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Rutting Based Evaluation of Asphalt Mixes

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Abstract

Pavement rutting is one of the most common and destructive pavement distresses being observed in flexible pavements, which is primarily due to axle loads that exceed legal limit and high ambient temperatures, and also poor mix design is one of the cause of rutting. The drastic increase in traffic volume during last few decades has resulted in premature pavement failures of almost the whole road structure in Pakistan. In this scenario it is the time to investigate this problem and propose appropriate solution. Physical properties of aggregates and bitumen were evaluated in the laboratory. Mechanical Properties of three mixes, i. e., Marshall, Superpave and Stone Mastic Asphalt (SMA) were evaluated by performing creep test, indirect tensile test and dynamic modulus in order to compare the performance of mixes under prevailing load and environmental conditions of Pakistan. The study revealed that Superpave mixes performed better than Marshall and SMA.

Key Words: *Asphalt, Creep, Performance, Rutting, Superpave*

1. Introduction

Rutting in Hot Mix Asphalt pavements has become one of the serious issues in pavement industry. Research efforts are being carried out for the improvement of mix quality and performance through the identification of mixture design parameters which relate to asphalt mix. Currently performance-based laboratory test methods and models is the main focus of pavement researchers for the evaluation of mix performance. The development and adoption of Superpave Volumetric Design Method, during 1993, was an attempt to improve HMA mixture performance (McGennis, R.B et al 1994).

Recently, Superpave has been reported as an improved system for performance based design, analysis of asphalt concrete mixes and asphalt pavement performance prediction. It is a structured approach consisting of selection of materials, selection of design aggregate structure, asphalt binder content, and evaluation of moisture susceptibility.

Qiu, et al. (2006), utilized aggregate packing concepts to design and quantify aggregate stone-to-stone contact in SMA. SMA is expected to provide high resistance to rutting, by maintaining volumetric properties and providing resistance to distresses. The stability and rutting resistance of SMA is obtained from coarse aggregate stone to stone contact and proper aggregate packing. Durability of SMA mix is achieved by proper mix design.

Ibrahim et al.(2006), compared SMA mixtures and conventional dense graded asphalt mixtures on the basis of laboratory performance testing which included Marshal stability, loss of Marshall stability, indirect tensile strength, loss of indirect tensile strength, resilient modulus, fatigue and rutting. Optimum Binder contents were 5.3% for control mixes and 6.9% for SMA mixtures, 0.3% mineral fibers by weight of mixture was used to avoid drain down of excess asphalt. SMA mix proved its superiority over the conventional mixes showing better resilience, rutting resistance and durability. Resistance to water damage of SMA mixtures is due to the higher asphalt film thickness between the aggregates. Chua et al. (1995), performed comprehensive evaluation of performance related properties of asphaltic concrete through dynamic modulus testing. The applied loads were 1112N, 2224N, 4448N and 8896N at frequencies of 1.Hz, 4Hz, 8Hz and 16Hz at +5^{o}C, +25^{o}C, +40^{o}C and

+60°C temperatures. Continuous haversine load cycles were applied and response to repeated loading was recorded. Thermal visco-elastic properties were determined from the deformation response at different temperatures. Through analysis of frequency data, changes in damping characteristics were studied. As a result, susceptibility of asphalt cracking and fatigue properties were related to the damping properties. It was also reported that strength, resilient modulus, the rutting characteristics and the fatigue-cracking are the parameters to be considered by the pavement engineers.

2. Characteristics of the Mixes

This study was conducted on three different asphalt mixes namely the Superpave mix, Marshall Mix and Stone Mastic Asphalt (SMA).Superpave samples of 6 inch diameter were prepared using gyratory compactor at the design asphalt binder content. Targeted aggregates grading and mix characteristics determined in the laboratory have been tabulated in **Table 1 and 2** respectively. Marshall Method of mix deign is a conventional asphalt mix design procedure laid down in ASTM (D1559). Samples of 4 inch diameter were prepared using Marshall Compactor. Mix characteristics have been reported in **Table 2.**

SMA is a gap graded mix. The gaps are filled with the mixture of bitumen, filler and fibers. Fibers are added to avoid binder drain down. Conventionally Stone Mastic Asphalt has 70 to 80% coarse aggregate, 8−12% filler, 6.0−7.0% binder, and 0.3(%) percent fibers. Cellulose fibers were used to prevent binder drain down in SMA which comprise of finely milled cellulose fibers derived either directly from wood or more commonly by reprocessing newsprint. In this study the most efficient stabilizer ("Interfibe Road-Cel™"), was used which has the property to separate fiber bundles into individual fibers essentially intact surface and produce a higher resistance. Interfibe Road-Cel™ specifications were adopted by the U.S. Federal Highway Administration as the guideline for cellulose stabilizers in SMA. Design aggregate gradations have been shown in **Table 1**, whereas various properties of the mixes obtained in the laboratory have been summarized in **Table 2**. Structural comparison of SMA, MARSHALL and SUPERPAVE mixes has been shown in **Figure 1** below.

Table 1. Design Aggregate Gradations

Sieve Size (mm)	Trial Blend Superpave (% Passing)	Trial Blend Marshall (% Passing)	Trial Blend SMA (% Passing)	NHA Class A Grading (Wearing Course)
37.5	100	100	100	100
25	100	100	100	100
19	95	95	100	90-100
12.5	80	82	95	80-95
9.5	63	66	65	60-70
4.75	43	44	28	40-50
2.36	29	30	20	20-30
0.075	5	4	10	2-10

Table 2. Mix Design Characteristics

C	Mix characteristics	Marshall	SMA	Superpave
1	Binder grade	60-70	60-70	PG 64-22
2	Binder content (%)	4.3	6	4
3	Compacting machine	Marshall Hammer	Marshall Hammer	Gyratory Compactor
4	Aggregate gradation	NHA Class A Wearing Course	Gap Graded	Superpave Criteria
5	Vma	12.9%	17%	13.5%
6	Air voids	4.7%	4%	5.6%
7	Type of additives	Nil	Cellulose fibre (Interfibe Road-Cel™)	nil
8	Amount of additive	Nil	0.3%	nil
9	Original Specimen size	4 inch	4 inch	4 inch

And Gradation curves are shown in **Figure 2.**

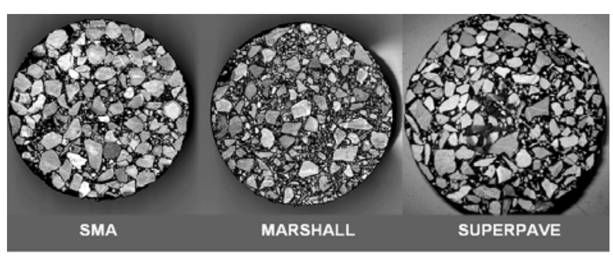

Fig.1 Structural comparison of SMA, MARSHALL and SUPERPAVE

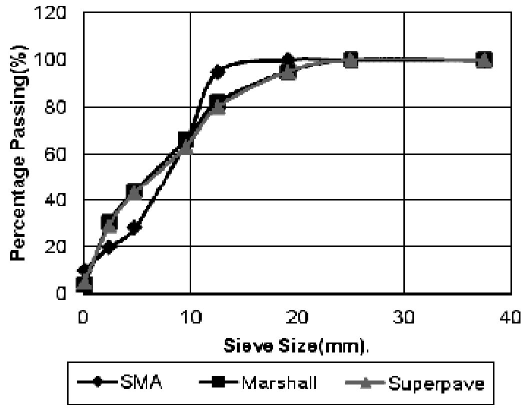

Fig. 2 Design Aggregate Gradation

3. Performance Evaluation Testing

Following tests were performed in the laboratory on each mix considering the test conditions tabulated in Table 3.

1. Permanent Deformation (Creep) Testing using UTM-5P (ASTM D4123)
2. Dynamic Modulus Testing using NU-14(AASHTO TP 62-4)
3. Indirect Tensile Testing using (UTM-5P) (ASTM D4123)

Table 3. Performance Based Test Conditions

Mix Type	Temp. (^{0}C)	Creep Test	Dynamic Modulus Test	Indirect Tensile Strength Test
		Stress Level (Kpa)	Stress Level (Kpa)	Test Pulse Period=1000ms
MARSHALL, SMA, SUPERPAVE	25	100	300	Pulse Width=400ms
		300	500	
		500	700	
	40	100	150	Peak Loading Force=500N
		300	200	
		500	250	
	55	100	35	
		300	50	
		500	65	

3.1 Repeated Creep Testing

In this testing, first of all a conditioning stress (of 10kpa for 100 sec) is applied to asphaltic concrete specimen. The Pulse Period and the pulse width were selected 2 sec and 0.5 sec respectively. Following the conditioning period, a fixed twenty seconds time delay was programmed where the applied stress was set to zero. Consequently, the specimen was tested for 3600 cycles at stress levels of 100, 300 and 500 Kpa, temperature was set to 25^{0}C, 40^{0}C and 55^{0}C. Test termination strain was taken as 10.0 percent. As the pulse of continuous loading, the strain was measured with two linear variable displacement transducer (LVDT) as shown in Figure 2. The results obtained from the creep tests are shown graphically in Figures **4-6.**

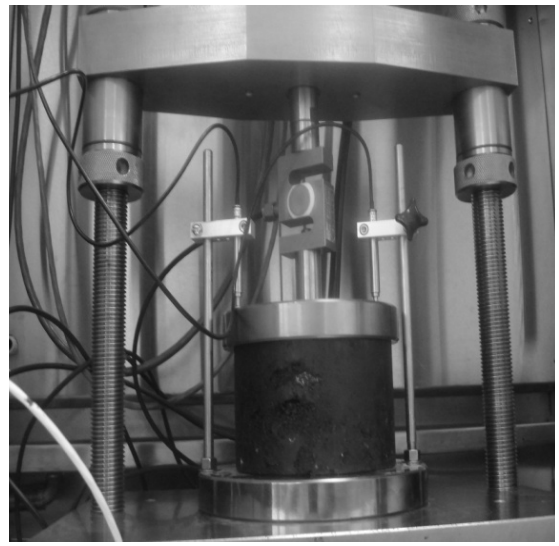

Fig. 3 Creep testing using UTM-5P

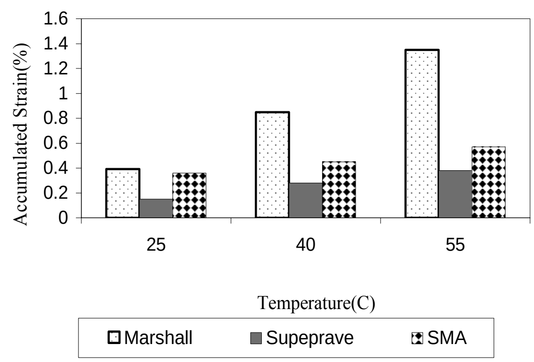

Fig.4 Accumulated stains of the mixes versus temperature at 100 kPa

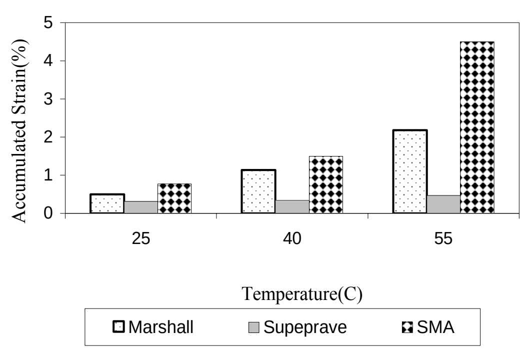

Fig. 5 Accumulated stains of the mixes versus temperature at 300 kPa

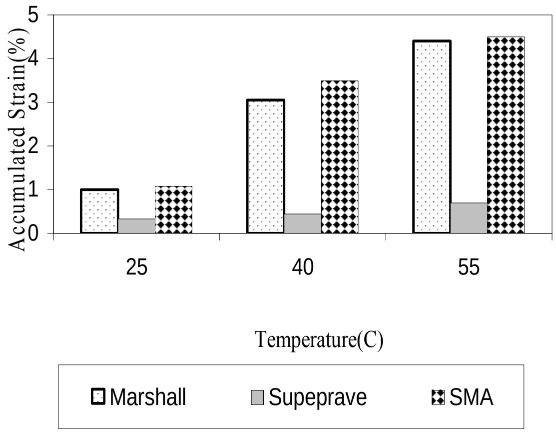

Fig. 6 Accumulated stains of the mixes versus temperature At 500 kPa

3.2 Dynamic Modulus Testing

Dynamic resilient modulus tests were performed on asphalt cylindrical specimens of 4 inch diameter at three temperatures and nine different stress levels. Samples for Superpave mixes were obtained by extracting cores from 6 inch diameter original Superpave samples. Dynamic modulus of asphalt is a viscoelastic test response developed under sinusoidal loading conditions. It is the absolute value of dividing the peak stresses by the peak strains for a material subjected to a sinusoidal loading. Strains were measured using gauges affixed at various positions

Fig.7 Dynamic modulus testing arrangement using NU-14

on the test specimens (Fig 6), and the data was automatically fed into a computer to calculate the test results. Dynamic modulus testing was used to accurately characterize the stiffness and load resistance of asphalt mixes.

The results obtained from the dynamic modulus tests have been shown in Figures **8-10**.

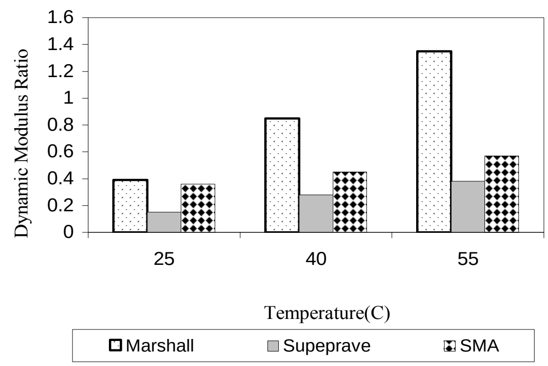

Fig.8 Dynamic modulus Stress Levels at 25º

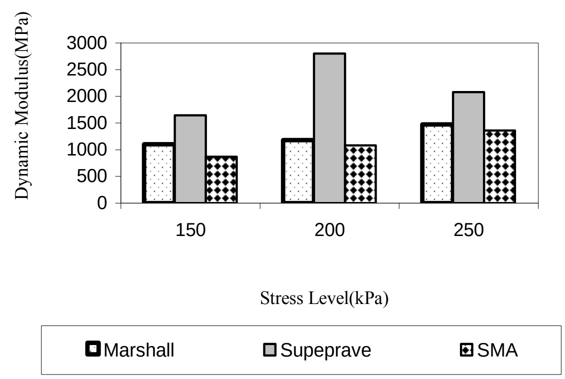

Fig.9 Dynamic modulus versus stress Levels at 40^0C

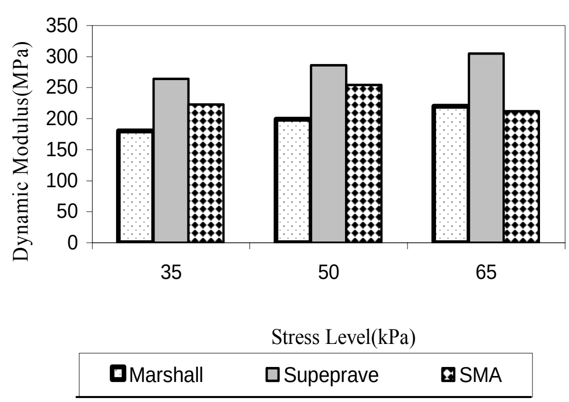

Fig.10 Dynamic modulus versus stress Levels at 55^0C

3.3 Indirect Tensile Testing

This test conforms to the ASTM D4123. In this test, a pulsed diametric loading force was applied to a specimen and the resulting total recoverable diametric strain is then measured from axes 90 degrees from the applied force. A dummy specimen was used to check the skin and core temperature of the asphalt concrete specimen during test. The specimens were mounted in the indirect test jigs as per procedure described by the manual (K.B.de Vos and A.J.Feeley 2002) and the results were collected through Data Acquisition System. Specimens were tested at test pulse period of 1000ms, pulse width of 400ms and peak loading force of 500N. The results have been shown in Figure **11**.

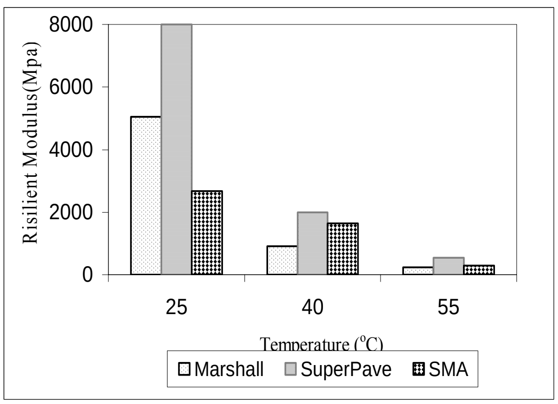

Fig.11 Resilient Modulus Vs Temperature

4. Discussion

It was observed during Creep test that accumulated strains (%) increased with the increase in temperature and number of cycles. At low temperatures, the amount of accumulated strains (%) was lower for all the mixes than that at higher temperatures. It was also observed that dynamic modulus increased with the increase in number of cycles and it was maximum for all the mixes after 200 cycles. Superpave mixes showed high values of dynamic modulus than that of Marshall and SMA, at tested temperatures and stress levels. The graphical representation between resilient modulus (Mr) and temperature shows that Mr decreases with the increase in temperature. The same trend of the mixes for resilient modulus has been observed i.e. Superpave mixes showed maximum values of Mr at all temperatures than other two mixes.

5. Observations

1. Superpave mix showed low permanent deformation strains, higher resilient modulus (Mr) and higher dynamic modulus as compared to Marshall and SMA mixes.
2. Rate of increase in accumulated strain was more for SMA and Marshall mixes than that of Superpave.
3. It was observed that accumulated strain increases with increase in temperature from 25 to 55°C. At maximum temperature i.e. at 55°C, Superpave mixes showed better performance than the other two mixes in terms of resistance to accumulated strain.
4. Increase in accumulated strain was also observed with an increase in loading strain from 100 to 500 kPa for all mixes.

6. Conclusions

1. During Indirect Tensile Strength Testing, Higher values of Resilient Modulus were observed in case of Superpave mixes. Even at maximum testing temperature (55°C), Superpave mix performed better than the other two mixes.
2. Dynamic modulus of Superpave mix was also fairly high at different dynamic stress levels as compared to SMA & Marshall.
3. With the increase in temperature during dynamic modulus testing, dynamic modulus decreased. But once again Superpave showed better performance at highest tested temperature (55°C).

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