fines. It is believed that carbon fines increase the resistance of asphalt to the effects of water and temperature variation.

CONCLUSIONS

The conclusions for this study are summarized as follows:

1. Filler affects the mix properties to a large extent. The lower percentages of the filler in the mix, as specified by the ASTM E11, should be used.
2. Decreasing the percentage of filler in the mix and increasing compaction and asphalt content will decrease loss of stability.
3. Baghouse fines, if properly blended with filler, should reduce stability loss and affect the optimum asphalt content of the mix.
4. Increasing the percentage of baghouse fines will increase the viscosity, shear strength, and softening point of the mortar.
5. Presence of larger percentages of carbon in the baghouse fines will have a major effect on the performance of baghouse fines in the mix. This will decrease the stability loss of the mix and increase the optimum asphalt content.
6. Mixes that use approximately a 50/50 ratio of filler to baghouse fines are the optimum mixes.

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Effect of Mix Variations on Asphalt Pavement Life: North Oakland-Sutherlin Project

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An increase in construction and short-term pavement performance problems has been noted in the Pacific Northwest and throughout the United States during the past five years. Several reasons have been suggested by others to explain this sudden change, such as recent variations in asphalt properties and new developments in paving technology. By using the data and construction materials from projects built in 1978-1979, the Oregon Department of Transportation and Oregon State University initiated a laboratory study to determine the relationship between asphalt-concrete mix performance and mix compaction, asphalt content, and percent passing the 2-mm and 0.075-mm (Nos. 10 and 200) sieves. Conventional and dynamic tests were run on laboratory-compacted samples to determine mix stiffness, fatigue life, and permanent deformation characteristics. By using the fatigue data generated as an example, pay-adjustment factors were developed by comparing the performance of mixes prepared at the design optimum with that of mixes from specifications. It was found that fatigue life is primarily affected by the level of compaction of the mix. Test results indicate that there is an optimum asphalt content for fatigue and that gradation slightly affects fatigue life. The most critical pay-adjustment factors for fatigue are presented. Additional work is being completed to combine the fatigue and permanent deformation test results.

Several changes in highway materials and in asphalt paving technology have occurred in recent years. New asphalt sources have been developed that introduce changes in asphalt properties. New equipment has been developed that affects mixing (drum mixers, more efficient dust-collector systems), storage (mix storage silos), and compaction (vibratory compactors). In the same period, economic constraints have resulted in increased 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. The main changes observed and their expected influence on the mix behavior are summarized below:

Change Observed	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 reveling, reduced resistance to damage from water and freeze-thaw effects
Aggregate:	
Reduced quality	Increased raveling, reduced resistance to damage from water and freeze-thaw effects
Single stockpile, elimination of plant screens	Reduced uniformity of gradation, segregation
Equipment:	
Use of dust collector	Reduced uniformity of gradation, flushing
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
Use of drum mixers	Incomplete coating of aggregate

Figure 1. Flow chart of study.

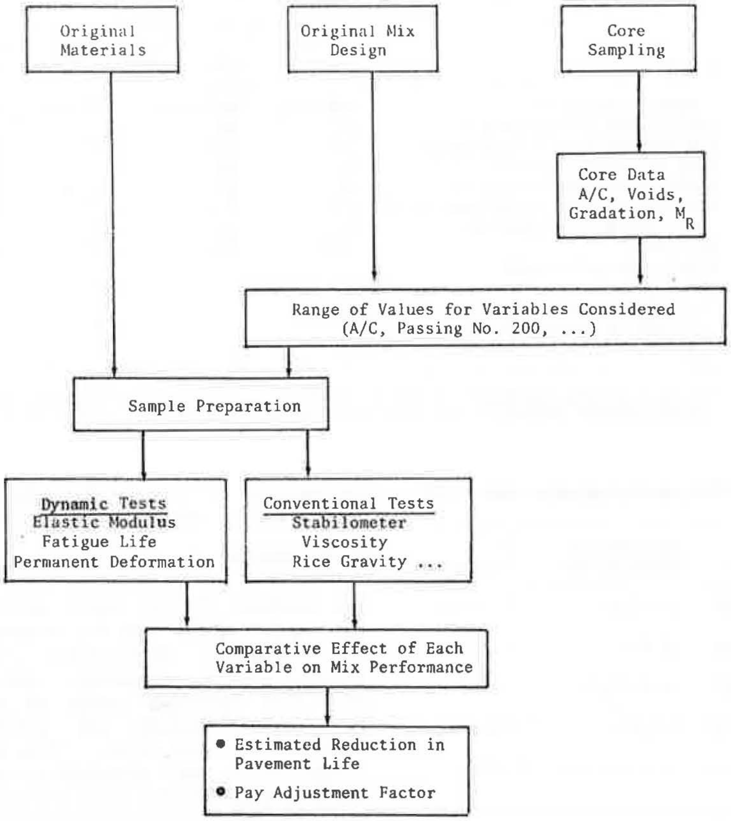
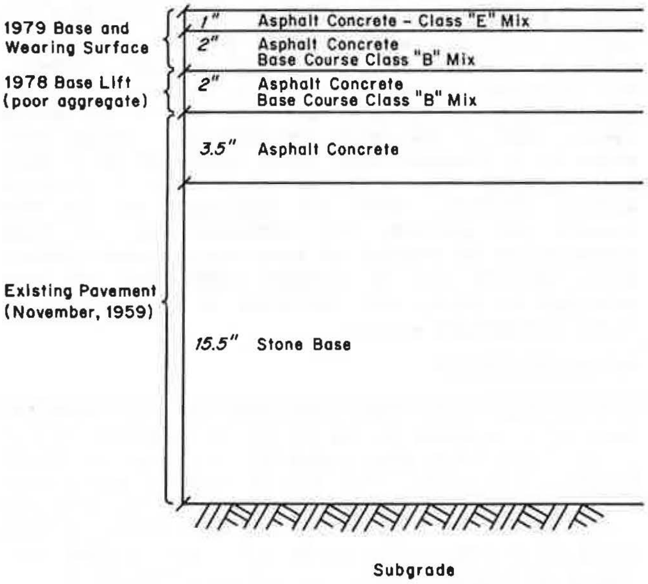


Figure 2. Pavement cross section.



Change Observed	Impact on Pavement
Mix storage silos and belly dump hauling equipment	Mix segregation from improper use

Three recently constructed paving projects in Oregon are being evaluated to develop an improved understanding of how mixture properties affect pavement performance. The paving project discussed in this paper is located on Interstate 5 between the North Oakland and Sutherlin Interchanges approximately 19 km (12 miles) north of Roseburg, Oregon. The overall project length is 5.1 km (3.2 miles).

The purpose of this paper is to obtain a better understanding of the causes of the pavement problems experienced in recent years and to develop relationships between mix performance and different mix variables. Such information should be useful in developing pay-adjustment factors for projects not complying fully with specifications. Figure 1 is a flowchart of the approach followed for the study of the North Oakland-Sutherlin Project.

PROJECT DESCRIPTION

Cross Section

The pavement cross section is shown in Figure 2. The original pavement, constructed in 1959, was composed of a 9-cm (3.5-in) asphalt concrete layer over a 39-cm (15.5-in) stone base layer. The new section of the pavement was built in 1978 and 1979. The 1978 lift was class B asphalt concrete base built with marginal-quality aggregate, which developed distress soon after construction. Patching of the first lift of base course was required prior to placement of the second 5-cm (2-in) lift of asphalt concrete in 1979. A 2.5-cm (1-in) class E open-graded friction course was placed as the final surface layer.

Mix Design

A summary of the mix design for the 1978 asphalt concrete base lift is presented in Table 1. To achieve an index of retained strength greater than 70 percent, 6.9 percent of an AR 8000 asphalt cement with 0.85 percent Pave Bond (antistrip agent) was recommended. The need for the antistrip agent was related to the quality of the aggregate. The aggregate soundness test (AASHTO T-104) indicated a per-

Table 1. Original mix design: results.

	Asphalt Content (AR 8000) (%)				
Property	5.5	6.0	6.5	7.0	7.5
Asphalt film thickness	Sufficient	Sufficient	Sufficient	Sufficient, thick	Thick
Stability value, first compaction	32	34	35	38	39
Bulk specific gravity, first compaction	2.23	2.25	2.27	2.29	2.31
Voids, first compaction (%)	11.2	9.6	8.1	6.5	4.9
Stability value, second compaction[a]	49	50	50	49	52
Bulk specific gravity, second compaction[a]	2.32	2.34	2.35	2.36	2.38
Voids, second compaction[a] (%)	7.6	6.0	4.9	3.7	2.1
Rice gravity	2.51	2.49	2.47	2.45	2.43
Index of retained strength					
AR 8000	11	–	20	–	45
AR 8000 + 1 percent Sucon	62	–	79	–	82
AR 8000 + 1 percent Pave Bond	64	–	81	–	84
AR 4000	16	–	25	–	53

[a] After each sample has been tested for stability and specific gravity, it is recompacted (by using the sample compaction effort) to simulate subsequent densification under traffic. The second compaction corresponds to the target density for field control.

Table 2. Summary of daily plant report, 1978 base lift, bituminous mix class B.

In-Place Mix Data	Avg Value	SD	Maximum and Minimum Values	Job-Mix Tolerance
Core bulk specific gravity	2.28 (24 tests)	±0.07	2.15-2.36	2.16 min
Asphalt content (% of total mix)	7.17 (72 tests)	±0.61	5.1-8.9	6.9 ± 0.5
Percent passing 2-mm sieve	25.66 (72 tests)	±3.55	16.00-35.00	25 ± 4
Percent passing 0.075-mm sieve	6.72 (72 tests)	±1.16	4.2-10.1	5.0 ± 2.0

Note: 1 mm = 0.04 in.

centage loss between 6.6 and 24.1 for the 10.1- to 6.4-mm (0.75- to 0.25-in) fraction and between 17.7 and 45.2 for the 6.4-mm minus fraction. The class B aggregate gradation for the asphalt concrete base course is given below (1 mm = 0.04 in):

	Percent Passing		
Sieve Size (mm)	Target Value	Mix Tolerance	Specification (broadband)
25	100	100	100
19	100	95-100	95-100
12.5	86	80-92	--
6.3	60	54-66	52-72
2	25	21-29	21-41
0.425	12	8-16	8-24
0.075	5.0	3.0-7.0	2-7

Construction Testing

Table 2 summarizes the results of field tests made during pavement construction. The variables considered are the mix bulk specific gravity, asphalt content, and percent passing the 2-mm and the 0.075-mm sieves (Nos. 10 and 200). It appears from the average field data that the asphalt content and the amount passing the 0.075-mm sieve were high and that the amount passing the 2-mm sieve and the specific gravity were within tolerance limits.

Table 2 also indicates that the mix variables ranged within a very wide band, which indicates quality-control variations during mixing (asphalt content, gradation) and during compaction (mix bulk specific gravity). Consequently, the mix quality was reduced. Oregon Department of Transportation (ODOT) field tests for production control of the mix indicated that the pavement deficiencies are mainly the result of an excess passing the 0.075-mm sieve and an excess amount of poor-quality aggregates. Based on past experience and specification requirements of various pavement structure components, ODOT recommended a 15 percent price reduction in the total cost of the mix and asphalt cement.

TEST PROGRAM

The purpose of the tests performed at Oregon State University (OSU) was to determine the fatigue life and permanent deformation characteristics of the asphalt mix in question. All tests were performed over the selected range of variables on standard laboratory samples by using the repeated-load indirect-tensile test. The samples were prepared according to ODOT standard procedures (2). Only the modulus and fatigue data are reported in this paper.

A minimum of 16 samples were prepared for each condition. Eight samples were tested as compacted, and eight samples were tested after conditioning (3). Figure 3 is the flowchart for the test program. The principal variables studied included (a) percent level of compaction, (b) percent passing the 0.075-mm sieve, and (c) percent asphalt content. Two secondary variables were also studied: percent passing the 2-mm sieve and use of an antistrip agent. Each of the above variables was studied relative to a standard mix, which consisted of 6 percent passing the 0.075-mm sieve and 6 percent asphalt content. When the influence of the mix density was studied, the reference mix was that compacted at 96 percent of laboratory second compaction, whereas the 92 percent compaction mix was selected to study the influence of the amount of fines and asphalt content.

Resilient Modulus

All modulus tests were performed in the diametral mode (4). Samples 10 cm (4 in) in diameter by 6.3 cm (2.5 in) high were prepared by using the Hveem kneading compactor. One set of samples was tested for modulus in the as-compacted state, whereas the other set was tested after vacuum saturation followed by a freeze-thaw cycle (3). All samples were tested at a load duration of 0.1 s, a frequency of 1 Hz, and a test temperature of 21°C ± 2°C (70°F ± 2°F).

Fatigue Life

Fatigue life is characterized by the number of load applications required to cause failure of the sample. Attempts to relate the number of load applications to the sample state of stress and strain showed that a strong correlation exists between the tensile strain and the number of load applications, according to the following model (5-10):

$$N_f = K_1(\epsilon_t)^{K_2} \quad (1)$$

Figure 3. Experimental test program.

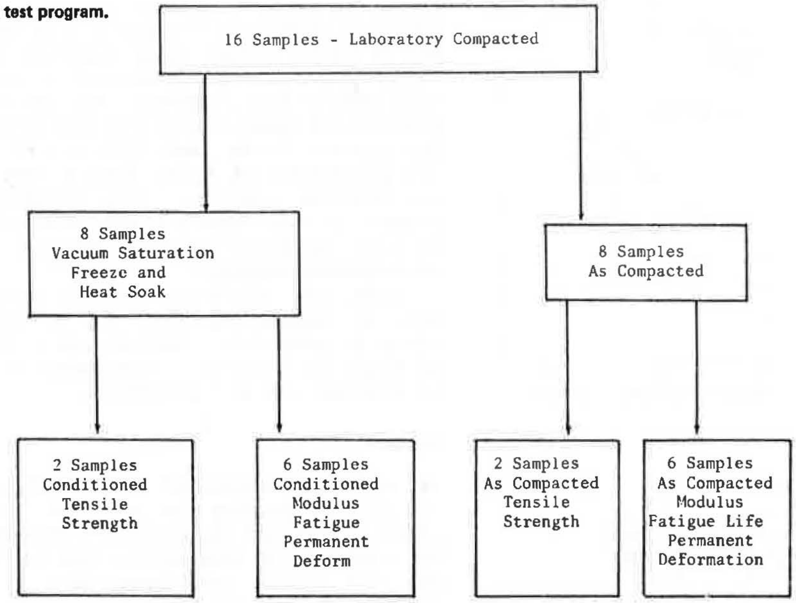
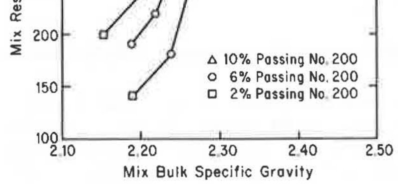


Table 3. Resilient-modulus data: as-compacted samples.

Level of Compaction (%)	Percent Passing 0.075-mm Sieve	Asphalt Content (%)	Resilient Modulus (psi)	Voids (%)	Bulk Specific Gravity
100	6	6	488 000	3.28	2.41
96	6	6	389 000	7.33	2.31
92	2	5	200 000	14.23	2.17
	2	7	143 000	10.46	2.19
	6	5	270 000	11.46	2.24
	6	6	220 000	10.85	2.22
	6	7	180 000	8.45	2.24
	10	5	381 000	10.47	2.27
	10	7	343 000	6.00	2.30
91	6	6	191 000	11.95	2.19

Note: 1 mm = 0.04 in.

Figure 4. Influence of bulk specific gravity on resilient modulus: as-compacted samples.



where

N_f = number of load repetitions to failure,
K_1, K_2 = regression constants, and
ϵ_t = initial tensile strain.

The fatigue life of a specific mix is therefore defined by the constants K_1 and K_2. For each set of mix variables, six samples were tested at different values of the initial tensile strain in the diametral test mode (test conditions were identical to those used for the modulus test). The number of load repetitions to failure was then measured and recorded. The constants K_1 and K_2 were determined by using linear regression by the method of least squares. The tensile strain ϵ_t is calculated from the following equation (4):

$$\epsilon_t = [(0.038\,96 + 0.1185\nu)/(0.0673 + 0.2494\nu)] \quad (2)$$

where ϵ_t is the horizontal elastic tensile strain and ν is Poisson's ratio. If we assume that Poisson's ratio is constant and equal to 0.35, Equation 2 becomes the following:

$$\epsilon_t = \Delta H \times 0.5203 \quad (3)$$

where H is the horizontal elastic tensile deformation in inches.

The number of load repetitions to fatigue failure was defined as that required to cause a vertical crack approximately 0.64 cm (0.25 in) wide in the sample. To stop the test at the specified level of deformation, a thin aluminum strip was attached to the sides of the samples along a plane perpendicular to that formed by the load platens. The aluminum strip was connected to a normally closed relay that controlled the dynamic-load system. As the sample deformed, the aluminum strip was stressed. When the sample deformation exceeded a certain level, the aluminum strip broke and opened the relay, which shut off the test. Proper calibration of the length of the aluminum strip caused the test to stop for a specific sample crack width.

TEST RESULTS

Resilient Modulus

The resilient-modulus data of the as-compacted samples are presented in Table 3. The influence of the bulk specific gravity on the mix resilient modulus, independent of the other variables, can be observed for the 6 percent asphalt content and the 6 percent passing the 0.075-mm sieve. Plotted in Figure 4, the relationship between modulus and bulk specific

Figure 5. Influence of amount of fines on resilient modulus: as-compacted samples.

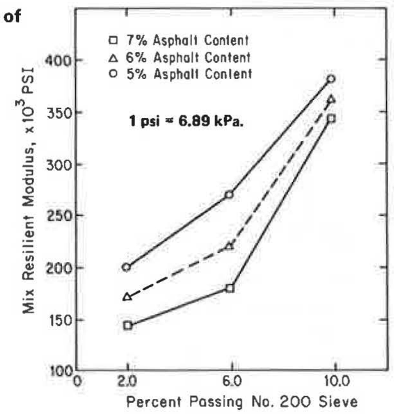


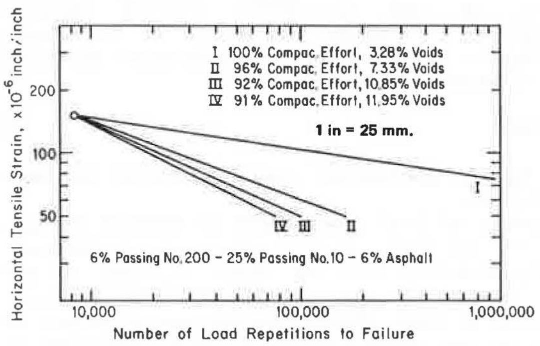
Table 4. Resilient-modulus data: conditioned samples.

Level of Compaction (%)	Percent Passing 0.075-mm Sieve	Asphalt Content (%)	Resilient Modulus (psi)	Retained Stiffness[a] (%)
100	6	6	435 000	89.1
96	6	6	214 000	55.0
92	2	5	93 000	46.5
	2	7	93 000	65.0
	6	5	136 000	50.4
	6	6	126 000	57.3
	6	7	103 000	57.2
	10	5	176 000	46.2
	10	7	279 000	81.3
91	6	6	109 000	57.3

Note: 1 mm = 0.04 in.

[a] (Conditioned modulus/as-compacted modulus) x 100.

Figure 6. Influence of mix density on fatigue life: as-compacted samples.



gravity appears to be almost linear and slightly affected by changes in asphalt content and percent passing the 0.075-mm sieve. The nonlinearity of the curves joining the points of equal asphalt content indicates the interaction of the asphalt content and fines on the mix stiffness. The resilient modulus increases at a rate of approximately 1120 Pa (160 000 psi) for each 0.1 increase in bulk specific gravity (or 6.2 lb of density).

Figure 5 illustrates the relation between the mix resilient modulus and the amount of fines at a constant level of compaction and 5, 6, and 7 percent asphalt content. The rapid increase in stiffness for an increasing percentage of fines is particularly important at higher percentages of asphalt content. The resilient modulus increases at a rate of approximately 175 Pa (25 000 psi) for each 1 percent increase in the 0.075-mm material.

Modulus values of conditioned samples are presented in Table 4 together with their percentage of retained stiffness (compared with as-compacted sample moduli). These data indicate that higher retained strengths are obtained at high asphalt content and/or mix density. The relationship between conditioned modulus and the mix bulk specific gravity appears to be less affected by asphalt content and percentage of fines than it was in the case of as-compacted samples. The resilient modulus increases at approximately the same rate for increases in bulk specific gravity as that given for the as-compacted samples.

Also, mix stiffness appears relatively independent of asphalt content for a low percentage of fines (2 percent). However, at a higher percentage of fines (10 percent), increasing amounts of asphalt do increase the mix stiffness.

Fatigue

The effect of degree of compaction, asphalt content, and percent passing the 2-mm and 0.075-mm sieves on fatigue life can be estimated directly by plotting, for each set of conditions, mix tensile strain versus the number of repetitions to failure. The level-of-compaction fatigue curves for 6 percent asphalt content and 6 percent passing the 0.075-mm sieve are presented in Figure 6 for the as-compacted samples. The as-compacted mix shows a substantial decrease in fatigue life as the mix level of compaction drops from 100 to 91 percent (a similar trend was found for the conditioned samples). The influence of the asphalt content on the as-compacted samples is illustrated in Figure 7. As indicated, asphalt content for unconditioned samples has very little influence on the fatigue life. Conditioned samples were more sensitive to changes in mix asphalt content in that the fatigue life increased with increases in asphalt content.

The influence of the percent passing the 0.075-mm sieve on the mix fatigue life is shown in Figures 8 and 9 for 5 and 7 percent asphalt content. These figures show the importance of the percentage of fines in the mix on fatigue performance. The fatigue life increases with increasing percent passing the 0.075-mm sieve, independent of the asphalt content. Conditioning the samples emphasizes the importance of the fines and indicates that a mix with 10 percent passing the 0.075-mm sieve performs better in the fatigue mode than a mix with 6 percent passing the 0.075-mm sieve (the higher percentage of fines, in this case, also results in a lower amount of air voids). The effect of increased fines on permanent deformation, however, is just the reverse. Figure 10 gives the effects of percent passing the 2-mm sieve. The as-compacted series clearly shows an optimum mix fatigue life for 25 percent passing the 2-mm sieve, as did the conditioned series.

DEVELOPMENT OF PAY-ADJUSTMENT FACTORS: FATIGUE BASIS

The testing program covered a wide range of mix variables. From this, it is possible to evaluate the reduction in pavement life when the design requirements are not satisfied. By using the mix that fulfills the design requirements as a reference mix, the fatigue life of mixes that do not meet specifications has been determined and compared with the standard mix fatigue life. The resulting ratios of fatigue lives have been used as an estimate of the corresponding pay factor.

The calculations were accomplished at three strain levels: 125, 100, and 50 με. Table 5 presents the estimated reduction in pavement life when the design mix density is not achieved. The reference mix is composed of 6 percent passing the 0.075-mm sieve, 25 percent passing the 2-mm sieve, and 6 percent asphalt content and is compacted at 96 percent of the laboratory second-compaction density. This standard mix is compared in Table 5 with mixes compacted at different levels (100, 92, and 91 percent compaction). The pay factors (defined as the ratio of the repetitions to failure for a mix when compared with the reference mix) shown in Table 5 indicate that the variations in mix density are extremely important for low strain values and less important for high strain values.

Table 6 shows pay factors for mixes with low and high asphalt contents. The reference mix is composed of 6 percent passing the 0.075-mm sieve, 25 percent passing the 2-mm sieve, and 6 percent asphalt and is compacted at 92 percent. The reference mix is fixed at 92 percent compaction because this is the minimum specified density required by ODOT. As the fatigue results indicate, the effects of a change in the asphalt content on fatigue life are less than that for density over the range of asphalt content studied.

The impact of the percentage of fines on fatigue life is shown in Table 7 for mixes containing 5 percent asphalt and for mixes containing 7 percent asphalt. Compared at 100 $\mu\epsilon$, the pay factors from Table 7 are relatively close, which tends to corroborate the fact that ±1 percent asphalt content does not make a substantial difference on the fatigue performance of the mix. However, the complex interaction between asphalt and fines substantially affects the fatigue life of the mix. Increasing the amount of fines from 2 to 10 percent increases the pay factor by approximately 3 points. This is due in part to the decrease in voids associated with the higher fines constant. However, when permanent deformation is considered, an increase in fines content will result in increased problems due to deformation.

Pay factors corresponding to different percentages passing the 2-mm sieve are presented in Table 8. Since compacted and conditioned results both indicate a reduction in pavement life when the percentage passing the 2-mm sieve is increased above optimum, results for 30 and 35 percent passing the 2-mm sieve are very similar.

Figure 7. Influence of asphalt content on fatigue life: as-compacted samples.

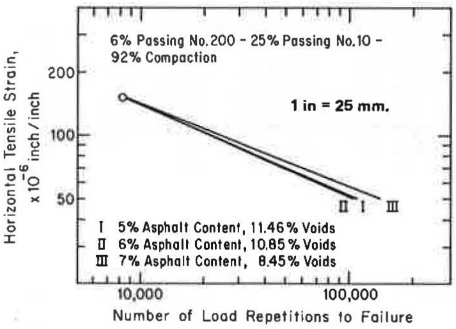


Figure 8. Influence of percent passing 0.075-mm sieve on fatigue life: as-compacted samples (5 percent asphalt content, 92 percent compaction).

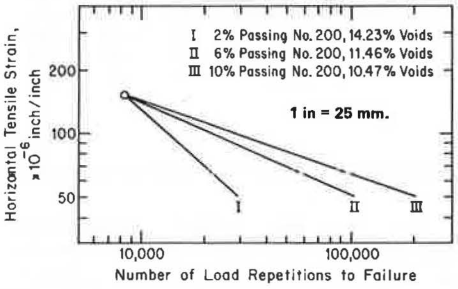


Figure 9. Influence of percent passing 0.075-mm sieve on fatigue life: as-compacted samples (7 percent asphalt content, 92 percent compaction).

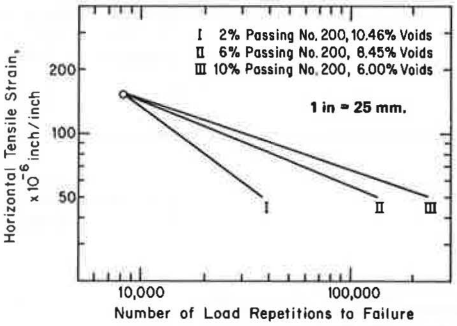


Figure 10. Influence of percent passing 2-mm sieve on fatigue life: as-compacted samples.

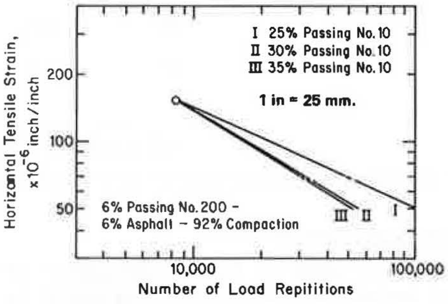


Table 5. Estimated pavement life and associated pay factors: four levels of mix density.

Level of Compaction (%)	Mix BSG	Test Condition[a]	Pavement Life: Strain Level ($\mu\epsilon$) 50	100	125	Pay Factor: Strain Level ($\mu\epsilon$) 50	100	125
Standard 96	2.31	B.C.	1.68×10^5	2.55×10^4	1.39×10^4	1.0	1.0	1.0
		A.C.	1.59×10^5	3.50×10^4	2.15×10^4	1.0	1.0	1.0
100	2.41	B.C.	1.37×10^7	1.29×10^5	2.86×10^4	8.5	5.06	2.06
		A.C.	6.80×10^5	7.75×10^4	3.97×10^4	3.91	2.21	1.84
92	2.22	B.C.	1.01×10^5	2.07×10^4	1.24×10^3	0.601	0.812	0.892
		A.C.	1.34×10^5	3.11×10^4	1.95×10^4	0.842	0.890	0.906
91	2.19	B.C.	7.91×10^4	1.94×10^4	1.23×10^4	0.471	0.761	0.885
		A.C.	2.80×10^4	1.26×10^4	9.76×10^3	0.177	0.361	0.456

[a] B.C. = before conditioning; A.C. = after conditioning.

Table 6. Estimated pavement life and associated pay factors: three levels of asphalt content.

Asphalt Content (%)	Mix BSG	Test Condition[a]	Pavement Life			Pay Factor		
			Strain Level ($\mu\epsilon$)			Strain Level ($\mu\epsilon$)		
			50	100	125	50	100	125
Standard 6	2.22	B.C.	1.01×10^5	2.07×10^4	1.24×10^4	1.0	1.0	1.0
		A.C.	1.34×10^5	3.11×10^4	1.95×10^4	1.0	1.0	1.0
5	2.24	B.C.	1.07×10^5	2.13×10^4	1.27×10^4	1.06	1.03	1.02
		A.C.	8.14×10^4	2.31×10^4	1.54×10^4	0.610	0.740	0.788
7	2.24	B.C.	1.40×10^5	2.39×10^4	1.35×10^4	1.39	1.16	1.09
		A.C.	1.53×10^5	3.34×10^4	2.05×10^4	1.14	1.07	1.05

[a] B.C. = before conditioning; A.C. = after conditioning.

Table 7. Estimated pavement life and associated pay factors for three levels of percent passing 0.075-mm sieve: 5 and 7 percent asphalt content.

Percent Passing 0.075-mm Sieve	Mix BSG	Test Condition[a]	Pavement Life			Pay Factor		
			Strain Level ($\mu\epsilon$)			Strain Level ($\mu\epsilon$)		
			50	100	125	50	100	125
5 Percent Asphalt Content								
Standard 6	2.24	B.C.	1.07×10^5	2.13×10^4	1.27×10^4	1	1	1
		A.C.	8.14×10^4	2.31×10^4	1.54×10^4	1	1	1
2	2.17	B.C.	2.90×10^4	1.31×10^4	1.01×10^4	0.272	0.612	0.794
		A.C.	1.08×10^4	7.16×10^3	6.27×10^3	0.133	0.311	0.493
10	2.27	B.C.	2.06×10^5	2.73×10^4	1.42×10^4	1.94	1.28	1.12
		A.C.	2.10×10^5	4.12×10^4	2.44×10^4	2.54	1.79	1.58
7 Percent Asphalt Content								
Standard 6	2.24	B.C.	1.40×10^5	2.39×10^4	1.35×10^4	1	1	1
		A.C.	1.53×10^5	3.34×10^4	2.05×10^4	1	1	1
2	2.19	B.C.	3.87×10^5	1.50×10^4	1.10×10^4	0.276	0.626	0.814
		A.C.	2.39×10^4	1.13×10^4	8.87×10^3	0.156	0.33	0.432
10	2.30	B.C.	3.94×10^5	4.66×10^4	2.34×10^4	2.81	1.95	1.73
		A.C.	4.38×10^5	6.24×10^4	3.33×10^4	2.87	1.87	1.62

Note: 1 mm = 0.04 in.

[a] B.C. = before conditioning; A.C. = after conditioning.

Table 8. Estimated pavement life and associated pay factors: three levels of percent passing 2-mm sieve.

Percent Passing 2-mm Sieve	Mix BSG	Test Condition[a]	Pavement Life			Pay Factor		
			Strain Level ($\mu\epsilon$)			Strain Level ($\mu\epsilon$)		
			50	100	125	50	100	125
Standard 25	2.22	B.C.	1.01×10^5	2.07×10^4	1.24×10^4	1.0	1.0	1.0
		A.C.	1.34×10^5	3.11×10^4	1.35×10^4	1.0	1.0	1.0
30	2.23	B.C.	5.50×10^4	1.67×10^4	1.14×10^4	0.55	0.81	0.92
		A.C.	2.23×10^4	1.09×10^4	8.67×10^3	0.17	0.35	0.45
35	2.21	B.C.	5.57×10^4	1.70×10^4	1.16×10^4	0.55	0.82	0.93
		A.C.	4.64×10^4	1.71×10^4	1.24×10^4	0.35	0.55	0.64

Note: 1 mm = 0.04 in.

[a] B.C. = before conditioning; A.C. = after conditioning.

CONCLUSIONS AND RECOMMENDATIONS

Performance of the mix used in the construction of the North Oakland-Sutherlin project was evaluated by dynamic testing of laboratory-compacted samples (11). Mix resilient modulus, fatigue life, and permanent deformation characteristics were determined for samples prepared within the following range of variables:

1. Mix level of compaction: 100, 96, 92, and 91 percent;
2. Asphalt content: 5, 6, and 7 percent;
3. Percentage of fines: 2, 6, and 10 percent; and
4. Percentage passing the 2-mm sieve: 25, 30, and 35 percent.

Conclusions

It was found that the mix level of compaction is the dominant factor for all mix dynamic properties. Increasing the mix density increases the mix stiffness and fatigue life. High mix density substantially reduces the damaging action of water and other environmental factors. A 1 percent change in asphalt content from the design optimum did not change the fatigue life of the mix significantly, but a slight increase in fatigue life was noted when the asphalt content was increased to 7 percent. Fatigue life improved substantially when the amount of fines was increased to 10 percent. The improved fatigue performance due to the higher percentage of fines may be related to the fact that the primary evaluation was conducted at a low level of compaction. Thus, the higher percentage of fines resulted in a lower amount of air voids. Increasing the amount passing the 2-mm sieve decreased the mix fatigue life slightly.

Based on fatigue curves, pay factors have been developed to show variations in mix performance resulting from changes in mix density, asphalt content, and percentage of fines. These data, shown in detail earlier, are summarized below. [The values presented were calculated for a mix tensile strain of 100 $\mu\varepsilon$. Laboratory test results indicated that fatigue life was generally shorter than permanent-deformation life. Therefore, the permanent-deformation pay factors are not included in this summary. Only the conditioned data have been considered in this summary, since conditioned data are assumed to more closely duplicate a cured-pavement condition. Pay factors developed at 2 and 10 percent passing the 0.075-mm sieve are the average pay factors calculated at 5 and 7 percent asphalt. The results corroborate earlier remarks that (a) lowering the mix density decreases the fatigue life and (b) fatigue life improves with increasing asphalt content.]

Variable	Pay Factor
Level of compaction (%)	
96	1.0
100	2.21
92	0.89
91	0.36
Asphalt content (%)	
6	1.0
5	0.74
7	1.07
Percentage of fines	
6	1.0
2	0.32
10	1.83
Percent passing 2-mm sieve	
25	1.0
30	0.35
35	0.55

Recommendations

The pay reduction used for this project was 15 percent based on ODOT experience. The results of the fatigue test should allow for a more realistic determination of the pay-adjustment factor. The results also indicate that control of density (or voids) should receive the highest priority. Work is now under way to finalize pay-adjustment factors by using the approach reported in this paper and by considering both fatigue and permanent-deformation data.

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