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SUPERPAVE design mixture performance evaluation using Epolene modifier for cold semi-arid climatic region of Saudi Arabia

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ABSTRACT

Purpose: To evaluate the superpave design performance using Epolene (EE-2) as modifier, since SUPERPAVE design is a modified and sophisticated aspect as compared to previous mix design for asphalt mixtures. This is primarily due to the fact that superpave design mix also takes into consideration properties of materials beside asphalt.

Design/methodology/approach: This study was conducted using Epolene (EE-2) as modifier in order to evaluate the performance of SUPERPAVE suitability for construction of roads in Alfaraa campus (King Khalid University) Abha, in Asir Province of Saudi Arabia. Glow number test, dynamic modulus test and indirect tensile strength test were conducted to evaluate the performance of EE-2 modifier against the control mixture.

Findings: The mixture modified with EE-2 gave better performance in terms of temperature-based performance and resistance to moisture damage. Also, larger values of E*/sinφ were obtained for EE-2 modified mixture at various loading frequencies and temperature in comparison to control mixture.

Research limitations/implications: The Epolene modifier successfully enhances and improves the SUPERPAVE mixture performance. Further studies are required to evaluate the performance of EE-2 modifier at much lower temperature ranges.

Practical implications: The results of the study allow us to recommend the investigated asphalt mixture for applied for the construction of roads in the Alfaraa (new campus of King Khalid University), Abha, Asir province, Saudi Arabia.

Originality/value: A modified asphalt mixture has been proposed that has better performance at higher and lower temperatures. The developed asphalt mixture is more resistant to moisture damage than the compared to control mixture.

Keywords: SUPERPAVE, Epolene, Dynamic modulus test, Flow number test, Indirect tensile test

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PROPERTIES

1. Introduction

Worldwide a number of design mixes are used for pavement design. Hveem mix design and Marshall mix design are mostly used [1]. The asphalt mix design evolves around basic properties viz. skid resistance, durability, stability and flexibility [2]. Determining optimum asphalt content has been core in hot mix asphalt (HMA) design [1]. Many, studies have reported impact of aggregate characteristics (angularity, gradation, surface texture, and shape) affecting the performance of HMA mixture. Hence, in 1993 Strategic Highway Research Program introduced SUPERPAVE system to overcome this problem and enhance the performance of asphalt mixtures [3]. Since then SUPERPAVE system has been adopted and put into use in many countries. Various modifiers were investigated to determine their ability to enhance the properties asphalt mixtures.

In scientific research [4] used chicken feather and evaluated hot mix asphalt concrete in terms of durability, mechanical and volumetric properties and rutting performance. Portland cement was also investigated as filler material in hot-mix asphalt concrete [5]. Also, rice husk was used by authors of the work [6] as mineral filler in hot mix asphalt concrete. SUPERPAVE asphalt mixtures have been tested for climatic condition of Jordan [2]. Hot-in place recycled SUPERPAVE mixture performance in Florida has been investigated [7]. SUPERPAVE performance using button rock asphalt has been evaluated by authors of the work [3]. Also, SUPERPAVE has been investigated with modifiers Epolene (EE-2), Date palm ash and crumb for Kingdom of Saudi Arabia at temperature range of 50-82°C [8]. However, Saudi Arabia also experiences colder climatic condition on region situated at higher altitudes.

This necessitated investigation of modifier performance at lower temperature range. Also, most of the published work have only investigated the impact of modifiers on the properties and performance of asphalt mixtures. However, literature on the developed research in field application still lacks in literature. The objective of this study was to evaluate the SUPERPAVE design performance using Epolene (EE-2) as modifier. Additionally, the developed asphalt mixture will be applied for the construction of roads in the Alfaraa (new campus of King Khalid University), Abha, Asir province, Saudi Arabia.

2. Materials and experimental setup

The SUPERPAVE mix design was calculated for heavy traffic (10-30 million ESAL's) for traffic speed of > 70 km/h, with layer thickness of 5 cm, nominal maximum size of 12.5 mm. The selected grade of temperature was in accordance to PG-64-10 and grade adjustment of traffic was used as 1. SUPERPAVE mix design consists of three major steps viz. selection of design aggregate structure, optimized asphalt content, and determining moisture sensitivity of design structure.

2.1. Aggregates

The coarse and fine aggregates consisted of crushed lime stone. The aggregates were sieved into particle size groups in order to reduce errors in test. There were three gradation of aggregates was 25.4 mm, 9.51 mm, 4.76 mm, 2.38 mm, 1.19 mm, 0.595 mm, 0.297 mm, 0.149 mm, and 0.074 mm. There were three blends used to select the nominal size of aggregate. Figure 1 presents the gradation of aggregate used for SUPERPAVE asphalt mixture and Table 1 presents the particle size group test values.

2.2. Asphalt binder

The asphalt binder was obtained from local supplier of grading Pen 70. The results of the asphalt binder were in accordance with the specifications of Saudi Code. The initial asphalt concentre was determined in four steps. First relative density of mineral aggregate, second calculation of volume of asphalt absorbed by aggregates third, effective asphalt volume calculation and fourth initial asphalt calculation. Equation 1 for calculating initial asphalt content in this study has been reported as efficient in previous literature [3]. Physical properties of asphalt is presented in Table 2.

$$P_a = \frac{100-V_a}{100-VMA} x \frac{1}{\gamma_{sb}} - \frac{1}{\gamma_{se}} \quad (1)$$

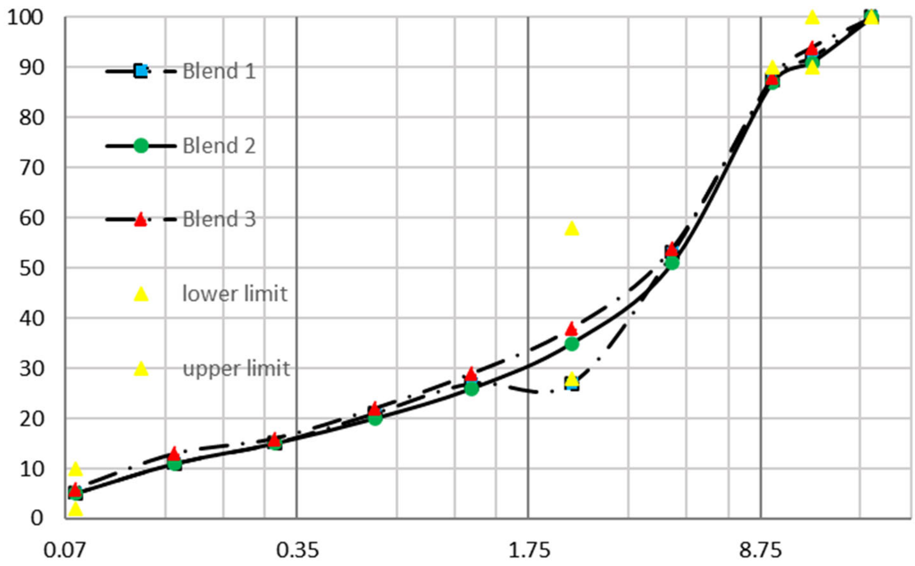

Fig. 1. Aggregate gradation curve

Table 1.
Aggregates gradation

Item	Particle size group test values								
	0.075	0.15	0.3	0.6	1.18	2.36	4.75	9.5	12.5
Crushed stone, %	18.3	18.3	18.3	18.3	--	--	--	--	--
Los Angeles Abrasion, %	17.9	16.2	17.2	15.7	14.8	17.2	--	--	--
Specific Gravity Bulk	2.691	2.695	2.692	2.712	2.705	2.695	2.687	2.701	2.593
Specific Gravity, Apparent	2.734	2.721	2.738	2.741	2.729	2.757	2.782	2.769	2.769
Flat and elongated particles, %	9.5	10.2	9.6	8.5	10.7	11.4	10.6	11.2	--
Water Absorption	0.55	0.57	0.57	0.65	0.75	1	0.81	1.3	1.2

Table 2.
Physical properties of asphalt

Test	Test value
Flash point	310
Penetration	68
Specific gravity, 25°C	1.021
Ductility, 25°C	135
Softening point, °C	54
Viscosity at 135 °C, cp	525
Viscosity at 185 °C	162
Dynamic shear rheometer G*/Sin δ at 70°C, KPa	1.577

Two specimens for each modified SUPERPAVE mixture was produced at four asphalt contents of 3.4%, 3.9%, 4.4% and 4.9 %. Figure 2 present the relationship between VA (Air voids), VFA (Voids filled with asphalt) DP (Dust proportion) and asphalt content. SUPERPAVE design takes into account 4% VA and asphalt content was found to be 3.9% for EE-2 and 4% for BRA. The VA and VFA were within the acceptable range of 3-5% and 65-75% respectively. Hence, asphalt content was obtained at 4% VA as optimum asphalt content.

The fundamental aspect of this paper is to evaluate EE-2 SUPERPAVE mixture performance with respect to control mixture. These effects include the performance of the SUPERPAVE mixture at varying temperature (low and high) and resistance to moisture. Freeze-thaw indirect tensile test, bending beam test and wheel tracking test were conducted to determine the impact of EE-2 on asphalt mixture. However, dynamic modulus test and flow number (FN) test were conducted to compare.

2.3. Wheel tracking test

The wheel tracking device was used for this test to determine the pavement rutting resistance performance at high temperature. For each mixture three samples were tested

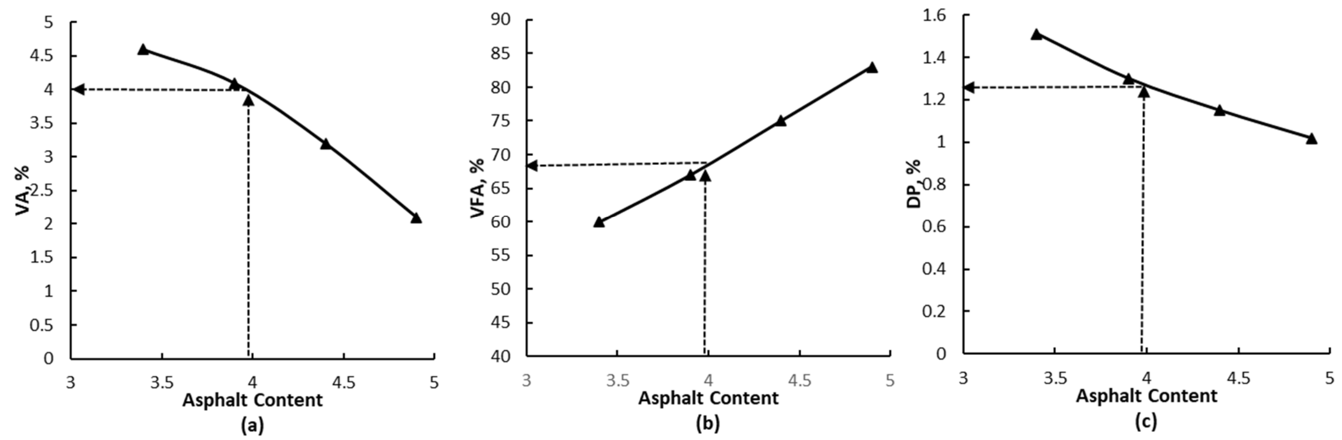

Fig. 2. Asphalt content and volumetric properties employed in this study

under 0.7 MPa and 60°C in dry condition. The results are represented by the DS (dynamic stability). DS value represent number of wheels passed in a given time interval (45-60 minute) on the specimen for every 1 mm of rutting depth. DS is obtained from Equation 2.

$$DS = \frac{(t_2 - t_1) x\, N}{d_2 - d_1} \qquad (2)$$

where, d_1 is rutting depth in mm at 45 min (t_1), d_2 is rutting depth in mm at 60 min (t_2), with 42 cycles per minute, speed of wheel is N. It can be compared between the two mixtures by the DS readings, where the higher the DS, higher is the resistance to permanent deformation at high temperature.

2.4. Bending beam test

This test evaluates cracking resistance performance at low temperature. The indicator of this test is the failure strain (FS) which can be calculated from Equation 3:

$$\mu_\varepsilon = \frac{6hd}{L^2} \qquad (3)$$

where, μ_ε is failure strain (FS), specimen length is L, h and d are height and displacement of specimen at mid span.

2.5. The indirect tensile strength ratio test

This test is performed in conformation to AASHTO T283. TSR values were calculated using Equation 4.

$$TSR = \frac{TS_c}{TS_d} \qquad (4)$$

where the TSR is the ratio of the indirect tensile strength measured using specimens without moisture conditioning (TSd) to that measured using specimens after the moisture conditioning (TSc). If the TSR value is higher it means that the mixture has higher resistance to moisture damage of the asphalt mixture.

3. Results and discussion

Three specimens were tested for obtaining average values of fundamental performance tests viz, bending test, freeze and thaw test and wheel tracking test. The average values of the three test are presented in Figure 3. for comparative performance evaluation against the control asphalt mixture. Figure 4 shows that using Epolene Modified SUPERPAVE mixture increased the three-wheel tracking tests results comparing with the control mixture. Firstly, the DS and FS value jumped dramatically about 53% and 50% comparing to the control mixture. Secondly, the impact on the TSR is less where the value increased in the Epolene modified SUPERPAVE by 16 %.

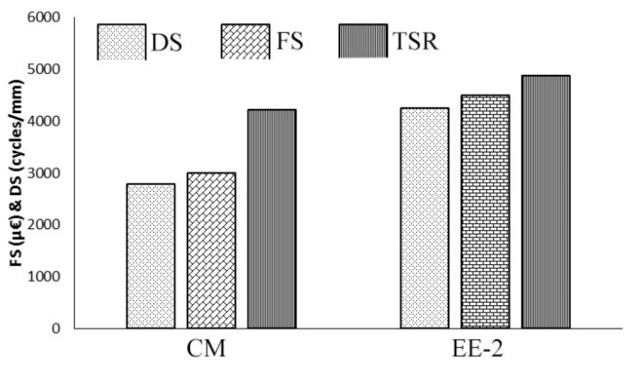

Fig. 3. Fundamental tests results of DS, FS and TSR: CM – control mixture and EE-2 – Epolene mixture

The flow number test (FN) is an important performance measure of the rutting resistance of SUPERPAVE mixture. The higher the FN value means better resistance. The test conducted with various temperatures (30°C, 40°C, 50°C, and 60°C). The results show significant increasing in the FN with EE-2 modifying comparing to the FN with control mixture (Fig. 4). This reveals the positive impact of adding Epolene to the SUPERPAVE mixture when it comes to the rutting resistance.

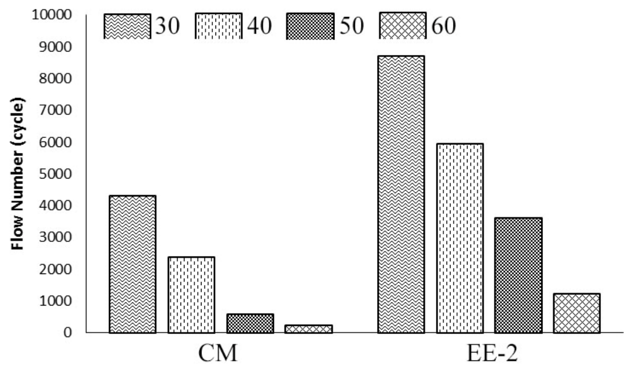

Fig. 4. Flow number test results: CM – control mixture and EE-2 – Epolene mixture

It is illustrated in this graph that within constant temperature, the value of E*/sinφ increases simultaneously with increasing the loading frequency for both the control mixture and the Epolene modified SUPERPAVE. On the other hand, the E*/sinφ decreased with increasing the temperature while keeping the loading frequency constant. After making tests under different temperatures and loading frequency (Fig. 5), it is proven that the Epolene modified SUPERPAVE has higher E*/sinφ values. Thus, the Epolene modified SUPERPAVE resistance of the high temperature permanent deformation is better than the control mixture.

4. Conclusions

This study can summarize the conclusions observed from using Epolene modified SUPERPAVE as follows:

1) Compared to the control mixture, EE-2 asphalt mixture had better efficiency at higher temperature.
2) It does not only give better efficiency at higher temperature but also enhanced the performance of EE-2 asphalt mixture at lower temperature.
3) Resistance to moisture damage was also observed to be in case of asphalt mixture modified with EE-2 as compared to control mixture.
4) The greater values of E*/sinφ coefficient from dynamic modulus test for EE-2 asphalt mixture infers that it has greater rutting resistance as compared to control mixture for all the temperature and frequency range.
5) Using Epolene modified SUPERPAVE mixture increases the FNs, comparing to the control mixture. Hence, at high temperature EE-2 asphalt mixtures have greater resistance against permanent deformation as compared to control mixture.
6) EE-2 is a polymer-based compound and hence is economical to use since Saudi Arabia is rich in oil resources. This makes EE-2 as a feasible and abundant modifier which can be used for construction of roads in the Alfaraa campus of King Khalid University, Abha, Asir Province, Saudi Arabia.

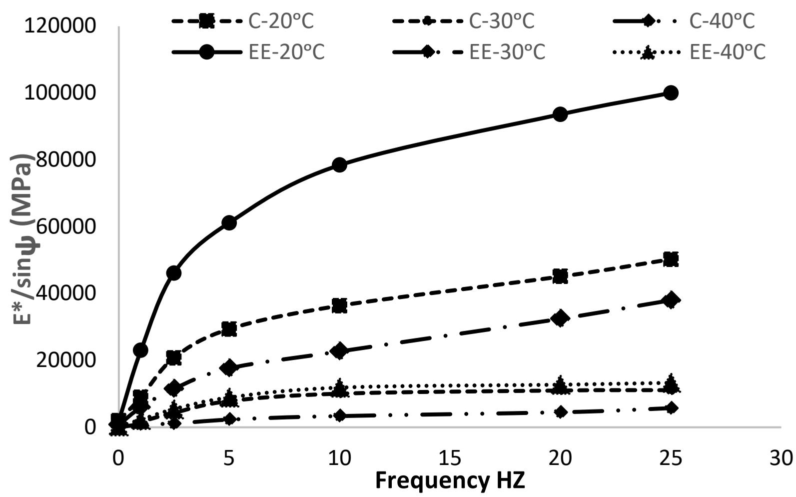

Fig. 5. Dynamic modulus test results: C – control mixture at temperature 20°C, 30°C and 40°C, EE – Epolene mixture at temperature 20°C, 30°C and 40°C

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