Development of a Simplified Mechanistic Pavement Evaluation and Overlay Design Procedure for Flexible Pavements

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A simplified mechanistic pavement evaluation and overlay design procedure is presented. The procedure assumes a three-layer model of a pavement structure and requires falling-weight sensor deflections for estimating remaining life and required overlay thickness. Linear elastic layered theory was used to develop strain-versus-deflection relationships for direct calculation of pavement strains from measured falling-weight deflections. This is believed to be a simpler and more straightforward approach than the back-calculation of layer moduli from measured surface deflections and the subsequent calculation of stresses or strains, or both, using elastic layered theory. To develop the strain-deflection relationships, the multilayer linear elastic program BISAR was used in a large factorial study. The program was modified for implementation on a microcomputer, thus making the factorial study feasible. Strain-versus-deflection relationships were developed for asphalt tensile and subgrade compressive strains. Pavement performance predictions that were calculated using strains from the deflection relationships were compared with those from deflection basin–fitting algorithms, using theoretically generated deflection data as well as field data. Relationships for designing overlay thicknesses were developed by evaluating the variation in pavement strains due to the addition of an overlay. The simplified mechanistic pavement evaluation and overlay design procedure presented can be readily implemented on a microcomputer, unlike other mechanistic procedures that require more computer resources.

The existing U.S. highway network represents a major investment in public transportation by state and federal agencies. Many of today's highways were constructed during the road-building boom of the 1950s and 1960s. Consequently, many of these roads are nearing or past the end of their design lives and are in need of major rehabilitation. Because of the increasing cost of new highway construction, and because of the need for protecting the investment made in the existing road network, pavement maintenance and rehabilitation have become a major concern of state and federal agencies.

The most widely used means of pavement rehabilitation is the design and construction of overlays. The design of overlays varies among highway agencies, depending on local conditions and experience. In general, current design practices range from empirical procedures that use limiting deflection criteria to more mechanistic procedures that consider stresses and strains in the pavement structure. Procedures that use limiting deflection criteria are considerably simpler and easier to implement; however, because these design relationships are based on local conditions and experience, they cannot be used with different materials, or in other regions, without extensive correlations.

In contrast, the more mechanistic procedures are more comprehensive and can be used for a much wider range of conditions because the design is based on a mechanistic analysis of the pavement structure and the material properties of the various pavement layers. The material properties (i.e., layer moduli) are typically determined by fitting deflection basin measurements or from laboratory testing of samples taken from the pavement sections being considered. Of the two methods, deflection basin fitting, using linear elastic layered theory, is probably the more widely used procedure for in situ determination of pavement properties. It is a nondestructive test procedure and is comparatively simpler than the laboratory determination of layer moduli. The resilient moduli are required in existing mechanistic design procedures for the purpose of determining the pavement response parameters (e.g., asphalt tensile strain, subgrade compressive strain) used in estimating the remaining life of an existing pavement structure.

In this paper, a simpler approach for flexible pavement evaluation and overlay design is presented. Instead of using measured surface deflections to estimate the layer moduli, the measured deflections are used to estimate the strains directly. This approach was used in the development of the flexible pavement evaluation procedure presented herein.

METHODOLOGY FOR DEVELOPING AN EVALUATION PROCEDURE FOR FLEXIBLE PAVEMENTS

In the development of this pavement evaluation procedure, the three-layer model shown in Figure 1 was assumed to represent

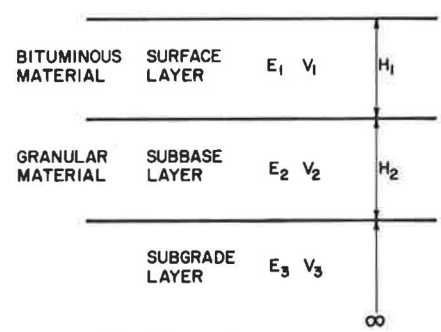

FIGURE 1 Three-layer pavement model used in the development of strain-versus-deflection relationships.

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the pavement structure. A three-layer model was selected instead of a four-layer model because it represents typical pavement conditions in Pennsylvania. Existing rational overlay design procedures, such as those developed by Shell *(1)* and Resources International, Inc. (RII) *(2)*, also use a three-layer representation of the pavement structure.

The assumptions of linear elastic layered theory were assumed to be valid. In addition, it was assumed that surface deflections are obtained using the falling-weight deflectometer at a load level of 9,000 lb. A design single axle load of 18 kips is used in the procedure. Consequently, corrections for stress dependency of unbound pavement materials are not necessary if falling-weight deflection measurements are taken at a load level of 9,000 lb. This simplifies the pavement evaluation procedure and makes practical use of the capability of the falling-weight deflectometer to provide a wide range of loadings.

A large factorial study was undertaken to develop relationships between strains and surface deflections. Specifically, equations were developed for estimating the tensile strain at the bottom of the existing asphalt layer and the compressive strain at the top of the subgrade. These two types of strains are used as criteria in several existing performance models *(1-4)*.

The factorial study used the three-layer model shown in Figure 1. To simplify the analysis, fixed values for the Poisson's ratios of the various layers were assumed. Specifically, the Poisson's ratios for the bituminous surface layer, the subbase, and the subgrade were assumed to be 0.30, 0.40, and 0.45, respectively. Consequently, there were five factors in the factorial design: *(a)* asphalt surface modulus, *(b)* subbase modulus, *(c)* subgrade modulus, *(d)* asphalt surface thickness, and *(e)* subbase thickness. Four different levels for each factor were assumed (Table 1). The levels fall within the normal range of values expected for each factor under actual field conditions. The resulting factorial design consisted of 4^5, or 1,024, possible combinations of moduli and thicknesses. For each of these combinations, the multilayer elastic BISAR program developed by Shell *(5)* was used to calculate surface displacements due to the falling-weight load of 9,000 lb applied through a circular plate of 5.9-in. radius.

The full factorial design established for the study is large, and under ordinary circumstances it would not have been practical to evaluate pavement response for all of the 1,024 combinations of moduli and thicknesses included in the factorial. Instead, only a fractional factorial would have been evaluated. It was, however, feasible to evaluate the full factorial for this project because the researchers modified the program, BISAR, to run on an IBM PC/XT microcomputer.

Theoretical surface displacements were determined at seven different positions, corresponding to the seven sensors of the falling-weight deflectometer (FWD). The spacing between sensors was assumed to be 1 ft. The theoretical displacements calculated by BISAR for the falling-weight loading conditions were compared with actual falling-weight deflections taken at the Pavement Durability Research Facility of the Pennsylvania Transportation Institute. The objective of the comparison was to verify whether the actual measured deflections were within the range of the theoretical deflections generated by BISAR. It was found that measured deflections for Sensors 4 through 7 were out of the range of the corresponding theoretical sensor deflections, which were larger in magnitude. Consequently, a new factorial design was established that contained higher levels of subgrade moduli. The levels selected were 5,000, 20,000, 35,000, 50,000, and 65,000 psi, respectively, and were established from an examination of back-calculated subgrade moduli using measured field deflections. Levels for the other factors were left unchanged. Consequently, the second factorial consisted of $4^4 \times 5$, or 1,280, possible combinations of moduli and thicknesses. Measured FWD deflections were again compared with the new set of theoretical deflections and were found to be within range.

The displacements calculated by BISAR for the FWD loading conditions, and for the combinations of layer moduli and thicknesses included in the first and second factorials, were subsequently correlated with computed strain values associated with an 18-kip load to establish strain-versus-deflection relationships. The program BISAR was used to compute strains for all possible combinations of moduli and thicknesses included in both factorials. The strains calculated were the tensile strain at the bottom of the bituminous surface layer and the compressive strain at the top of the subgrade.

The 18-kip single axle load was assumed to be transmitted to the pavement through a pair of dual wheels, each of which carried 4,500 lb. Tires were assumed to be inflated to a pressure of 100 psi, and the tires of each dual wheel were assumed to be separated by 13.1 in. For simplicity in the analysis, only strains directly under one tire of the 18-kip single axle design load were considered.

TABLE 1 THICKNESS AND MODULUS VALUES USED IN THE FACTORIAL STUDY

Layer	Thickness (in.)	Modulus (psi)	
Surface	1.0, 4.0, 7.0, 10.0	100,000	450,000
		800,000	1,150,000
Subbase	3.0, 7.0, 11.0, 15.0	10,000	30,000
		50,000	70,000
Subgrade	infinite	3,000	8,000
		13,000	18,000

Values of Poisson's ratio used for the surface, subbase and subgrade were 0.30, 0.40, and 0.45 respectively.

STRAIN-DEFLECTION RELATIONSHIPS DEVELOPED FROM THE FACTORIAL STUDY

The method of least squares was used to establish relationships between theoretical strains due to an 18-kip axle load and FWD surface deflections. Through regression analysis of the data generated from the factorial study, the following relationships for estimating strains from measured surface deflections were developed:

$$\log_{10}[\varepsilon_{yy}/\log_{10}(H_1+1)] = -2.261 - 0.944\log_{10}(W_1 - W_2) + 1.947\log_{10}[(W_1 - W_3)/W_2] + 0.175(W_1{*}H_2) + 0.926\log_{10}(W_1{*}W_2) \quad (1)$$

$R^2 = 0.915$, SEE = 0.141, N = 2,256 observations

$$\log_{10}(\varepsilon_{zz}) = -0.054 + 1.941\log_{10}(W_1 - W_2) - 2.004\log_{10}[(W_1 - W_3)/W_2] - 1.465\log_{10}(H_1 + H_2) - 0.136(H_2)^{1/2} + 0.725\log_{10}(W_1{*}H_2) + 0.285(W_1{*}H_1)^{1/2} - 0.910\log_{10}(W_1{*}W_2) \quad (2)$$

$R^2 = 0.963$, SEE = 0.084, N = 2,304 observations

where

- ε_{yy} = tensile strain at the bottom of the bituminous surface layer,
- ε_{zz} = compressive strain at the top of the subgrade,
- W_i = deflection at the ith sensor of the FWD (in.),
- H_1 = thickness of the existing bituminous surface layer (in.),
- H_2 = thickness of existing subbase (in.),
- R^2 = coefficient of determination, and
- SEE = standard error of the estimate.

In the formulation of Equations 1 and 2, analyses of residuals were used to verify model assumptions concerning linearity, independence of error terms, and homogeneity of variance. In addition, correlations between independent variables were examined to prevent problems associated with multicollinearity. These steps were taken to ensure that the relationships established were statistically sound and robust.

Figure 2, which is a plot of the predicted versus the theoretical asphalt tensile strains, shows good agreement between the predicted and theoretical values for most of the 2,256 observations used to develop Equation 1. However, there are also several cases in which the agreement is not good. For these cases, an effort was made to establish possible reasons for the poor agreement between predicted and theoretical values. Combinations of layer moduli and thicknesses, for which the absolute values of the residuals were greater than twice the standard error of the estimate, were examined to determine if there was any consistent pattern among the various combinations. No consistent patterns were found, nor did the combinations represent unrealistic cases. Consequently, the observations for which there was poor agreement between predicted and theoretical values were not deleted from the data set used to develop the relationship for estimating asphalt tensile strain. It should be mentioned that these observations for which the residuals were larger represent only a small percentage of the total number of observations used to develop the equation.

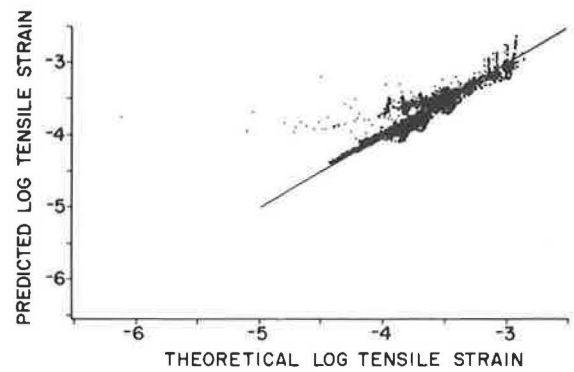

FIGURE 2 Comparison of predicted and theoretical asphalt tensile strains.

Figure 3 shows the accuracy of the predictions of subgrade compressive strain from Equation 2. In the figure the logarithms of predicted and theoretical compressive strains are compared. To illustrate better the accuracy of the predictions, a histogram of the ratios of the residuals to the standard error of the estimate is shown in Figure 4. It can be seen that a majority of the residuals (about 90 percent of the total number of observations) are within one standard error of the estimate, which is 0.084 for Equation 2. The antilog of this number is 1.21, which indicates that the percentage difference between predicted and theoretical compressive strains would be within 21 percent for most of the 2,304 observations used to develop the equation. In addition, Figure 4 shows that approximately 48 percent of the total number of residuals are actually within one-half of the standard error of the estimate.

The preceding discussion indicates that the relationships established in this paper can be used, with a reasonable degree of confidence, for estimating asphalt tensile and subgrade compressive strains directly from measured deflection basin indices and existing layer thicknesses.

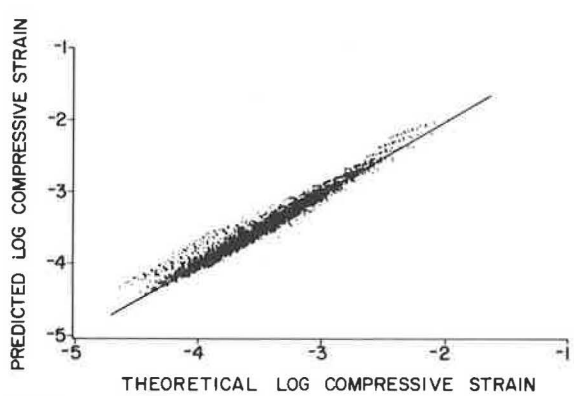

FIGURE 3 Comparison of the logarithms of predicted and theoretical subgrade compressive strains.

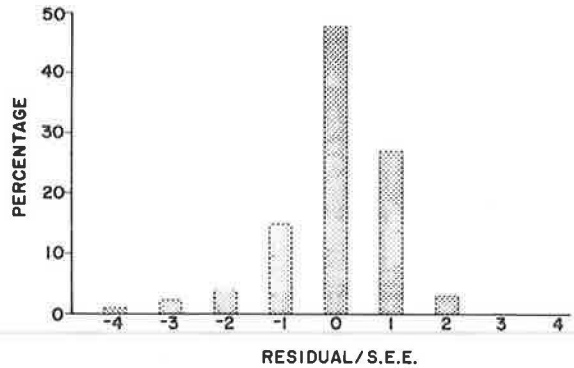

FIGURE 4 Histogram of the ratios of the residuals to the standard error of the estimate for Equation 2.

COMPARISON OF STRAIN-VERSUS-DEFLECTION AND DEFLECTION BASIN–FITTING METHODOLOGIES

To evaluate the equations developed, 15 combinations of layer moduli and thicknesses were randomly generated (Table 2), and the program BISAR was used to calculate theoretical FWD pavement deflections and strains due to an 18-kip axle load for each combination. The theoretical deflections generated were used in the strain-versus-deflection relationships (Equations 1 and 2) to estimate the asphalt tensile and subgrade compressive strains due to an 18-kip load.

The deflections obtained were also used as inputs to two overlay design procedures that use the deflection basin–fitting methodology for pavement evaluation. These two procedures are OAF, developed by RII for FHWA *(2)*, and FPEDD1, developed by Uddin at the University of Texas at Austin *(6)*. Using the theoretical FWD deflections, these two procedures back-calculated the known theoretical layer moduli (Table 2). The program BISAR was used with the back-calculated layer moduli from each procedure to calculate the asphalt tensile and subgrade compressive strains due to an 18-kip axle load. Performance prediction estimates were then generated using the calculated strain values. In connection with this, the tensile strains were used with the ARE fatigue equation *(3)*, and the subgrade strains were used with the performance model developed by Luhr et al. *(4)*. These two performance equations are defined, respectively, as follows:

$$W_{18} = 9.73 \times 10^{-15} (1/\varepsilon_t)^{5.16} \quad (3)$$

$$\log_{10} N_X = 2.15122 - 597.662 (\varepsilon_{SG}) - 1.32967 (\log_{10} \varepsilon_{SG}) + \log_{10} [(PSI_i - TSI)/(4.2 - 1.5)]^{1/2} \quad (4)$$

where

W_{18} = weighted 18-kip applications before Class-2 cracking,
ε_t = tensile strain at the bottom of the asphalt surface layer,
$\log_{10} N_X$ = $\log_{10}$ of allowable applications of axle load X,
ε_{SG} = subgrade compressive strain due to axle load X,

TABLE 2 COMBINATIONS OF LAYER MODULI AND THICKNESSES USED IN THE EVALUATION OF STRAIN-DEFLECTION RELATIONSHIPS

	Layer Moduli (psi)			Thickness (in.)	
	Surface	Subbase	Subgrade	Surface	Subbase
1)	411,200	29,200	12,000	2.0	3.0
2)	733,200	31,600	15,450	4.0	7.0
3)	871,200	45,400	6,600	5.0	3.0
4)	120,000	33,000	13,400	4.5	11.0
5)	220,000	62,200	10,000	7.5	6.0
6)	190,400	44,000	14,000	3.0	5.0
7)	246,000	18,500	9,000	2.5	4.0
8)	798,000	20,000	6,000	7.5	3.5
9)	430,000	63,000	4,500	5.5	7.0
10)	227,000	29,000	7,000	7.0	11.0
11)	328,000	64,000	18,000	7.0	7.0
12)	457,000	26,000	10,000	6.5	3.0
13)	540,000	33,000	11,000	4.0	15.0
14)	160,000	20,000	12,000	2.0	3.0
15)	108,000	18,000	15,000	4.5	3.0

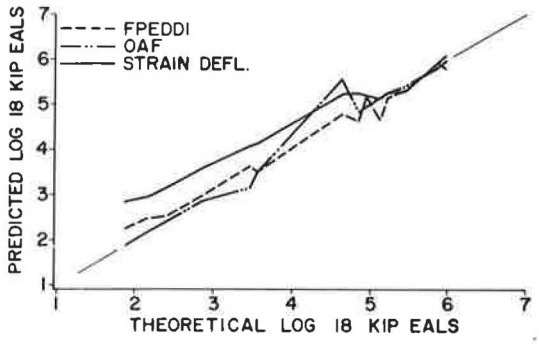

FIGURE 5 Comparison of predicted and theoretical pavement performance based on asphalt tensile strain.

PSI_i = initial PSI of pavement, and
TSI = terminal serviceability index.

Figures 5 and 6 show comparisons of the performance predictions using the theoretical strains with the predictions using the strains from programs OAF, FPEDD1, and the strain-versus-deflection relationships. In general, the performance predictions from the deflection basin–fitting procedures match more closely the predictions generated from the theoretical strains than those generated from the simplified strain-versus-deflection procedure. In most cases, the performance predictions from the simplified procedure are higher than the theoretical number of 18-kip equivalent axle loads (EALs) to failure. However, in all cases the differences in performance estimates among the various procedures are within one order of magnitude, and for a normal range of traffic expected in the field (e.g., 100,000 to 10,000,000 18-kip EALs) the performance estimates from both methodologies tend to compare more favorably. Thus the strain-deflection methodology presented herein does yield reasonable results compared with theoretical pavement response. It should also be noted that, for some combinations of layer moduli and thicknesses, unrealistic estimates of fatigue life (i.e., less than 1,000 18-kip EALs) are obtained from the theoretical tensile strains. The unrealistically low performance estimates occurred for hypothetical pavement sections with low asphalt modulus or thin layer thickness. For these cases, however, the strain-versus-deflection methodology yielded higher performance estimates.

Field-measured FWD deflections taken from eight different pavement sections at the Pennsylvania Transportation Research Facility were also used with the strain-versus-deflection relationships. The field-measured deflections were entered into programs OAF and FPEDD1, and the back-calculated layer moduli generated were used in a linear elastic layered analysis to predict strains in the pavement sections. Performance estimates for the various sections were subsequently calculated using the predicted strains, as was done in the preceding theoretical analysis. In addition, performance estimates were obtained using resilient modulus values determined from laboratory tests performed on the field materials. Consequently, performance estimates were calculated using the strain values determined from *(a)* the strain-versus-deflection relationships (Equations 1 and 2), *(b)* the back-calculated layer moduli from programs OAF and FPEDD1, and *(c)* modulus data determined in the laboratory. The calculated performance estimates for each section are plotted in Figure 7 (based on asphalt strain) and Figure 8 (based on subgrade strain).

It can be observed that, for the eight sections included in the analysis, performance estimates based on tensile strain, and determined from the basin-fitting procedures, and the asphalt strain-versus-deflection relationship are in better agreement than are those calculated using laboratory-determined moduli. Thus performance evaluation using the simplified procedure

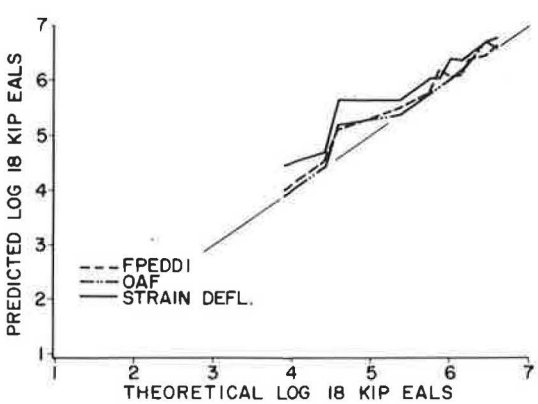

FIGURE 6 Comparison of predicted and theoretical pavement performance based on subgrade compressive strain.

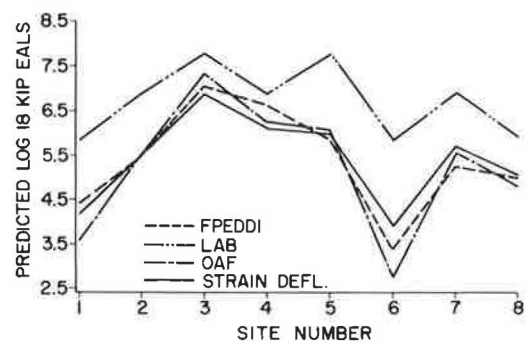

FIGURE 7 Comparison of pavement performance estimates based on asphalt tensile strain using field data.

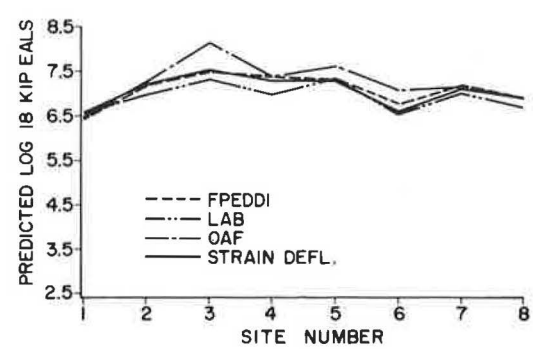

FIGURE 8 Comparison of pavement performance estimates based on subgrade compressive strain using field data.

yields results that are comparable to those obtained from procedures that back-calculate layer moduli from measured deflections. However, on the basis of the field performance of the various sections, the performance estimates calculated using laboratory-determined moduli are more realistic. This may be because the model used to estimate performance from asphalt tensile strains was calibrated using laboratory-determined moduli, the values of which may be quite different from those obtained using field deflection measurements.

Figure 8 shows a comparison of the performance predictions based on subgrade compressive strain. In contrast with the results presented previously, the performance predictions based on subgrade compressive strain show a relatively smaller amount of variation among the various sections and the procedures used to estimate pavement performance. In all cases, the differences are within an order of magnitude. Thus, for the sections included in the analysis, performance estimates based on subgrade compressive strain appear to be more stable and less sensitive to the procedure used to estimate pavement strains.

DEVELOPMENT OF A THICKNESS DESIGN PROCEDURE FOR FLEXIBLE PAVEMENT OVERLAYS

The strain-versus-deflection relationships allow for a simpler determination of remaining pavement life and permit the practical use of deflection measurements in a network-level pavement management system for screening pavements that are in need of overlays. However, a procedure for determining actual overlay thicknesses is also required. In the development of the simplified mechanistic pavement evaluation and overlay design procedure, linear elastic layered theory was used to develop the thickness design procedure for overlays. In the formulation of the method, the overlay was assumed to be an additional layer placed on top of the existing three-layer pavement (Figure 1), and the overlaid pavement is assumed to be represented by a four-layer model.

The required overlay thickness is based on the reduction in strains that results from the application of an overlay. The reduced strains are used to calculate pavement life after an overlay. In the development of the procedure, the strains after an overlay (four-layer model) were correlated with the strains before the overlay (three-layer model) and the overlay thickness.

To establish the equations for strains after an overlay, the factorial designs were modified to take into account the additional overlay layer. The additional factors were the modulus and the thickness of the overlay. The Poisson's ratio of this layer was assumed to be constant at 0.30.

Three levels for the overlay thickness were selected: 1, 3, and 5 in. These levels represent a typical range of overlay thicknesses found in practice. The overlay modulus was set at one typical value because, if several levels for the overlay modulus were selected, use of the overlay design procedure would require that the overlay modulus be known by the user. The value selected was 450,000 psi. With the addition of overlay thickness as a factor at three levels and overlay modulus as a factor at only one level, the size of each factorial established previously was increased threefold. In the analysis, the levels of the factors in the original factorials were retained, and the only modifications made were *(a)* inclusion of overlay thickness as a factor having three different levels and *(b)* inclusion of overlay design modulus as a factor set at just one level.

The program BISAR was then used to calculate strains for each combination of moduli and thicknesses in both factorials. Strains were also calculated at the top of the subgrade and at the bottom of the original bituminous surface layer. The computed values represent the strains due to an 18-kip load after the placement of an overlay. By the method of least squares, these values were subsequently correlated with the corresponding strains before the overlay and the overlay thickness. The relationships developed for estimating the tensile and compressive strains of a pavement after an overlay are given by Equations 5 and 6:

$$\log_{10} (\varepsilon_{yy})_{ov} = -0.689 + 0.793 \log_{10} (\varepsilon_{yy}) - 0.041 (H_{ov})^{1/2} + H_1 - 0.057 (H_{ov}) \quad (5)$$

R^2 = 96.63 percent, SEE = 0.057, N = 6,180 observations

$$\log_{10} (\varepsilon_{zz})_{ov} = -0.359 + 0.870 \log_{10} (\varepsilon_{zz}) - 0.051 (H_{ov}) -0.109 [(H_{ov} + H_1)/H_1]^{1/2} \quad (6)$$

R^2 = 97.34 percent, SEE = 0.062, N = 6,912 observations

where

$(\varepsilon_{yy})_{ov}$ = tensile strain at the bottom of the original bituminous surface layer after an overlay,
$(\varepsilon_{zz})_{ov}$ = compressive strain at the top of the subgrade after an overlay,
ε_{yy} = tensile strain at the bottom of the original bituminous surface layer before an overlay,
ε_{zz} = compressive strain at the top of the subgrade before an overlay,
H_{ov} = overlay thickness (in.), and
H_1 = thickness of the original bituminous surface layer (in.).

Predicted and theoretical strain values are compared in Figures 9 and 10 to show the accuracy of the estimates resulting

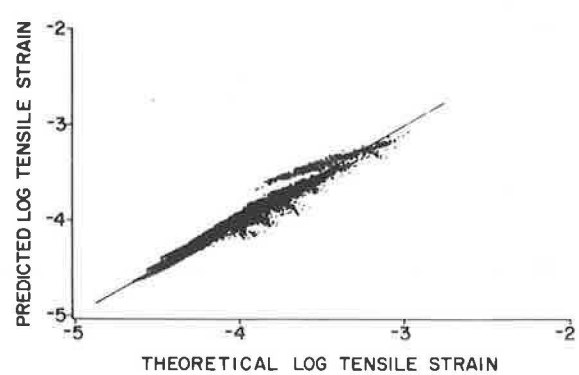

FIGURE 9 Comparison of predicted and theoretical log tensile strains after an overlay.

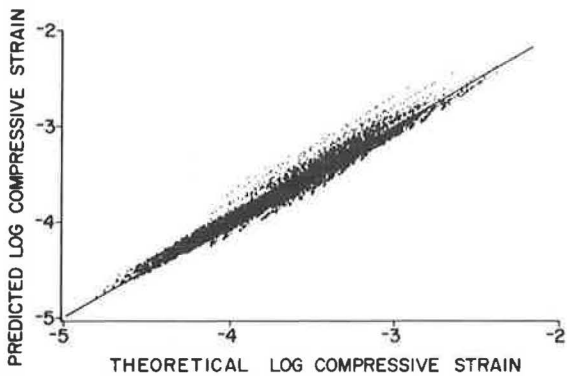

FIGURE 10 Comparison of predicted and theoretical log compressive strains after an overlay.

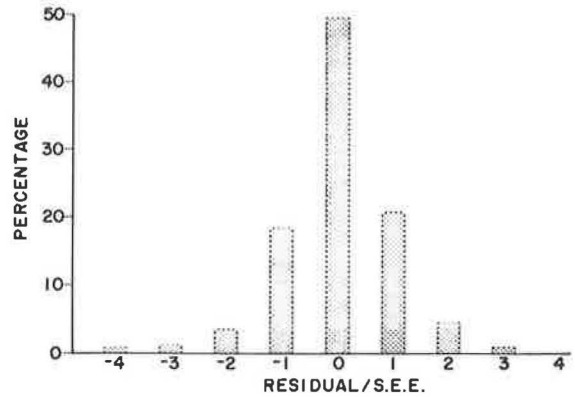

FIGURE 12 Histogram of the ratios of the residuals to the standard error of the estimate for Equation 6.

from Equations 5 and 6. In addition, histograms of the ratios of residuals to the standard error of the estimate for each equation are shown in Figures 11 and 12. As indicated in Figures 9 and 11, the equation for tensile strain after an overlay produces reasonably good estimates. In particular, Figure 11 shows that most of the differences between the predicted and the theoretical logarithms of the tensile strains after an overlay are within one standard error of the estimate, which is equal to 0.057 for Equation 5. Because the antilog of this number is 1.14, the difference between most of the predicted and theoretical strains is within 14 percent. About 50 percent of the 6,180 residuals included in Figure 11 are actually within one-half of the standard error of the estimate for the equation. Figures 10 and 12 likewise show reasonable agreement between the compressive strains predicted by Equation 6 and the theoretical strains. In particular, Figure 12 indicates that most of the differences between the predicted and the theoretical logarithms of the compressive strains after an overlay are within one standard error of the estimate, which is 0.062 for Equation 6. The antilog of this number is 1.15, which indicates that the differences between most of the predicted and actual strains are within 15 percent. Figure 12 also shows that about 50 percent of the 6,912 residuals from the regression analysis of subgrade compressive strain are actually within just one-half of the standard error of the estimate.

Equations 5 and 6, therefore, provide a means for determining the required overlay thicknesses based on either an asphalt tensile strain or a subgrade compressive strain criterion. The thickness design procedure is iterative: trial overlay thickness values are assumed until the strains computed after an overlay yield satisfactory estimates of design life from performance equations based on either of the aforementioned strain criteria.

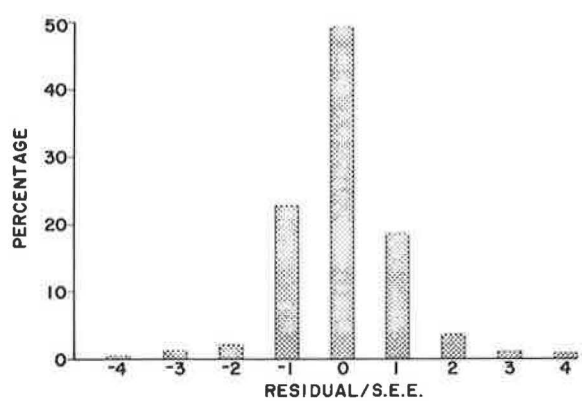

FIGURE 11 Histogram of the ratios of the residuals to the standard error of the estimate for Equation 5.

SUMMARY AND CONCLUSIONS

A simplified mechanistic pavement evaluation and overlay design procedure has been presented. In the development of the procedure, the concept of estimating pavement strains directly from measured surface deflections was introduced. The findings from the study indicate that the prediction of strains directly from measured surface deflections is a viable approach to the performance evaluation of flexible pavements. The procedure is much simpler than existing mechanistic design methods that back-calculate layer moduli from measured surface deflections and subsequently calculate from elastic layer theory the performance-related response parameters (e.g., asphalt tensile strain, subgrade compressive strain). The simplified procedure does not require iterative basin fitting or use of elastic layer programs that require considerable computer capabilities and time. The simplified procedure can be implemented on a small microcomputer *(7)* and requires little time to execute.

There may be occasions when knowledge of the in situ layer moduli is necessary. However, for routine pavement performance evaluation, application of the simplified procedure shows great promise. The method allows for the practical use of surface deflection measurements in a network-level pavement management system for screening pavements in need of rehabilitation.

Strain-versus-deflection relationships were developed for estimating asphalt tensile and subgrade compressive strains directly from measured deflections. Most performance equations available today are based on one of these two strain criteria. The strain-deflection equations were developed assuming linear elastic layered theory, and the relationships are applicable for estimating strains from surface deflection measurements taken with the FWD at a load level of 9,000 lb. The

primary reason for selecting this load level is that, if designs are based on 18-kip EALs, then corrections for stress dependency of unbound pavement materials need not be considered.

Comparison of performance estimates from both strain-deflection and deflection basin–fitting methodologies were made using theoretically generated deflection data and field-measured data. The results from field data included in the analysis indicate that performance predictions based on tensile strain, and calculated using laboratory-determined moduli, are more realistic than those obtained from the back-calculation procedures and the asphalt strain-versus-deflection relationship. The reason may be that the model used to estimate performance from asphalt tensile strain was calibrated using laboratory-determined moduli, the values of which may be quite different from those obtained using field deflection measurements. However, a better agreement was observed among the performance predictions based on subgrade strain. The results of the analysis therefore indicate that performance estimates based on subgrade strain are more stable and less sensitive to the procedure used to analyze the pavement. In addition, comparisons of performance estimates calculated from theoretically generated deflection data indicate that the strain-deflection relationships yield results that compare reasonably with performance predictions from existing deflection basin–fitting algorithms.

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