INFLUENCE OF AGEING ON THE PERFORMANCE OF STONE MATRIX ASPHALT STABILIZED WITH CELLULOSE FIBER

[1]LINGAM V S PHANI RAMA VIJAYA ADITYA, [2]B.RAMESH,

[1]Student, [2]Assistat professor,
[1]Transportation,
[1]PYDAH COLLEGE OF ENGINEERING, kakinada, india

***Abstract*: Stone Matrix Asphalt (SMA) consists of coarse aggregate skeleton with high binder content and fiber intended to increase the durability and decrease the rutting of the mix, because of highbinder content which leads to draindown. Topcel fiber has been used in SMA to reduce the draindown of SMA mixes. Gyratory Compactor is used to compact the specimen at different air void content such as short term aged specimen (7% air voids) and Long Term Aged specimen (4% Air Voids). This investigation focused on evaluating the effect of the ageing of SMA mixtures by keeping it in oven at specified temperature. In the current study, two aggregate gradations, with nominal maximum aggregate sizes (NMAS) 19 and 13.2 mm as binder and wearing course were adopted to prepare SMA mixtures and their laboratoryperformances were compared. Further the effect of ageing on the rutting performance and the tensile strength ratio of the SMA specimen was evaluated. The ITS value for short term and long term aged (4% air void) for binder and wearing course is 20-22% higher than short term aged (7% air void) for binder and wearing course sample. Thus short term and long term aged(4% air void) there is no significant change in TSR values as compared to short term aged (7%air void) where there is significant difference in TSR values. Hence rutting performance of short term and long term aged (4% air void) sample is almost similar as compared to short termaged (7% air void) which failed earlier due to high air voids representing that effective stone to stone contact is not established. The long term aged sample (4% air void) behaviour shows thatinfluence of ageing affect the strength as well as resistance to permanent deformation as material performs similar when compared to short term aged sample**

***Index Terms*: SMA, Cellulose fiber, Gyratory Compactor, Ageing.**

I. INTRODUCTION

II. The global increase in the traffic volume has raised the need for better performing pavements.In India most of the National Highways and State Highways are flexible pavements. Proper performance of the flexible pavement is expected when all the pavement layers and subgrade support the traffic throughout its life span. These pavements are overloaded with higher stressesdue to the increase in traffic volumes, higher axle loads and rise in tire pressure. These increasein stress creates different types of failures like surface wear, permanent deformation and fatigueon the life of the pavement. Hence, the important type of distress acting on the bituminous pavement is permanent deformation along the wheel path of the bituminous layer which affectsthe movement of vehicles at high speeds and remain the main reason behind hydroplaning. In late 1970s and early 1980s it has been observed that the moisture has the detrimental effect onthe flexible pavements. Thus loss of material from the bituminous pavement due to presence ofwater in bituminous mixtures leads to moisture damage. Different factors such as heavier axleloads, increase in traffic volume, slow moving vehicles, channelized traffic, overloading of vehicles, inadequate maintenance and extreme temperature led to the failure of flexible pavements constructed in India especially in urban areas. To control these effects and to minimize the damage, Stone Matrix Asphalt (SMA) was found to be most effective to control the permanent deformation on the pavement surface and also to control the hydroplaning occurring on the road surface. SMA is a gap-graded bituminous mixture that has coarser aggregate particle in the mix which creates stone on stone contact which in turn helps in resisting more loads. In 1990 the European country showed its success with SMA design, encouraged to conduct the test for its use as intermediate surface courses and comparing its usage with Bituminous mix design. Thus more mixing time is required for SMA with fibers toprevent ball formation and thus doing homogeneous mixing which was not so usual in the densegraded mixtures. Hence it was suggested that stone chippings improves the frictional resistanceof surface but later it proved that there is no use of chippings as the time passes by its micro texture gives the better frictional resistance as compared to other dense bituminous mixes and resistant to permanent deformation.

Stone Matrix Asphalt (SMA)

The SMA mix or "Split mastic asphalt" was founded in mid 1960s in Germany by the Germanengineer named Dr. Zinchner, German Central laboratory Manager for the construction of roadat Strabag Bau AG. It was development as a part of research on the deterioration of the wearingcourses caused by studded tires. It was used in Europe to keep better rutting resistance for morethan 20 years. Thus due to the success of SMA in Europe some states in US through the authority of the Federal Highway Administration, constructed SMA pavements in the year 1991in the United States. Since that time SMA is used extensively in US and also started in Japan with good success.

Huge increase in volume of tandem and tridem axle vehicles in India and huge differences in maximum and minimum temperatures and with the maximum temperatures reaching up to 50 ºC, it is important to go for a new type of bituminous mix to look after these

factors. SMA is one such bituminous mix which can take care of the above factors. With its success in variousother countries, India has come forward to look into the new mix in 2006.

The Working Phenomena of the SMA

The working phenomena of the SMA can be summarized as:

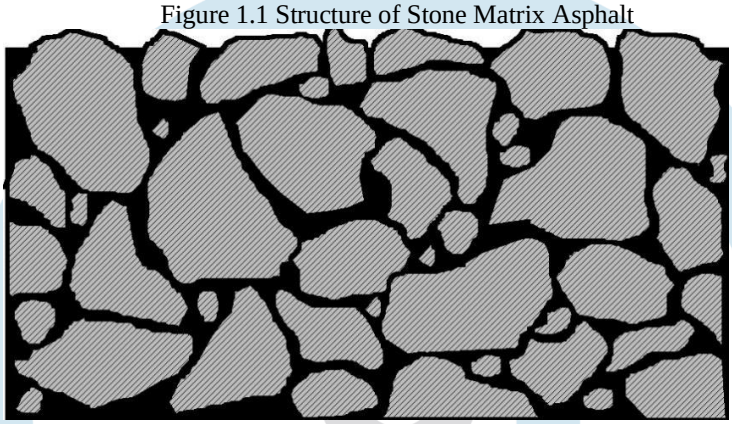
✓ Higher rut resistance to permanent deformation and greater wearing course resistance by the best interlocking of the particle and better coarse aggregate particles.

✓ Durability to earlier cracking and ravelling by a higher bitumen content and a minimum void in bituminous mix which fills the stone skeleton voids and bind the mix together. Better quality and rich quantity of bitumen are important for a long lasting life of design of pavement.

✓ Stabilizing additives provides the homogeneity of the mix in transportation, manufacturing and laying of the mix. Hence it improves the stability of mixer.

Thus better quality and rich quantity of bitumen and good quantity of coarse aggregates are important for the long life of SMA.

Figure 1.1 Structure of Stone Matrix Asphalt



1.4 Stone-on-Stone contact

The deformation of aggregates as compared to the asphalt binder is lesser under wheel load, thus stone on stone contact reduces the chances of rutting. The structure of stone matrix asphalt is shown in Figure 1.2. Following point addresses the establishment of stone-on-stone contact

- Percent passing 4.75 mm plays a major role in the formation of stone on stone contact.
- The stone on stone contact is ensured when the percentage passing 4.75mm is less than 30%.
- Aggregate gradation plays an important role in the formation of stone to stone contact.
- The percentage of fine aggregate is 30 % and that of coarse aggregate is 70%.

Draindown

Drain down occurs when the small quantity of mixture (bitumen and fines) which segregates from the specimen and flows down through that mix. Draindown test is important for SMA than the dense graded mixes. Hence amount of draindown is measured for the mixture should be within the specified limits (0.3% by weight of the mixture).

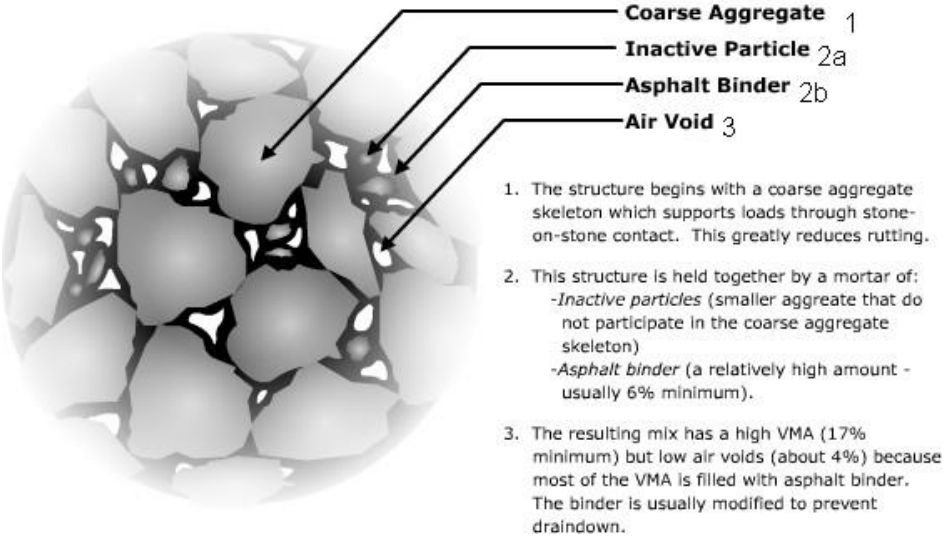


Figure 1.2 Detailed structure of Stone Mastic Asphalt

Properties of SMA

The following are the properties of SMA:

- With rise in temperature, SMA mix has a strong stone structure of good quality coarse aggregate, it leads to increase in shear resistance and frictional strength hence stability to mix.
- With temperature reduction, SMA mix having rich binder content leads to good quality against graded bituminous pavement to resist thermal cracking.
- SMA mix has low air voids, in which impermeable mix is obtained hence it provides moisture susceptibility, resistance in ageing and durability.
- With the rise in the quantity of filler, stabilizer are used which is a cellulose fibres .The cellulose Fibre having three dimensional structure to modify the bitumen to maintain thickness of the bituminous film, improved viscosity, and provide better aggregate/bitumen adhesion.
- Effective stabilization of the mix to prevents the segregation of mix from coarse aggregate.
- Due to the macro-texture of surface of the road and the use of high Polished Stone Value coarse aggregates hence better level of skid resistance is achieved in SMA pavement.
- Due to its better texture depth at night fewer glares are seen on the surface of road and road markings having good visibility.
- SMA road provides reduction in noise due to its texture properties.
- Advantages

The advantages of SMA are as follows:

- SMA gives a durable, textured and rut resistance surface.
- 20-30% increase in life of pavement over conventional pavement surface.
- SMA surface texture property is same as Open graded asphalt (OGA) thus the noise produced in traffic is lesser than Dense Graded Asphalt (DGA) but equal to OGA.
- SMA can be produced and compacted in the same equipment for normal hot mix plant.
- SMA is used at high traffic conditions such as intersections and where Open graded asphalt is unsuitable.
- SMA surfacing provides reduction in reflection cracking from underneath cracked surface due to the better mix.
- The durability of SMA is better than DGA and hence greater than OGA also.
- Better aggregate interlock property and lower permeability.At the end of its life surface of pavement is 100% recyclable.

Objectives of the study

The main objectives of this study are:

1. To Evaluate the Performance of Short-Term Aged Stone Mix Asphalt used in Binder Course (19 mm) Stabilized with Topcel Cellulose Fibre.
2. To Evaluate the Performance of Short-Term Aged Stone Matrix Asphalt used in Wearing Course (13 mm) Stabilized with Topcel Fibre.
3. To Evaluate the Performance of Long-Term Aged Stone Matrix Asphalt used in Binder Course (19 mm) Stabilized with Topcel Fibre.
4. To Evaluate the Performance of Long-Term Aged Stone Matrix Asphalt used in Wearing Course (13 mm) Stabilized with Topcel Fibre.

Organization of the report

In addition to the present chapter, this dissertation work is presented in four other chapters as mentioned below:

Chapter 2 presents the literature review on importance of Ageing of stone matrix asphalt mixture as per field condition, Tensile Strength Ratio and rutting of stone matrix asphalt and cellulose fibres which improve mixture performance.

Chapter 3 describes the methodology adopted in this study. This chapter also includes detailsof experiments performed on SMA according to IRC: SP: 79:2008.

Chapter 4 describes the results and analysis of the present study.

Chapter 5 describes the conclusions and future scope of the study.

LITERATURE REVIEW

GENERAL

In this chapter, details of the literature regarding effect of Ageing on the properties of SMA with the help of Fibre and resistance to rutting on SMA mixes are presented. The resistance offered by SMA is essentially due to the strong mechanical interlocking of coarser fraction because of proper aggregate stone-on-stone contact (Brown and Haddock, 1997). The coarse aggregate skeleton arrange for providing shear strength and effective load distribution pattern of vehicles to tolerate heavier axle loadings as compared to the dense-graded mixtures (Tashman and Pearson, 2011). This significant ability made it sustainable to environmental changes. In order to obtain these results, the aggregate type and its interlocking provide a significant feature in the gap-graded mixes. The basic structure to resist the permanent deformation of the bitumen pavements with SMA, different types of fibers used in SMA mix, and the SMA mix and normal mix performance have been discussed below

Brief History of SMA

The (SMA) or the "Splittmastixasphalt" was developed in mid 1960s in Germany by the German engineer named Dr. Zinchner, German Central laboratory Manager for the constructionof road at Strabag Bau AG was its designer (Blazejowski, 2011). In the sixties the surface courses in Germany was to use "gussasphalt" (mastic asphalt) and also the asphaltic pavementhaving higher air voids, lower coarse aggregate fractions and lower bitumen content (Sehgal and Abele, 2011) making its performance degrade especially in winter due to studded tyres resulting into the poor mix property of the wearing courses thus surface is not able to resist these studded tyres affecting the pavement service period.

During 1975, use of studded tires was stopped, and due to high pavement rehabilitation measures, need for advanced surface mixes which could resist the studded tyres was introducedby Zichner during his course proposed that, blend of coarse aggregate bear the dynamic shattering or crushing so, the durability of pavements can be modified by increasing the proportions of stone quantity and content of mastic and binders

MATERIALS AND METHODOLOGY

The study is well centered on the gap-graded mix called the SMA, thus it is made to rut resistance performance against the permanent deformation with the formation of the stone-on-stone contact skeleton. The volumetric properties of an asphalt mix depend on the kind of gradation adopted. For this study, comparisons between two aggregate gradations namely, the nominal aggregate size of 19 mm and 13.2 mm respectively are chosen. Those are tabulated inTable 3.1 and also the requirement of SMA mix as per IRC:SP:79-2008 is tabulated in Table3.2. To overcome the problem of draindown the natural stabilizer i.e., cellulose fiber Topcel which is biodegradable and it is easily available is chosen with conventional binder VG-20. Theexperimental research approach followed in this study is shown in the flow chart i.e, Figure 3.1.

Table 3.1 Different gradations for SMA Mix (as per IRC: SP: 79- 2008)

SMA Designation	**13 mm NMAS**	**19 mm NMAS**
Course where used	Wearing course	Binder course
Layer thickness	40 to 50 mm	45 to 75 mm
Sieve size,	% passing	
26.5	100	100
19	100	90-100
13.2	90-100	45-70
9.5	50-75	25-60
4.75	20-28	20-28
2.36	16-24	16-24
1.18	13-21	13-21
0.6	12-18	12-18
0.3	10-20	10-20
0.075	8-12	8-12

Study Methodology

The study methodology is briefly illustrated in the Figure 3.1

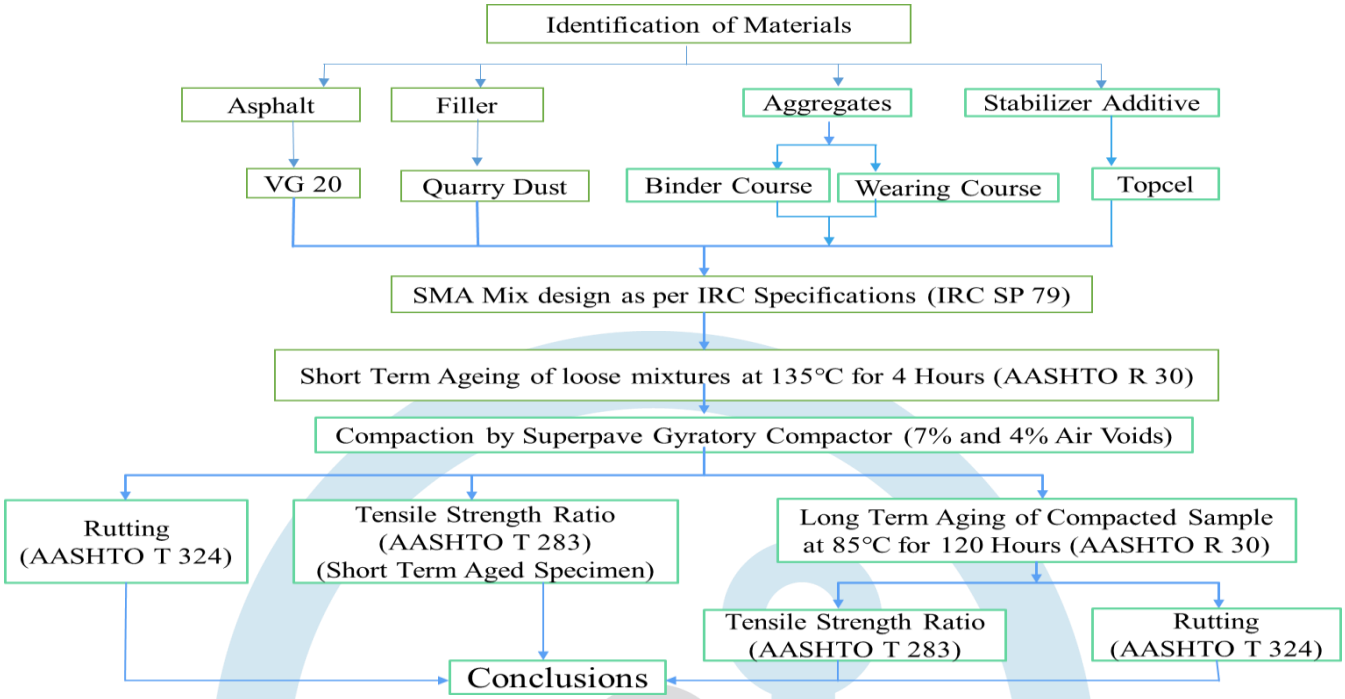


Figure 3.1 Study Methodology

The study methodology of the present study is briefly discussed in the following paragraphs:

Stage 1: In the first stage the type of materials like grade of bitumen, stabilizers, aggregates and type of warm mix additives used were selected and also tests on the bitumen and aggregates were conducted.

Stage 2: In the second stage mix design was conducted by targeting 4% air voids by varying bitumen content in the mix for both 13 and 19 mm NMAS SMA mixes for with or without Evotherm and also tests mentioned in the IRC: SP: 79 (2008).

Stage 3: Short term ageing of the loose specimens by keeping in oven for 4 hours at 135°C as per AASHTO R 30 keeping the same optimum binder content for both SMA mixes with or without Evotherm.

Stage 4: Compacting the sample by Gyratory compactor for short term ageing (7% air void) and long term ageing (4% air void) SMA mixes with topcel fibre.

Stage 5: Calculating the Tensile Strength Ratio as per AASHTO T 283 and Rutting as per AASHTO T 324 of short term aged specimen.

Stage 6: Thus after compaction at 4% air void for long term ageing of specimen by keeping it in oven at 85°C for 120 hrs. As per AASHTO R 30.Thus calculating the Tensile Strength Ratio (TSR) as per AASHTO T 283 and Rutting as per AASHTO T 324 for long term aged specimen.

Figure 3.17 Placing the SMA Binder Course and Wearing Course in the Mould

Thus Figure 3.17 represents the SMA sample after cutting the sample by cutting machine ofdesired shape and hence adjusting in the mould to keep in wheel tracking machine.

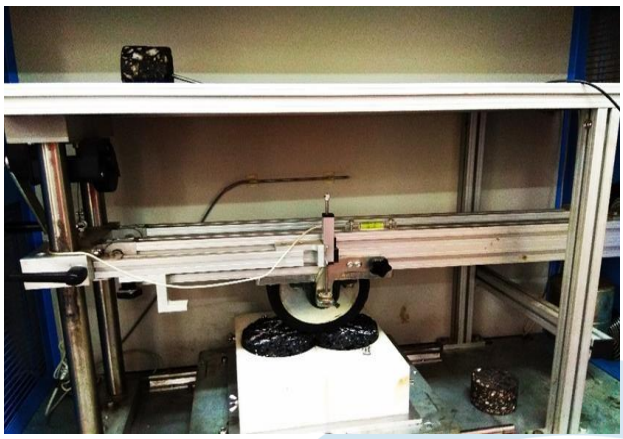


Figure 3.18 Placing the Mould in Wheel Tracking Machine and Setting the Temperature.Hence the wheel load acting on the SMA specimen and temperature is maintained at 60°C.

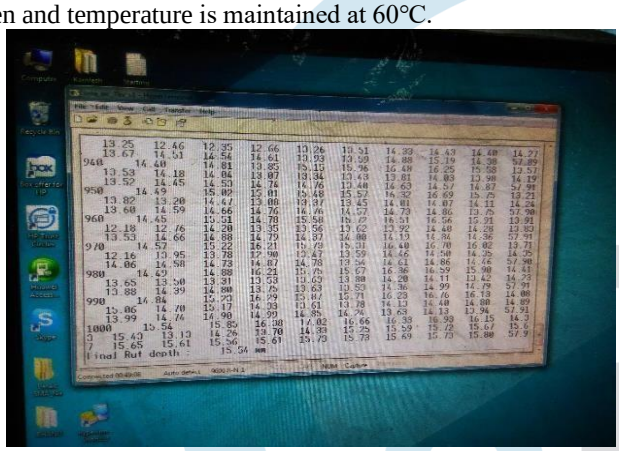


Fig. 3.19 Connection between System and WTM

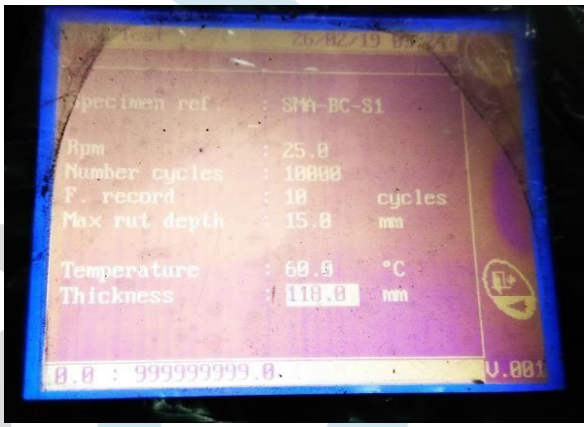


Fig. 3.20 Giving the Input in WTM

Results and Analysis

In this chapter results obtained from different tests including tests on bitumen and aggregates performed. In this study mid gradation was adopted for aggregate mix for both 19 NMAS (Binder course) and 13 NMAS (wearing course). The adopted gradation is shown in the Table 4.1.

SMA designation	13 mm SMA		19 mm SMA	
Course where used	Wearing course		Binder course	
IS Sieve (mm)	Cumulative % by weight of totalaggregate passing		Cumulative % by weight of totalaggregate passing	
	Specified limits	Adopted	Specified limits	Adopted
26.5	-	-	100	100
19	100	100	90-100	95
13.2	90-100	95	45-70	57.5
9.5	50-75	62.5	25-60	42.5
4.75	20-28	24	20-28	24
2.36	16-24	20	16-24	20
1.18	13-21	17	13-21	17
0.600	12-18	15	12-18	15
0.300	10-20	15	10-20	15
0.075	8-12	10	8-12	10

Tests on aggregates

The tests specified in the IRC SP 79 2008 were shown in the Table 4.2.

Table 4.2 Results of tests on aggregate and specifications specified in IRC SP 79 2008

S. No	Test	Results	Method	Specification
1	Combined Flakiness andElongation Index	27 %	IS:2386(P-1)	Max. 30 %
2	Los Angeles Abrasion Value	21.89 %	IS:2386(P-4)	Max. 30 %
3	Aggregate Impact value	15.82 %	IS:2386(P-4)	Max. 24 %
4	Water absorption	0.60 %	IS:2386(P-3)	Max. 2 %

Tests on Binder

. The physical properties of VG-20 are tabulated in Table 4.3.

Table 4.3 Properties of Bitumen as per IS: 73 -2013

S. No.	Characteristics	Test Result	Specification(IS 73-2013)
1	Penetration at 25 ºC, 100g, 5sec.,0.1mm	62	60 min.
2	Absolute Viscosity at 60 ºC, Poises	1665	1600-2400
3	Kinematic Viscosity at 135 ºC, cSt	302	300 min.
4	Flash Point, ºC	272.5	220 min.
5	Softening Point, ºC	51.5	45 min.
6	Test on Residue from RTFO test		
a	Viscosity Ratio At 60 ºC	3.34	4 max.
b	Ductility at 25 ºC, cm	>100	50 min.

Summary and Conclusions

General

Detailed experimental results are evaluated and compared with different percentages of air void such as (4% and 7% air void) for short term and long term aged sample with gyratory compactor thus all the laboratory work was performed. This chapter provides the information about the conclusions obtained from the result and the future scope of the study performed.

The influence of ageing on the properties of the SMA mix are obtained and conclusions are drawn as follows-

1. ITS value for SMA binder course is slightly higher than wearing course for short term aged and long term aged (4% air void) sample and hence short term aged (7% air void) sample performs opposite as compared to short term and long term aged (4% air void) sample where wearing course ITS is slightly higher than indirect tensile strength of binder course. This is caused due to the proper bonding of the wearing course at 7% air void as compared to binder course and hence significant rise in ITS value is obtained.

2. The ITS values of SMA short term and long term aged aged (4% air void) shows 20-25% higher indirect tensile strength than short term aged (7% air void).Thus due to the lesser air void the compaction takes place effectively and hence strength of SMA (4% air void) sample increases and for long term aged sample

3. The TSR from statistical t-test of SMA binder course and wearing course short term and long term aged (4% air void) is similar as compared to TSR of binder and wearing course of short term aged (7% air void) sample where TSR is slightly less than short term and long term aged (4% air void) sample due to the higher air void of 7% as compared to 4% air void as well as long term ageing and hence the performance of wet ITS lower than dry ITS.

4. The rutting performance of SMA short term aged (7% air void) sample fails before 20000 passes for both binder and wearing course as in between them binder course performs better rutting than wearing course.

5. SMA short term and long term aged sample (4% air void) performs better than short term aged (7% air void) for binder and wearing course in terms of rutting. Thus the rutting performance of binder course short term aged sample (4% air void) is slightly better than long term aged (4% air void).The performance of short term aged (4% air void) sample for binder and wearing course is significantly same as compared to long term aged sample the wearing course performs slightly better than binder course in

terms of permanent deformation.

6. Thus it shows that long term aged sample behaves similar as short term aged sample in terms of ITS, TSR as well as rutting characteristics. Hence long term ageing of sample for 5 days at 85°C shows similar strength with short term aged sample simulates at 4 Hr. at 135°C at same air void.

REFERENCES

1. Al-Qadi, I.L., Wang, H., Baek, J., Leng, Z., Doyyen, M. and Gillen, S. (2012)." Effects of Curing Time and Reheating on Performance of Warm Stone-Matrix Asphalt". J. Mater. Civ. Eng., 24(11): 1422-1428.

2. 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.

3. ASTM D6931. (2012)"Standard test method for indirect tensile (IDT) strength of bituminous mixtures." ASTM International, formerly known as the American Society for Testing Materials, USA.

4. AASHTO T283. (2014) "Standard method of test for resistance of compacted asphalt mixtures to moisture-induced damage" American Association of State Highway and Transportation Officials, Washington, D.C., USA.

5. Bhargava, N., Das, B.P. and Siddagangaiah, A. K. (2018). "Synergistic influence of aging and moisture on performance of warm mix asphalt". International Journal of Pavement Research and Technology. 15(2), 50-61.

6. Gandhi, T., Rogers, W. and Amirkhanian, S. (2010). "Laboratory evaluation of warm mix asphalt ageing characteristics". International Journal of Pavement Engineering. 11(2), 13-142.

7. Imaninasab, R. Bakhshi, B., and Shirini, B. (2016). "Rutting resistance and resilient modulus evaluation of polymer-modified SMA mixtures". Petroleum Science and Technology. 34(16), 1483-1489.

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

9. Indian standard paving bitumen – specification, IS 73, Bureau of Indian Standards, New Delhi, 2013.

10. Khosla, N. P., Tayebali, A. A., Ayyala, D. and Malladi, H. (2014). "Laboratory Evaluation of Warm-Mix Asphalt Mixtures for Moisture and Rutting Susceptibility". J. Mater. Civ. Eng., 27(5), 110-116.

11. Khedmati, M., Khodaii, A. and Haghshenas, H. F. (2017). "A study on moisture susceptibility of stone matrix warm mix asphalt". Construction and Building Materials. 14(4), 42-49.