Cellulose Fibers (Banana Fibers) As A Stabilization Additive In Stone Matrix Asphalt

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Abstract - Asphalt pavement is the most prevalent type of highway pavement because of its advantages low noise, skid resistance convenience and recyclability. However asphalt pavement subjected to distress of cracking and rutting under the effects of repeated vehicle loading and freeze law cycles for these reason increase the performance of pavement stone matrix asphalt (SMA) modified. SMA is gap graded HMA that is designed to minimize deformation(rutting) resistance and durability by using structural basis of stone to stone contact because the aggregate are all in contact rut resistance relies on aggregate properties rather than asphalt binder properties. Since aggregates do not deform as much as asphalt binder under load this stone on stone contact greatly reducing rutting SMA originally in Europe to resist rutting and studded tire wear has been used in since about 1990

SMA mixture effectively improve engineering properties of asphalt mixture including visco elasticity, dynamic modulus, moisture susceptibility, creep compliance, rutting service ,added fibers in SMA reducing rutting failures in asphalt pavement these fibers or cellulose fibers ,lignin fibers ,polyester fibbers..High asphalt contents and fibber additives as stabilizers Here fibber used non- conventional natural fibber, namely banana bamboo fibber .Banana fibber is polyester fibber Banana fibber is high thermal resistance .In this research SMA was taken from MORTH specification and binder content 4%, 4.5%, 5%, 5.5%, 6%, 6.5%, 7% by weight of aggregate and fibber used 0.3% by weight of aggregate binder used 60/70 grade bitumen.

Key words: Stone Matrix Asphalt (SMA), Banana Fibre, Marshall Properties, cement filler, HMA**.**

1. INTRODUCTION

GENERAL

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) Environment friendly (v) economical and so on. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one. 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 EVOLUATION OF MIX DESIN

As per Das et al.(2004); During 1900’s, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. The first formal mix design method was Hubbard field method, which was originally developed on sand-asphalt mixture. Mixes with large aggregates could not be handled in Hubbard field method. This was one of the limitations of this procedure. Francis Hveem, a project engineer of

California Department of Highways developed the Hveem stabilometer. Hveem did not have any prior experience on judging the just right mix from its color, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen. Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

1.2 OBJECTIVE OF PRESENT INVESTIGATION:

A comparative study has been made in this investigation between Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA) mixes with varying binder contents (4% - 7%) and Fibre contents (0.3% - 0.5%). In the present study 60/70 penetration grade bitumen is used as binder and Sisal fiber is used as stabilizing additive. The whole work is carried out in four different stages which is explained below.

- Study of Marshall Properties of BC mixes using three different types of fillers without fiber(fly-ash, cement, stone dust)
- Study of BC mixes with fly ash as filler and sisal fiber as stabilizer
- Study of SMA mixes with fly ash as filler and sisal fiber as stabilizer

Evaluation of SMA and BC mixes using different test like Drain down test, Static Indirect tensile Strength test, Static Creep test.

2. Literature Survey

2.1 Bradley et.al. (2004) studied on Utilization of waste fibers in stone matrix asphalt mixtures. They used carpet, tire and polyester fibers and other materials to improve the strength and stability of mixture compared to cellulose fiber. They found no difference in moisture susceptibility and permanent deformation in SMA mix containing waste fibers as compared to the SMA mix which contains cellulose or mineral fiber.

***2.2* Kama raj C., G. Kumar, G. Sharma, P.K. Jain and K.V. Babe (2004)** carried laboratory study by using natural rubber powder with 80/100 bitumen in SMA by wet process and also as dense graded bituminous mix with cellulose fiber and stone dust and lime stone as filler and found its suitability as SMA mix through various tests.

2.3 Punish V.S., Sridhar R., Bose Sunil, Kumar K.K., Veeraragavan A (2004) did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep and aging.

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2.4 Muniandy R., Huat, B.B.K. (2006) used Cellulose oil palm fiber (COPF) and found fiber-modified binder showed improved rheological properties when cellulose fibers were preblended in PG64-22 binder with fiber proportions of 0.2%,0.4%,0.6%,0.8 %and 1.0% by weight of aggregates. It showed that the PG64-22 binder can be modified and raised to PG70-22 grade. The Cellulose oil palm fiber (COPF) was found to improve the diameter fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fiber content of about 0.6%, whilst the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fiber content of 0.6%.

2.5 Kumar Pawan, Chandra Satish and Bose Sunil (2007) tried to use an indigenous fiber in SMA Mix by taking low viscosity binder coated jute fiber instead of the traditionally used fibers and compared the result with the imported cellulose fiber, using 60/70 grade bitumen and found optimum fiber percentage as 0.3% of the mixture. Jute fiber showed equivalent results to imported patented fibers as indicated by Marshall stability test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fiber showed better result than patented fiber.

2.6 Chui-Te Chiu, Li-Cheng Lu, (2007) used asphalt rubber (AR),produced by blending the ground tire rubber (GTR) (I) 30% of a coarse GTR with a maximum size of #20 sieve and (ii)20% of a fine with a maximum size of #30 sieve with an asphalt, as a binder for SMA and found these mixtures were not significantly different from that of conventional SMA in terms of moisture susceptibility but showed better rutting resistance than that of conventional dense graded mixture.

2.7 Bindu C.S1, Beena K.S2 Presence of fibers in SMA mixture enhances the stone to stone contact of aggregates in the gap graded mixture by strengthening the bonding between them. These fibers also enhance the adhesion between aggregate and bitumen, which results in less stripping of SMA mixture. All these give rise to a stiffer and tougher mix with considerable improvement in compressive strength. Fibers do not cause the SMA mixture to weaken when exposed to moisture. Actually they are enhancing the resistance to moisture susceptibility of the mixture. The indices of retained strength for all stabilized mixtures satisfy the limiting value of 75%. But for control mixture, it is only about 60%, which substantiate the necessity of additives in SMA mixtures. Although all the fibers significantly improve the performance of the SMA mixtures in terms of compressive strength, coir fiber gives the best result.

3. METHODOLOGY

3.1 Materials used:

1. Coarse and Fine aggregate
2. Bitumen as binder (60/70)
3. Fibre as stabilizer (Banana fibres)
4. Cement (filler)

Coarse and fine aggregates:

The aggregates are crushed by using jaw crusher to get different sizes of aggregates which vary from 16mm to 75micron. Quality of aggregates are checked through various tests as per MORTH

3.1.1 Impact value test:

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

Aggregate impact value = (B/A) x 100 where

B=weight of fraction passing 2.36-mm IS Sieve, and

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A =weight of oven-dried sample

SL no	WT of oven dried sample (gm)	Wt of aggregate retained through 2.36 mm sieve (gm)	Wt of passing aggregate (gm)	Impact value	Average impact value
1	673.5	602.4	71.1	10.56	
2	693.1	619.4	73.7	10.63	11.06
3	678	605.4	72.6	11.99	

Table 3.1.1 determining of Impact value

Fig 3.1.1 Impact value

4. EXPERIMENTAL INVESTIGATION

4.1 Bulk specific gravity of mix Gm:

The bulk specific gravity or the actual specific gravity of the mix Gm is the specific gravity considering air voids and is found out by:

$$Gm = Wm/(Wm-Ww)$$

Where,

Wm is the weight of mix in air,

Ww is the weight of mix in water,

Note that Wm -Ww gives the volume of the mix. Sometimes to get accurate bulk specific gravity, the specimen is coated with thin film of paraffin wax, when weight is taken in the water. This however requires considering the weight and volume of wax in the calculations.

4.2Effective specific gravity (Ge) of aggregate mix

Ge = (Mmix-Mb)/(Mmix/Gmm-Mb/Gb)

Where Mb is mass of bitumen used in mix

Gb is the specific gravity of bitumen

4.3 Voids in mineral aggregate (VMA):

VMA=[(Mmix/Gmb-Mmix/PsGb)/(Mmix) /Gmb]100

Where Ps is the percent of aggregate present by total mass of the mix (that is Magg = Ps*Mmix)

So VMA

So VMA =(1−Gmb/Gsb Ps) 100

4.4 Air voids (VA)

VA = [1−Gmb/Gmm] 100

4.5 Percent volume of bitumen Vb:

The volume of bitumen Vb is the percent of volume of bitumen to the total volume and given by:

$$Vb = [(Wb/Gb)/(W1+W2+W3+Wb)/Gm)]$$

where, $W1$ is the weight of coarse aggregate in the total mix, $W2$ is the weight of fine aggregate in the total mix, $W3$ is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, Gb is the apparent specific gravity of bitumen, and Gm is the bulk specific gravity of mix

4.6 Weights of samples:

After the sample is prepared its dry weight, weight after coating of wax and weight in water is taken. By these values the bulk volume of the sample is evaluated and after that Gmb is calculated by formula given above. For calculation of bulk volume, volume of paraffin is deducted from total volume. Specific gravity of wax is taken as 0.9 g/cc and for water, as 1 g/cc for calculation. Data obtained in this case is tabulated below:

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Here

Wpca = wt. of wax coated sample in air.

Wpcw = wt. of paraffin coated sample in water.

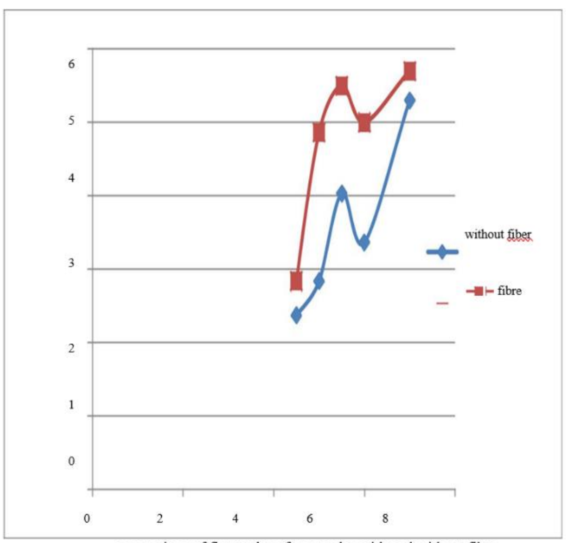
Ws = wt. of sample in air

Bvs = bulk volume of sample

Gmb = bulk specific gravity of the mix For every percentage average specific gravity is calculated.

Binder%	Bulk v	Gmb	Gsb	Avg VMA	VMA	Gmm	Va	Avg Va	VFB
4	483.66	2.51	2.786	13.39	13.51	2.62	4.19	4.066	69.89
	475.44	2.53			12.82		3.43		
	469.4	2.54			13.85		4.58		
4.5	478.55	2.53	2.785	13.24	13.24	2.6	2.69	2.816	78.72
	478.55	2.52			13.58		3.07		
	476.77	2.53			12.9		2.69		
5	482.77	2.52	2.785	14.01	14.03	2.587	2.59	2.46	82.46
	479.88	2.52			14.03		2.59		
	491.22	2.53			13.96		2.2		
5.5	481.22	2.57	2.78	14.29	12.82	2.57	1.56	1.79	86.03
	478.33	2.53			14.18		3.5		
	491.22	2.53			15.87		.31		
6	477.88	2.52	2.76	15.2	14.97	2.55	1.17	1.43	90.44
	479	2.51			15.32		1.56		
	477.77	2.51			15.31		1.56		
7	482	2.49	2.786	16.74	16.88	2.52	1.19	1.02	93.93
	485	2.49			16.67		.94		
	479.62	2.49			16.67		.94		

Table 4.6 Marshall Parameters of samples without fibres'



comparison of flow values for samples with and without fibre

VMA vs. bitumen content:

Graph between VMA values in % and bitumen content in bitumen in % are plotted against bitumen in x-axis and VMA in y-axis.

Binder content	VMA	Avg VMA
4	13.67	13.6
	13.3	
	13.6	
4.5	13.55	13.48
	13.36	
	13.55	
5	15.67	15.56
	15.67	
	5.34	
5.5	14.73	14.82
	14.39	
	15.75	
6	16.34	15.89
	15.67	
	15.67	
7	17.76	18.09
	18.42	
	18.42	

5. RESULTS

1. The SMA samples were prepared using varying bitumen content of 4%, 4.5%, 5%, 5.5%, 6%, and 7%. This was done to find out the effect of increasing bitumen content on the stability value. This plot also helps us to find the Optimum binder content for this mix. The plot below indicates that the stability value increases initially with increase in bitumen content but then decreases gradually. This can be attributed to the fact that with initial increase in bitumen content, the aggregate bitumen bond gradually gets stronger, but with further increase in the 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 falls.

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.

2. Flow is the deformation undergone by the specimen at the maximum load where failure occurs. The flow value increases with the increase in the bitumen content both the mixes with and without fibers .The increase is slow initially, but later the rate increases with the increase in the bitumen content. The flow value of mixes with fibers is more than that without fibers initially, This may be due to the reason that , at lower bitumen content the fibers fills up the voids effectively contributing to the homogeneity and thus providing the stability required to resist any deformation under load . But as the bitumen content increases the this homogeneity is lost , due to which the binder property dominates which makes the fibers to form lumps , reducing stability and increasing deformation under load .
3. The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. The initial fall in VMA value is due to the re-orientation of the aggregates in the presence of bitumen. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly moves apart resulting in an increase in VMA.

The VMA values are quite similar in both the mix with and without fiber , but at larger bitumen content of 6%, VMA of mix with fiber is slight more , which can be attributed to the fact that at more bitumen content the fibers will form lump thus causing the further movement of aggregates apart increasing the VMA.

4. The Air Voids (VA) decreases with increase in the bitumen content because with increase in bitumen content it goes on filling the air voids progressively.

The VA of mix with fiber is much less than that without fiber. This is because the fiber already filled up some portion of air voids (VA) which further decreases as the bitumen goes on filling the air voids with increase in bitumen content. At 6% binder the VA values for sample with fiber are quite more than that without fiber which may be due to improper mixing

5. The Voids Filled Bitumen (VFB) is expressed basically as a fraction of VMA. . The VFB of a mix generally increases with the increase in the bitumen content. Here in our result too, we can clearly observe that VFB increases since increase in bitumen content causes more and more bitumen to fill the voids present in the mix as well as that inside the aggregates causing the overall increase in the bitumen inside the voids or VFB.

6. The drain down remains to be one of the most important problems associated with SMA due to its high bitumen content .To counter this fibers as stabilizers are generally used . Here the drain down tests was carried out to compare the drain down characteristics of samples with and without fibers at OBC.

It was found out that with the use of fibers no drain down was obtained. Hence we can easily observe that use of fibers significantly reduce the drain down in a SMA Mix.

7. The result of the indirect tensile test clearly indicates that the indirect tensile strength of the SMA sample decreases considerably with increase in temperature. At low temperature the

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tensile strength is very high but it reduces significantly with increase in temperature. This may be attribute to the fact that at lower temperature the binder becomes very stiff thus increasing the binding ability considerably, but at higher temperature the bitumen softens, loosens its binding ability , thus attributing to the loss of its tensile strength .The results are very high in case of 5^0C and very less for 40^0C

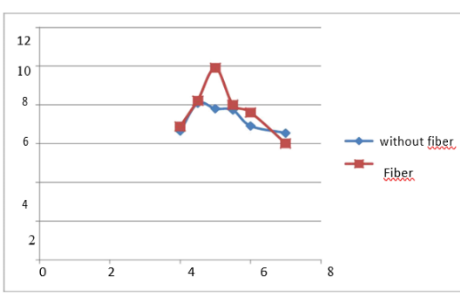
From the graph of stability vs. bitumen we learnt that optimum binder content for samples prepared by use of banana fiber is found to be 4.15 %.

8. Here maximum stability obtained is 10.1 KN. When compared to other fibers it is a bit higher. So because of this banana fiber can be used in case of general heavy traffic requirements and it would be suitable for severe traffic situations also.

From graph of flow value and binder content we can see that flow value increases with binder content.

9. From graph of stability vs. binder with and without fiber we can see that the stability gets increases for almost all binder contents after using banana fiber.

binder content(fibre)	4	4.5	5	5.5	6	7
without fibre	6.65	8.079	7.8	7.73	6.91	6.54
fiber	6.886	8.214	9.9	8	7.6	6



Graph of stability vs. binder with and without banana fiber.

6. CONCLUSION AND FUTURE SCOPE

In this experimental used banana fiber in stone matrix asphalt result may compared with and without banana fibers material strength increase 15% of original stone matrix asphalt. In this experiment cellulose fibre only banana fibers used in lot of natural fibers like bamboo fibers, abaca, hemp jute, kapok, kenaf, pine, ramie etc.. Natural fibers also may try animal fibres materiel for their investigation of SMA in future.

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