US FEDERAL HIGHWAY ADMINISTRATION STUDY ON PERMANENT DEFORMATION OF MIXES WITH MODIFIED BITUMEN

National Cooperative Highway Research Program

(NCHRP) Project 90-07

"Modified Asphalt Binders in Mixtures"

Topical Report:

Permanent Deformation Using a Mixture With Diabase Aggregate

FHWA-RD-02-042

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by

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FOREWORD

This report documents the effects of polymer-modified asphalt binders on the rutting resistance of a mixture with diabase aggregate. It is part of a research study titled "Understanding the Performance of Modified Asphalt Binders in Mixtures." This study is partially funded through National Cooperative Highway Research Program (NCHRP) Project 90-07. The objective of NCHRP Project 90-07 is to determine if asphalt binder performance is captured by the Superpave asphalt binder specification developed under the 1987 to 1993 Strategic Highway Research Program, with an emphasis on evaluating the performances of mixtures containing polymer-modified asphalt binders with identical Superpave performance grades, but varied chemistries. Asphalt binder tests developed under NCHRP Project 09-10, titled "Superpave Protocols for Modified Asphalt Binders," are also being evaluated. NCHRP Project 09-10 was completed in February 2001. For the materials tested in this study, good correlations between asphalt binder properties and laboratory mixture rutting resistance were found, which indicate that the current Superpave asphalt binder specification and testing protocols are valid. Additional mixtures will be tested by FHWA to verify these findings. This report will be of interest to highway personnel who use polymer-modified asphalt binders and Superpave.

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1. **Background & Objective**: Pavement and laboratory tests performed on five surface course mixtures during the Federal Highway Administration's (FHWA) 1993 to 2001 Superpave Validation Study provided a good correlation between the rut depth in the asphalt pavement layer at 58°C and several laboratory mixture properties, including: (1) dynamic shear modulus, G*, at 40°C, (2) dissipated energy in the form of G*/sind at 40°C, (3) cumulative permanent shear strain at 40°C, (4) rut depths from the French Pavement Rutting Tester (French PRT) at 60°C, and (5) the creep slopes from the Hamburg Wheel-Tracking Device (Hamburg WTD) at 50°C. The objective of this study was to determine if the Superpave high-temperature rheological properties of polymer-modified asphalt binders correlate to asphalt mixture rutting resistance. The emphasis of this study was on evaluating the rutting resistances of mixtures containing polymer-modified asphalt binders with identical high-temperature PG's, but varied chemistries..

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2. **Materials**: Eleven asphalt binders were obtained for this study. They consisted of eight polymer-modified asphalt binders: (1) styrene-butadiene-styrene [SBS] Linear, (2) SBS Linear Grafted, (3) SBS Radial Grafted, (4) ethylene vinyl acetate [EVA], (5) EVA Grafted, (6) Elvaloy, (7) ethylene styrene interpolymer [ESI], and (8) chemically modified crumb rubber asphalt [CMCRA]. As shown by this list, the asphalt binders include elastomeric and plastomeric modifiers, some with the same chemistry, but different geometry (linear vs. radial geometries, and grafted vs. ungrafted geometries). The term "grafted" includes any mode of chemically reacting a polymer with an asphalt binder, for example, vulcanization. There were three control asphalts: (1) air-blown, (2) unmodified PG 70-22, and (3) an unmodified PG 64-28.

3. **Cumulative Permanent Shear Strain**: Cumulative permanent shear strain was measured at 7.0-percent air voids, 50°C, and 5,000 cycles. The applied shear stress was 69 ±5 kPa. The loading time was 0.1 s and the rest time was 0.6 s. Three replicate specimens were tested per mixture. Cumulative permanent shear strain is generally a better measure of rutting resistance compared to G* and G*/sind because it accounts for changes in the amount of damage from cycle to cycle. Lower cumulative permanent shear strains indicate more resistance to rutting.

4. **French Permanent Rut Tester**: The French PRT tests a slab for permanent deformation using a smooth, rubber tire inflated to 600 ±30 kPa.(1) Each slab had a length of 500 mm, a width of 180 mm, and a thickness of 50 mm. The applied load was 5000 ±50 N and the test temperature was 70°C. The air-void level was 7.0 percent. The test normally ends at 6,000 wheel passes. In this study, the test was continued to 20,000 wheel passes to provide supplementary information. The French PRT is shown in figures 17 and 18.

5. **Hamburg Wheel Tracking Device**: The Hamburg WTD tests a slab of hot-mix asphalt submerged in hot water by rolling a steel wheel across its surface. The slabs tested in this study had a length of 320 mm, a width of 260 mm, and a thickness of 80 mm. Thicknesses up to 120 mm can be tested, and the thickness should be at least three times the nominal maximum aggregate size. The device tests two slabs simultaneously using two reciprocating solid steel wheels, each having a width of 47 mm. The applied load is 685 N and the average speed is 1.1 km/h. The rut depth in each slab is measured continuously over a length of 200 mm by a linear variable differential transformer. This rut depth does not include any upward heaving outside the wheelpath. After each user-specified increment of wheel passes is applied, the device stores the maximum rut depth along the 200-mm wheelpath relative to a rut depth of zero for the first wheel pass. It does not calculate an average rut depth. The standard maximum number of wheel passes is 20,000. This requires approximately 6.5 h. The pass/fail rut depth is 10 mm at 20,000 passes. Additional information on the Hamburg WTD is given elsewhere.

6. **Results**: The results of the study are as summarized in the tables below.

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DATA FROM HAMBURG WHEEL TRACKING DEVICE

Table 16. Replicate data for the Hamburg WTD.

Asphalt Mixture	Creep Slope (passes/mm)			CV[1] (percent)
	Specimen No. 1	Specimen No. 2	Average	
Elvaloy	4650	5070	4900	6.1
Air-Blown	4340	3510	3900	15.0
CMCRA	5970	1330	3650	89.9
CMCRA (Repeat)	3770	1555	2700	58.8
PG 70-22	1000	3390	2200	80.0
EVA	2770	1200	2000	55.9
SBS Linear Grafted	1560	1090	1300	25.1
EVA Grafted	1080	1430	1300	19.7
SBS Radial Grafted	610	1600	1100	63.4
SBS Linear	690	1130	900	34.2
ESI	690	930	800	21.0
PG 64-28	450	550	500	14.1

[1]CV = Coefficient of Variation, percent = (standard deviation ÷ average)*100.

Best Performer

Worst Performer

Table 15. G*/sind's of the binders vs. the creep slopes from the Hamburg WTD with the materials listed from highest to lowest slope (highest to lowest resistance to rutting).

Asphalt Binder or Mixture Designation	Binder		Mixture				
	High Temp. PG	G*/sind, 0.125 rad/s, 58°C (Pa)	Creep Slope, 58°C (passes/mm)				
Styrelf (Validation Study)	88	2480	7000				
Elvaloy	77	639	4900	A			
CMCRA	76	482	3200	A			
Air-Blown	74	387	3900	A	B		
PG 70-22	71	213	2200		B	C	
Novophalt (Validation Study)	77	651	2040				
EVA	75	751	2000			C	
SBS Linear Grafted	72	297	1300			C	
EVA Grafted	74	727	1300			C	
SBS Radial Grafted	71	249	1100			C	
AC-20 (Validation Study)	70	226	1000				
SBS Linear	72	248	900			C	
ESI	76	321	790			C	
PG 64-28	67	114	500			C	

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Table 17. Rankings by test type with the material having the most resistance to rutting listed at the top.

SST			French PRT		
Mixture	**Binder**		**Mixture**	**Binder**	
Cumulative Permanent Shear Strain, 50°C	**G*/sind, 0.125 rad/s, 50°C**	**High Temp. Continuous PG**	**Rut Depth, 70°C**	**G*/sind, 0.9 rad/s, 70°C**	**High Temp. Continuous PG**
EVA	EVA	Elvaloy	Elvaloy	Elvaloy	Elvaloy
Elvaloy	EVA Grafted	CMCRA	Air-Blown	CMCRA	CMCRA
EVA Grafted	Elvaloy	ESI	CMCRA	ESI	ESI
CMCRA	CMCRA	EVA	EVA Grafted	Air-Blown	EVA
SBS Radial Grafted	Air-Blown	Air-Blown	ESI	EVA Grafted	Air-Blown
Air-Blown	SBS Linear Grafted	EVA Grafted	EVA	SBS Linear Grafted	EVA Grafted
ESI	ESI	SBS Linear Grafted	SBS Linear Grafted	SBS Radial Grafted	SBS Linear Grafted
SBS Linear Grafted	SBS Linear	SBS Linear	SBS Radial Grafted	SBS Linear	SBS Linear
PG 70-22	PG 70-22	PG 70-22	PG 70-22	PG 70-22	PG 70-22
SBS Linear	SBS Radial Grafted	SBS Radial Grafted	SBS Linear	EVA	SBS Radial Grafted
PG 64-28	PG 64-28	PG 64-28	PG 64-28	PG 64-28	PG 64-28

Best Performer

Worst Performer