STUDY ON CONVENTIONAL PAVEMENTS AND STONE MASTIC ASPHALT PAVEMENTS

Boddeda Tejaswini[1], Hari Krishna Karanam[2]
M.Tech Student[1] , Professor[2]
Department of Civil Engineering
Sankethika Vidya Parishad Engineering College, Visakhapatnam, Andhra Pradesh, India

ABSTRACT - A good amount of research is going on all over the country in this field to solve the problems associated with pavements. It is observed that Stone Matrix Asphalt (SMA) is an ideal mixture for long lasting Indian Highways. SMA is successfully used by many countries in the world as highly rut resistant bituminous course, both for binder (intermediate) and wearing course. The major difference between conventional mixes and SMA is in its structural skeleton. The SMA has high percent about 70-80 percent of coarse aggregate in the mix. This increases the interlocking of the aggregates and provides better stone to stone contact which serves as load carrying mechanism in SMA and hence provides better rut resistance and durability. On the other hand, conventional mixes contain about 40-60 percent coarse aggregate. The stability of the mix is primarily controlled by the cohesion and internal friction of the matrix which supports the coarse aggregates. The second difference lies in the binder content which lies between 5-6 percent for conventional mixes. Below this the mix becomes highly unstable. Above this percent will lead to abrupt drop of stability because the binder fills all the available voids and the extra binder makes the aggregates to float in binder matrix. The high bitumen content contributes to the longevity of the pavements. Samples were prepared as per Indian (NMAS -13.2mm) by varying trail binder contents from 5.5-7% using Marshall method by Super pave Gyratory Compaction to ensure the specified percentage void contents. These specimens are further tested for their stability, flow and volumetric properties. The optimum bitumen content for the mix with unmodified VG-30 graded bitumen for fiber were calculated. These samples prepared with optimal fiber and bitumen contents are analyzed for different Marshall stability properties. Then all the results were compared between conventional pavement and stone mastic asphalt pavements.

Key words: Stone Matrix Asphalt (SMA), Conventional mix.

1. INTRODUCTION

There are three major types of asphalt surfacing, characterized by a mixture of bitumen and stone aggregate. These are Dense Graded asphalt, Stone Mastic Asphalt and Open Graded Asphalt. SMA is best explained as two-component hot mix asphalt HMA which comprises a coarse aggregate skeleton derived from a gap-graded gradation and a high bitumen content mortar. Since 1960s, Stone Mastic Asphalt (SMA) pavement surfaces have been used successfully in Germany on heavily trafficked roads The SMA mixtures are designed to have high aggregate content, high asphalt content typically 5.5– 7% and high filler content. For ordinary SMA, the use of unmodified bitumen together with fibrous material as a drainage inhibitor is sufficient. Under high temperatures and heavy loading, a harder bitumen grade will also suffice. Stone matrix asphalt refers to coarse aggregate- sand group with porous asphalt typically closest to straight coarse aggregate form. A coarse aggregate skeleton is a structure of grains with the suitable sizes resting against each other to interlock, whose structural requirements converge when proper mechanical resistance was provided by the blend of aggregates to withstand the vehicular loadings. To provide high rut resistant asphalt mixture proper volumetric properties need to be maintained for promoting the proper aggregate packing. The mixtures derived are based on following principles

- The Stability and deformation resistance was offered when there is a proper stone-to-stone contact brought by selecting suitable gradation

A long lasting pavements are achieved with proper mix design to volumetric, including voids in mineral aggregate (VMA), asphalt film thickness and mineral filler fractions. Indian Roads Congress (IRC) had guidelines for SMA in (**IRC:SP:79-2008**) a manual containing design and construction of SMA mixtures was made by the author in the US for Indian engineers. Some of the merits of using the Stone matrix asphalt mixture are stated below

- Long serviceable life
- Enhanced strength and better wear resistance due to aggregate interlock by coarser fractions.
- Higher binder content improve its fatigue resistance
- Delayed aging and durability to early cracking of the asphalt

Mastic is next important constituent in the Stone matrix asphalt. It is combination of finer aggregate, filler, stabilizer or drainage inhibitor and bituminous binder. The function of fine aggregate is to fill up the voids among the coarse aggregate particles and need to bring ease in interlocking.

Filler is an aggregate constituent which passes through 0.075 mm sieve. Some of the used fillers are the fly ash, hydrated lime and bag house fines.

- Size of the particles still more smaller than bitumen film makes it an additive quantity in bitumen film causing instability in surface course, bleeding ,fat spots and rut formations
- Size of the particles if larger, then binder film over aggregates behave like a fill up aggregate forming mastic and take part in filling the voids

Asphalt works as a thermoplastic and better water-resistant adhesive. It acts as a medium to bond the mineral aggregates all together forming a structural layer. In order to have good results or improvements in its consistency, temperature, susceptibility, service aging binders are classified as paving grade binder (unmodified), polymer modified bitumen (PMB) and some of the special binders like multi grades. paving grade 0bitumen is 50/70 (VG-30), this is mainly used in the manufacture of hot mix asphalt for bases and wearing courses. Stabilizers enhance the binder to be in place. Adding the fibre make the bitumen film thickness over aggregates change. It was reported that there was reduction of 70 times binder drain-down when 0.3% cellulose was used as compares to mix without stabilizer.1.They investigated on aggregate gradation and filler type in properties of SMA. Four of different aggregate gradations with two types of fillers, such as Hydrated Lime and Crushed Stone Dust have been tried for preparation of mixes. Hydrated Lime of SMA mixes has been improves air voids and moisture susceptibility in the same gradation of samples with Crushed Stone (**Salam Ridha Al-Etba ,,Sravana & Amrendkumar, 2013**). **2.** Conducted experimental on Influence of Additives on the Drain down Characteristics of Stone Matrix Asphalt Mixtures. This paper focuses on the influence of additives like coir, sisal, banana fibres (natural fibres), 0.1,0.2,0.3,0.4 respectively and waste plastics (waste material) and polypropylene (polymer), 1,3,5,7,9 respectively in the drain down characteristics of SMA mixtures. **Bindu et al. (2014). 3.** An attempt has been made to study the resilient properties of mixtures of stone matrix asphalt made with two types of conventional binders namely bitumen 80/100 and 60/70, with 0.3% by weight of a non –conventional natural fiber, namely coconut fiber. **Arpita et al. (2011) 4.** Studied the use of modified bitumen with the addition of processed waste plastic (size 2-4mm) of about 5- 10% by weight of bitumen helps in substantially. **Amit et al (2012)**

2. OBJECTIVES & SCOPE

- Comparision of drain down results at varying finer contents with 7% bitumen at 160C and 170C temperature.
- Comparison of stability, flow, VG30, by using Marshall stability method.

The scope of the present study covers, methodology to determine the engineering properties of SMA mixtures using the Glass fibre by means of the laboratory procedures. In order to ensure the suitable Glass content, using the drain-down test results experiments are carried out choosing constant fiber content. These specimens are further tested for their stability, flow and volumetric properties. The optimum bitumen content for the mix with unmodified VG-30 graded bitumen for fibre were calculated. These samples prepared with optimal fibre and bitumen contents are analyzed for different Marshall stability properties. Then all the results were compared between conventional pavement and stone mastic asphalt pavements.

3. MATERIALS USED

Aggregate

Coarse aggregate: Aggregate retained on 2.36mm sieve are generally used as coarse aggregate

Fine aggregate: In general aggregates passing through 2.36mm sieve and retained on 0.075mm sieve are taken as fine aggregates.

Filler: The filler is the 0.075mm passing, where for the total 10% filler content, 2% of hydrated lime and 8% of the granite dust is used for sample preparation.

Stabilizer: SMA mixtures have the problem of drain down because of more binder which needs to be held by increasing surface area of aggregate skeleton by using either filler or stabilizer. For the present study, Glass fibre is chosen.

Glass fibre: Glass fibre have a high tensile modulus, i.e., about 60 GPA, an elongation of 3-4%, and elastic recovery of 100%.

Binder: The bitumen for the fibre-stabilized stone matrix asphalt adopted was viscosity grade VG-30 73:2006. The obtained physical properties of VG-30 such as penetration, ductility, softening point and specific gravity and their requirements as per specifications.

4. METHODOLOGY

Specific Gravity of coarse aggregate is determined.

Aggregate crushing test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386 (PART IV) – 1963.

The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Los Angeles abrasion test is done .To find the suitability of aggregate for use in road construction.

Flakiness test is used to determine the particle shape of the aggregate and each particle shape being preferred under specific conditions.

Elongated particles are the particles having length considerably larger than the other two dimensions and it is the particle whose greater dimension is 1.8 times its mean size.

Optimal fibre content: In order to derive the standard or the fixed content of stabilizer to be added, the drain down test is conducted for reference. These drain down experiments are tested for the loose SMA mixes prepared for cellulose fibre.

Method of fibre addition: The method of fibre distribution in the SMA mix influences the bind between fiber and mastic which further influence the strength and volumetric properties of mix. So, fabrication of samples was made using the dry process i.e., the fibres are added to the mix before the binder or bitumen is added.

Drain down Test: Drain down test was led as per ASTM D 6390 in a wire basket made up of standard sieve cloth of 6.3 mm size. The test was conducted for loose mixtures at OBC (Optimum Binder Content) and at maximum binder content of 7 % to ensure that the mastic draining property of the SMA mixtures was within permissible values of 0.30 % for Indian gradation. It also provided an evaluation of the drain down potential of SMA mix in the field. The test is to be conducted one at plant production temperature (160°C) and other at 10°C above the anticipated production temperature (170°C).The test was repeated at a temperature 100C higher i.e., at 170°C

The amount of binder drain down was calculated using equation,

$$Draindown\,(\%) = 100 * \frac{(D-C)}{(B-A)}$$

where,

A= mass of empty wire basket (g)

B= mass of wire basket plus sample (g)

C = mass of the empty catch plate (g)

D = mass of the catch plate plus drained material (g)

Marshall Stability Test: Marshall Stability test was conducted on cylindrical SMA specimens to find out their stability and flow values. The principal features of the method were a density-voids analysis and a stability-flow test of compacted specimen. The specimen was kept in thermostatically controlled water bath maintained at 60 ±1^{0}C for 30 to 40 minutes. Then it was placed in Marshall test head and tested to determine Marshall stability value which was a measure of strength of the mixture. It was the maximum resistance in kilo Newton, which it would develop at 60^{0}C when tested in the standard Marshall equipment. The flow value was the total deformation in units of mm, occurring in the specimen between no load and maximum load during the test. The test specimens were prepared with varying bitumen content in 0.5 per cent increments over a range that gives a well-defined maximum value for specimen density and stability.

5. RESULTS AND DISCUSSIONS

COARSE AGGREGATE

Determination of specific gravity of coarse aggregate:

Weight of Pycnometer (W_1) = 470 gm

Weight of Pycnometer + $\frac{2}{3}^{rd}$ of coarse aggregate (W_2) = 1270 gm

Weight of Pycnometer + $\frac{2}{3}^{rd}$ of coarse aggregate + $\frac{1}{3}^{rd}$ of water (W_3) = 1970 gm

Weight of Pycnometer + full of water (W_4) = 1455 gm

Sp. Gravity= $\frac{W2-W1}{(W2-W1)-(W3-W4)}$

= $\frac{1270-470}{(1970-1270)-(1455-470)}$

= 2.65

Therefore, specific gravity of coarse aggregate = 2.65

Crushing value of coarse aggregate:

Diameter of the mould = 15.2cm

Diameter of piston = 15 cm

Plunger height = 11.5cm

Thickness of mould = 1.6cm

Weight of mould = 14.2 kg

Weight of mould + coarse aggregate = 17.24 kg

Weight of aggregate (A) = 3.040 kg

Passing of 2.36mm sieve weight (B) = 530 gm

Therefore aggregate crushing value = $\frac{530}{3040}$*100

=17.43%

Aggregate impact value Calculation:

Empty weight of the mould (w1) = 1870 gm

Weight of aggregate + mould = 2550 gm

Weight of aggregates = 2550-1870

= 680 gm

W2 = after impact the crushed aggregate 2.36 mm sieve passing = 60 gm

Impact value = $\frac{w2}{w1}$*100

= $\frac{60}{680} * 100$

= 8.82 (strong)

Los Angeles abrasion value Calculation:

Total weight of aggregate (w1) = 5kg

Weight retained in 1.7 mm sieve = 4590 gm

Passing weight = total weight –retained weight

= 5000-4590

= 410 gm

Los Angeles abrasion value = $\frac{passingweight}{retainedweight}$ ×100

= 8.2%

Calculation for Flaky Particles:

Weight of sample = 1940 gm. The Flakiness Index is calculated by the values obtained in Table

Table 1. Flakiness Index Test Values

S. No	Size of Seive	Weight of passing	Weight of retained
1	6.3mm to 10mm	0	1940
2	10mm to 12.5mm	60	`1880
3	12.5mm to 16	110	1770
4	16mm to 20mm	210	1560
5	20mm to 25mm	330	1230
6	25mm to 31.5mm	425	805
7	31.5mm to 40mm	230	575
8	40mm to 50mm	320	255
9	50mm to 63mm	255	0

Flakiness index = $\frac{totalweightpassing}{total\ weight\ retained}$*100

= $\frac{1940}{10015}$*100

Flakiness index = 19%

Calculation for Elongated Particles: The Elongation Index is calculated by the values obtained in Table 2.

Table 2: Elongation Index Test Value

S. No	Sieve size	Passing (wt)	Retained (wt)
1	6.3mm-10mm	0	1940
2	10mm-12.5mm	80	1860
3	12.5mm-16mm	144	1716
4	16mm-20mm	310	1406
5	20mm-25mm	545	861
6	25mm-40mm	665	196
7	40mm-50mm	196	0

Elongation index value = $\frac{totalweightpassing}{total\ weight\ retained}$*100

$= \frac{1940}{7979}$*100

= 24.3%

The Physical properties of binder are shown in Table 3.

Table 3. Physical properties of binder

Property tested	Test method	Results obtained	Requirements as per IS-73
Penetration (100gm,5sec at250c) (1/10thof mm)	IS 1203-1978	62.78mm	50-70
Softening point	IS 1205-1978	48.5▫C	Min 47

Marshall Stability Test

FOR SMA SAMPLE:

For 6% bitumen content:

Marshall stability =1013.91KN

For 7% bitumen content:

Marshall stability = 1014.52KN

FOR CONVENTIONAL SAMPLE

For 4% bitumen content

Marshall stability = 848.5 KN

For 5% bitumen content

Marshall stability = 939.6 KN

The SMA mix test Values are shown in Table 4.

Table 4:Test values of SMA mix sample

NOMINAL AGGREGATE SIZE		SMA MIX SAMPLE	
		MARSHALL STABILITY	FLOW
BITUMEN CONTENT	6%	1013.91	2.75
	7%	1014.52	3.71

The Conventional mix test Values are shown in Table 4.

Table 5 :Test values of conventional mix sample

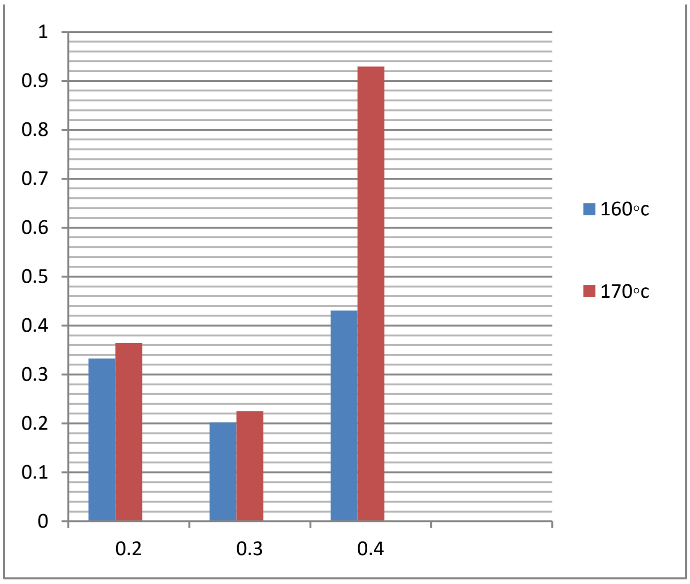
NOMINALAGGREGATE SIZE		CONVENTIONAL MIX SAMPLE	
		MARSHALL STABILITY	FLOW
BITUMEN CONTENT	4%	848.5	1.65
	5%	939.6	2.71

Drain down of binder: The Drain Down values are as in Table 6.

Table 6 : Drain down values of SMA mix (Glass fibre)

Fibre Content %	Drain down %		
	Drain down at 160°C	Drain down at 170°C	MORT&H Specification
0.2	0.345	0.485	0.3 Maximum
0.3	0.1912	0.2095	
0.4	0.0194	0.0456	

The Drain Down values for binder and fiber content are plotted in below fig 1.



Fiber content

Fig 4.1: Comparison of drain down results at varying binder and fibre contents

6. CONCLUSIONS

The basic purpose of this study was to compare between conventional pavements and Stone Mastic Asphalt pavements. The glass fibre is locally available material and economical. Thus, the results of the use of 10-15mm length fibres with along with conventional VG-30 graded binder in the SMA can be summarized as follows:

- Marshall stability of SMA mix was found to be greater than conventional mix so SMA pavements are more durable than conventional pavements.
- The fibre content of 0.3% was found to be optimum satisfying the drain down of the binder and also at the Optimum binder content of bitumen.
- The percent drain down at OBC the range was 0.0021% -0.0648 %.

7. REFERENCES

1. Abtahi, S.M.,M.Sheikhzadeh., S.M, Hejazi. (2010). "Fiber-reinforced asphal-concrete- A review."*Construction and Building Materials,24 (6)*, 871-877.

2. Ahmed, M.A., Attia, M.I.E. (2013). "Impact of aggregate gradation and type on Hot mix asphalt rutting in Egypt."*Engineering research and applications,3(4)*, 2249-2258.

3. Al-Hadidy, A.I., Tan, Y.Q. (2009). "Mechanistic analysis of ST and SBS-modified flexible pavements."*Construction Building Materials,23*, 2941-2950.

4. Al-Hadidy,A.I.,Tan, Y.Q. (2011). "Performance of the SMA mixes made with the various binders."*Construction and Building Materials,25*, 3668-3673.

5. ASTM D6390. (2005). "Standard test method for determination of draindown characterstics in Uncompacted Asphalt mixtures."ASTM

International, formerly known as the American Society for Testing and Materials,USA.

6. ASTM D2041. (2011). ″Standard test method for Theoretical Maximum specific gravity and density of Bituminous paving mixtures.″ASTM International, formerly known as the American Society for Testing and Materials,USA.

7. ASTM D6931. (2012). ″Standard test method for Indirect tensile (IDT) strength of bituminous mixtures.″ASTM International,formerly known as the American Society for Testing and Materials,USA.

8. IRC:SP: 79. (2008). *"Tentative specifications for Stone Matrix Asphalt".* Indian Road Congress, New Delhi,India.

9. NHAI, Ministry of Road Transport and Highways, Government of India. (2013). "Indian Road Network.",National Highways Authority of India, http://www.nhai.org/roadnetwork.htm (Dec 8th, 2013).