Supplement to the

AASHTO Guide For

Design of Pavement Structures

Part II, - Rigid Pavement Design & Rigid Pavement Joint Design

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Preface

The Joint Task Force on Pavements—composed of members from the Highway Subcommittee on Design, one member each from the Highway Subcommittees on Materials, Construction, and Maintenance, and one from the Standing Committee on Planning—has developed this Supplement to the *AASHTO Guide for the Design of Pavement Structures*. This Supplement includes alternative design procedures that can be used in place of or in conjunction with Part II, Section 3.2 "Rigid Pavement Design" and Section 3.3 "Rigid Pavement Joint Design."

The development of these alternative design procedures began with AASHTO's NCHRP Project 1-30. This project was to utilize new data available as a result of the LTPP database to incorporate new data on loss-of-support for use in the design of rigid pavements and overlays and to improve the selection of k values. The document was then validated and revised under an FHWA contract and then finally developed into design procedures for use by AASHTO. These alternative design procedures and a "Rigid Pavement Design Example" are included herein for those who would like to make use of the LTPP data in rigid pavement design.

This supplement has been ballotted and approved for publication by AASHTO's Standing Committee on Highways.

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SUPPLEMENTAL VERSION OF THE AASHTO GUIDE, PART II, SECTION 3.2 RIGID PAVEMENT DESIGN FOR DESIGN OF PAVEMENT STRUCTURES AND SECTION 3.3 RIGID PAVEMENT JOINT DESIGN

This supplement has been prepared as an alternate method for rigid pavement design, in the form of an addendum to the current AASHTO Guide. It contains the recommendations from NCHRP 1-30, modified based on the results of the verification study conducted using the LTPP database.

3.2 RIGID PAVEMENT DESIGN

This section describes the design for Portland cement concrete pavements, including jointed plain (JPCP), jointed reinforced (JRCP), and continuously reinforced (CRCP). As in the design for flexible pavements, it is assumed that these pavements will carry traffic levels in excess of 70,000 18-kip [80-kN] (rigid pavement) ESALs over the performance period. Examples of use of this rigid pavement design procedure are presented at the end of this supplement.

Design of Different Types of Concrete Pavement. The JPCP design concept is to provide a sufficient slab thickness and joint spacing to minimize the development of transverse cracking. The JRCP and CRCP design concepts provide sufficient slab thickness and reinforcement to hold very tight the transverse cracks that form so that aggregate interlock will be maintained. The thickness of the design model upon which this guide is based was developed and validated specifically for JPCP, for which joint spacing is one of the important required design inputs affecting thermal curling stresses and, thus, transverse cracking. A proper selection of slab thickness and joint spacing is required to control the development of transverse cracking for a given climate, base, and subgrade. JRCP has much longer joint spacing and CRCP has no joints, and the transverse cracks that eventually form in these types of pavements must be held tight by sufficient steel reinforcement.

The use of this design method to determine an appropriate slab thickness for JRCP or CRCP requires the selection of an input "hypothetical" joint spacing. Research using the LTPP database has shown that the following input values of joint spacing will result in reasonable design thicknesses using this design method.

JPCP: Actual joint spacing, ft.

JRCP: Actual joint spacing if less than 30 ft [9 m], or 30 ft maximum (use this value only to obtain slab design thickness).

CRCP: 15 ft [4.6 m] (use this hypothetical value only to obtain slab design thickness).

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Load Transfer at Joints. The AASHTO design procedure is based on the AASHO Road Test pavement performance algorithm that was extended to include additional design features. Inherent in the use of the AASHTO procedure is the use of dowels at transverse joints. Joint faulting was not a distress manifestation at the Road Test due to the adequacy of the dowel design. A faulting design check is provided for doweled joints to ensure that the dowels are sized properly. If a significant faulting problem is expected, an increase in dowel diameter or other design change may be warranted. The non-doweled faulting check was developed using more recent measurements of field data.

If the designer wishes to consider undoweled joints, a design check for faulting is provided. If the faulting check indicates inadequate load transfer, design modifications such as the use of dowels or changes in base type, drainage, and joint spacing may be made.

In addition, if the designer wishes to consider undoweled joints, a design check is also made for critical stresses due to axle loads applied near the transverse joint, along with a negative thermal gradient, creating a corner loading situation that would lead to premature cracking. If this check shows a potential problem, design modifications such as the use of dowels, increased slab thickness, or changes in base type may be made.

3.2.1 Develop Effective Modulus of Subgrade Reaction (k-Value)

The modulus of subgrade reaction (k-value) is defined as that measured or estimated on top of the finished roadbed soil or embankment upon which the base course and/or concrete slab will eventually be constructed. The k-value represents the subgrade (and embankment, if present); it does not represent the base course. The base course is considered a structural layer of the pavement along with the concrete slab, and thus its thickness and modulus are important design inputs in determining the required slab thickness in Section 3.2.2.

The k-Value input defined. The elastic k-value on top of the subgrade or embankment is the required design input. The gross k-value incorporated in previous versions of the AASHTO Guide represents not only elastic deformation of the subgrade under a loading plate, but also substantial permanent deformation. Only the elastic component of this deformation is considered representative of the response of the subgrade to traffic loads on the pavement. The elastic k-value test was the main subgrade test conducted extensively at the AASHO Road Test. When the elastic k-value was used in structural analysis of the AASHO Road Test pavements, it was found that slab stresses computed with a three-dimensional finite element model were approximately equal to those measured in the field under full-scale truck axle loadings at creep speed, providing further justification for use of the elastic k-value in the design.

Steps in determining design k-value. The k-value input required for this design method is determined by the following steps, which are described in this section:

1. Select a subgrade k-value for each season, using any of the three following methods:
   (a) Correlations with soil type and other soil properties or tests.
   (b) Deflection testing and backcalculation (most highly recommended).
   (c) Plate bearing tests.

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2. Determine a seasonally adjusted effective k-value.
3. Adjust the seasonal effective k-value for effects of a shallow rigid layer, if present, and/or an embankment above the natural subgrade.

Note that the AASHTO design methodology requires the mean k-value, not the lowest value measured or some other conservative value. Note also that no additional adjustment to the k-value is applied for loss of support. **Substantial loss of support existed for many sections at the** AASHO Road Test, which led to **increased slab cracking and loss of serviceability. Therefore,** the performance data, upon which the AASHO Road Test performance model is based, already reflect the effect of considerable loss of support.

Step 1. Select a Subgrade k-Value for Each Season. A season is defined as a period of time within a year, such as 3 months (i.e., spring, summer, fall, winter). The number of seasons and the length of each season by which a year is characterized depend on the climate of the pavement's location.

There are several ways to measure or estimate the subgrade elastic k-value. Procedures are provided for three methods described below—correlation methods, backcalculation methods, and plate testing methods.

Correlation Methods. Guidelines are presented for selecting an appropriate k-value based on soil classification, moisture level, density, California Bearing Ratio (CBR), or Dynamic Cone Penetrometer (DCP) data. The CBR may also be estimated from the R-value. These correlation methods are anticipated to be used routinely for design. The k-values obtained from soil type or tests correlation methods may need to be adjusted for embankment above the subgrade or a shallow rigid layer beneath the subgrade.

The k-values and correlations for cohesive soils (A-4 through A-7). The bearing capacity of cohesive soils is strongly influenced by their degree of saturation (S_r, percent), which is a function of water content (w, percent), dry density (γ, lb/ft^3), and specific gravity (G_s):

$$S_r = \frac{w}{\left(\frac{62.4}{\gamma}\right) - \left(\frac{1}{G_s}\right)} \qquad [25]$$

Recommended k-values for each fine-grained soil type as a function of degree of saturation are shown in Figure 40. Each line represents the middle of a range of reasonable values for k. For any given soil type and degree of saturation, the range of reasonable values is about ± 40 psi/in [11 kPa/mm]. A reasonable lower limit for k at 100 percent saturation is considered to be 25 psi/in [7 kPa/mm]. Thus, for example, an A-6 soil might be expected to exhibit k-values between about 180 and 260 psi/in [49 and 70 kPa/mm] at 50 percent saturation, and k-values between about 25 and 85 psi/in [7 and 23 kPa/mm] at 100 percent saturation.

Two different types of materials can be classified as A-4: predominantly silty materials (at least 75 percent passing the #200 sieve, possibly organic), and mixtures of silt, sand, and gravel (up to 64 percent retained on #200 sieve). The former may have a density between about 90 and 105

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lb/ft^3 [1442 and 1682 kg/m^3], and a CBR between about 4 and 8. The latter may have a density between about 100 and 125 lb/ft^3 [1602 and 2002 kg/m^3], and a CBR between about 5 and 15. The line labeled A-4 in Figure 40 is more representative of the former group. If the material in question is A-4, but possesses the properties of the stronger subset of materials in the A-4 class, a higher k-value at any given degree of saturation (for example, along the line labeled A-7-6 in Figure 40) is appropriate.

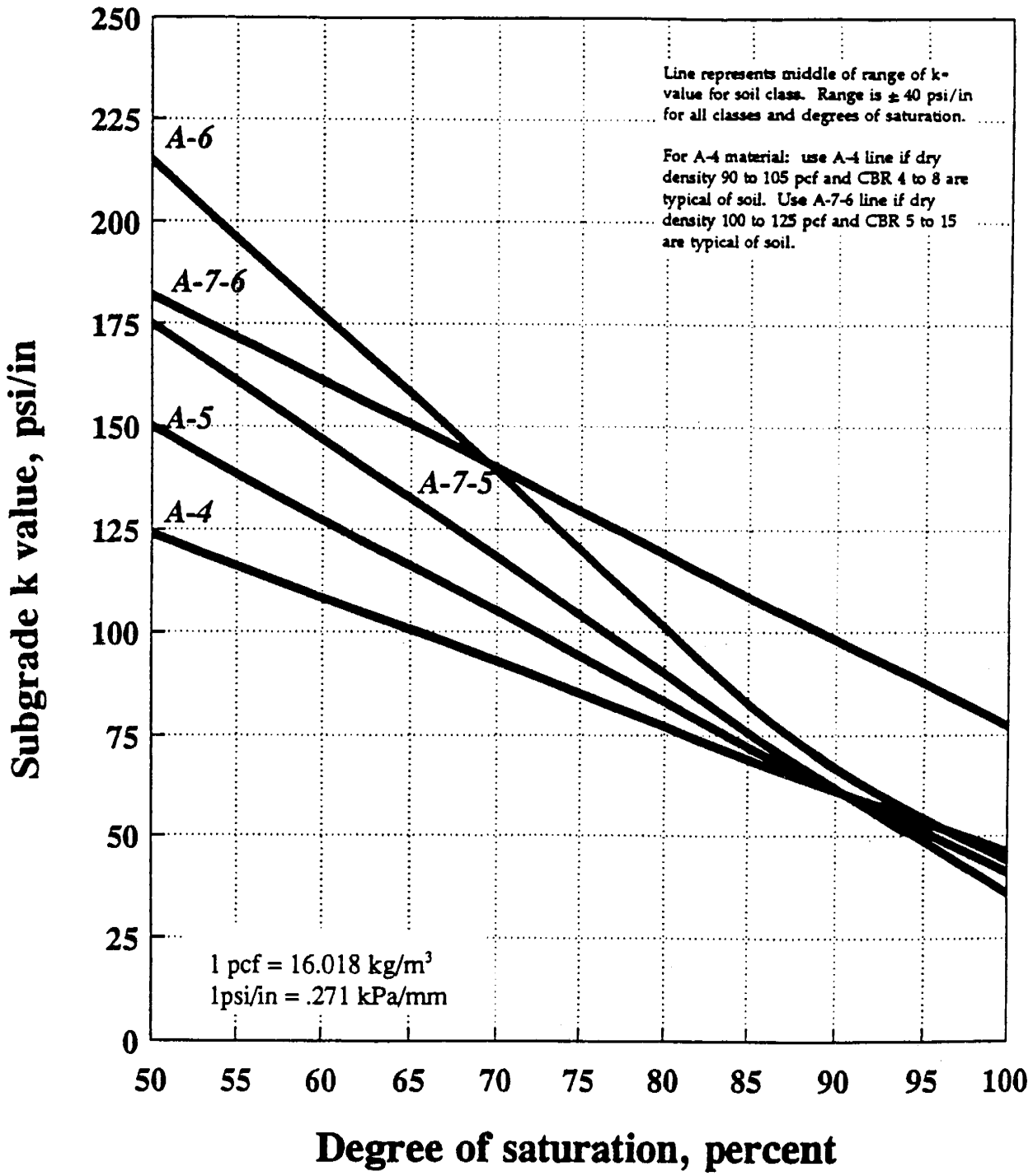


Figure 40. The k-value versus degree of saturation for cohesive soils.

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Recommended k-value ranges for fine-grained soils, along with typical ranges of dry density and CBR for each soil type, are summarized in Table 11.

The k-values and correlations for cohesionless soils (A-1 and A-3). The bearing capacity of cohesionless materials is fairly insensitive to moisture variation and is predominantly a function of their void ratio and overall stress state. Recommended k-value ranges for cohesionless soils, along with typical ranges of dry density and CBR for each soil type, are summarized in Table 11.

The k-values and correlations for A-2 soils. Soils in the A-2 class are all granular materials falling between A-1 and A-3. Although it is difficult to predict the behavior of such a wide variety of materials, the available data indicate that in terms of bearing capacity, A-2 materials behave similarly to cohesionless materials of comparable density. Recommended k-value ranges for A-2 soils, along with typical ranges of dry density and CBR for each soil type, are summarized in Table 11.

Correlation of k-values to California Bearing Ratio. Figure 41 illustrates the approximate range of k-values that might be expected for a soil with a given California Bearing Ratio.

Correlation of k-values to penetration rate by Dynamic Cone Penetrometer. Figure 42 illustrates the range of k-values that might be expected for a soil with a given penetration rate (inches per blow) measured with a Dynamic Cone Penetrometer. This is a rapid hand-held testing device that can be used to quickly test dozens of locations along an alignment. The DCP can also penetrate AC surfaces and surface treatments to test the foundation below.

Assignment of k-values to seasons. Among the factors that should be considered in selecting seasonal k-values are the seasonal movement of the water table, seasonal precipitation levels, winter frost depths, number of freeze-thaw cycles, and the extent to which the subgrade will be protected from frost by embankment material. A "frozen" k may not be appropriate for winter, even in a cold climate, if the frost will not reach and remain in a substantial thickness of the subgrade throughout the winter. If it is anticipated that a substantial depth (e.g., a few feet) of the subgrade will be frozen, a k-value of 500 psi/in [135 kPa/mm] would be an appropriate "frozen" k.

The seasonal variation in degree of saturation is difficult to predict, but in locations where a water table is constantly present at a depth of less than about 10 ft [3 m], it is reasonable to expect that fine-grained subgrades will remain at least 70 to 90 percent saturated, and may be completely saturated for substantial periods in the spring. County soil reports can provide data on the position of the high-water table (i.e., the typical depth to the water table at the time of the year that it is at its highest). Unfortunately, county soil reports do not provide data on the variation in depth to the water table throughout the year.

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Table 11. Recommended k-value ranges for various soil types.

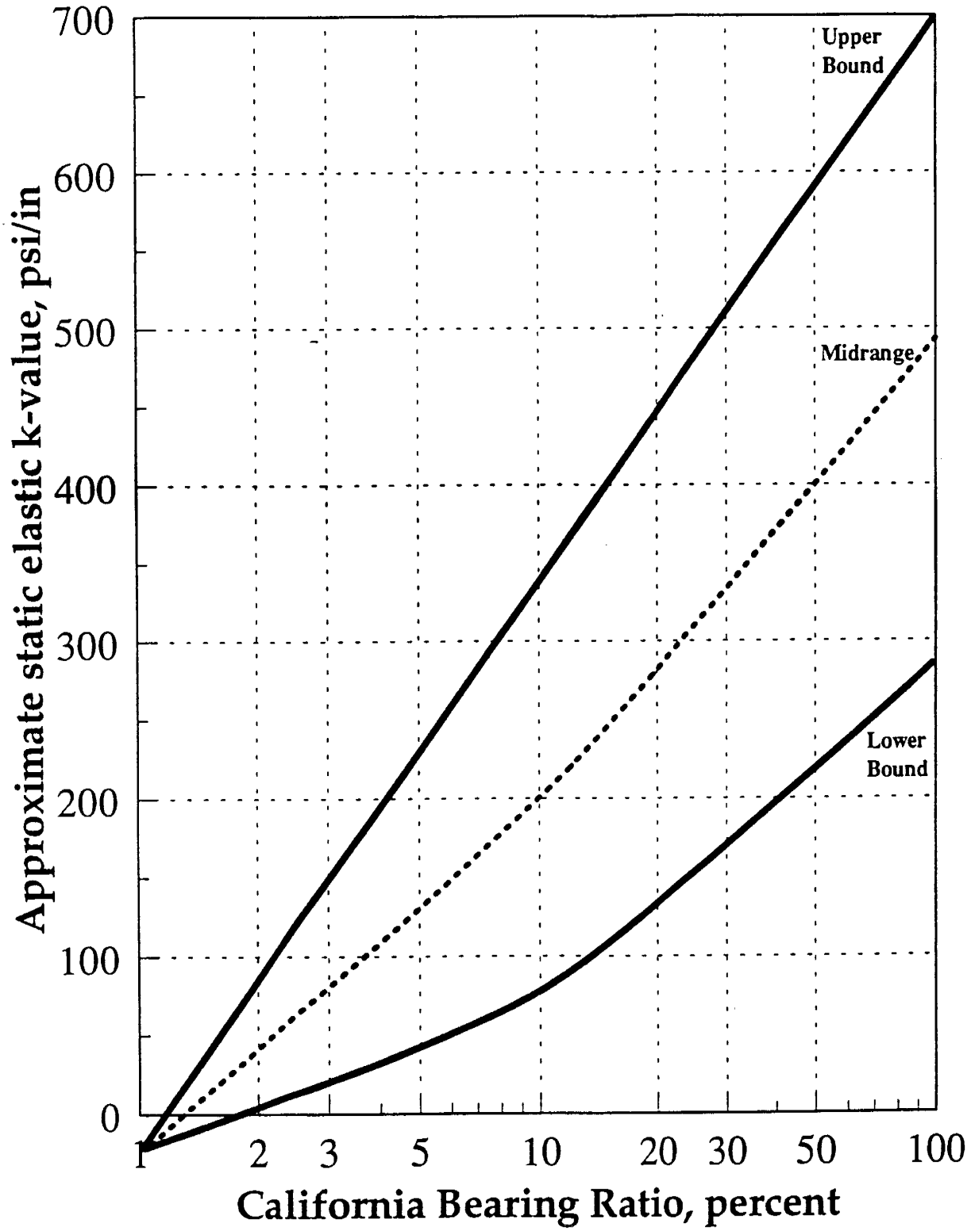
AASHTO class	Description	Unified class	Dry density (lb/ft^3)	CBR (percent)	k-value (psi/in)
Coarse-grained soils:					
A-1-a, well graded	gravel	GW, GP	125 - 140	60 - 80	300 - 450
A-1-a, poorly graded			120 - 130	35 - 60	300 - 400
A-1-b	coarse sand	SW	110 - 130	20 - 40	200 - 400
A-3	fine sand	SP	105 - 120	15 - 25	150 - 300
A-2 soils (granular materials with high fines):					
A-2-4, gravelly	silty gravel	GM	130 - 145	40 - 80	300 - 500
A-2-5, gravelly	silty sandy gravel				
A-2-4, sandy	silty sand	SM	120 - 135	20 - 40	300 - 400
A-2-5, sandy	silty gravelly sand				
A-2-6, gravelly	clayey gravel	GC	120 - 140	20 - 40	200 - 450
A-2-7, gravelly	clayey sandy gravel				
A-2-6, sandy	clayey sand	SC	105 - 130	10 - 20	150 - 350
A-2-7, sandy	clayey gravelly sand				
Fine-grained soils:					
A-4	silt	ML, OL	90 - 105	4 - 8	25 - 165 *
	silt/sand/ gravel mixture		100 - 125	5 - 15	40 - 220 *
A-5	poorly graded silt	MH	80 - 100	4 - 8	25 - 190 *
A-6	plastic clay	CL	100 - 125	5 - 15	25 - 255 *
A-7-5	moderately plastic elastic clay	CL, OL	90 - 125	4 - 15	25 - 215 *
A-7-6	highly plastic elastic clay	CH, OH	80 - 110	3 - 5	40 - 220 *

* k-value of fine-grained soil is highly dependent on degree of saturation. See Figure 40.

These recommended k-value ranges apply to a homogeneous soil layer at least 10 ft [3 m] thick. If an embankment layer less than 10 ft [3 m] thick exists over a softer subgrade, the k-value for the underlying soil should be estimated from this table and adjusted for the type and thickness of embankment material using Figure 43. If a layer of bedrock exists within 10 ft [3 m] of the top of the soil, the k should be adjusted using Figure 43.

1 lb/ft^3 =16.018 kg/m^3, 1 psi/in = 0.271 kPa/mm

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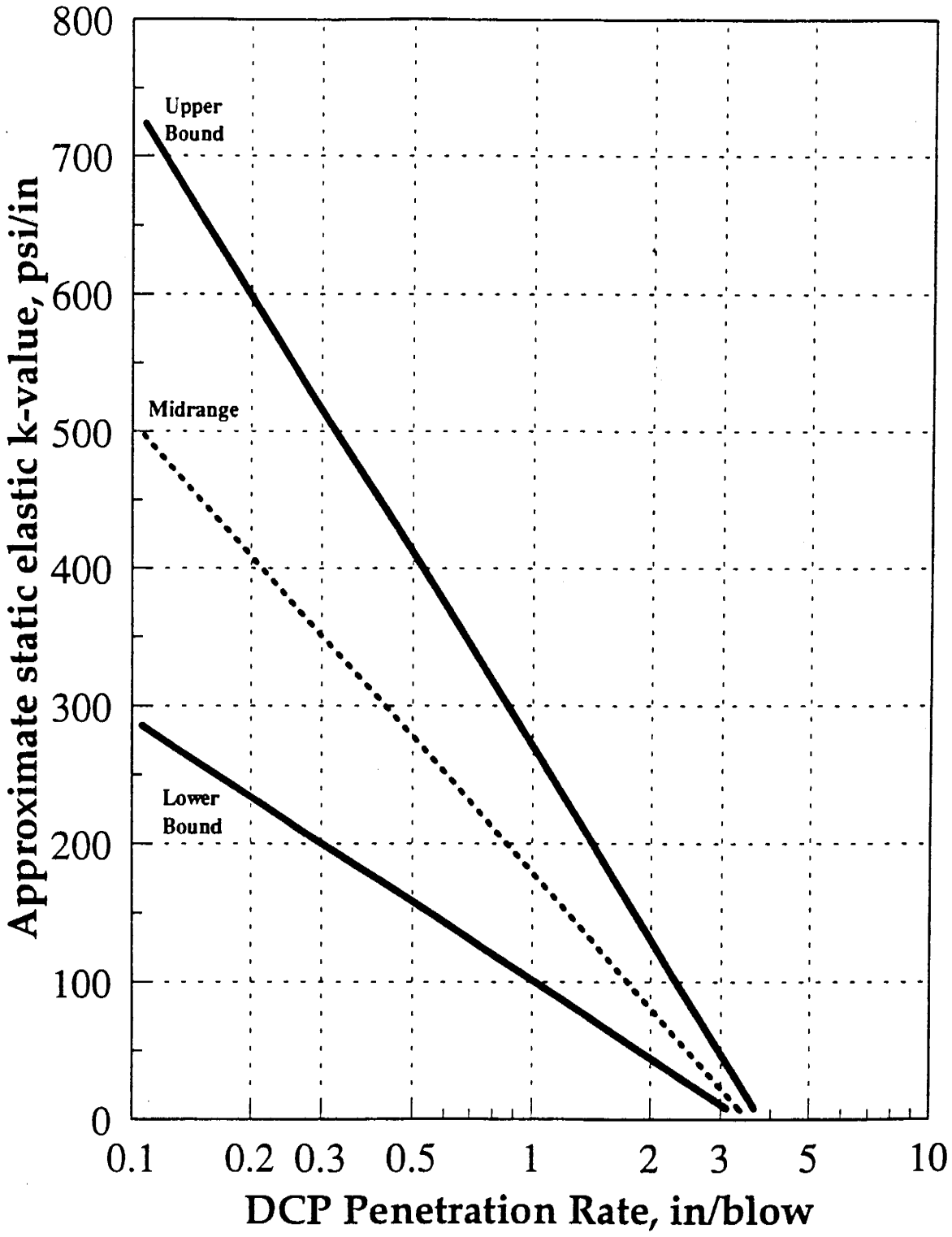
1 psi/in = 0.271 kPa/mm

Figure 41. Approximate relationship of k-value range to CBR.

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1 psi/in = 0.271 kPa/mm
1 in = 25.4 mm

Figure 42. Approximate relationship of k-value range to DCP penetration rate.

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Deflection Testing and Backcalculation Methods. These methods are suitable for determining k-value for design of overlays of existing pavements, for design of a reconstructed pavement on existing alignments, or for design of similar pavements in the same general location on the same type of subgrade. An agency may also use backcalculation methods to develop correlations between nondestructive deflection testing results and subgrade types and properties. Cut and fill sections are likely to yield different k-values. No embankment or rigid layer adjustment is required for backcalculated k-values if these characteristics are similar for the pavement being tested and the pavement being designed, but backcalculated dynamic k-values do need to be reduced by a factor of approximately 2 to estimate a static elastic k-value for use in design.

An appropriate design subgrade k-value for use as an input to this design method is determined by the following steps:

1. Measure deflections on an in-service concrete or composite (AC-overlaid PCC) pavement with the same or similar subgrade as the pavement being designed.
2. Compute the appropriate AREA of each deflection basin.
3. Compute an initial estimate (assuming an infinite slab size) of the radius of relative stiffness, ℓ.
4. Compute an initial estimate (assuming an infinite slab size) of the subgrade k-value.
5. Compute adjustment factors for the maximum deflection d_0 and the initially estimated ℓ to account for the finite slab size.
6. Adjust the initially estimated k-value to account for the finite slab size.
7. Compute the mean backcalculated subgrade k-value for all of the deflection basins considered.
8. Compute the estimated mean static k-value for use in design.

These steps are described below, with the relevant equations for bare concrete and composite pavements given for each step.

Measure deflections. Measure slab deflection basins along the project at an interval sufficient to adequately assess conditions. Intervals of 100 to 1000 ft [30 to 300 m] are typical. Measure deflections with sensors located at 0, 8, 12, 18, 24, 36, and 60 in [0, 203, 305, 457, 610, 915, and 1524 mm] from the center of the load. Measure deflections in the outer wheel path. A heavy-load deflection device (e.g., Falling Weight Deflectometer) and a load magnitude of 9,000 lbf [40 kN] are recommended. ASTM D4694 and D4695 provide additional guidance on deflection testing.

Compute AREA. For a bare concrete pavement, compute the $AREA_7$ of each deflection basin using the following equation:

$$AREA_7 = 4 + 6\left(\frac{d_8}{d_0}\right) + 5\left(\frac{d_{12}}{d_0}\right) + 6\left(\frac{d_{18}}{d_0}\right) + 9\left(\frac{d_{24}}{d_0}\right) + 18\left(\frac{d_{36}}{d_0}\right) + 12\left(\frac{d_{60}}{d_0}\right) \quad [26]$$

where d_0 = deflection in center of loading plate, inches
d_i = deflections at 0, 8, 12, 18, 24, 36, and 60 in [0, 203, 305, 457, 610, 915, and 1524 mm] from plate center, inches

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For a composite pavement, compute the $AREA_5$ of each deflection basin using the following equation:

$$AREA_5 = 3 + 6\left(\frac{d_{18}}{d_{12}}\right) + 9\left(\frac{d_{24}}{d_{12}}\right) + 18\left(\frac{d_{36}}{d_{12}}\right) + 12\left(\frac{d_{60}}{d_{12}}\right) \quad [27]$$

Estimate ℓ assuming an infinite slab size. The radius of relative stiffness for a bare concrete pavement (assuming an infinite slab) may be estimated using the following equation:

$$\ell_{est} = \left[\frac{ln\left(\frac{60 - AREA_7}{289.708}\right)}{-0.698}\right]^{2.566} \quad [28]$$

The radius of relative stiffness for a composite pavement (assuming an infinite slab) may be estimated using the following equation:

$$\ell_{est} = \left[\frac{ln\left(\frac{48 - AREA_5}{158.40}\right)}{-0.476}\right]^{2.220} \quad [29]$$

Estimate k assuming an infinite slab size. For a bare concrete pavement, compute an initial estimate of the k-value using the following equation:

$$k_{est} = \frac{P\ d_0^*}{d_0\left(\ell_{est}\right)^2} \quad [30]$$

where k = backcalculated dynamic k-value, psi/in
P = load, lb
d_0 = deflection measured at center of load plate, inch
ℓ_{est} = estimated radius of relative stiffness, inches, from previous step
d_0^* = nondimensional coefficient of deflection at center of load plate:

$$d_0^* = 0.1245\ e^{\left[-0.14707\ e^{(-0.07565\ \ell_{est})}\right]} \quad [31]$$

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For a composite pavement, compute an initial estimate of the k-value using the following equation:

$$k_{est} = \frac{P\ d_{12}^*}{d_{12}\left(\ell_{est}\right)^2} \quad [32]$$

d_{12} = deflection measured 12 in [305 mm] from center of load plate, inch
ℓ_{est} = estimated radius of relative stiffness, in, from previous step
d_{12}^* = nondimensional coefficient of deflection 12 in [305 mm] from center of load plate:

$$d_{12}^* = 0.12188\ e^{\left[-0.79432\ e^{(-0.07074\ \ell_{est})}\right]} \quad [33]$$

Compute adjustment factors for d_0 and ℓ for finite slab size. For both bare concrete and composite pavements, the initial estimate of ℓ is used to compute the following adjustment factors to d_0 and ℓ to account for the finite size of the slabs tested:

$$AF_{d_0} = 1 - 1.15085\ e^{-0.71878\left(\frac{L}{\ell_{est}}\right)^{0.80151}} \quad [34]$$

$$AF_{\ell} = 1 - 0.89434\ e^{-0.61662\left(\frac{L}{\ell_{est}}\right)^{1.04831}} \quad [35]$$

where, if the slab length is less than or equal to twice the slab width, L is the square root of the product of the slab length and width, both in inches, or if the slab length is greater than twice the width, L is the product of the square root of two and the slab length in inches:

$$\begin{aligned} &\text{if } L_l \le 2 * L_w, \quad L = \sqrt{L_l\ L_w} \\ &\text{if } L_l > 2 * L_w, \quad L = \sqrt{2} * L_l \end{aligned} \quad [36]$$

Adjust k for finite slab size. For both bare concrete and composite pavements, adjust the initially estimated k-value using the following equation:

$$k = \frac{k_{est}}{AF_{\ell}^2\ AF_{d_0}} \quad [37]$$

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Compute mean dynamic k-value. Exclude from the calculation of the mean k-value any unrealistic values (i.e., less than 50 psi/in [14 kPa/mm] or greater than 1500 psi/in [407 kPa/mm]), as well as any individual values that appear to be significantly out of line with the rest of the values.

Compute the estimated mean static k-value for design. Divide the mean dynamic k-value by two to estimate the mean static k-value for design.

A blank worksheet for computation of k from deflection data and example computations of k from deflection basins measured on two pavements, one bare concrete and the other composite, are given in Table 12.

Seasonal variation in backcalculated k-values. The design k-value determined from backcalculation as described above represents the k-value for the season in which the deflection testing was conducted. An agency may wish to conduct deflection testing on selected projects in different seasons of the year to assess the seasonal variation in backcalculated k-values for different types of subgrades.

Plate Bearing Test Methods. The subgrade or embankment k-value may be determined from either of two types of plate bearing tests: repetitive static plate loading (AASHTO T221, ASTM D1195) or nonrepetitive static plate loading (AASHTO T222, ASTM D1196). These test methods were developed for a variety of purposes, and do not provide explicit guidance on the determination of the required k-value input to the design procedure described here.

For the purpose of concrete pavement design, the recommended subgrade input parameter is the static elastic k-value. This may be determined from either a repetitive or nonrepetitive test on the prepared subgrade or on a prepared test embankment, provided that the embankment is at least 10 ft [3 m] thick. Otherwise, the test should be conducted on the subgrade, and the k-value obtained should be adjusted to account for the thickness and density of the embankment, using the nomograph provided in Step 3.

In a repetitive test, the elastic k-value is determined from the ratio of load to elastic deformation (the recoverable portion of the total deformation measured). In a nonrepetitive test, the load-deformation ratio at a deformation of 0.05 in [1.25 mm] is considered to represent the elastic k-value, according to extensive research by the U.S. Army Corps of Engineers.

Note also that a 30-in-diameter [762-mm-diameter] plate should be used to determine the elastic static k-value for use in design. Smaller diameter plates will yield substantially higher k-values, which are not appropriate for use in this design procedure.

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Table 12. Determination of design subgrade k-value from deflection measurements.

BARE CONCRETE PAVEMENT

Step	Equation	Calculated Value	Example
d_0 d_8 d_{12} d_{18} d_{24} d_{36} d_{60}		_____ _____ _____ _____ _____ _____ _____	0.00418 0.00398 0.00384 0.00361 0.00336 0.00288 0.00205
$AREA_7$	[26]		45.0
Initial estimate of ℓ	[28]		40.79
Nondimensional d_0* and initial estimate of k	[31] [30]		0.1237 160
AF_{d_0} AF_ℓ	[34] [35]		0.867 0.934
Adjusted k	[37]		212
Mean dynamic k			212
Mean static k for design			106

COMPOSITE PAVEMENT

Step	Equation	Calculated Value	Example
d_{12} d_{18} d_{24} d_{36} d_{60}		_____ _____ _____ _____ _____	0.00349 0.00332 0.00313 0.00273 0.00202
$AREA_5$	[27]		37.8
Initial estimate of ℓ	[29]		48.83
Nondimensional d_{12}* and initial estimate of k	[33] [32]		0.1189 128
AF_{d_0} AF_ℓ	[34] [35]		0.823 0.896
Adjusted k	[37]		195
Mean dynamic k			195
Mean static k for design			97

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Step 2. Determine Seasonally Adjusted Effective k-Value. The effective k-value is obtained by combining the seasonal k-values into a single "effective" value for use in concrete pavement design. The effective k-value is essentially a weighted average based on fatigue damage. The effective k-value results in the same fatigue damage over the entire year that is caused by the seasonal variation in k-value. The seasonally adjusted effective k-value is determined by the following steps:

1. Select tentative values for the slab thickness D, concrete flexural strength S'_c, concrete elastic modulus E_c, base elastic modulus E_b and friction coefficient f (both depending on base type), base thickness H_b, design temperature differential TD (for a given climatic region, as a function of the trial slab thickness D), joint spacing L, and initial and terminal serviceability P1 and P2. The tentative values selected for these parameters need only be approximate.
2. Select a k-value to represent each distinct season of the year.
3. Using each of the seasonal k-values in turn, calculate W_{18}, the allowable number of 18-kip [80-kN] ESALs for the design traffic lane, using the rigid pavement performance model given in Section 3.2.2.
4. Compute the relative damage for each season as the inverse of the calculated W_{18}.
5. Compute the total relative damage for the year and divide by the number of seasons to obtain the mean annual damage.
6. Compute a W_{18} corresponding to the mean damage as the inverse of the mean damage.
7. Use the rigid pavement performance model to determine a single k-value that produces a predicted W_{18} matching the W_{18} obtained in Step 6. This k-value is the seasonally adjusted effective k-value.

Table 13 may be used to determine the effective k-value. The example shown in Table 13 was developed using the following tentative design parameters:

D	=	9 in	[229 mm]
E_c	=	4,200,000 psi	[28,959 MPa]
S'_c	=	690 psi	[4758 kPa]
E_b	=	25,000 psi for aggregate base	[172 kPa]
H_b	=	6 in	[152 mm]
L	=	180 in	[4.57 m]
TD	=	+7.92°F	[+4.4°C]
P1	=	4.5	
P2	=	2.5	

Step 3. Adjust the Effective k-Value for the Effects of Embankment and/or Shallow Rigid Layer. A nomograph is provided in Figure 43 for adjustment of the seasonally adjusted effective subgrade k-value if: (a) fill material will be placed above the natural subgrade, and/or (b) a rigid layer (e.g., bedrock or hardpan clay) is present at a depth of 10 ft [3 m] or less beneath the existing subgrade surface. Note that the rigid layer adjustment should only be applied if the subgrade k was determined on the basis of soil type or similar correlations. If the k-value was determined from nondestructive deflection testing or from plate bearing tests, the effect of a rigid layer, if present at a depth of less than 10 ft [3 m], is already represented in the k-value obtained.

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Table 13. Determination of seasonally adjusted effective subgrade k-value.

Season	k-value (psi/in)	W_{18} (millions)	Relative Damage ($1 / W_{18}$)
		Mean Damage	
		W_{18}	million
		Effective k-value	psi/in

Notes: W_{18} is computed from the rigid pavement performance model given in Section 3.2.2.
A year may be divided into as many seasons as desired to represent distinct subgrade conditions.
1 psi/in = 0.27 kPa/mm

EXAMPLE

Seasons	k-value (psi/in)	W_{18} (millions)	Relative Damage ($1 / W_{18}$)
Spring	100	13.18	0.0759
Summer	200	14.60	0.0685
Fall	300	15.71	0.0637
Winter	400	16.72	0.0598
		Mean Damage	0.0670
		W_{18}	14.92 million
		Effective k-value	229 psi/in

1 psi/in = 0.27 kPa/mm

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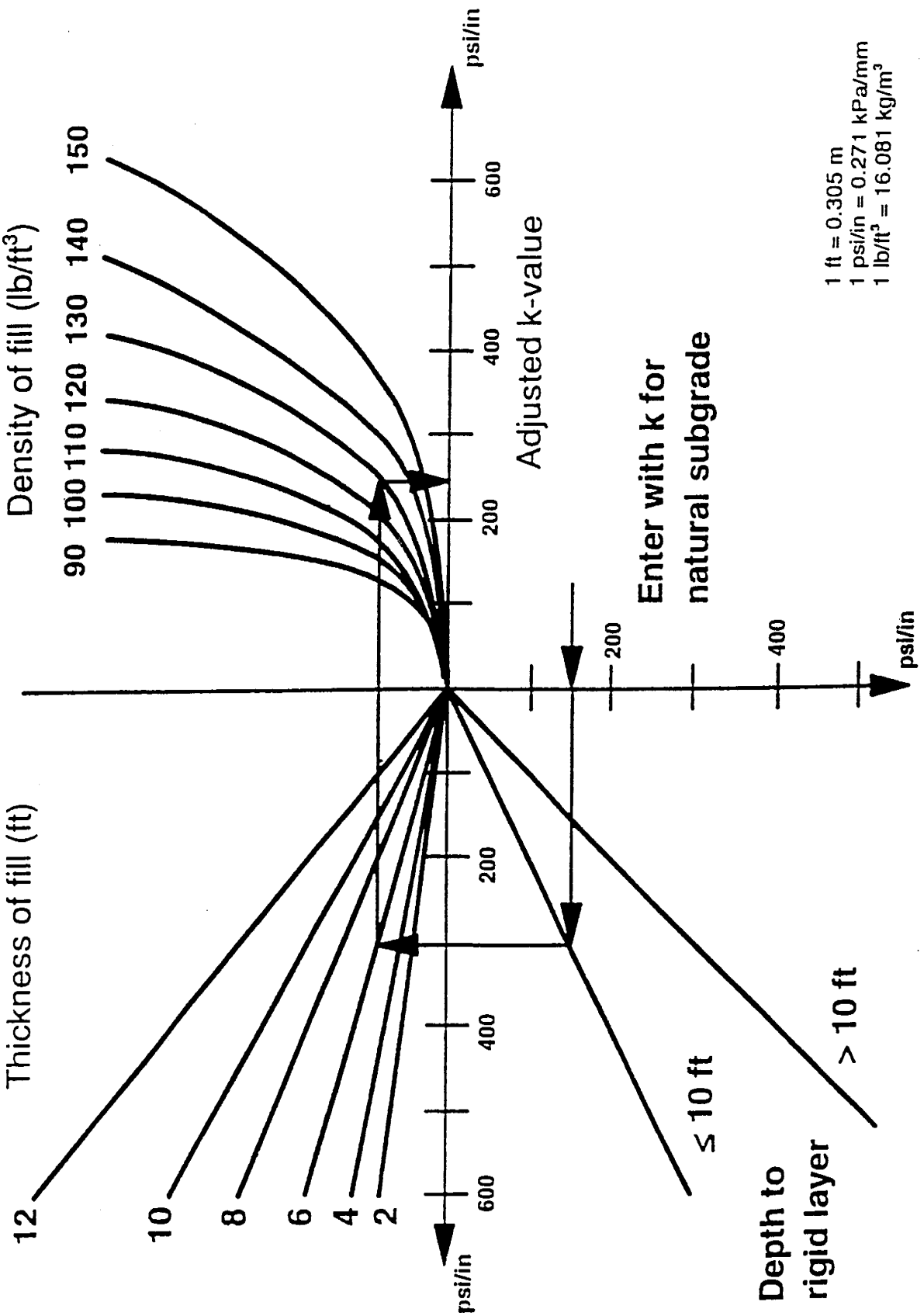


Figure 43. Adjustment to k for fill and/or rigid layer.

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3.2.2 Determine Required Structural Design

A slab thickness is determined for the midslab loading position, shown in Figure 44, because for doweled pavements this is the critical fatigue damage location. Most cracks initiate at the edge of the slab as a result of this loading. This slab thickness becomes the design thickness if the transverse joints are doweled. If the joints are not doweled, a design check is made to see if the joint loading position causes a more critical stress at the top of the slab. Also, a design check is made for joint design adequacy with respect to faulting, as described in Section 3.3.

Determine Required Inputs. The following inputs must be selected or obtained.

		Section of Guide
1.	Estimated ESALs, W_{18}, for the performance period in the design lane.	2.1.2
2.	Design reliability, R, percent.	2.1.3
3.	Overall standard deviation, S_o.	2.1.3
4.	Design serviceability loss, $PSI = P_1 - P_2$.	2.2.1
5.	Effective (seasonally adjusted) elastic k-value of the subgrade, psi/in.	3.2.1
6.	Concrete modulus of rupture, S'_c, psi.	2.3.4
7.	Concrete elastic modulus, E_c, psi.	2.3.3
8.	Joint spacing, L, inches.	3.3.2
9.	Base modulus, E_b, psi.	2.3.3

10. Slab/base friction coefficient, f.

11. Base thickness, H_b, inches.

12. Effective positive temperature differential through concrete slab, TD, °F.

13. Lane edge support condition:

    a. Conventional lane width (12 ft [3.7 m]) with free edge.

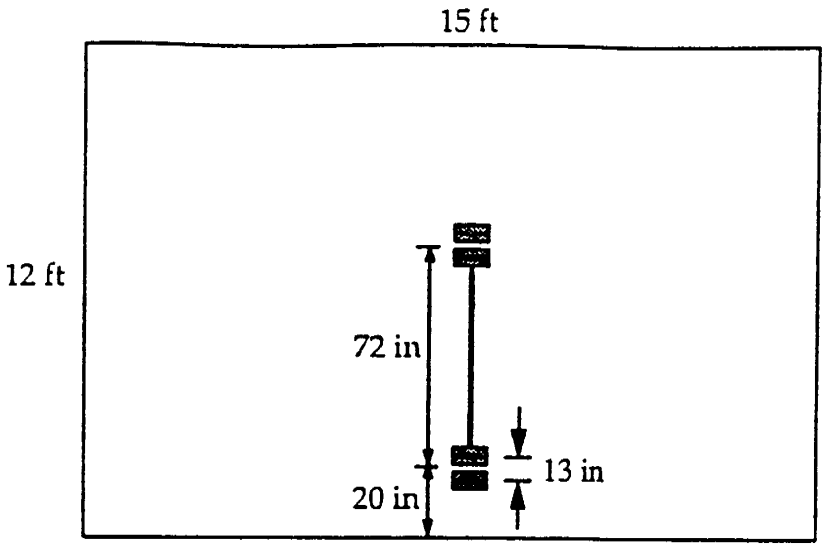
    b. Conventional lane width (12 ft [3.7 m]) with tied concrete shoulder.

    c. Wide slab (e.g., 14 ft [4.3 m]) with conventional traffic lane width (12 ft [3.7 m]).

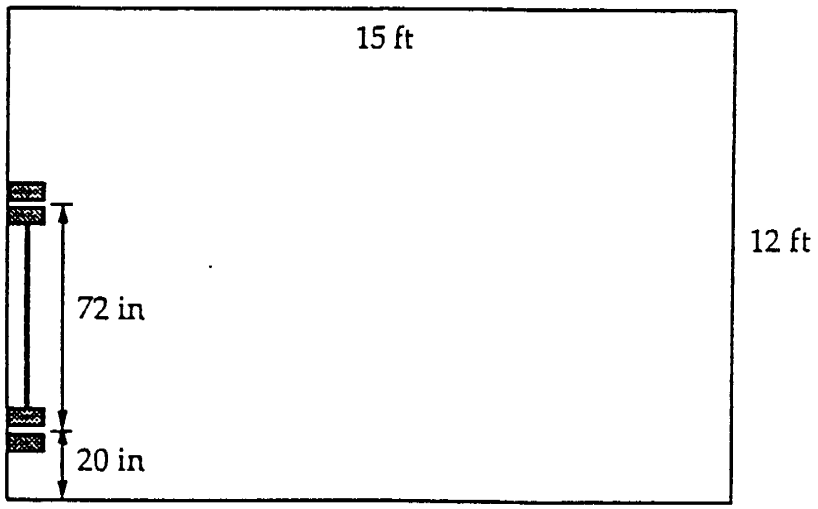
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Midslab Loading



Joint Loading

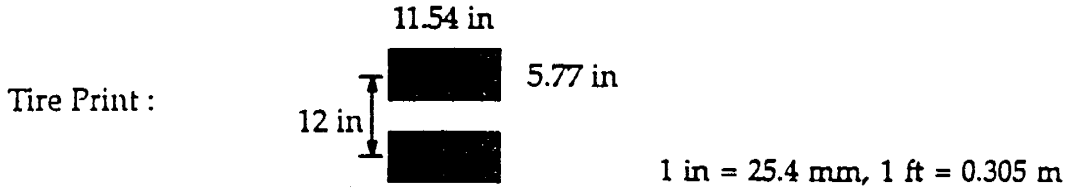


Figure 44. Midslab and joint loading positions defined.

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