

Coir fiber as a sustainable material in pavement construction. Fibra de bonote como material sostenible en la construcción de pavimentos.

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ABSTRACT

Traffic is increasing day by day due to increased vehicle ownership and infrastructure development. As the modern highway transportation has high speed, high traffic density, heavy load and channelized traffic, bituminous concrete is subjected to various types of distress such as rutting, fatigue cracking and raveling. Fatigue cracking occurs because bituminous layers are weak in tension. Therefore reinforcement of the bituminous mixes is one approach to improve tensile strength. Natural fibers can be used for reinforcing as a substitute for synthetic fibers due to their lower cost, ecological recycling and low specific gravity. Among natural fibers growing attention is being paid to coir fiber due to its easy availability, good wearing resistance and more durable property. Also rutting along wheel path causes vehicle hydroplaning during rainy seasons due to loss of skid resistance. As well as water accumulated over the longitudinal depressions damages bond between binder and aggregates. Therefore there is a need for a durable mix which can increase the service life of pavement thus reduces life cycle cost. This study is about use of coir fiber in pavement construction to improve the performance characteristics of the asphalt mixture being used. Stone matrix asphalt mixture is a rut resistant and durable mix which is reinforced with coir fiber and tested for various performance characteristics. Coir fiber is a sustainable material which can be used for rutting resistant mixture.

Keywords: Stone matrix asphalt, Coir fiber, rutting.

RESUMEN

El tráfico aumenta día a día debido al aumento de la propiedad de vehículos y al desarrollo de la infraestructura. Como el transporte por carretera moderno tiene alta velocidad, alta densidad de tráfico, carga pesada y tráfico canalizado, el hormigón bituminoso

está sujeto a varios tipos de angustia, como formación de surcos, agrietamiento por fatiga y desmoronamiento. El agrietamiento por fatiga se produce porque las capas bituminosas son débiles en tensión. Por lo tanto, el refuerzo de las mezclas bituminosas es un enfoque para mejorar la resistencia a la tracción. Las fibras naturales se pueden utilizar como refuerzo como sustituto de las fibras sintéticas debido a su menor costo, reciclaje ecológico y baja gravedad específica. Entre las fibras naturales, se está prestando una atención creciente a la fibra de bonote debido a su fácil disponibilidad, buena resistencia al desgaste y propiedad más duradera. También los surcos a lo largo de la trayectoria de las ruedas provocan el hidroplaneo del vehículo durante las temporadas de lluvia debido a la pérdida de resistencia al deslizamiento. Así como el agua acumulada sobre las depresiones longitudinales daña la unión entre el ligante y los agregados. Por lo tanto, existe la necesidad de una mezcla duradera que pueda aumentar la vida útil del pavimento y reducir así el costo del ciclo de vida. Este estudio trata sobre el uso de fibra de coco en la construcción de pavimentos para mejorar las características de rendimiento de la mezcla de asfalto que se está utilizando. La mezcla de asfalto de matriz de piedra es una mezcla duradera y resistente a los surcos que está reforzada con fibra de coco y probada para varias características de rendimiento. La fibra de coco es un material sostenible que se puede utilizar para mezclas resistentes a la formación de surcos.

Palabras clave: Asfalto de matriz de piedra, Fibra de coco, surcado.

INTRODUCTION

Stone matrix asphalt mix was developed to maximize rutting resistance and to have great durability. Due to the process of production, this asphalt mix is more expensive than regular dense-graded mixes. Its design is based on higher asphalt content, modified asphalt binder, and fibers. The SMA mixtures are composed to have a high coarse aggregate content (typically 70-80%), high bitumen content (typically over 6%) and high percentage of mineral filler content (approximately 10% by weight). High coarse aggregate content results in stone-on-stone contact that produces a mixture that is highly resistant to rutting (Mahrez & Karim,2007). These gap graded bituminous mixtures (minimizing medium sized aggregates and fines) result in a structurally tough skeleton. Due to high content of bitumen it fills the voids between the aggregates effectively and binds them together, thus contributing to its durability from premature cracking and raveling (Satyawati, et.al,2016). A potential problem associated with SMA is drainage and bleeding. Bleeding is caused due to difficulty in obtaining the required compaction. High bitumen content causes drainage and as storage and

placement temperatures cannot be lowered it remain a major problem associated with SMA. Therefore stabilizing additives such as fibers, rubber, and polymers are being used to stiffen the matrix thereby reducing the drain down and bleeding significantly (Bindu & Beena,K.,2015).Stabilizing additives have been introduced into SMA mixes to alleviate the drain down and bleeding problems. Because of compaction issues, storage and placement temperatures cannot be lowered (Subramani ,2012). Additives have been added to stiffen the mastic at high temperatures. Fibers do the best job of preventing drain down, where polymers improve the bitumen properties at low and high temperatures (Thulasirajan.,& Narasimha,2011). The inclusion of fibers or polymer during the mixing process as a stabilizing agent has several advantages including increased film thickness on the aggregate, increased mix stability, interlocking between the additives and the aggregates which improve strength and reduction in the possibility of drain down during transport and paving (Mahabir,2013).

MATERIAL AND METHODS

Aggregates of Nominal maximum size 13mm used for wearing course is chosen for the study as per IRC SP: 79-2008. Plain bitumen of VG 30 is used as binder. Binder content is varied from 5 to 7%. Coir fiber added in different proportions varying from 0.3 to 0.5% of total weight of aggregates. Clean neat fiber is cut in different lengths such as 10mm, 15mm and 20mm.Various laboratory studies on aggregates and binder is conducted to assess its conformity to the required standards. Tests on aggregates such as Impact test, Crushing value test, Abrasion test, Water absorption test, Specific gravity test and Angularity test is conducted to study mechanical properties of aggregates. To judge the suitability of the binder various physical tests like Penetration, Softening point, Ductility, Specific Gravity and Viscosity test is conducted.

Preparation of test specimen: stone mastic asphalt used for wearing course of nominal layer thickness 40-50 mm is selected for the study. Gradation was fixed based on IRC:SP-79-2008.Modified Marshall samples are prepared for various performance tests. The coarse and fine aggregate were taken in the specified proportions to produce a compacted bituminous mix specimen of thickness 95mm approximately.4.0 kg of aggregates were required to produce desired thickness. Required quantity of aggregates as per the gradation was dried at 105°C for 1hour duration in hot air oven. The required quantity of bitumen was calculated as per percentage of binder by weight of total aggregates specified. Then weighted quantity of bitumen corresponding to each percentage was added to the heated aggregate and thoroughly mixed at the specified mixing temperature. It is specified that the bituminous binder is heated

such that the kinematic viscosity is in the range of 170 ± 20 centistokes. The mixing temperature was found out from viscosity versus temperature. It is found out as 160°C . Compaction temperature is found out corresponding to viscosity in the range of 280 ± 20 centistokes. It is observed as 150°C . Mixture is transferred to the gyratory compactor mould of standard size 150 mm diameter. Compaction is done at 150°C using super pave gyratory compactor to get a specimen height of 95mm. Specimen is taken out after compaction and kept in room temperature for 24 hours.

Super pave gyratory compactor is used for compacting sample. The primary operating parameters for the SGC include the pressure applied to the specimen during compaction; the speed of gyration/rotation; the number of gyrations applied to the specimen; and the angle of gyration. Values for these parameters were established during the development of the Super-pave system under the Strategic Highway Research Program. It is correctly and commonly assumed that gyratory compactors in which the gyration angle, speed of gyration, and applied pressure are properly calibrated will produce hot mix asphalt specimens having similar volumetric properties.

The degree of homogeneity of dispersion of the fibers determines the strength of the mixtures (Zhaoxing & Junan, 2016). There are two methods for the introduction of fibers that is by dry process and wet process. Dry process is easy way to add fiber which minimizes problem of balling (Zaharan & Fatani, 1999).

Determination of stability and flow: the specimens to be tested were kept immersed under water in temperature controlled water bath maintained at 60°C for 30 to 40 minutes. One specimen was taken out from the water bath placed in the Marshall test head and is placed in loading machine. Loading machine was raised until the top of test head is in contact with the load cell. The loading unit of Marshall stability testing machine was started as load is applied at the rate of 50mm/minute. The load and deformation readings were closely observed. The maximum load cell reading and the corresponding deformation at the time of failure of the specimen were recorded. The maximum load value expressed in kN was recorded as the Marshall stability value of the specimen. The vertical deformation of the test specimen corresponding to maximum load in mm was noted as the flow value. Then the specimen was removed from the test head and another specimen taken from the water bath inserted in the test head of the machine and test was repeated.

The SMA samples were prepared using varying binder content of 5.0%, 5.5%, 6.0%, 6.5%, 7.0% and the fiber length varied from 10mm, 15mm and 20mm and fiber content

varied from 0.3%, 0.4% and 0.5. Volumetric analysis was done using the result obtained and optimum binder content was found out. Binder content corresponding to maximum stability, bulk specific gravity and 4% air voids were obtained from Marshall curves. Optimum binder content was 6.25% for all fiber dosages.

Drain down test: this test determines the amount of drain down in asphalt mixture when the sample is held at elevated temperatures comparable to those encountered during Production, storage, transport, and placement of the mixture. The test is particularly applicable to mixtures such as open graded courses and Stone matrix asphalt. A compacted sample was placed in a catch plate of known weight. Weight of compacted sample was also taken. Then sample with the catch plate kept in an oven for a specified amount of time at the production temperature. At the end of the heating period, sample is removed from oven along with the catch plate and weight of catch plate is taken. The amount of drain down is considered to be that portion of material that separates itself from the sample as a whole and is deposited in the catch plate. The material that drains may be composed of either binder or a combination of binder and fine aggregate.

$$\% \text{ Drain down} = (A - B) \times \frac{100}{C} \quad (1)$$

A= Final weight of catch plate (g), B= Initial weight of catch plate (g),C= Initial weight of sample (g)

Retained Marshall stability: It is well known that presence of moisture in a bituminous mix is a critical factor, which leads to premature failure of the flexible pavement. The loss of adhesion of aggregates with bitumen is studied by utilizing Retained Stability Test to examine the effect of additive on resistance to moisture induced damage (Thulasirajan & Narasimha ,2011). This test measures the stripping resistance of a bituminous mixture. The test is specified in IRC: SP 53-2002 and is conducted as per ASTM D 1075-1979 specifications. The modified Marshall specimens of 150 mm diameter and 95 mm height are prepared. Marshall Stability of compacted specimens is determined after conditioning them by keeping in water bath maintained at 60°C for 24 hours prior to testing. This stability, expressed as a percentage of the stability of Marshall specimens determined under standard conditions, is the retained stability of the mix. A higher value indicates lower moisture susceptibility (higher moisture damage resistance). For SMA mixture Retained Marshall stability is minimum 70%.

$$\text{Retained stability} = (\text{Soaked stability}/\text{Standard stability}) \times 100 \quad (2)$$

RESULTS AND DISCUSSION

Test of stability: stability value increases initially with increase in bitumen content but decreases gradually. This can be attributed to the fact that with increase in bitumen content, the aggregate bitumen bond gradually gets stronger, but with further increase in bitumen content, the applied load is transmitted as hydrostatic pressure, keeping the fraction across the contact points of aggregates immobilized. This makes the mix weak against plastic deformation and the stability reduced. The same principle applies to mix with fibers, but this mix shows higher stability value at the same binder content than the mix without fibers. This can be attributed to the fact that, the fibers in the mixes act as stabilizers which not only fills up the voids in the sample but also reduces the drain down significantly, thus holding up the binder in the mix. The addition of fibers also provides homogeneity to the mix. Use of coir fiber resulted in Marshall Stability value as high as 19.25kN in SMA. It is higher by 13% than control mixes with a satisfactory level of air voids and flow values.

Effects of flow: flow is the deformation undergone by the specimen at maximum load where failure occurs. The flow value increases with the increase in the bitumen content both the mixes with and without fibers. It was observed that the flow value initially increase within the fiber content. This is because addition of fibers increases the resistance against deformation of the mixture.

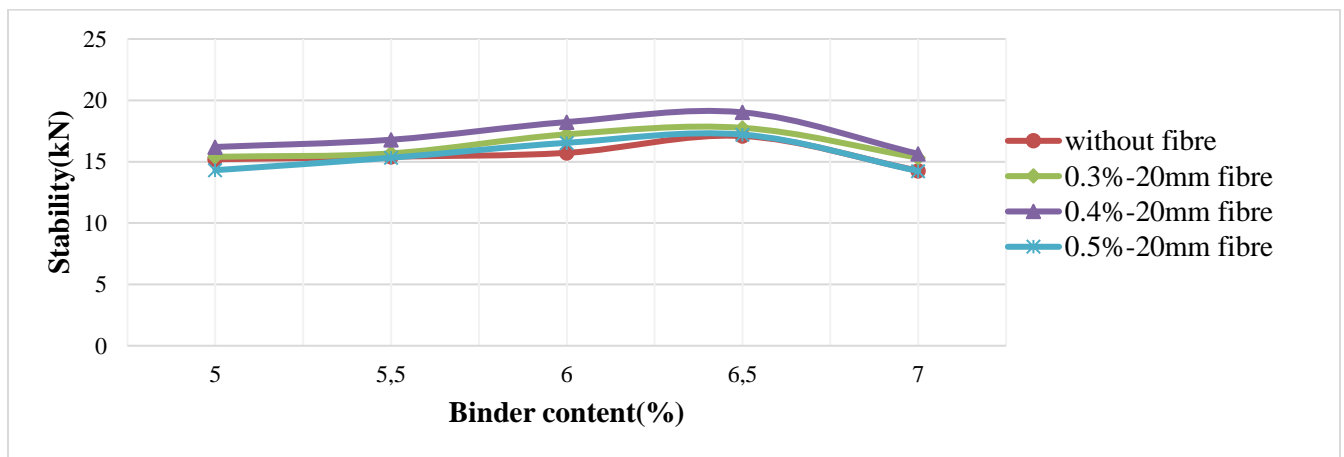


Fig 3. Variation of Stability with binder content

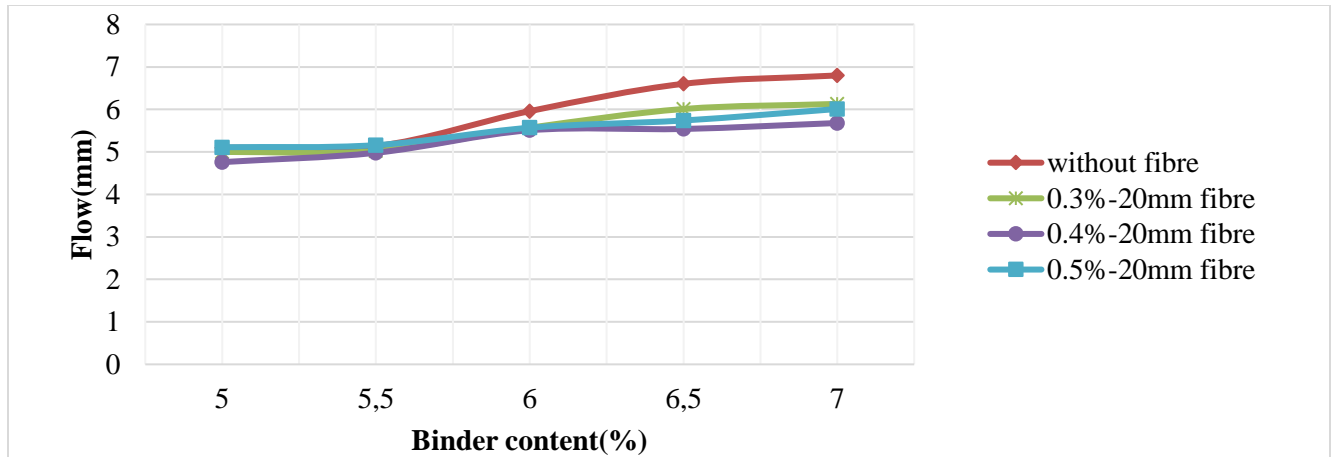


Fig 4. Variation of Flow with binder content

Drain down characteristics: drain down samples were prepared at OBC 6.25%, coir fiber length varied from 10mm, 15mm and 20mm and % of coir varied from 0%, 0.3%, 0.4% and 0.5%. It was observed that 10mm coir fiber at 0.4% gives good results compared to without fiber samples. When adequate amount of fiber is present in voids between the aggregates it forms a fiber matrix and prevent draining of binder. Test results are illustrated in Figure 5.

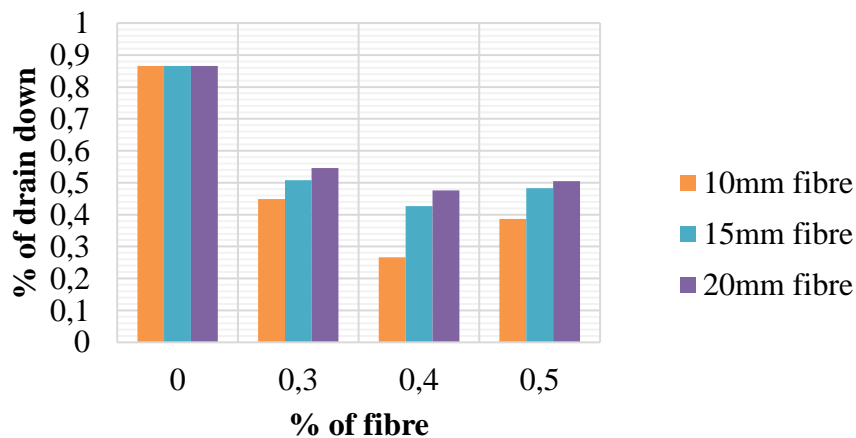


Fig 5. Variation of % drain down with % of fiber

Moisture susceptibility: resistance to moisture is studied using Retained Marshall Stability (RMS) values. Results are given in Table 1. It is observed that 10mm fiber at 0.4% fiber gives maximum RMS values. At lower percentage resistance to moisture damage is less

because fiber proportion is not adequate to fill the voids thereby moisture enter into the mix causing loss of adhesion between binder and aggregates.

Table 1. RMS Values for different fiber percentage

Fibre length	Fibre %	RMS
Without Fibre	0	72.66
10mm	0.3	76.53
	0.4	82.65
	0.5	80.54
15mm	0.3	75.03
	0.4	80.54
	0.5	77.39
20mm	0.3	72.26
	0.4	79.02
	0.5	75.57

As conclusions, Performance characteristics of the Stone matrix asphalt mixture found to be improved by fiber addition. Use of fiber resulted in Marshall Stability value as high as 18.42 kN in SMA. It is higher by 20% than control mixes with a satisfactory level of air voids and flow values. The optimum fiber content is 0.4% and optimum fiber length is 10mm. Retained Marshall Stability value also found to be increasing by fiber addition. Coir fiber also acting as a reinforcement in the mixture preventing drain down during mixing and placing. Coir fiber can be used in stone matrix asphalt mixture to improve mix properties. Coir fiber is a natural fiber which is easily available and eco-friendly material, proved to be a sustainable material for pavement construction.

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