SUPERPAVE BINDER IMPLEMENTATION

Final Report

SPR 353

by

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16. Abstract

Oregon Department of Transportation (ODOT) has specified performance-based asphalts (PBAs) since 1991. Developed by the Pacific Coast Conference on Asphalt Specifications (PCCAS) in 1990, the PBA concept uses conventional test methods for classification and facilities binder selection based on climatic conditions. The Conference plan was to use the PBA concept and conventional tests as an interim approach which would eventually be replaced with the Strategic Highway Research Program performance grade (SHRP PG) specification and supporting tests. As a first step in the SHRP implementation/validation effort ODOT has evaluated its commonly used PBA grades in terms of the SHRP (now called Superpave) protocols. The limited binder evaluation to date suggests the following equivalencies: PBA-2s may be classified as PG 64-16 or PG 64-28; PBA-3s as PG 58-34 or PG 64-28; PBA-5s as PG 64-22; and PBA-6s as PG 58-28 or PG 64-34. There was not always agreement with regard to PG classification between the research results and the supplier data, nor was there always agreement among the suppliers. As described by the number of different performance grades for a particular PBA, PBA-2 appeared to be the least consistent whereas PBA-5 and PBA-6 appeared to be the most consistent. Comparison of Superpave PG and conventional binder test data indicates that there was no relationship between the high temperature performance grade and kinematic viscosity. However, there was a moderate relationship between the high temperature performance grade and absolute viscosity as values of explained variation (R^2) of the unaged and RTFO-aged binders were 0.38 and 0.52, respectively. The relationship between the low temperature performance grade and penetration at 4°C and 25°C were significantly higher with values of explained variation for the RTFO-aged binders of 0.80 and 0.84, respectively. The diversity of Oregon's climate suggests that as many as 13 to 14 binder grades might be "needed" at the 98 percent level of reliability, although many grades overlap. Realistic constraints and practical considerations such as readily available binder sources and state-maintained-road-miles associated with a particular performance grade led to the recommendation that four PG binders be specified: PG 58-22 and PG 64-22 west of the Cascades; PG 58-28 and PG 64-28 in the central part of the state; and PG 64-28 in the eastern part of the state. Preliminary economic analysis suggests that implementation of the PG system could provide substantial savings. Because of Oregon's extensive use of open-graded friction courses, additional work must be done to determine what effects, if any, the PG classification might have on this mix type in terms of field performance
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DISCLAIMER

SUPERPAVE BINDER IMPLEMENTATION

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1.0 BACKGROUND AND OBJECTIVES

1.1 OBJECTIVES

Implementation of the Strategic Highway Research Program (SHRP)/Superpave binder tests and specifications, still underway, has required a significant commitment of time and personnel by the Oregon Department of Transportation (ODOT). Embracing the Superpave technology in 1993, ODOT decided that the most efficient way to make the transition from its current performance-based asphalt (PBA) system to the Superpave performance graded (PG) system was to perform parallel testing with both conventional and Superpave tests. ODOT's philosophy was to replace the conventional tests used in the PBA system with performance based tests developed by SHRP as they became available.

To make the transition to the Superpave PG system, ODOT considered several approaches: hiring additional personnel; using a combination of ODOT and Oregon State University (OSU) personnel and equipment; dispatching personnel to the Arizona DOT lab where the Pacific Coast Conference on Asphalt Specifications (PCCAS) equipment was then stationed; or some combination of the preceding. For purposes of this research it was originally envisioned that all testing would be conducted at the ODOT and OSU laboratories using equipment belonging to both agencies. As expected with any new equipment there were difficulties which forced some modification to the original plan. Adjustments to the original testing plan are addressed in Chapter 2.

The overall objectives of the research were to test the full range of PBAs used by ODOT to determine the equivalent Superpave performance grade, and to develop nomographs which would facilitate binder selection to optimize resistance to thermal cracking. The specific objectives in the work plan included the following:

1. Determination of the Superpave PG classification for binders currently used by ODOT;
2. Determination of the time required for testing and training;
3. Comparison of conventional and Superpave binder test data;
4. Development of guidelines for PG binder usage; and
5. Assessment of economic impacts of PG implementation.

1.2 BACKGROUND

1.2.1 Performance Based Asphalts (PBAs)

ODOT has specified PBAs since 1991. Developed by the Pacific Coast Conference on Asphalt Specifications (PCCAS) in 1990, the PBA system is intended to facilitate binder selection without compromising performance. The climatic conditions used in the PBA system are as shown in Table 1.1. In general, the PBA grade is inversely proportional to temperature susceptibility, i.e., properties of PBA-2 are more sensitive to temperature than are the properties of PBA-6. PBA specifications used by ODOT at the onset of this research are shown in Appendix A.

Table 1.1: Climatic Conditions for PBAs

Lowest Recorded Air Temperature	Highest Mean Monthly Air Temperature		
	Below 32°C	**Between 32°C and 38°C**	**Above 38°C**
Above -23°C	Moderate PBA-1	Hot PBA-4	Very hot PBA-7
Between -23°C and -29°C	Moderate/Cold PBA-2	Hot/Cold PBA-5	
Below -29°C	Moderate/Very cold PBA-3	Hot/Very cold PBA-6	

In the PBA system, binder performance is defined in terms of the following: temperature susceptibility (including thermal cracking, rutting, tenderness, mix production and placement); short- and long-term (PBA-7) aging; purity; safety; and mix properties (adhesion, permanent deformation and fatigue cracking). Conventional tests initially used for classification included penetration, viscosity and ductility on both original and rolling thin film oven (RTFO) aged binders. As noted previously, it was ODOT's plan to use the PBA concept and conventional tests as an interim approach that would eventually be replaced with the Superpave PG specification and supporting tests. As evidence of its evolutionary nature, the PBA specification shown in Appendix A had integrated some aspects of the Superpave technology as early as 1993.

1.2.2 PBAs Used by ODOT

As shown in Figure 1.1, ODOT typically specifies PBA-2 and PBA-3 for dense-graded mixes west and east of the Cascades, respectively; and PBA-5 and PBA-6 for open-graded mixes west and east of the Cascades, respectively. PBA-6 is also used west of the Cascades on some high-volume roads. PBA-6GR is allowed as an alternative to PBA-6.

1.2.3 SHRP/Superpave

A highly focused, product-oriented effort, the Strategic Highway Research Program (SHRP) directed nearly $50 million toward the development of performance based tests for asphalt binders and asphalt-aggregate mixes. With the conclusion of the research in 1993, SHRP asphalt products emerged as Superpave — SUperior PERforming Asphalt PAVEments — a system that includes a binder specification and a framework for mix design and analysis, with supporting tests and equipment for each. The Superpave binder tests measure physical properties that are related to field performance using fundamental engineering properties, i.e., stress and strain.

In Superpave, performance is defined in terms of permanent deformation, fatigue cracking and low temperature cracking. Also considered are aging and moisture sensitivity. Binder selection, however, is driven primarily by environmental conditions at the site, i.e., the anticipated

Figure 1.1: PBAs Currently Specified by ODOT

extremes in pavement service temperatures. Secondary considerations are anticipated traffic volume and rate of loading.

Shown in Table 1.2 is a list of the binder equipment and its purpose in the Superpave system. A thorough description of Superpave concepts, equipment and specification may be found elsewhere *(McGennis, Shuler, and Bahia 1994; Kennedy, et al. 1994)*. A copy of the Superpave binder specification is shown in Appendix B.

Table 1.2: Superpave Binder Equipment

Equipment/Procedure	Purpose
Dynamic Shear Rheometer (DSR)	Measure properties at intermediate and high temperatures
Rotational Viscometer (RV)	Measure properties at high mixing temperatures
Bending Beam Rheometer (BBR) Direct Tension Test (DTT)	Measure properties at low temperatures
Rolling Thin Film Oven (RTFO)	Simulate short-term aging
Pressure Aging Vessel (PAV)	Simulate long-term aging

To address the inevitable problems associated with the implementation of any new material specification and/or equipment, the Federal Highway Administration (FHWA) formed a Binder Expert Task Group (ETG). With representatives from state agencies, industry, equipment manufacturers, and FHWA as well as former SHRP researchers, the Binder ETG is currently debating several topics that may result in modifications to the current binder specification and/or test protocols. Of immediate concern are the suitability of the fatigue criterion, use of the bending beam rheometer (BBR) and direct tension test (DTT) for determining low temperature binder grade, and applicability of the specification to modified binders. Despite the dynamic environment, ODOT is using the results reported herein to begin its Superpave implementation. As of this date ODOT is planning to specify PG binders on selected "pilot" projects in 1999. Implementation beyond 1999 is as yet uncertain.

1.3 IMPLEMENTATION PLAN

Results from this research form the basis for ODOT's implementation of the Superpave binder concepts and involve three key steps: 1) classification of its commonly used PBA grades in terms of the Superpave PG system; 2) review of the Superpave weather database; and 3) development of guidelines for anticipated binder use. Each is addressed in Chapter 2.

2.0 BINDER EVALUATION AND GUIDELINES FOR PG USE

2.1 BINDER TESTING

As noted previously, ODOT typically specifies PBA-2, -3, -5 and -6. In this study 14 binders from six sources (i.e., suppliers) were classified in accordance with AASHTO PP6-93 *(AASHTO 1995)*. Note that all binder equipment listed in Table 1.2 except the direct tension test (DTT) was available for this research. The binders tested are shown in Table 2.1.

Table 2.1: PBA Binders Tested

Binder Source/Supplier	PBA Grade
Albina	3, 5, 6
Chevron	2, 3, 5, 6
EOTT	5, 6
Huntway	2, 6
Idaho	3
McCall	5, 6

2.1.1 Dynamic Shear Rheometer (DSR) Testing

Since asphalt behavior depends on both time and temperature, the ideal test procedure would account for both. SHRP researchers adapted readily-available technology from the plastics industry in the form of a dynamic shear rheometer (DSR). The DSR is used to measure rheological properties (complex shear modulus and phase angle) at intermediate (≈7° to 40°C) and high (≈46° to 82°C) temperatures. In the Superpave system DSR testing is done on unaged (i.e., tank) binders, as well as rolling thin film oven (RTFO) and pressure aging vehicle (PAV) conditioned binders.

In this study, DSR testing was accomplished using three Bohlin shear rheometers in the controlled strain mode at 10 rad/s: two Bohlin DSR II (one each at OSU Civil Engineering and Bohlin Instruments laboratory in New Jersey); and one Bohlin CS-50 (at OSU Chemical Engineering). Personnel of OSU Civil Engineering prepared samples (approximately 50 g) for use by the other laboratories (OSU Chemical Engineering and Bohlin). Binder samples were provided by suppliers in December 1994 and January 1995. At the onset of this research, there were no readily available data on test repeatability, or precision and bias statements. Accordingly, an attempt was made to try to gather data toward that end. DSR testing of unaged and RTFO conditioned binders was done using all three rheometers. Testing of PAV conditioned binders was done exclusively on the DSR in OSU Civil Engineering.

DSR test data are shown in Table 2.2 and Figures 2.1 to 2.2. Included with the DSR data in Table 2.2 are descriptive statistics which give some indication of the test repeatability. As is evident from Figures 2.1 and 2.2, there is more variability than might be desired, or acceptable.

For the unaged and RTFO-aged binders the average coefficients of variation were approximately 18 and 25 percent, respectively. For both the unaged and RTFO-aged binders the DSR data were somewhat consistent in their variability. Measurements of G*/sin δ on the unaged binders made with rheometers in the Civil and Chemical Engineering labs were fairly close, but usually greater than those reported by the Bohlin lab. Measurements of G*/sin δ on the RTFO-aged binders were generally more variable, though there was greater agreement between the Chemical Engineering and Bohlin labs. Values reported by the Civil Engineering lab generally tended to exceed those reported by the other labs. Though the data are variable one must consider the fact that the DSR protocol does not require replicate samples for testing.

A review of recent round robin test data indicates that this level of variability is not uncommon *(Morgenstern 1997; AMRL 1997).* Round robin testing coordinated by the Western Cooperative Testing Group (WCTG) included data from as many as 18 laboratories. Testing was conducted

Table 2.2: Dynamic Shear Rheometer Data (Unaged and RTFO-Aged Binder)

Binder Source	PBA Grade	Test Temp (°C)	G*/sinδ (kPa)			Unaged		
			Bohlin - NJ	Civil Engr	Chem Engr	Mean	Std Dev	CV (%)
Albina	3	58	1.78	n/a	n/a	1.78	0.00	0.00
		64	1.00	1.43	1.33	1.25	0.23	17.95
	5	64	1.67	2.49	3.93	2.70	1.14	42.43
		70	0.78	1.38	1.32	1.16	0.33	28.49
	6	64	1.59	1.87	1.81	1.76	0.15	8.39
		70	0.89	1.11	1.13	1.04	0.13	12.76
Chevron	2	64	1.29	1.44	1.77	1.50	0.25	16.37
		70	0.61	0.75	0.84	0.74	0.12	15.80
	3	64	1.12	1.36	1.83	1.44	0.36	25.14
		70	0.60	0.82	1.05	0.82	0.23	27.33
	5	64	1.70	1.94	2.29	1.98	0.30	15.01
		70	0.78	0.96	1.14	0.96	0.18	18.75
	6	64	1.37	1.56	1.58	1.51	0.12	7.71
		70	0.83	0.94	0.97	0.91	0.07	8.07
EOTT	5	64	1.45	1.84	2.12	1.81	0.34	18.66
		70	0.69	1.05	1.00	0.91	0.20	21.35
	6	64	1.79	1.90	1.96	1.88	0.09	4.58
		70	0.75	1.07	1.00	0.94	0.17	17.90
Huntway	2	64	1.05	1.33	1.45	1.28	0.21	16.08
		70	0.51	0.66	0.64	0.60	0.08	13.50
	6	64	1.12	1.42	1.44	1.33	0.18	13.51
		70	0.73	0.94	0.86	0.84	0.11	12.57
Idaho	3	64	1.12	1.55	1.98	1.55	0.43	27.74
		70	0.60	0.90	1.05	0.85	0.23	26.96
McCall	5	64	1.33	1.96	2.40	1.90	0.54	28.36
		70	0.60	0.95	1.17	0.91	0.29	31.71
	6	64	1.31	1.58	1.45	1.45	0.14	9.33
		70	0.74	0.90	0.85	0.83	0.08	9.74
						Avg	0.24	17.72

Table 2.2: DSR Data (Unaged and RTFO-Aged Binder) (continued)

Binder Source	PBA Grade	Test Temp (ºC)	G*/sinδ (kPa)			RTFO-Aged		
			Bohlin - NJ	Civil Engr	Chem Engr	Mean	Std Dev	CV (%)
Albina	3	58	2.87	3.99	3.10	3.32	0.59	17.82
		64	1.45	2.09	2.54	2.03	0.55	27.03
	5	64	3.08	5.61	17.39	8.70	7.64	87.85
		70	1.52	2.13	8.01	3.91	3.57	91.23
	6	64	2.59	3.34	2.61	2.85	0.43	15.01
		70	1.53	1.94	1.35	1.61	0.30	18.82
Chevron	2	64	2.26	3.39	2.74	2.80	0.57	20.28
		70	1.08	1.79	1.31	1.39	0.36	26.00
	3	64	2.00	2.75	1.20	1.98	0.78	39.08
		70	1.09	1.65	0.63	1.12	0.51	45.15
	5	64	3.14	3.89	3.49	3.51	0.38	10.70
		70	1.57	2.03	1.67	1.75	0.24	13.77
	6	64	2.24	3.03	2.44	2.57	0.41	15.98
		70	1.39	1.86	1.36	1.54	0.28	18.25
EOTT	5	64	2.85	4.21	3.66	3.58	0.68	19.15
		70	1.31	2.00	1.64	1.65	0.34	20.65
	6	64	3.15	3.90	3.93	3.66	0.44	12.07
		70	1.48	1.97	1.80	1.75	0.25	14.22
Huntway	2	64	2.19	2.87	2.61	2.55	0.34	13.42
		70	1.00	1.32	1.18	1.16	0.15	13.02
	6	64	1.62	2.01	1.79	1.89	0.33	17.54
		70	0.87	1.32	0.97	1.05	0.24	22.43
Idaho	3	64	2.62	3.82	2.81	3.08	0.65	20.92
		70	1.21	2.05	1.32	1.53	0.46	29.90
McCall	5	64	3.05	3.96	4.16	3.72	0.59	15.89
		70	1.33	1.88	1.82	1.68	0.30	18.00
	6	64	2.35	3.17	2.76	2.76	0.41	14.86
		70	1.23	1.86	1.44	1.51	0.32	21.24
						Avg	0.79	25.01

over the course of 18 months using nine binder samples of five grades. The ranges in coefficient of variation for G*/sin δ on "tank" and RTFO-aged material were 9.7 to 39.6 and 9.2 to 33.5 percent, respectively. For G*sin δ on PAV conditioned material the range in coefficient of variation was 8.4 to 40.6 percent. AMRL data from 120 to 130 participating laboratories reported coefficients of variation as follows: G*/sin δ on original binders of 10.5 to 11.3 percent; G*/sin δ on RTFO-aged binders of 11.8 to 12.7 percent; and G*sin δ on PAV binders of 21.5 to 21.7 percent.

Average DSR results at 64°C for unaged and RTFO-aged binders are shown in Figures 2.3 and 2.4. Based on the unaged binder data all the PBAs meet the criterion for classification as a PG 64. Based on RTFO-aged binder data, however, several fail to meet criterion for classification as a PG 64, suggesting that the binders age differently.

Figure 2.1a: Dynamic Shear Rheometer Data (Unaged Binders: BPA-2 and PBA-3)

Figure 2.1b: Dynamic Shear Rheometer (DSR) Data (Unaged Binders: PBA-5 and PBA-6)

Figure 2.2a: Dynamic Shear Rheometer (DSR) Data (RTFO-Aged Binders: PBA-2 and PBA-3)

Figure 2.2b: Dynamic Shear Rheometer (DSR) Data (RTFO-Aged Binders: PBA-5 and PBA-6)

Figure 2.3: Average DSR Test Results at 64°C (3 Labs -- Unaged Binder)

Figure 2.4: Average DSR Test Results at 64°C (3 Labs -- RTFO-Aged Binder)

2.1.2 Bending Beam Rheometer (BBR) Testing

SHRP researchers suggested that most DSRs could not be used to reliably measure binder properties at low temperatures (≈ 0 to -36°C). Thus, the bending beam rheometer (BBR), a relatively simple device that measures stiffness and creep rate, was developed. The BBR measures beam deflection under a constant load at temperatures that correspond to the lowest pavement service temperature when the binder tends to behave like an elastic solid. BBR testing can be done on RTFO and PAV conditioned binders.

In this study, all testing was accomplished with ODOT's BBR (manufactured by Applied Test Systems). Problems with the BBR's cooling system precluded testing at temperatures below -24°C, though the Superpave protocol indicated that some binders should have been tested at -30°C. When needed for PG classification, the stiffness (S) and m were extrapolated to -30°C. BBR stiffness and m-value data are shown in Table 2.3 and Figures 2.5 and 2.6.

Table 2.3: Bending Beam Rheometer (BBR) Data

Binder Source	PBA Grade	Test Temp (°C)	Individual Beam Stiffness (MPa)	Difference in Stiffness (MPa)	Average Stiffness (MPa)	Individual Beam m-Value	Difference in m-Value	Average m-Value
Albina	3	-18	71.67	7.24	75.29	0.408		
		-18	78.91			0.405	0.004	0.406
		-24	196.31	1.17	196.90	0.347	0.002	0.348
		-24	197.48			0.349		
	5	-12	166.21	0.86	166.64	0.338	0.004	0.340
		-12	167.07			0.342		
		-18	310.77	27.96	324.75	0.246	0.030	0.261
		-18	338.73			0.276		
	6	-18	86.13	1.34	86.80	0.404		
		-18	87.47			0.394	0.010	0.399
		-24	212.24			0.336		
		-24	206.11	6.13	209.18	0.335	0.001	0.336
Chevron	2	-18	233.08			0.305	0.036	0.323
		-18	218.42	14.66	225.75	0.340		
		-24	501.61			0.245	0.012	0.251
		-24	467.07	34.54	484.34	0.257		
	3	-18	108.96	5.37	111.64	0.371		
		-18	114.33			0.364	0.007	0.367
		-24	254.25	10.82	259.66	0.311		
		-24	265.07			0.308	0.003	0.310
	5	-12	130.11			0.356		
		-12	127.55	2.56	128.83	0.352	0.003	0.354
		-18	257.62	21.47	268.36	0.295		
		-18	279.09			0.292	0.003	0.294
	6	-18	106.24			0.369	0.005	0.371
		-18	105.46	0.78	105.85	0.373		
		-24	262.96	1.76	263.84	0.306	0.008	0.310
		-24	264.72			0.314		

Table 2.3: BBR Data (continued)

Binder Source	PBA Grade	Test Temp (°C)	Individual Beam Stiffness (MPa)	Difference in Stiffness (MPa)	Average Stiffness (MPa)	Individual Beam m-Value	Difference in m-Value	Average m-Value
EOTT	5	-18	257.87	15.90	265.82	0.294	0.004	0.296
		-18	273.77			0.298		
	6	-18	119.26			0.368	0.010	0.373
		-18	117.27	1.99	118.26	0.378		
		-24	256.79	8.98	261.28	0.308	0.013	0.315
		-24	265.77			0.321		
Huntway	2	-12	223.66			0.326	0.009	0.330
		-12	207.36	16.30	215.51	0.335		
		-18	450.30	27.91	464.26	0.270	0.003	0.271
		-18	478.21			0.273		
	6	-18	161.34	3.20	162.94	0.369	0.008	0.374
		-18	164.54			0.378		
		-24	345.85			0.288	0.003	0.290
		-24	320.11	25.74	332.98	0.291		
Idaho	3	-18	147.69			0.329		
		-18	146.33	1.36	147.01	0.323	0.006	0.326
		-24	286.88	4.49	289.12	0.274		
		-24	291.37			0.267	0.007	0.270
McCall	5	-12	123.20			0.347	0.004	0.350
		-12	121.51	1.69	122.36	0.352		
		-18	393.02	4.70	395.37	0.292	0.002	0.293
		-18	397.72			0.294		
	6	-18	116.49	1.48	117.23	0.386		
		-18	117.97			0.385	0.000	0.386
		-24	269.32	13.55	276.10	0.322	0.001	0.323
		-24	282.87			0.324		

As an indication of relative binder performance, BBR test data at -18°C for all fourteen binders are shown in Figures 2.7 and 2.8. Note the similarities in stiffness (*S*) and *m* for PBA-2 and -5, and PBA-3 and -6. At -18°C the stiffness for all the PBA-2 and -5 binders exceeds 200 MPa, and *m* (with one exception) is less than 0.300. For all the PBA-3 and -6 binders, the stiffness is about 80 to 150 MPa, and *m* exceeds 0.300. The BBR data are less variable. The test seems to be more repeatable, primarily because the test is less sensitive to operator technique, and because duplicate samples are required.

Data shown in Figure 2.9 are indicative of relationship between test temperature and stiffness, i.e., that variability increases with stiffness. More importantly, these data suggest that test variability is directly correlated with binder stiffness: the stiffer the binder, the more variable the data. However, the data shown in Figure 2.10 suggest that test variability, as measured by *m,* is independent of binder rheology. The average differences in BBR stiffness and *m* between samples were 8.9 MPa and 0.007, respectively. Though there were insufficient samples to make a realistic assessment of variability (i.e., coefficient of variation), the data are believed to be

Figure 2.5: Bending Beam Rheometer (BBR) Stiffness Data

Figure 2.6: Bending Beam Rheometer (BBR) *m* Data

comparable to those reported elsewhere *(Morgenstern, 1997)*. The WCTG round robin testing yielded coefficients of variation for BBR stiffness (*S*) and *m* in the ranges of 3.7 to 45.5 percent and 2.1 to 8.5 percent, respectively. The later AMRL report noted coefficients of variation for BBR stiffness and m-value in the ranges of 12.9 to 13.9 and 6.2 to 10.1 percent, respectively

Figure 2.7: Average BBR Stiffness at -18°C

Figure 2.8: Average BBR *m* at -18°C.

Figure 2.9: Bending Beam Rheometer (BBR) Test Variability -- Stiffness

Figure 2.10: Bending Beam Rheometer (BBR) Test Variability -- *m*

2.1.3 Performance Grade (PG) Classification

Based on the DSR and BBR data outlined in the preceding sections, the binders were classified in accordance with AASHTO PP6-93. Data for each binder (RV, DSR and BBR) are shown in Appendix C. A summary of the performance grade (PG) classification data is shown in Table 2.4. Differences in the high temperature grades are shown by the shaded cells. Reviewing the data in Table 2.2, note the following: the Bohlin-NJ value of G*sin/δ at 64°C for the RTFO conditioned Huntway PBA-2 material was 2.19 kPa, missing the required 2.2 kPa by only 0.01 kPa; the Chemical Engineering value of G*sin/δ at 64°C for the RTFO conditioned Albina PBA-5 is clearly an outlier; and the Chemical Engineering value of G*sin/δ at 64°C for the RTFO conditioned Albina PBA-3 exceeds the required 2.2 kPa by only 0.34 kPa. The small differences in test data can easily alter the classification, perhaps distorting the difference in anticipated performance. Still, there must be a cutoff for specification enforcement and fairness to suppliers competing for a project. It is only with the accumulation of more data and the development of precision and bias statements that one can determine the significance of the differences shown in Table 2.4.

Table 2.4: Summary of Superpave Performance Grade (PG) Classification

		Superpave PG Classification			
		High Temperature Grade			Low Temperature Grade
Binder Source	**PBA Grade**	**Civil Engr**	**Bohlin-NJ**	**Chemical Engr**	
Chevron	2	64	64	64	-28
Huntway	2	64	58	64	-16
Albina	3	58	58	64	-34
Chevron	3	64	58	58	-34
Idaho	3	64	64	64	-28
Albina	5	64	64	70	-22
Chevron	5	64	64	64	-22
EOTT	5	64	64	64	-22
McCall	5	64	64	64	-22
Albina	6	64	64	64	-34
Chevron	6	64	64	64	-34
EOTT	6	64	64	64	-34
Huntway	6	58	58	58	-28
McCall	6	64	64	64	-34

Differences in high temperature grade shown by shaded cells.

2.1.4 Comparison of PG and Conventional Test Data

Conventional test data accumulated by ODOT during the 1995 construction season were compared to the Superpave PG data. The complete data set is shown in Appendix D and summarized in Table 2.5. The conventional test data included absolute and kinematic viscosities, and penetration. Conventional test data were available for nine of the fourteen binders tested with the Superpave protocols (two PBA-3's, three PBA-5's, and four PBA-6's).

Table 2.5: Summary of ODOT's Conventional Binder Test Data

		Absolute Viscosity (POISE)	Residual Absolute Viscosity (POISE)	Residual Penetration at 4°C (0.1 mm)	Kinematic Viscosity (cSt)	Residual Kinematic Viscosity (cSt)	Residual Penetration at 25°C (0.1 mm)	PG	
								High	Low
Albina 3	min	1190	4170	31	560	849	76		
	max	2620	8540	44	666	1018	91		
	mean	1946	5380	39	592	890	84	58	-34
	std	265	898	3	29	45	4		
	cv (%)	14	17	9	5	5	5		
Albina 5	min	1880	4750	14	400	563	37		
	max	2500	6840	28	437	659	60		
	mean	2252	5962	16	422	620	41	64	-28
	std	130	433	2	10	20	5		
	cv (%)	6	7	13	2	3	11		
Albina 6	min	1870	5570	34	644	920	70		
	max	3730	8940	45	940	1570	89		
	mean	2467	6678	40	713	1073	81	64	-34
	std	377	902	3	74	157	5		
	cv (%)	15	14	7	10	15	6		
Chevron 3	min	1370	3190	33	477	680	86		
	max	1660	4410	34	563	726	96		
	mean	1480	3708	33	522	703	92	58	-34
	std	115	508	0	35	23	4		
	cv (%)	8	14	1	7	3	5		
Chevron 5	min	1640	5260	14	416	607	36		
	max	2630	10400	22	480	767	52		
	mean	2334	6222	18	452	686	45	64	-22
	std	145	711	2	16	38	4		
	cv (%)	6	11	11	3	6	8		
Chevron 6	min	1710	5400	15	758	953	67		
	max	7500	14300	40	928	1230	103		
	mean	3885	8049	35	846	1051	92	64	-34
	std	1582	2132	5	67	81	10		
	cv (%)	41	26	15	8	8	11		
EOTT 5	min	2030	5600	15	408	576	39		
	max	3950	12600	24	478	722	45		
	mean	2573	8038	20	428	661	43	64	-22
	std	339	1590	2	17	35	2		
	cv (%)	13	20	11	4	5	5		
McCall 5	min	1359	3497	14	48	405	31		
	max	3460	8730	39	1070	1130	84		
	mean	2354	6281	17	409	624	42	64	-22
	std	216	689	3	87	71	6		
	cv (%)	9	11	18	21	11	13		
McCall 6	min	2060	5180	16	374	499	42		
	max	3470	6510	38	800	1030	87		
	mean	2455	5806	34	659	865	76	64	-34
	std	348	359	5	135	175	15		
	cv (%)	14	6	16	20	20	20		

Table 2.5: Summary of ODOT's Conventional Binder Test Data (continued)

		Absolute Viscosity (POISE)	Residual Absolute Viscosity (POISE)	Residual Penetration at 4°C (0.1 mm)	Kinematic Viscosity (cSt)	Residual Kinematic Viscosity (cSt)	Residual Penetration at 25°C (0.1 mm)	PG	
								High	Low
Idaho 2	min	1260	3030	20	233	458	48		
	max	1376	3497	22	323	481	53		
	mean	1341	3353	22	278	470	51		
	std	47	190	1	45	12	3		
	cv (%)	4	6	4	16	2	5		
Idaho 6	min	2170	4700	17	417	629	37		
	max	3450	11000	37	1380	1610	86		
	mean	2453	5713	32	1034	1306	74		
	std	276	1440	4	271	246	13		
	cv (%)	11	25	11	26	19	17		
Koch 3	min	0	4030	29	836	1000	65		
	max	2740	7890	40	1250	1430	84		
	mean	2034	5297	33	1051	1193	73		
	std	598	806	3	135	139	6		
	cv (%)	29	15	8	13	12	8		
Asphalt Conn 5	min	2100	5620	15	382	574	37		
	max	2280	6000	16	412	639	40		
	mean	2218	5780	16	391	597	39		
	std	64	154	0	12	25	1		
	cv (%)	3	3	3	3	4	3		

NOTE: *Residual* denotes that the viscosity and penetration were measured on RTFO-aged binders.

Comparison of the conventional binder data and PG classification are shown in Figures 2.11 to 2.16. In general, there was little or no correlation between viscosity and the Superpave high temperature performance grade. However, as shown in Table 2.6, there was much better correlation between penetration and the low temperature performance grade.

Shown in Figure 2.11 are average values of absolute viscosity for PBA-3, -5 and -6. Note that all the PBAs except two have an absolute viscosity above 2000 Poise. The mean values of absolute viscosity for PBA-3, -5 and -6 ranged from approximately 1500 to 2000 Poise, 2200 to 2600 Poise, and 2400 to 3900 Poise, respectively. Regression of absolute viscosity on the high temperature performance grade yielded an R^2-value of 0.38. Though slightly more variable, the absolute viscosity data of RTFO-aged binders show similar results, as is evident in Figure 2.12. The mean values of absolute viscosity for PBA-3, -5 and -6 ranged from approximately 3700 to 5400 Poise, 6000 to 8000 Poise, and 5800 to 8000 Poise, respectively. Regression of absolute viscosity on the high temperature performance graded yielded an R^2-value of 0.52.

From Figures 2.13 and 2.14, there does not appear to be any relationship between kinematic viscosity and high temperature performance grade. Regression of kinematic viscosity on the high temperature performance for "tank" and RTFO-aged binders yielded an R^2-value of 0.0.

Figure 2.11: Absolute Viscosity Versus High Temperature Performance Grade

Figure 2.12: Absolute Viscosity Versus High Temperature Performance Grade (RTFO-aged)

Figure 2.13: Kinematic Viscosity Versus High Temperature Performance Grade

Figure 2.14: Kinematic Viscosity Versus High Temperature Performance Grade (RTFO-aged)

Conversely, penetration and low temperature performance grade appear to be related as shown in Figures 2.15 and 2.16. Regression of penetration at 4°C and 25°C on low temperature performance graded yielded R^2-values of 0.80 and 0.84, respectively.

Figure 2.15: Penetration At 4°C Versus Low Temperature Performance Grade (RTFO-aged)

Figure 2.16: Penetration At 25°C Versus Low Temperature Performance Grade (RTFO-aged)

Table 2.6: Regression Data (Conventional Binder Data Versus Superpave PG)

Variable	Regressed On	Explained Variation (R^2)
Absolute Viscosity	Superpave High Temperature PG	0.38
Absolute Viscosity (RTFO-aged)		0.52
Kinematic Viscosity		0.00
Kinematic Viscosity (RTFO-aged)		0.00
Penetration At 4°C (RTFO-aged)	Superpave Low Temperature PG	0.80
Penetration At 25°C (RTFO-aged)		0.84

2.2 SHRP/SUPERPAVE WEATHER DATABASE

Climatic data from Oregon's 175 weather stations were used to determine the recommended binder grade at several levels of reliability. For the low temperature binder grade, two algorithms were considered: the original SHRP, in which pavement surface temperature is assumed to be equal to the air temperature; and that proposed by Canadian researchers, in which pavement surface temperature is derived from air temperature as shown below:

$$T_{surface} = 0.859 \times T_{air} + 1.7$$

where $T_{surface}$ and T_{air} are pavement surface and air temperatures in degrees Celsius *(Asphalt Institute 1995)*. The Canadian algorithm is based on years of pavement temperature data gathered from instrumented field sections. This approach is less conservative than the original SHRP approach as it allows for the selection of a stiffer (and perhaps cheaper) binder (e.g., PG XX-28 instead of a PG XX-34) *(Robertson 1997)*.

Shown in Table 2.7 and Appendix E are the PG binders needed at several levels of reliability. High temperature grades ranged from 46 to 70°C; low temperature grades ranged from -40 to -4°C. Because of the environmental diversity as many as 14 to 18 performance grades could be specified, depending upon level of reliability. Superimposed on a map of Oregon, the data for 50 percent and 98 percent levels of reliability are shown graphically in Figures 2.17 to 2.22. With increasing reliability, the range of binders increases as shown in Figures 2.23 to 2.25.

Table 2.7: PG Binders Needed Based on Oregon Weather Database

High Temperature Grade	Level Of Reliability For Low Temperature Grade					
	SHRP Low Temperature Algorithm			Canadian Low Temperature Algorithm		
	98%	95%	50%	98%	95%	50%
46	-10 to -16	-10 to -16	-4 to -22	-4 to -16	-4 to -16	-4 to -16
52	-10 to -34	-10 to -28	-4 to -34	-4 to -28	-4 to -22	-4 to -28
58	-16 to -40	-16 to -40	-10 to -28	-10 to -40	-10 to -40	-4 to -28
64	-16 to -40	-16 to -40		-10 to -40	-10 to -34	
70	-34			-28		

NOTE: PG grades in degrees Celsius

Figure 2.17: High Temperature Performance Grade (PG) Binders Needed at 98% Level of Reliability

Figure 2.18: High Temperature Performance Grade (PG) Binders Needed at 50% Level of Reliability

Figure 2.19: Low Temperature Performance Grade (PG) Binders Needed at 98% Level of Reliability (SHRP Algorithm)

Figure 2.20: Low Temperature PG Binders Needed at 98% Level of Reliability (Canadian Algorithm)

Figure 2.21: Low Temperature PG Binders Needed at 50% Level of Reliability (SHRP Algorithm)

Figure 2.22: Low Temperature PG Binders Needed at 50% Level of Reliability (Canadian Algorithm)

Figure 2.23: Range Of PG Binders Needed Based On Weather Database (50% Level Of Reliability)

Figure 2.24: Range Of PG Binders Needed Based On Weather Database (95% Level Of Reliability)

Figure 2.25: Range Of PG Binders Needed Based On Weather Database (98% Level Of Reliability)

2.3 GUIDELINES FOR ANTICIPATED USE

The guidelines for anticipated use evolved using an iterative process with ODOT staff. Using the weather database to determine PG binders needed, contour maps were drawn "free-hand" as shown in Figures 2.26 and 2.27. Although many binder grades overlap, the contour maps indicate that as many as 13 to 14 binders might be specified at the 98 percent level of reliability. Realistic constraints and practical considerations, such as readily available binder sources and state-maintained road miles associated with a particular performance grade were factored into the decision-making process. Flexible pavements in central and eastern Oregon, where the lowest temperatures were recorded and cold-mix is typically used, were also considered.

Shown in Figure 2.28 is the approximate distribution of state-maintained road miles associated with a particular binder grade. The binder grades shown are those based on the 98 percent level of reliability and the SHRP low temperature algorithm. As Figure 2.28 shows, high temperature grades of 58 and 64 will accommodate nearly 90 percent of the state-maintained road miles. Low temperature grades of -22 and -28 cover approximately 28 percent of the state-maintained road miles. Although the -34 grade could be specified for nearly 35 percent of the road miles, a substantial portion of this network is located in the region where cold-mix is routinely used. In view of the preceding, the four PG binders likely to be specified are shown in Table 2.8 and Figure 2.29. Note that either a PG 64-28 or PG 58-28 may be used in the central one-third (north to south) of the state. The former is more likely to be used in the northern half of the state whereas the latter is more likely to be used in the southern half.

Figure 2.26: Contour Map of PG Binders Needed (98% Level of Reliability, SHRP Low Temperature Algorithm)

Figure 2.27: Contour Map of PG Binders Needed (98% Level of Reliability, Canadian Low Temperature Algorithm)

Figure 2.28: State-Maintained Road Miles Associated with PG Binders

Table 2.8: PG Binders Likely to Be Specified

Anticipated use of PG binders SHRP low temperature algorithm 98% level of reliability	PG 58-22 PG 58-28 PG 64-22 PG 64-28

Figure 2.29: Anticipated Use of PG Binders

3.0 ECONOMIC CONSIDERATIONS

Shortly after the conclusion of the Strategic Highway Research Program (SHRP), the Transportation Research Board SHRP Committee suggested that an objective assessment of the program and products be conducted as a benefit-cost study. In a broad, collaborative effort to determine whether the benefits of the SHRP products exceeded the research implementation costs, a team of engineers and economists at Texas Transportation Institute (TTI) reviewed numerous case studies as part of their analyses. They estimated that implementation costs of the Superpave binder specification alone might approach $230 million over 20 years. However, they concluded that even "... if it takes highway agencies 10 years to fully implement the Superpave binder specification, they will save more than twice the total cost of implementation every year for the next 20 years" *(Federal Highway Administration 1998).*

For ODOT, quantifying the initial capital costs (equipment) and those associated with personnel training is fairly easy. Assessing benefits would be a more subjective and time consuming task. As it is only through field performance data that ODOT will be able to quantify the long-term benefits of the Superpave binder technology, this discussion is limited to that associated with material costs — current use of PBA versus potential use of Superpave PG binders.

3.1 PBA USE AND COST DATA

As noted previously, ODOT typically specifies PBA-2 and PBA-5 west of the Cascades, and PBA-3 and PBA-6 east of the Cascades. Historical cost and usage data provided by ODOT are shown in Tables 3.1 and 3.2 and Figures 3.1 and 3.2. As is evident from Figure 3.1, prices have remained essentially constant except for slight decreases in PBA-3 and PBA-6 beginning about March 1994. PBA use, however, changed dramatically between 1991 and 1995. In 1991, PBA-2 constituted about 46 percent of the binder used. PBA-2 has seldom been used since 1995 because of tenderness problems observed during construction. However, it should be noted that the cause of the tenderness was not identified, i.e., natural sand or excess fines may have caused the tenderness.

Table 3.1: Historical PBA Cost Data

	Average Posted Price in $/Mg ($/Ton) August 1992 through November 1995		
	PBA-2 and PBA-5	**PBA-3**	**PBA-6**
Minimum	138 (125)	235 (212)	268 (242)
Maximum	153 (139)	270 (245)	306 (277)
Mean	147 (133)	254 (230)	272 (247)
Standard Deviation	4.09 (3.71)	15.86 (14.39)	9.26 (8.40)
Coefficient of Variation (%)	2.8	6.3	3.4

Data provided by ODOT – "rack" prices.

Table 3.2: Historical PBA Use Data

PBA Grade	Annual Binder Use in Mg (Tons)				
	1991	**1992**	**1993**	**1994**	**1995**
2	24,943 (27,499)	11,042 (12,173)	4,215 (4,646)	4,090 (4,509)	0
3	7,730 (8,522)	14,734 (16,244)	11,531 (12,712)	4,303 (4,743)	0
5	16,628 (18,332)	25,763 (28,403)	37,923 (41,810)	36,809 (40,581)	54,796 (60,412)
6	5,154 (5,682)	14,811 (16,329)	36,595 (40,345)	25,683 (28,315)	14,869 (16,393)
6GR	0	0	771 (850)	544 (600)	1,510 (1,665)
total	54,455 (60,035)	66,350 (73,149)	91,035 (100,363)	71,429 (78,748)	71,175 (78,470)

Data provided by ODOT

Figure 3.1: PBA Cost Data

Figure 3.2: PBA Use Data

3.2 POTENTIAL SAVINGS

Shown in Table 3.3 is a comparison of binder classification (i.e., PBA versus PG) based on data reported in Chapter 2. Also included in Table 3.3 are the PG binders likely to be specified by ODOT. Table 3.4 shows the results of a recent survey of suppliers which reflect PBAs typically specified by ODOT and their equivalent performance grades (PG). If one were to assume that there is overlapping of grades, i.e., PG 58-28 with PG 58-22, and PG 64-28 with PG 58-22, there are numerous combinations of PBAs that would meet ODOT's recommended guidelines: PBA-3 and PBA-5, PBA-2 and PBA-6, PBA 3 and PBA-6, PBA-2 and PBA-5, to name just a few.

Table 3.3: Binder Equivalencies Based on Laboratory Testing

Binder Classification		Binders likely to be specified
PBA	**Superpave PG**	PG 58-22
2	64-16, 64-28	PG 58-28 PG 64-22
3	58-34, 64-28	PG 64-28
5	64-22	98% reliability
6	58-28, 64-34	SHRP low temp algorithm

Table 3.4: Binder Equivalencies Reported by Suppliers in December 1997

PBA	Binder Source					
	Albina	Chevron	Huntway	Idaho	Koch	McCall
2		58-22		64-22		58-28
3	58-34	58-28			64-28	58-28
5	64-22 & 28	64-22				64-22
6	64-34	58-28	64-28	64-28	64-28	64-28

From the data shown in Tables 3.3 and 3.4 it appears as if specifying PG binders may result in substantial savings: for example, substituting PBA-2 and PBA-5 for PBA-3 and PBA-6, respectively. To illustrate, consider the following: a 75 mm overlay on a 10 km two-lane rural road of 9 m width. Assuming 2400 kg/m^3 for the unit weight of hot mix, approximately 16,200 Mg of material would be needed. For a binder content of 5 percent, about 810 Mg of asphalt cement would be required. Shown in Table 3.5 are the estimated project costs for various PBAs and potential savings.

Table 3.5: Example of Potential Savings

Binder	Binder Cost ($/Mg)	Total Binder Cost ($)	Binder Cost Per Kilometer ($/km)
PBA-2 or PBA-5	$147	$119,070	$11,907
PBA-3	$254	$205,740	$20,574
PBA-6	$270	$218,700	$21,870

Savings Per Kilometer ($/km)

PBA-2 or PBA-5 relative to PBA-3	$8,667
PBA-2 or PBA-5 relative to PBA-6	$9,963

As Superpave binder selection is driven by the environment and the level of reliability, potential benefits may vary with region. Figure 2.18 indicates that at the 50 percent level of reliability, all the binders tested as part of this research would provide adequate high temperature performance throughout the state. Increasing the level of reliability to 98 percent (Figure 2.17) suggests that some PBA-3s and PBA-6s would be inadequate in the central eastern portions of the state.

West of the Cascades where low temperatures ranged from -4 to -16°C (Figure 2.21), all the binders tested would provide adequate low temperature performance. East of the Cascades the low temperatures ranged from -22 to -28°C with a few isolated weather stations recording lows of -34°C. The data shown in Table 3.3 indicate that all binders except some of the PBA-2s and PBA-5s would be suitable. Use of the Canadian algorithm (Figure 2.22) would permit the use of all binders but the PBA-5.

Increasing the reliability to 98 percent with the SHRP low temperature algorithm (Figure 2.19) shifts the low temperature ranges to -10 to -22°C west of the Cascades, and -28 to -40°C east of the Cascades. In both cases, this increase in reliability precludes the use of some PBA-2s and

PBA-5s. Using the Canadian low temperature algorithm (Figure 2.20) extends the range from -4 to -40°C yielding results similar in kind but different in number.

In general, the Canadian algorithm tends to shift the low temperature grades “up,” i.e., to a warmer grade, extending the areas in which some PBA-2s and PBA-5s would be acceptable. In summary, regional savings are quite possible depending upon level of reliability and low temperature algorithm selected. At the 50 percent level of reliability with the Canadian low temperature virtually all the binders tested are acceptable. At the 98 percent level of reliability with the SHRP low temperature algorithm it is very likely that only PBA-3s and PBA-6s would be acceptable east of the Cascades.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The primary objectives of this research were to determine the Superpave performance grade (PG) classification of performance based asphalts (PBAs) traditionally specified by ODOT and to develop guidelines for anticipated use as a first step in the implementation of the SHRP/ Superpave technology. Secondary objectives were to assess personnel training needs and the potential benefits/costs of implementing the binder technology. A final objective was to determine what, if any, relationships existed between conventional and Superpave binder test data. Conclusions and recommendations with regard to the aforementioned are addressed in Sections 4.1 and 4.2, respectively.

4.1 CONCLUSIONS

4.1.1 Binder Classification and Guidelines for Anticipated Use

As noted in Section 1.2.2, ODOT typically specifies PBAs by mix type and region as shown in Table 4.1.

Table 4.1: PBAs Traditionally Specified by ODOT

PBA	Mix Type	Direction Relative To The Cascades
2 and 5	Dense	West
3 and 6	Dense	East
5	Open	West
6	Open	East

In this research, 14 binders from six sources (i.e., suppliers) were classified in accordance with AASHTO PP6-93. From the laboratory testing the following conclusions are drawn:

- All the PBAs evaluated had a high temperature grade of 58 or 64.
- Low temperature grades ranged from -16 to -34, though -22 and -28 were by far the most common.
- PBA-2s may be classified as PG 64-16 or PG 64-28; PBA-3s as PG 58-34 or PG 64-28; PBA-5s as PG 64-22; and PBA-6s as PG 58-28 or PG 64-34.
- As is evident from the data presented, all PBAs are not created equal. As shown in Table 4.2, there is not always agreement with regard to PG classification between the research results and the supplier data, nor is there always agreement among the suppliers. As described by the *number* of different performance grades for a particular binder, PBA-2 appears to be the least consistent whereas PBA-5 and PBA-6 appear to be the most consistent.

Table 4.2: PG Comparison — Research Results Versus Supplier Data

PBA	Superpave PG Classification						
	Research Results	Supplier Data					
		Albina	Chevron	Huntway	Idaho	Koch	McCall
2	64-16 64-28		58-22		64-22		58-28
3	58-34 64-28	58-34	58-28			64-28	58-28
5	64-22	64-22 64-28	64-22				64-22
6	58-28 64-34	64-34	58-28	64-28	64-28	64-28	64-28

Shaded cells reflect agreement in PG classification (research results versus supplier data of December 1997)

- As precision and bias statements are not yet available for the DSR or the BBR, the significance of these differences in PG classification is impossible to assess. However, a comparison of the DSR data generated in this research with that of the available round robin test data suggests that coefficients of variability reported herein (14 to 20 percent) are comparable to those reported elsewhere *(Morgenstern 1997, and AMRL 1997)*.

- As noted in Chapter 2, mechanical problems with the BBR cooling system precluded testing at temperatures below -24°C, though some binders *should have been*. Hence, some stiffness (*S*) and *m* values were extrapolated from the available data leading to some uncertainty as to the accuracy of the low temperature PG classification. Compounding this uncertainty is the FHWA's Binder Expert Task Group (ETG) reporting that there were consistent differences between the *m* values measured with the ATS and Canon BBRs. The Canon BBR yielded *m* values consistently higher than the ATS BBR by 0.010. Manufacturers' changes to the software have remedied the problem.

- Comparison of Superpave PG and conventional binder test data indicates that there was no relationship between the high temperature performance grade and absolute viscosity. However, there was a moderate relationship between the high temperature performance grade and kinematic viscosity as values of explained variation for the unaged and RTFO-aged binders were 0.38 and 0.52, respectively. The relationship between the low temperature performance grade and penetration at 4°C and 25°C were significantly higher with values of explained variation for the RTFO-aged binders of 0.80 and 0.84, respectively. These values of explained variation were shown previously in Table 2.6.

- The diversity of Oregon's climate suggests that as many as 13 to 14 binder grades might be "needed" at the 98 percent level of reliability, although many grades overlap.

- Realistic constraints and practical considerations (such as readily available binder sources, storage tanks, and state-maintained road miles associated with a particular performance grade) led to the recommendation that four PG binders be specified: PG 58-22 and PG 64-22 west of the Cascades; PG 58-28 and PG 64-28 in the central part of the state; and PG 64-28 in the eastern part of the state. Elsewhere in the Northwest, Washington and Idaho have tentatively specified the following PG binders: 58-22, 58-34, and 64-28; and 58-28/34, 64-28/34, and 70-28, respectively. Given this overlap of PG binders likely to be specified in the Northwest, suppliers do not anticipate logistical problems.

4.1.2 Costs and Benefits

Conclusions with respect to costs and benefits of the Superpave binder implementation are as follows:

- Binder equipment (dynamic shear and bending beam rheometers, rotational viscometer) was secured though the FHWA's pooled fund purchase at a cost of approximately $80,000. The Brookfield rotational viscometer was purchased in 1993; the Bohlin DSR and ATS BBR in 1994; the Canon BBR in 1997; and the Paar Physica DSR in 1998. FHWA officials indicate that the Direct Tension Test (DTT) device *may* be delivered to the Superpave regional training centers in the Spring of 1998. It is unlikely that SHAs will purchase this device until extensive round robin testing is completed by the regional centers. FHWA officials estimate the cost of the DTT to be approximately $40,000.

- OSU staff spent two weeks at the ODOT laboratory providing "hands-on" assistance as part of this research effort. In addition, ODOT laboratory personnel attended training courses at the Asphalt Institute's National Asphalt Training Center (NATC) in Lexington, Kentucky, at minimal cost to ODOT. Should the need arise, additional binder training is readily available at all the Superpave Regional Training Centers at a cost of $1000-$1500.

- Although binder costs have been fairly stable since 1991, there has been a dramatic reduction in the use of PBA-2 and PBA-3 since 1991 as shown in Table 4.3. The reduction in PBA-2 was attributed to tenderness problems though the cause of tenderness was not identified. The tenderness may have been caused by natural sands or excess fines. Although PBA-3 is still used, there have been few dense-graded mixes placed east of the Cascades in 1995, hence the reduction in its use. For all practical purposes, only PBA-5 and PBA-6 were routinely used by ODOT in 1995.

Table 4.3: PBA Use Since 1991

PBA	Percent Of Total Binder Used				
	1991	1992	1993	1994	1995
2 and 3	60	39	17	12	0
5 and 6	40	61	82	87	98
6GR	0	0	1	1	2

- From the data shown in Table 4.2, it appears as if specifying PG binders may result in substantial savings. By substituting PBA-5 for PBA-3 or PBA-6 on a typical overlay, the estimated savings per kilometer were approximately $8,667 or $9,963, respectively. PBA-5 that meets a PG 58-28 or PG 64-28 classification may be substituted for PBA-3 or PBA-6 since these grades are recommended for use east of the Cascades.

- Although substitution of PBA-5 for PBA-3 or PBA-6 may result in substantial savings, there is some concern with drain down of open-graded mixes. Accordingly, a very limited laboratory study was undertaken to address this concern. A standard ODOT F-mix gradation was used with six binders from three suppliers and evaluated in accordance with the NCAT drain down procedure. As shown in Figure 4.1, drain down is much more sensitive to temperature than binder grade. Individual data points suggest that there is a consistent 0.06 percent difference in drain down between the PG 58-XX and PG 64-XX binders. However, the average percent drain down at the appropriate mixing temperatures for the PG 58-XX and PG 64-XX binders is 0.28 and 0.30 percent, respectively. Neither binder exceeds ODOT's recommended upper limit of 0.30 percent drain down. These limited data suggest that substitution of a PG 58-XX for a PG 64-XX should not be a concern, at least with regard to drain down in open-graded mixes. A cautionary note however, though drain down is considered in the design of open-graded mixes its effectiveness is widely debated. All data pertaining to this very limited study are contained in Appendix F.

Figure 4.1: Drain Down Test Results

4.2 RECOMMENDATIONS FOR IMPLEMENTATION AND FUTURE RESEARCH

4.2.1 Implementation

Recommendations with regard to implementation are as follows:

- The data presented suggest that there is not a consistent match between PBA and PG classifications. For example, PBA-3 does not always "equal" a PG-64-28. Thus, ODOT is advised to "think PG", somewhat analogous to "thinking meters" rather than the more comfortable approach of "thinking feet" then converting to meters.

- It is recommended that ODOT begin specifying the PG binders as outlined in Figure 2.29, i.e., PG 58-22/28 and PG 64-22/28. Realistic constraints and practical considerations (available binder sources, storage facilities, state-maintained-road miles and compatibility with other states in the Pacific Northwest) indicate that specifying PG binders should not present any logistical problems. Furthermore, specifying PG binders may reduce costs without compromising performance.

4.2.2 Future Research

Recommendations with regard to future research are as follows:

- The differences in performance grades, which may be attributed to crude sources, refinery processes, novelty of the equipment and the relatively broad range of the PG classification interval (i.e., 6°C range), underscore the need for extensive and accurate testing. Extensive testing has local and global benefits. It will help the laboratory staff gain familiarity with the equipment and enhance confidence in the data generated, as well as provide a long-term "picture" of the binders ODOT typically specifies. Globally, this testing will yield data to facilitate the development of precision and bias statements, a critical key to successful implementation of the Superpave technology. Though there is some uncertainty with regard to the Superpave binder specification (use of BBR) and supporting equipment (DTT), it is only with the accumulation of data that ODOT, and the asphalt industry in general, will be able to assess the long-term benefits and costs of this technology. Problems previously noted with the BBR cooling system make some of the low temperature grades suspect. For this reason alone, additional testing of typical binders is warranted.

- It appears that binder selection based on geography, i.e., east versus west of the Cascades, should be reconsidered based on the data reported. PG classification and drain down test results suggest that some binders formerly used exclusively "on the west side" might perform adequately "on the east side." Although the binder's influence on the low temperature properties of asphalt concrete is well documented, it may be prudent to test this hypothesis with local materials using the thermal stress restrained specimen test (TSRST).

- Though the concern with drain down of open-graded mixes is valid, the limited data indicate that there is little difference between a PG 58-XX and PG 64-XX. Given ODOT's success with open-graded mixes, a parallel effort is recommended: side-by-side test sections of PG 58-XX and PG 64-XX binders, and the development of a more discriminating laboratory test method, perhaps a performance-related test.

- Implementation of the Superpave technology has begun with the recommendation of guidelines for binder use. Extending this binder implementation effort, consideration of the mix technology is underway with the evaluation of a portable gyratory for field quality control. It is recommended that the ODOT continue its efforts to implement Superpave as a "system," rather than piecemeal as some states have.

5.0 REFERENCES

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