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Fatigue and Rutting Performance of Asphalt Mixes Using Reclaimed Asphalt Pavement Materials

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ABSTRACT: In the recent years road construction has been increasing rapidly due to urbanization and the infrastructure development, due to this development there is increase in volume of vehicles and traffic hence there will be increase in axle loads from vehicles which will cause distress to the pavement surface and reduce the service life of the pavement due to this there will be increase in cost of maintenance and rehabilitation. A new attempt is made by using reclaimed asphalt pavement (RAP) as a partial replacement for virgin materials, without compromising in the quality of the mix.
The objective of the present study is to determine Fatigue and Rutting properties of Fine Stone Matrix Asphalt mix and Fine RAP mix and the comparison between the two mixes is given. Marshall Method of mix design is adopted for preparation of samples as per ASTM D 6926-16 and in accordance with IRC SP-79:2008. For the determination of OBC, specimens are prepared with VG-30 binder.
According to IRC specifications, the greatest RAP percentage admissible for road base hot mix asphalt is up to 30%; hence further addition of RAP content (up to 100%), characterized by a fatigue life lesser than that of conventional bituminous mixtures. Test results showed that the number of cycles deceased with the increase in load intensity i.e, 100,150 and 200kg loading. The RAP samples also showed good fatigue resistance under this loading condition. In the rutting analysis the rut depth increases with the increase in the number of cycles, for conventional samples the number of cycles taken were more to cause 12mm rut depth as compared to the RAP samples.

KEYWORDS: Stone Matrix Asphalt (SMA), Fine Stone Matrix Asphalt (FSMA), Reclaimed Asphalt Pavement (RAP)

I.INTRODUCTION

Recycling asphalt pavement creates a cycle of reusing materials that optimizes the use of natural resource. Reclaimed asphalt pavement (RAP) is a useful alternative to virgin materials because it reduces the use virgin aggregate, which is a scarce commodity in some areas across the globe. It also reduces the amount of costly new asphalt binder required in the production of asphalt paving mixtures. Existing asphalt pavement materials are commonly removed during resurfacing, rehabilitation, and reconstruction activities. Once removed and processed, the pavement material becomes RAP, and contains valuable asphalt binder and aggregate. There are four major asphalt production cost categories: materials, plant production, trucking, and lay down. Out of these four materials is the most expensive production cost category, which may comprise about 70 percent of the cost of production. The most expensive and economically variable material in an asphalt mixture is the asphalt binder. It is most commonly used in the intermediate and surface layers of flexible pavement to provide tensile strength to resist distortion, protect the asphalt pavement structure and subgrade from moisture, and provide a smooth, skid-resistant riding surface that withstands wear from traffic. As a result, the most economical use of RAP is in the intermediate and surface layers of flexible pavements where the less expensive binder from RAP can replace a portion of the more expensive virgin binder. Hence there is lot of benefits in using RAP in hot mix asphalt mixtures as it reduces the cost of construction and also the use of natural and virgin materials.

Stone matrix asphalt (SMA) is a gap-graded HMA that is designed mainly to maximizedeformation or rutting resistance and durability by using a structural basis of stone-tostonecontact. Since the aggregates are all in contact, rut resistance relies on aggregateproperties rather than asphalt binder properties. Hence the aggregates do not deform as much as asphalt binder under load, this stone-to-stone contact greatly reduces rutting. SMA is generally more expensive than a typical dense-graded HMA (about 20 – 25 percent) because it requires more durable aggregates, higher asphalt content and, typically, a modified asphalt binder and fibers. In the right situations it should be cost effective because of its increased rut resistance and improved durability. SMA, originally developed in Germany to resist rutting and studded tire wear, has been used in the U.S. since about 1990 (NAPA, 1999). SMAs have been shown to be effective in reducing traffic noise. SMA is typically used as a surface course and occasionally as an intermediate course. They have also been used successfully in thin overlay and mill-and fill resurfacing applications.

A.OBJECTIVES

The main objective of the present study is to give the comparison between conventionalFine SMA and Recycled Fine SMA mixes

1. The study mainly focuson the use of conventional fine SMA and recycled Fine SMA in the construction of highway pavements
2. The study also helps in evaluating the strength parameters between conventional Fine SMA and also replacement of Fine SMA by 100% recycled Fine SMA mix
3. To determine the fatigue and rutting potential of conventional and recycled Fine

II.METHODOLOGY

Methodology adoptedfor conventional Fine SMA mixes and Fine reclaimed asphalt mixes consists of collection of materials and performing basic tests on them. The methodologyadopted is as per IRC SP: 79-2008, and NCHRP report. The physical properties of conventional and RAP mixes are determined and the Marshall Stability, Indirect tensilestrength, Fatigue and Rutting properties of the RAP and conventional mixes aredetermined..

The Marshall Properties, indirect tensile strength, Fatigue and Rutting properties of the Conventional Fine SMA and 100% Fine RAP are determined for following combinations.

In this study mid gradation is adopted for,

1. Conventional Fine SMA with VG-30 binder
2. 100% RAP- with VG-30 binder

The methodology adopted for the study is shown in figure 1 below.

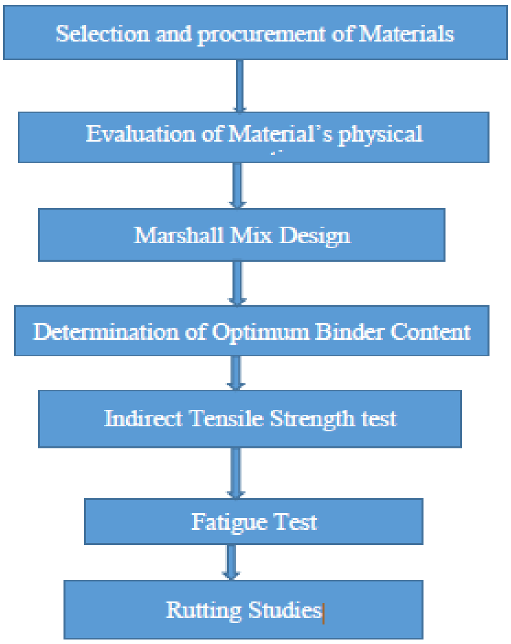

Figure 1: Experimental Methodology

III. EXPERIMENTAL INVESTIGATIONS

Fine SMAand Fine RAP SMA are both prepared as per gradation and with bitumen contents varying from 5.5 to 7% by weight of aggregates. The specomens were compacted by giving 50 blows on either face of the specimens. Three samples were prepared for each SMA mixture and the average of three values was considered. The various tests results are presented in the following tables

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Table 1: Test results of Mineral aggregates

Sl. No	properties	Test value	Permissible limits as per IRC:SP 79-2008
1	Aggregate impact Value(AIV)%	17.3	Max 18
2	Los Angeles Abrasion Value, LAV (%)	18.1	Max 24
3	Water Absorption value (%)	0.43	Max 2
4	Specific Gravity Test	2.64	2.5 – 3.0

Table 2:Test results of binder

SL. No	Properties	Test Value	Permissible limits as per MoRTH(5th revision)	Test Method
1	Penetration at 25oc	58	50-70	IS– 1203: 1978
2	Softening point	59.6	Min 47	IS– 1205: 1978
3	Ductility value at 27oc, cm	87	Min 75	IS– 1208: 1978
4	Specific gravity of RAP binder	1.06	Min 0.99	IS– 1202: 1978
5	Viscosity of bitumen @135oc	544.2	Min 350	IS– 1206: 1978

Mix Design

Marshall Mix design was carried out for conventional Fine SMA mixes and Fine RAP mixes. Grading of aggregate was adopted as per MoRTH 2013 and is given in table 3

Table3: AggregateGradation for Fine SMA

Sieve size, mm	Cumulative % by weight of total aggregate passing	
	Fine SMA(4.75mm NAMS)	
	Range	Mid
19	100	100
13.2	100	100
9.5	100	100
4.75	90-100	95
2.36	28-65	46.5
1.18	22-36	29.0
0.6	18-28	23.0
0.3	15-22	18.5
0.075	12-15	13.5

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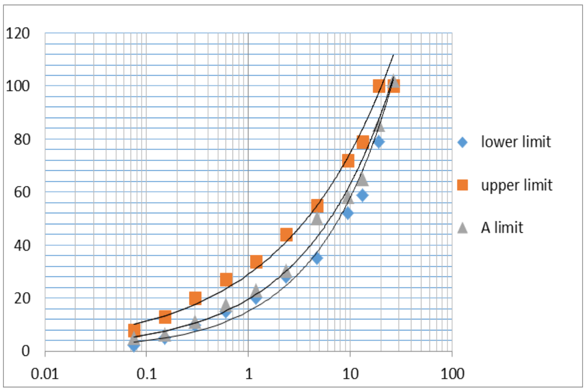

Figure 2: Aggregate Gradation For Fine And Conventional RAP SMA

Table 4: Fine SMA Mix requirements

Mix design papameters	Requirements
Air void content (%)	4.0
Bitumen content (%)	5.8 min
Voids in mineral aggregate (VMA,%)	17 min
Tensile strength ratio, TSR (min 80%)	80min

The optimum binder content for conventional Fine SMA and Fine RAP SMA was found to be 6.20 and 5.8 respectively. All the Marshall test results of conventional and RAP mixes are found satisfactory as per design criteria and also as per MoRTH(5^{th} revision). The summary of the test is presented in table 5

Table 5: Marshall Properties of conventional and Fine RAP mixes

Property	Conventional Fine SMA	RAP SMA
OBC%	6.2	5.8
Stability	10.63	31.1
Flow , mm	2.7	2.7
Air Voids %	4	4
VMA %	17.35	16.80
VFB%	73.85	76

Indirect tensile strength(ITS)

This test is mainly conducted to determine the tensile strength of bituminous mixes as per AASHTO specifications in this research the specimens are tested for both Conditioned and Unconditioned methods. And then the samples were tested for tensile strength ratio (TSR). The test results are shown in table 6.

Table 6: ITS and TSR of conventional and RAP SMA

Type of mix	ITS(Mpa)		TSR(%)
	Unconditioned	Conditioned	
Fine SMA	0.92	0.79	85.86
Fine RAP SMA	3.13	2.97	94.88

IV. FATIGUE TEST

The fatigue resistance of an asphalt concrete mix is its ability to withstand repeated loading without fracture. The primary purpose of this project is to evaluate the effects of high RAP content and air void content on the fatigue performance of asphalt pavement. Test results showed that the number of cycles deceased with the increase in load intensity i.e, 100,150 and 200kg loading, The RAP samples also showed good fatigue resistance under this loading condition. Table 7 and 8 gives the results of fatigue studies that has been carried out.

Frequency: 1 Hz
Load Amplitude: 100,150,200Kg
No of cycles: 5cycles/sec
Hydraulic pressure: 30 bar or 30Kg/sqcm
Failure criteria: 4mm
Load selection: 2Tonnes

Table 7: Test results of conventional Fine SMA

Sample no	No of cycles for 100 kg load	No of cycles for 150 kg load	No of cycles for 200 kg load
1	22664	16203	12965
2	21783	15841	11846
3	21243	15426	12734

Table 8: Test results of Fine RAP SMA

Sample no	No of cycles for 100 kg load	No of cycles for 150 kg load	No of cycles for 200 kg load
1	6984	3629	2364
2	6732	3418	2478
3	6828	3524	2443

V.RUTTING STUDIES

Rutting in pavement occurs in two ways:

(a) Due to deformation in subgrade and other unbound layers.
(b) Due to rutting in bituminous layer

The maximum permissible rutting depth as per IRC 37-2012 (for design traffic up to 30 msa) is 20mm. Rutting / deformation study has been carried out for the conventional and RAP mixes and graph has been plotted as no of cycles in X-axis and Rut depth along Y-axis. The results are shown in table 4.

Input data
Area = 5x2.5 =12.5sqcm
Load
1 Disc = 10Kg
Liver Arm Ratio (LAR) = 8
Load = 10x8=80Kg
Tyre pressure P= Load/area
P=6.4Psi

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Figure 3:Rutting properties of Conventional Fine SMA

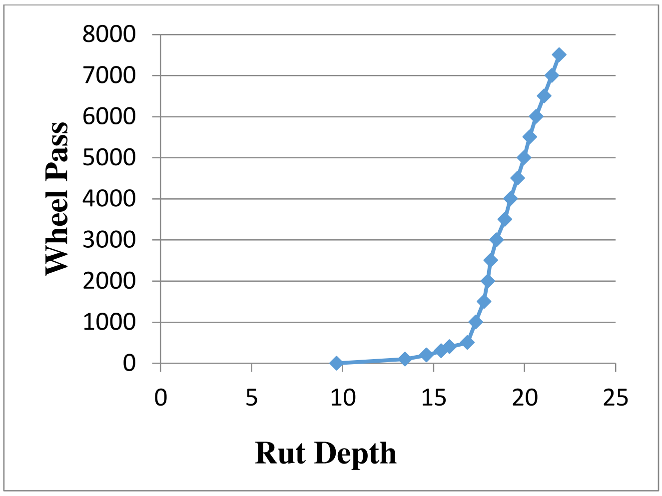
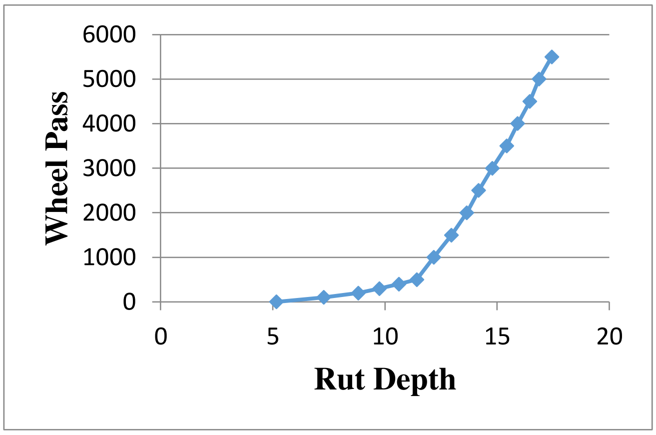


Figure 4: Rutting properties Fine RAP SMA



VI. SUMMARY AND CONCLUSIONS

Based on the testing and analysis work carried out the result obtained from the study include:

1. The tests performed for physical properties of Conventional and RAP mixes showed that the requirements were satisfying as per MoRTH 5th Revision.
2. The laboratory compaction and mixing temperature for VG – 30 Binder is 155^{o} C and 145^{o} C respectively

The results obtained from the various tests carried out for Conventional and RAP mixes are discussed here

Marshall Stability

The maximum stability was found to be 10.63 KN for conventional Fine SMA mix prepared with VG 30 binder and the maximum stability for 100% RAP was found to be 31.1. It has been found that with the increase in RAP content the stability also increases.

Indirect Tensile Strength

The Indirect Tensile Strength of Conventional Fine SMA was found to be 0.96 Mpa and the strength of RAP mix was found to be 2.97 which were prepared with VG 30binder. It has been observed that the ITS values increase with increase in RAP content.

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Fatigue test

According toIRC specifications, the highest RAP percentage admissible for road base hot mix asphalt is up to 30%; hence further addition of RAP content (up to 100%), characterized by a fatigue life lesser than that of conventional bituminous mixtures. Test results showed that the number of cycles deceased with the increase in load intensity i.e, 100,150 and 200kg loading. The RAP samples also showed good fatigue resistance under this loading.

VII. CONCLUSION

Usage of RAP in HMA is beneficial in many ways, but increasing the percentage of RAPin HMA beyond certain limit can result in a very stiff mix that is susceptible to cracking. The rutting test has been carried out for Conventional and Fine RAP mixes with tyre pressure of 6.4 Psi. The rutting for any pavement will be determined by computing the mean rut depth and there three types of levels of rutting according to AASHTO, 1986. Low 6-12mm, Medium 12-25mm, High more than 25mm. From the results it has been observed that when the no of wheel passes increases the rut depth also increase and the results are within permissible limits

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