Effect of Thickness and Temperature Corrections on Prediction of Pavement Structural Capacity Using Falling Weight Deflectometer Data

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Deflection measurements are commonly used for evaluating the structural capacity of pavements. Prediction of pavement performance from these measurements requires estimating the modulus of the pavement layers through backcalculation, estimating the critical response parameters, and using limiting criteria for determining the life of the pavement. In addition to the deflection data, the thickness of the pavement layers must be known, and the type of layer materials is used as a guide in the selection of the moduli values. The influence of two variables on the performance predictions generated in the pavement evaluation process were studied. These variables are the thicknesses of the pavement layers and the temperature correction factor used to adjust the modulus of bituminous materials from the test temperature to a standard temperature. The study demonstrated that for thick pavement structures, compensating effects of the analysis procedure make the prediction of pavement performance relatively insensitive to the thicknesses used in the analysis. Criteria are presented for the need for coring of the pavement structure on the basis of the variability of the thicknesses as recorded in construction quality control tests. On the other hand, the performance predictions are very sensitive to the temperature correction factor as presented in the AASHTO *Guide for Design of Pavement Structures*. The test procedures used to establish the temperature sensitivity of the asphalt concrete modulus in the laboratory may overestimate the sensitivity of the asphalt in field conditions. This is an area requiring further research.

Nondestructive testing (NDT) for deflection measurement is now widely recognized as an important tool for pavement structural evaluation. State-of-the-art NDT evaluation measures a pavement's deflection response to a known load. The load generated by an NDT device may be static (Benkelman beam), steady-state vibratory (Dynaflect and Road Rater), or impulse [falling weight deflectometers (FWDs)]. Although surface deflection data analysis is a matter of continuing research, nondestructive testing for measuring surface deflection is accepted by most highway agencies as a standard practice for the advantages of being fast and reliable in most of the cases. The new AASHTO *Guide for Design of Pavement Structures* (*1*) recommends the use of "dynamic" NDT deflection measuring devices for surface deflection measurements. With deflection testing, a thorough evaluation pavement response can be obtained by closely spacing test sites.

The deflections measured with NDT are used to estimate the moduli of pavement layers. The pavement is modeled by a suitable approach such as linear elastic theory, or linear or nonlinear finite element methods. Moduli estimates are determined with a "backcalculation" technique. For the test load-pavement combination, computed deflections are compared with measured deflections. The moduli of the layers are varied until the computed and measured deflections are approximately equal. The surface layer and other asphaltic layer moduli thus obtained are modified to take into account the temperature at the time of testing. These moduli are then used to compute the effective structural capacity of the pavement according to a pavement design procedure such as the AASHTO guide (*1*).

The FWD employs a mass falling onto a buffered circular load plate. Developed in Europe, FWDs have become popular in the United States. The load pulse shape of FWDs simulates traffic loads better than other deflection devices (*2,3*). FWDs can transmit relatively heavy loads to the pavements compared with the other deflection testing devices. Usually the load range is 1,500 to 35,000 lb, depending on the FWD model. The magnitude of the dropping mass and drop height are altered to change the applied load levels. The FWD has a small preload, 3 to 14 per cent of the maximum load. The applied load is measured by a load cell. The load pulse is approximately of a half sine waveform with a duration of 30 to 40 msec.

The Dynatest FWD uses velocity transducers to measure the peak deflection under the load and at several locations away from the load. The sensors are mounted on a bar that is automatically lowered with the loading plate. Measured deflections can be plotted as deflection basins.

The Arizona Department of Transportation (ADOT) purchased a Dynatest Model 8000 FWD unit in 1982 and updated it in 1987. The operating sequence of the Dynatest FWD is fully automated. The load is applied by a single falling mass. Factory-calibrated geophones register the peak deflections from an applied load. The load range is from 1,500 to 27,000 lb.

PROBLEM DEFINITION

Calculating the pavement structural capacity in terms of the ability to carry 18-kip equivalent single axle load (ESAL)

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repetitions from FWD data is a three-step procedure. First, the layer moduli are backcalculated from the FWD, layer type, and thickness data. Second, the critical pavement response, usually the tensile strain at the bottom of the asphalt concrete (AC) layer, is calculated. Finally, empirical relationships are used for estimating the number of 18-kip ESALs on the basis of the critical pavement response. The relationship estimates the number of 18-kip ESAL repetitions the pavement can carry before fatigue failure. Evidently, the variability in layer thickness affects the estimation of structural capacity by the mechanistic-empirical method.

OBJECTIVES

This paper reports the study to determine the coring needs to extract thickness information about pavement cross sections at FWD test points on existing pavements. The effect of the temperature correction factor for asphaltic layer moduli on the estimated structural capacity was also examined.

DATA COLLECTION

Table 1 lists the sites selected in this study, and Table 2 shows the pavement sections of these sites. All deflection data were collected with a Dynatest Model 8000 FWD. The deflection sensors were spaced at 12-in. intervals, with the first sensor located at the center of the load. The target load was 9,000 lb. At Sites 1 through 3, deflections were measured in the outer wheel path at 10 locations spaced at 10-ft intervals. For Site 4, deflection data were collected every tenth of a mile.

TABLE 1 Location of Test Sites and Pavement Types

Site	Location	Route	Mile Post	Pavement Type	Test Type
1	Benson East	I10W	303.00	4-layer	10 tests/90 ft.
2	Flagstaff	I17N	337.00	4-layer	10 tests/90 ft.
3	Morristown	US60W	120.00	4-layer	10 tests/90 ft.
4	Tombstone	U80E	316.50	4-layer	10 tests/mile

TABLE 2 Layer Type and Thickness at Various Sites

Site/ Sta	Layer 1 Mat	Layer 1 Thk (in)	Layer 2 Mat	Layer 2 Thk (in)	Layer 3 Mat	Layer 3 Thk (in)	Layer 4 Mat	Layer 4 Thk (in)
1/1	AC	6	AB	6	SB	18	SC-SM*	--
2/1	AC	9	AB	4	SB	12	-	-
3/1	AC	4.25	AB	4	SB	15	-	-
4/1	AC	3.0	AB	4	SB	15	-	-

* Subgrade Classification based on Unified Method.

Note: AC: Asphalt Concrete, AB: Aggregate Base, SB: Sub Base (Select Material)

ANALYSIS METHOD

The analysis process consists of (a) backcalculation of layer moduli of the pavements from FWD data and (b) computation of structural capacity of the existing pavement through fatigue analysis. Backcalculation of layer moduli was done with the Arizona deflection analysis method (ADAM) developed by Hossain (*4*). ADAM uses the CHEVRON (*5*, *6*) computer program for pavement response analysis. A robust optimization routine iterates the moduli values to minimize the squared error between the measured and calculated deflection basins. The backcalculated layer moduli were used to determine the tensile strain at the bottom of the asphalt concrete layer. The structural capacity of the pavement in terms of the theoretical number of 18-kip ESALs was determined using the following equation for fatigue analysis developed by Hossain (*4*):

$$N = (2.265 \times 10^{-7}) (1/e_{ac})^{3.84} \qquad (1)$$

where N is the theoretical number of 18-kip ESAL repetitions to fatigue failure and e_{ac} is the tensile strain at the bottom of AC layer (μin./in.). Figure 1 shows the flow chart of the analysis process.

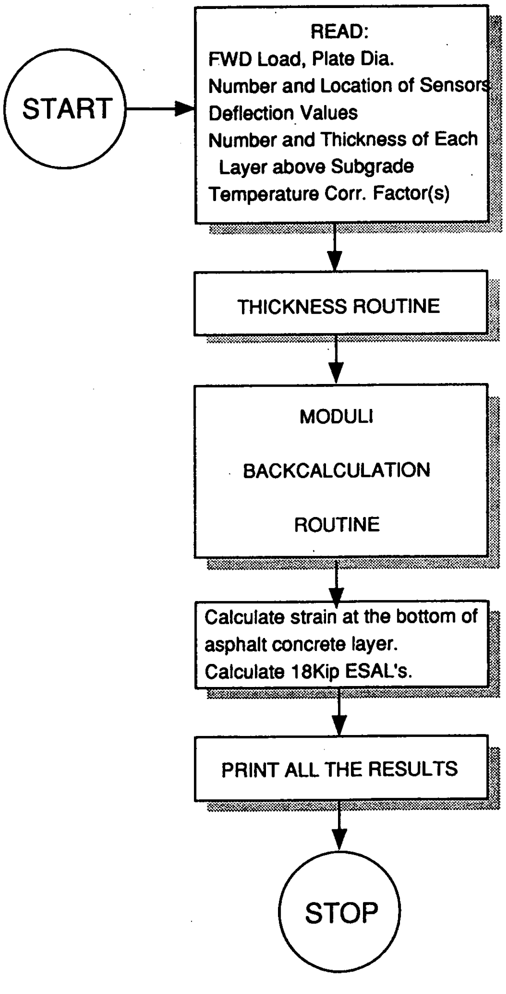


FIGURE 1 Flow chart of analysis process.

EFFECT OF VARIATION IN LAYER THICKNESS ON STRUCTURAL CAPACITY

Pavement layer thickness is a primary input of all backcalculation procedures. Thickness data can be obtained from either construction data or cores taken from the pavement. These thicknesses may vary from the design thickness because of variability in the construction process. Also, existing pavements may receive treatments, such as an AC friction course, that are not expected to increase the structural capacity but contribute to the total thickness of the AC layer. Little information is available in the literature about the effect of thickness variation on the estimated structural capacity from FWD deflection data. Rwebangira et al. (*7*) concluded that variation of AC and base layer thicknesses affect the backcalculated layer moduli. However, the backcalculated layer moduli are more sensitive to AC thickness than base layer thickness. Irwin et al. (*8*) showed that random deflection measurement errors combined with random variability of pavement layer thickness can lead to a high degree of "pseudovariability" in the backcalculated layer moduli. They recommend accurate determination of layer thicknesses to reduce the inaccuracy of the resultant backcalculated layer moduli.

To study the effect of layer thickness on the calculated structural capacity of the pavements, Sites 1 through 3 from Table 1 were selected. The thickness for the AC layer for these sites ranges from 4.3 to 9.0 in., whereas the aggregate base (AB) layer thickness ranges from 4.0 to 6.0 in. The subbase layer thickness ranges from 12.0 to 18.0 in. Two sets of deflection basins from 10 stations within each site were analyzed for each site, representing deflection basins with the highest and lowest first sensor deflections (normalized to 9,000 lb).

The experiment was designed to capture the effect of layer thickness on the response parameter or the theoretical structural capacity (expressed in terms of 18-kip ESALs) of the pavement section from backcalculated layer moduli and fatigue analysis. The factors and levels selected to capture the effect of variability of layer thickness on the calculated structural capacity of Site 1 are

Thickness (in.)	*Levels*
Surface	−1.0, −0.5, 0.0, 0.5, 1.0
Base	−2.0, −1.0, −0.5, 0.0, 0.5, 1.0, 2.0
Subbase	−2.0, −1.0, −0.5, 0.0, 0.5, 1.0, 2.0

Thus, a 7^3 factorial was designed for this site.

Analysis of variance (ANOVA) was used to describe the variation in calculated 18-kip ESALs with the following variance components:

Source of Variation	*Definition*
ACT	Thickness of AC layer
ABT	Thickness of AB layer
SMT	Thickness of SM layer
ACT*ABT	Interaction of thickness of AC and AB layers
ACT*SMT	Interaction of thickness of AC and SM layers
ABT*SMT	Interaction of thickness of AB and SM layers
ACT*ABT*SMT	Interaction of thickness of AC, AB, and SM layers

The following model was proposed for Site 1:

$$\begin{aligned} N18_{ijkl} = {} & \mu + \mathrm{ACT}_i + \mathrm{ABT}_j + \mathrm{SMT}_k \\ & + \mathrm{ACTABT}_{ij} + \mathrm{ACTSMT}_{ik} \\ & + \mathrm{ABTSMT}_{jk} + \mathrm{ACTABTSMT}_{ijk} \\ & + \varepsilon_{(ijkl)} \\ & i = 1, \ldots, 7, j = 1, \ldots, 7, \\ & k = 1, \ldots, 7, l = 1,2 \end{aligned} \tag{2}$$

where

N_{18ijkl} = theoretical 18-kip ESALs calculated from *l*th deflection basin at *i*th level of AC thickness, *j*th level of AB thickness, and *k*th level of SM thickness;
μ = overall mean;
ACT_i = effect of *i*th level of (fixed) treatment AC thickness;
ABT_j = effect of *j*th level of (fixed) treatment AB thickness;
SMT_k = effect of *k*th level of (fixed) treatment AB thickness;
ACTABT_{ij} = interaction effect between *i*th level of AC thickness and *j*th level of AB thickness;
ACTSMT_{ik} = interaction effect between *i*th level of AC thickness and *k*th level of SM thickness;
ABTSMT_{jk} = interaction effect between *j*th level of AB thickness and *k*th level of SM thickness;
$\mathrm{ACTABTSMT}_{ijk}$ = interaction effect between *i*th level of AC thickness, *j*th level of AB thickness, and *k*th level of SM thickness; and
$\varepsilon_{(ijkl)}$ = (random) within error. The $\varepsilon_{(ijkl)}$'s are assumed to be normally and independently distributed with mean zero and variance σ^2.

It is important to note that the replicate of deflection basins used in the backcalculation of layer moduli made it possible to estimate the error in the model. Table 3 shows the ANOVA

TABLE 3 ANOVA for Site 1

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo
ACT	4.9E14	6	8.1E13	4.3*
ABT	3.8E14	6	6.3E13	3.3*
SMT	6.1E12	6	1.0E12	0.05
ACT*ABT	1.4E14	36	3.9E12	0.20
ACT*SMT	2.4E13	36	6.5E11	0.03
ABT*SMT	3.4E13	36	9.6E11	0.05
ACT*ABT*SMT	2.9E14	216	1.3E12	0.07
Error	6.6E15	343	1.9E13	
Total	7.96E15	685		

* Significant at $\alpha = 5\%$

table for Site 1. From this table, it is evident that various levels of AC and AB thickness result in a significantly different structural capacity for Site 1.

The quality of the estimate of variation of structural capacity for each thickness level depends on the stability of the variation in structural capacity across thickness combinations. This variation depends on how much the estimate of structural capacity variance calculated from the two deflection basins for each thickness combination fluctuates. To test this statistically, Bartlett's test for constant variance was applied. The Bartlett's chi-square statistic was found to be 353. The critical value applicable to this statistic at the 5 percent level of significance is approximately 124, so the hypothesis of homogeneity of variance assumed in this test was rejected. Transformation of 18-kip ESAL data was necessary to make the variances stable. The correlation coefficient between means of N18 for each thickness combination and the corresponding variance was +0.89. The suggested transformation in this case of positive correlation between mean and variance is the square root of original data (*9*). This transformation was applied to N18 data, and Bartlett's test was repeated. The test statistic for the transformed data was 125, which is significant at 5 percent but insignificant at 2.5 percent. Anderson and McLean (*10*) state that the *F*-test used in the analysis of variance is robust against minor deviation from homogeneity of variance; thus the square root transformation appeared to be appropriate.

The ANOVA was repeated for the transformed data, as shown in Table 4. The degrees of freedom for the error were reduced by 1 because of the transformation applied to the data (*9*). It is clear that levels of thickness of AC and AB layers significantly affect the structural capacity estimated by the mechanistic method.

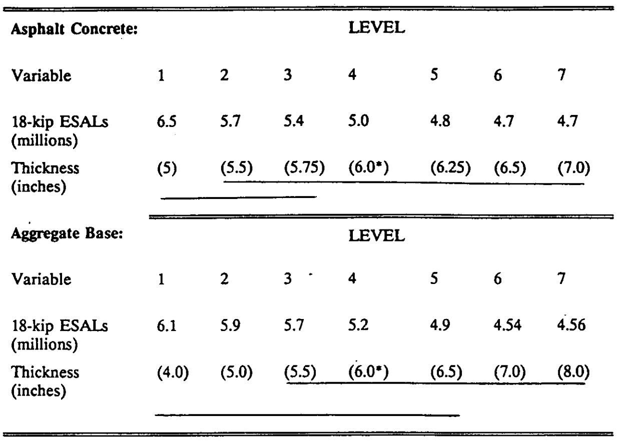
To determine the levels of AC and AB thickness that are significantly different from each other, Duncan's multiple range test (*9*) was applied to the means of 18-kip ESALs corresponding to various levels of AC and AB thickness.

Figure 2 illustrates the results. The means that do not share a common underline are statistically different. It is evident from the results that if the thickness for the AC layer is decreased by more than 1 in., the corresponding calculated 18-kip ESALs are significantly different; however, if it is increased by 1 in., the calculated 18-kip ESALs remain statistically the same.

TABLE 4 ANOVA of Transformed Data for Site 1

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo
ACT	1.2E7	6	2.0E6	2.5*
ABT	1.1E7	6	1.9E6	2.4*
SMT	0.4E6	6	.06E6	0.07
ACT*ABT	3.2E7	36	.09E6	0.11
ACT*SMT	0.9E6	36	.02E6	0.03
ABT*SMT	1.3E7	36	.04E6	0.05
ACT*ABT*SMT	1.03E7	216	.05E6	0.06
Error	2.7E8	342	.08E6	
Total	3.5E8	685		

* Significant at α = 5%



Asphalt Concrete:	LEVEL						
Variable	1	2	3	4	5	6	7
18-kip ESALs (millions)	6.5	5.7	5.4	5.0	4.8	4.7	4.7
Thickness (inches)	(5)	(5.5)	(5.75)	(6.0*)	(6.25)	(6.5)	(7.0)

Aggregate Base:	LEVEL						
Variable	1	2	3	4	5	6	7
18-kip ESALs (millions)	6.1	5.9	5.7	5.2	4.9	4.54	4.56
Thickness (inches)	(4.0)	(5.0)	(5.5)	(6.0*)	(6.5)	(7.0)	(8.0)

* Control Thickness

FIGURE 2 Duncan's multiple range test for means of 18-kip ESALs for Site 1. (Means that do not share a common underline are statistically different.)

For AB, a 2-in. deviation from the control thickness of 6-in. AB does not affect the calculation of 18-kip ESALs. However, there is significant difference between means of 18-kip ESALs computed from 5 in. AB and 7-in. AB. Thus, this site needs only knowledge of AC thickness within 0.5 in. of actual thickness to estimate the structural capacity.

On the basis of the analysis for Site 1, the number of levels for layer thickness for Sites 2 and 3 were decreased by 2, and the factorial was redefined to have five levels of thickness. The layer thicknesses for the AC layer for both sites varied by ±0.5 and ±1.0 in., whereas for AB and SM layers they varied by ±1.0 and ±2.0 in., producing 5^3 combinations.

The model assumed for ANOVA was similar to the one for Site 1. Two deflection basins from a 90-ft span of each site were selected that correspond to maximum and minimum first-sensor deflections normalized to a 9,000-lb load. The ANOVA tables for the 18-kip ESALs computed from these deflection basins are shown in Table 5.

From the tables it is clear that only AC and AB thicknesses significantly affect the structural capacity calculation. The homogeneity of variances in each of the various layer thickness combinations for these sites were checked using Bartlett's test. Site 2 had a Bartlett's chi-square statistic of 116, whereas for Site 3 the statistic was 55. The critical value of this statistic at the 5 percent level of significance for the data from both sites was 124. So, the variances for the 18-kip ESALs computed for these sites were homogeneous, and no transformation of data was necessary.

To determine the levels of AC and AB thickness that predicted significantly different 18-kip ESALs, Duncan's multiple range test was applied. Figure 3 shows the test results for both sites. The means of 18-kip ESALs corresponding to various levels of AC and AB thickness that do not share a common underline were found to be statistically different. For Site 2, an AC thickness of 8 in. produced significantly different 18-kip ESALs when compared with other levels of thickness. Here also, a decrease in 1 in. of AC thickness from the control thickness (9 in.) resulted in significantly different 18-kip ESALs, whereas an increase of 1 in. of AC thickness did not significantly affect the calculated 18-kip ESALs. For AB, a

TABLE 5 ANOVA for Sites 2 and 3

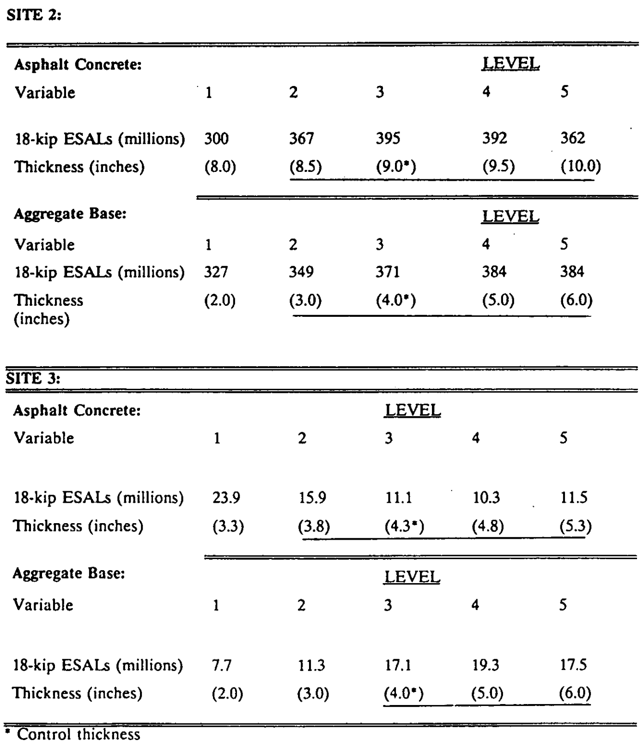
SITE 2

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo
ACT	2.90E17	4	7.2E16	6.5*
ABT	1.20E17	4	3.0E16	2.7*
SMT	8.50E16	4	2.1E16	1.9
ACT*ABT	1.50E17	16	9.5E15	0.86
ACT*SMT	9.70E16	16	6.1E15	0.55
ABT*SMT	1.30E16	16	7.9E14	0.07
ACT*ABT*SMT	6.80E16	64	1.1EE15	0.10
Error	1.40E18	125	1.1E16	
Total	2.23E18	249		

SITE 3

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo
ACT	6.48E15	4	1.62E15	7.7*
ABT	4.70E15	4	1.20E15	5.7*
SMT	7.20E13	4	1.79E13	0.09
ACT*ABT	2.64E15	16	1.65E14	0.77
ACT*SMT	4.38E14	16	2.74E13	0.13
ABT*SMT	2.40E14	16	1.49E13	0.07
ACT*ABT*SMT	1.70E15	64	2.64E13	0.13
Error	2.62E16	125	2.10E14	
Total	3.25E16	249		

* Significant at $\alpha = 5\%$



SITE 2:

Asphalt Concrete:			LEVEL		
Variable	1	2	3	4	5
18-kip ESALs (millions)	300	367	395	392	362
Thickness (inches)	(8.0)	(8.5)	(9.0*)	(9.5)	(10.0)

Aggregate Base:			LEVEL		
Variable	1	2	3	4	5
18-kip ESALs (millions)	327	349	371	384	384
Thickness (inches)	(2.0)	(3.0)	(4.0*)	(5.0)	(6.0)

SITE 3:

Asphalt Concrete:			LEVEL		
Variable	1	2	3	4	5
18-kip ESALs (millions)	23.9	15.9	11.1	10.3	11.5
Thickness (inches)	(3.3)	(3.8)	(4.3*)	(4.8)	(5.3)

Aggregate Base:			LEVEL		
Variable	1	2	3	4	5
18-kip ESALs (millions)	7.7	11.3	17.1	19.3	17.5
Thickness (inches)	(2.0)	(3.0)	(4.0*)	(5.0)	(6.0)

* Control thickness

FIGURE 3 Duncan's multiple range test for means of 18-kip ESALs for Sites 2 and 3. (Means that do not share a common underline are statistically different.)

2-in. deviation from a control thickness of 4 in. yielded significantly different 18-kip ESALs, whereas overestimation of thickness by 2 in. did not affect the calculation.

For Site 3, an AC thickness of 3.3 in., which is 1 in. less than the control thickness of 4.3 in., gave significantly different 18-kip ESALs, whereas 5.3 in. of AC did not yield significantly different 18-kip ESALs. There was a significant difference between the 18-kip ESALs computed for 3.8 in. of AC and 3.3 in. of AC, implying that a 0.5-in. decrease in AC thickness for pavements having 3.8 in. or less of AC thickness will produce significantly different 18-kip ESALs. For AB thickness, a 1-in. decrease from the control thickness of 4 in. resulted in significantly different 18-kip ESALs, whereas overestimation of thickness by 2 in. did not produce any 18-kip ESALs that were significantly different from control thickness.

From the results of ANOVA analysis of these sites it is evident that for pavements with AC thickness of 4.0 to 9.0 in., a 1-in. decrease in AC thickness will produce significantly different 18-kip ESALs. For thin pavements, a 1-in. decrease in base thickness would result in different 18-kip ESALs, whereas for thick pavements the calculated 18-kip ESALs may or may not be affected by a 2-in. decrease in base layers, depending on the thickness of the AC layers. These results support the greater effect of base layer thickness on the calculation of 18-kip ESALs for thin pavements as outlined earlier. Again, the overestimation of thickness of these layers above the actual layer thickness for which deflection test results are available do not affect the calculated 18-kip ESALs.

If construction records for quality control show that as built thicknesses of AC and AB layers are varying by more than 1 in., then coring will be necessary to have an accurate thickness of AC and AB layers at the FWD test locations for pavements having an AC thickness of 4.0 to less than 6.0 in. and AB thickness of 4.0 in. For pavements having an AC thickness less than 4.0 in., only a 0.5-in. deviation from the mean value of AC thickness can be allowed, and variation of AB thickness should be less than 1 in. However, the base thickness variation may be more than 1 in. for thick pavements having an AC thickness of 6 in. or more.

EFFECT OF TEMPERATURE CORRECTION FACTOR ON COMPUTED STRUCTURAL CAPACITY

Asphalt properties, especially the modulus of elasticity, are highly dependent on temperature. Since modulus affects the deflection measurements, the modulus of the layers that are temperature-dependent (such as AC, and hot-mix asphalt concrete base) must be corrected to a standard temperature, usually 70°F (*1*). The AASHTO guide (*1*) has a graph for temperature corrections of the asphaltic layer moduli to this standardized temperature that is based on

1. The air temperature at the time of FWD testing,
2. Five-day mean air temperature before the testing date, and
3. Thickness of the asphalt bound layer.

The backcalculated asphalt concrete or asphalt-treated base layer moduli are multiplied by these factors. These adjusted moduli can be used for determination of the structural layer coefficient from the nomographs in the AASHTO guide (*1*).

In the mechanistic analysis, the moduli are used as inputs for critical response calculation in fatigue analysis. Because there is no limit on the value of layer moduli, the resulting structural capacity analysis from fatigue criterion could result in a very high number of 18-kip ESAL repetitions. This is particularly true when the temperature at the time of the test is greater than the reference temperature, resulting in an upward adjustment of the asphalt modulus. At high modulus values there are low strains calculated corresponding to a stiff asphaltic layer.

To study the effect of the temperature correction factor on the estimated structural capacity by mechanistic analysis developed in this study, the pavement section in Site 4 was evaluated. The pavement temperature of this site was calculated from the nomograph in the AASHTO guide (*1*) corresponding to air temperature at the time of deflection testing plus a 5-day mean air temperature before deflection testing and thickness of AC layer. The temperature adjustment factor of 2.5, corresponding to the pavement temperature of 88°F, was determined from the nomograph in the guide. The backcalculated AC layer modulus was corrected with this factor and six other factors, which are derived by varying the actual temperature correction factor by ±25, ± 50, and ±75 percent. The corresponding temperature correction factors were 4.375, 3.75, 3.125, 1.875, 1.25, and 0.625. The theoretical number of 18-kip ESALs calculated corresponding to the temperature adjusted moduli are shown in Table 6.

A close inspection of a temperature correction factor nomograph shows that the correction factor is very sensitive to the changes in temperature, thus making the surface modulus very sensitive to test temperature. Consequently, the calculated structural capacity of the pavement becomes very sensitive to the temperature factor. By varying the temperature correction factor from −75 to +75 percent, the estimated 18-kip ESALs vary from −69 to +153 percent.

TABLE 6 Effect of Temperature Correction Factor on Estimated Structural Capacity

Var.[1] (%)	Factor[2]	Temp.[3] (°F)	EAC[4] (ksi)	18-kip ESALs[5] (millions)	Diff[6] (%)
+75	4.375	101	897	14.7	+153
+50	3.750	98	780	11.1	+91
+25	3.125	94	650	8.2	+41
0.0	2.50*	88	520	5.8	0.0
-25	1.875	83	390	3.9	-33
-50	1.250	80	260	2.6	-55
-75	0.625	62	130	1.8	-69

* Actual value

Note: Uncorrected asphalt concrete modulus = 208 ksi

[1] Variation between the actual value and the level of the factor used in the analysis.

[2] Factor = 2.5 x (1 + VAR/100)

[3] Temperature corresponding to the correction factor.

[4] Elastic modulus of asphalt concrete corrected for temperature effect.
EAC = 520 x FACTOR/2.5

[5] Predicted fatigue life of the pavement for different values of EAC.

[6] Diff = (18-kip ESAL - 5.8)/5.8 x 100

To find a relationship between the 18-kip ESALs and temperature adjustment factor (*Fc*) for the pavement in Site 4 an exponential curve of the following form was fitted:

$$N_{18} = 1.315 \times e^{0.568 \times Fc} \qquad R^2 = .996,\ n = 7,\ SEE = 0.055$$

From the previous relation it is obvious that if the temperature correction factor changes by one-tenth of a unit, that is, from 2.4 to 2.5, the calculated 18-kip ESALs change by 0.08 millions for the pavement in Site 4. The temperature correction factor is a very sensitive parameter, especially in the calculation of 18-kip ESALs. It is apparent that the temperature correction factors for asphaltic layer moduli are major sources of variation in structural capacity estimation of pavements by the mechanistic method. It is questionable at this time whether this factor is a very good adjustment parameter for the AC modulus to represent the field condition, especially when the pavement temperature is very high (greater than 130°F).

CONCLUSIONS

In this paper, the variability of the structural capacity determination by the mechanistic methods was presented with respect to layer thicknesses and the temperature correction factor for asphaltic layer moduli.

The variability in thickness of AC and AB layers affects the estimated structural capacity, but their interaction is not significant. This happens because in a deflection-matching backcalculation scheme, the thickness variation is compensated by a corresponding increase or decrease in modulus. For pavements with AC thickness of 4 in. or more, input thickness in FWD data analysis should not vary from the actual thickness by more than 1 in., whereas for pavements with less than 4 in. of AC thickness, the AC thickness should be known within 0.5 in. The AB thickness for such pavements should be known within less than 1.0 in. of actual thickness. For thick pavements with AC thickness of 6 in. or more, base thickness should be known within less than 2.0 in. of actual thickness. Thus, coring of FWD test locations is necessary for only AC layers for thick pavements and AC and AB layers for thin pavements.

The temperature correction factor suggested in the AASHTO guide for correcting asphalt-bound layer moduli was found to be very sensitive to the temperature of the pavement and has a tremendous effect on the estimated structural capacity of the pavement.

RECOMMENDATIONS

The thickness sensitivity analysis should be extended to include more projects with granular bases and with AC layer thicknesses different from those used in this study. The findings will supplement the suggested coring requirements for pavements with a wide range of AC thickness. The study should also include pavements with stabilized bases so that coring needs for extracting thickness information for these types of pavements can also be addressed.

The temperature correction factors from the AASHTO guide for asphaltic layer moduli should be studied in detail to find a better correlation between temperature and in situ layer moduli.

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