IMPACT OF VARIATION IN MATERIAL PROPERTIES ON ASPHALT PAVEMENT LIFE

EVALUATION OF CASTLE ROCK-CEDAR CREEK PROJECT

HP & R Study: 0815157

Interim Report

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16. Abstract

Construction and short-term pavement performance problems were noted in the Pacific Northwest and throughout the United States during the past five years. Several reasons have been suggested to explain this sudden change in pavement performance, such as recent variabilities in asphalt properties and new developments in paving technology. Using the data and construction materials issued from a recent project built in 1979, Oregon State Highway Department and Oregon State University conducted a laboratory study to determine the relationship between asphalt concrete pavement performance and mix level of compaction, asphalt content, and mix gradation.

Conventional tests and improved dynamic tests were run on laboratory compacted samples to determine mix stiffness, fatigue life and permanent deformation characteristics. Based on fatigue and permanent deformation test results, preliminary pay adjustment factors were developed by comparing performance of mix specimens prepared at the design optimum with the performance of mix out of specifications. It was found that performance is primarily affected by the mix level of compaction. Fatigue data corroborated the design optimum asphalt content (6%), and showed a strong interaction between the asphalt content and the amount of fines. Mix susceptibility to permanent deformation decreased when increasing the amount of fines and decreasing the asphalt content. A summary table giving the most critical pay adjustment factors between the fatigue and the permanent deformation criteria is developed in the conclusions and recommendations chapter.

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This report is the third of a series of reports concerned with the impact of variations in material properties of asphalt pavement life. The data developed in this report will be combined with that developed for two other projects (North Oakland-Sutherlin and Warren-Scappose). All projects will be analyzed together to formulate recommendations for pay adjustment factors. These recommendations will appear in the final report. Assistance provided by Glen Boyle and staff, Oregon Department of Transportation, in the testing associated with Chapter 3 and that provided by Jose R. Montalvo and Michael Wynkoop, students of Oregon State University, in testing associated with Chapter 4 is acknowledged. The project was conducted in cooperation with the U.S. Department of Transportation Federal Highway Administration.

DISCLAIMER

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1.0 INTRODUCTION

Problem Definition

Several changes have occurred in recent years in highway materials and in asphalt paving technology. New asphalt sources have been brought on line, introducing changes in asphalt properties. New equipment has also been developed, affecting mixing (dryer drum mixers, more efficient dust collector systems), storage (mix storage silos) and compaction (vibratory compactors). In the same period, economic constraints have resulted in increasing use of lower quality aggregate. As a result, there has been an increase in construction or short-term performance problems throughout the Pacific Northwest (1). The impact of such changes on the mix properties is, however, difficult to evaluate. Table 1 summarizes the main changes observed and their expected influence on the mix behavior.

One recent project, located on the Three Rivers Highway, between Hebo and Valley Junction, referred to as the Castle Rock-Cedar Creek project, was built in 1979. Progressive pavement raveling and potholing were noticed during the months following construction of this project. Evaluation of the reduction in pavement life resulting from changes in the design specifications (e.g., aggregate quality, gradation, density, asphalt content) requires a study of the mix dynamic properties under controlled conditions. A rational approach is needed to assess the effects of these mix variables on pavement life.

Purpose

The purpose of this report is to obtain a better understanding of the causes of the pavement problems noticed in the past years, and to develop relationships between pavement performance and the different mix variables. Such information will be useful in developing pay-adjustment factors for projects not complying fully with specifications.

Table 2 illustrates a flow chart of the approach followed for the study of the Castle Rock-Cedar Creek project. Three mix variables were considered in the study:

(1) Asphalt content

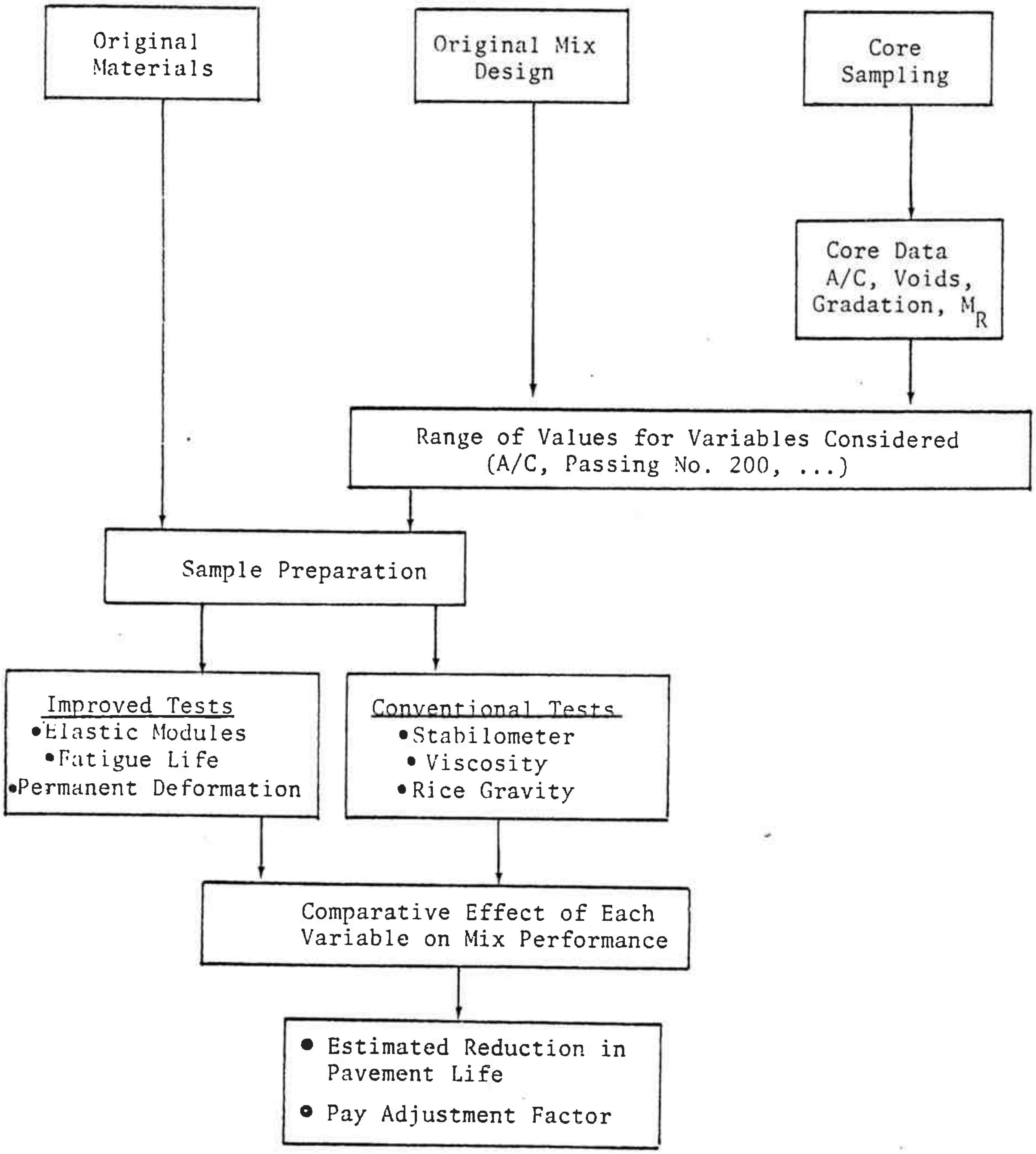
(2) Percent Passing No. 200 sieve (.074 mm).

(3) Mix density.

Table 1. Recent Changes in Asphalt Paving Technology Affecting Pavement Behavior

ITEM	CHANGES OBSERVED	EXPECTED IMPACT ON PAVEMENT
ASPHALT	Wide difference between asphalt temperature-viscosity curves from various suppliers. Increased temperature - susceptibility	Compaction difficulty Slow setting mixes Reduced resistance to thermal and fatigue cracking
	Reduced compatibility between asphalt and aggregate	Increased ravelling Reduced resistance to damage from water and freeze-thaw effects
AGGREGATE	Reduced aggregate quality	Increased ravelling Reduced resistance to damage from water and freeze-thaw effects
	Single stockpile Elimination of Plant Screens	Reduced uniformity of gradation Segregation
EQUIPMENT	Use of collector dust	Reduced uniformity of gradation Flashing
	High Mix production rate	Reduced uniformity of gradation and asphalt content
	Lower mixing and laydown temperatures	Reduced uniformity of asphalt viscosity. Increased moisture. Reduced asphalt-aggregate adhesion
	Use of vibratory compactors	Breakage of aggregates Low compaction from improper use
	Drum mixers	Incomplete coating of aggregate
	Mix storage silos and Belly dump hauling equipment	Mix segregation from improper use

Table 2. Flow Chart of Study.



The range of values selected for each of the above variables was determined from project sampling and from cores taken in the spring of 1980 (See Appendix A). These are as follows:

(1) Asphalt content: 5% - 6% - 7%

(2) Percent Passing No. 200: 2% - 6% - 10%

(3) Mix level of compaction: 100% - 97% - 92% - 90%

Following the standard ODOT procedure, 4 inches (10 cm) in diameter by 2.5 inches (6 cm) high samples were fabricated for each set of conditions, using the same materials (asphalt and aggregate) as used during construction of the Castle Rock-Cedar Creek project.

The main types of pavement failure considered during the test program include fatigue cracking and rutting. All samples are tested in the diametral mode for elastic modulus, fatigue life and permanent deformation. To obtain complete characterization of the mixture, conventional tests were also run (stabilometer, void content, index of retained strength).

To identify the potential for stripping and raveling, elastic modulus, fatigue life and permanent deformation tests are performed both before and after vacuum saturation of the samples, followed by a freeze-thaw cycle.

Scope of Report

After a description of the Castle Rock-Cedar Creek project (Chapter 2), the test results will be presented in Chapter 3 (ODOT research) and in Chapter 4 (OSU research). Tests performed by Oregon Department of Transportation include conventional tests. All dynamic tests were performed at Oregon State University. Analysis of data include the development of fatigue life and permanent deformation criteria for the as compacted samples and the conditioned samples. Finally, pay adjustment factors are determined in Chapter 5 using the fatigue and permanent deformation models developed in Chapter 4.

2.0 PROJECT DESCRIPTION

Location

The Castle Rock-Cedar Creek project is a section of the Hebo-Valley Junction Highway, located in Tillamook and Yamhill counties (Figure 1). Precise location of the project is shown on Figure 2. The project overall length is 11.7 miles (18.7 km).

Cross-Section

Reconstruction of this section of the Hebo-Valley Junction highway included an asphalt concrete base course and an asphalt concrete wearing surface, on top of the existing bituminous surface. Both layers were built using an ODOT class B mix. The average for the as constructed thickness is 2.0" (5.1 cm) for the base and 1.7" (4.3 cm) for the wearing surface.

Mix Design

A summary of the original mix design is presented in Table 3. This mix design was used for both the base and the top layers. The aggregate gradation was also the same for both layers, and correspond to a type B mix (Table 4). The recommended asphalt content was 6.1 percent for the wearing surface and 6.7 percent for the base course. The asphalt grade recommended was an AR 4000, from Chevron. The recommended mix temperature at time of placement was 270°F (132°C).

Project Data

Pavement raveling, potholing, variation in mix gradation and asphalt content were noticed during construction of the Castle Rock-Cedar Creek project in 1979.

Inspection of the mix showed that the coarse aggregate were 40 to 95 percent coated. Aggregates were dirty and contained soft materials (AASHTO T-112), and the asphalt was not uniformly mixed with the aggregates.

Table 5 summarizes the field test results run during pavement construction. The variables considered are the mix bulk specific gravity, asphalt content and percent passing No. 200 and No. 10. Compared to the core data and the specified job mix tolerances (Table 6), it appears from the average field

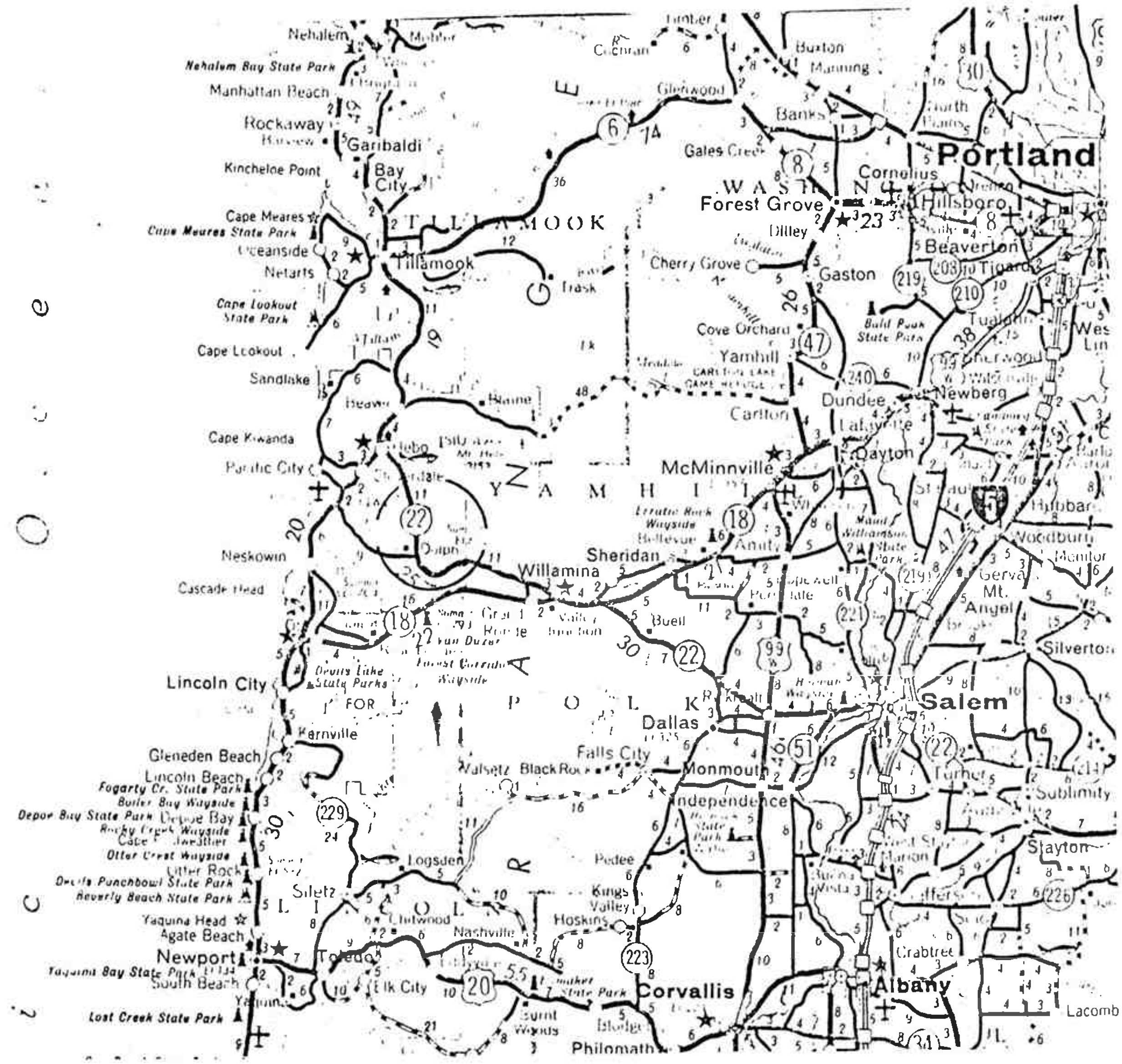


Figure 1. Map of Northwestern Oregon
Project Location

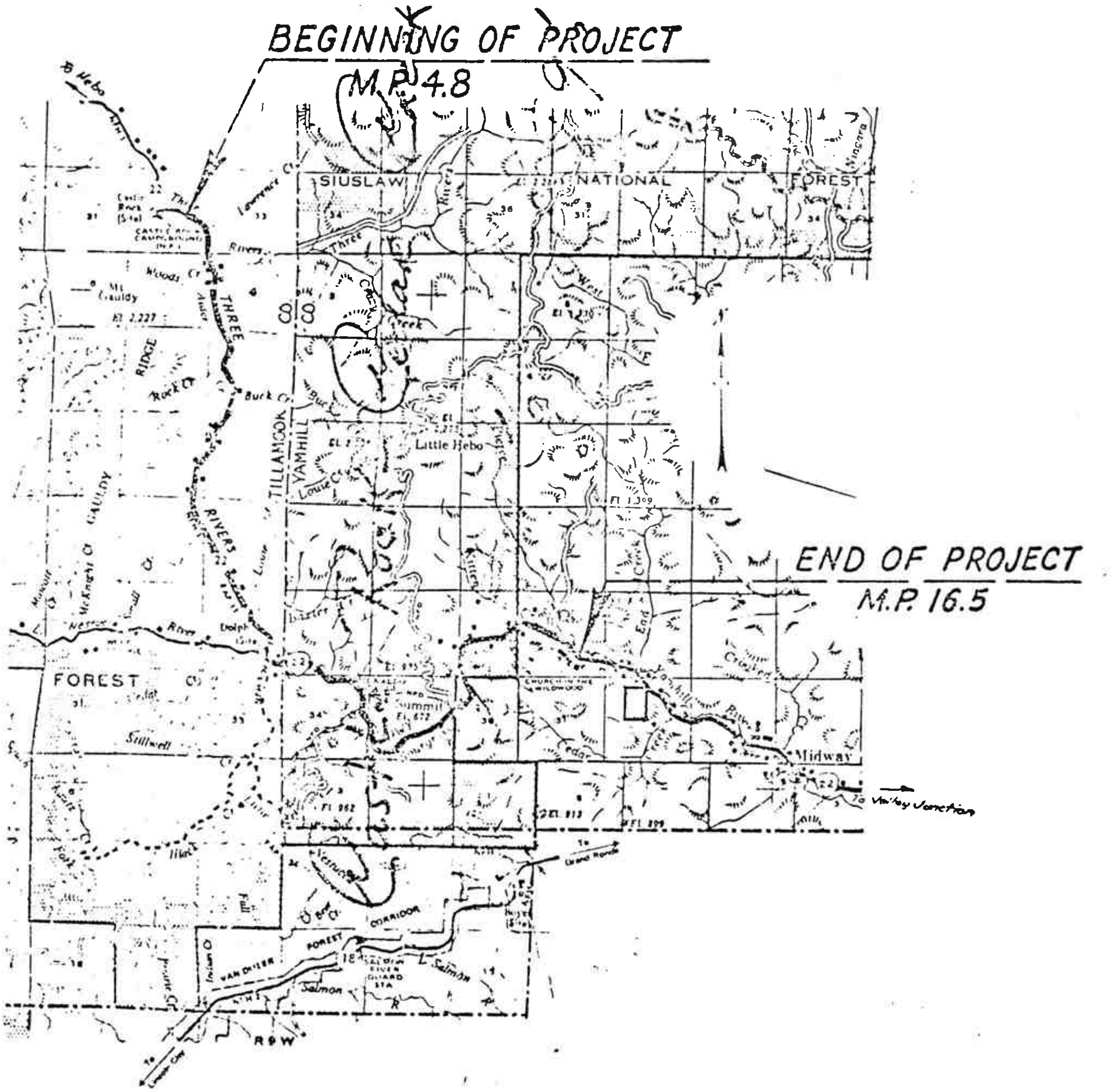


Figure 2. Castle Rock - Cedar Creek
Detail of Project Location

Table 3. Original Mix Design Test Results (ODOT)
Hebo Valley Junction Project

Asphalt Content - AR 4000	5.0	5.5	6.0	6.5	7.0
Asphalt Film Thickness	Suff.	Suff.	Suff. Thick.	Thick	V. Thick
Stability Value, 1st Compaction	41	41	37	37	39
Bulk Spe. Gravity, 1st Compaction	2.22	2.24	2.26	2.28	2.29
Percent Voids, 1st Compaction	11.2	9.7	8.1	6.6	5.4
Stability Value, 2nd Compaction	49	51	51	51	50
Bulk Spe. Gravity, 2nd Compaction	2.31	2.33	2.35	2.37	2.38
Percent Voids, 2nd Compaction	7.6	6.0	4.5	2.9	1.7
Rice Gravity	2.50	2.48	2.46	2.44	2.42
Index of Retained Strength AASHTO-T-165	56	-	79	-	87

Table 4. Mix Design: Aggregate Gradation, Class B

SIEVE SIZE	COMBINED AGGREGATE AASHTO-T-27	WASHED SIEVE AASHTO-T-11	JOB MIX TOLERANCE	SPECIFICATION
1"	100	100	100	100
3/4"	99	99	95 - 100	95 - 100
1/2"	90	90	81 - 93	-
1/4"	63	65	57 - 69	52 - 72
# 10	26	28	22 - 30	21 - 41
# 40	10	11	8 - 16	8 - 24
#200	3.6	4.6	3 - 7	3 - 7

Table 5. Summary of Construction Reports - 1979
Base and Top Lift Bituminous Mix Class "B"

IN PLACE MIX DATA	TOP LIFT		BASE LIFT	
	Average Value	Max. and Min. Values	Average Value	Max. and Min. Values
Mix Bulk Specific Gravity	2.15 ± .03 (10 tests)	2.11 - 2.19	2.21 ± .02 (5 tests)	2.17 - 2.23
Asphalt Content	6.04 ± .28 (27 tests)	5.4 - 6.5	6.56 ± .51 (30 tests)	5.1 - 7.2
Percent Passing No. 200	5.54 ± .47 (28 tests)	4.4 - 6.3	5.75 ± .42 (30 tests)	4.7 - 6.4
Percent Passing No. 10	27.23 ± 3.48 (28 tests)	20.6 - 35.8	27.87 ± 2.93 (30 tests)	22 - 34

Table 6. Comparison Between Construction Information, Core Data and Mix Specification

	TOP LIFT			BASE LIFT		
	Daily Plant Test Results	Core Data	Job Mix Tolerance	Daily Plant Test Results	Core Data	Job Mix Tolerance
Mix Bulk Specific Gravity	2.15	2.12	-	2.21	2.14	-
Asphalt Content	6.04	6.0	5.6 - 6.6	6.56	7.0	6.2 - 7.2
Percent Passing No. 200	5.54	6.2	3 - 7	5.75	6.6	3 - 7
Percent Passing No. 10	27.23	27	22 - 30	27.87	29	22 - 30

data that the asphalt content and the amount passing No. 10 sieve were high, but the amount passing No. 200 was reasonably within specifications.

Table 5 also indicates that the mix variables were ranging within a very wide band, indicating quality control problems during mixing (asphalt content, gradation) and during compaction (mix bulk specific gravity). This is corroborated by the ODOT inspector's report which noted that the contractor's quality control was nonexistent, production erratic and workmanship sloppy.

Consequently, the pavement quality was largely reduced. ODOT field tests for production control of the mix indicated that the pavement raveling and potholing are the result of inadequate asphalt coating of aggregate, excess variation in mix gradation and asphalt content and excess soft material contained in the aggregate.

3.0 TEST RESULTS - ODOT

The Oregon State Highway Division testing program included the conventional tests such as standard mix design for each mix variable, gradation, asphalt content, void percent compaction content and resilient modulus of pavement samples from five locations and recovered asphalt properties. This chapter presents the results of their work.

Mix Design Data

The results of the mix design tests are presented in Table 7. For each set of variables, standard samples were tested to determine mix characteristics. The percent voids of all samples prepared for this project were determined using the Rice gravities indicated on Table 7. Modulus and bulk specific gravities shown on this table were used as reference values during sample preparation at Oregon State University.

Core Data

Five core sampling sites were selected on the Castle Rock-Cedar Creek project. For each site, asphalt concrete cores were sampled across each panel at two foot intervals starting from the road centerline (See Appendix A for details). Table 8 summarize the results of the tests run on a total of 25 core samples. The mix density was low in both lifts which resulted in unusually high voids. The gradation limits shown for each aggregate size are minimum and maximum values. Shown on Figures 3 and 4 are the aggregate gradation for the surfacing and the base mixes, along with the job mix tolerances. Both mix gradations are out of specification below the No. 10 sieve size, with an excess amount of fines for both the top and the base layers. In both cases, the specified amount of passing No. 10 sieve has been respected. Above the No. 10 sieve size, the wearing surface gradation shows wide variability, with a tendency toward a fine gradation. Less variability can be noticed in the coarse part of the base gradation, which is within the specified gradation range. The excess amount of fines and the relatively finer gradation of the surface course can be partially explained by the presence of some soft materials in the mix aggregate.

Study of the cores also showed insufficient asphalt coating of the aggregate. From the inspection of the cores, it appears that the coarse aggregate is 40 to 95 percent coated. Tests run on the asphalt recovered from the mix

Table 7. Summary of OSHD Mix Designs for Variables Evaluated: Castle Rock - Cedar Creek

MIX TYPE	2% PASSING NO. 200			6% PASSING NO. 200			10% PASSING NO. 200			92% COMPACTION			88% COMPACTION		
Asphalt Content	5.0	6.0	7.0	5.0	6.0	7.0	5.0	6.0	7.0	5.0	6.0	7.0	5.0	6.0	7.0
Rice Grav. T 209	2.46	2.41	2.37	2.47	2.43	2.39	2.46	2.42	2.38	2.43	2.39	2.36	2.44	2.40	2.38
1st Bulk Spe. Grav.	2.17	2.19	2.21	2.23	2.27	2.29	2.24	2.28	2.30	2.08	2.10	2.12	2.05	2.07	2.08
Voids, %	11.8	9.1	6.8	9.7	6.6	4.2	8.9	5.8	3.4	14.4	12.1	10.2	16.0	13.8	12.6
2nd Bulk Spe. Grav.	2.23	2.27	2.31	2.32	2.35	2.37	2.30	2.35	2.37	-	-	-	-	-	-
Voids, %	9.3	5.8	2.5	6.1	3.3	0.8	6.5	2.9	0.4	-	-	-	-	-	-
Modulus x 10^3 psi	353	305	310	381	420	355	757	479	401	236	191	189	173	132	131
Stability 1st	37	39	34	32	34	31	40	32	26	25	25	24	24	20	22
Stability 2nd	49	49	47	44	51	34	55	45	28	-	-	-	-	-	-
Indi. Tens. Test: Dry	248	237	237	318	302	276	308	327	329	170	178	202	185	186	172
Indi. Tens. Test: Wet	127	143	170	160	196	231	157	224	257	111	154	170	124	168	161
Indi. Tens. Test: Index, %	51	60	72	50	65	84	51	69	78	65	87	84	67	90	94
P 200 Batched	-	1.6	-	-	4.8	-	-	8.0	-	-	-	-	-	-	-
P 200 Extracted	-	2.9	-	-	5.8	-	-	8.2	-	-	-	-	-	-	-
Asphalt Extracted	-	5.4	-	-	5.3	-	-	5.5	-	-	-	-	-	-	-