STRUCTURAL DESIGN PROCEDURE FOR STABILIZED PAVEMENT LAYERS

William O. Hadley, Department of Civil Engineering,
Louisiana Technical University; and
W. Ronald Hudson and Thomas W. Kennedy, Center for Highway Research,
University of Texas at Austin

A design procedure is presented that can be used as an aid in the structural design of stabilized pavement layers. The system is based primarily on the prevention of tensile failures in the surface and base layers of a three-layer pavement structure and can be applied to take full advantage of those highway materials that possess cohesion or tensile strength. The design method consists of a series of design equations based on linear elastic layered theory, which can be used for computing tensile stresses and strains in the surface layer, tensile stresses and strains in the base layer, and compressive strains in the subgrade. Separate equations are presented for use in the design of high-modulus portland cement concrete pavements and for the design of flexible pavements and low-modulus portland cement concrete pavements. Procedures for proper application of the design equations are presented and include methods for selection of a critical design thickness. Characterization techniques are also provided for estimating limiting design stress criteria for the materials proposed for the various pavement layers. In addition, minimum design strain criteria are recommended for various cohesive highway materials.

•THE widespread use of pavements having stabilized pavement layers has created interest in development of procedures for the effective use of these pavement types. In particular there is need for a structural design method that is based on fundamental considerations and that emphasizes the contribution of stabilized layers to the behavior of the total pavement structure.

This paper presents a structural design procedure for the stabilized layers in a pavement structure, which is based on tensile resistance to a large number of applications of vehicle loads. The system is applicable to the design of cohesive pavements, i.e., those that have tensile strength.

DESIGN APPROACH

The formalized design system (1, 2) is shown in Figure 1 and is broken down into three phases. The first phase is concerned with characterization of the highway materials in the laboratory and requires techniques for estimating fundamental material properties, including modulus of elasticity, tensile strength, and tensile strain for all highway materials.

The second phase involves special material characterization techniques for considering the effects of temperature and loading rate on the properties of asphaltic materials to provide flexibility in the design. The other special consideration involves the establishment of minimum allowable stress and strain values (based on repeated loading studies) for each of the highway materials.

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The culmination of the design process occurs in the third phase where the minimum design criteria established in the second phase are used with design equations to obtain the required layer thickness. Because the thickness requirement of a stabilized layer can be affected by changes in the material properties of the layers, the design process can produce a large number of adequate design sections from which to choose. Economic analyses can then be used in the selection of the final design section.

SELECTION OF PAVEMENT THEORY

Layered theory has been used extensively since its development by Burmister in 1943; however, limited work has been done to incorporate the theory into a comprehensive structural design system. The design system presented here is based on a practical interpretation of layered theory, which emphasizes the contribution of each individual pavement layer to the behavior of the total pavement structure.

The hypothetical pavement design section adopted for this design system (Fig. 2) consists of three layers: a surface course, a base course (the stabilized layer underneath the surface layer is designated as the base layer regardless of pavement type), and the subgrade. The pavement is assumed to be loaded by two 4,500-lb loads uniformly distributed over circular areas and located 12 in. apart, center to center. This loading represents the present single-axle legal load limit of 18,000 lb.

The materials in each of the layers are assumed to be homogeneous, isotropic, and elastic. The surface and base layers are assumed to be infinite in extent in the lateral direction but of finite depth, whereas the subgrade layer is assumed to be infinite in both the horizontal and vertical directions. In addition, the continuity conditions require that there be continuous contact between the surface and base layers and between the base and subgrade layers.

DEVELOPMENT OF DESIGN EQUATIONS

Because layered theory provides a deterministic model for predicting stresses, strains, and deflections in a given pavement system, it has direct application to evaluation of existing pavement sections. The inputs required in the theory, i.e., number and thickness of layers, moduli, and Poisson's ratio, can be estimated for existing pavement materials.

On the other hand, layered theory cannot be used directly for the structural design of the individual layers of a pavement because the thicknesses of the layers are required as input for the theory. Iterative solutions of layered theory equations for variation in the pavement section could be used in the design process; however, this technique could require a large number of computer solutions and would be feasible for only the simplest of design problems. The greatest value of layered theory in design of pavement structures appears to be its use in development of design equations relating stresses and strains to the important variables in the design section, i.e., layer thickness and modulus of elasticity. These equations can then be used to obtain directly the combination of layer thickness and modulus of elasticity corresponding to a specified critical design stress or strain.

Mathematical models were developed for this design system by approximating the layered theory results with polynomial mathematical equations that included all of the important variables of the design section. Regression analysis techniques were used to develop the approximate models from a series of solutions obtained from the Chevron STRESS-N computer program (3) for various levels of the design variables. A stepwise regression technique was used to relate specific stresses and strains obtained from the Chevron STRESS-N computer program to the design variables.

TECHNIQUE OF DEVELOPING DESIGN EQUATIONS

The variables considered in the development of the design equations were modulus of elasticity, E_s; thickness of surface layer, T_s; modulus of elasticity, E_b; thickness of base layer, T_b; and modulus of elasticity of the subgrade, E_g. The ranges in these variables, which were used in the development of the design equations, are shown in

Figure 2. The values of modulus of elasticity in the surface layer provided for evaluation of low-modulus as well as high-modulus layers, whereas the range of modulus values for the base layer spanned the range expected for lime-treated, asphalt-treated, and cement-treated materials. The thicknesses selected were considered to be representative of those normally used in highway pavements.

Regression techniques were used to obtain equations for tensile stresses and strains in the bottom fibers of the upper two layers and vertical strain in the top of the subgrade in terms of the moduli and thicknesses of the pavement layers. The general form of the equation is $\log_{10}(Y) = f(X_1, X_2, \ldots X_n)$, where $\log_{10}(Y)$ is the logarithm of the dependent variable Y (i.e., stress or strain in a particular layer), and $X_1, X_2, X_3, \ldots X_n$ are the independent variables under consideration (i.e., layer moduli and thicknesses).

Separate equations were obtained for low- and high-modulus layers to provide flexibility in the type of highway pavement to be designed. The equations for low-modulus layers can be used for design of flexible pavements as well as for design of low-modulus portland cement concrete pavements, whereas the equations for high-modulus layers can be used for design of high-strength portland cement concrete pavements.

Design Equations for High-Modulus Surface Layers

The regression equations for pavement structures with surface layers exhibiting modulus-of-elasticity values in the range of 3.5×10^6 psi to 6.50×10^6 psi are given in this section. The pertinent statistical information concerning the equations is given in Table 1. The predictive capability of the equations is indicated by the standard errors of estimate, $\hat{S}_r$. Consequently, the tensile stress and strain in the base layer and compressive strain in the subgrade can be predicted within closer limits than can the tensile stress and strain in the surface layer. All five equations, however, provide adequate approximation to layered theory[1].

1. Tensile stress in bottom of base layer, σ_b:

$$\begin{aligned} \mathrm{Log}_{10}(\sigma_b) \times 10^3 = [&1{,}333.84 + 46.868 (E_b - 5.5) - 23.774 (T_b - 7.5) \\ &-3.3610 (E_b - 5.5)(T_b - 7.5) - 11.008 (E_b - 5.5)^2 \\ &+1.6306 (E_b - 5.5)^3 + 4.3026 (T_s - 7.5)(T_b - 7.5) \\ &-39.310 (E_s - 5.0) - 21.572 (E_g - 8.0) + 1.7254 (E_g - 8.0)^2 \\ &-80.972 (T_s - 7.5) + 4.0607 (E_b - 5.5)(T_s - 7.5) \\ &+3.4019 (T_s - 7.5)^2] \end{aligned} \qquad (1)$$

2. Tensile strain in bottom of base layer, ϵ_b:

$$\begin{aligned} \mathrm{Log}_{10}(\epsilon_b) \times 10^3 = [&1{,}412.12 - 34.516 (E_b - 5.5) - 19.891 (T_b - 7.5) \\ &-3.3677 (E_b - 5.5)(T_b - 7.5) + 2.0650 (E_b - 5.5)^2 \\ &+3.9519 (T_s - 7.5)(T_b - 7.5) - 37.103 (E_s - 5.0) \\ &-21.293 (E_g - 8.0) + 1.7920 (E_g - 8.0)^2 - 76.216 (T_s - 7.5) \\ &+3.9517 (E_b - 5.5)(T_s - 7.5) + 2.7973 (T_s - 7.5)^2] \end{aligned} \qquad (2)$$

3. Compressive strain in subgrade, ϵ_c:

$$\begin{aligned} \mathrm{Log}_{10}(\epsilon_c) \times 10^3 = [&1{,}744.52 - 34.206 (E_b - 5.5) - 17.860 (T_b - 7.5) \\ &-3.3359 (E_b - 5.5)(T_b - 7.5) + 2.09191 (E_b - 5.5)^2 \\ &-74.426 (T_s - 7.5) + 4.1675 (T_s - 7.5)(T_b - 7.5) \end{aligned}$$

[1] The original manuscript of this paper contained an appendix, Comparisons Between Design Equations and Layered Theory Equations. This appendix is available in Xerox form at cost of reproduction and handling from the Highway Research Board. When ordering, refer to XS-45, Highway Research Record 431.

$$+3.1465\,(T_s - 7.5)^2 - .44062\,(T_s - 7.5)^2\,(T_b - 7.5)$$
$$+3.9401\,(E_b - 5.5)\,(T_s - 7.5) - .44431\,(E_b - 5.5)^2\,(T_s - 7.5)$$
$$-11.482\,(E_g - 8.0) + 1.7026\,(E_g - 8.0)^2 - .16881\,(E_g - 8.0)^3$$
$$-38.520\,(E_s - 5.0) - 3.5104\,(E_s - 5.0)\,(T_s - 7.5)] \quad (3)$$

4. Tensile stress in bottom of surface layer, σ_s:

$$\mathrm{Log}_{10}\,(\sigma_s + 26.4) \times 10^3 = [2{,}084.50 - 31.179\,(E_b - 5.5) - 37.176\,(T_b - 7.5)$$
$$-4.9726\,(E_b - 5.5)\,(T_b - 7.5) + 6.5353\,(T_s - 7.5)\,(T_b - 7.5)$$
$$-24.615\,(T_s - 7.5) - 1.2956\,(E_b - 5.5)\,(T_s - 7.5)^2$$
$$+8.2011\,(E_b - 5.5)\,(T_s - 7.5) - 9.3803\,(E_s - 5.0)\,(T_s - 7.5)$$
$$-7.2608\,(E_g - 8.0)] \quad (4)$$

5. Tensile strain in bottom of surface layer, ϵ_s:

$$\mathrm{Log}_{10}\,(\epsilon_s + 5.15) \times 10^3 = [1{,}233.72 - 40.073\,(E_b - 5.5) - 35.042\,(T_b - 7.5)$$
$$-4.1767\,(E_b - 5.5)\,(T_b - 7.5) + 6.1426\,(T_s - 7.5)\,(T_b - 7.5)$$
$$-15.756\,(T_s - 7.5) + 7.0680\,(E_b - 5.5)\,(T_s - 7.5)$$
$$-8.1402\,(E_g - 8.0)] \quad (5)$$

Design Equations for Low-Modulus Surface Layers

The regression equations for pavement structures with surface layers exhibiting modulus-of-elasticity values in the range of 0.5 to 3.5 $\times$ 10^6 psi are given in this section. The pertinent statistical data concerning the equations are given in Table 2. From these results, it is obvious that the equation for tensile strain in surface layer (R^2 = 0.100) is not as adequate as the others in approximating layer theory equations; however, the equation can provide general design information at least through tensile strains of 50 micro-units. The predictive capability of the four other equations, as indicated by standard errors of estimate, $\hat{S}_r$, is adequate.

1. Tensile stress in bottom of base layer, σ_b:

$$\mathrm{Log}_{10}\,(\sigma_b) \times 10^3 = [1{,}532.25 - 66.290\,(T_s - 7.5) - 35.264\,(T_b - 7.5)$$
$$+3.6935\,(T_s - 7.5)\,(T_b - 7.5) - 89.256\,(E_s - 2.0)$$
$$-8.3627\,(E_s - 2.0)\,(T_s - 7.5) + 44.289\,(E_b - 4.90)$$
$$-12.508\,(E_b - 4.90)^2 + 1.7468\,(E_b - 4.90)^3 + 2.9460\,(E_b - 4.90)$$
$$(T_s - 7.5) - 21.341\,(E_g - 8.0) + 1.7005\,(E_g - 8.0)^2] \quad (6)$$

2. Tensile strain in bottom of base layer, ϵ_b:

$$\mathrm{Log}_{10}\,(\epsilon_b) \times 10^3 = [1{,}614.23 - 60.373\,(T_s - 7.5) - 30.108\,(T_b - 7.5)$$
$$+3.1786\,(T_s - 7.5)\,(T_b - 7.5) - 81.580\,(E_s - 2.0)$$
$$-8.9055\,(E_s - 2.0)\,(T_s - 7.5) - 50.011\,(E_b - 4.9)$$
$$+3.7758\,(E_b - 4.9)^2 + 2.7682\,(E_b - 4.9)\,(T_s - 7.5)$$
$$-21.619\,(E_g - 8.0) + 1.7407\,(E_g - 8.0)^2] \quad (7)$$

3. Compressive strain in subgrade, ϵ_c:

$$\mathrm{Log}_{10}\,(\epsilon_c) \times 10^3 = [1{,}949.16 - 64.339\,(T_s - 7.5) - 33.750\,(T_b - 7.5)$$
$$+3.5397\,(T_s - 7.5)\,(T_b - 7.5) - 86.598\,(E_s - 2.0)$$
$$-8.4973\,(E_s - 2.0)\,(T_s - 7.5) - 49.905\,(E_b - 4.9)$$

Figure 1. System for structural design of stabilized pavement layers.

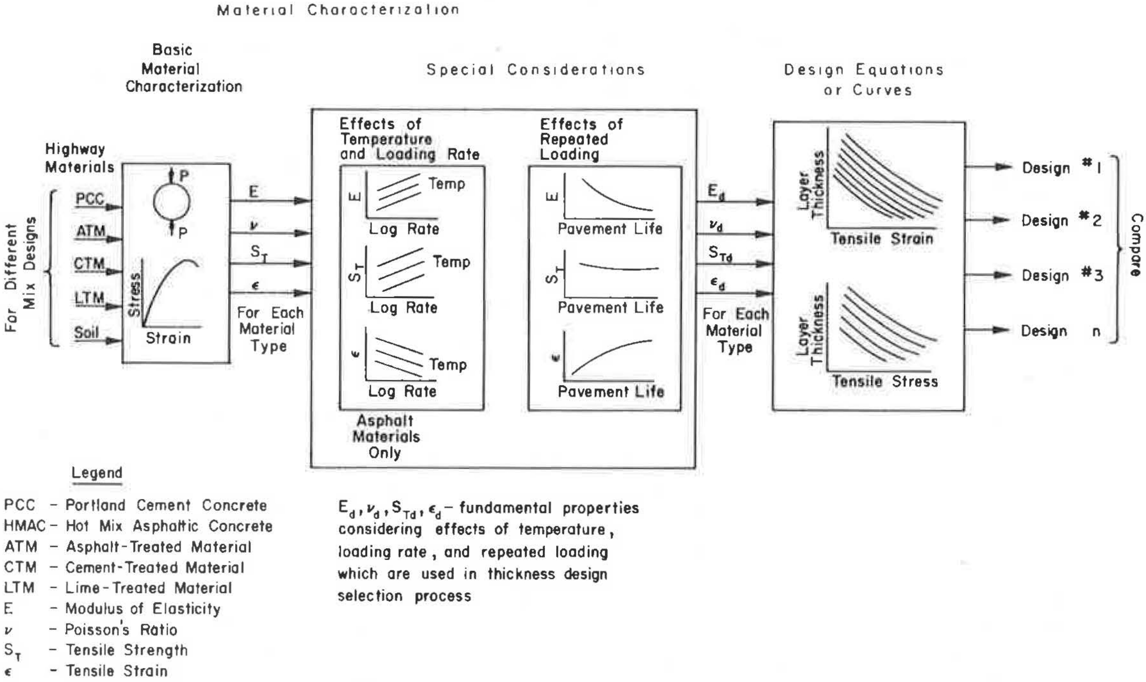

Figure 2. Hypothetical pavement section.

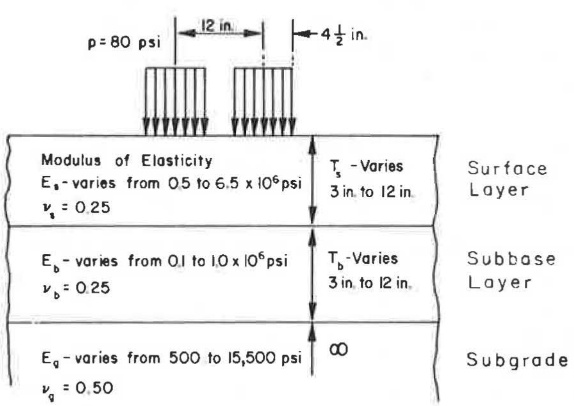

Table 1. Statistical data for regression equations: high-modulus surface layers.

Response Variable	Log Form	Coefficient of Determination	Standard Error of Estimate
Tensile stress in base layer	Log σ_b	0.989	±0.04635
Tensile strain in base layer	Log ϵ_b	0.983	±0.04388
Compressive strain in subgrade	Log ϵ_c	0.991	±0.03321
Tensile stress in surface layer	Log(σ_s + 26.4)	0.680	±0.18694
Tensile strain in surface layer	Log(ϵ_s + 5.15)	0.635	±0.1716

Table 2. Statistical data for regression equations: low-modulus surface layers.

Response Variable	Log Form	Coefficient of Determination	Standard Error of Estimate
Tensile stress in base layer	Log σ_b	0.969	±0.06649
Tensile strain in base layer	Log ϵ_b	0.964	±0.06212
Compressive strain in subgrade	Log ϵ_c	0.965	±0.06323
Tensile stress in surface layer	Log(σ_s + 55.0)	0.847	±0.10570
Tensile strain in surface layer	Log(ϵ_s + 56.4)	0.100	±0.40665

$$+3.7417\,(E_b - 4.9)^2 + 2.8438\,(E_b - 4.9)\,(T_s - 7.5)$$
$$-20.156\,(E_g - 8.0) + 1.6349\,(E_g - 8.0)^2] \qquad (8)$$

4. Tensile stress function for surface layer, σ_s:

$$\text{Log}_{10}\,(\sigma_s + 55.0) \times 10^3 = [2{,}043.83 - 27.372\,(T_b - 7.5) - 4.3388\,(T_s - 7.5)^2$$
$$+3.66404\,(T_s - 7.5)\,(T_b - 7.5) + 126.90\,(E_s - 2.0)$$
$$-15.756\,(E_s - 2.0)\,(T_s - 7.5) - 35.357\,(E_s - 2.0)^2$$
$$-47.247\,(E_b - 4.90) + 3.9371\,(E_b - 4.90)^2$$
$$+6.6099\,(E_b - 4.9)\,(T_s - 7.5)] \qquad (9)$$

5. Tensile strain function for surface layer, ϵ_s:

$$\text{Log}_{10}\,(\epsilon_s + 56.4) \times 10^3 = [1{,}845.4 - 13.892\,(T_b - 7.5) - 26.686\,(E_b - 4.90)$$
$$+14.129\,(E_s - 2.0)\,(E_b - 4.90)\,(T_s - 7.5)$$
$$+4.9443\,(E_b - 4.90)\,(T_s - 7.5)] \qquad (10)$$

APPLICATION OF DESIGN EQUATIONS

The equations can be solved for any one of the variables so long as estimates of the others are available. Generally, the inputs for the equations would include a critical design stress or strain and modulus of elasticity for each of three pavement layers as well as an estimate of surface layer thickness. The resulting output from these solutions would then be the corresponding base design thickness. The equations can also be used to obtain the design thickness of the surface layer as well as the critical design tensile stress or strain for the upper two layers if proper estimates of the other variables are provided as inputs for the equations.

THICKNESS SELECTION PROCEDURE

The procedure for selecting a base thickness is shown in Figure 3 for a constant surface thickness and given material properties. The process is broken down into five separate designs. The first two design thicknesses are based on allowable tensile stress or strain in the base layer. The third design is based on compressive strain in the subgrade and is provided to ensure that lateral movement of the subgrade will not occur and that the integrity of the pavement system is maintained. The final two design thicknesses are obtained by checking to ensure that the tensile stresses and strains produced in the surface layer do not exceed the allowable values for the surface layer materials.

All five base thicknesses are compared in order to select a critical design thickness that will satisfy all conditions. A typical design analysis would involve a number of iterative computations because changes in types of material as well as different combinations of surface and base thicknesses can be evaluated in the process of selecting the most economical design section.

The equations presented in this paper are based on a pavement structure that includes a base layer with a modulus of elasticity in the range of 0.1×10^6 to 1×10^6 psi and cannot be used to evaluate the situation of a surface layer lying directly on the subgrade. Therefore, the fact that a base is not required for a given design stress or strain (i.e., $T_b = 0.0$) does not mean that a base is not required. Rather it indicates that a minimum thickness is adequate or that a lower quality material (i.e., one with a lower tensile strength) may be used for the particular design criteria.

MATERIAL CHARACTERIZATION

One of the more important aspects in the use of a theorectical design approach involves the estimation of the fundamental properties of the materials comprising the different stabilized pavement layers. Consequently the method of obtaining estimates of these properties is then an important link in the total design system.

BASIC CHARACTERIZATION

Because the design equations are based on linear elastic theory, it is necessary to characterize the pavement materials by the elastic constant of modulus of elasticity. It is equally important that estimates of design stresses and strains be obtained to ensure the proper selection of a critical design thickness. The method of obtaining estimates of these properties is then an important link in the design analysis. Because the method is based on tensile failures, material characterization by some type of tensile test is essential.

Recent developments in the use of the indirect tensile test have included a technique for estimating fundamental properties of modulus of elasticity, Poisson's ratio, tensile strength, and tensile failure strains (4, 5, 6) for different stabilized materials. This technique appears to be the most practical method available for obtaining estimates of fundamental material properties of cohesive highway materials. The test has been used to evaluate a wide variety of materials, including portland cement concrete and asphalt-treated materials (4, 18-25), lime-treated materials (26, 27, 28), and untreated cohesive soils (29, 30).

REPEATED LOADING CONSIDERATION

Because pavement failures have been attributed in some cases to fatigue of the pavement layers, the behavior of stabilized materials subjected to repeated applications of tensile stresses and strains is important in the design of the various pavement layers. In this design system (Fig. 1), the fatigue or repeated loading behavior of the various stabilized materials is used to establish the design stresses and strains that will ensure a longer fatigue life and thus a longer pavement life.

Design Tensile Stress

The design tensile stress is obtained by multiplying the tensile strengths of the materials to be used in the surface and base layers by an appropriate fatigue strength ratio. (Fatigue strength ratio of a material is defined here as the ratio of the fatigue strength of the material at 10^7 load applications to the ultimate strength of the material.) The following fatigue strength ratios were developed for a variety of materials from available fatigue studies:

Material	Fatigue Strength Ratio
Portland cement concrete	0.52
Soil cement; cement-treated materials	0.35
Lime-treated materials	0.35
Asphalt-treated materials	0.125

A lower bound on all test data for a particular study was used in this development (1, 2).

Design Tensile Strains

Most fatigue studies have been concerned primarily with an evaluation of fatigue strength; therefore, there is a definite lack of information concerning fatigue strain ratios, i.e., ratio of repeated applied strain to ultimate failure strain at some preselected number of load applications. Because information about fatigue strain ratios is unavailable, it was necessary to establish the following recommended allowable tensile strains based on available fatigue data (1, 2):

Material	Allowable Tensile Strain (micro-unit)
Portland cement concrete	20
Cement-treated materials	20
Lime-treated materials	20
Asphalt-treated materials	50

Compressive Strain in Subgrade

Information concerning the allowable compressive strain for subgrade materials is limited to that suggested by Dormon and Metcalf (34). Based on their recommendations, a critical design compressive strain of 420 micro-units, which corresponds to 10 million load applications, is accepted for use in this design subsystem.

EFFECTS OF TEMPERATURE AND RATE OF APPLICATION OF LOAD ON PROPERTIES OF ASPHALTIC MATERIALS

The use of asphalt-stabilized pavement layers creates a special problem for the design of a pavement section because material properties such as modulus of elasticity, Poisson's ratio, tensile strength, and tensile strain at failure are a function of both the rate of application of load and the temperature of the stabilized layer. Therefore, another important part of this design approach is a requirement for a technique with which to evaluate the effects of temperature and rate of loading on the properties of asphalt-stabilized mixtures. A characterization technique based on a study by Hudson and Kennedy (18) has been developed (1, 2, 35) and provides a method of estimating the temperature and rate dependence of asphaltic materials.

DESIGN APPLICATIONS

A design example is presented to illustrate the overall approach necessary in the structural design of a base. This problem illustrates the steps necessary in the design of an asphalt-stabilized base layer for a rigid pavement structure. The total design analysis included an evaluation of asphalt-stabilized base thickness requirements for summer and winter conditions as well as design considerations for two surface thicknesses and two portland cement concrete mixes.

The first step in the design process involves characterization of the materials used in the various pavement layers. The properties assumed for the portland cement concrete mixes and the asphalt-treated material are given in Table 3. The modulus of elasticity of the subgrade is assumed to be 8,000 psi, and the average ambient summer and winter temperatures are expected to be 85 F and 65 F respectively. The resulting estimates of material properties for the two design periods are also given in Table 3.

The second step involves determination of the design stress criteria for the various pavement layers. The design stress criteria are obtained from the product of the design tensile strength (Table 3) and the recommended fatigue strength ratios for the various pavement materials. The results of the procedure for obtaining the design stresses are given in Table 4. The design strain criteria used are those given previously.

The third step involves substitution of the various material properties, design criteria, and surface layer thickness in the design equations and solving for the base thicknesses that satisfy each of the five design criteria. The solutions to each of the eight individual designs evaluated in this example are given in Table 5.

The final step in the design process includes a comparison of the different design thicknesses and, with the aid of a set of decision criteria, the selection of a final base design thickness. For this example, only the eight different critical design thicknesses are compared. After the decision criteria are established, the final design could be selected from these eight critical base designs. From these results, it can be seen that, for this particular example problem, (a) an increase in surface layer thickness reduced the required base thickness and (b) the change in surface layer mix designs had very little effect on base requirements.

SUMMARY

In this paper a formalized design system, based on the prevention of tensile failures in pavement layers, has been presented for use in the structural design of stabilized pavement layers. Layered theory was selected as the basic design theory and was used in the development of a series of design equations relating tensile stresses and strains at selected locations in the pavement layers to a number of the more important design variables. Applications of the design equations to the structural design of stabilized

Figure 3. Process for selecting final base thickness.

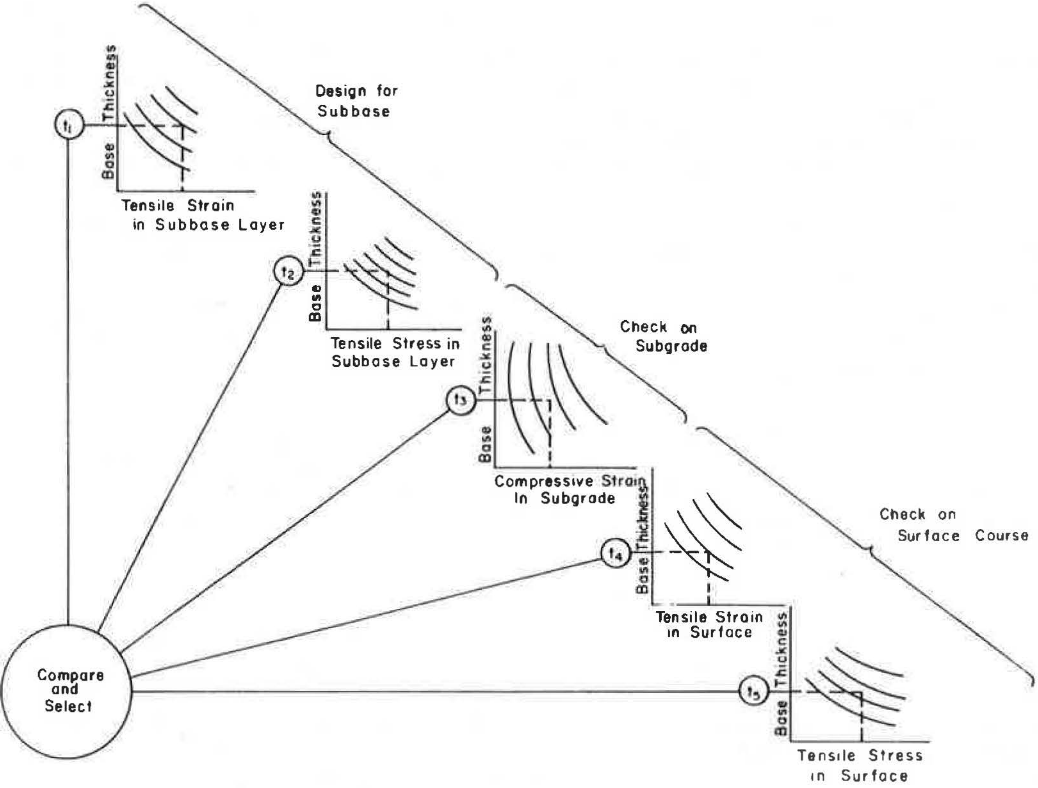

Table 3. Properties of portland cement concrete and asphalt-treated material.

Material	Measure
Portland cement concrete	
Mix 1	
Modulus of elasticity	4.75×10^6 psi
Tensile strength	310 psi
Mix 2	
Modulus of elasticity	3.50×10^6 psi
Tensile strength	270 psi
Asphalt-treated	
Summer conditions	
Modulus of elasticity	1.500×10^5 psi
Tensile strength	100 psi
Winter conditions	
Modulus of elasticity	3.50×10^5 psi
Tensile strength	180 psi
Subgrade (modulus of elasticity)	8.00×10^3 psi
Average summer temperature	85 F
Average winter temperature	65 F

Table 4. Determination of design criteria for use in design equations.

Material	Design Tensile Strength (psi)	Fatigue Strength Ratio	Design Stress[a] (psi)	Design Strain (micro-units)
Portland cement concrete				
Mix 1	310	0.52	160	20
Mix 2	270	0.52	140	20
Asphalt-treated				
Summer conditions	100	0.125	12.5	50
Winter conditions	180	0.125	22.5	50

[a]Design stress equals fatigue strength ratio times tensile strength.

Table 5. Base thickness requirements for design conditions.

Surface Layer Thickness (in.)	Mix Design	Modulus of Elasticity: Surface (10^6 psi)	Base (10^5 psi)	Subgrade (10^3 psi)	Base Thickness for Design Criteria of: σ_b	ϵ_b	ϵ_c	σ_s	ϵ_s
7.5	1	4.75	3.50(w)[a]	8.0	0	0	0	3.0	4.3
7.5	1	4.75	1.5(s)	8.0	0	0	0	4.0	7.1
8.5	1	4.75	3.5(w)	8.0	0	0	0	0	1.8
8.5	1	4.75	1.5(s)	8.0	0	0	0	0	3.4
7.5	2	3.5	3.5(w)	8.0	1.8	0	0	4.8	4.3
7.5	2	3.5	1.5(s)	8.0	0	0	0	6.8	7.1
8.5	2	3.5	3.5(w)	8.0	0	0	0	2.7	1.8
8.5	2	3.5	1.5(s)	8.0	0	0	0	2.8	3.4

[a]The letter in parentheses following the modulus of elasticity indicates the design temperature for the asphalt-stabilized layer; i.e., s is average summer temperature of 85 F, and w is average winter temperature of 65 F.

bases were also presented, including definite procedures for the selection of a critical base design thickness. Characterization techniques were also presented to provide necessary estimates of limiting design criteria for the materials proposed for the various pavement layers. The application of the total design approach to the structural design of various types of stabilized base layers is illustrated in an example problem.

The design system presented here is based on a practical interpretation of layered theory that emphasizes the contribution of each individual layer to the behavior of the total pavement structure. The new design system, because of its dependence on layered theory, requires verification through trial use and field observation. This design system, however, offers the basis for correcting and updating by comparing designs based on the theoretical equations against observed pavement performance.

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