from or are constrained to around 15 % by weight of the complete total.

4.1.2. *Los Angeles Abrasion Test:*

Objective: This technique for test strategies for deciding the scraped spot estimation of coarsetotal by the utilization of Los Angeles machine.

Hypothesis: Abrasive Charge-The grating charge will comprise of cast iron circles or steelcircles around 48 mm in. distance across and each weight somewhere in the range of 390 and 445 g.

4.1.6 Specific gravity and Water absorption of Aggregate (14-6mm)

S.no	Description	Sample-1	Sample-2	Average
1	Weight of SSD aggregate in water (W1) g	545	595	1140
2	Weight of SSD aggregate in Air (W2) g	872.6	950	1823
3	Weight of Oven dry Aggregate in Air (W3) g	865	940	1805
4	Specific gravity = W3/ (W2-W1)	2.642	2.64	2.642
5	Apparent Specific gravity = W3/(W3-W1)	2.703	2.715	2.709
6	Water Absorption = [(W2-W3)/W3] *100	0.88	1.06	0.97%

Average Specific gravity of Aggregate (14-6mm) – 2.642
Average Apparent Specific gravity of Aggregate – 2.709
Average Water Absorption of Aggregate – 0.97%

4.2 TESTS PERFORMED ON BITUMEN

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

Specific Gravity of bitumen = $\frac{(w3-w1)}{(w2-w1)-(w4-w3)} =$ 1.029

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.
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.
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: Softening point – 50.5 ◦C
4.2.5 Flash point (IS:1209)
Objective: To determine the flash point and fire point of Bitumen under specified conditions using pensky martens' apparatus.
Hypothesis: The flash point of Bitumen material is the lowest temperature at which the application of test flame causes the vapors from the material momentarily catch fire in the form of a flash under specified test conditions and fire point is the lowest temp. at which the application of test flame cause the material ignite and burn atleast for 5 s under specified test conditions.
Result: The flash point shall be taken as the temp. read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup.

4.2.6 Ductility after TFOT (IS:1208)
Objective: To determine the ductility of Bitumen after thin film oven test (TFOT).

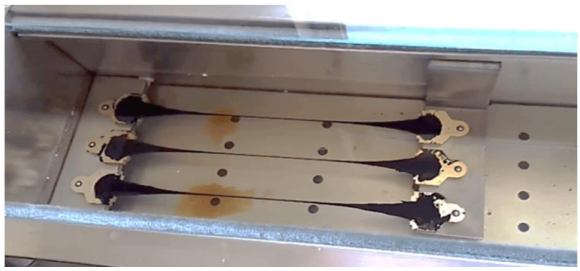

Fig.4.1 Ductility testing

Ductility value – 87.8 mm

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 MARSHALL METHOD OF MIX DESIGN

The Marshall strategy is the best and generally utilized technique for the blend plan of bituminous blends and is point by point in ASTM D 1559.
Marshall Apparatus
Vertical upward development from the underlying situation at zero burden. The dial check ought to have the option to quantify precisely the absolute vertical development upward

Fig.: 6.1. Marshall Test setup

Fig.6.2 Marshal Specimen

Specific gravities of individual aggregate
Then Gse will be calculate taking GMM values of above binder contents As per MS-2 Clause 5.1 (c).

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.

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