FLEXIBLE PAVEMENT DESIGN WITH RAP MIXTURE

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ABSTRACT

Recycled asphalt pavement (RAP) is now being widely used in the construction of new and rehabilitated pavements. In this study, a flexible pavement section was designed using the AASHTOWare Pavement ME Design software with recycled HMA mixes containing varying percentages of RAP from different sources. Extensive laboratory tests have been done to characterize HMA mixtures with recycled asphalt materials. The rheological and mechanical properties of these mixes were used as input parameters in the ME design software to predict long-term performance. Both level 3 traffic inputs (Pavement ME default) and level 2 traffic inputs developed rural arterials was used in the design analysis. Results show that the required HMA thickness increases with inclusion of higher percentages of RAP. In addition, ME design software predicted significant increase in top-down fatigue cracking for pavements with 40% RAP in the mix compared to pavements with 20% RAP.

Keywords: *Keywords*: AASHTOWare, Mechanistic-Empirical, Pavement Design, RAP

1. INTRODUCTION

RAPs consist of reusable asphalt pavement materials that are result from resurfacing, rehabilitation, and reconstruction operations (*1*). Although use of RAP is attractive from the viewpoints of sustainability and economy, there have been concerns regarding the long-term performance and durability of asphalt pavements containing RAP (*2*). Part of the issue has been the pavement design that is still being done based on the properties of virgin materials. In this study, design new flexible pavement sections have been designed with HMA mixtures containing recycled materials.

2. PROBLEM STATEMENT

The Kansas Department of Transportation (KDOT) is increasing allowing Superpave mixtures with higher percentages of recycled asphalt materials. Past researchers have evaluated performance of RAP in HMA especially in terms of rutting potential and fatigue cracking resistance. Although there were efforts in the past to quantify long-term effect of RAP in HMA mixes, there were not too many studies to assess the effects of mixtures containing RAP on pavement design (*3*). Part of the limitation was due to the inability to handle such mixtures in the 1993 AASHTO Guide for Design of Pavement Structures.

Cooper and Samuel (*4)* used the MEPDG software (predecessor of the AASHTOWare Pavement ME design software) to analyse three different pavement structures at three traffic levels (low, medium and high) in Louisiana with varying percentage of RAP in HMA. They found out that the predicted performance improved with the presence of RAP in the mix. Daniel et al. (*5*) investigated the sensitivity of the MEPDG software ouputs to RAP binder grade using level 3 inputs and concluded that the predicted performance vary significantly with the variation in RAP binder content.

For level 1 mechanistic-empirical design analysis, AASHTOWare Pavement ME Design software requires dynamic modulus (E*), creep compliance and indirect tensile strength of the asphalt mix. Dynamic shear modulus (G*) and phase angle (δ) values of the asphalt binder are also required for level 1 analysis (*6*). The design process is iterative. Based on input parameters, the software predicts selected pavement distresses and smoothness (International Roughness Index, IRI). For a successful design, a pavement section needs to satisfy the distress and smoothness criteria at a specified reliability (*7*).

3. METHODOLOGY

The section used for this study is located on US-59 in Douglas County, Kansas. The pavement section, designed using the 1993 AASHTO Guide for Design of Pavement Structures, is a full-depth HMA on top of 6-in. lime-treated subgrade (LTSG). The HMA layer consists of a 1.5-in. thick dense-graded asphalt concrete (AC) surface course (3/8" nominal maximum aggregate Size, NMAS), 2.5-in. thick dense-graded AC binder course (3/4" NMAS) and 8-in. bituminous base course (3/4" NMAS).

In this study, three RAP sources were considered with varying RAP content (20, 30, and 40%) on HMA mixtures. The sources were Shilling Construction Company, Konza Construction Company, and a KDOT project on US 73 near Kansas City. All mixtures had 1/2" NMAS. Since the test section did not have any 1/2" NMAS AC layer, in this study, the pavement structure was considered with two AC layer; a 2.5" surface layer (1/2" NMAS) and a bituminous base course (3/4" NMAS). The thicknesses of the surface layer were kept constant and the required AC base thickness was determined.

4. DESIGN INPUTS

4.1 AC Layer Properties

Superpave mix designs were developed based on the criteria for ½" NMAS. The design number of gyrations was 75. Table 1 shows the volumetric properties of all mixtures along with the KDOT volumetric requirements for the ½"NMAS Superpave mixtures. All mixtures met KDOT requirements.

TABLE 1 Volumetric Properties of Different Mixtures and KDOT Requirements

Mixtures		Total Asphalt Content (%)	Air void @N_{des} (%)	Voids in Mineral Aggregate (%)	Voids Filled Asphalt (%)	Dust Binder Ratio	% G_{mm} @ N_{ini}	% G_{mm} @ N_{des}
Shilling	20% RAP	4.7	3.9	14.1	71.6	0.60	88.5	96.0
	30% RAP	4.8	4.0	14.0	71.3	0.60	88.0	96.0
	40% RAP	4.3	4.0	14.2	71.9	0.70	87.8	96.0
Konza	20% RAP	4.3	4.0	14.0	71.5	0.61	88.5	96.0
	30% RAP	4.4	3.9	14.1	71.3	0.62	88.0	96.0
	40% RAP	4.1	4.0	14.1	71.9	0.61	87.8	96.0
US-73	20% RAP	4.8	3.9	16.2	68.4	0.65	83.5	95.0
	30% RAP	4.6	3.9	15.9	67.3	0.65	84.8	94.0
	40% RAP	4.5	4.1	14.8	71.5	0.68	87.6	95.0
KDOT Requirements		-	2-6	Minimum 14	65-78	0.6-1.2	Maximum 90.5	Maximum 98.0

Dynamic modulus test was performed according to the AASHTO TP62-07 test method (*8*). Tests were conducted using an AMPT machine at six different frequencies of 25, 10, 5, 1, 0.5, and 0.1 Hz and three different temperatures of 4°C, 21°C, and 37°C. Figure 1 illustrates the master curve for the mixtures considered for this study.

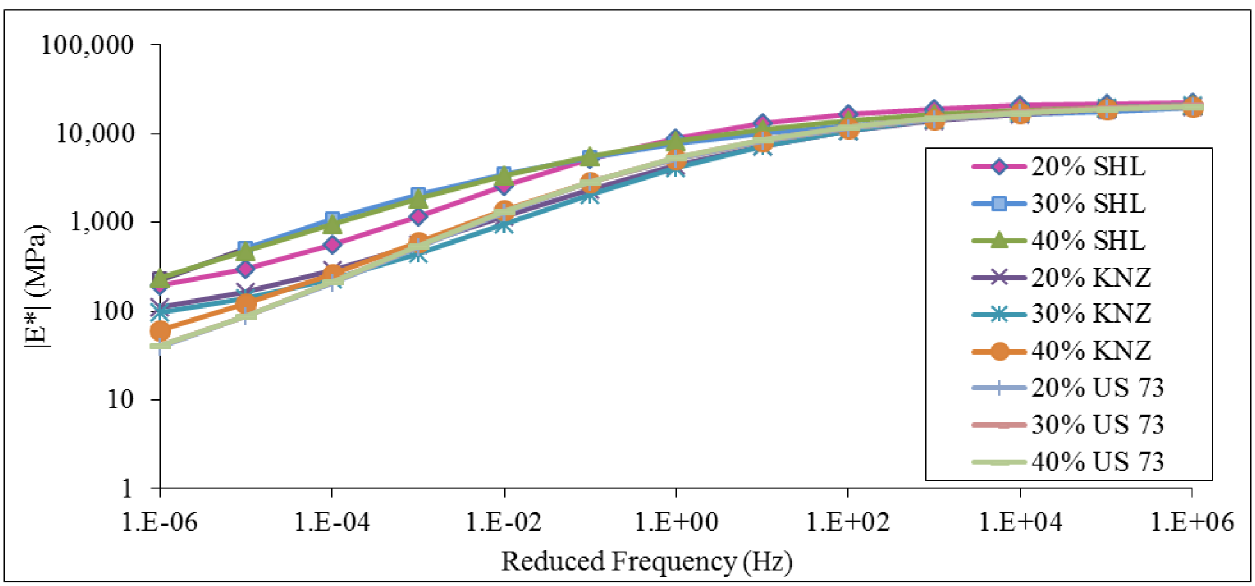

Figure 1 Dynamic modulus master curves

4.2 Base and Subgrade Properties

Level 3 inputs were used for the bituminous base layer. A 19-mm Superpave gradation was specified for the original project with PG 64-22 binder. In addition, the gradation and Atterberg limits of the subgrade soil are necessary inputs of the AASHTOWare Pavement ME Design process. These base and subgrade soil properties are shown in Table 2.

Table 2 Base and Subgrade Properties

Bituminous Base	% Retained									
	1”	¾”	#4	#8	#16	#50	#200			
	0	2	37	59	73	91	96			
Soil Type	% Passing								PI	LL Max.
	1”	3/4”	1/2”	#4	#10	#40	#80	#200		
A-7-6	100	100	100	99	98	91	87	84	27	46

The resilient modulus (M_r) value for the A-7-6 subgrade soil was taken to be 2,700 psi as suggested by KDOT for Douglas County. The resilient modulus for the LTSG layer was obtained using Equation (1) (*9*).

LTSG M_r (psi) = 2.03 * untreated subgrade M_r (psi) + 225 (1)

4.3 Traffic

. The traffic inputs used in this study for the US-59 project have been taken corresponding to those used in the 1993 AASHTO Design Guide design and are shown in Table 2.

Table 3 General Traffic Inputs

Initial two-way AADTT	Percent Trucks	Directional Distribution	Operational Speed (mph)	Traffic Growth Rate
10,400	7%	60%	60	3%

AASHTOWare software requires axle load spectra to represent loads due to mixed traffic. These spectra were derived from traffic data collected at WIM stations and represent the percentages of total axle load applications within designated load intervals for various axle configurations. Vehicle class distributions and monthly adjustment factors were also developed for Kansas by analyzing automated vehicle classification (AVC) data of eight stations located on rural principal arterials in Kansas. The description of level 2 traffic data developed for Kansas can be found elsewhere (*7*).

4.4 Climate Data

The selected weather station is at Lawrence, Kan. which is just north of the project. A default water table depth of 10 ft. was assumed.

5. RESULTS AND ANALYSIS

The surface course thickness of the US-59 project was kept constant at 2.5 in and the required thickness for the base layer was determined by the AASHTOWare ME Design analysis to satisfy failure criteria at 90% reliability. The required thicknesses for the design strategies listed in Table 1 to meet the failure criteria at 90% reliability are tabulated in Table 4. For all design strategies, required HMA base thickness was higher for level 2 traffic inputs generated for Kansas rural arterials than that for the AASHTOware Pavement ME Design software default traffic inputs. In addition, for both traffic data sets, the required HMA base thickness increases with increasing RAP percentages.

TABLE 4 Required Bituminous Base Thickness

Mix / Traffic	Shilling			Konza			US-73		
	20%	30%	40%	20%	30%	40%	20%	30%	40%
Default	7.5”	8.0”	9.0”	7.5”	8.5”	9.0”	8.0”	8.5”	9.0”
Kansas	6.5”	6.5”	7.5”	6.0”	6.5”	7.5”	6.5’	7”	7.5”

To investigate the rut depth and longitudinal cracking predicted by the AASHTOWare Pavement ME, the bituminous base for all the design strategies was fixed at 2.5 in. Figure 2 shows the predicted rutting in the asphalt concrete (AC) layer. There was no significant increase in AC rutting with higher amount of RAP in the mix. However, AC rutting was higher when the software default traffic inputs were used compared to the level 2 traffic inputs for Kansas.

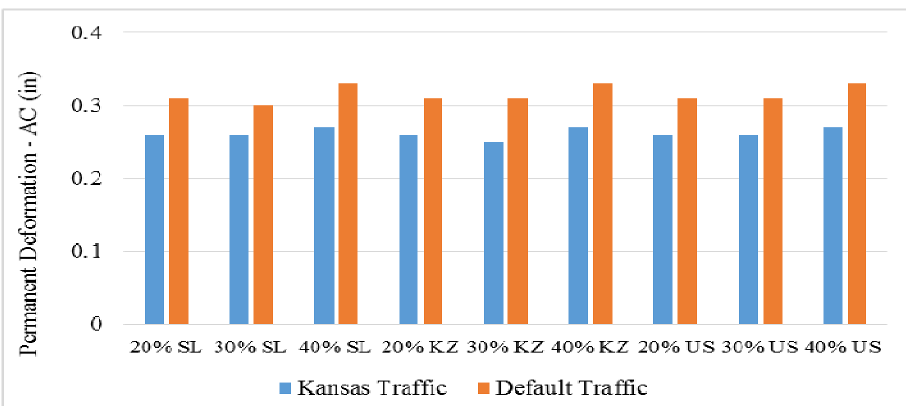

Figure 2 AC rutting for HMA mixes with varying percentages of RAP

The total top-down longitudinal cracking as predicted by AASHTOWare design software bituminous base is shown in Figure 3. Longitudinal cracking increased significantly with inclusion of higher percentages of RAP. Again cracking was higher when software default traffic inputs were used compared to the level 2 traffic inputs for Kansas.

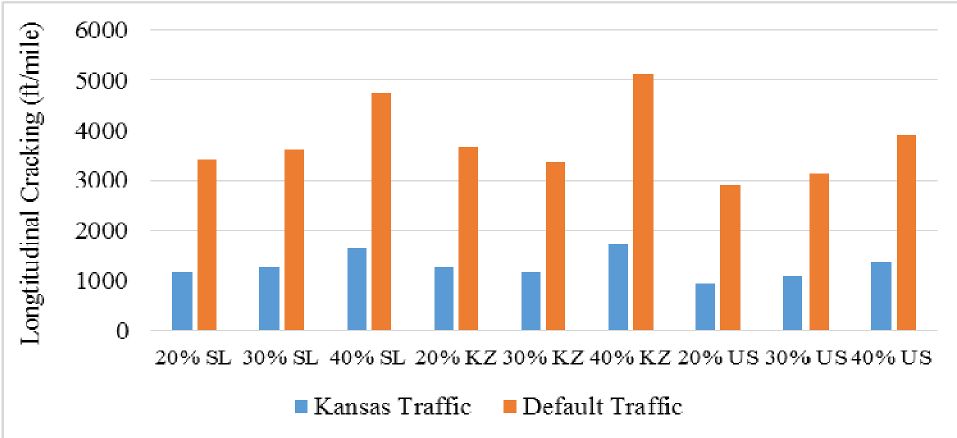

Figure 3 Longitudinal cracking for HMA mixes with varying percentages of RAP

6. CONCLUSION

The following conclusions can be drawn based on this study:

- The required HMA thickness increases with inclusion of higher percentage of RAP.
- AASHTOWare Design software predicted greater top-down fatigue cracking in pavements with higher percentage of RAP, especially when designed with software default level 3 traffic inputs. However, the increase appears to be low when the pavement sections were designed with the level 2 traffic inputs developed for Kansas
- AASHTOWare software did not show significant difference in asphalt concrete layerrut depth for mixtures containing varying percentage of RAP irrespective of traffic input level.
- Pavements designed with the state-wide level 2 traffic inputs required lower HMA thickness compared to the pavements designed with the AASHTOWare Pavement ME software level 3 traffic inputs.

6. REFERENCES

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