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Quality improvised of bituminous mix by natural fiber

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ABSTRACT

Increase in traffic load in terms of numbers of axles and high pressure from heavy vehicles resulted into traffic related pavement distresses. Modified asphalt binder is one of the approaches to improve pavement performance. Natural fibers have become a research focus for scientist & engineering. Type of natural fibers, their surface treatment & reinforcement of asphalt concrete with natural fibers are presented. Generally the review demonstrated an improvement in the fatigue life & structural resistance to distress occurring in pavement when modified. Generally a bituminous mixture is a mixture of course aggregate, fine aggregate, filler & binder. A hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed & compacted at high temperature. HMA can be Dense Grade Bitumen (DGM) known as Bituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fiber to prevent drain down of the mix. In the present study an attempt has been made to study the effects of use of a natural fiber (SISAL FIBRE as stabilizer in SMA) & as an additive in BC.For preparation of the mixes aggregate gradation has been taken as per Morth Specification, binder content, has been varied regularly from 4% to 7% & fire content varied from 0% to maximum 0.5% of total mix. Then the BC [&SMA] mixes prepared are subjected different performance test like Drain down Test, Static Indirect Tensile strength & Static creep test to evaluate the effects of fiber additions on mix performance.

Keywords*: SMA, DGM, Bituminous mix, Natural fiber*

1. INTRODUCTION

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well as reliable performance of the in – service highway can be achieved. Two things are of major considerations in flexible pavement engineering-pavement design & mix design.

A good design of bituminous mix is expected to result in a mix which is adequately 1) Strong 2) Durable 3) resistive to fatigue 4) environment 5) economical and so on. The present research work tries to identify some of the issues involved in this art of bituminous mix design and the direction of current research.

1.1 Need for Research

Increase in traffic loading density in terms of numbers of axles and density in terms of numbers of axles and high tyre pressure resulting fang heavy vehicles, places great demand on the existing great demand on the existing rood network. The horizontal stresses induced between the layers soon result in crack formation and any local settlement also leads to cracking of asphalt layers. Pavement distresses, such as: cracking, pot-holes, are constantly reported by highway agencies.

Reflection cracking is one of the major distresses that occur frequently in asphalt concert overlap in which the existing cracking pattern from the old pavement propagates into and through the new overlay. Asphalt binder with additives like crumb rubber, natural rubber and polymers have been used to overcome rutting and raveling in flexible pavements.

However, the problem of fatigue cracking still persists. Fatigue cracking occurs because bituminous layers are weak in tension. Fiber reinforcement improves fatigue life by increasing the resistance to cracking and permanent deformation.

Modification of bitumen is one of the approaches to improve the pavement performance when the asphalt produces does not meet the climatic, traffic and pavement structure requirement as reported by Fitzgerald and Kim. The concept of modifying asphalt binders and mixtures is not new. In its earliest stages, asphalt modification consisted of mixing two or more asphalt binders of different paving grades from different sources. The problem with this technique, however, lies in the possibility that the asphalt cement will be chemically incompatibility cannot always be effectively predicated and it can bad to premature asphalt pavement distresses.

Currently, Natural fibers such as hemp coir, jute, sisal fiber & flex are a new class of material which has good potential in bituminous mixes. Depending on their origin, Natural fibers can be grouped into bast (just, banana, flax, hemp, kemaf, Mesta), leaf (pineapple, sisal), seed or fruits fibers (coir, cotton, palm). Therefore, reinforcement of the bitumen mazes is one approach to improve the tensile strength and fibers are the most suitable reinforcing material.

1.2 Test on material used

- **Aggregates**

For the preparation of bituminous mixes (B.C) aggregates as per MORTH grading as given in table 1, particular types of binder & fiber is required quantities were mixes as per Marshall Procedure.

Table 1: Adopted aggregate gradation for BC (Morth)

Sieve Size(mm)	Percentage passing
26.5	100
19	95
9.5	70
4.75	50
2.36	35
0.30	12
0.075	5

1. Coarse Aggregates

Coarse Aggregates consisted of stone chips collected from local sources, up to 4.75 mm IS sieve size. Its specific gravity was found as 2.75. Standard tests were conducted to determine their physical properties as summarized in Table 3.2

2. Fine Aggregates

Fine Aggregates consisting of stone crusher dust were collected from local crusher with fraction passing 4.75 mm and retained on 0.075 mm I.S. sieve. Its Specific Gravity was found 2.6.

- **Filler**

Aggregate passing through 0.075 mm IS sieve is called as filler. Here, cement and stone dust used as filler whose specific gravity is 3.0 & 2.7 respectively. First a comparative study is done on BC where all these two types of fillers is used but later on only fly ash is used as filler where a comparative study is done on BC with or without using fiber.

Table 2: Physical Properties of coarse aggregate

Property	Test Method	Test Result
Aggregate Impact Value (%)	IS:2386(PIV)	14.3
Aggregate Crushing Value (%)	IS:2386(PIV)	13.02
Los Angles Abrasion Value (%)	IS:2386(PIV)	18
Flakiness Index (%)	IS:2386(PI)	18.83
Elongation index (%)	IS:2386(PI)	21.5
Water Absorption (%)	IS:2386(PIII)	0.1

- **Binder**

Here 60/70 penetration grade bitumen is used as binder for penetration of mix, whose specific gravity was 1.01. Its important property is given in table 3.3.

Table 3: Properties of Binder

Property	Test Method	Test Result
Penetration at 25°C (mm)	IS : 1203-1978	67.7
Softening Point(°C)	IS : 1203-1978	48.5
Specific Gravity	IS : 1203-1978	1.03

- **Fiber**

Here Sisal fiber is used as additive whose length is about 900 mm and diameter varied from 0.2 to 0.6 mm. The Sisal fiber were cleaned and cut into small pieces of 15-25mm in length to ensure proper mixing with the aggregate and binder the process of mixing.

1.3 Preparation of Mixes

The mixes were prepared according to Marshall Procedure specified in ASTMD 1559. For BC the course aggregate, fine aggregate and filler were mixed according to the adopted gradation as given in Table 3.1. First a comparative study is done by taking two filler of different types i.e. cement & stone dust. Here Optimum Binder Content (OBC) was found by Marshall Test where binder content is varying from 0% to 7% and fiber content is varying from 0.3% to 0.5%. The Sisal Fiber after being cut into small pieces (15-20 mm) were added directed to the aggregate sample in different proportions. The mineral aggregate with binders and fibers were heated separately to the prescribed mixing temperature. The temperature of the minerals aggregates was maintained at the temperature 10°C higher than the temperature of the binder. Required quality of binder was added to the pre-heated aggregate fiber mixture and through mixing was done manually till the color & consistency of the mixture appeared to be uniform. The mixing was then poured into preheated Marshall Moulds and the samples were prepared using a compactive effort of 75 blows on each side. The specimen was kept overnight for cooling to room temperature. Then the samples were extracted and tested at 60°C according to the standard testing procedure.

1.4 Tests on Mixes

Presented below are the different tests conducted on the bituminous mixes with variation of binder types & quantity & fiber concentration in the mix.

I. Marshall Test

Marshall Mix Design is a Standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous mixes. This test method is widely accepted because of its simplicity and low of cost. Considering various advantages of Marshall Method it was decided to use this method to determine the OBC of the mixes and also study various Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids etc.

Fig. 1: Marshall Test in progress

Fig. 2: Marshall Sample

II. Drain Down Test

There are several methods to evaluate the drain-down characteristics of bituminous mixture. The Drain down Method suggested by MORTH (2001) was adopted in this Study.

The drainage baskets fabricated locally according to the specifications given by MORTH (2001) is shown in fig 3. The loose un-compacted mixes were then transferred to the drainage baskets to collect the drained out binder drippings. From the drain down test the binder drainage has been calculated from the equations:-

Drain down equation is

$$d= (W_2-W_1)/ (1200+X)$$

Where; W_1=initial mass of the plate

W_2=final mass of the plate & drained binder

X= initial mass of fiber in the mixture

For a particular binder three mixes were prepared at its Optimum binder content and the drain down was reported as an average of the three. Figure 3 shows the drainage of 60/70 bitumen.

Fig. 3: Drainage of 60/70 bitumen sample (SMA without fiber)

III. Indirect Tensile Strength Test

It is used to determine the Indirect Tensile Strength of bituminous mixes. In this test, a compressive load is applied on a cylindrical specimen (Marshall Sample) along a vertical diametrical plane through two curved strips the radius of curvature of which is same as that of the specimen. A uniform tensile stress is developed perpendicular to the direction of applied load and along the same vertical plane causing the specimen to fail by splitting. This test is also otherwise known as **Splitting Test**.

IV. Static Indirect Tensile Test

This test was conducted using the Marshall Test apparatus with a deformation rate of 51 mm per minute. A compressive load was applied along the vertical diametrical plane and a proving ring was used to measure the load. A Perspex water bath (270mm*250mm*195mm) was prepared and used to maintain constant testing temperature. Two loading strips, 13 mm wide, 13 mm deep and 75 mm long made up of stainless steel were used to transfer the applied load to the specimen. The inside diameter of the strip made was same as that of Marshall Sample (102 mm). Figure 4 shows the static indirect tensile test being carried out on a specimen. Figure 5 shows a close view of the loaded specimen. The sample was kept in the water bath maintained at the required temperature for minimum 30 min before test. The sample was then kept inside the Perspex water bath within the two loading strips. Loading rate of 51mm/minute was adopted. The test temperature was varied from 5°C to 40°C at an increment of 5°C. In this test three Marshall Sample were tested at particular temperature and the tensile strength was reported as the average of the three test results.

Fig. 4: Static Indirect Tensile Test in progress

Fig. 5: Close view of loaded sample

Fig. 6: Specimen Tested at 5°C

Fig. 7: Specimen Tested at 10°C

Fig. 8: Specimen Tested at 40°C

V. Static Creep Test

For Static Creep Test Sample were prepared at their OBC and OFC. The test consists of two stages. In first stage a vertical load of 6N is applied for 30 min. The deformation was registered during these 0,10,20,30 min using a dial gauge graduated in units of 0.002 mm and it was able to register a maximum deflection of 5 mm. Secondary, the load was removed and its deformation had been registered during next 10 min interval of time i.e. 40, 50, 60 min. Here throughout the test temperature maintained 40°C.

Fig. 9: Static Creep Test in Progress

2. LITERATURE REVIEW

The history of the use of fibres can be traced back to a 4000 year old arch in China constructed with a clay earth mixed with fibres or the Great Wall built 2000 years ago (Hongu and Philips,1990). However, the modern developments of fibre reinforcement started in the early 1960s (Mahrez, 2003). Zube (1956) published the earliest known study on the reinforcement of bituminous mixtures. This study evaluated various types of wire mesh placed under an overlay in an attempt to prevent reflection cracking. The study concluded that all types of wire reinforcement prevented or greatly delayed the formation of longitudinal

Fibres are added as reinforcement in bituminous mixtures. Reinforcement consists of incorporating certain materials with some desired properties within other material which lack those properties (Maurer and Gerald, 1989). Fundamentally, the principal functions of fibres as reinforcing materials are to provide additional tensile strength in the resulting composite and to increase strain energy absorption of the bituminous mixtures (Mahrez et al., 2005).

Some fibres have high tensile strength relative to bituminous mixtures, thus it was found that fibres have the potential to improve the cohesive and tensile strength of mixes. They are believed to impart physical changes to bituminous mixtures (Brown et al., 1990). Research and experience have shown that fibres tend to perform better than polymers in reducing the drain down of bituminous concrete mixtures 14 fibres are mostly recommended (Hassan et al., 2005). Because of the inherent compatibility of fibres with bitumen and its excellent mechanical properties, adding fibres to bitumen enhances material strength and fatigue characteristics while at the same time increasing ductility (Fitzgerald, 2000). According to Maurer and Gerald (1989), fibre reinforcement is used as a crack barrier rather than as a reinforcing element whose function is to carry the tensile loads as well as to prevent the formation and propagation of cracks,mixtures with fibre showed a slight increase in the optimum binder content compared to the control mix. In this way, adding fibres to bitumen is very similar to the addition of very fine aggregates to it. Thus, fibre can stabilize bitumen to prevent leakage (Peltonen, 1991).

Fundamentally, fibre improves the different properties of the resulting mix. It changes the viscoelasticity of the modified bitumen (Huang and White 1996), increases dynamic modulus (Wu, Ye and Li,2007), moisture susceptibility (Putman and Amirkhanian, 2004), creep compliance, rutting resistance (Chen et al., 2004) and freeze– thaw resistance (Echols, 1989), while reducing the reflective cracking of bituminous mixtures and pavements (Echols, 1989; Tapkın et al., 2009, Maurer and Malasheskie,1989). Goel and Das (2004) reported that fibre-reinforced materials develop good resistance to ageing, fatigue cracking, moisture damage, bleeding and reflection cracking.

Bushing and Antrim (1968) used cotton fibres in bituminous mixtures. These were degradable and were not suitable as long term reinforcement. Metal wires has been proposed by Tons and Krokosky (1960), but they were susceptible to rusting with the penetration of water. Asbestos fibres were also used in pavement mixes until it was determined as a health hazard (Kietzman, 1960; Marais, 1979). With the new developments in the technology of production, natural fibre reinforced bituminous mixtures can be cost competitive when compared with modified binders. The natural coir fibre which is a cheaper and an ecofriendly alternative to synthetic fibre, can be effectively used as a stabilizing additive in bituminous concrete (Bindu and Beena, 2009). The percentage increase in retained stability of the mixture as compared to the conventional mix was about 14% at the optimum fibre content of 0.3% and the reduction in bitumen content is 5% giving an appreciable saving in binder.

3. FUTURE SCOPE

Many properties of SMA and BC mixes such as Marshall Properties, drain down Characteristics, tensile strength characteristics have been studied in this investigation. Only 60/70 penetration grade bitumen and a modified natural fiber called sisal fiber have been tried in this investigation. However, some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting and dynamic creep behavior can further be investigated. Some other synthetic and natural fibers and other type of binder can also be Tried in mixes and compared. Sisal fiber used in this study is a low cost material; therefore a cost-benefit analysis can be made to know its effect on cost of construction. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performances monitored.

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