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RESEARCH REPORT

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Materials Acceptance Risk Analysis: Superpave Hot Mix Asphalt

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16. Abstract

The objective of this study is to review Superpave Hot Mix asphalt used by other state DOTs and make recommendation to Idaho Transportation Department (ITD) in using this product in its roadways and in particular in low-traffic roadways.   Based on the literature review, it is concluded that Superpave mix design provides better performance for roadways that experience heavy to medium traffic volumes. For low-traffic roadways, Superpave, Marshall, and Hveem-designed mixes perform about the same. Considering the unit price, it appears that there are no significant differences among the three mix-design methods.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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List of Acronyms

ACRONYM	DEFINITION
AADT	Annual Average Daily Traffic
ESAL	Equivalent Single Axle Loads
FHWA	Federal Highway Administration
HMA	Hot Mix Asphalt
IRI	International Roughness Index
NCHRP	National Cooperative Highway Research Program
PSC	Pavement Structural Condition
RAP	Reclaimed Asphalt Pavement
SGC	Superpave Gyratory Compactor
SHRP	Strategic Highway Research Program
USACE	U.S. Army Corps of Engineers
WES	Waterways Experiment Station
WSPMS	Washington State Pavement Management System

Abstract

The objective of this study is to review Superpave Hot Mix asphalt used by other state Department of Transportations (DOT) and make recommendation to Idaho Transportation Department (ITD) in using this product in its roadways and in particular in low-traffic roadways. Based on the literature review, it is concluded that Superpave mix design provides better performance for roadways that experience heavy to medium traffic volumes. For low-traffic roadways, Superpave, Marshall, and Hveem-designed mixes perform about the same. Considering the unit price, it appears that there are no significant differences among the three mix-design methods.

Chapter 1

Introduction

Superpave is an abbreviation for “Superior Performing Asphalt Pavement”, which was developed in the early 1990’s under the Strategic Highway Research Program (SHRP). This is a design and analysis system based on desired performance. Originally, the Superpave design method for Hot-Mix Asphalt (HMA) mixtures consisted of 3 proposed phases: 1) materials selection, 2) aggregate blending, and 3) volumetric analysis of specimens compacted using the Superpave Gyratory Compactor (SGC). Superpave was intended to have a fourth step which would provide a method to analyze the mixture properties and to determine performance potential, however this fourth step is not yet available for adoption. Most highway agencies in the United States have now adopted the volumetric mixture design method. However, there is no strength test to complement the Superpave volumetric mixture design method. The traditional Marshall and Hveem mixture design methods had associated strength tests. Even though the Marshall and Hveem stability tests were empirical, they did provide some measure of the mix quality.

Superpave is designed to overcome some of the problems that existed in some of the old methods like the Marshall and Hveem methods such as rutting and temperature cracking. Superpave enables engineers to select the appropriate material and mixture design to meet climate and traffic conditions of specific roadway paving projects. The method allows engineers and contractors to design pavements that last longer and have lower maintenance and reduced life-cycle costs. Superpave design requires binder testing, a series of aggregate analyses for the required specifications, a HMA design and analysis system, and computer software to integrate the system components. For low-volume traffic roads in moderate (50^oC-70^oC) climate, the method requires material selection and volumetric mix design; however, for reliability improvements on roads with heavy traffic, the design requirements increase and extensive material and performance testing is necessary. One of the most unique features of Superpave is that the gyration tests are performed under temperature and aging conditions which are more representative of service conditions.(1)

Chapter 2
History

From 1987 through 1993, SHRP carried out several major research projects to largely develop the Superpave method for performance based HMA design. This method has now widely superseded the Marshall and Hveem design methods in the U.S. and Canada.

The first Superpave pavement was constructed on July 8, 1992, by the Mathy Construction Company of Onalaska, Wisconsin, and the Wisconsin Department of Transportation placed the first 500 feet of hot mix asphalt conforming to the then-prototypical Superpave asphalt binder and mixture specifications. This 3-inch-thick overlay was part of a pilot study for a larger pavement performance experiment designed to validate the Superpave system. The first 95 full-scale production projects designed in accord with the Superpave system were placed in 1996.

Considering that approximately two million tons of HMA is placed in the U.S. during a typical construction day, contractors and state agencies must have some means to better evaluate performance potential of HMA. These test methods do not have to be perfect, but they should be available in the immediate future to assure good mix performance. Research from WesTrack, NCHRP 9-7 and other experimental construction projects have shown that the Superpave volumetric mixture design method alone is not sufficient to ensure reliable mixture performance over a wide range of materials, traffic and climatic conditions. The HMA industry needs a simple performance test to help ensure that a quality product is produced. Controlling volumetric properties alone is not sufficient to ensure good performance.(2)

There are five areas of distress for which guidance is needed: fatigue cracking, rutting, thermal cracking, loss of friction, and moisture susceptibility. All of these distress factors can result in loss of performance, but rutting is the one distress that is most likely to produce a rapid failure as a result of unsatisfactory HMA. Other distresses are typically long-term failures that develop generally 3 to 4 years after a few years of traffic.

Six years after the first full-scale production projects designed in accord with the Superpave system were placed in 1996, the asphalt industry awarded its highest honor to projects built with Superpave. That has remained the case for three consecutive years, illustrating that the system has become a mainstreamed technology. A survey conducted by the TRB Superpave Committee to determine current use of Superpave found that 50 of the 52 responding transportation agencies report general use of the Superpave asphalt binder standard specification; the other two agencies are initiating plans to do so.(2)

A distinct shortcoming of the Superpave method is that it makes no specific provision for the use of Reclaimed Asphalt Pavement (RAP) in the mix design process. This shortcoming has hindered RAP use by agencies that have adopted the Superpave mix design method. To remedy this situation, the FHWA’s

Superpave Mixtures Expert Task Group used past experience to develop interim guidelines for the use of RAP in the Superpave method.

When HMA pavement reaches the end of its usable service life, the pavement material remains valuable. In the early 1970s, states and paving contractors began making extensive use of RAP as a component in new HMA pavements. Besides possible cost savings, the use of RAP represents an environmentally positive method of recycling. Further, experience has shown that properly designed HMA containing RAP performs as well as HMA prepared exclusively with virgin materials.

The North Central Superpave Center at Purdue University was assigned the tasks of developing recommended guidelines for incorporating RAP in the Superpave mix design method and preparing a technician's manual to implement these guidelines into routine laboratory operations.

The research team first conducted a comprehensive laboratory-testing program to test the null hypothesis that RAP does not act as a black rock, as the level of RAP in HMA increases, the analogy of black rock breaks down. RAP materials recovered from field projects in Florida, Connecticut, and Arizona RAP binders of distinctly different stiffness values. They were investigated in combination with 2 different virgin binders at RAP contents of 10 and 40 percent. Mix specimens fabricated to simulate three cases of blending—actual practice, black rock, and total blending—were evaluated through the use of the Superpave shear tests at high temperatures and indirect tensile creep and strength tests at low temperatures.(3)

The research findings largely confirm current practice as exemplified by the Superpave Mixtures Expert Task Group's interim guidelines. Low amounts of RAP, typically 10 to 20 percent, can be used without characterization of its recovered binder properties; there is not enough of the old, hardened RAP present to significantly change the properties of the asphalt binder, and the RAP may be solely accounted for as a component of the aggregate. When RAP is added in amounts greater than 20 percent, recovery and testing of its binder is recommended, along with the use of blending charts to determine what performance grade of virgin asphalt binder should be used in the mix design. The RAP aggregate properties should be considered as if the RAP is another aggregate stockpile. In the Superpave mix design, the RAP aggregates should be blended with the virgin aggregates so that the final blend meets the Superpave consensus properties. Most state highway agencies will find that the results of the research largely agree with their usual practice. This agreement should give highway agencies and contractors greater confidence in more widely extending the use of RAP in HMA, regardless of the mix design method used.(4)

Chapter 3
Advantages of Hot Mix Asphalt

- Versatility of HMA
  - HMA pavements can be designed to handle virtually any traffic loads, soils and materials. It can be used to salvage old pavements as well as to build new ones.
  - Phased construction can easily be incorporated.
- Economy of HMA
  - Are economical to construct.
  - Constructed rapidly and are immediately ready for use.
  - Can be recycled.
  - Require minimal maintenance.
  - Provide outstanding performance.
- HMA pavements are not affected by ice control chemicals.
- Performance can be improved using HMA pavement because it contains binders which help in increasing resistance to rutting and stability
- Traffic noise is minimized when HMA pavement is used.
- Pavement striping is highly visible on the black HMA surface.

Chapter 4

Methods of HMA Mix Design

Marshall Method(5)

Marshall mix design was first developed by Bruce G. Marshall, who was working with Mississippi Highway Department around 1939. When inducted into the U.S. Army Corps of Engineers (USACE) during World War II, Marshall began developing different mix design methods for airfield pavement design. USACE became concerned with new mix designs because of heavy wheel loads and high tire pressures associated with larger military aircraft. The Marshall method seeks to select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values. (5) The Marshall mix design was recommended and adopted by USACE because it was designed to stress the whole sample rather than part of the sample.

The Marshall mix design consists of 3 major steps, 1) aggregate selection, 2) asphalt binder selection, and 3) optimum asphalt binder content determination. The USACE Waterways Experiment Station (WES) continued improving on the Marshall method by performing various tests on different materials according to traffic loading and weather conditions. WES added a deformation measurement method with the help of a flow meter which was used to detect asphalt contents. At present, 38 states in the U.S. are using the Marshall method. The reasons are that it is simple and inexpensive. The wide U.S. military experience with the method contributes to its credibility.

WES continued to refine the Marshall method throughout the 1950's with various tests on materials, traffic loading and weather variables. Today the Marshall method, despite its shortcomings, is probably the most widely used mix design method in the world. The Marshall method's advantages and disadvantages are listed below.

Advantages:

- Inexpensive equipment.
- Easy to use in process control/acceptance.
- Attention on voids, strength, and durability.

Disadvantages:

- Does not consider shear strength.
- Load perpendicular to compaction axis.
- Impact method of compaction.

Hveem Mix Design Method(6)

Hveem Mix design was introduced by Francis Hveem who worked with the California Division of Highways in the late 1920's and 1930's. The application of Hveem method started in the west coast states, and the method remains in use in California and Idaho. The procedure used for determining approximate asphalt content was the Centrifuge Kerosene Equivalent test. This is followed by a stability test. Hveem mix design yields the highest durability without reducing stability.

The Hveem mix design, a Kneading Compactor is used to prepare specimens. The stability of the specimens is subsequently measured by a Hveem Stabilometer. Specimens are loaded along the axis of compaction, and the Hveem stabilometer measures horizontal deformation under axial loads. The advantages and disadvantages of the Hveem method are listed below.

Advantages:

- Strength parameter direct indication of internal friction component of shear strength.
- Attention to voids, strength, and durability.
- Kneading compaction is similar to field.

Disadvantages:

- Equipment is expensive and not easily portable (it would be costly for road with low traffic volume).
- Does not have a wide range in stability measurement. As the asphalt content increases the stability of Hveem method deceases. Also, as the traffic level increases requirements increases.

Superpave Method

The Superpave mix design method was introduced to replace Marshall and Hveem methods. It was one of the best products developed by SHRP. Superpave was developed in the early 1990s. The volumetric analysis is common to the Hveem and Marshall methods in which one can observe the origins of the Superpave mix design method. The Superpave system ties asphalt binder and aggregate selection into the mix design process. It also considers traffic and climate. The Marshall and Hveem compaction devices have been replaced by a gyratory compactor in Superpave mix design. One of the primary differences between the Marshall and Superpave methods is the aggregate specifications. The primary elements of Superpave volumetric design are:

- Selection of component materials.
- Volumetric proportioning of aggregate and binder.
- Evaluation of the compacted mixture.

The advantages of Superpave method are listed below.

- Better binder properties than other two mix designs.
- More detailed, low temperature testing procedure.
- The Gyratory compactors which better represent compaction characteristics in the field are dependent on traffic volume.

The disadvantages of Superpave method are:

- This method is not able to find the effects of asphalt binder stiffness.
- Initial cost is higher.
- Superpave method requires more testing and control.

Chapter 5

Use of Superpave in Different States

- **Washington:**(7) The Washington State Department of Transportation (WSDOT) started using Superpave in 1996 and has increased the number of its Superpave projects every year. These total approximately 2.1 million tons and covers 1,753 lane kilometers (1,089 lane miles). After the Superpave projects had been in place for 6 years (maximum), an evaluation of the field performance, unit prices, and costs per lane kilometer were compared with WSDOT's conventional (Hveem) HMA. Although none of the Superpave projects have reached the end of their performance life, the purpose of this limited study was to answer the question: Is Superpave performing as well as conventional HMA in Washington State? The data presented show that, in most cases, Superpave is performing as well as, if not better than, the conventional HMA and the cost is approximately the same.

- **Indiana:**(8) The Indiana Department of Transportation (InDOT) conducted a cost–benefit analysis as part of an independent review of the cost-effectiveness of the InDOT's research program. The findings are documented in a report posted on the web. Because the costs of this project were shared with 6 other states. InDOT contributed only $15,000 – $^{1}/_{7}$th of the study cost of $105,000. According to the conservative estimate of the cost-effectiveness review, InDOT's savings in materials was nearly $330,000 per year when adding only 5 percent RAP to more than 5 million tons of base and intermediate mixes. RAP contents of 15 to 20 percent are more typical suggesting even greater savings. The review did not assess the environmental benefits of reusing RAP.

- **Alabama:**(8) The Alabama Department of Transportation (AlDOT) uses most of the dense-graded HMA mixes for Superpave design. However, there was concern that the number of design gyrations (N_{design}) depends on the specified traffic levels. The following conclusions made by AlDOT are based on an evaluation of Marshall and Superpave projects placed at approximately the same time and under approximately the same traffic conditions: 1) Both mix design methods perform quite well with little rutting and cracking after a period of about 4 years. 2) During the life of the pavement, both Marshall and Superpave designs will not reach the design air voids of 4 percent. After 4 years, the average air voids measured in the wheelpaths was 5.3 percent for Marshall mixtures and 5.9 percent for Superpave mixtures. 3) It was found that durability of Superpave mix design can be improved by increasing the asphalt content.

- **Arkansas:**(9) Arkansas Department of Transportation (ArDOT) experience regarding the cost of Superpave is summarized here. According to ARDOT price comparisons, there were changes made to binder specifications in 1995. These changes make it difficult to isolate the individual costs and compare Superpave jobs to those completed with other methods. However, from their studies of 97 projects, ARDOT has been able to make some assessments regarding Superpave performance and a cost comparison with Marshall mix design.

- The percentage of asphalt binder in Superpave surface course mixes is about the same as conventional Marshall mixes (sp 5.46, ml 5.35); about 0.50 percent more in binder course (sp 5.00, ml 4.44); and about 0.10 percent less in base courses (sp 4.43, ml 4.54)
- 1997 prices indicate that the Superpave surface course mixes cost about $1.40 per ton more than the standard Marshall mix; Superpave binder course mix costs about $1.34 less than the standard Marshall and Superpave base costs about $3.53 less than the standard Marshall mix.
- 1997 prices for performance grade binder are about $22 a ton more than 1995 viscosity grade binder.

Chapter 6
Cost of Hot Mix Asphalt

The additional costs associated with the use of Superpave mixes cannot be easily identified. Although it would seem likely that costs would be higher due to the requirements of the contractor to: 1) provide a Superpave Gyratory Compactor (SGC), 2) perform the mix design, and 3) perform quality control; the bid items did not separate the costs for equipment, mix design or quality control. It could be assumed then that these costs would be buried in the unit price per ton of in-place HMA. The price ranged from $30.80 to $32.04 per ton with the higher bid price for Class-1 RAP and the lowest for Superpave RAP.

The actual prices paid for the asphalt do, however, provide some indication of the effect the Performance Grade (PG) asphalts had on the project. Table 1 contains the price paid per U.S. ton of liquid asphalt. It is obvious that the anti-strip agent, which was used in all of the Superpave mixes, but none of the Class-1 mixes, and the modifier for the Superpave significantly affected the cost. Since, the cost of asphalt depends on the market demand and price, quantity, and location, the following tables provides relative costs in a 1997 construction project. The cost analysis could be projected to the new projects at the time of construction. Table 2 shows the cost of HMA for 2007 construction projects in four states. In Table 3, the benefits and the costs of HMA are compared for several states for the year 2005.

Table 1. Comparison of Costs of Liquids Used on Project 28-185(10)

Pavement Type	Asphalt Type	Cost ($ per ton)
Class 1 Virgin	AC-20	151.00
SUPERPAVE Virgin	PG64-28 w/0.25% anti-strip	181.50
SUPERPAVE Alternate Virgin	PG64-22 w/0.25% anti-strip	166.50
Class 1 RAP	AC-20	151.00
SUPERPAVE RAP	PG58-34 w/0.375% anti-strip & modifier	295.00
SUPERPAVE Alternate RAP	PG58-28 w/0.375% anti-strip	185.00

Table 2. Average Unit Cost of Hot Mix Asphalt Placed by the Bidders in Different States as of 2005[2]

State	Unit Cost	Quantity
Utah	$34.00/ton	747,053
Wyoming	$23.17/ton	71,500
Montana	--	--
Idaho	$32.00/ton	32,000

Table 3. Benefits of HMA in Different States[2]

1	**Arkansas**	Problems that were common with Marshall mixes occurred considerably less often
2	**Connecticut**	Noticed reduced rutting on pavement segments prone to rutting
3	**Louisiana**	Less rutting observed
4	**Minnesota**	Better ride & pavement sufficiency, slightly lower cost
5	**New York City**	No cost increase, 1 - 3 years in extra performance
6	**Ontario**	2 percent lower in cost, 1 - 2 years increased performance
7	**Pennsylvania**	Seems to have resolved the rutting problem
8	**Utah**	3-year life increase, 10% LCC savings
9	**Utah DOT Region 2**	Crack sealing costs are down 70%, patching costs down 20%
10	**Washington State**	3% higher in cost, 12 - 20% longer performance
11	**City of Calgary**	Better performance at same cost
12	**City of Ottawa**	Marked reduction in cracking

Chapter 7

Superpave for Low-Volume Roads

In 1975, the first International Conference on Low-Volume Roads was conducted in Boise, Idaho.(11) The committee on low volume roads defined low-volume roads as those that have less than 500 vehicles per day. The importance of low-volume roadways has drastically increased over the last decade. These roadways not only serve the transportation needs of a certain area, but they also improve the economic and social status of that area. The definition of a low-volume road varies from state to state. A survey completed by New England DOTs shows that low volume roads can be defined either in terms of vehicles per day or Equivalent Single Axle Loads (ESAL).

Asphalt binder selection is now based on local climate conditions and traffic loading. To avoid confusion and help producers plan production, the Iowa DOT, Office of Materials reviewed the climate data for Iowa and selected PG 58-28 as the standard paving grade of asphalt binder. PG 58-28 provides the low-temperature flexibility of AC-5 while maintaining the high-temperature stiffness of AC-10. For very high traffic, or for slow moving heavy traffic, the high-temperature grade is often increased by one or two grades. For example PG 64-22 is used for Interstate overlays. In Table 4, the definition of low-volume roads by several state DOTS is presented.(11)

Table 4. Low Volume Roads Categorization by Different States.

State	Definition
Connecticut	<300,000 ESAL in design period
Maine	<1,000 AADT
Massachusetts	<2,000 AADT, <45 mph speed
New Hampshire	≤10,000 vehicles per day
Rhode Island	≤1000 vehicles per day for 2-lane and ≤15,000 vehicles per day for 4-lanes
Vermont	≤ 100,000 ESAL in design period

Chapter 8

Comparison Between Superpave Mix Design and Marshall Mix Design(8,12)

The comparison between Superpave mix design and Marshall mix design is based on a project that was done in Kansas. For both mix designs, the same local aggregates were used. The project site was Kansas Route 177 in the northeast part of the state. Three locally available aggregates: crushed limestone, course river sand, and fine river sand were used in the study. Five blends with varying proportions of coarse and fine river sands were selected. Mix samples (Superpave) were compacted in the Superpave Gyratory Compactor with the applicable number of gyrations. For the Marshall mix, a Marshall hammer was used to apply 50 blows per face. Bulk densities of the compacted samples and maximum specific gravities of loose samples were also measured for each blend. The results show that the Superpave mix design for low-volume roads and shoulders results in lower estimated asphalt content than that for the Marshall method.

The asphalt content increases as the proportion of coarse river sand increases in the mix. Superpave requirements for voids filled with asphalt for low-volume traffic (less than 0.3 million equivalent single-axle loads) appeared to be too high. High asphalt film thicknesses were computed for the mixtures that did not meet the Superpave VFA (Voids in the mineral aggregate filled with the Asphalt Binder) requirements. Lowering the design number of gyrations (N_{design}) for compaction of samples would result in increased asphalt requirement for the Superpave mixture with a given gradation.

The differences between Marshall and Superpave design methods for low-volume roads can be observed in asphalt content. The Kansas study indicated that VMA (Voids in the Mineral Aggregate) and VFA of the Superpave mix design were lower than that for the Marshall mixes.(8) The Superpave mixes required a higher percentage of asphalt for the 100 percent limestone mixes, while the Marshall mixes required a higher asphalt content with 13 percent sand in the mix. The VFA of the Marshall mixes was higher than the Superpave mixes in 3 of the 4 cases. Table 5 compares the percent asphalt, VMA and VFA for different mix types.

Table 5. Marshall and Superpave Design Parameters. (5)

Mix Type	Percent Asphalt	VMA	VFA
SP HVY 100% LS	5.7	15.3	73.5
MR HVY 100% LS	5.2	15.0	74.0
SP MED 100% LS	6.3	16.9	74.0
MR MED 100% LS	5.5	15.1	72.5
SP HVY 13% NS	5.5	15.0	72.6
MR HVY 13% NS	5.9	16.1	75.0
SP MED 13% NS	5.8	15.4	74.0
MR MED 13% NS	6.0	16.1	75.5

SP - Superpave, MR- Marshall method, MED – Medium, HVY – Heavy

Chapter 9

Superpave Performance and Cost Comparison by Washington State DOT(7)

The Washington Department of Transportation (WSDOT) placed its first Superpave test section in 1996. By the end of 2002, WSDOT had placed over 2.1 million tons on approximately 1,090 lane miles. In 2007, WSDOT conducted a performance and cost comparison for wearing course mixes. This compared ½ and ¾ in. Superpave mixes to Hveem-designed HMA Classes-A, B, E, and F. The Pavement Structural Condition (PSC), International Roughness Index (IRI), and rut depth that characterized Superpave and Hveem designs were analyzed and compared using the data from the 2002 Washington State Pavement Management System (WSPMS). The PSC was a measure of pavement distress including longitudinal, alligator, and transverse cracking along with patching. It ranges from 100 for no distress to 0 for extensive distress. The roughness of road was measures by IRI which ranges from 0 in./mile for a perfectly smooth surface to values in excess of 230 in./mile for a very rough surface. The rut depth was measured in the wheel path and ranges from 0 in. to values in excess of ½ inch. The WSDOT calls for rehabilitation of its pavement for PSC values between 40 and 60, IRI measurements equal to or in excess of 220 in./mile, and/or a rut depth exceeding ⅜ inch.

In this study, each Superpave project was compared to the overlay or construction to limit the environmental and traffic variables. The Superpave project ages ranged from 3 to 6 years; 70 percent fell into the 3-year-old category. The Hveem-designed pavements were constructed between 1967 and 1998 with approximately 68% built prior to 1990. All Superpave projects had utilized a PG binder whereas 94 percent of the Hveem-designed pavements had used AR4000W (type of binder used by WSDOT).

Pavement Structural Condition Performance

Figure 1 compares the PSC for Superpave and Hveem-designed projects. In this comparison, the PSC for Superpave ranges from 47 to 100 while the Hveem-designed mixes ranges from 22 to 100. The majority of the Superpave pavements had higher PSC than Hveem-designed projects.

- 48 percent of Superpave sections have a higher PSC
- 29 percent of the comparable sections had the same PSC
- 23 percent of the Superpave sections have a lower PSC

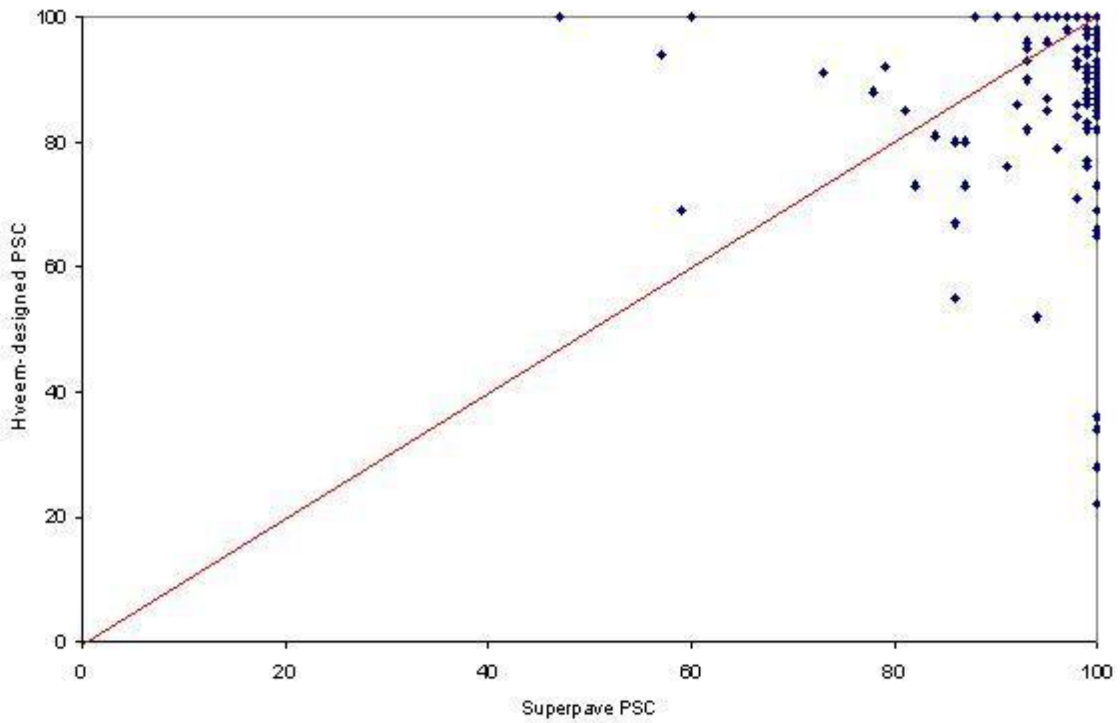


Figure 1. Comparison of PSC for Superpave and Hveem Designed Projects.

Roughness Performance

The roughness of Superpave and Hveem-designed surfaces was compared using IRI. Figure 2 presents the IRI comparison for both projects. For Superpave, IRI ranges from 25 in./mile to 204 in./mile. For the Hveem-designed projects, IRI ranges from 48 in./mile to 319 in./mile. About 91 percent of the Superpave displayed lower IRI values.

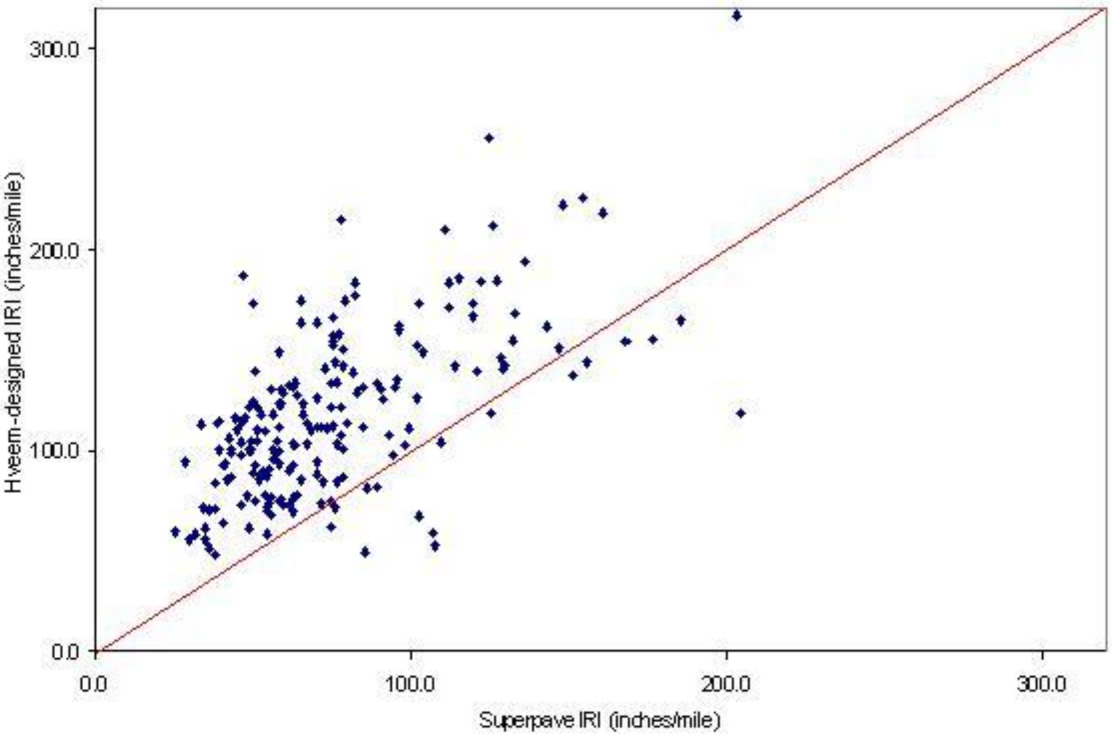
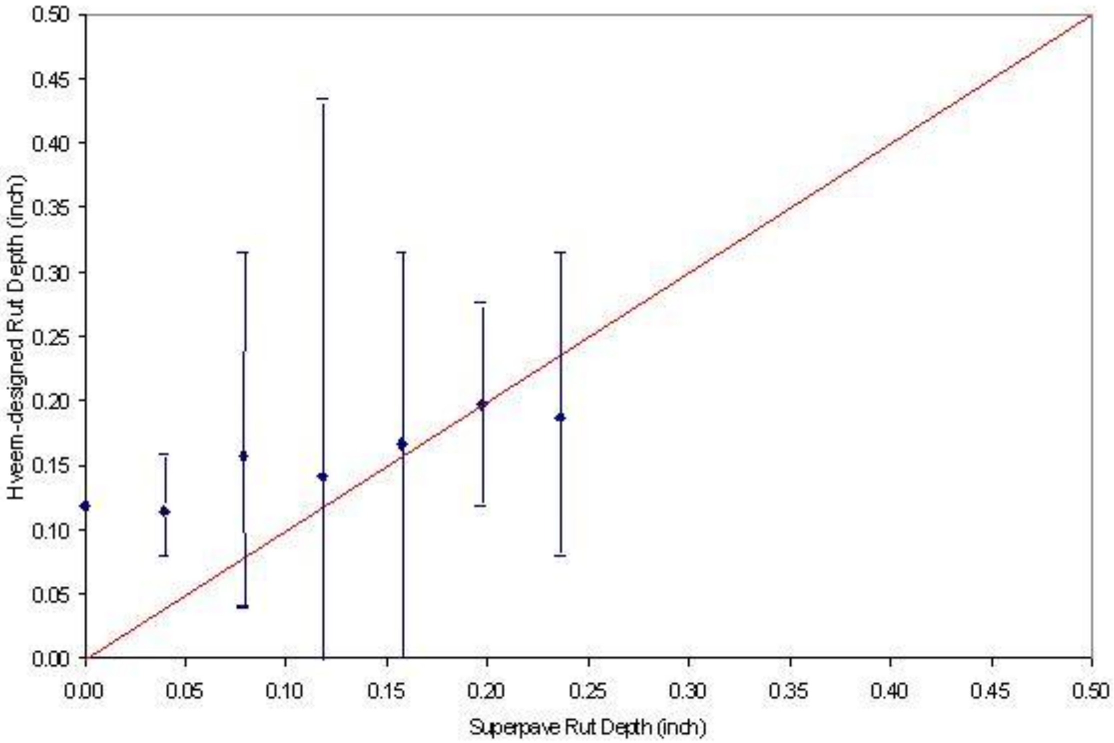


Figure 2. Comparison of IRI for Superpave and Hveem Designed Projects.

Rutting Performance

Figure 3 compares the rutting depth for Superpave and Hveem-designed projects. The range of the rutting for Superpave was measured between 0 in. and ¼ inch. For the Hveem-designed projects, it ranged between $^{1}/_{32}$ in. and $^{7}/_{16}$ inches.   After a maximum of six years, the rut depths for Hveem-designed projects were higher than those for the Superpave projects. The comparison of rut depth showed that 60 percent of the Superpave sections had rut depth lower than Hveem-designed sections; 12 percent had the same rut depths and the remaining 28 percent of the Superpave sections had higher rut depths than the Hveem-designed sections.



Vertical lines represent variations in the rut depth in the Hveem-designed projects.

Figure 3. Comparison of Rut Depth for Superpave and Hveem Designed Projects.

The comparison of the result from the above study favors Superpave over Hveem-designed pavements; however, it was found that most of the Hveem-designed projects were constructed prior to 1990. WSDOT conducted another comparative study for performance between Superpave and Hveem-designed pavements, all placed between 1997 and 1998.(7) The result of this study did not significantly favor Superpave over the Hveem-designed mixes in regard to PSC, IRI, and rut depth. In this study, 75 percent of the Superpave projects had the same or lower PSC than Hveem-designed projects, but the IRI results overwhelmingly favored the Superpave sections. It was concluded that about 63 percent of the Superpave sections had smoother surfaces. WSDOT concluded that, at this time, both design methods display comparable performance. WSDOT will conduct another study at the end of the life cycle of these projects for a more realistic comparison.

Chapter 10
Unit Price Comparison

WSDOT has also conducted a cost comparison of Superpave and Hveem-designed projects. In this study, two types of cost comparisons were performed, unit price per ton and cost per lane-mile. Table 6 and Table 7 shows the comparisons for the Superpave and the Hveem-designed projects. Although the price comparison depends on the market price, the quantity of the material purchased and the location, this table can be used for a relative cost comparison. Note that the unit price in western Washington is higher than that in eastern Washington. Since the market price and the quantity purchased cannot be factored into the cost analysis, the results indicate that there is no significant difference in cost between the Superpave and the Hveem-design hot mix asphalt.

Table 6. Washington Unit Price Comparison ($/ton).(7)

	Superpave		**Hveem-Method**		
	½ inch	**¾ inch**	**A**	**B**	**E**
East	26.38	25.01	24.11	25.15	26.57
West	34.12	35.44	28.59	28.67	27.86
Average	28.66	26.40	27.41	27.44	27.64

Table 7. Washington Unit Price Comparison Cost per Lane-Mile.(7)

Superpave HMA			
	Rural	**Urban**	**Average**
East	$76,694	$76,056	$76,375
West	$80,739	$134,257	$107,498
Average	$78,717	$105,157	$91,937
Hveem-Designed HMA			
	Rural	**Urban**	**Average**
East	$79,500	$91,550	$85,525
West	$88,100	$120,200	$104,150
Average	$83,800	$105,875	$94,835

Chapter 11

Conclusions

Based on this study and the literature review, it is concluded that Superpave mix design provides better performance for roadways that experience heavy to medium traffic volumes. For low-traffic roadways, Superpave, Marshall, and Hveem-designed mixes perform about the same. Considering the unit price, it appears that there are no significant differences among the three mix-design methods.

References

1. **D'Angelo, J. A.** "Superpave Mix Design Tests Methods and Requirements", pgs 103-115 in *"Innovations in Urban Infrastructure, 1999: a Seminar at the APWA International Public Works Congress and Exhibitio,."*Ottawa, ON: Institute for Research in Construction, 1999.
2. **Transportation Research Board.** *"Superpave, Performance by Design, Final Report of the TRB Superpave Committee."*Washington, D.C: National Academies Press, 2005.
3. **McDaniel, R. and R. M. Anderson**. *Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician's Manual.* Washington, DC: Transportation Research Board, NCHRP Report No. 452, 2001.
4. **McDaniel, R. and M. Anderson**.*"Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method. Washington, DC:* NCHRP Report 452, National Academy Press, 2001.
5. **Roberts, F. L., L. N. Mohammad, and L. B. Wang.** "History of Hot Mix Asphalt Mixture Design in the United States." *Journal of Materials in Civil Engineering.* Volume 14, Number 4 (July/August 2002): 279-293.
6. **Roberts, F. L., P. S. Kandhal, E. R. Brown, D. Y. Lee, and T. W. Kennedy.** *Hot Mix Asphalt Materials, Mixture Design, and Construction*. Lanham, MD: National Asphalt Pavement Association Education Foundation, 1996.
7. **Pierce, L. M.** *"Superpave Performance and Cost Comparison."* Olympia, WA: Washington State Department of Transportation, Materials Laboratory, Tech Notes, 2004.
8. **Habib, A., M. Hossain, R. Kaldate, and G. A. Fager.** "Comparison of Superpave and Marshall Mixtures for Low-Volume Roads and Shoulders." *Transportation Research Record*, Volume 1609, (1998): 44-50.
9. **Yildirim, Y., and C. LaVaye.** *The Superpave Asphalt Research Program*, Austin, TX: The University of Texas at Austin, 1996.
10. **Larsen, D. A., and N. Rodriguez.** *"Demonstration and Evaluation of Superpave Technologies Construction Report for Route 2."* Rocky Hill, CT: Connecticut Department of Transportation, Research Project: SPR-2219, FHWA-CT-RD-2219-1-97-5, 1997.
11. **Brown, E. R., D. Decker, R. B. Mallick, and J. Bukowski.** "Superpave Construction Issues and Early Performance Evaluations." *Journal of the Association of Asphalt Paving Technologists*, Volume 68, (1999): 209-220.

12. **Muench, S. T., J. P. Mahoney, W. Wataru, L. Chong, and J. Romanowski.** "Best Practices for Long-Lasting Low-Volume Pavements." *Journal of Infrastructure Systems.* Volume 13, No. 4 (2007): 311-320.