IDENTIFICATION AND QUANTIFICATION OF THE EXTENT OF ASPHALT STRIPPING IN FLEXIBLE PAVEMENTS IN OREGON-PHASE I

by

R.G. Hicks
Professor of Civil Engineering
Oregon State University

James E. Wilson, Jr.
Assistant Engineer of Materials
Oregon Dept. of Transportation

and

Glenn E. Boyle
Bituminous Mixture Group Leader
Oregon Dept. of Transportation

prepared for

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16. Abstract

This report is the first phase of a study in Oregon to evaluate the effect of material sources, void content and additive type on the retained strength (AASHTO T-165) or retained modulus (NCHRP 196). A total of 20 projects were evaluated. The results clearly indicate that material and additive type affect asphalt-aggregate interaction.

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DISCLAIMER

The contents of this report reflect the views of the authors who are solely responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views of either the Federal Highway Administration or Oregon Department of Transportation.

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INTRODUCTION

The problem of asphalt stripping or the separation of the asphalt film from the aggregate through water displacement or emulsification has long been recognized (1,2). In recent years there has been an increase in the expressed concern of stripping related distress in pavements. Such distress has been reported in areas where in the past there had not been any identified stripping problems.

This study, undertaken by Oregon Department of Transportation to evaluate stripping in Oregon pavements, was carried out under Basic Agreement No. DOT-FH-11-8866.

Objective

As stated in the project statement the study objective is to identify and quantify the extent of asphalt stripping in flexible pavements in order to provide a better understanding of the problem and guidance to alleviate future pavement distress. This report addresses specifically the problem of stripping in the state of Oregon. Other agencies are to present similar findings in their states.

Scope

The entire project is intended to provide a national survey of the asphalt stripping problem in flexible pavements. The approach consists of two phases which include a laboratory study of bituminous mixes and a field survey of flexible pavements. The laboratory study examines materials and combination of materials used in bituminous mixtures. The field survey will attempt to evaluate pavements constructed using these materials.

LABORATORY EVALUATION PLAN - PHASE I

This chapter of the report describes the projects evaluated in this study and the test methods used in evaluation. As stated in the work plan guidelines for development of the plan were to include:

1) Aggregates: Those selected should be typical of the aggregate sources in Oregon mixes. It is desirable to have as many sources as possible. Aggregate sources with suspected stripping susceptibility should represent about 75 percent of the aggregates studied.

2) Asphalt Cements. They should be representative of those in common use in Oregon State mixes, and should preferably be field obtained samples (not off the laboratory shelf). To the extent possible, replicate testing of mixtures should be performed using different asphalt cements.

3) Anti-strip Agents. They should be representative of those in common use in Oregon State mixes and, preferably, should include lime and liquid chemical agents.

4) Tests. Mix design data on the laboratory prepared specimens should include those listed in Table 1.

Projects Evaluated

A total of 24 projects were selected for evaluation; however only 20 were evaluated. They are identified in Table 2. For each project aggregates, asphalt cement, anti-strip agent, and asphalt concrete mix were submitted to the central laboratory for extensive testing. Criterian used to select the projects included:

Table 1. Suggested Data on Laboratory Batched Specimens and Project Materials

Data	Test Method
Aggregate Source	Descriptive
Aggregate Type	Descriptive
Aggregate Gradation	AASHTO T-27
Sand Equivalent	AASHTO T-176
Aggregate Specific Gravities	AASHTO T-84, T-85
Asphalt Cement Grade	Descriptive
Asphalt Cement Source	Descriptive
Asphalt Content	-
Dust/Asphalt Ratio	-
Maximum Mix Specific Gravity	AASHTO T-209
Immersion - Commersion	AASHTO T-165

Table 2. Projects Selected for Evaluation

	Project	Indentification	Total Tons of Mix
1.	Hanley Road-Fish Lake	115-1029	42,560
2.	Sunny Valley-Jumpoff Joe Cr.	617-1009	47,800
3.	Beede Reservoir-Drinkwater Pass	13-1066	60,000
4.	Port Orford-Cape Sebastion	8-1066	18,400
5.	Burnt Hill-Thomas Creek	8-1064	32,500
6.	Ridge Dr. N.E.-Pine St. N.E.	324-1079	38,000
7.	Nyland Rd.-Roaring Cr.	22-1013	26,500
8.	Emigrant Hill-Meacham	630-1082	58,300
9.	Midland-California St. Line	18-1010	63,500
10.	Vail Cr.-Nyland Rd.	22-1012	31,000
11.	Weston-Weston Mountain	130-1079	45,000
12.	Hermiston-Umatilla	30-1080	41,200
13.	Golf Club Rd.-Stayton Jct.	124-1063	22,500
14.	N. Albany-N. Jefferson Int.	622-1007	55,000
15.	Willamette Hwy. @ Cloverdale Rd.	20-1049	2,050
16.	Powder River Section*	1-1008	--
17.	Juniper Canyon-Lexington	525-1073	7,800
18.	32nd St.-Crest Motel (Astoria)	4-1039	7,500
19.	Reedsport-Dean Creek	10-1007	30,000
20.	Wallace Bridge-Willamina ECL	127-1002	12,000
21.	Roberts Cr.-Dillard Int.*	610-1006	--
22.	Cascade Const. Project*	(Rap-20%)	--
23.	Elkhead Rd.- Rice Hill NB	610-1008	45,000
24.	Willamette Western Project*	(Oregon City Plant)	--

* not evaluated

1) Aggregate type.

2) Asphalt type.

3) Region of the state.

Figure 1 shows the location of each project in the state.

Test Methods

A variety of tests were performed on the mix from each of the 20 projects evaluated. These are summarized in Table 3. Tests were performed on laboratory compacted specimens using mix submitted from the field as well as those batched and compacted in the laboratory using aggregate and asphalt obtained from the field.

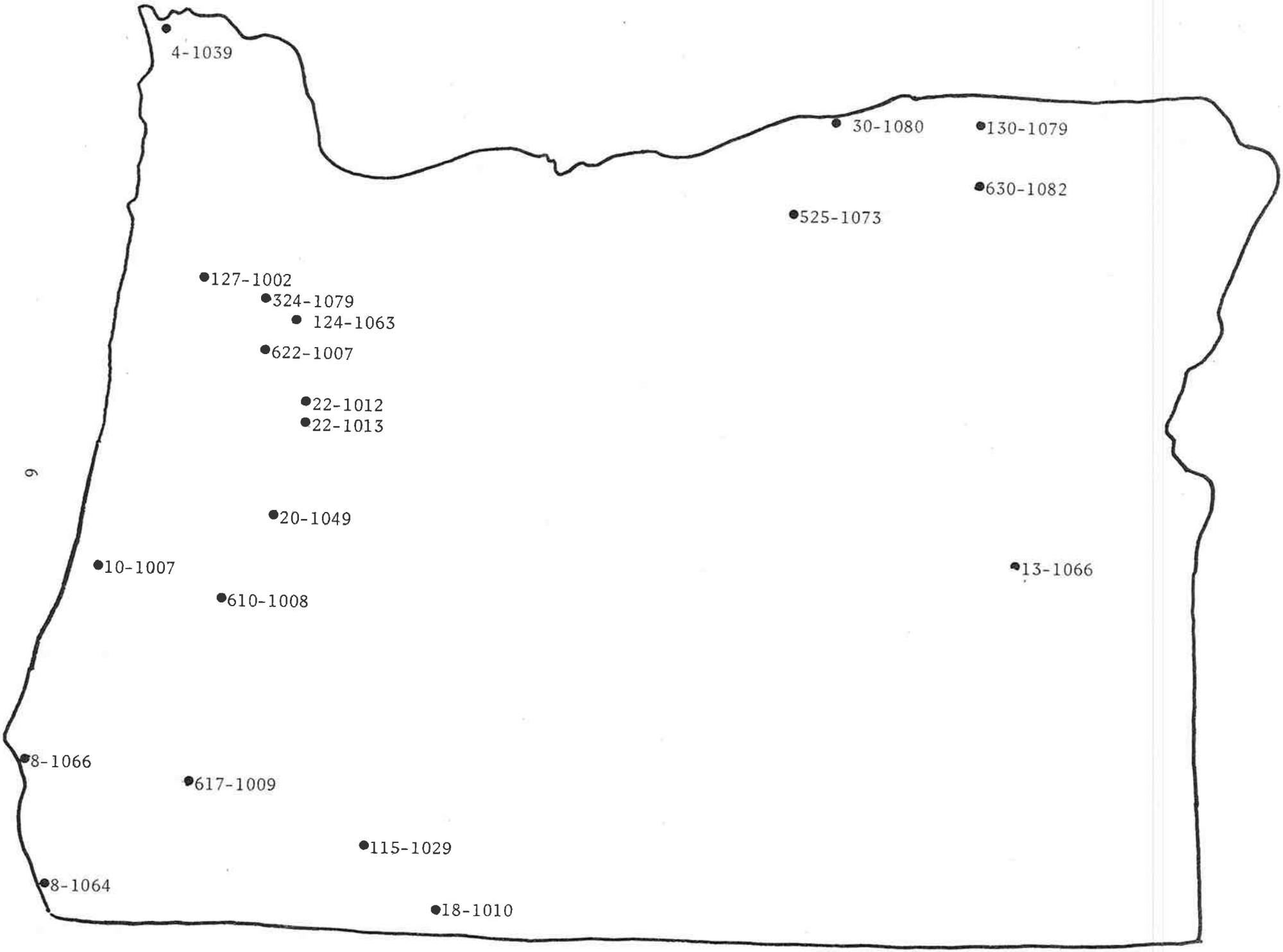

Figure 1 Project Locations

Table 3. Tests Used by Oregon DOT

Test	Method
Aggregates	
1. Gradation	T-27
2. Specific Gravity	T-84, T-85
3. DMSO	---
Mixture	
1. Specific Gravity	T-246
2. Maximum Specific Gravity	T-209
3. Stability	T-247
4. Index of Retained Strength	T-165
Standard - 3,000 psi	---
Two Alternates - 1,000 and 500 psi	---
5. Modulus*	
As Compacted	---
After Vacumm Saturation	---
After Freeze Thaw	---

* Method described in NCHRP Report 192(1).

TEST RESULTS - PHASE I

This section summarizes the results of the tests performed on mix and/or aggreate from each of the 20 projects.

Mix Design Recommendations

Table 4 summarizes the results of standard Oregon DOT mix design testing for the development of mix recommendations. For each project, the following information is provided:

1) Type of Mix
2) Recommended Gradation
3) Recommended Asphalt Content, % by weight of total mix
4) Asphalt Retention during extraction, %
5) Asphalt Grade and Supplier. Source is not available.
6) Mix specific gravity after first compaction with the kneading compactor; after second compaction which was used in the past for compaction control; and maximum theoretical (T-209).
7) Index of retained strength (T-165).
8) Modulus of as compacted samples and samples subjected to vacuum saturation and freeze thaw conditions for modulus ratio determination (see NCHRP Report 192, Appendix A for test procedure).

All materials (aggregates, asphalts and additives) were obtained from the field and are representative of materials used in paving.

Mix and Aggregate Properties - Submitted Material

Table 5 summarizes properties of paving aggregates and mix submitted from the field. Normally the mix was obtained from the street; however, on occa-

Table 4. Summary of Construction Mix Design Test Results and Recommendations

PROJECT	HANLEY RANCH–FISH LAKE		SUNNY VALLEY INT.–JUMPOFF JOE CR.		NEWBURG–M.P. 26.0		PORT ORFORD–CAPE SEBASTION		BEEDE RESEVOIR–DRINKWATER PASS		BURNT HILL–THOMAS CR.		RIDGE DR. N.E.–PINE ST. N.E.	
COURSE	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base
TYPE MIX	B	B	B	B	B	B	B	B	B	B	B	B	B	B
REC. GRADATION, % PASSING*														
3/4 in	100	100	100	100	99	99	100	100	99	99	100	100	100	100
1/2 in	87	87	87	87	87	87	87	87	87	87	87	87	87	87
3/8 in	75	75	75	75	76	76	72	72	79	79	75	75	76	76
1/4 in	60	60	58	58	60	60	60	60	65	65	60	60	60	60
No. 10	28	28	29	29	29	29	30	30	29	29	29	29	29	29
No. 40	12	12	12	12	12	12	12	12	12	12	12	12	12	12
No. 200	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0
REC. ASPHALT CONTENT (%)	6.0	6.5	5.1	5.6	6.3	6.9	6.1	6.6	7.2	7.7	5.0	5.5	5.5	6.0
RETENTION (%)	0.4	0.4	0.0	0.0	0.9	0.9	0.4	0.4	0.3	0.3	0.2	0.2	0.3	0.3
REC. ASPHALT GRADE	Chevron AR4000W		Witco AR2000		Chevron AR4000W		Chevron AR4000W		Chevron AR4000W		Witco AR4000		Chevron AR4000W	
REC. ANTI-STRIP ADDTIVE	---		---		---		---		---		---		---	
MIX SPECIFIC GRAVITY														
1ST COMPACTION	2.26	2.28	2.53	2.55	2.28	2.31	4.8	3.4	2.28	2.32	2.42	2.44	2.30	2.32
2ND COMPACTION	2.33	2.35	2.58	2.60	2.35	2.38	2.35	2.37	2.36	2.38	2.48	2.49	2.36	2.38
MAX.	2.373	2.364	2.671	2.657	2.36	2.38	2.406	2.392	2.403	2.378	2.518	2.499	2.449	2.430
INDEX RETAINED STRENGTH(%)	100	100	81	88	94	100	77	77	90	96	87	93	98	100
IRS WITHOUT ADDITIVES	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MODULUS, 10^3 PSI*														
(a) UNCONDITIONED	232	215	262	244	257	272	267	260	142	106	664	662	215	209
(b) VACUUM SATURATED	245	231	147	130	345	251	252	273	86	74	528	562	187	186
(c) FREEZE THAW	262	293	123	127	268	264	199	232	80	72	443	516	156	143
b/a RATIO	1.06	1.07	0.56	0.53	1.34	0.92	0.94	1.05	0.61	0.70	0.80	0.85	0.87	0.89
c/a RATIO	1.13	1.36	0.47	0.52	1.04	0.97	0.75	0.89	0.56	0.63	0.67	0.78	0.73	0.68

* Expected Percentage in produced mixture.

Table 4. Summary of Construction Mix Design Test Results and Recommendations (continued)

PROJECT COURSE TYPE MIX	NYLUND RD.- ROARING CO. Wearing B	NYLUND RD.- ROARING CO. Base B	EMIGRANT HILL- MEACHAN** Wearing B	EMIGRANT HILL- MEACHAN** Base B	MIDLAND- CALIFORNIA STATE LINE Wearing B	MIDLAND- CALIFORNIA STATE LINE Base B	WESTON- WESTON MOUNTAIN Wearing B	WESTON- WESTON MOUNTAIN Base B	UMATILLA- HERMISTON Wearing B	UMATILLA- HERMISTON Base B	N. JEFFERSON - N. ALBANY INT. Wearing B	N. JEFFERSON - N. ALBANY INT. Base B	WILLAMETTE HIGHWAY @ CLOVERDALE RD. Wearing B	WILLAMETTE HIGHWAY @ CLOVERDALE RD. Base B
REC. GRADATION, % PASSING														
3/4 in	100	100	99	99	100	100	98	98	100	100	99	99	100	100
1/2 in	87	87	87	87	87	87	87	87	87	87	87	87	87	87
3/8 in	78	78	76	76	75	75	76	76	76	76	68	68	72	72
1/4 in	63	63	63	63	65	65	60	60	60	60	60	60	60	60
No. 10	29	29	31	31	30	30	29	29	30	30	30	30	29	29
No. 40	12	12	12	12	14	14	12	12	12	12	12	12	18	18
No. 200	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
REC. ASPHALT CONTENT (%)	6.0	6.6	5.1	5.5	5.5	6.0	6.0	6.5	5.5	6.0	5.4	5.9	5.3	5.8
RETENTION (%)	0.2	0.2	0.1	1.1	0.1	0.1	0.6	0.6	0.5	0.5	0.1	0.1	0.5	0.5
REC. ASPHALT GRADE REC. ANTI-STRIP ADDITIVE	Chevron AR4000W 0.2% Pave Bond		Chevron AR4000W 0.2% Pave Bond		Witco AR2000 ---		Chevron AR4000W ---		Chevron AR4000W 0.2% Pave Bond		Chevron AR4000W ---		Douglas AR4000W ---	
MIX SPECIFIC GRAVITY														
1ST COMPACTION	2.27	2.29	2.35	2.37	2.44	2.46	2.36	2.38	2.40	2.42	2.34	2.36	2.38	2.40
2ND COMPACTION	2.35	2.37	2.42	2.44	2.50	2.52	2.44	2.45	2.45	2.46	2.41	2.43	2.44	2.46
MAX.	2.435	2.423	2.465	2.496	2.530	2.513	2.48	2.47	2.506	2.494	2.452	2.448	2.473	2.462
INDEX RETAINED STRENGTH(%)	85	90	87	95	98	100+	76	88	89	98	75	79	79	86
IRS WITHOUT ADDITIVE	62	77	68	73	-	-	-	-	66	84	-	-	-	-
MODULUS, 10^3 PSI*														
(a) UNCONDITIONED	227	-	242	-	390	408	222	225	236	233	220	210	213	-
(b) VACUUM SATURATED	155	-	218	-	280	306	227	236	206	196	230	214	251	-
(c) FREEZE THAW	78	-	275	-	265	319	131	156	137	128	107	150	218	-
b/a RATIO	0.68	-	0.90	-	0.72	0.75	1.02	1.05	0.87	0.84	1.05	1.02	1.18	-
c/a RATIO	0.34	-	1.14	-	0.68	0.78	0.59	0.69	0.58	0.55	0.49	0.71	1.02	-

* Asphalt treated with additives

** Mixture contained 25% recycled asphalt concrete pavement.

Table 4. Summary of Construction Mix Design Test Results and Recommendations (continued)

PROJECT	JUNIPER CANYON-LEXINGTON/ECHO HWY		POWDER RIVER SECTION		REEDSPORT-DEAN CREEK		32ND ST. CREST MOTEL (ASTORIA)		WALLACE BRIDGE WILLAMINA ECL		ELKHEAD RD. INT.-RICE HILL INT.		VAIL CREEK NYLUND ROAD	
COURSE	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base	Wearing	Base
TYPE MIX	B	B	B	B	B	B	B	B	B	B	B	B	B	B
REC. GRADATION, % PASSING*														
3/4 in	100	100	99	99	100	100	100	100	99	99	98	98	98	98
1/2 in	87	87	87	87	87	87	87	87	87	87	87	87	87	87
3/8 in	75	75	72	72	81	81	82	82	73	73	71	71	78	78
1/4 in	60	60	62	62	60	60	65	65	60	60	60	60	65	65
No. 10	28	28	31	31	30	30	31	31	30	30	29	29	32	32
No. 40	11	11	14	14	12	12	10	10	11	11	11	11	12	12
No. 200	5.0	5.0	5.0	5.0	4.0	4.0	5.0	5.0	5.0	5.0	4.0	4.0	5.0	5.0
REC. ASPHALT CONTENT (%)	6.0	6.5	5.5	6.0	5.5	6.0	6.2	6.7	5.5	6.0	5.2	5.7	5.3	5.8
RETENTION (%)	0.3	0.3	0.0	0.0	0.2	0.2	0.3	0.3	0.5	0.5	0.3	0.3	0.2	0.2
REC. ASPHALT GRADE	Chevron AR4000W		CENEX 85/100		Chevron AR4000W		Chevron AR4000W		Shell AR 2000		Chevron AR 4000W		Chevron AR 4000W	
REC. ANTI-STRIP ADDITIVE	0.3% Pave Bond		---		---		---		---		---		0.5% Pave Bond	
MIX SPECIFIC GRAVITY														
1ST COMPACTION	2.37	2.39	2.41	2.43	2.32	2.34	2.41	2.43	2.30	2.32	2.36	2.38	2.27	2.28
2ND COMPACTION	2.44	2.46	2.47	2.49	2.37	2.39	2.48	2.50	2.36	2.38	2.43	2.45	2.33	2.35
MAX.	2.489	2.468	2.512	2.494	2.443	2.434	2.542	2.513	2.42	2.40	2.486	2.463	2.435	2.411
INDEX RETAINED STRENGTH(%)	80	85	83	90	81	84	100	100	89	92	77	79	80	86
IRS WITHOUT ADDITIVES	56	64	-	-	-	-	-	-	-	-	-	-	79	85
MODULUS, 10^3 PSI*														
(a) UNCONDITIONED	331	-	-	-	306	282	217	163	244	240	199	188	257	-
(b) VACUUM SATURATED	282	-	-	-	238	233	383	107	262	247	198	188	179	-
(c) FREESE THAW	217	-	-	-	212	232	146	119	228	235	129	131	145	-
b/a RATIO	0.85	-	-	-	0.78	0.83	1.76	-	1.07	1.03	1.00	1.00	0.70	-
c/a RATIO	0.66	-	-	-	0.69	0.82	0.67	-	0.93	0.98	0.65	0.70	0.56	-

* Asphalt Treated with Additive

Table 5. Properties For Project Submitted Asphalt Concrete Mixture and Aggregates

PROJECT	HANLEY RANCH FISH LAKE		SUNNY VALLEY INT. JUMPOFF JOE CR.		NEWBURG M.P. 26.0	PORT ORFORD CAPE SEBASTION		BEEDE RESEVOIR-DRINKWATER PASS	BURNT HILL-THOMAS CR.	RIDGE DR. N.E. PINE ST. N.E.
SOURCE	Trumix Brownsboro #15-180-3		Blencourt Pit #17-23-2		Rex Hill # 36-8-2	Harold Knapp # S-107-3		MP 158 # 13-15-5	River End Ranch # 8-116-3	Jone Pit # 24-38-2
TYPE OF AGGREGATE	Crushed Gravel		Crushed Gravel		Quarry	Quarry		Quarry	Crushed Gravel	Crushed Gravel
COURSE	Wearing	Base	Wearing	Base	Wearing	Wearing	Base	Wearing	Wearing	Wearing
GRADATION, % PASSING*										
3/4 in	98	99	100	100	100	100	100	99	100	-
1/2 in	86	87	89	87	92	92	87	86	90	-
3/8 in	71	78	77	72	70	80	76	76	80	-
1/4 in	58	66	59	55	51	66	62	64	66	-
No. 10	27	32	25	27	21	32	34	31	32	-
No. 40	10	12	11	13	9	14	15	10	15	-
No. 200	4.0	4.6	4.7	5.4	3.8	5.2	5.2	3.7	5.6	-
ASPHALT CONTENT (%)*	6.3	6.7	5.4	5.4	5.7	5.8	6.9	7.2	5.7	-
MOISTURE CONTENT (%)*	1.05	1.06	0.23	0.32	0.57	0.69	0.57	0.42	0.32	-
DMSO, % WEIGHT LOSS**										
COARSE	2.75		0.13		9.38	0.24		10.12	.61	
FINE	8.35		3.14		15.53	2.63		12.30	2.00	

* Mix Sample as Received

** Aggregate Sample as Received

Table 5. Properties For Project Submitted Asphalt Concrete Mixture and Aggregates (continued)

PROJECT	NYLUND RD-ROARING CO.	EMIGRANT HILL MEACHAN	MIDLAND-CALIFORNIA STATE LINE	WESTON-WESTON MOUNTAIN	UMATILLA-HERMISTON	N. JEFFERSON INT.-N. ALBANY INT.	WILLAMETTE HIGHAY @ CLOVERDALE RD.
SOURCE	Sweet Home #22-30-2	Meacham Quarry #30-10-5	Long Lake Rd. # 18-48-4	MP 2.8 HWY #330 # 30-43-5	# 30-1-5	Hilroy Pit #24-2-2	Eugene # 20-45-3
TYPE OF AGGREGATE	Crushed Gravel	Quarry	Quarry	Quarry		Crushed Gravel	Crushed Gravel
COURSE	Wearing	Wearing	Wearing	Wearing	Wearing	Wearing	Wearing
GRADATION, % PASSING*							
3/4 in.	-	99	99	-	-	100	98
1/2 in.	-	91	90	-	-	89	83
3/8 in.	-	82	84	-	-	77	71
1/4 in.	-	67	75	-	-	62	56
No. 10	-	31	37	-	-	32	27
No. 40	-	11	16	-	-	14	12
No. 200	-	3.9	6.4	-	-	5.7	4.7
ASPHALT CONTENT (%)*	-	5.0	5.9	-	-	5.6	5.7
MOISTURE CONTENT %*	-	0.63	0.2	-	-	0.56	0.63
DMSO, % WEIGHT LOSS**							
COARSE	13.93	1.99	0.14	18.53	1.71	6.88	2.76
FINE	9.90	7.93	1.59	21.65	6.52	3.13	7.25

* Mix Sample as Received

** Aggregate Sample as Received

Table 5. Properties For Project Submitted Asphalt Concrete Mixture and Aggregates (continued)

PROJECT	JUNIPER CANYON RD.-LEXINGTON/ECHO HWY	POWDER RIVER SECTION	REEDSPORT-DEAN CREEK		32ND STREET-CREST MOTEL (ASTORIA)		WALLACE BRIDGE WILLAMINA ECL	ELKHEAD RD. INT.-RICE HILL INT.
SOURCE	Pit Rt. of Sta. 22 #25-29-5	Sumpter #1-57-5 Dredge Tailing	Umpqua River # 10-71-3		Taylorville # 4-22-2		Wildish Corvallis #2-2-2(Termine Pit)	Umpqua Sand & Gr. # 10-18-3
TYPE OF AGGREGATE	Crushed Gravel	Gravel	Gravel		Quarry		Crushed Gravel	Gravel
COURSE	Wearing	Wearing	Wearing	Base	Wearing	Base	Wearing	Wearing
GRADATION, % PASSING*								
3/4 in	99	-	99	99	100	100	97	100
1/2 in	84	-	84	85	99	98	85	90
3/8 in	68	-	73	74	85	84	68	73
1/4 in	53	-	58	60	64	65	58	60
No. 10	25	-	31	32	28	29	31	31
No. 40	11	-	15	14	15	14	13	13
No. 200	5.1	-	4.5	4.3	4.0	5.0	5.4	4.5
ASPHALT CONTENT (%)*	5.9	-	6.2	5.9	5.8	6.7	5.4	5.6
MOISTURE CONTENT (%)*	0.73	-	0.52	0.77	0.89	0.57	0.59	0.68
DMSO, % WEIGHT LOSS**								
COARSE	3.51	-	1.37		0.86		9.71	3.55
FINE	6.70	-	6.85		3.67		11.47	4.77

* Mix Sample as Received

** Aggregate Sample as Received

sion it was obtained at the plant. Aggregates were sampled from stockpiled material to be used in the paving mix. The mix was extracted using vacuum extraction techniques (OSHD Method - 309) for the determination of:

1) Aggregate Gradation
2) Asphalt Content, %
3) Moisture Content, %

In addition, some of the mix was used to compact specimens to determine index of retained strength and modulus. The submitted aggregate, asphalt and additives were used for lab batching and fabrication of asphalt concrete mixture specimens to determine index of retained strength and modulus. These results are presented in the following sections. Also, DMSO weight loss tests were run on aggregate samples from the stockpile using both coarse (3/4 - 1/4) and fine (1/4 - 0) materials.

Index of Retained Strength - (IRS)

The results of IRS tests are summarized for submitted mix (Table 6a) and for laboratory batched mix (Table 6b) using three different procedures:

1) Standard T-165 with a 3,000 psi molding pressure,
2) Modified T-165 with a molding pressure of 1,000 psi,
3) Modified T-165 with a molding pressure of 500 psi.

For each mix, the compacted and maximum specific gravity was measured by T-246 and T-209 procedures and void content calculated as follows:

$$\text{Void content, \%} = \left[\frac{\text{Max. Sp. Gr.} - \text{Mix Sp. Gr.}}{\text{Max. Sp. Gr.}}\right] \times 100$$

Table 6a. Summary of AASHTO T-165 Index of Retained Strength For Submitted Asphalt Concrete Mixtures

	PROJECT	MAX SP. GR T-209	COMPRESSIVE STRENGTH, PSI (Void Content, %) Dry	Wet	RETAINED STRENGTH, %
1)	Hanley Ranch - Fish Lake				
	Wearing	2.364	423 (7.8)	393 (7.4)	93
	Base	2.364	467 (14.6)	441 (14.6)	94
2)	Sunny Valley Int. - Jump Joe Creek				
	Wearing	2.657	733 (6.7)	644 (6.7)	88
	Base	2.657	482 (6.3)	424 (6.3)	88
3)	Newberg - M.P 26.0				
	Wearing	2.460	437 (11.0)	371 (11.0)	85
4)	Port Orford - Cape Sebastion				
	Wearing	2.412	609 (6.7)	557 (6.7)	91
	Base	---	483 (4.4)	494 (4.0)	102
5)	Beede Reservoir - Drinkwater Pass				
	Wearing	2.390	508 (7.1)	486 (7.1)	96
	Base	2.378	---	---	-
6)	Burnt Hill - Thomas Creek				
	Wearing	2.499	652 (4.8)	528 (4.8)	81
7)	Emigrant Hill - Meacham*				
	Wearing	2.519	584 (9.9)	419 (9.5)	72
8)	Midland - California State Line				
	Wearing	2.513	388 (6.1)	419 (6.1)	108
9)	N. Jefferson Int. - N. Albany Int.				
	Wearing	2.452	425 (6.2)	374 (6.2)	88
10)	Willamette Highway @ Cloverdale Road				
	Wearing	2.468	536 (6.8)	426 (6.8)	79

* With Anti-Strip Additive

Table 6a. Summary of AASHTO T-165 Index of Retained Strength For Submitted Asphalt Concrete Mixtures (continued)

PROJECT	MAX SP. GR T-209	COMPRESSIVE STRENGTH, PSI (Void Content, %) Dry	Wet	RETAINED STRENGTH, %
11) Juniper Canyon Road - Lexington/Echo Highway*				
Wearing	2.489	658 (6.4)	560 (6.4)	85
12) Reedsport - Dean Creek				
Wearing	2.430	362 (4.5)	312 (4.5)	86
13) 32nd Street - Crest Motel (Astoria)				
Wearing	2.550	423 (5.9)	433 (5.9)	102
Base	2.516	734 (4.6)	655 (4.2)	89
14) Wallace Bridge - Willamina E.L.C.				
Wearing	2.420	598 (7.9)	598 (7.9)	100
15) Elkhead Road Int. - Rice Hill Int.				
Wearing	2.469	654 (5.2)	549 (5.2)	84

* With Anti-Strip Additive

Table 6b. Summary of Index of Retained Strength Values For Lab Batched Asphalt Concrete Mixture

PROJECT	MAX SP. GR T-209	COMPRESSIVE STRENGTH, PSI (Void Content, %) Dry	Wet	RETAINED STRENGTH, %
1) Hanley Ranch - Fish Lake				
Wearing - Standard	2.373	206 (8.6)	207 (8.1)	100
- 1000 Psi	2.373	138 (11.9)	133 (11.9)	96
500 Psi	2.373	93 (15.6)	91 (15.5)	98
Base - Standard	2.364	216 (6.9)	185 (6.5)	86
2) Sunny Valley Int. - Jumpoff Joe Creek				
Wearing - Standard	2.671	408 (7.5)	365 (7.5)	89
- 1000 Psi	2.671	252 (11.6)	203 (11.6)	81
- 500 Psi	2.671	169 (13.1)	164 (13.1)	97
Base - Standard	2.657	254 (6.7)	251 (6.3)	99
3) Newburg - M.P. 26.0				
Wearing - Standard	2.440	273 (5.7)	274 (5.7)	100
4) Port Orford - Cape Sebastion				
Wearing - Standard	2.406	247 (6.5)	234 (6.5)	95
- 1000 Psi	2.406	149 (10.2)	136 (10.2)	91
- 500 Psi	2.406	106 (12.3)	112 (12.3)	106
Base - Standard	2.392	255 (5.1)	282 (5.1)	111
5) Beede Reservoir - Drink Water Pass				
Wearing - Standard	2.395	174 (8.1)	196 (8.1)	113
- 1000 Psi	2.395	108 (13.2)	121 (12.3)	112
6) Burnt Hill - Thomas Creek				
Wearing - Standard	2.518	346 (7.5)	342 (7.1)	99
- 1000 Psi	2.518	215 (11.0)	200 (11.0)	93
- 500 Psi	2.518	185 (12.2)	168 (12.2)	91
7) Nylund Road - Roaring Creek*				
Wearing - Standard	2.435	213 (9.2)	149 (9.2)	70
8) Emigrant Hill - Meacham*				
Wearing - Standard	2.519	260 (8.7)	250 (8.3)	96

* With Anti-Strip Additive

Table 6b. Summary of Index of Retained Strength Values For Lab Batched Asphalt Concrete Mixture (continued)

PROJECT	MAX SP. GR T-209	COMPRESSIVE STRENGTH, PSI (Void Content, %) Dry	Wet	RETAINED STRENGTH, %
9) Midland - California State Line				
Wearing - Standard	2.530	278 (6.3)	263 (6.3)	95
- 1000 Psi	2.530	186 (10.3)	207 (9.9)	111
- 500 Psi	2.530	133 (11.5)	127 (11.8)	95
10) Weston - Weston Mountain				
Wearing - Standard	2.480	230 (5.6)	224 (5.6)	97
11) Umatilla - Hermiston*				
Wearing - Standard	2.506	211 (6.6)	214 (6.2)	101
12) N. Jefferson Int. - N. Albany Int.				
Wearing - Standard	2.452	259 (7.8)	176 (7.8)	68
13) Willamette Highway @ Cloverdale Road				
Wearing - Standard	2.493	294 (7.7)	262 (7.7)	89
14) Juniper Canyon Road - Lexington/Echo Highway*				
Wearing - Standard	2.489	248 (6.8)	226 (6.8)	91
15) Reedsport - Dean Creek				
Wearing - Standard	2.443	177 (8.7)	154 (8.7)	87
16) 32nd Street - Crest Motel (Astoria)				
Wearing - Standard	2.537	249 (6.6)	282 (6.6)	113
Base - Standard	2.516	264 (5.4)	254 (5.4)	96
17) Wallace Bridge - Willamina E.C.L.				
Wearing - Standard	2.420	231 (8.3)	222 (7.9)	96
18) Elkhead Road Int. - Rice Hill Int.				
Wearing - Standard	2.486	201 (8.7)	157 (8.7)	78
19) Vail Creek - Nylund Road*				
Wearing - Standard	2.427	248 (8.5)	212 (8.5)	85

* With Anti-Strip Additives

Diametral Modulus Ratio

Table 7 summarizes the results of tests for modulus values on submitted mix (Table 7a) and laboratory batched mix (Table 7b) for three different types of conditioning:

1) Unconditioned. For this case the sample (2 1/2 in high x 4 in diameter) was compacted using standard Hveem compaction.

2) After Vacuum Saturation. In this case the sample was saturated in water for a period of 1/2 hours using 26 in. Hg vacuum then held for 1/2 hour in water without vacuum before testing.

3) After Freeze-Thaw. After vacuum saturation the sample was frozen for 15 hours at 0°F and then thawed for 24 hours in a 140°F water bath and then conditioned at 77°F for 3 hours before testing.

For each project, modulus ratios were also calculated. These appear in Table 7.

Table 7a. Modulus Ratio For Field Submitted Asphalt Concrete Mixture

PROJECT	MODULUS, 10^3 PSI			MODULUS RATIO	
	UNCONDITIONED (a)	VAC. SAT (b)	FREEZE-THAW (c)	(b/a)	(c/a)
1) Hanley Ranch - Fish Lake					
Wearing	333	319	313	0.96	0.94
Base	446	480	453	1.08	1.02
2) Newburg - MP 26.0					
Wearing	427	552	378	1.30	.89
3) Port Orford - Cape Sebastion					
Wearing	714	549	489	.77	.68
Base	601	479	373	.80	.62
4) Beede Reservior - Drinkwater Pass					
Wearing	381	332	255	.87	.67
5) Burnt Hill - Thomas Cr.					
Wearing	1201	1057	840	.88	.70
6) Emigrant Hill - Meacham*					
Wearing	846*	618*	424*	.73*	.50*
7) Midland - California State Line					
Wearing	550	471	467	.86	.85
8) N. Jefferson Int. - N. Albany Int.					
Wearing	620	450	368	.73	.59
9) Juniper Canyon Road - Lexington/Echo Highway*					
Wearing	911	753	653	.83	.71

* With Anti-Strip Additive

Table 7a. Modulus Ratio For Field Submitted Asphalt Concrete Mixture

PROJECT	MODULUS, 10^3 PSI			MODULUS RATIO	
	UNCONDITIONED (a)	VAC. SAT (b)	FREEZE-THAW (c)	(b/a)	(c/a)
10) Reedsport - Dean Creek					
Wearing	1050	832	894	.79	.85
11) 32nd Street - Crest Motel (Astoria)					
Wearing	498	470	452	.94	.91
Base	610	517	484	.85	.79

Table 7b. Modulus Ratio For Lab Batched Asphalt Concrete Mixture

PROJECT	MODULUS, 10^3 PSI									MODULUS RATIO					
	UNCONDITIONED (a)			VAC. SAT (b)			FREEZE-THAW (c)			(b/a)			(c/a)		
1) Hanley Ranch - Fish Lake															
Wearing	204	-	-	143	-	-	145	-	-	.70	-	-	.71	-	-
Base	215	-	-	149	-	-	212	-	-	.69	-	-	.99	-	-
2) Sunny Valley Int. - Jumpoff Joe Creek															
Wearing	610	-	-	445	-	-	378	-	-	.73	-	-	.62	-	-
Base	276	-	-	201	-	-	174	-	-	.73	-	-	.63	-	-
3) Newburg - MP 26.0															
Wearing	250	-	-	216	-	-	121	-	-	.86	-	-	.48	-	-
4) Port Orford - Cape Sebastion															
Wearing	488	-	-	350	-	-	356	-	-	.72	-	-	.73	-	-
Base	304	-	-	220	-	-	230	-	-	.72	-	-	.76	-	-
5) Beede Reservior - Drinkwater Pass															
Wearing	121	-	-	99	-	-	91	-	-	.82	-	-	.75	-	-
6) Burnt Hill - Thomas Cr.															
Wearing	512(1576 @ 32°F)			437	-	-	362	-	-	.85	-	-	.71	-	-
7) Nylund Rd. - Roaring Co.															
Wearing	227	261*	286**	155	211*	195**	78	131*	135**	.68	.81*	.68**	.34	.50*	.47**
8) Emigrant Hill - Meacham															
Wearing	390	439*	480**	269	312*	394**	256	258*	328**	.69	.71*	.82**	.66	.59*	.68**
9) Midland - California State Line															
Wearing	436	-	-	388	-	-	353	-	-	.89	-	-	.81	-	-
10) Weston - Weston Mountain															
Wearing	299	-	-	222	-	-	158	-	-	.74	-	-	.53	-	-

* With Anti-Strip Additive
** With 1% Hydrated Lime

Table 7b. Modulus Ratio For Lab Batched Asphalt Concrete Mixture (continued)

PROJECT	MODULUS, 10^3 PSI									MODULUS RATIO					
	UNCONDITIONED (a)			VAC. SAT (b)			FREEZE-THAW (c)			(b/a)			(c/a)		
11) Umatilla - Hermiston															
Wearing	321	210*	204**	247	248*	270**	196	210*	245**	.77	1.19*	1.32**	.61	1.00*	1.20**
12) N. Jefferson Int. - N. Albany Int.															
Wearing	314	-	-	253	-	-	130	-	-	.81	-	-	.41	-	-
13) Willamette Highway @ Cloverdale Road															
Wearing	213	-	-	251	-	-	218	-	-	1.18	-	-	1.02	-	-
14) Juniper Canyon Road - Lexington/Echo Highway															
Wearing	331	215*	332**	282	249*	223**	217	228*	269**	.85	1.16*	.67**	.66	1.06*	.81**
15) Reedsport - Dean Creek															
Wearing	279	-	-	174	-	-	130	-	-	.62	-	-	.47	-	-
16) 32nd Street - Crest Motel (Astoria)															
Wearing	217	-	-	383	-	-	146	-	-	1.76	-	-	.67	-	-
Base	163	-	-	107	-	-	119	-	-	.66	-	-	.73	-	-
17) Wallace Bridge - Willamina ECL															
Wearing	218(537 @ 32°F)			161	-	-	173	-	-	.74	-	-	.79	-	-
18) Elkhead Road Int. - Rice Hill Int.															
Wearing	207(4307 @ 32°F)			150	-	-	144	-	-	.72	-	-	.70	-	-
19) Vail Creek - Nylund Road															
Wearing	257	285*	354**	179	191*	264**	145	166*	212**	.70	.67*	.75**	.56	.58*	.60**

* With Anti-Strip Additive

** With 1% Hydrated Lime

DISCUSSION OF RESULTS

General

Of the twenty-one projects in Table 4 for which construction mix designs were performed, five exhibited some tendency for stripping when tested without additive treatment of asphalt as indicated by Index of Retained Strength values of less than 70% at the recommended asphalt contents. Projects identified in Table 8 are those constructed with a stripping tendency as indicated by Index of Retained Strength or Modulus Ratio Values of less than 70%.

When the materials from these projects were tested for aggregate quality using a modified sulfate soundness test (with DMSO) the following was noted:

1) Project with Low IRS Before Treatment of Asphalt in Mix Design. All of the projects on which aggregates were tested had a weight loss in excess of 6.0% (Table 9a).

2) Projects with Less than 0.70 Modulus in Mix Design. Six of ten projects on which aggregates were tested had a weight loss in excess of 6.0% (Table 9b).

3) Projects with Acceptable IRS in Mix Design. Nine of fifteen projects on which aggregates were tested had a weight loss in excess of 6.0% (Table 10a).

4) Project with Greater than 0.70 Modulus Ratio in Mix Design. Four of the six projects on which aggregates were tested had a weight loss in excess of 6.0% (Table 10b).

Table 8. Projects Detected in Construction Mix Design For Potential Stripping Problems in Wearing Course

	Project	Test Result Indicting Stripping
1)	Sunny Valley Int. - Jumpoff Joe Creek	Diametral Modulus Ratio below 0.70.
2)	Beede Reservior - Drinkwater Pass	Diametral Modulus Ratio below 0.70.
3)	Nylund Rd. - Roaring Creek*	Chevron AR 4000W treated with 0.2% Pave Bond Special to provide 70% IRS. Diametral Modulus Ratio below 0.70.
4)	Midland - California State Line	Diametral Modulus Ratio (c/a) below 0.70.
5)	Weston - Weston Mountain	Diametral Modulus Ratio below 0.70.
6)	Umatilla - Hermiston*	Chevron AR 4000W treated with 0.2% Pave Bond Special to provide 70% IRS. Diametral Modulus Ratio (c/a) below 0.70.
7)	N. Jefferson Int. - N. Albany Int.	Diametral Modulus Ratio (c/a) below 0.70.
8)	Juniper Canyon Road - Lexington Echo Highway*	Chevron AR 4000W treated with 0.3% Pave Bond Special to provide 70% IRS. Diametral Modulus Ratio (b/a) below 0.70.
9)	Reedsport - Dean Creek	Diametral Modulus Ratio (c/a) below 0.70.
10)	32nd Street - Crescent Motel (Astoria)	Diametral Modulus Ratio (c/a) below 0.70.
11)	Elkhead Road Int. - Rice Hill Int.	Diametral Modulus Ratio (c/a) below 0.70.
12)	Vale Creek - Nylund Road*	Chevron AR 4000W treated with 0.5% Pave Bond Special to provide 70% IRS. Diametral Modulus Ratio (c/a) below 0.70.
13)	Emigrant Hill - Meacham*	Chevron AR 4000W treated with 0.2% Pave Bond Special to provide 70% IRS.

* Asphalt Treated with Anti-Stripping Additive

Table 9 (a). Aggregate Quality for Projects with Less than 70% IRS in Mix Design

	Project	DMSO - Weight Loss, %	
		Coarse	Fine
1)	Nylund Road - Roaring Creek	13.93	9.90
2)	Emigrant Hill - Meacham	1.99	7.93
3)	Umatilla - Hermiston	1.71	6.52
4)	Juniper Canyon Road - Lexington/ Echo Highway	- -	
5)	Vale Creek - Nylund Road	16.57	34.85

Table 9 (b). Aggregate Quality for Projects with Less than 0.70 Modulus Ratio in Mix Design

	Project	DMSO - Weight Loss, %	
		Coarse	Fine
1)	Sunny Valley Int. - Jumpoff Joe Creek	0.13	3.14
2)	Beede Reservior - Drinkwater Pass	10.12	12.30
3)	Nylund Road - Roaring Creek	13.93	9.90
4)	Midland - California State Line	0.14	1.59
5)	Weston - Weston Mountain	18.53	21.65
6)	Umatilla - Hermiston	1.71	6.52
7)	N. Jefferson Int. N. Albany Int.	6.88	3.13
8)	Juniper Canyon Road - Lexington/ Echo Highway	-	-
9)	Reedsport - Dean Creek	1.37	6.85
10)	32nd Street - Crest Hotel (Astoria)	0.86	3.67
11)	Elkhead Road Int. Rice Hill Int.	3.55	4.77
12)	Vale Creek - Nylund Road	-	-

Table 10 (a). Aggregate Quality for Projects with Greater than 70% Index of Retained Strength in Mix Design

	Project	DMSO - Weight Loss, %	
		Coarse	Fine
1)	Hanley Ranch - Fish Lake	2.75	8.35
2)	Sunny Valley Int. - Jumpoff Joe Creek	0.13	3.14
3)	Port Orford - Cape Sebastion	0.24	2.63
4)	Beede Reservoir - Drinkwater Pass	10.12	12.30
5)	Burnt Hill - Thomas Creek	0.61	2.00
6)	Ridge Drive N.E. - Pine Street N.E.	---	---
7)	Midland - California State Line	0.14	1.59
8)	Weston - Weston Mountain	18.53	21.65
9)	Willamette Highway @ Cloverdale Road	2.76	7.25
10)	Juniper Canyon Road - Lexington/ Echo Highway	3.51	6.70
11)	Powder River Section	---	---
12)	32nd Street - Crest Motel	0.86	3.67
13)	Wallace Bridge - Willamina ECL	9.71	11.47
14)	Newberg - MP 26.0	9.38	15.53
15)	N. Jefferson Int. - N. Albany Int.	6.88	3.13
16)	Reedsport - Dean Creek	1.37	6.85
17)	Elkhead Road Int. - Rice Hill Int.	3.55	4.77

Table 10 (b). Aggregate Quality for Projects with Greater than 0.70 Modulus Ratio in Mix Design

	Project	DMSO - Weight Loss, %	
		Coarse	Fine
1)	Hanley Ranch - Fish Lake	2.75	8.35
2)	Newberg - MP 26.0	9.38	15.53
3)	Port Orford - Cape Sebastion	0.24	2.63
4)	Burnt Hill - Thomas Creek	0.61	2.00
5)	Ridge Drive N.E. - Pine Street N.E.	-	-
6)	Emigrant Hill - Meacham	1.99	7.93
7)	Willamette Highway - Cloverdale Road	2.76	7.25
8)	Powder River Section	-	-
9)	Wallace Bridge - Willamina ECL	-	-

Index of Retained Strength

Table 6 presents results of tests on submitted and laboratory batched asphalt concrete mixtures which contain asphalt treated with additive as recommended in the mix design. Of the 15 projects for which submitted mix was tested (Table 6a) all had an index of retained strength greater than 70% and wet strengths greater than 300 psi. All but four had wet strengths greater than 400 psi.

Table 6b summarized the results of Index of Retained Strength tests on laboratory batched specimens. A total of 19 projects were evaluated, including both the wearing and base course mixtures. For all projects (but one -- N. Jefferson Int. - N. Albany Int.), the Index of Retained Strength exceeded 70%. Although compressive strength values are lower for laboratory batched specimens from less curing or aging of asphalt, satisfactory resistance to damage from water effect is indicated.

Six of these mixes were also evaluated using a modified version of AASHTO T-165 where the compaction pressure was reduced to 1000 or 500 psi. These results are summarized in Table 11. As indicated in this table, the compressive stengths are greatly reduced by lowering compaction pressure, while the Index of Retained Strength remains more or less constant.

Diametral Modulus Ratio

Table 7 summarized results of tests for diametral modulus on submitted mixes (Table 7a) and on laboratory batched mixes (Table 7b), some of which contained asphalt treated with additive when recommended in the mix design. Eleven projects (Table 7a) were evaluated for modulus ratio using mix submitted from the field (the remainder were not tested because of insufficient

Table 11. Effect of Level of Compaction on Index of Retained Strength, Wearing Course

	Project	Compressive Strength, PSI		Retained
		Dry	Wet	Strength, %
1)	Hanley Ranch - Fish Lake			
	Standard	206	207	100
	1000 psi	138	133	96
	500 psi	93	91	98
2)	Sunny Valley Int. - Jumpoff Joe Creek			
	Standard	408	365	89
	1000 psi	252	203	81
	500 psi	169	164	97
3)	Port Orford - Cape Sabastion			
	Standard	247	234	95
	1000 psi	149	136	91
	500 psi	100	112	91
4)	Beede Reservoir - Drinkwater Pass			
	Standard	174	196	113
	1000 psi	108	121	112
5)	Burnt Hill - Thomas Creek			
	Standard	346	342	99
	1000 psi	215	200	93
	500 psi	185	168	91
6)	Midland - California State Line			
	Standard	278	263	95
	1000 psi	186	207	111
	500 psi	133	127	95

material). After vacuum saturation, the modulus generally dropped; the lowest modulus ratio for the submitted mix specimens was 0.73 which would indicate satisfactory resistance to damage from water effect. In two instances (Hanley Ranch - Fish Lake and Newberg - MP 26.0) the modulus ratio actually exceeded 1.0. When the same samples were subjected to the Lottman's Freeze/Thaw cycle (Reference 1), the modulus is reduced even further. Samples subjected to this conditioning procedure exhibited modulus ratios as low as 0.5. In fact, four of the eleven projects evaluated had modulus ratios below the generally accepted value of 0.7. These include:

1) Port Orford - Cape Sebastion
2) Beede Reservoir - Drinkwater Pass
3) Emigrant Hill - Meacham
4) N. Jefferson Int. - N. Albany Int.

Nineteen projects were evaluated for modulus using laboratory batched specimens (Table 7b). Again, the result of increased curing or aging of asphalt in submitted mix specimen results in difference in modulus. Most of the submitted mix had modulus values greater than 400,000 psi while most of the lab prepared mixes had modulus values less than 400,000 psi. If one analyzes the results in Table 7b, the modulus ratio after vacuum saturation ranges from .68 to 1.76 with 5 of the 19 projects having ratios below 0.7. For samples subjected to freeze-thaw conditioning, the modulus ratios ranged from 0.34 to 1.02; however, the number of projects with ratios below 0.7 increased from 5 to 10.

Projects with modulus ratio values of less than 0.70 include:

1) Sunny Valley Int. - Jumpoff Joe Creek
2) Newberg - MP 26.0

3) Nylund Road - Roaring Creek

4) Emigrant Hill - Meacham

5) Weston - Weston Mountain

6) N. Jefferson Int. - N. Albany Int.

7) Juniper Canyon Road - Lexington/Echo Highway

8) Reedsport - Dean Creek

9) 32nd Street - Crest Motel (Astoria)

10) Vale Creek - Nylund Road

Effect of Additives

A limited test program was undertaken to evaluate the effect of additive type on Index Retained Strength (Table 12) and diametral modulus ratio (Table 13). Only two additives were studied, hydrated lime and Pave Bond Special. Pave Bond Special was added to the asphalt one day prior to use and lime was added to the hot aggregate just prior to the addition of asphalt for mixing. As indicated in Table 12, Index of Retained Strength for each project is increased from the treatment of asphalt with anti-stripping additive. On four of the five projects, IRS values are increased with the addition of hydrated lime.

For each project, IRS test results are higher for this study than those for construction mix design testing. This is likely the result of changes in aggregate and/or changes in asphalt obtained for the study.

Modulus ratio values are increased from the addition of additive in all cases, except one. The Modulus Ratio values are in excess of 0.70 with the use of Pave Bond on four of five projects for vacuum saturated specimens and on two of five projects after freeze-thaw conditioning.

Table 12. Effect of Additive on Index of Retained Strength For Lab Batched Mixture at Wearing Surface Asphalt Content

Project	Compressive Strength, PSI		Retained Strength, %	
	Dry	Wet		
1) Emigrant Hill - Meacham				
without additive	282	206	73	68*
with 0.2% Pave Bond	260	250	96	87*
with 1% Lime	317	267	84	
2) Umatilla - Hermiston				
without additive	203	191	94	66*
with 0.2 Pave Bond	211	214	101	89*
with 1% Lime	224	230	103	
3) Juniper Canyon Road - Lexington/Echo Highway				
without additive	264	200	76	56*
with 0.3% Pave Bond	248	226	91	80*
with 1% Lime	282	221	79	
4) Vail Creek - Nylund Road				
without additive	256	191	75	79*
with 0.2% Pave Bond	248	212	85	80*
with 1% Lime	281	221	79	
5) Nylund Road - Roaring Creek				
without additive	213	149	70	62*
with 0.2% Pave Bond	228	192	84	85*
with 1% Lime	250	176	70	-

* Values from Construction Mix Design Testing - Table 4

Table 13. Effect of Additive of Diametral Modulus Ratio For Lab Batched Mixtures at Wearing Course Asphalt Content

PROJECT	MODULUS, 10^3 PSI			MODULUS RATIO	
	UNCONDITIONED (a)	VAC. SAT (b)	FREEZE-THAW (c)	(b/a)	(c/a)
1) Emigrant Hill - Meacham					
without additive	390	269	256	.69	.66
with 0.2% Pave Bond	439	312	258	.71	.59
with 1.0% Lime	480	394	328	.82	.68
2) Umatilla - Hermiston					
without additive	321	247	196	.77	.61
with 0.2% Pave Bond	210	249	210	1.19	1.00
with 1% Lime	204	270	245	1.32	1.20
3) Juniper Canyon Road - Lexington/Echo Highway					
without additive	331	282	217	.85	.66
with 0.2% Pave Bond	215	249	228	1.16	1.06
with 1% Lime	332	223	269	.67	.81
4) Vail Creek - Nyland Road					
without additive	257	179	145	.70	.56
with 0.2% Pave Bond	285	191	166	.67	.58
with 1% Lime	354	264	212	.75	.60
5) Nylund Road - Roaring Creek					
without additive	227	155	78	.68	.34
with 0.2% Pave Bond	261	211	131	.81	.50
with 1% Lime	286	195	135	.68	.47

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of this portion of the study (Phase I) generally indicated that:

1) Present mix design procedures may not always detect problem from asphalt-aggregate stripping.
2) Aggregate quality appears to relate to low values for Index of Retained Strength and Modulus Ratio.
3) Significant differences existed for Index of Retained Strength and Modulus Ratio values for construction mix design, submitted mix and later laboratory batched specimens.
4) Level of compaction greatly affected the compressive strength. However, Index of Retained Strength values show little change.
5) Conditioning greatly affected modulus and modulus ratio values.
6) The use of additives generally increases both the Modulus Ratio and Index of Retained Strength.

Recommendations

This study should be continued into Phase II, the field evaluation portion of the project. Six projects should be selected; three likely to have problems and three not likely to have problems. For each project, cores should be taken at several locations in between wheel paths and in the case of freeways in both the traffic and passing lanes. Each core should then be tested for:

1) In-place void content

1) In-place void content

2) Percent compaction

3) Diametral modulus as received and conditioned,

4) Aggregate gradation, and

5) Asphalt content and properties

6) Percent of aggregates with asphalt coating.

These results together with an performance evaluation of the project should yield valuable information in answering the reliability of present mix design procedures to predict stripping problems.

REFERENCES

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