Characterization of Asphaltic Mixtures for Prediction of Pavement Performance

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ABSTRACT

Presented in this paper are the results of a test method chosen for characterization of asphaltic mixtures. Five pavement sections in different geographic locations of North Carolina were selected for this study. The layer materials from these pavement sections were characterized in the laboratory by subjecting specimens to a series of creep and dynamic load tests under environmental conditions representative of those experienced in the field. The characterization of asphaltic mixtures was done using the direct compression test and the diametral tension test. On the basis of the mechanical properties of the layer materials, the actual traffic volume, and the local environmental conditions, the performance of the pavement sections was predicted using the VESYS IIIA structural subsystem. The predicted performance parameters (rutting, cracking, and present serviceability index) were compared with the actual measured performance parameters. The performance predicted using the mechanical properties, as determined by the direct compression test, matched quite well with the actually measured performance. On the other hand, the input of the mechanical properties, as determined by diametral tension test, almost always overestimated the performance of the pavements.

During the last decade the state of the art in paving materials has seen a notable increase in the ability to accurately characterize materials needed in highways. These methods could be incorporated into a mechanistic design procedure, by which realistic predictions of pavement life in terms of distress, structural adequacy, and serviceability could be obtained. If this were achieved, optimum designs could be generated for new pavements and failures of pavements in service could be investigated by predicting their present performance.

One such design procedure is VESYS structural subsystem. The procedure is the result of various studies and the expenditure of many thousands of dollars by the FHWA. To use the predictive capability of this design procedure, the materials in multilayered systems have to be characterized with respect to expected field conditions. In VESYS structural subsystem the characterization of asphaltic mixtures involves the use of creep and dynamic load tests on cylindrical specimens to determine their mechanical properties. These properties are then used as input to the VESYS model to predict the pavement performance.

In recent years diametral testing has been gaining popularity among researchers. This is because the diametral test has advantages such as being relatively inexpensive and an easy and efficient method to use. It was thus considered plausible to examine the effect of characterization of asphaltic mixtures by diametral tests on the pavement performance.

RESEARCH APPROACH

To reduce the risk of unsatisfactory pavement performance to an unacceptable level, engineers must be able to reliably predict pavement behavior. Several methods for predicting such behavior, known as rational or mechanistic design procedures, are currently in use (1-4, unpublished interim VESYS III user's guide, June 1, 1979, and unpublished VESYS IV user's guide, May 15, 1981, ARE, Austin, Texas). On the basis of the mechanical properties of the layer materials, the anticipated traffic loads, and the local environmental conditions, this method predicts pavement behavior. The current simplified version, VESYS IIIA structural subsystem, was selected for use in this study. The inputs to this predictive model are

1. Geometry of the pavement system: the geometry requirement for the first (N-1) layers with the thickness of the Nth layer being infinite.
2. Traffic loadings: number of 18,000-lb equivalent axle loads per day, intensity, and duration of loads.
3. Temperature: average seasonal temperature and winter design temperature.
4. Material response properties: modulus of resilience and Poisson's ratio of every layer for every season; these properties are needed to calculate the stresses, strains, and deflection responses in a pavement system under the application of external loadings.
5. Material damage properties: fatigue coefficients of the surface layer and permanent deformation parameters of every layer; these coefficients and parameters together with the stress, strain, and deflection responses in the pavement system are used to estimate the pavement damage in terms of cracking, rutting, and roughness at various stages of its life.
6. Subgrade type.

It is well known that considerable variation exists in the properties of materials within in situ pavements. These variations exist because of variation in the materials during mixing and during laydown, compaction techniques, temperatures, and construction practices. These variations in material properties have significant effects on the behavior of the pavement throughout its service life because the probability of pavement distress increases with the variability of material properties.

The previously mentioned pavement performance prediction model is capable of considering the variability (uncertainty) of materials and construction procedures by using statistical estimates of the means and variances of the material properties expected to occur in the field. The outputs of the model are as follows:

1. Rutting,
2. Cracking index, and
3. Present serviceability index.

To measure the effectiveness of the model in predicting distress and performance of flexible pavements in service, a group of five pavement sections of primary roads in North Carolina was selected for analysis.

Field investigations were conducted of each selected pavement section. In situ density and moisture content, as well as the profile of every layer across the wheel path, were measured at distressed and undistressed locations. In addition, the present condition of the sections was rated using the pavement condition rating system (5), developed by the North Carolina Department of Transportation (NCDOT).

In the laboratory the mechanical properties of the pavement layer materials were determined by subjecting specimens of the materials to a series of laboratory load tests under environmental conditions similar to those experienced in the field. In the case of asphaltic mixtures, the tests were conducted on cylindrical as well as diametral specimens.

Computed output of distress in the form of rutting, cracking, and performance expressed in terms of the present serviceability index (PSI) was generated for comparison with actual measured values.

TABLE 1 Layer Thicknesses of Subsections (in.)

Layer Type	Section US-64 01	US-64 11	US-264 01	US-264 11	US-220 01	US-220 02	US-19A 01	US-19A 11	NC-213 01	NC-213 11
I-2	1.25	2.0	1.5	2.0	1.0	1.0	2.0	2.0	1.0	2.0
H	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	1.5	3.0
ABC	7.5	7.5	8.0	10.0	12.0	11.0	13.0	13.0	11.0	9.5
SSB	–	–	–	5.0	–	–	–	–	–	–

Note: I-2 = surface course, H = binder course, ABC = aggregate base course, and SSB = stabilized subbase course.

TEST SECTIONS

Five primary road sections in North Carolina were selected for study. These sections were chosen to represent a wide range in material properties, mix properties, subgrade types, base course thicknesses, traffic loadings, and environmental conditions.

To investigate why part of a section performed satisfactorily and another part of the same section performed unsatisfactorily, two test subsections were selected in each road. One of the subsections, denoted 01, represented a section with poor performance, and the other subsection, denoted 11, represented a section with relatively better performance. Where performance throughout a section was homogeneously poor, two subsections (01) and (02) were selected for the purpose of getting representative materials.

The actual layer thicknesses of each of the selected test subsections are given in Table 1.

Traffic Data

Design and actual average daily traffic (ADT) on each section and the percentages of actual and design truck traffic were obtained from NCDOT. The yearly average truck traffic was converted to an equivalent number of 18-kip single axle loads as given in Table 2.

Seasonal Pavement Temperature

It is important to establish, in terms of environmental data readily available, the average pavement temperature expected for the particular environment in which the pavement exists. Pavement temperature has been found to be a strong function of air temperature and of solar radiation as well as of other variables, but only air temperature is generally readily available. To estimate pavement temperatures for environmental zones of interest, the relationship between air temperature and pavement temperature is needed so that the pavement temperature can be predicted from air temperature for each environmental zone.

The Witczak approach (6,7) was used to determine from the mean air temperature (Ma) the mean pavement temperature (Mp) at the upper-third point of any layer, which would be indicative of the weighted average layer temperature.

The seasonal mean air temperature for every pave-

TABLE 2 Yearly Average Daily Number of Actual and Design Equivalent 18-Kip Axles

Year	US-64 Design	US-64 Actual	US-264 Design	US-264 Actual	US-220 Design	US-220 Actual	US-19A Design	US-19A Actual	NC-213 Design	NC-213 Actual
1971										
1972										
1973										
1974										
1975										
1976	117	198					105	83		
1977	123	209	151	181			107	71	21	18
1978	128	232	156	186			110	67	22	19
1979	133	306	161	191	156	300	114	66	23	24
1980	138	283	166	193	162	258	116	62	25	25
1981	144	300	171	200	169	272	120	65	26	26
1982	150	306	176	203	175	275	123	65	27	26
1983	155	311	181	205	182	286	126	65	29	26

TABLE 3 Seasonal Air and Pavement Average Temperature (degrees Fahrenheit)

	Summer		Fall		Winter		Spring	
Section	Ma	Mp	Ma	Mp	Ma	Mp	Ma	Mp
US-64	77	90	60	70	40	47	60	70
US-264	77	90	60	70	40	47	60	70
US-220	77	90	60	70	40	47	60	70
US-19A	72	85	55	65	35	41	55	65
NC-213	72	85	55	65	35	41	55	65

ment section and the corresponding seasonal mean pavement temperature are given in Table 3.

MATERIALS AND FABRICATION OF SAMPLES

Materials

All the sections considered in this study had two asphalt layers, an I-2-type asphalt surface course and an H-type binder course. The materials used for these asphaltic mixtures are described next.

All the bituminous layers of the road sections included in this study were built using AC-20 asphalt cement. According to the construction records, American Oil Company (AMOCO) was the main supplier of AC-20, Wilmington was the shipping point for the eastern and central regions of the state, and Atlanta, Georgia, and Chattanooga, Tennessee, were the shipping points for the western region of the state. Penetration, viscosity at 140°F, and viscosity at 275°F of AMOCO AC-20 for each shipping point are given in Table 4.

TABLE 4 Properties of Asphalt Cements

	Shipping Point		
Property	Wilmington, N.C.	Atlanta, Ga.	Chattanooga, Tenn.
Penetration at 77°F	67	73	70
Viscosity at 140°F (poise)	2150	1975	2050
Viscosity at 275°F	475	415	435

The sources, specific gravities, and mix formulas of the aggregates used in construction of the five pavement sections are given in Tables 5-8. The aggregates for each of the sections were first mixed together according to the mix formulas and then sieved to separate different size fractions. The coarser fractions (retained on No. 4 sieve) were washed and dried. All the different size fractions

TABLE 5 Type and Source of Aggregates Used in Bituminous Mixtures for US-64 and US-264[a]

Aggregate Type	Source	Specific Gravity
No. 67 stone	Neverson quarry	2.66
78m[b]	Neverson quarry	2.66
Screenings	Neverson quarry	2.66
Coarse sand	Whorton pit	2.65
Fine sand	Lewis pit	2.65

[a] Mix formulas (percentage by weight): I-2 = 30 78m + 31 screenings + 22 coarse sand + 17 fine sand; H = 50 No. 67 stone + 11 78m + 25 screenings + 14 fine sand.
[b] AASHTO M 43-82.

TABLE 6 Type and Source of Aggregates Used in Bituminous Mixtures for US-220[a]

Aggregate Type	Source	Specific Gravity
No. 67 stone	Rockingham quarry	2.74
78m[b]	Rockingham quarry	2.75
Screenings	Rockingham quarry	2.71
Sand	Jordan pit	2.66
Sand	Kellis pit	2.66

[a] Mix formulas (percentage by weight): I-2 = 33 78m + 29 screenings + 28 sand + 10 sand; H = 61 No. 67 + 17 screenings + 22 sand.
[b] AASHTO M 43-82.

TABLE 7 Type and Source of Aggregates Used in Bituminous Mixtures for US-19A[a]

Aggregate Type	Source	Specific Gravity
No. 67 stone	Dillsboro quarry	2.86
78m[b]	Dillsboro quarry	2.85
Screenings	Dillsboro quarry	2.8
Sand	Franklin, N.C.	2.56

[a] Mix formulas (percentage by weight): I-2 = 33 78m + 31 screenings + 36 sand; H = 60 No. 67 + 20 screenings + 20 sand.
[b] AASHTO M 43-82.

TABLE 8 Type and Source of Aggregates Used in Bituminous Mixtures for NC-213[a]

Aggregate Type	Source	Specific Gravity
No. 67 stone	Riverside quarry	2.70
78m[b]	Riverside quarry	2.70
Sand	Riverside quarry	2.70
Screenings	Enka, N.C.	2.60

[a] Mix formulas (percentage by weight): I-2 = 30 78m + 30 screenings + 40 sand; H = 58 No. 67 + 22 screenings + 20 sand.
[b] AASHTO M 43-82.

of the aggregates were stored in separate containers. Table 9 gives the gradations that were used in making the laboratory samples of bituminous mixtures.

Fabrication of Samples

The diametral specimens of bituminous mixtures were 4 in. in diameter and 2.5 in. in height and were compacted in accordance with the Marshall method of mix design (8). The cylindrical specimens were 4 in. in diameter by 8 in. in height and were compacted in several layers in 4-in. by 9-in. molds. Each layer was prepared for compaction in accordance with the procedure outlined by the Asphalt Institute (8).

To draw meaningful conclusions from the test results, it was essential to prepare the Marshall specimens and cylindrical specimens with the same densities. Efforts were thus made to obtain densities of cylindrical specimens similar to those of the Marshall specimens. Numerous variations of sample preparation were tried in order to develop a procedure that would produce required densities in the compacted cylindrical specimens.

A series of trials led to the development of a procedure that is capable of producing quite homogeneous specimens. In this procedure, every cylindrical specimen consisted of four unequal layers. The sequence of weights, starting from the bottom layer, was 1200, 1000, 800, and 600 g, respectively. The

TABLE 9 Gradations of Aggregates and Asphalt Content in Bituminous Mixtures

	Percentage Passing for Section									
	US-64		US-264		US-220		US-19A		NC-213	
	I-2	H	I-2	H	I-2	H	I-2	H	I-2	H
Percentage asphalt	6.5	4.7	6.3	4.7	6.4	5.2	6.5	5.2	6.5	5.3
Sieve size										
1½ in.	100	100	100	100	100	100	100	100	100	100
1 in.	100	100	100	100	100	100	100	100	100	100
½ in.	100	77	100	77	100	75	100	78	100	77
No. 4	77	54	77	54	77	54	78	54	82	54
No. 8	65	39	65	39	65	39	60	37	65	37
No. 40	39	21	39	21	40	20	32	20	32	20
No. 80	15	12	15	12	12	12	13	12	13	12
No. 200	5.1	3.1	5.1	3.1	5	3	5	4	5	3

number of blows on each layer, starting from the bottom, was 55, 70, 75, and 80, respectively.

EXPERIMENTAL SETUP AND TESTING PROCEDURES

Experimental Setup

Temperature Control System

Specimens made from bituminous mixtures were tested in the high-low temperature chamber manufactured by Blue M Electric Company. The inside dimensions of the test chamber were 2 ft x 2 ft x 2 ft. The temperature in the chamber was controlled by two switches, a cooling switch and a cooling capacity switch, and a master calibrating cam. The temperature in the chamber could be controlled from -100°F to +200°F. The temperature control using this equipment was found to be quite efficient and showed the capability of maintaining plus or minus one degree for a sufficient period of time.

Temperature Monitoring of Specimens

To sense the temperature at the geometric center of the specimen, an OMEGA Linear Response Thermistor Composite was used. This device is a digital thermistor thermometer that has two probes, A and B. Probe A was inserted in a drilled hole in a dummy specimen of the same size and shape as the test specimens, and Probe B was hung in the controlled temperature chamber. The specimens to be tested were conditioned in the testing chamber along with the dummy specimen. The temperature of the specimen and the chamber could be monitored by switching to Probe A or to Probe B. Equilibrium between the two probes indicated that the test specimens were ready for testing.

Resilient Modulus Test Equipment

The diametral resilient modulus test proposed by Schmidt (9) was modified slightly and used in this study for testing creep, permanent deformation, resilient modulus, and fatigue properties of diametral specimens. The original equipment consisted mainly of a loading frame, a diaphragm air cylinder, a load cell, a solenoid valve system, a surge tank, a pressure regulator, two statham UC-3 transducers, an electronic readout, a yoke, an alignment stand, and a compressed air source.

The modifications included replacing the two statham UC-3 transducers by a pair of linear variable differential transducers (LVDTs), which had a deformation measurement capacity range of ±0.25 in. A two-channel chart recorder was connected to the equipment for plotting the output voltage of the two LVDTs; the electronic readout was used only for load monitoring and load duration selection. The horizontal deformation of the diametral specimens was measured by the two LVDTs and was plotted on the chart.

Modified Resilient Modulus Test Equipment

The modified resilient modulus test equipment was used in this study for conducting creep, permanent deformation, and resilient modulus tests on cylindrical specimens of bituminous mixtures in a direct compression mode.

The setup of modified resilient modulus test equipment involved the following two main modifications in the original resilient modulus test equipment:

1. The loading frame was replaced with a taller one that could accommodate a specimen 4 in. in diameter and 8 in. in height.
2. The LVDT holder was replaced by a specially designed holder that could hold the LVDTs vertically for measuring vertical deformation.

Testing Procedures

Creep, permanent deformation, and resilient modulus of the asphaltic mixtures were determined by testing diametral specimens in indirect tension mode and cylindrical specimens in direct compression mode. The fatigue properties of the mixtures were determined by testing only the diametral specimens in indirect tension mode. The details of the testing procedures are given elsewhere (10).

EXPERIMENTAL RESULTS AND ANALYSIS

Stiffness (creep modulus)

Master curves for bituminous mixtures in all the pavement sections were generated from the direct compression and indirect tension creep test measurements made for the 1000-sec loading time. As mentioned earlier, asphalt concrete materials are considered to be thermorheologically simple. Thermorheological simplicity is the ability to generate a master curve by shifting horizontally the individual isothermal stiffness curves at each temperature along the log-log time axis to a reference temperature. The master curves for the bituminous layers of US-64 are shown in Figures 1 and 2. Similar master

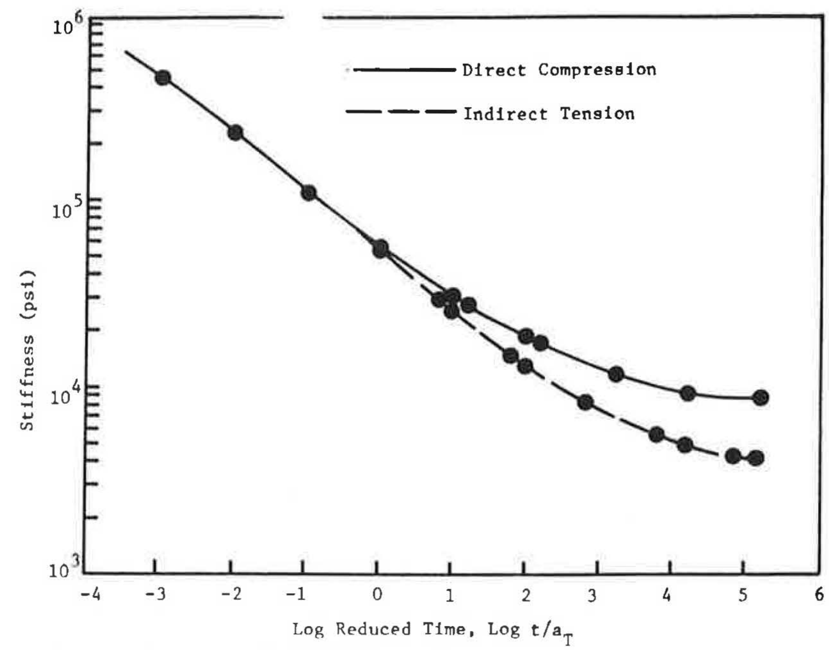

FIGURE 1 Master curve for US-64 (Layer 1).

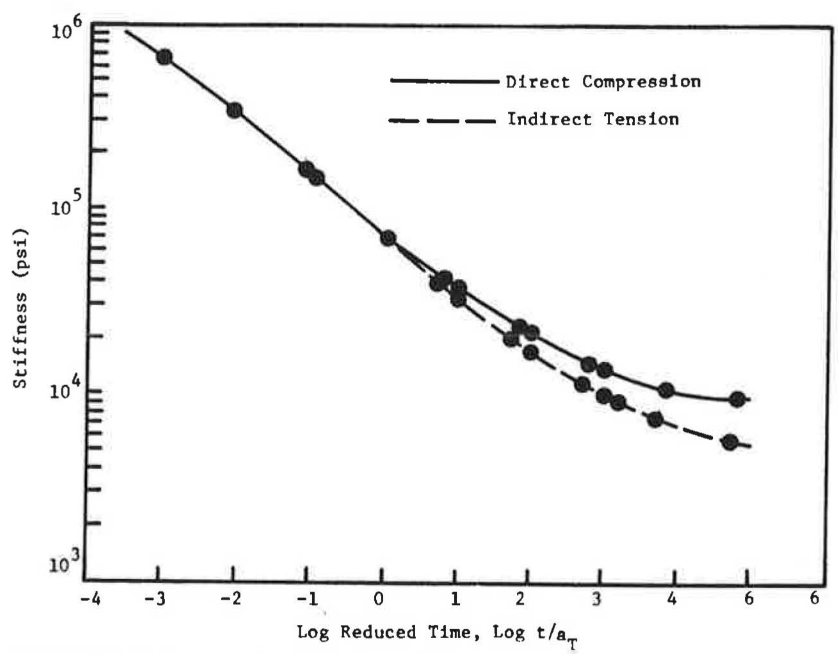

FIGURE 2 Master curve for US-64 (Layer 2).

curves were prepared for other pavement sections (10).

With a master curve of stiffness versus reduced time, plus the shift factor relationship, the stiffness values for any loading time and temperature desired can be quickly obtained. The effects of duration of loading, temperature, and method of testing on the stiffness of bituminous mixtures employed for US-64 are shown in Figures 3 and 4. Similar data for bituminous mixtures for other sections are presented elsewhere (10).

The data show no disagreement between stiffness values, measured by both testing methods, at low temperatures or at short duration of loading, or both. This difference becomes more evident as the temperature or duration of loading, or both, increase. Furthermore, it is evident from the data that indirect tension test results are more sensitive to temperature and duration of loading than are direct compression test results.

Resilient Modulus

The resilient modulus of the bituminous mixtures representing the bituminous layers in service was also determined by two test methods: direct compression and indirect tension. A duration of loading of 0.05 sec was used in the resilient modulus tests.

The test data showed no significant difference

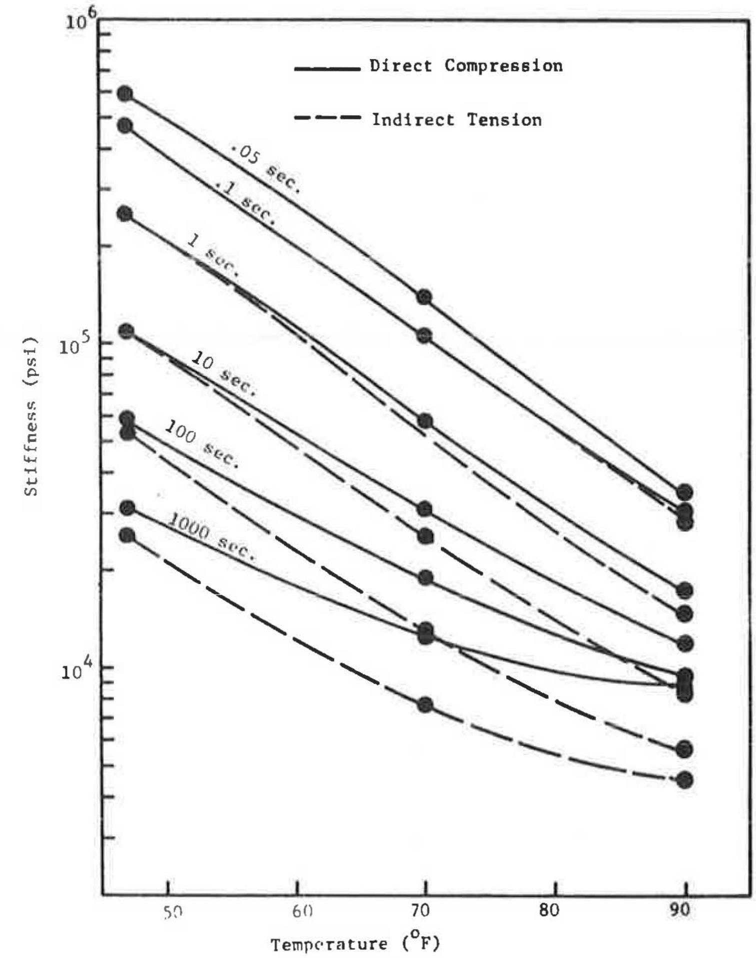

FIGURE 3 Stiffness values for US-64 (Layer 1) using different test methods.

between the resilient modulus values as determined by the two test methods. The average resilient modulus values at the average temperature of each of the four seasons are given in Table 10.

Permanent Deformation Parameters

Permanent deformation tests were performed for each layer at the same stress levels as were the creep tests. Permanent deformation parameters (μ and α) were determined from the incremental creep tests using direct compression and indirect tension tests. The calculated values of μ and α were used as input values in VESYS computer program. Permanent deformation parameters of the layers of all the sections included in this study are given in Tables 11 and 12.

Fatigue Coefficients

The fatigue curves of the lowermost bituminous layer in every section were obtained by plotting the initial tensile strain (ε_r) versus the number of cycles to failure (N_f). The fatigue loading included a 0.05-sec loading period and a 2.95-sec unloading period. To produce a wide range in fatigue life, various initial strain levels were applied to the test specimens. The fatigue tests were conducted at 70°F.

Fatigue life predicted from laboratory test data is usually considerably less than that experienced in the field. This is because laboratory tests do not take into account a number of important factors such as healing of the pavement between stress applications; rest time between stresses; variability in the position of the load within the wheelpath, which results in a reduction of stress due to the passage of a certain number of vehicles; and so forth.

It has been suggested that field fatigue curves can be approximated from laboratory curves by using a horizontal shift. The ratio of load applications in the field to those in the laboratory is termed the shift factor. Finn has suggested a shift factor of 13.03 (11). That is,

$$N_{field} = 13.03\ N_{lab}$$

In this study field fatigue curves were approximated from laboratory curves by using the shift factor. From the shifted fatigue curves, the values of K_1 and K_2 were calculated and are given in Table 13. These fatigue coefficients were used as input values in the performance prediction program for predicting alligator cracking.

Properties of Granular Base Course and Subgrade Soil

To predict the performance of the pavement sections included in this study, the characteristic seasonal

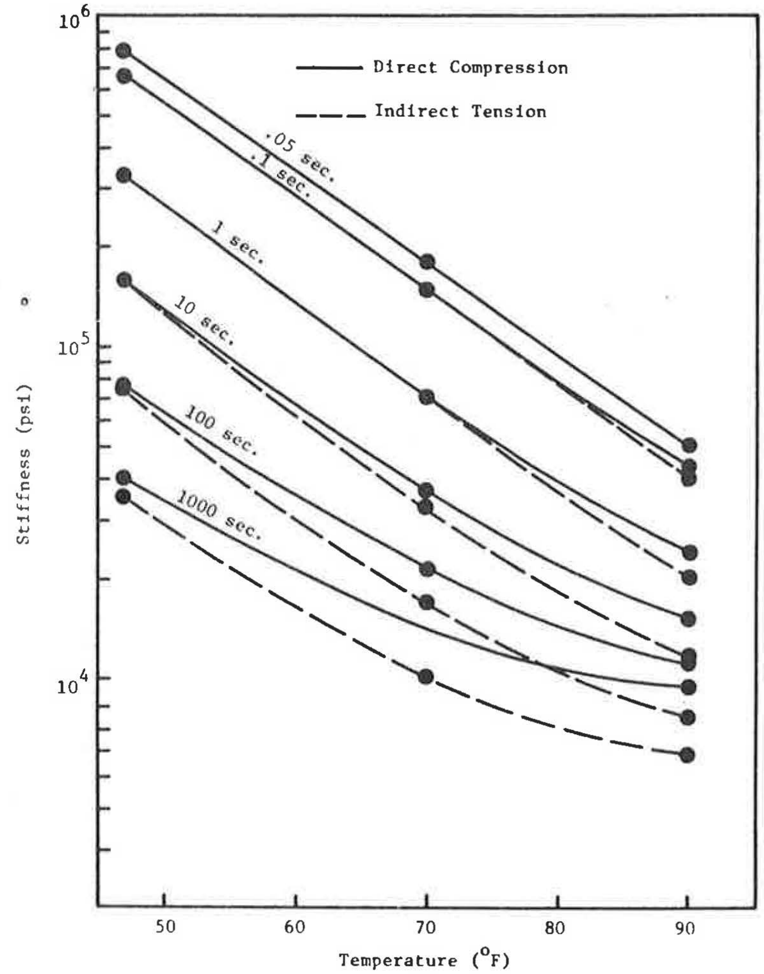

FIGURE 4 Stiffness values for US-64 (Layer 2) using different test methods.

TABLE 10 Seasonal Resilient Moduli for Bituminous Layers

		Seasonal Resilient Modulus (psi)			
Section	Layer	Winter	Spring	Summer	Fall
US-64	1	485,000	110,000	31,500	110,000
	2	750,000	150,000	50,000	150,000
US-264	1	485,000	110,000	31,500	110,000
	2	750,000	150,000	50,000	150,000
US-220	1	485,000	110,000	31,000	110,000
	2	735,000	145,000	48,000	145,000
US-19A	1	580,000	135,000	40,000	135,000
	2	850,000	180,000	57,000	180,000
NC-213	1	550,000	125,000	35,000	125,000
	2	800,000	170,000	55,000	170,000

properties of all the layer materials are required to be used as input to the VESYS predictive model. The properties of the base courses and subgrade soils were determined by triaxial tests in the laboratory and are described elsewhere (10).

COMPARISON OF PREDICTED AND MEASURED PERFORMANCE

The VESYS IIIA structural subsystem was used to predict performance of the pavement sections. The performance was predicted in terms of three distress parameters, rutting, cracking, and the present serviceability index.

Rut Depth

Rut depth is a measure of the permanent deformation in the wheelpath created by traffic loads. Rut depths were measured using a 5-ft (1.524-m) straightedge and an adjustable scale. Several measurements of rut depths were taken in the vicinity of each test location and the average values were recorded.

In the rut depth model, rutting is primarily a function of the laboratory-determined permanent deformation characteristics and stiffness of the materials in pavement layers and of truck traffic volume. Furthermore, the values of the mechanical properties of asphaltic mixtures vary with different test methods. The predicted and measured rut depth values are given in Table 14.

It is evident from the test data in Table 14 that the input of the material properties as determined by the direct compression tests produced more accurate rut depth predictions than were obtained by using diametral (indirect tension) test properties. The use of diametral test properties in the predictive model resulted in overestimation of the predicted rut depths.

The effect of truck traffic on the predicted and measured rut depths is also quite evident from the data in Table 14. In cases where actual truck traf-

TABLE 11 Seasonal Permanent Deformation Parameters for Bituminous Layers—Direct Compression Method

		Winter		Spring		Summer		Fall	
Section	Layer	μ	α	μ	α	μ	α	μ	α
US-64	1	.402	.42	.052	.57	.048	.704	.052	.57
	2	.045	.50	.064	.64	.038	.69	.064	.64
US-264	1	.042	.42	.052	.57	.048	.704	.052	.55
	2	.045	.50	.064	.64	.038	.69	.064	.64
US-220	1	.042	.42	.052	.56	.048	.70	.052	.56
	2	.045	.50	.064	.638	.0375	.695	.064	.638
US-19A	1	.02	.34	.065	.604	.057	.71	.065	.604
	2	.007	.24	.05	.61	.04	.67	.05	.61
NC-213	1	.017	.30	.043	.58	.058	.73	.043	.58
	2	.009	.26	.07	.61	.0586	.72	.07	.61

TABLE 12 Seasonal Permanent Deformation Parameters for Bituminous Layers—Indirect Tension Method

		Winter		Spring		Summer		Fall	
Section	Layer	μ	α	μ	α	μ	α	μ	α
US-64	1	.05	.45	.12	.53	.08	.60	.12	.53
	2	.055	.52	.13	.59	.08	.67	.13	.59
US-264	1	.05	.45	.12	.53	.08	.60	.12	.53
	2	.055	.52	.13	.59	.08	.67	.13	.59
US-220	1	.049	.455	.12	.53	.081	.605	.12	.53
	2	.056	.53	.131	.595	.0815	.668	.131	.595
US-19A	1	.0242	.3535	.17	.56	.12	.65	.17	.56
	2	.013	.29	.059	.533	.04	.67	.059	.533
NC-213	1	.0216	.326	.26	.60	.0855	.556	.26	.60
	2	.02	.28	.15	.57	.116	.69	.15	.57

TABLE 13 Fatigue Coefficients

	Fatigue Coefficients at 70°F	
Section	K_1	K_2
US-64	0.170×10^{-12}	5.625
US-264	0.170×10^{-12}	5.625
US-220	0.375×10^{-12}	5.50
US-19A	0.675×10^{-12}	5.35
NC-213	0.590×10^{-12}	5.30

fic was more than design truck traffic, it resulted in an increased rut depth.

Fatigue Cracking

The predicted cracking index using the VESYS IIIA program is an indicator of the expected fatigue cracking. The present predicted cracking indexes, as well as the measured cracking severities for the 10 subsections, are given in Table 15. The predicted values are mainly a function of fatigue curve parameters K_1 and K_2, primary response properties,

TABLE 14 Predicted and Measured Rut Depths

		Predicted Rut Depths (in.)				Measured Values of Actual Truck Traffic
		Truck Traffic		Test Methods[a]		
Section	Subsection	Actual	Design	Direct Compression	Indirect Tension	
US-64	01	0.840	0.78	0.840	1.33	0.80
	11	0.36	0.33	0.36	0.75	0.35
US-264	01	0.55	0.50	0.55	1.05	0.65
	11	0.27	0.25	0.27	0.57	0.25
US-220	01	0.725	0.59	0.725	0.98	0.75
	02	0.52	0.436	0.52	0.76	0.60
US-19A	01	0.45	0.595	0.45	0.59	0.50
	11	0.22	0.25	0.22	0.37	0.25
NC-213	01	0.38	0.38	0.38	0.55	0.40
	11	0.27	0.27	0.27	0.40	0.25

[a] For actual truck traffic.

TABLE 15 Predicted and Measured Cracking Index

		Predicted Cracking Index for Truck Traffic		
Section	Subsection	Actual	Design	Measured Values of Cracking Index for Actual Truck Traffic
US-64	01	3.74	1.9	Severe
	11	1.33	0.687	Slight
US-264	01	1.82	1.642	Slight to moderate
	11	0.59	0.51	None
US-220	01	1.04	0.63	Slight
	02	1.15	0.69	Slight
US-19A	01	1.12	1.85	Sight to moderate
	11	0.93	1.71	Slight
NC-213	01	1.65	1.75	Slight to moderate
	11	0.42	0.45	None

traffic loading, pavement temperature variations, and layer thicknesses. The cracking index is a dimensionless parameter, which estimates the occurrence of fatigue cracking, for which a value of one corresponds to the time when the cracks are just initiated at the bottom of the bituminous layer.

It can be seen from the data presented in Table 15 that traffic loading was the major factor affecting the cracking index values for the sections included in this study.

Present Serviceability Index

The present serviceability index (PSI) gives an indication of the rideability of pavement in relation to present pavement condition. The mean serviceability index at time zero was assigned a value of 4.5 and the terminal serviceability index was assigned a value of 2.5.

For given conditions of a subgrade soil and base course, the PSI is a function of the testing method used for bituminous mixtures and of truck traffic. The predicted and measured PSI values are summarized in Table 16, in which it can be seen that the PSI was significantly affected by traffic loading and that the measured PSI values were closely predicted using the direct compression method and overestimated using the indirect tension method.

TABLE 16 Predicted and Measured Present Serviceability Index

		Predicted Values of PSI				Measured Values of PSI (actual truck traffic)
		Truck Traffic		Test Methods[a]		
Section	Subsection	Actual	Design	Direct Compression	Indirect Tension	
US-64	01	1.50	1.75	1.50	0.5	1.25
	11	3.40	3.85	3.40	2.0	3.20
US-264	01	2.50	2.60	2.50	0.70	2.25
	11	4.05	4.06	4.05	3.0	4.10
US-220	01	2.20	2.91	2.20	1.15	2.50
	02	2.90	3.41	2.90	2.0	2.50
US-19A	01	3.10	2.80	3.10	2.40	2.90
	11	3.95	3.75	3.95	3.50	4.00
NC-213	01	3.30	3.33	3.30	2.70	3.10
	11	3.85	3.85	3.85	3.40	3.75

[a] For actual truck traffic.

CONCLUSIONS

Within the limits of this study, the following principal conclusions can be drawn:

1. There is no disagreement between stiffness values, measured by direct compression test and diametral test, at low temperatures or at short duration of loading, or both. This difference becomes more evident as the temperature or duration of loading, or both, increase.

2. The diametral test results are more sensitive to temperature and duration of loading than are those of the direct compression test.

3. The choice of test method for the characterization of asphaltic mixtures has a pronounced effect on predicted performance. The findings of this study indicate that the performance predicted using mechanical properties, as determined by direct compression test, matched quite well with the actually measured performance. On the other hand, the input of mechanical properties, as determined by diametral tension test, almost always overestimated the performance of the pavements.

4. The VESYS IIIA structural subsystem predicts the performance of pavements accurately. Thus it has the potential for providing optimum thickness design for pavements in order to mitigate distresses and maintain adequate serviceability during design life.

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