Illinois Department of Transportation
2300 South Dirksen Parkway / Springfield, Illinois / 62764

August 31, 1995

Pavement Design Procedures #95-11

COUNTY ENGINEERS/COUNTY SUPERINTENDENT OF HIGHWAYS
MUNICIPAL ENGINEERS/ DIRECTORS OF PUBLIC WORKS
CONSULTING ENGINEERS

Three new pavement design procedures have been developed for use on local agency projects funded with MFT, federal-aid and any other funds administered by the department. The design procedures are based on University of Illinois research documents and developed by the department under the guidance of the IHR-527 Project Advisory Committee (PAC). The PAC is composed of representatives from IDOT, FHWA, Illinois Association of County Engineers and the Public Works Committee of the Illinois Municipal League.

Enclosed are the design procedures for rigid, conventional flexible, and full- depth asphalt concrete pavements. Comments from previous reviews by local agency policy groups, industry, and this department have been taken into consideration in the development of the enclosed pavement design procedures. The procedures are written in a “stand-alone” format. They will be incorporated into the Administrative Policies and the Federal-Aid Procedures for Local Highway Improvements manuals at a later date.

Also enclosed are a “Definition of Terms,” a two-part soil document, and LR 302 “Soil-Lime Mixture,” all of which are to be used in conjunction with the new pavement design procedures.

The following details give highlights about each of the enclosures:

- Rigid - Jointed non-reinforced PCC pavements which may or may not utilize mechanical load transfer devices (dowel bars and/or hinge joints).
- Conventional Flexible - Asphalt concrete over an aggregate base and, where warranted, a stabilized subgrade.
- Full-Depth Asphalt Concrete - A slight modification to the Bureau of Design and Environment procedure. Class I, Type 1 or 2 mixtures are required.
- Subgrade Inputs for Local Road Pavement Design - Provides the procedures and guidance in the selection of subgrade input values used in the pavement design procedures. Various methods of determining input values are provided to give the designer flexibility based on available subgrade data.
- Subgrade Stability Requirements for Local Roads - A condensation of the IDOT Subgrade Stability Manual and is to be used as a guide to treat unsuitable subgrade materials.
- Definition of Terms - Terms used in reference to the pavement design procedures and the soil documents are defined.
- LR 302, Soil-Lime Mixture - A specification to be used when soil-lime mixture is required on local agency projects.

Selection of pavement type remains a local decision. These procedures do not involve a life cycle cost analysis.

Use of the new pavement design procedures will be required on projects let after March 31, 1996, regardless of fund type. In the interim, either the enclosed design procedures or the design procedures found in the Administrative Policies or Federal-Aid Procedures for Local Highway Improvements manuals may be used.

You will note that these procedures are not in metric units. In order to expedite the implementation of the procedures, we chose to issue them in English units. They will be issued in metric units at a later date. In the interim, the design procedures should be used with English values and final thicknesses converted to metric units for plans developed in metric.

Design procedures for composite pavements, surface treatments, asphalt treated bases and high-strength stabilized bases are being developed. During this development period, continue to use the Administrative Policies or Federal-Aid Procedures for Local Highway Improvements manuals to address these design issues.

Computer versions of the design procedures will be developed following the completion of all the pavement design procedures.

If you have any questions, please contact your district office or Darrell McMurray of this office at (217)782-3972.

Very truly yours,

Bill Sunley

William T. Sunley, P. E.
Engineer of Local Roads and Streets

cc- James C. Slifer
Jay W. Miller
District Engineers
IHR-527 Project Advisory Committee
Professor E. J. Barenberg
Professor Marshall Thompson
Associated Concrete Pavement Association, Illinois Chapter, Inc.
Associated General Contractors of Illinois
Illinois Road Builders Association
Illinois Asphalt Pavement Association
Illinois Association of Aggregate Producers

RIGID PAVEMENT DESIGN
FOR LOCAL AGENCIES

SECTION 1 - INTRODUCTION

TYPES OF RIGID PAVEMENTS

Rigid pavement is a pavement structure whose surface and principal load-distributing component is a Portland cement concrete slab of relatively high bending resistance. The two types of rigid pavements and a description of each are as follows:

(1) Non-reinforced jointed- Jointed pavement without steel reinforcement which may or may not utilize mechanical load transfer devices (dowel bars and/or hinge joints).

(2) Continuously Reinforced - Pavement with continuous longitudinal steel reinforcement and no joints. It is typically used on high volume Class I roads such as interstate routes and freeways.

The non-reinforced jointed pavement design procedure is discussed in the ensuing pages. Designers should refer to Section 700 of the IDOT Design Manual for the design procedure for continuously reinforced concrete pavements.

USAGE OF PROCEDURE

The pavement design procedure shall be used for all local road and street projects in which a rigid pavement is desired. If the local agency intends to transfer jurisdiction following pavement construction, both agencies involved in the jurisdictional transfer should agree on the design.

A pavement design is not required when small quantities of pavement are to be constructed. Small quantities are defined as follows:

- Less than one city block in length, or
- Less than 3000 square yards, or
- Widening less than one lane-width,

When small quantities are to be constructed adjacent to existing pavement, the designer should:

- Duplicate the existing total pavement structure,
- or provide a structurally equivalent pavement,
- or design assuming a “poor” subgrade support rating
- and provide a minimum pavement thickness of 6.5 inches

SECTION 2 - BASIC DESIGN ELEMENTS

MINIMUM MATERIAL REQUIREMENTS

The design thicknesses are based on Portland cement concrete having a 650 psi minimum modulus of rupture at an age of 14 days (center point loading).

CLASS OF ROADS OR STREETS

The class of the road or street for which the pavement structural design is being determined is dependent upon the structural design traffic.

Class I — Facilities with four or more lanes, and one-way streets with a structural design traffic greater than 3500 ADT.

Class II — Two- or three-lane streets with a structural design traffic greater than 2000 ADT and all one-way streets with a structural design traffic less than 3500 ADT.

Class III — Roads and streets with structural design traffic between 400 and 2000 ADT.

Class IV — Roads and streets with structural design traffic less than 400 ADT.

DESIGN PERIOD

The design period (D.P.) is the length of time in years that the pavement is being designed to serve the structural design traffic. For all classes of rigid pavements, the design period shall be a minimum of 20 years.

STRUCTURAL DESIGN TRAFFIC

The structural design traffic is the estimated average daily traffic (ADT) for the year representing one-half of the design period. For example, when the design period is 20 years, the structural design traffic will be an estimate of the ADT projected to ten years after the construction date.

The structural design traffic is estimated from current traffic count data obtained either by manual counts or from traffic maps published by IDOT. If single-unit (S.U.) and multiple-unit (M.U.) counts are not available for Class III and IV roads and streets, an estimate of those counts may be made from the following component percentages of the total traffic.

Class of	Percentage of Structural Design Traffic		
Road or Street	P.V.	S.U.	M.U.
III	88	7	5
IV	88	9	3

TRAFFIC FACTORS

For Class I, II and III roads and streets, the design Traffic Factor (T.F.) for rigid pavements is determined from the 73,280- and 80,000-pound load limit formulae shown in Tables 1 and 2. The formulae shown are based on the statewide average distribution of vehicle types and axle loadings, which are directly applicable to most roads and streets. However, cases will arise in which a formula cannot be used, and a special analysis will be necessary. One such case would be a highway adjacent to an industrial site with Heavy Commercial Vehicles (HCV's) entering and leaving the site generally traveling empty in one direction and fully loaded in the other. Such cases should be referred to the Bureau of Local Roads and Streets for special analysis. The local agency must provide the Bureau of Local Roads and Streets with the structural design traffic, the design period, and traffic distribution by passenger vehicles (P.V.), S.U., and M.U. vehicles.

The T.F. equations in Table 2 are provided to accommodate 80,000-pound trucks. In Illinois these larger and heavier trucks are permitted to use the Interstate system and a system of designated state primary routes. In addition, trucks operating on this system are allowed to have limited access to points of loading and unloading and facilities for food, fuel, repairs, and rest. Local authorities of roads and streets also have the authority to designate 80,000-pound truck routes. The pavement design procedure for 73,280- and 80,000- pound routes is the same except for the T.F. equations.

For Class IV rigid pavements, thicknesses are provided in Table 6 based on the daily volume of HCV's, thus a design T.F. is not necessary.

TABLE 1
Traffic Factor Equations (73,280-lb. load limit)

CLASS I ROADS AND STREETS	
Four-and five lane Pavement (Rural and Urban)	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.047\ \text{P.V.} + 52.232\ \text{S.U.} + 247.199\ \text{M.U.})}{1{,}000{,}000}$
Six- or more lane Pavement (Rural)	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.029\ \text{P.V.} + 46.428\ \text{S.U.} + 219.732\ \text{M.U.})}{1{,}000{,}000}$
Six- or more lane Pavement (Urban)	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.012\ \text{P.V.} + 42.946\ \text{S.U.} + 203.252\ \text{M.U.})}{1{,}000{,}000}$
One-way streets & Pavements (Rural & Urban)	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.073\ \text{P.V.} + 58.035\ \text{S.U.} + 274.665\ \text{M.U.})}{1{,}000{,}000}$
CLASS II ROADS AND STREETS	
Two- or three-lane Pavement	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.073\ \text{P.V.} + 53.29\ \text{S.U.} + 237.070\ \text{M.U.})}{1{,}000{,}000}$
CLASS III ROADS AND STREETS	
Two- or three-lane Pavement	$\text{T.F.} = \text{D.P.}\,\dfrac{(0.073\ \text{P.V.} + 52.380\ \text{S.U.} + 230.680\ \text{M.U.})}{1{,}000{,}000}$ T.F. minimum = 0.5

TABLE 2
Traffic Factor Equations (80,000-lb. load limit)

CLASS I ROADS AND STREETS	
Four- or five lane Pavement (Rural and Urban)	$T.F. = D.P. \dfrac{(0.047\ P.V. + 64.715\ S.U. + 313.389\ M.U.)}{1{,}000{,}000}$
Six- or more lane Pavement (Rural)	$T.F. = D.P. \dfrac{(0.029\ P.V. + 57.524\ S.U. + 278.568\ M.U.)}{1{,}000{,}000}$
Six- or more lane Pavement (Urban)	$T.F. = D.P. \dfrac{(0.012\ P.V. + 53.210\ S.U. + 257.675\ M.U.)}{1{,}000{,}000}$
One-way streets & Pavements (Rural & Urban)	$T.F. = D.P. \dfrac{(0.073\ P.V. + 71.905\ S.U. + 348.210\ M.U.)}{1{,}000{,}000}$
CLASS II ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \dfrac{(0.073\ P.V. + 67.89\ S.U. + 283.605\ M.U.)}{1{,}000{,}000}$
CLASS III ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \dfrac{(0.073\ P.V. + 64.790\ S.U. + 281.235\ M.U.)}{1{,}000{,}000}$ T.F. minimum = 0.5

TRANSVERSE PAVEMENT JOINTS

For Class I, II and III pavements, thickness design curves are given for transverse joint spacings of 12.5, 15, and 20 feet (Figures 1, 2, and 3). Pavement thicknesses for each of the three joint spacings can be determined through the pavement design procedure. Then the designer can determine the desired combination of transverse joint spacing and pavement slab thickness. The maximum recommended transverse joint spacing for jointed PCC pavements is as follows:

TABLE 3
Maximum Transverse Joint Spacing

Slab Thickness	Maximum Transverse Joint Spacing
less than 7.5 inches	12.5 feet *
7.5 to 10 inches	15.0 feet
over 10 inches	20.0 feet

* Appropriate for all Class IV pavements.

Transverse joint spacing must be considered carefully. Longer joint spacing will result in higher curling and warping stresses, which when combined with load stresses could promote premature failure by fatigue. Longer joint spacing will also result in greater joint movement which may result in increased joint distress. Shorter joint spacing may result in unstable slabs which may rock and pump under repeated loadings. Shorter joint spacing also results in more joints which will increase the expense of joint maintenance over the life of the pavement. Shorter joint spacing is recommended when dowel bars are not used.

The volume of traffic the pavement will carry determines the type of load transfer device necessary to control faulting at the joints. Mechanical load transfer devices (normally dowel bars) are required on pavements which have a design T.F. of 3.0 or greater. For pavements with a T.F. less than 3.0, the designer has the option of using dowel bars or relying on aggregate interlock for load transfer.

SUBGRADE SUPPORT RATING

The general physical characteristics of the roadbed soil affect the design thickness and performance of the pavement structure. For pavement design purposes there are three subgrade support ratings (SSR), "poor", "fair", and "granular". The SSR is determined by using geotechnical grain size analysis and Figure 4. The SSR should represent the average or majority classification within the design section. Figure 4 assumes a high water table and a frost penetration depth typical of an Illinois subgrade soil. For small projects, the SSR may be estimated by using USDA county soil reports or assumed to be “poor”. The pavement thickness design curves (Figures 1, 2, and 3) are based on a SSR of fair. Adjustments in the design thickness are made for the poor and granular subgrades.

The designer should also take into consideration the susceptibility of the roadbed soil to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave and nonuniform support. The designer should address these types of issues by recommending corrective actions, such as undercutting, moisture density control or lime treatment, in the design plans and specifications. The designer should follow the guidelines found in the Subgrade Stability Requirements for Local Roads. Necessary corrective measures would be in addition to the subbase requirements of the pavement design.

SUBBASE

A subbase under a pavement serves two purposes. Initially it provides a stable construction platform for the base and surface courses. After construction it can improve the pavement performance by alleviating pumping of fine-grained soils and providing positive drainage for the pavement system. The usage and thickness requirements are as follows:

TABLE 4
Subbase Requirements

Road Class	Subbase Material	Usage[1]	Minimum Thickness
Class I & II	Stabilized Material	Required	4 inches
Class III & IV	Granular, T.F. ≥ 0.7 Granular, T.F. < 0.7	Required Optional	4 inches 4 inches

1. Subbase will not be required for urban sections having curbs and gutters and storm sewer systems. However, at the designer's option, a 4-inch minimum subbase may be used to serve as a working platform where poor soil conditions exist.

When placing a PCC pavement directly over a flexible pavement with an asphalt surface, the designer shall consult the Bureau of Local Roads and Streets for design assistance.

<u>DESIGN RELIABILITY</u>
Design reliability is taken into account through traffic multipliers applied to the design T.F. Figures 1, 2, and 3 contain curves for both high and medium reliability levels. The minimum reliability levels are as follows:

TABLE 5
Reliability Levels

Road Class	Minimum Reliability Levels	Percent Reliability
Class I and II	High	90’s
Class III	Medium	70’s and 80’s
Class IV (Table 6)	Medium	70’s and 80’s

SECTION 3 - THICKNESS DESIGN

<u>"PREADJUSTED" SLAB THICKNESS</u>
The jointed pavement thickness design procedure is based on determining the thickness of the "preadjusted" rigid pavement, then adjusting for shoulder type, anticipated overloads, and subgrade support conditions. The "preadjusted" rigid pavement slab thicknesses were developed for pavements with flexible or untied PCC shoulders and fair subgrade support. For Class I, II, and III pavements, the "preadjusted" slab thicknesses are determined from Figures 1, 2, and 3 for joint spacing of 12.5, 15, and 20 feet. If the designer does not desire a specific joint spacing, slab thicknesses for all the potential joint spacings should be evaluated.

For Class IV PCC pavements, Table 6 provides “preadjusted” slab thicknesses for 12.5 foot joint spacing. Overloads and “poor” soil conditions have been taken into consideration when developing these thicknesses, **thus no further overload adjustment is necessary**. In no case shall any thickness adjustments reduce the pavement thickness below the previously specified minimum thickness.

Fifteen- and 20-foot joint spacings are not provided for Class IV pavements because the thicknesses would be less than 7.5 inches, thus the maximum recommended joint spacing would be 12.5 feet.

TABLE 6
Class IV Pavement
Preadjusted Slab Thickness (inches)

HCV's/day	Slab Thickness for 12.5-foot Joint spacing, inches
Less than 40	6.5 *
More than 40	**
* No reduction in thickness will be allowed. ** Use the Class III T.F. equations or a T.F. of 0.5, whichever is greater, in conjunction with Figures 1, 2, and 3.	

<u>SLAB THICKNESS ADJUSTMENTS</u>
Adjustments to the "preadjusted" slab thickness should be made based on shoulder type, anticipated overloads, and subgrade support. The final design thickness should be rounded to the next highest 0.25 inches.

A. SHOULDER TYPE - The "preadjusted" rigid pavement thickness is to be adjusted if the PCC pavement has one of the following shoulder types:

1. Tied PCC Slab (including tied PCC widening)
2. Tied Curb and Gutter
3. Integral Curb and Gutter
4. Extended Lanes

The preceding shoulder types must be tied with #6 tie bars or larger in order to receive the pavement thickness adjustment. A # 6 bar or larger is needed to assure that load transfer is obtained between the pavement and curb/shoulder. Designers may specify smaller tie bars, but no deduction in pavement thickness will be allowed based on shoulder type.

If slab thickness adjustments are required based on shoulder type, the adjustments are as follows:

Slab Thickness	Thickness Adjustment
> 8.00 inches	deduct 0.500 inch
7.50 - 7.99 inches	deduct 0.375 inch
7.00 - 7.49 inches	deduct 0.250 inch
6.50 - 6.99 inches	deduct 0.125 inch

Note: No thickness adjustment is made for flexible or untied PCC shoulders.

B. SUBGRADE SUPPORT - Pavement thickness adjustments are based on the subgrade support and whether the pavement structure will have a subbase or not. The subgrade support adjustment factors are as follows:

SSR	With Subbase	Without Subbase ***
Poor	no adjustment	add 0.25 inches
Fair	deduct 0.25 inches	no adjustment
Granular	deduct 0.25 inches	deduct 0.25 inches
Existing pavement	deduct 0.25 inches	deduct 0.25 inches

*** A subbase is optional for all Class IV pavements and any pavement with a T.F. < 0.7.

C. OVERLOADS - The PCC pavement thickness can be adjusted for the number of anticipated overloads per week by using Figure 5. The overloads are those loads that are anticipated to exceed the load limits from which the design T.F.s were developed. The rigid pavement design procedure is based on 18-kip Equivalent Single Axle Loads (ESAL's) and 80 psi tire pressure conditions. Typical overloads are created from commercial, garbage, construction, and farm trucks, permit loads, as well as buses and some farm implements. No overload correction is necessary if the T.F. is greater than 2.0.

Projects adjacent to an industrial site with HCV's entering and leaving the site should be referred to the Bureau of Local Roads and Streets for special analysis.

Table 6 has already taken overloads into consideration and no further overload adjustment is necessary.

DOWEL BARS

Dowel bars must be used in all pavements with a T.F. of 3.0 or greater. Dowel bar diameter requirements are as follows:

Slab Thickness, inches	Dowel Diameter, inches
$\geq$ 8.00	1.5
7.00 to 7.99	1.25
< 7.00	1.0

HINGE-JOINTED PAVEMENT

The effectiveness of aggregate interlock can be enhanced through the use of deformed bars across the transverse joint to minimize joint opening and closing. This is referred to as a "hinge-joint". Figure 6 shows a longitudinal cross-section and joint details for hinge-jointed pavement.

PCC pavements with a T.F. of 3.0 or greater must use dowels or a combination of dowels and hinges at all transverse joints. When hinge joints are used, doweled joints must also be used at every third joint and have a maximum doweled joint spacing of 45 feet. This is to allow for the relief of curling stress due to temperature gradients and stresses from friction between the slab and subbase.

Designers desiring skewed or randomized transverse joints must submit a written request to the district Bureau of Local Roads and Streets.

MINIMUM DESIGN THICKNESS

Once all pavement thickness adjustments have been made, the design thickness must be 6.5 inches or greater.

SECTION 4 - EXAMPLE CALCULATION

EXAMPLE

Design a jointed concrete pavement for the following conditions:

1. Class I, one-way urban street
2. Design Period - 20 years
3. Design Traffic
    a. ADT 8900
    b. 94% P.V. (8366), 5% S.U. (445), 1% M.U. (89)
    c. 73,280-lb. load limit
4. Subgrade Support Rating - poor
5. Shoulders - tied curb and gutter
6. Overload vehicles - 5 per week

The T.F. equation for a one-way Class I pavement with a 73,280-pound load limit should be used (Table 1). The design T.F. is 1.02

One-way streets & Pavements (Rural & Urban)

$$\text{T.F.} = \text{D.P.}\ \frac{(0.073\ \text{P.V.} + 58.035\ \text{S.U.} + 274.665\ \text{M.U.})}{1{,}000{,}000}$$

$$1.02 = 20 \times \frac{(0.073 \times [8366] + 58.035 \times [445] + 274.665 \times [89])}{1{,}000{,}000}$$

Since the pavement is a Class I road with tied curb and gutter, a subbase is optional (Table 4, note 1). For this example, assume a subbase is used. From Table 4, the minimum subbase requirement is 4 inches. Dowels, a combination of hinge joints and dowels, or aggregate interlock are design options since the T.F. is less than 3.0.

Since this is a Class I facility, the high reliability curves of Figures 1, 2, and 3 should be used. The "preadjusted" slab thicknesses for fair subgrade support, flexible shoulders, and high reliability are:

Transverse Joint Spacing, feet	"Preadjusted" Thickness, inches
12.5	7.10
15.0	7.45
20.0	7.95

Pavement thickness adjustments for tied curb and gutter are listed below based on the "preadjusted" pavement thickness determined above and the shoulder adjustment factors.

Transverse Joint Spacing, feet	Adjustments for Shoulder Type, inches
12.5	deduct 0.250
15.0	deduct 0.250
20.0	deduct 0.375

Pavement thickness adjustments for subgrade support are based on the SSR and whether the pavement structure will have a subbase or not. Since we are assuming the designer opts for a stabilized subbase, no pavement thickness adjustment is required for a pavement with a "poor" SSR.

NOTE: If the designer had opted not to use a stabilized subbase, a pavement thickness adjustment of +0.25 inch would be required.

Pavement thickness adjustments (increases) for overloads can be taken directly from Figure 5. An adjustment of +0.09 inch is necessary for a pavement structure where 5 overloaded vehicles per week are anticipated in conjunction with a design T.F. of 1.02.

Adjustments of the "preadjusted" pavement thicknesses for the different transverse joint spacings are summarized below.

Transverse Joint Spacing, feet	"Preadjusted" thickness, inches	Adjustments, inches			Final thickness, inches
		Shoulder	Subgrade	Overloads	
12.5	7.10	- 0.250	0	+0.09	6.94
15.0	7.45	- 0.250	0	+0.09	7.29
20.0	7.95	- 0.375	0	+0.09	7.67

The designer should round the final design thicknesses up to the next highest 0.25 inch. Thus the recommended design thicknesses for the preceding joint spacings are:

Transverse Joint Spacing, feet	Recommended Thickness, inches
12.5	7.00
15.0	7.50
20.0	7.75

The 20-foot joint spacing is not allowed because it exceeds the maximum joint spacing for a 7.75 inch pavement.

If the designer opts to use dowel bars at the transverse joints, even though they are not required (T.F. < 3.0), the longer joint spacing (15.0-foot) would be a reasonable selection to reduce the cost of the load transfer steel. If the designer chooses not to use dowel bars, the 12.5- or 15.0-foot joint spacing would be recommended. If dowel bars are to be used, the designer may opt to use the hinge joint configuration. The designer must choose which option is preferred.

file:pcctext.doc

Slab Thickness

12.5' Joint Spacing; Fair Subgrade

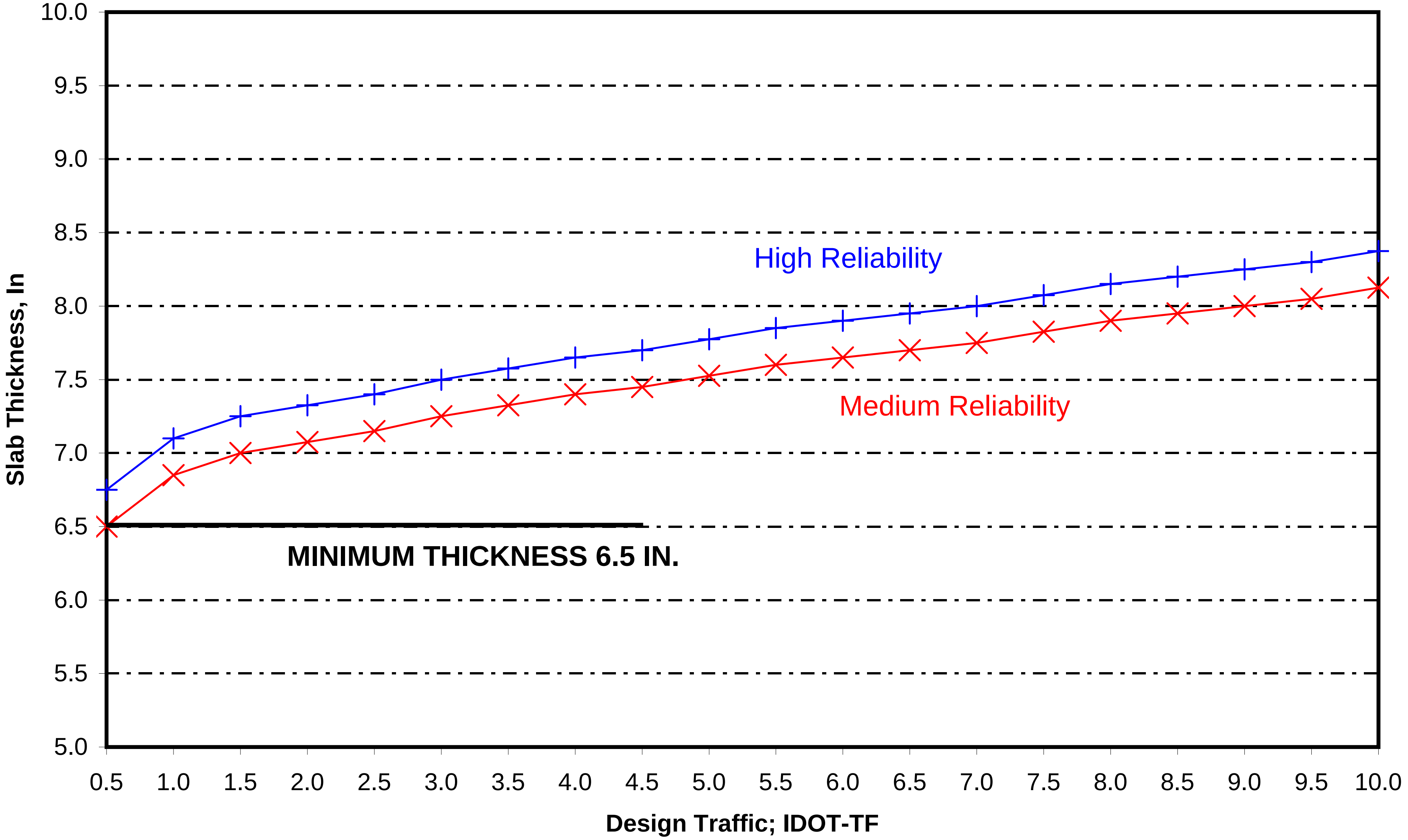


Figure 1

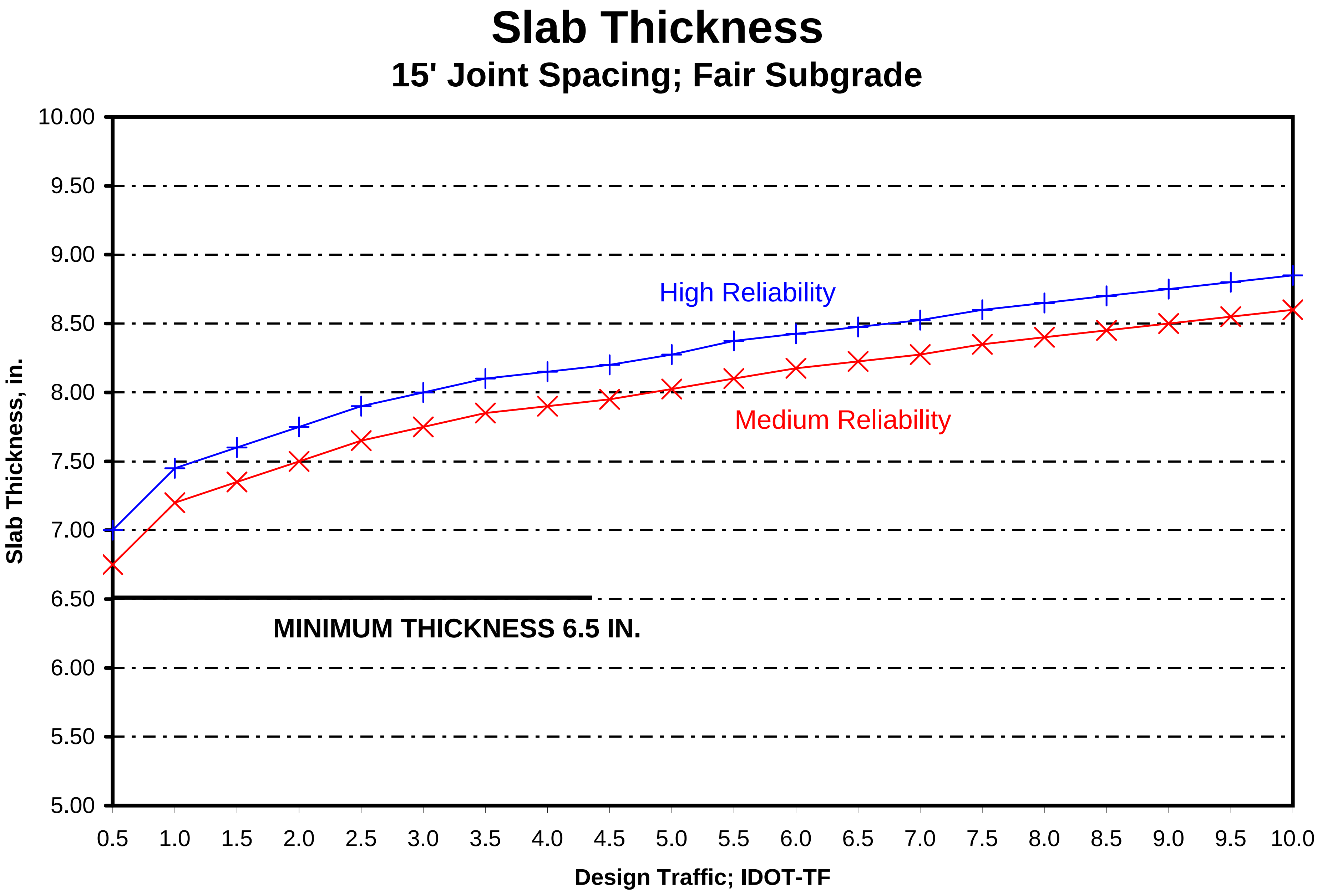
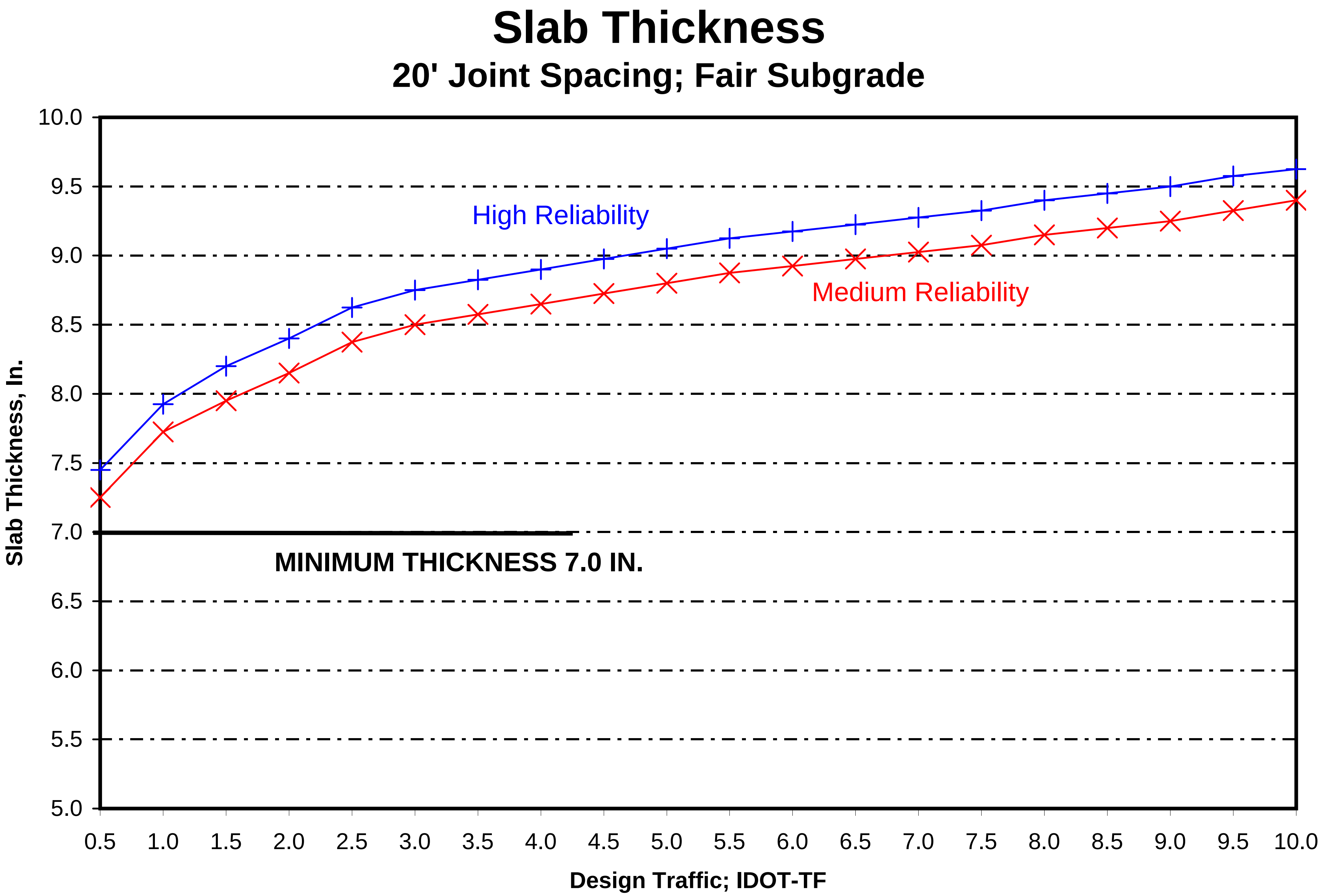
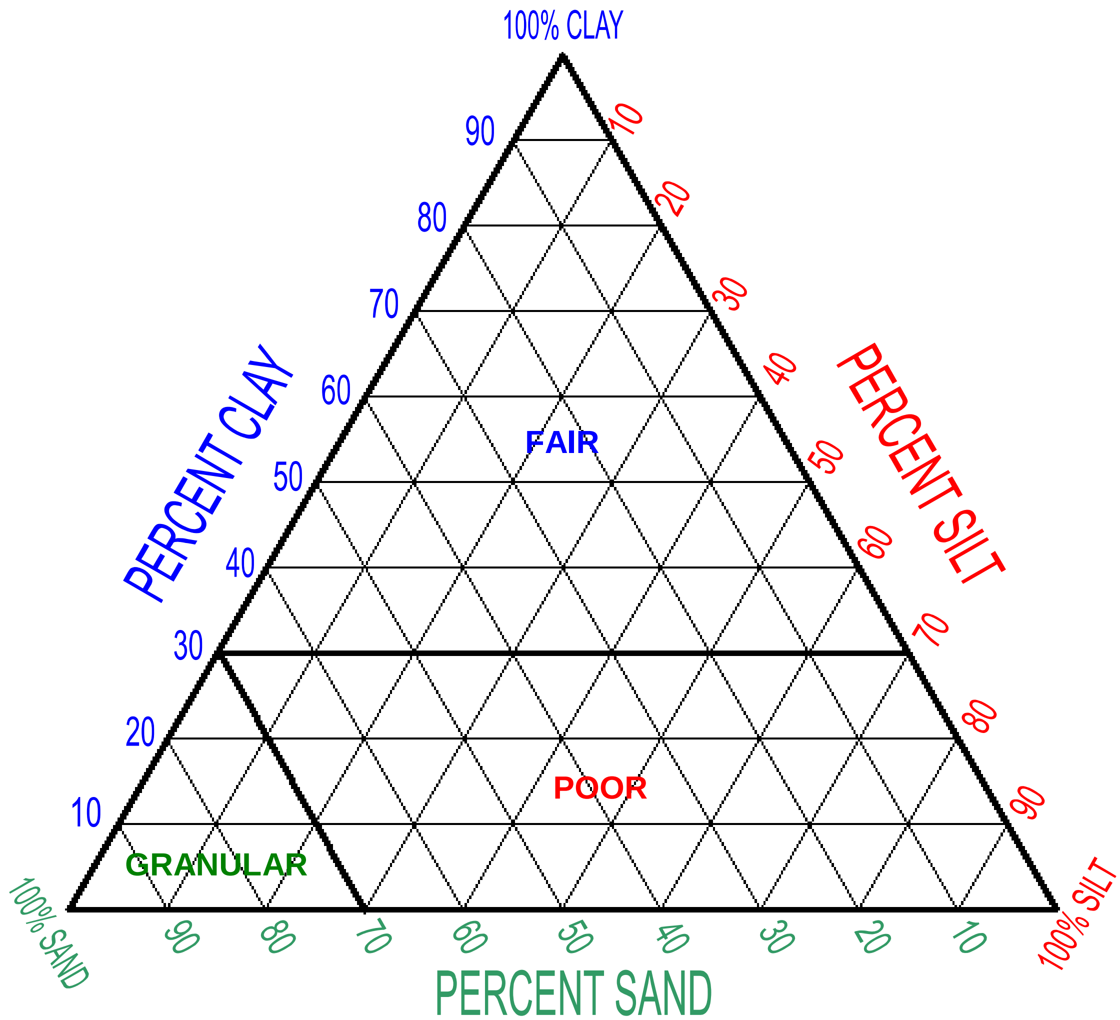

Slab Thickness
15' Joint Spacing; Fair Subgrade
Slab Thickness, in.
10.00
9.50
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
High Reliability
Medium Reliability
MINIMUM THICKNESS 6.5 IN.
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
Design Traffic; IDOT-TF

Figure 2



Slab Thickness
20' Joint Spacing; Fair Subgrade
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Slab Thickness, In.
High Reliability
Medium Reliability
MINIMUM THICKNESS 7.0 IN.
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
Design Traffic; IDOT-TF

Figure 3



Particle-Size Limits

Sand	2.000 – 0.075 mm
Silt	0.075 – 0.002 mm
Clay	< 0.002 mm

Figure 4. Subgrade Support Rating (SSR)

Slab Thickness Adjustment for Overloads

Number of Vehicles Equivalent to a Heavy Garbage Truck

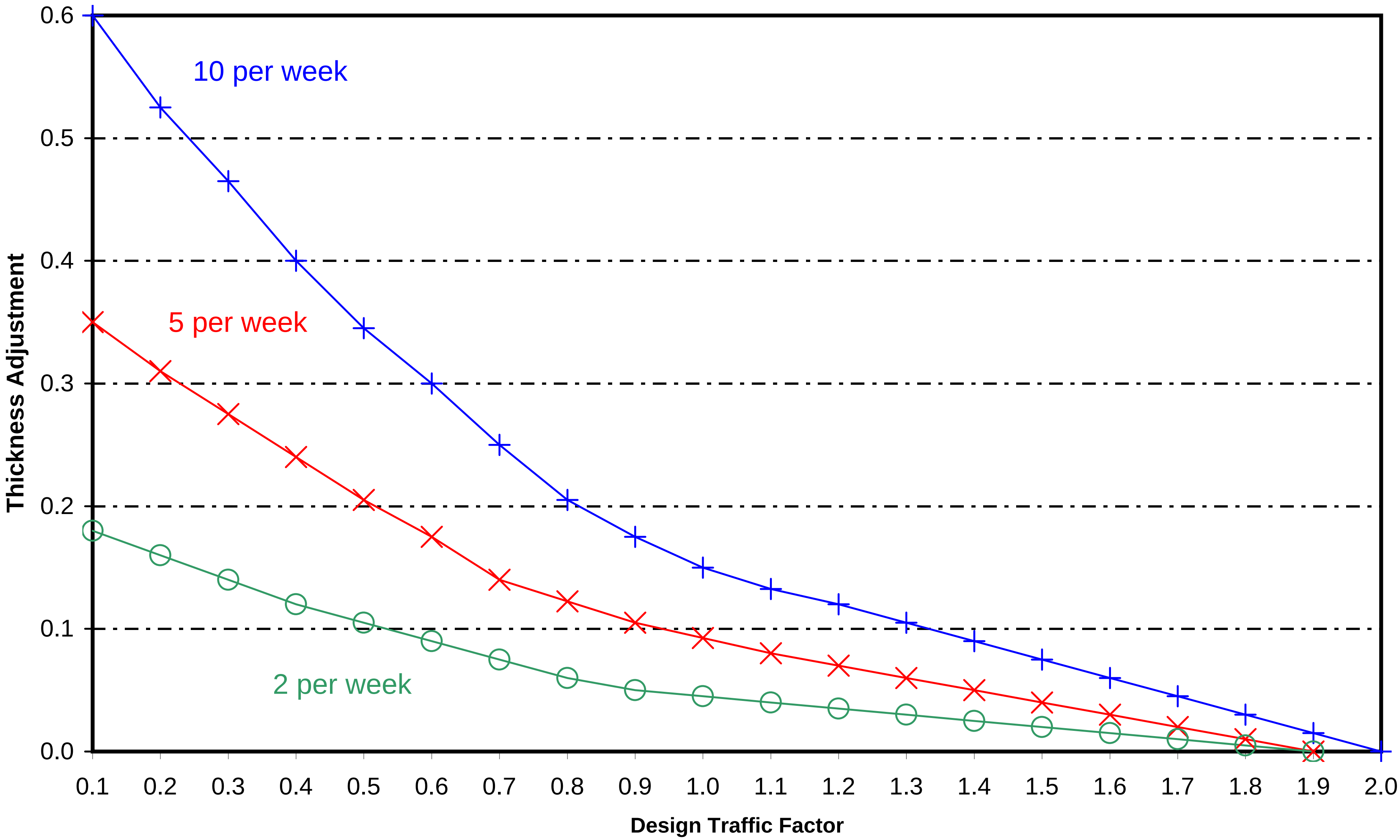
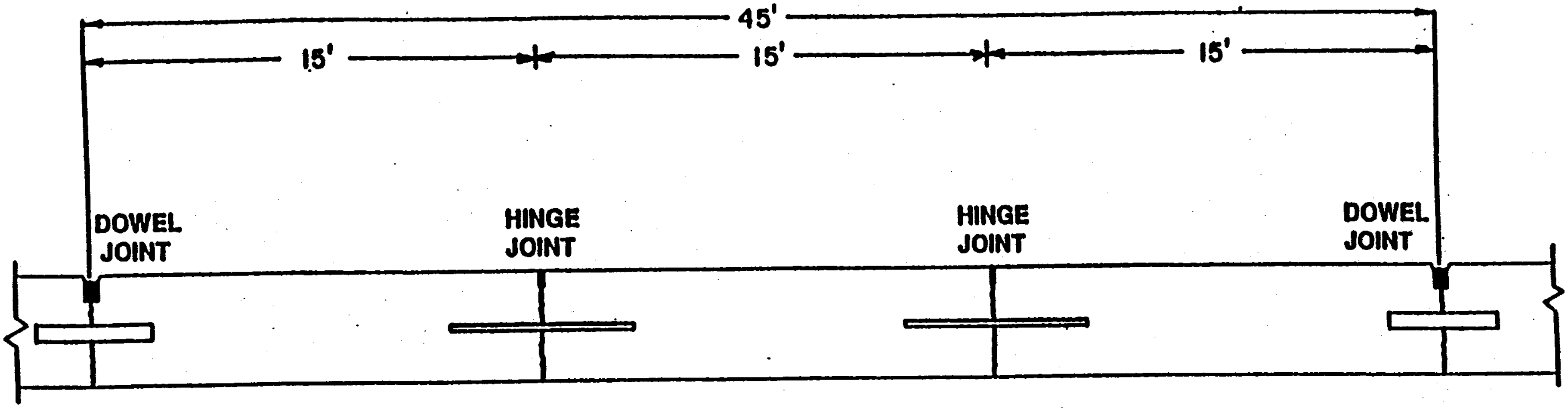
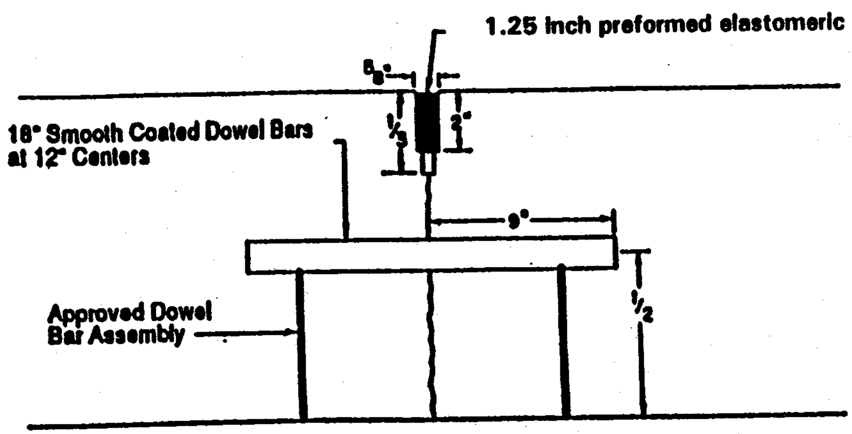


Figure 5

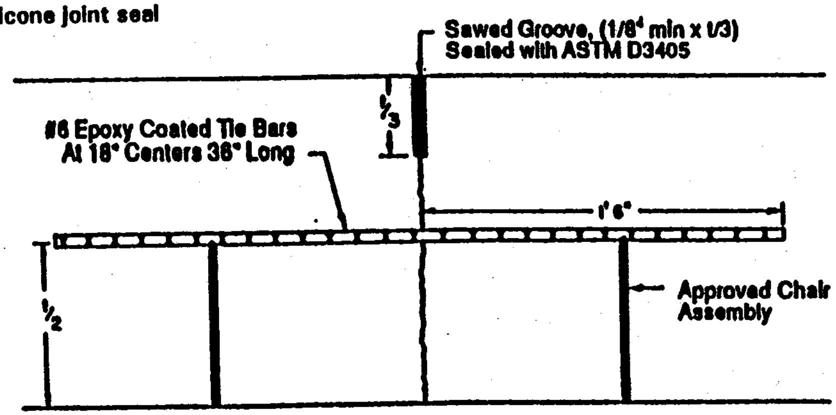
HINGE JOINTED PCC PAVEMENT DETAIL



LONGITUDINAL CROSS - SECTION



DOWEL JOINT DETAIL



HINGE JOINT DETAIL

FIGURE 6

CONVENTIONAL FLEXIBLE PAVEMENT DESIGN
FOR LOCAL AGENCIES

SECTION 1 - INTRODUCTION

DESIGN OF CONVENTIONAL FLEXIBLE PAVEMENTS
A conventional flexible pavement is a Class I or Class B plant mix bituminous concrete surface in combination with a granular base and, and if needed, additional subbase layers.

The design criteria for conventional flexible pavements are bituminous concrete fatigue and subgrade stress. A Subgrade Stress Ratio (SSR) criterion is used to accommodate subgrade rutting considerations. The conventional flexible design procedure is based on 18-kip Equivalent Single Axle Loads (ESAL's) and 80 psi tire pressure conditions.

Conventional flexible pavements are allowed for traffic factors (T. F.) up to 0.25. Class I bituminous concrete mixture can be used for all conventional flexible pavements. Class B bituminous concrete plant mix can be used when Heavy Commercial Vehicles (HCV's) per day are 40 or less. (HCV's are the sum of single- and multiple-unit vehicles.)

Conventional flexible pavements with bituminous concrete surface courses are designed for the following levels of reliability:

Bituminous Concrete Type	Level of Reliability	Percent Reliability *
Class B	Average	50
Class I	Medium	70’s and 80’s

* The estimated Percent Reliability for Class I is based on a representative 9-kip FWD (Falling Weight Deflectometer) surface deflection coefficient of variation of 25 percent.

Due to the high variability of Class B mixtures, an average level of reliability is used. Both levels of reliability are deemed appropriate for the level of service the pavement will provide and are built into the design charts, thus no additional adjustments need to be made by the designer.

SECTION 2 - BASIC DESIGN ELEMENTS

CLASSES OF ROADS AND STREETS
The Class of the road or street for which the pavement structural design is being determined is dependent upon the structural design traffic.

Class I	Facilities with four or more lanes, and one-way streets with a structural design traffic greater than 3500 ADT.
Class II	Two- or three-lane facilities with a structural design traffic greater than 2000 ADT and all one-way streets with a structural design traffic less than 3500 ADT.
Class III	Roads and streets with structural design traffic between 400 and 2000 ADT.
Class IV	Roads and streets with structural design traffic less than 400 ADT.

MINIMUM MATERIAL REQUIREMENTS

Bituminous concrete binder and surface course, Class I or Class B plant mix materials, are required for conventional flexible pavement design. A minimum of 3-inches of Class I or 2-inches of Class B bituminous concrete plant mix is required.

Type A aggregate base material, a minimum thickness of 8 inches, must be used. Soil-lime treated subgrade (8-inch minimum) or Type B granular subbase material (4-inch minimum) may be used at a 1:1 ratio to satisfy granular layer thickness requirements in excess of 8 inches. (For Example, A 12-inch base requirement could be satisfied by using 12 inches of Type A aggregate base material or 8 inches of Type A and 4 inches of Type B aggregate material.)

Class IV pavements with less than 20 HCV's per day may consist of Type B granular base material in place of Type A granular base material for the entire base thickness needed.

DESIGN PERIOD

The design period (D.P.) is the length of time in years that the pavement is being designed to serve the structural design traffic. For conventional flexible pavements, the minimum D.P. allowed is 20 years for Class I and II roads and streets. For Class III roads and streets, a minimum D.P. of 15 years is allowed. For Class III roads and streets, designers are encouraged to determine thicknesses for both 15- and 20-year D.P.'s prior to selecting the final design thickness. In most cases, going from a 15-year design to a 20-year design requires only 0.5- to 1-inch of additional bituminous concrete.

Class IV pavement thicknesses provided in Tables 4 and 5 for Class I mixtures should be satisfactory for D.P.'s of 15- or 20-years. Class IV pavements constructed with Class B plant mix to the thicknesses provided in Table 6 should be satisfactory for a 15-year D.P.

STRUCTURAL DESIGN TRAFFIC

The structural design traffic is the estimated average daily traffic (ADT) for the year representing one-half of the design period. For example, when the design period is 20 years, the structural design traffic will be an estimate of the ADT projected to ten years after the construction date.

The structural design traffic is estimated from current traffic count data obtained either by manual counts or from traffic maps published by IDOT. If passenger vehicle (P.V.), single-unit (S.U.), and multiple-unit (M.U.) counts are not available for Class III and IV roads and streets, an estimate of those counts may be made from the following component percentages of the total traffic.

Class of	Percentage of Structural Design Traffic		
Road or Street	P.V.	S.U.	M.U.
III	88	7	5
IV	88	9	3

TRAFFIC FACTORS

The maximum allowable Traffic Factor (T.F.) for conventional flexible pavements is 0.25. For Class I, II and III roads and streets, the design T.F. for flexible pavements can be determined for various D.P.'s from the 73,280- and 80,000-pound load limit formulae shown in Tables 1 and 2 respectively. The formulae shown are based on the statewide average distribution of vehicle types and axle loadings, which are directly applicable to most roads and streets.

However, cases will arise in which the average formula should not be used. One such case is a highway where HCV's entering and leaving a site generally travel empty in one direction and fully loaded in the other. Such cases should be referred to the Bureau of Local Roads and Streets for special analysis. The local agency must provide the Bureau of Local Roads and Streets with the structural design traffic, the D.P., and traffic distribution by P.V.'s, S.U.'s, and M.U.'s.

For Class IV roads and streets, thicknesses are provided in Tables 4 and 5 based on the daily volume of HCV's; thus, a design T.F. is not necessary.

TABLE 1
Traffic Factor Equations (73,280-lb. load limit)

CLASS I ROADS AND STREETS	
Four-lane Pavement (Rural and Urban)	$T.F. = D.P. \dfrac{(0.047\ P.V. + 47.961\ S.U. + 169.178\ M.U.)}{1{,}000{,}000}$
Six- or more lane Pavement (Rural)	$T.F. = D.P. \dfrac{(0.029\ P.V. + 42.632\ S.U. + 150.380\ M.U.)}{1{,}000{,}000}$
Six- or more lane Pavement (Urban)	$T.F. = D.P. \dfrac{(0.012\ P.V. + 39.435\ S.U. + 139.102\ M.U.)}{1{,}000{,}000}$
One-way streets & Pavements (Rural & Urban)	$T.F. = D.P. \dfrac{(0.073\ P.V. + 53.290\ S.U. + 187.975\ M.U.)}{1{,}000{,}000}$
CLASS II ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \dfrac{(0.073\ P.V. + 44.530\ S.U. + 156.403\ M.U.)}{1{,}000{,}000}$
CLASS III ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \dfrac{(0.073\ P.V. + 44.350\ S.U. + 154.943\ M.U.)}{1{,}000{,}000}$

TABLE 2
Traffic Factor Equations (80,000-lb. load limit)

CLASS I ROADS AND STREETS	
Four-lane Pavement (Rural and Urban)	$T.F. = D.P. \frac{(0.047\ P.V. + 59.625\ S.U. + 217.139\ M.U.)}{1,000,000}$
Six- or more lane Pavement (Rural)	$T.F. = D.P. \frac{(0.029\ P.V. + 53.000\ S.U. + 193.012\ M.U.)}{1,000,000}$
Six- or more lane Pavement (Urban)	$T.F. = D.P. \frac{(0.012\ P.V. + 49.025\ S.U. + 178.536\ M.U.)}{1,000,000}$
One-way streets & Pavements (Rural & Urban)	$T.F. = D.P. \frac{(0.073\ P.V. + 66.25\ S.U. + 241.265\ M.U.)}{1,000,000}$
CLASS II ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 56.03\ S.U. + 192.72\ M.U.)}{1,000,000}$
CLASS III ROADS AND STREETS	
Two- or three-lane Pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 54.57\ S.U. + 192.175\ M.U.)}{1,000,000}$

STAGE CONSTRUCTION

Stage construction is the planned construction of the pavement structure in two or more stages. Stage construction will be allowed on conventional flexible pavements with a design T.F. greater than 0.1 and the approval of the District Bureau of Local Roads and Streets. The maximum time period that may elapse between the completion of the first stage and the scheduled construction date of the final stage is 2 years.

If a bituminous concrete mixture (base or surface course) is part of the initial stage, the minimum bituminous concrete thickness shall be 3 inches. The total bituminous concrete thickness resulting from the stages shall be the bituminous concrete design thickness plus an additional 0.5-inch.

If a bituminous concrete mixture is not part of the initial stage, an A-2 or A-3 surface treatment shall be placed over the aggregate base. The aggregate base thickness will be determined on a project by project basis by the Bureau of Local Roads and Streets.

Any evidence of fatigue cracking, raveling, or other deterioration prior to the construction of the final stage will necessitate a re-evaluation of the structural design of the pavement.

ASPHALT CEMENT VISCOSITY GRADES

When determining the design asphalt cement viscosity grade, the designer must take into consideration the project location, the traffic volume, and whether the facility is in an urban or rural area. Projects in northern Illinois should use softer asphalt cements in order to minimize thermal cracking. In general, a softer asphalt cement, such as AC-5 or AC-10, should be used when ADT levels are below 2000. Urban areas with stop and go traffic may need stiff asphalt cements to prevent rutting and shoving. The asphalt grade selection should take into account the above variables and be determined on a project by project basis.

BASE AND SUBBASE

A subbase under a pavement serves two purposes. Initially it provides a stable construction platform for the base and surface courses. After construction it can improve the pavement performance by alleviating pumping of fine-grained soils and providing positive drainage for the pavement system.

Type A aggregate base material, a minimum thickness of 8 inches, must be used. A minimum 8-inch soil-lime treated subgrade or minimum 4-inch Type B granular subbase may be used to satisfy granular layer thickness requirements in excess of 8 inches. The 8-inch Type A aggregate base material would still be required, but additional base thickness requirements could be satisfied by using Type B granular subbase material or soil-lime treated subgrade.

Class IV pavements with less than 20 HCV's per day may use Type B aggregate base material in place of Type A aggregate base material for the entire base thickness needed.

SUBGRADE SUPPORT RATING

The general physical characteristics of the roadbed soil affect the design thickness and performance of the pavement structure. For the design of conventional flexible pavement, a critical subgrade modulus (E_{Ri}) is used. The critical E_{Ri} is the expected spring season E_{Ri} value (usually when the water table is highest and after the spring thaw). The critical E_{Ri} is determined by one of the methods outlined in Subgrade Inputs for Local Road Pavement Design. The pavement design thicknesses from Figure 4 are based on an E_{Ri} value of 3 ksi. Pavement thicknesses must be adjusted for E_{Ri} values between 2 and 3 ksi. E_{ri} values less than 2 ksi require subgrade stabilization. Pavement thickness adjustments are not necessary for sandy/granular subgrade materials.

The designer should also take into consideration the susceptibility of the roadbed soil to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave, and nonuniform support. The designer should use the Subgrade Stability Requirements for Local Roads to address these types of issues by recommending corrective actions, such as undercutting, moisture density control, or soil-lime treating the subgrade in the design plans and specifications. The Local Roads special provision entitled "soil-lime treated subgrade" should be used in lieu of the "lime-modified soils" section of the Standard Specifications for Road and Bridge Construction. Necessary corrective measures would be in addition to the subbase requirements of the pavement design.

SECTION 3 - THICKNESS DESIGN
CLASS I MIXTURES

CLASS I, II, AND III ROADS AND STREETS

(1) BITUMINOUS CONCRETE DESIGN MIXTURE TEMPERATURE
The bituminous concrete mixture temperatures are given in Figure 1 based on geographic locations in Illinois. The design mixture temperature should be interpolated to the nearest 0.5 degree Fahrenheit. The minimum design mixture temperature shall be 72º Fahrenheit.

Note: The Design Time dates are not the same for Conventional Flexible and Full-Depth bituminous concrete pavements. Conventional Flexible Design Time dates occur earlier in the Spring. Thus, for the same location, the Conventional Flexible "Bituminous Concrete Design Mixture Temperature" is lower than Full-Depth "Bituminous Concrete Design Mixture Temperature". (Figure 1 of the conventional flexible pavement design is not the same as Figure 1 in the full-depth pavement design procedures.)

(2) BITUMINOUS CONCRETE DESIGN MODULUS (E_{ac})
The design E_{ac} is the bituminous concrete modulus that corresponds to the design mixture temperature. Determine the design E_{ac} value from Figure 2 for typical Class I mixtures with AC-5, AC-10 or AC-20.

(3) BITUMINOUS CONCRETE DESIGN STRAIN
The bituminous concrete design strain is the tensile strain at the bottom of the bituminous concrete pavement layer. Figure 3 shall be used in conjunction with the design T.F. to determine the design strain.

(4) CLASS I THICKNESS REQUIREMENTS
Figure 4 shall be used in conjunction with the bituminous concrete design strain from step 3 to determine the thickness of Class I mixture required. The thicknesses from Figure 4 are based on an 8-inch minimum aggregate base thickness and an E_{Ri} of 3 ksi.

(5) SUBBASE THICKNESS ADJUSTMENTS
The fine-grained soils that predominate in Illinois commonly have an E_{Ri} greater than 3 ksi. For pavements with an E_{Ri} of 3 ksi or greater, an 8-inch Type A aggregate base is structurally adequate, thus no pavement structure thickness adjustment is necessary. For subgrades with an E_{Ri} value equal to or greater than 2 ksi and less than 3 ksi, Table 3 should be used to determine the appropriate structure enhancement category for the pavement. Subgrades with an E_{ri} less than 2 ksi must follow the Subgrade Stability Requirements for Local Roads.

TABLE 3

Class I Bituminous Concrete
Class I, II and III Roads and Streets
Pavement Structure Enhancement
($E_{Ri} \geq 2$ ksi and < 3 ksi)

Original Bituminous Concrete Design Thickness (inch)	Bituminous Concrete Design Modulus (E_{ac}, ksi)				
	400	500	600	700	800
3.0 - 3.49	E^2	E^2	E^2	E^1	E^1
3.5 - 3.99	E^2	E^1	E^1	O	O
$\geq$ 4.0	O	O	O	O	O

Note:

E: Enhancement of the pavement structure is required.

O: Enhancement of the pavement structure is optional. If no enhancement is desired, an 8-inch aggregate base course is necessary.

If the subgrade E_{Ri} is less than 2 ksi, the IDOT Subgrade Stability Requirements for Local Roads should be used to determine the appropriate subgrade treatment necessary.

A pavement structure consisting of an 8-inch aggregate base course can be enhanced by one of the following alternatives, based on the appropriate category from the above table.

E^1
(1) Increase the Class I bituminous concrete thickness by 0.5 inch or,
(2) Increase the Type A aggregate base thickness by 2 inches or,
(3) Add a 4-inch minimum Type B granular subbase or,
(4) Soil-lime treat the subgrade a minimum of 8 inches

E^2
(1) Increase the Class I bituminous concrete thickness by 1.0 inch or,
(2) Increase the Type A aggregate base thickness by 4 inches or,
(3) Add a 4-inch minimum Type B granular subbase or,
(4) Soil-lime treat the subgrade a minimum of 8 inches.

CLASS IV ROADS AND STREETS
THICKNESS REQUIREMENTS
Tables 4 and 5 provide the Class I bituminous concrete and aggregate base thicknesses for various E_{Ri} values and traffic levels. Pavements with less than 20 HCV's per day may use Type B aggregate base material in lieu of Type A aggregate base material.

TABLE 4
Class IV Pavements
Aggregate Base Thickness (inches)
necessary for a
3- or 3.25-inch Class I Bituminous Concrete Surface

District	1 - 4		5 - 6		7 - 9	
Traffic	Eri (ksi)		Eri (ksi)		Eri (ksi)	
Level	$\geq$ 3	2 - 3	$\geq$ 3	2 - 3	$\geq$ 3	2 - 3
< 10 HCV's	8	11	8	11	8	12
10 - 19 HCV's	8	11	8	11	8	12
20 - 40 HCV's	8	11	10	11	13	14

TABLE 5
Class IV Pavements
Aggregate Base Thickness (inches)
necessary for a
3.5- or 3.75-inch Class I Bituminous Concrete Surface

District	1 - 4		5 - 6		7 - 9	
Traffic	Eri (ksi)		Eri (ksi)		Eri (ksi)	
Level	$\geq$ 3	2 - 3	$\geq$ 3	2 - 3	$\geq$ 3	2 - 3
< 10 HCV's	8	8	8	9	8	10
10 - 19 HCV's	8	8	8	9	8	10
20 - 40 HCV's	8	8	8	9	11	12

NOTE: E_{Ri} values less than 2 ksi require use of the Subgrade Stability Requirements for Local Roads.

When 4 inches or more of Class I bituminous concrete are used, 8 inches of Type A aggregate base material is satisfactory for all combinations of soil types and traffic levels for all districts.

SECTION 4 - THICKNESS DESIGN
CLASS B PLANT MIXTURES

(1) DESIGN MIXTURE TEMPERATURE AND MODULUS (E_{ac})
A bituminous concrete mixture temperature of 77º F is assumed for Class B mixtures. This is based on a design time of early-May for southern Illinois and mid-May for northern Illinois. Since the bituminous concrete modulus at 77º F generally exceeds 250 ksi, this design procedure is based on an E_{ac} value of 250 ksi.

This design procedure applies only to Class B plant mixtures which contain asphalt cement. If a mixture using bituminous materials other than asphalt cement is desired, the Bureau of Local Roads and Streets must be contacted to provide thickness requirements.

(2) AGGREGATE BASE THICKNESS REQUIREMENTS

Select the aggregate base thickness from Table 6 based on the desired Class B plant mix thickness, the HCV's per day, and the critical E_{Ri}. Roads and streets with more than 40 HCV's per day shall use Class I bituminous concrete mixture and the Class I thickness design procedure. In this case, the structural design T.F. should be calculated using a Class III T.F. equation.

The aggregate base shall be Type A aggregate base material, a minimum of 8 inches thick. Type B granular subbase material, minimum thickness of 4 inches, or soil-lime treated subgrade, minimum thickness of 8 inches, may be used to satisfy aggregate base thickness requirements in excess of 8 inches. Thus a 10-inch aggregate base requirement can be satisfied by using 10-inches of Type A aggregate base material, or a minimum 8-inch layer of Type A aggregate base material and a minimum 4-inch layer of Type B granular subbase material. Another alternative would be to use a minimum 8-inch layer of Type A aggregate base material and a minimum 8-inch layer of soil-lime treated subgrade.

Class IV pavements with less than 20 HCV's per day may use Type B aggregate base material in lieu of Type A aggregate base material for the entire base thickness needed.

Table 6

Thickness Requirements for
Conventional Flexible Pavements with
Class B, Bituminous Concrete Plant Mix

HCV's (per day)	Class B Thickness (inches)	Granular Base Layer Thickness, inches			
		Critical E_{Ri}, ksi			
		2	3	4	5
< 10	2	16	13	10	8
10 - 19	3	13	10	8	8
20 - 39	4	10	8	8	8
$\geq$ 40	Use Class I bituminous concrete mixture and design procedures and Class III T.F. equation.				

Note 1. Granular layer thicknesses are based on a bituminous surface plant mix - Class B with E_{ac} greater than 250 ksi at 77º F.

2. Class I, Type 3 bituminous concrete may be substituted for Class B mixture when the ADT is less than 750.

SECTION 5 - EXAMPLE CALCULATIONS

EXAMPLE 1

Design a conventional flexible pavement with Class I bituminous concrete surface for the following conditions:

1. Class III, two-lane pavement
2. D.P. - 20 years
3. Design Traffic
   a. ADT 420
   b. 85% P.V. (357), 10% S.U. (42), 5% M.U. (21)
   c. 73,280-pound load limit
4. Location: Urbana, IL
5. Critical Subgrade E_{Ri}: 3 ksi

SOLUTION 1:

1. The T.F. equation for a two-lane Class III pavement with a 73,280-pound load limit should be used (Table 1). The design T.F. is 0.103.

   Two or three-lane Pavement

   $$T.F. = D.P. \frac{(0.073\ P.V. + 44.350\ S.U. + 154.943\ M.U.)}{1{,}000{,}000}$$

   $$0.103 = 20 \frac{(0.073x[357] + 44.350x[42] + 154.943\ [21])}{1{,}000{,}000}$$

2. Bituminous concrete design mixture temperature: 76.5 ^{o} F (from Figure 1).

3. Assume an AC-10 is to be used due to the low volume of traffic. The bituminous concrete design modulus (E_{ac}) would be 540 ksi (from Figure 2).

4. The bituminous concrete design strain (from Figure 3) would be 290 microstrain.

5. Class I bituminous concrete thickness (from Figure 4) is 3.75 inches.

6. Final design: 3.75-inch Class I bituminous concrete surface + 8-inch Type A aggregate base (8-inch minimum Type A aggregate base is satisfactory since E_{Ri}=3 ksi.)

EXAMPLE 2

Design a conventional flexible pavement with Class I bituminous concrete surface for the following conditions:

1. Class II, two-lane pavement
2. D.P. - 20 years
3. Design Traffic
   a. ADT 3015
   b. 97% P.V. (2925), 2% S.U. (60), 1% M.U. (30)
   c. 73,280 pound load limit
4. Location: Chicago
5. Critical Subgrade E_{Ri}: 2 ksi

SOLUTION 2

1. The T.F. equation for a two-lane Class II pavement with a 73,280-pound load limit should be used (Table 1). The design T.F. is 0.15.

   Two- or three-lane Pavement

   $$\text{T.F.} = \text{D.P.}\ \frac{(0.073\ \text{P.V.} + 44.530\ \text{S.U.} + 156.403\ \text{M.U.})}{1{,}000{,}000}$$

   $$0.15 = 20\ \frac{(0.073x[2925] + 44.530x[60] + 156.403\ [30])}{1{,}000{,}000}$$

2. An AC-20 grade of asphalt cement should be used to compensate for the stopping and starting traffic patterns common in urban areas.

3. Bituminous concrete design mixture temperature: 73º F (from Figure 1)

4. The bituminous concrete design modulus (E_{ac}) is 740 ksi (from Figure 2).

5. The bituminous concrete design strain (from Figure 3) would be 256 microstrain.

6. Class I bituminous concrete thickness (from Figure 4) is 4 inches. Figure 4 is based on an 8-inch Type A aggregate base and an E_{Ri} value of 3 ksi or greater. Since the E_{Ri} value is 2 ksi, Table 3 must be used to determine if pavement thickness enhancements are necessary.

7. Table 3 designates the pavement thickness adjustment requirement as a category "O" (4.0-inch bituminous concrete thickness and 700 ksi E_{ac}). Enhancement of the pavement structure is optional.

   The final design would be 4 inches of Class I mixture and 8 inches of Type A aggregate base material. The designer could opt to enhance the pavement structure by increasing the bituminous concrete thickness or the aggregate base thickness or by lime-soil treating the subgrade.

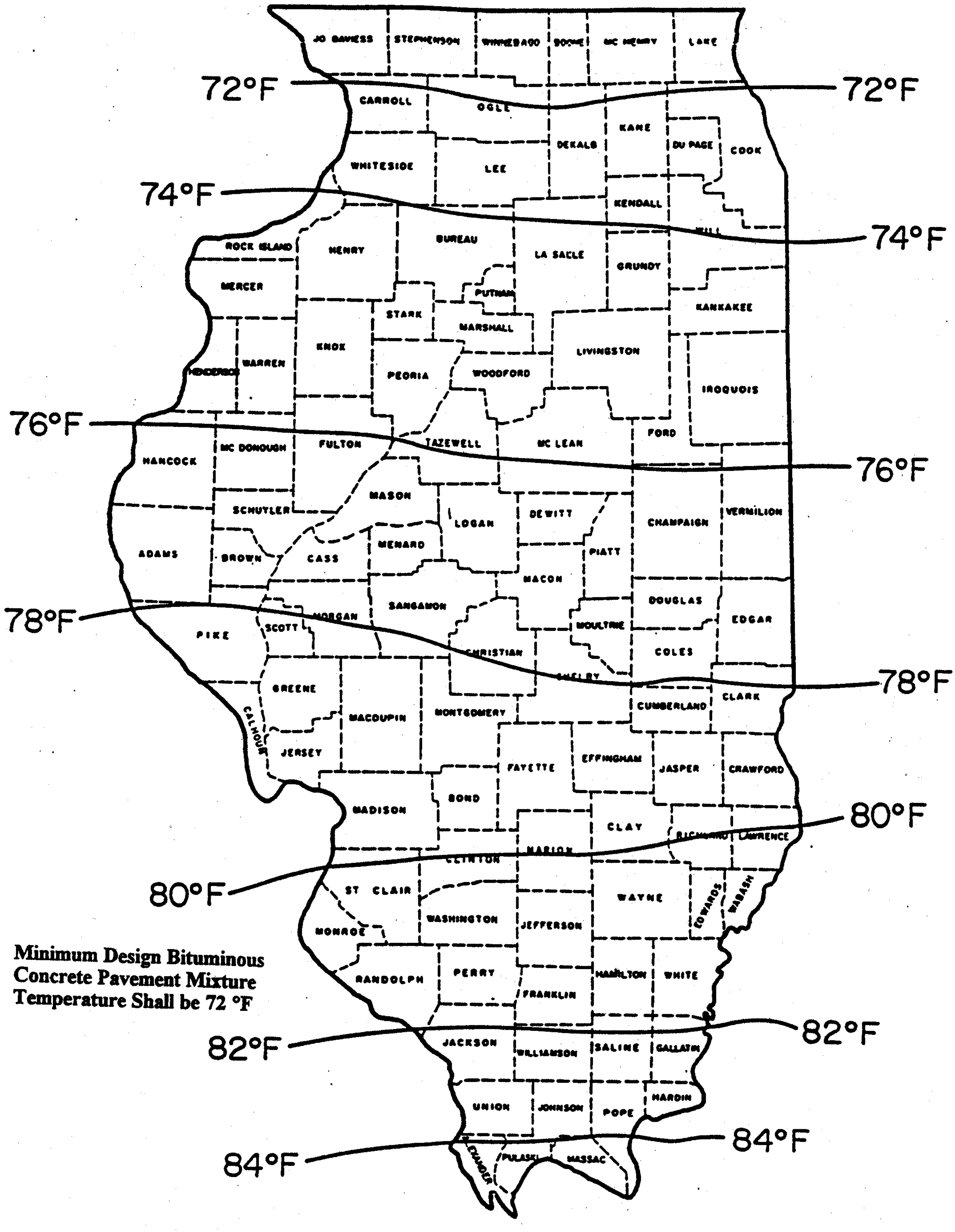
EXAMPLE 3

Design a conventional flexible pavement with a Class B bituminous concrete surface for the following conditions:

1. Class IV, two-lane pavement
2. D.P. - 15 years
3. Design Traffic
   a. ADT 350
   b. 94.5% P.V. (331), 3.5% S.U. (12), 2% M.U. (7)
   c. 73,280 pound load limit
4. Critical Subgrade E_{Ri}: 4 ksi
5. Location: District 5

SOLUTION 3

With 19 HCV's (S.U.'s + M.U.'s) per day and critical subgrade E_{ri} of 4 ksi, (from Table 6) a 3-inch Class B plant mixture and an 8-inch Type A aggregate base is necessary. Since the HCV’s are less than 20 per day, Type B aggregate base material may be substituted for Type A aggregate base material.



Note: Minimum Design Bituminous Concrete Pavement Mixture Temperature Shall be 72 °F

Figure 1. Bituminous Concrete Mixture Temperature (Conventional Flexible)

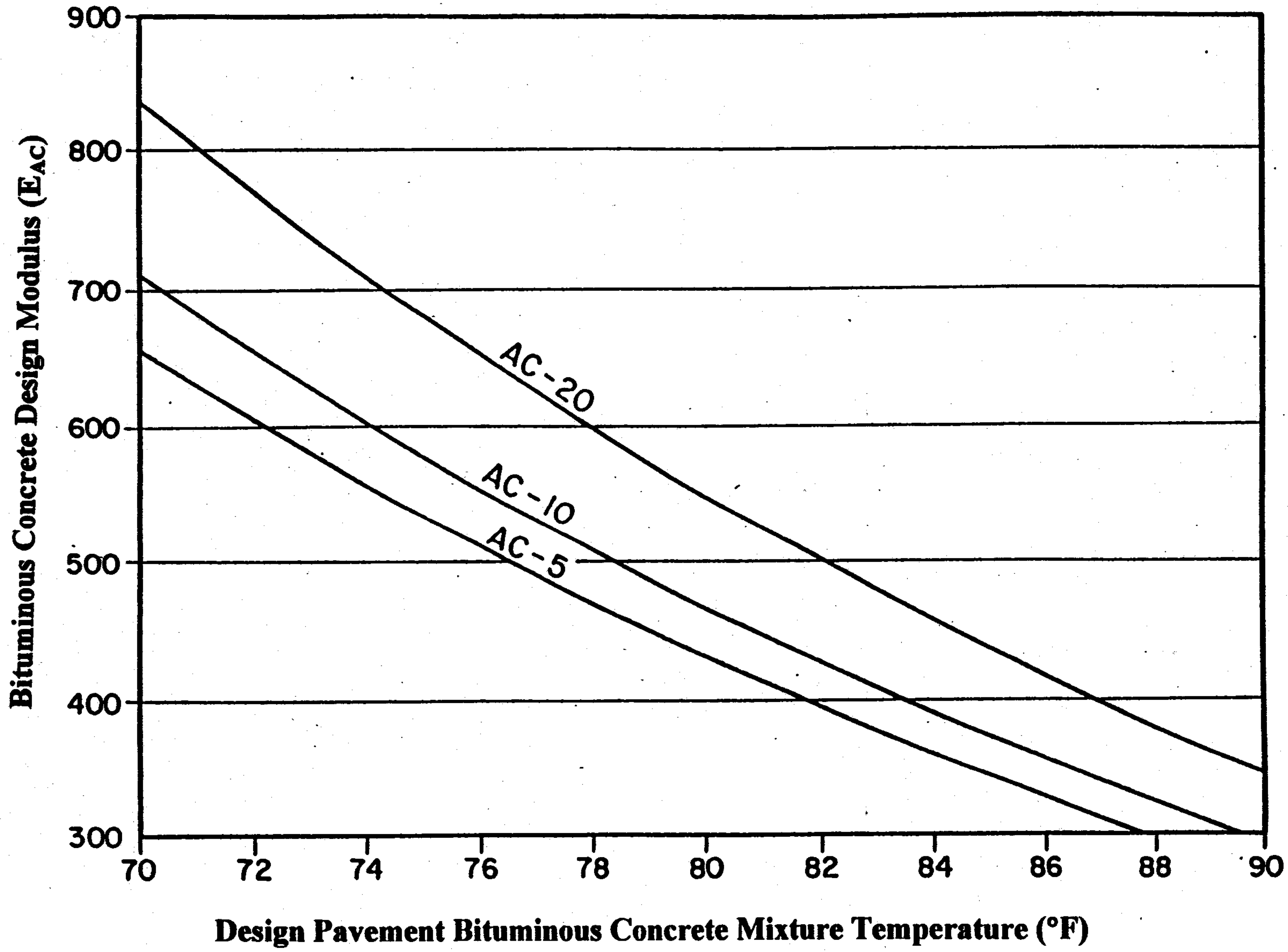


Figure 2. Bituminous Concrete Modulus-Mixture Temperature Relations.

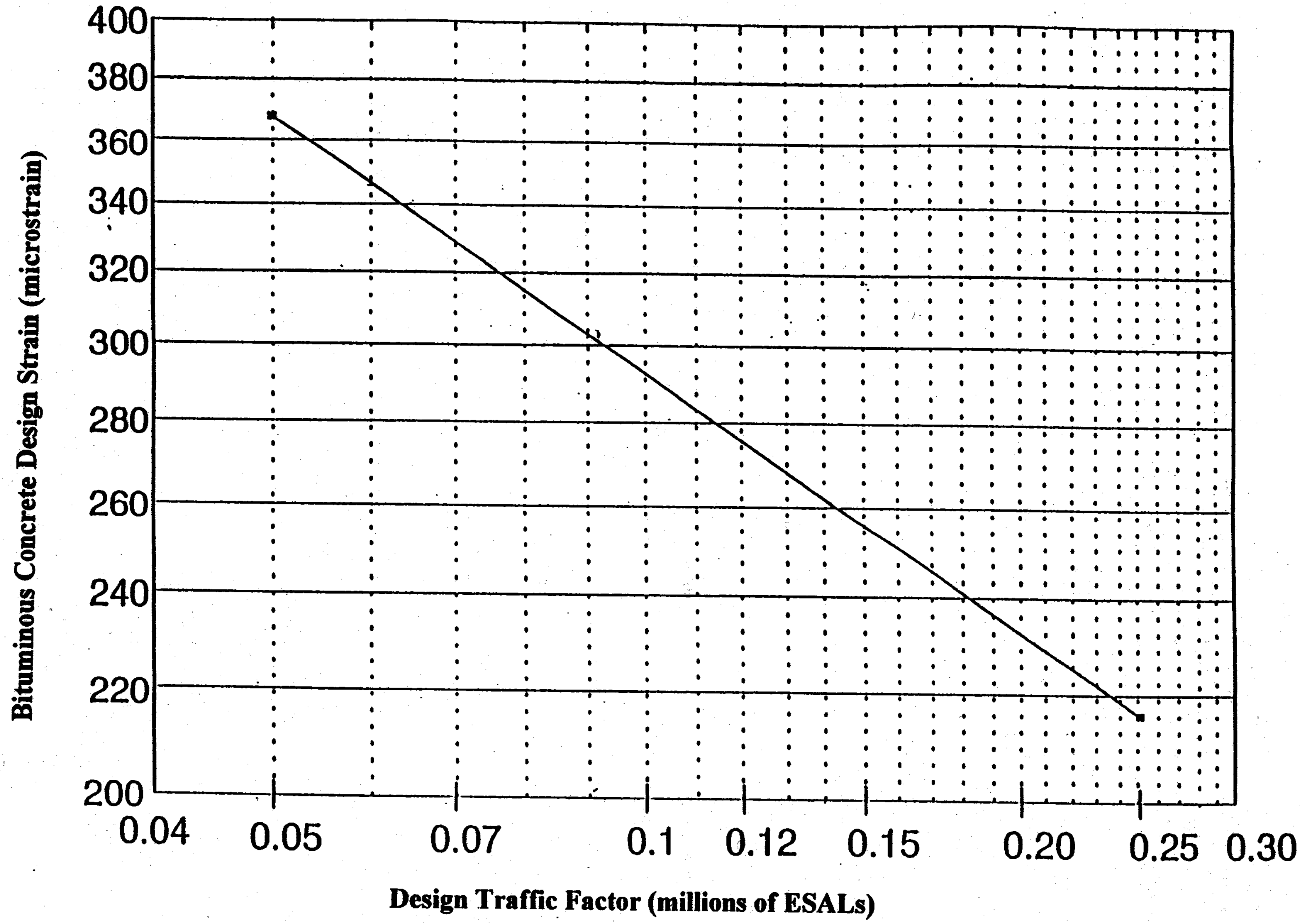


Figure 3. Bituminous Concrete Design Strain - Traffic Factor Relation for Class I Bituminous Concrete

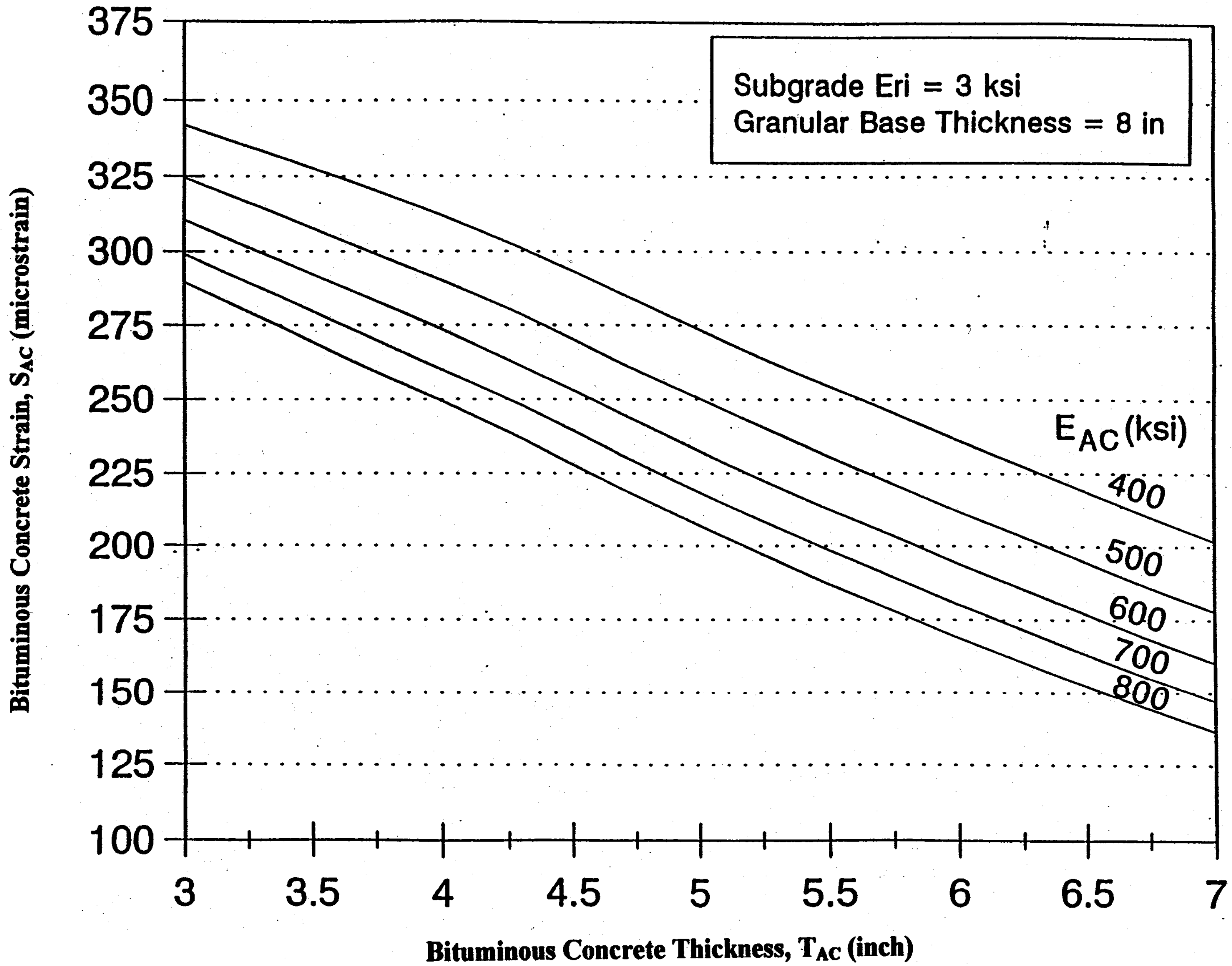


Figure 4. Bituminous Concrete Strain - Thickness Relations for Class I Mixture

**FULL-DEPTH BITUMINOUS CONCRETE
PAVEMENT DESIGN FOR
LOCAL AGENCIES**

SECTION 1 - INTRODUCTION

DESIGN OF FULL-DEPTH BITUMINOUS CONCRETE PAVEMENTS

Full-depth bituminous concrete pavements are those pavement structures whose surface and principle load-carrying component is bituminous concrete. This design procedure assumes that bituminous concrete rutting and thermal cracking are adequately considered in the material selection and mixture design process. The design procedure controls subgrade rutting by limiting the deviator stress at the bituminous concrete-subgrade interface to an acceptable level. The governing design criterion is the bituminous concrete tensile strain. Reduced strain corresponds to increased fatigue life.

USAGE OF PROCEDURE

The pavement design procedure shall be used for all local road and street projects in which a full-depth bituminous concrete pavement is desired. If the local agency intends to transfer jurisdiction following pavement construction, both agencies involved in the jurisdictional transfer should agree on the design.

The pertinent charts, tables, equations, limitations, and requirements of the policy are included in this procedure, as well as specific instructions to be followed in applying the method of design to full-depth bituminous concrete pavements for local agency projects involving MFT and Federal funds. This procedure shall not be used for the design of projects on the State Highway System.

When small quantities of pavement are to be constructed, a soil investigation is not required, unless field conditions warrant such an effort. Small quantities will be as follows:

- Less than one city block in length,
- Less than 3000 square yards,
- Widening less than one lane-width.

When small quantities are to be constructed adjacent to or in extension of an existing pavement, the designer should:

- Design a new section assuming a “poor” subgrade support rating,
- <u>And</u> provide a minimum of 6.0 inches of thickness.

SECTION 2 - BASIC DESIGN ELEMENTS

MINIMUM MATERIAL REQUIREMENTS

Class I surface and binder courses, either Type 1 or 2, are allowed. Any combination of surface course or binder course may be used to arrive at the total bituminous concrete design thickness. However, for economic reasons, a minimum surface course thickness of 1.5 inches should be used unless the designer has compelling reasons to deviate.

CLASSES OF ROADS AND STREETS

The Class of the road or street for which the pavement structure is being designed depends on the structural design traffic. The structural design traffic is the average daily traffic (ADT) estimated for the year representing one-half the design period.

Class I	Facilities with four or more lanes, and one-way streets with a structural design traffic greater than 3500 ADT.
Class II	Two- or three-lane facilities with a structural design traffic greater than 2000 ADT and all one-way streets with a structural design traffic less than 3500 ADT.
Class III	Roads and streets with structural design traffic between 400 and 2000 ADT.
Class IV	Roads and streets with structural design traffic less than 400 ADT.

DESIGN PERIOD

The design period (D.P.) is the length of time in years that the pavement is being designed to serve the structural design traffic. For Class I and II full-depth bituminous concrete pavements, a D.P. of 20 years should be used. For Class III roads and streets, a minimum D.P. of 15 years is allowed. The pavement thickness provided for Class IV pavements with 40 or less Heavy Commercial Vehicles (HCV's) should be satisfactory for a 15- or 20- year D.P. (HCV's are the sum of single- and multiple-unit vehicles).

TRAFFIC FACTORS

For Class I, II and III roads and streets, the design Traffic Factor (T.F.) for flexible pavements can be determined for various D.P.'s and Classes of roads and streets from the 73,280- and 80,000-pound load limit formulae in Tables 1 and 2, respectively. The formulae shown are based on the statewide average distribution of vehicle types and axle loadings, which are directly applicable to most roads and streets.

However, cases will arise in which the average formula should not be used. One such case is a highway where HCV's entering and leaving a site generally travel empty in one direction and fully loaded in the other. Such cases should be referred to the Bureau of Local Roads and Streets for special analysis. The local agency must provide the Bureau of Local Roads and Streets with the structural design traffic, the D.P., and traffic distribution by passenger vehicles (P.V.), single-unit vehicles (S.U.), multiple-unit vehicles (M.U.) and loading conditions of HCV traffic.

For Class IV roads and streets, thicknesses are determined based on the volume of HCV's per day. Thus, a design T.F. is not necessary.

TABLE 1
Flexible Traffic Factor Equations (73,280-lb. load limit)

CLASS I ROADS AND STREETS	
Four- or five-lane pavement (Rural and Urban)	$T.F. = D.P. \frac{(0.047\ P.V. + 47.961\ S.U. + 169.178\ M.U.)}{1{,}000{,}000}$
Six- or more lane pavement (Rural)	$T.F. = D.P. \frac{(0.029\ P.V. + 42.632\ S.U. + 150.380\ M.U.)}{1{,}000{,}000}$
Six- or more lane pavement (Urban)	$T.F. = D.P. \frac{(0.012\ P.V. + 39.435\ S.U. + 139.102\ M.U.)}{1{,}000{,}000}$
One-way streets & pavements (Rural & Urban)	$T.F. = D.P. \frac{(0.073\ P.V. + 53.290\ S.U. + 187.975\ M.U.)}{1{,}000{,}000}$
CLASS II ROADS AND STREETS	
Two- or three-lane pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 44.530\ S.U. + 156.403\ M.U.)}{1{,}000{,}000}$
CLASS III ROADS AND STREETS	
Two- or three-lane pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 44.350\ S.U. + 154.943\ M.U.)}{1{,}000{,}000}$

TABLE 2
Flexible Traffic Factor Equations (80,000-lb. load limit)

CLASS I ROADS AND STREETS	
Four- or five-lane pavement (Rural and Urban)	$T.F. = D.P. \frac{(0.047\ P.V. + 59.625\ S.U. + 217.139\ M.U.)}{1{,}000{,}000}$
Six- or more lane pavement (Rural)	$T.F. = D.P. \frac{(0.029\ P.V. + 53.000\ S.U. + 193.012\ M.U.)}{1{,}000{,}000}$
Six- or more lane pavement (Urban)	$T.F. = D.P. \frac{(0.012\ P.V. + 49.025\ S.U. + 178.536\ M.U.)}{1{,}000{,}000}$
One-way streets & pavements (Rural & Urban)	$T.F. = D.P. \frac{(0.073\ P.V. + 66.25\ S.U. + 241.265\ M.U.)}{1{,}000{,}000}$
CLASS II ROADS AND STREETS	
Two- or three-lane pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 56.03\ S.U. + 192.72\ M.U.)}{1{,}000{,}000}$
CLASS III ROADS AND STREETS	
Two- or three-lane pavement	$T.F. = D.P. \frac{(0.073\ P.V. + 54.57\ S.U. + 192.175\ M.U.)}{1{,}000{,}000}$

SUBGRADE SUPPORT RATING

There are three subgrade support ratings used in this design procedure; namely, "poor," "fair," and "granular." The designer should use Figure 1 in conjunction with the soil grain size analysis to determine the subgrade support rating. The subgrade support rating should represent the average or majority rating classification within the design section. Figure 1 assumes a high water table and appropriate frost penetration in the subgrade soil. For some small projects, in the absence of laboratory tests, the subgrade support rating may be estimated by using the USDA county soil reports.

SUBGRADE WORKING PLATFORM

An improved subgrade layer provides a working platform and uniform support for pavement layer construction. Soil-lime mixture may be used to satisfy the improved subgrade layer requirement. In areas where a soil-lime mixture is not practical, granular material or other approved materials may be used to provide a stable working platform. The improved subgrade layer will not be structurally credited in the design procedure. Thus, additional improved layer thickness will not reduce the bituminous concrete pavement thickness.

For Class I and II pavements, a 12-inch minimum improved subgrade layer is required, unless the subgrade is granular. When a granular subgrade is encountered, the local agency may obtain a waiver to the subgrade working platform requirement by documenting the subgrade suitability.

For Class III and IV pavements, the 12-inch minimum improved subgrade layer is optional. However, documentation must be provided that indicates the subgrade will provide suitable support during construction in accordance with the Subgrade Stability Requirements for Local Roads. Since the improved subgrade layer should improve the constructability and possibly the performance of the pavement, it should be seriously considered.

ASPHALT CEMENT VISCOSITY GRADE SELECTION

When determining the design asphalt cement viscosity grade, the designer must take into consideration the project location, the traffic volume, and whether the facility is in an urban or rural area. Projects in northern Illinois should use softer asphalt cements in order to minimize thermal cracking. In general, a softer asphalt cement, such as AC-10, should be used when ADT is below 2000. Urban areas with stop and go traffic may need stiff asphalt cements to prevent rutting and shoving. The asphalt grade selection should take into account the above variables and be determined on a project-by-project basis.

STAGE CONSTRUCTION

Stage construction is the planned construction of the pavement structure in two or more stages. Stage construction is not allowed on full-depth bituminous concrete pavements.

SECTION 3 - THICKNESS DESIGN

DESIGN OF FULL-DEPTH BITUMINOUS CONCRETE PAVEMENTS

1. Class I, II and III roads and streets.

   - Calculate the T.F. from the appropriate equation found in Tables 1 and 2,
   - Use Figure 1 in conjunction with the subgrade soil grain-size analysis to determine the subgrade support rating,
   - Use Figure 2 to determine the bituminous concrete pavement mixture temperature. The design mixture temperature should be interpolated to the nearest 0.5 °F.

   Note: The Design Time dates are not the same for Full-Depth bituminous concrete and Conventional Flexible pavements. Full-Depth bituminous concrete Design Time dates occur later in the Spring. Thus, for the same location, the Conventional Flexible "Bituminous Concrete Design Mixture Temperature" is lower than Full-Depth "Bituminous Concrete Design Mixture Temperature". **(Figure 1 of the conventional flexible pavement design is not the same as Figure 2 in the full-depth pavement design procedures.)**

   - Use Figure 3A (T.F. < 0.5) or 3B (T.F. $\geq$ 0.5) to determine the bituminous concrete design strain.
   - Use Figure 4 to determine the design pavement mixture modulus (E_{AC}).
   - Use Figure 5A, 5B, or 5C (depending on the subgrade support rating) to determine the design bituminous concrete thickness. The final design thickness should be rounded to the next highest 0.25 inch.
   - The minimum full-depth bituminous concrete design thickness is 6 inches.
   - A 12 inch improved subgrade is required for Class I and II pavements and is optional for Class III pavements. Class III pavement subgrades must satisfy the requirements of the Subgrade Stability Requirements for Local Roads during construction.

2. Class IV roads and streets.

   a. If HCV's per day $\leq$ 40:

   - Use a minimum 6 inch Class I bituminous concrete pavement.
   - A 12 inch improved subgrade layer is optional. Class IV pavement subgrades must satisfy the requirements of the Subgrade Stability Requirements for Local Roads during construction.

   b. If HCV's per day > 40:

   - Use a Class III T.F. equation and design procedure.

SECTION 4 - EXAMPLE CALCULATION

EXAMPLE 1

Design a full-depth bituminous concrete pavement for the following conditions:

1. Class I, four-lane pavement
2. Design Period - 20 years
3. Design Traffic
   a) ADT 14,000
   b) 86 % P.V. (12,040), 8% S.U. (1,120), 6% M.U. (840)
   c) 80,000-lb. load limit
4. Location: Lake County
5. Design subgrade support rating “fair”
6. Asphalt Cement type is AC-20

SOLUTION 1

The T.F. equation for a four-lane Class I pavement with an 80,000-pound load limit should be used (Table 2). The design T.F. is 4.99.

Four- or five-lane pavement (Rural and Urban)

$$T.F. = D.P. \frac{(0.047\ P.V. + 59.625\ S.U. + 217.139\ M.U.)}{1{,}000{,}000}$$

$$4.99 = 20 \times \frac{(0.047 \times [12{,}040] + 59.625 \times [1{,}120] + 217.139 \times [840])}{1{,}000{,}000}$$

From Figure 2, the bituminous concrete mixture temperature would be 76 °F.

Use Figure 3B (T.F.$\geq$ 0.5) in conjunction with the design T.F. of 4.99 to determine the bituminous concrete design strain is 63 microstrain.

Use Figure 4 in conjunction with a bituminous concrete mixture temperature of 76 °F to determine the bituminous concrete design modulus is 655 ksi for AC-20.

Use Figure 5B (subgrade support rating is “fair”) in conjunction with the bituminous concrete strain of 63 microstrain and the design modulus of 655 ksi to determine the design bituminous concrete thickness is 12.25 inches. (After rounding to the next higher 0.25 inch.)

A 12-inch improved subgrade is required for all Class I and II full-depth bituminous concrete projects unless built upon a granular subgrade.

EXAMPLE 2

Design a full-depth bituminous concrete pavement for the following conditions:

1. Class II, two-lane pavement
2. Design Period - 20 years
3. Design Traffic
   a) ADT 3000
   b) 95% P.V. (2850), 3% S.U. (90), 2% M.U. (60)
   c) 73,280-lb. load limit
4. Location: Bloomington, McLean County
5. The subgrade particle sizes are as follows:
   - 20% Sand
   - 55 % Silt
   - 25 % Clay
6. Asphalt Cement type is AC-20

SOLUTION 2

The T.F. equation for a two-lane Class II pavement with a 73,280-pound load limit should be used (Table 1). The design T.F. is 0.27

Two- or three-lane pavement

$$\text{T.F.} = \text{D.P.}\ \frac{(0.073\ \text{P.V.} + 44.530\ \text{S.U.} + 156.403\ \text{M.U.})}{1{,}000{,}000}$$

$$0.27 = 20\ \frac{(0.073 \times [2850] + 44.530 \times [90] + 156.403 \times [60])}{1{,}000{,}000}$$

Based on the subgrade particle sizes and Figure 1, the subgrade support rating is “poor."

From Figure 2, the bituminous concrete mixture temperature for McLean County would be 80.0 °F.

Use Figure 3A (T.F. is less than 0.5) in conjunction with the design T.F. of 0.27 to determine the bituminous concrete design strain is 215 microstrain.

Use Figure 4 in conjunction with a bituminous concrete mixture temperature of 80.0 °F to determine the bituminous concrete design modulus is 540 ksi for an AC-20.

Use Figure 5A (subgrade support rating is “poor,") in conjunction with the bituminous concrete strain of 215 microstrain and the design modulus of 540 ksi to determine the design bituminous concrete thickness is 6.5 inches. (This thickness is after rounding to the next higher 0.25 inch.)

A 12-inch improved subgrade is required for all Class I and II full-depth bituminous concrete projects unless built upon a granular subgrade.

EXAMPLE 3

Design a full-depth bituminous concrete pavement for the following conditions:

1. Class IV, two-lane pavement
2. Design Period - 20 years
3. Design Traffic
    a) ADT 350
    b) 90% P.V. (315), 6% S.U. (21), 4% M.U. (14)
    c) 73,280-lb. load limit
4. Location: Marion, Williamson County
5. Design subgrade support rating is “poor”
6. Asphalt Cement type is AC-10
7. Fall construction is expected.

SOLUTION 3

There are 35 HCV’s per day (21 S.U.’s + 14 M.U.’s).

Since the pavement is a Class IV road with less than 40 HCV’s per day, a minimum 6 inch Class I bituminous concrete pavement is required. A 12-inch improved subgrade layer should be included as part of the design.

> NOTE: A 12-inch improved subgrade is optional for Class III and IV full-depth bituminous concrete projects. The subgrade still must satisfy the Subgrade Stability Requirements for Local Roads. In this case, due to the “poor” subgrade support rating and possible late fall construction with little chance of good drying weather, a 12-inch improved subgrade layer should be included as part of the initial design. The improved subgrade layer requirement and pay items can be deleted by the resident engineer, (Class III and IV pavements only) if deemed unnecessary at the time of construction.

FULL-DEPTH BITUMINOUS CONCRETE
PAVEMENT DESIGN CALCULATIONS
FOR LOCAL AGENCIES

Date ______________________________

Calculations by: ____________________

Checked by: _______________________

Class _________ Roads and Streets

Limits of Analysis:

Station ________________________To

Station ___________________________

Length __________Feet ________Miles

Structural Design Traffic:

ADT =______________

PV = ______________

SU = ______________

MU = ______________

Route _______________________

Section ______________________________

County ______________________________

Location ______________________________

Pavement Design

Subgrade Support Rating (SSR) -

"______________" (fair, poor, or granular)

Flexible Traffic Factor ________________

Selected Design AC Type _____________

Design AC Mixture Temperature ______°F

Design Bituminous Concrete Modulus -

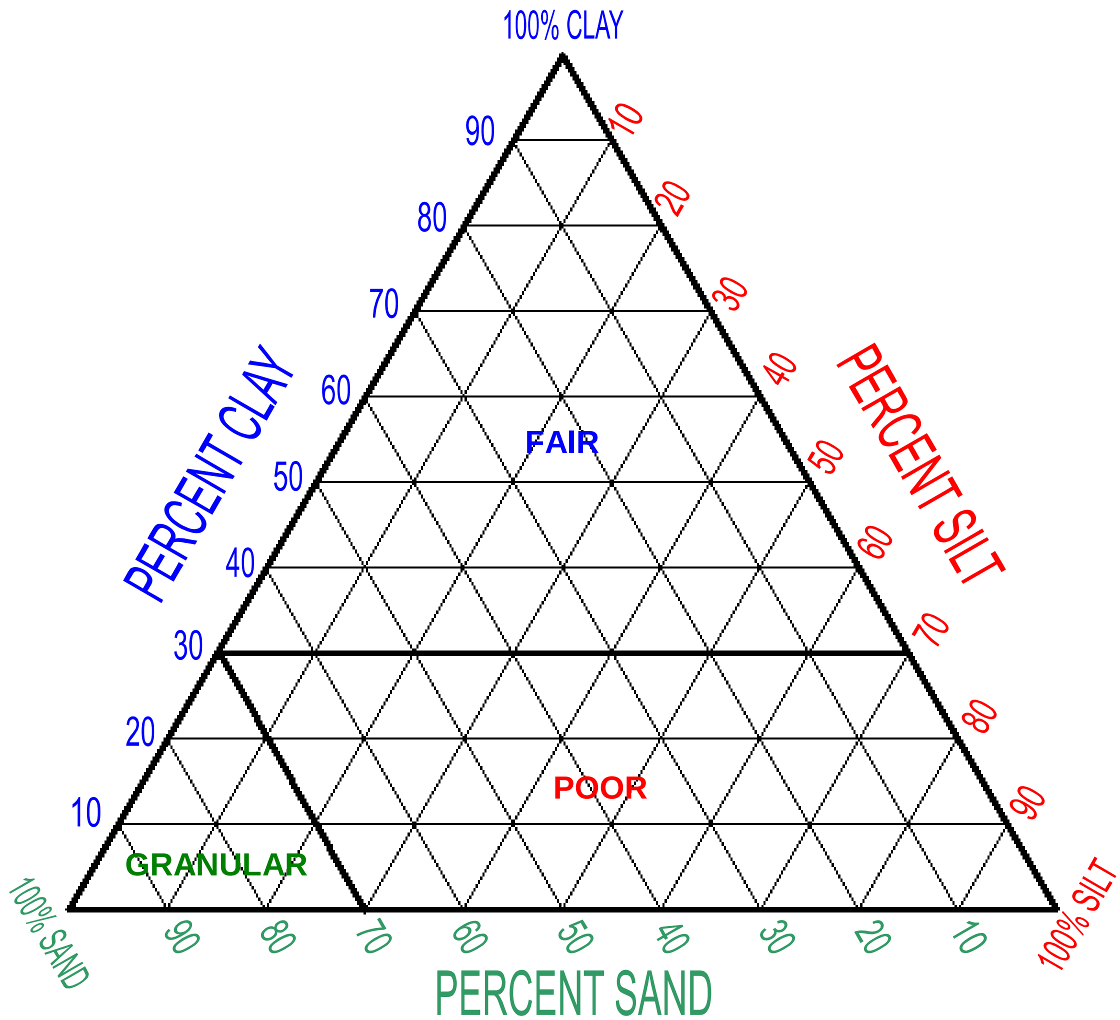
(E_{AC}) - ____________ksi

Design AC Microstrain _______________

Pavement Thickness ______________Inch

Subgrade: ___________________________

Comments: ___________________________



Particle-Size Limits

Sand	2.000 – 0.075 mm
Silt	0.075 – 0.002 mm
Clay	< 0.002 mm

Figure 1. Subgrade Support Rating (SSR)

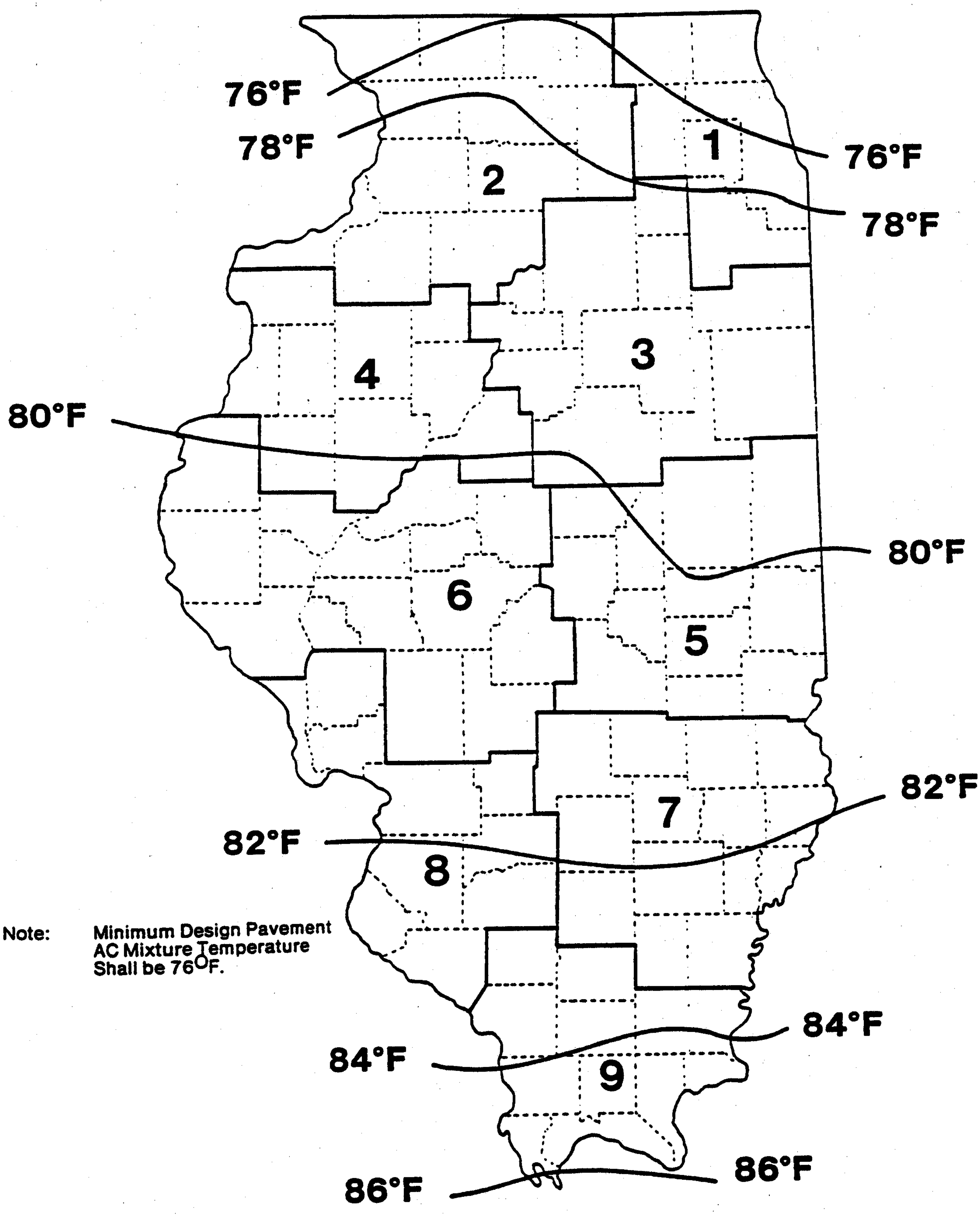


Figure 2. Design Pavement Bituminous Concrete Mixture Temperature, (Full-Depth)

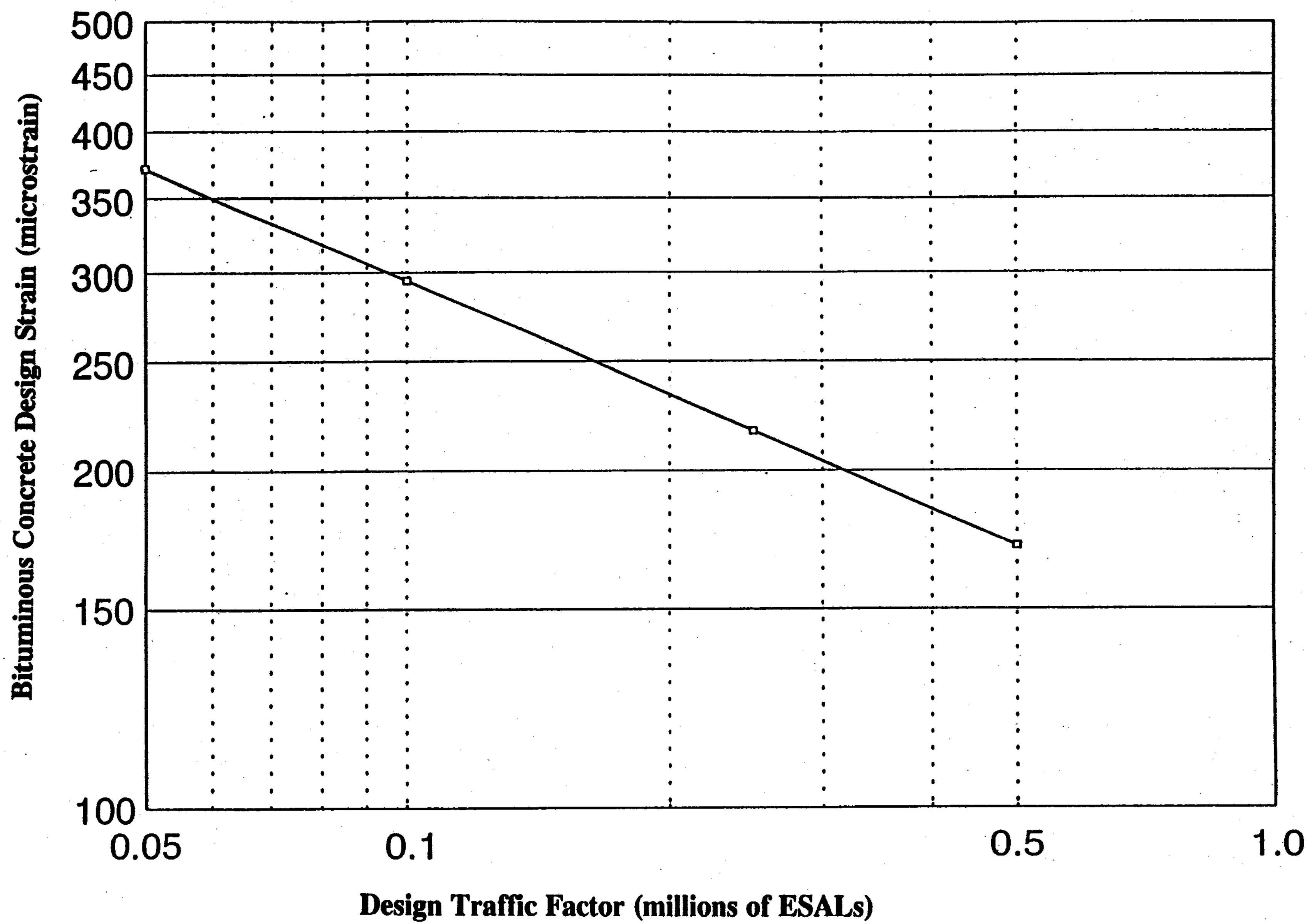


Figure 3A. Bituminous Concrete Design Strain - Traffic Factor Relation for Traffic Factor < 0.5

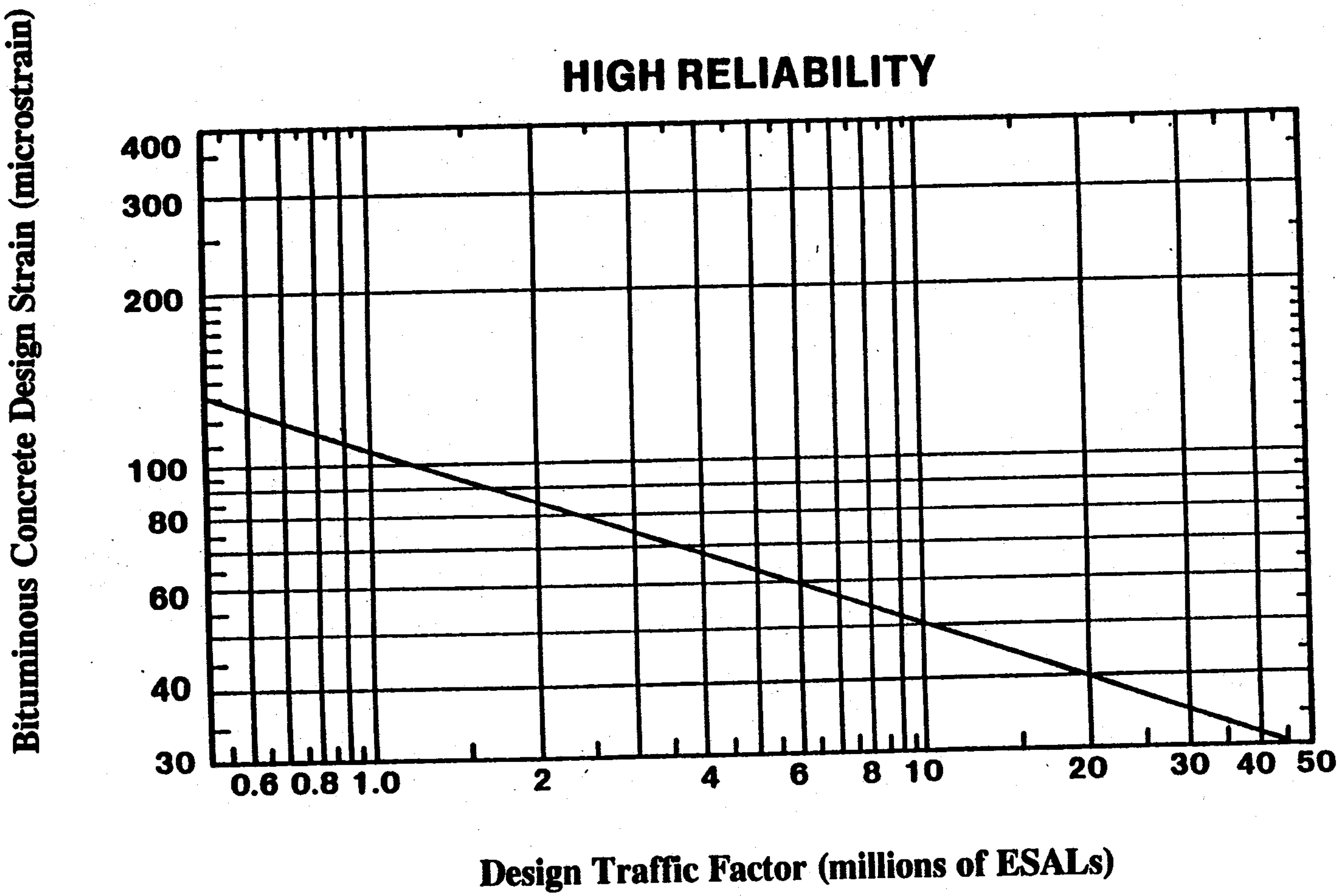


Figure 3B. Bituminous Concrete Design Strain - Traffic Factor Relation for Traffic Factor $\geq$ 0.5

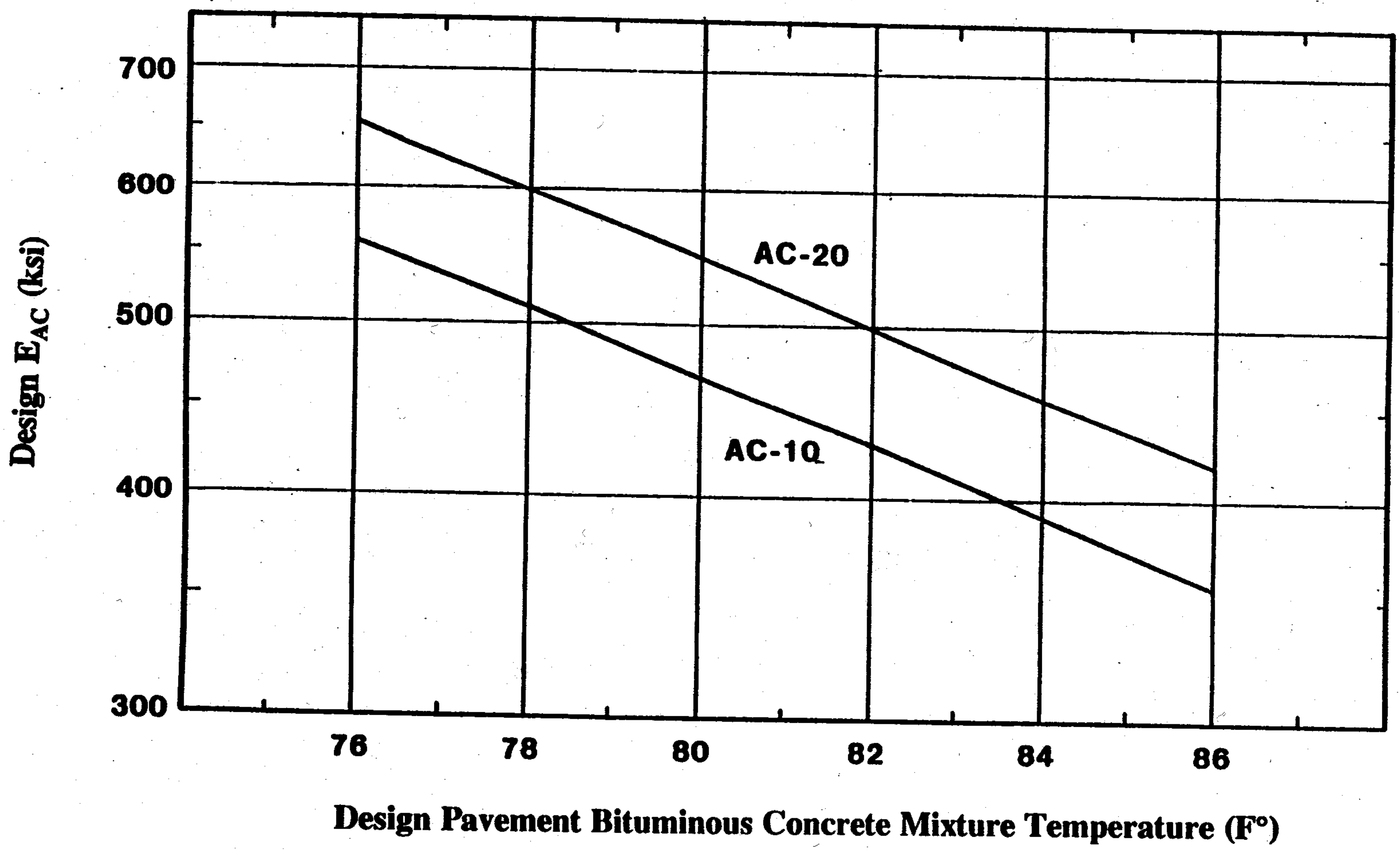


Figure 4. - Design Pavement Bituminous Concrete Modulus

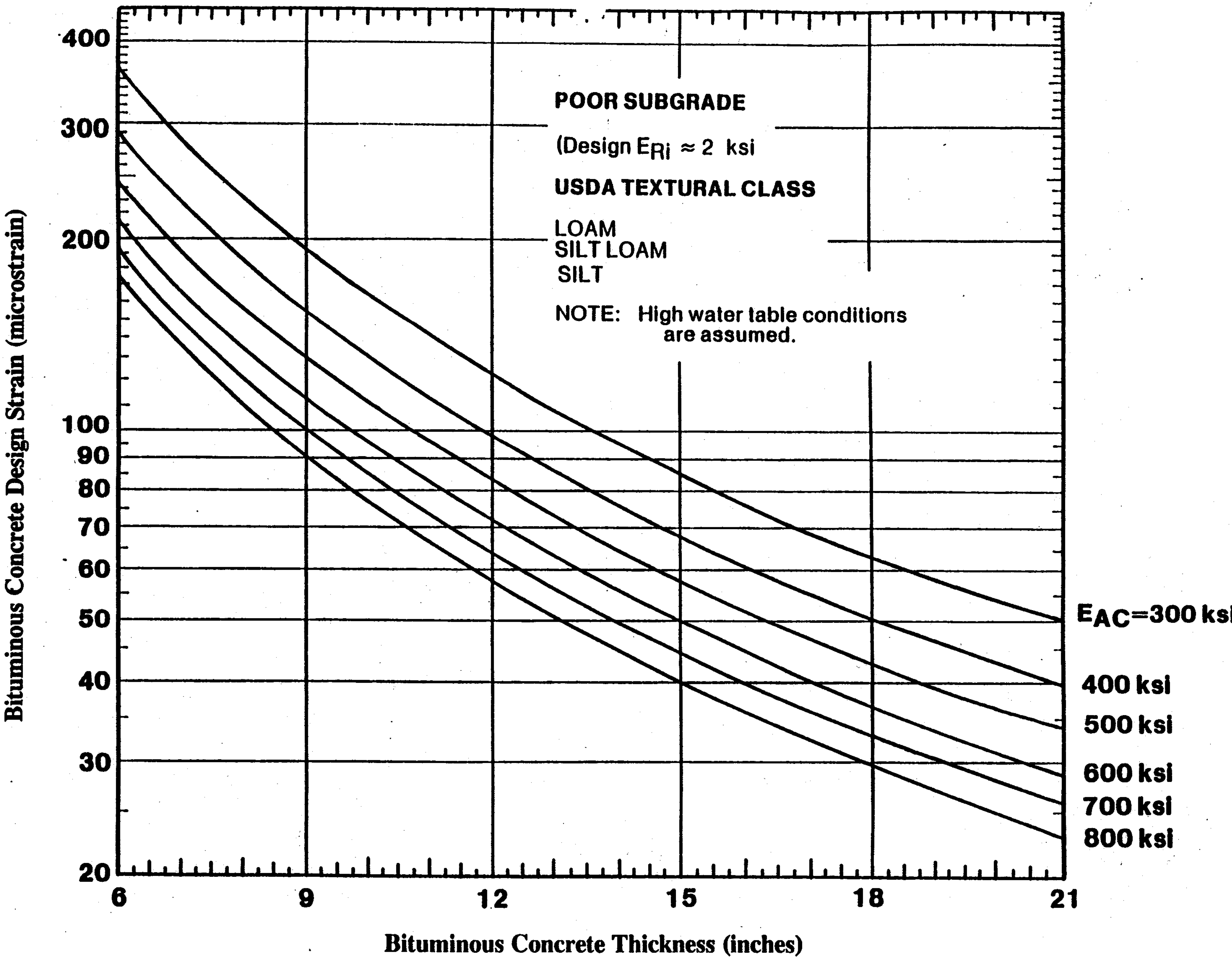


Figure 5A - "Poor" Subgrade Design Chart

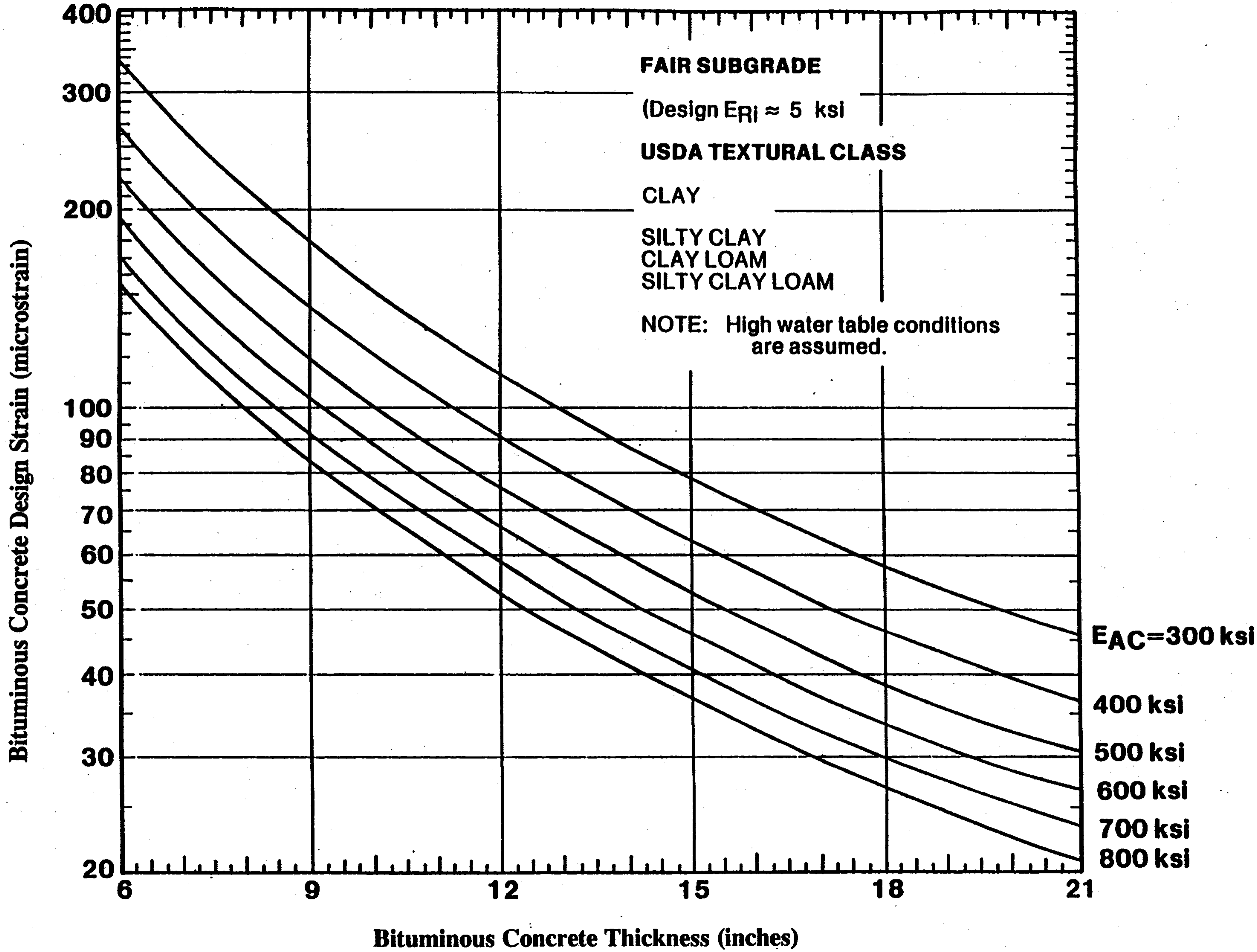


Figure 5B - "Fair" Subgrade Design Chart

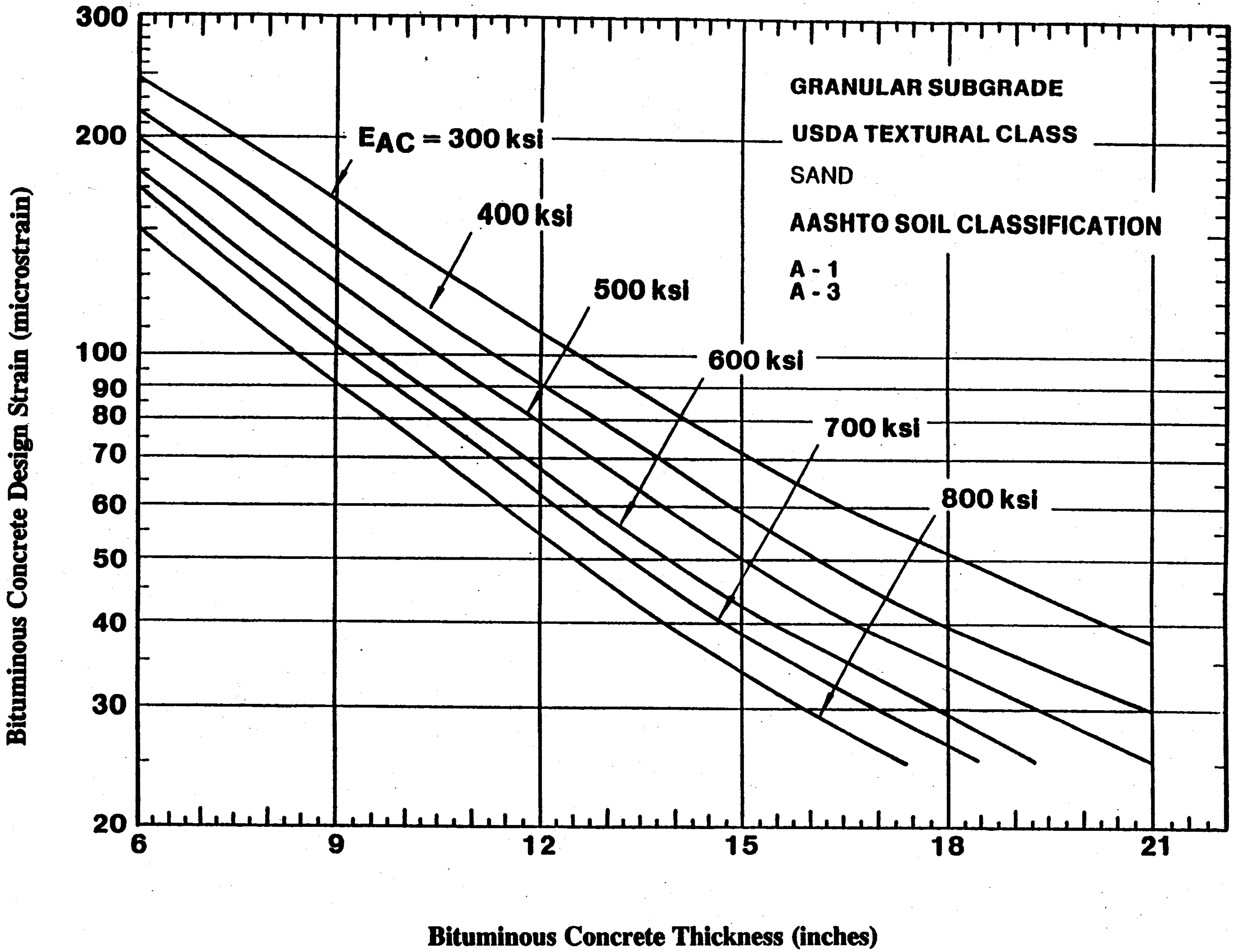


Figure 5C - "Granular" Subgrade Design Chart

SUBGRADE INPUTS FOR
LOCAL ROAD PAVEMENT DESIGN

INTRODUCTION

The variability of insitu subgrade strengths can be quite large. Subgrade strength can vary with depth, distance along the roadway, or location across the pavement width. Knowledge of the soil present on the section of roadway being designed is essential to produce a satisfactory design. Flexible and rigid pavement designs require different subgrade design inputs. These are discussed below.

I. FULL-DEPTH ASPHALT CONCRETE, JOINTED PCC, AND COMPOSITE PAVEMENTS

A Subgrade Support Rating (SSR) is used as the design subgrade input for full-depth asphalt concrete, jointed PCC, and composite pavement designs. The SSR is based on a grain size analysis of the subgrade soil. Figure 1 is a graphical method to determine the SSR (poor, fair, or granular) based on the percentage of clay, silt, and sand in the subgrade soil.

II. FLEXIBLE PAVEMENT DESIGN (Except full-depth asphalt concrete)

The majority of soils found in Illinois are fine-grained soils. The subgrade resilient modulus (E_{Ri}) is used as the design subgrade input for all flexible pavement designs except full-depth asphalt concrete. The E_{Ri} is an indicator of a soil's resilient behavior under loadings. A springtime E_{Ri}, which reflects high moisture content and a thaw-weakened condition, is used for design purposes. Design E_{Ri} values can be obtained through field testing or laboratory testing, or estimated from soil property or strength data. The County Soil Report, prepared by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service, can be an excellent source of information. The County Soil Report includes a soil report map and listings of engineering index properties and physical and chemical properties of the soils. The data are listed by soil series, which have similar profile features and characteristics wherever they are located.

Listed below are five methods to determine preliminary E_{ri}.values, which are later adjusted for moisture. The methods vary in complexity from requiring field or laboratory tests to using county soil maps. The most accurate methods appear first in the listing. The results are acceptable in all cases, but are more accurate and reliable for the method involving field or laboratory tests.

- Resilient Modulus Testing
- Falling Weight Deflectometer (FWD) Testing
- Estimating E_{Ri} from Strength Data
- Estimating E_{Ri} from Soil Properties
- Typical E_{Ri} Values

A. Preliminary E_{Ri} Determination

1. Resilient Modulus Testing
   The E_{Ri} of a soil may be determined by performing repeated unconfined compression testing in the laboratory. Subgrade specimens from insitu soil or laboratory-prepared specimens may be tested. Laboratory-prepared specimens with a range of moisture contents and densities can be tested to simulate the variable conditions found in the field. The Bureau of Local Roads and Streets may be contacted for additional information regarding a resilient modulus testing format.

2. Falling Weight Deflectometer (FWD) Testing
   Design E_{Ri} values can be backcalculated from FWD data taken from existing pavements. County soil maps can be used to identify the major soil series found in an area. A FWD testing scheme that targets existing typical flexible pavements constructed in the major soil series of the area can be developed using this information. A county-wide FWD testing program that provides comprehensive coverage can be completed in 3 to 5 days in most cases. Springtime FWD testing is preferred, but a seasonal adjustment factor may be applied to the backcalculated E_{Ri} if the FWD testing is conducted during other seasons. Contact the Bureau of Local Roads and Streets if a seasonal adjustment factor is needed. The average E_{Ri} backcalculated from FWD testing should be used as the design E_{ri}.

   Design E_{Ri} values may be obtained from FWD testing in a cost-effective manner. Backcalculated E_{Ri} values do not represent a single point location, but reflect the composite influence of a large volume of insitu soil, including the different soil horizons.

3. Estimating E_{Ri} from Strength Data
   An E_{Ri} value can be estimated from strength data obtained with a Corps of Engineers hand-held cone penetrometer, or a dynamic cone penetrometer (DCP). Both the Corps of Engineers hand held cone penetrometer and the DCP are field testing devices used to rapidly evaluate the insitu strength of fine-grained and granular soils and granular base and subbase materials. The Corps of Engineers hand held cone penetrometer is limited to an 18-inch depth of penetration and a maximum load of 150 pounds (CBR = 7.5). Data obtained from Corps of Engineers hand held cone penetrometer and DCP testing can be used to estimate CBR and E_{Ri} through the following equations. (Note: The Department's Illinois Bearing Ratio (IBR) is considered equal to CBR.)

$$CBR = \frac{CI}{40} \qquad \text{(Eqn. 1.)}$$

Where:
CBR = California Bearing Ratio
CI = Corps of Engineers Cone Index, psi

$$\text{LOG } CBR = 0.84 - 1.26 \text{ LOG } (PR) \qquad \text{(Eqn. 2)}$$

Where:
CBR = California Bearing Ratio
PR = DCP penetration rate, in./blow

$$Qu = 4.5\ CBR \qquad \text{(Eqn. 3)}$$

Where:
Qu = Unconfined compressive strength, psi
CBR = California Bearing Ratio

$$E_{Ri}{}^{*} = 0.86 + 0.307\ Qu \qquad \text{(Eqn. 4)}$$

Where:
E_{Ri} * = Subgrade resilient modulus, ksi
Qu = Unconfined compressive strength, psi
* Moisture adjustment is necessary

An E_{Ri} can be established with Corps of Engineers cone penetrometer or DCP testing at the project site or on existing flexible pavement sections constructed on the same soil series as the roadway being designed. Ideally, such testing should be conducted during the springtime. If testing is not conducted during the spring, the E_{Ri} value calculated from Equation 4 will need to be corrected as discussed under Moisture Adjustment Procedure.

4. Estimating E_{Ri} from Soil Properties
Design E_{Ri} values can be estimated based on a soil's clay content (< 2 micron) and plasticity index (PI). These values are easily obtainable from an analysis of the project's soils or the County Soil Report. Equation 5 may be used to predict E_{Ri} at optimum water content and 95 percent of AASHTO T-99 maximum dry density:

$$E_{Ri}(OPT)^* = 4.46 + 0.098\ (\%\ Clay) + 0.119\ (PI) \qquad \text{(Eqn. 5)}$$

Where $E_{Ri}(OPT)^*$ = E_{Ri} at optimum moisture content and 95 % of AASHTO T-99 maximum dry density, ksi
% Clay = Clay content (<2 microns), %
PI = Plastic Index
* Moisture adjustment is necessary

Figure 2 is a graphical solution to Equation 5. If the County Soil Report is used to estimate the soil's clay content and PI, the designer should use the midpoint of clay content and PI values given.

5. Typical E_{Ri} Values
If data are not available to estimate E_{Ri} values using the previously discussed methods, Tables 1 or 2 may be used to estimate typical E_{Ri} values. If the water table and frost penetration levels are known, Table 1 may be used to determine typical E_{Ri} values based on the AASHTO soil classification system.

TABLE 1:
Average E_{Ri} Values (ksi)
Based on Soil Classification, Water
Table Depth, and Freeze-Thaw Conditions

	High Water Table*		Low Water Table**	
AASHTO Soil Class	With Frost Penetration into Subgrade	Without Frost Penetration into Subgrade	With Frost Penetration into Subgrade	Without Frost Penetration into Subgrade
A-4, A-5, and A-6	2.0	4.0	3.0	6.0
A-7	2.0	5.0	3.5	7.0

*Water table seasonally within 24 inches of subgrade surface
**Water table seasonally within 72 inches of subgrade surface

If the frost penetration and water table levels are not known, the designer may use Table 2 to estimate a typical E_{Ri} value. These E_{Ri} values were developed from resilient modulus testing of fine-grained Illinois soils, represent 95 percent of AASHTO T-99 maximum dry density and moisture contents 2 percent wet of optimum.

TABLE 2:
Average E_{Ri} Values for Various Soil Classifications

Soil Classification	Average E_{Ri}**, ksi
AASHTO	
A-7-6	9.2
A-7-5	6.3
A-6	5.6
A-4	3.8
A-5*	4.5
USDA Textural Class	
Silty Clay, Clay	9.5
Silty Clay Loam, Clay Loam	7.3
Silt Loam, Loam, Silt	6.2
Sandy Clay*	9.0
Sandy Clay Loam*	7.0

* Estimated

** Moisture adjustment necessary.

Note: (95 percent of AASHTO T-99 maximum dry density and moisture contents 2 percent wet of optimum)

B. Moisture Adjustment Procedure

The "preliminary E_{Ri}" determined by one of the above procedures (except for the resilient modulus laboratory or FWD methods) should be corrected to reflect the insitu moisture present under springtime conditions (if the test data reflects conditions other than those of a normal spring).

If the AASHTO T-99 maximum dry density (MDD), the optimum moisture content (OMC), and the specific gravity of soil solids (Gs) are known, Equation 6 can be used to calculate the moisture content for a given degree of saturation and 95 percent compaction.

$$MC_{\%SR} = \left[\frac{65.7}{MDD} - \frac{1}{Gs} \right] [SR] \qquad \text{(Eqn. 6)}$$

Where:
$MC_{\%SR}$ = Moisture content for a given degree of saturation, %
MDD = AASHTO T-99 maximum dry density, pcf
Gs = Specific gravity of soil solids
SR = Degree of Saturation, % *

*For "very poorly, poorly, and imperfectly drained" soils, the E_{Ri} estimate should be adjusted to a 100 percent SR. All other drainage classes should be adjusted to a 90 percent SR. The drainage classification for a soil series can be found in the County Soil Report.

If the MDD and OMC have not been determined, they can be estimated using Equations 7 and 8 and then used to solve Equation 6.

$$OMC = 1.86 + 0.499\ (LL) - 0.354\ (PI) + 0.044\ (P_{200}) \quad \text{(Eqn. 7)}$$

$$MDD = 138.96 - 1.10\ (LL) + 0.796\ (PI) - 0.062(P_{200}) \quad \text{(Eqn. 8)}$$

Where: OMC = Optimum moisture content, %
LL = Liquid limit, %*
PI = Plasticity index *
P_{200} = Percent passing #200 sieve *

*These inputs can be obtained from laboratory testing or selected from the midpoint of the range of values presented for the given soil series in the County Soil Report.

Once the moisture content for the required degree of saturation is calculated, the field moisture adjustment and design E_{Ri} can be calculated.

$$FMA = MC_{\%SR} - OMC \quad \text{(Eqn. 9)}$$

Where: FMA = Field moisture adjustment, %
$MC_{\%SR}$ = Moisture content for a given degree of saturation, %
OMC = Optimum moisture content, %

$$\text{Design } E_{Ri} = E_{Ri}(OPT) - [(FMA)(MAF)] \quad \text{(Eqn. 10)}$$

Where: Design E_{Ri} = E_{Ri} for flexible pavement design, corrected for insitu moisture conditions, ksi
$E_{Ri}(OPT)$ = E_{Ri} at OMC and 95% of MDD, ksi
FMA = Field moisture adjustment, %
MAF = Moisture adjustment factor, E_{Ri} decrease per 1 % moisture increase, ksi/% *

*MAF is selected from Table 3 based on USDA soil textural classification.

TABLE 3:
E_{Ri} Moisture Adjustment Factors
Based on USDA Textural Classification

USDA Textural Classification	E_{Ri} Decrease/1% Moisture Increase, ksi/%
Clay, Silty Clay, Silty Clay Loam, Clay Loam, Sandy Clay*, Sandy Clay Loam*	0.7
Silt Loam, Sandy Loam	1.5
Loam, Silt	2.1

*Estimated

Minimum Design E_{Ri} values

A design E_{Ri} of 2 ksi is the lowest allowable design E_{Ri}. If the design E_{Ri} value calculated from Equation 10 is less than 2 ksi or does not reasonably compare with historical data for the soil series, other means for determining design E_{Ri} should be investigated. Soft subgrades with low E_{Ri} or CBR values may require remedial subgrade treatments as outlined in Subgrade Stability Requirements For Local Roads. Engineering judgment may also be required to decrease the design E_{Ri} to account for the effect of freeze-thaw cycles on the insitu springtime design condition.

C. Composite E_{Ri} Estimate

A soil profile (vertical sections) contains distinct soil layers, called horizons. The County Soil Report contains thicknesses and properties for each horizon in the soil series. In a typical flexible pavement, approximately 70 to 75 percent of the subgrade deflection occurs in the upper 60 inches of the subgrade. For this reason, a composite E_{Ri} which considers the contributing effect of the E_{Ri} values of the different soil horizons in the 60-inch zone should be calculated using Equation 11.

E_{Ri} values determined from FWD testing reflect the composite E_{Ri} value of the subgrade, thus no further adjustment for composite influences should be made.

$$\text{Design Composite } E_{Ri} \text{ (ksi)} = \sum_{i=1}^{n} (F_i)(T_i)(E_i) \qquad \text{(Eqn. 11)}$$

Where: i = Layer designator; i = 1 for the top layer
n = Number of layers
F_i = Deflection coefficient, (Table 4)
T_i = Thickness of soil horizon in 60-inch depth zone, inches
E_i = E_{Ri} for the soil horizon, adjusted for springtime conditions, ksi

TABLE 4:
Deflection Coefficients as a Function of Depth

Depth Zone, * Inches	F_i,
0-12	0.038
12-24	0.015
24-36	0.008
36-60	0.011

*Measured from surface of subgrade

The design composite E_{Ri} value should be used as the design subgrade input in all pavement design procedures requiring the E_{Ri} input value.

SUBGRADE DESIGN INPUT EXAMPLES

I. GRAIN SIZE ANALYSIS

A grain size analysis shows that the subgrade soil contains 43 percent clay, 48 percent silt, and 9 percent sand. From Figure 1, the Subgrade Support Rating (SSR) is FAIR. An SSR value is necessary for rigid and full-depth bituminous concrete pavement design procedures.

II. RESILIENT MODULUS (E_{Ri}) FROM LABORATORY TESTING

Repeated compression testing in the laboratory is performed on subgrade specimens from insitu soil sampled during the spring or on laboratory-prepared specimens. The results should be adjusted to reflect the composite influence of the soil layers. If the soil samples were not taken during the spring, moisture adjustment factors would need to be applied prior to correcting for the composite influence of the soil layers.

III. ESTIMATING E_{Ri} FROM STRENGTH DATA

A DCP was used to evaluate the insitu strength of a subgrade soil. Average DCP penetration rates for the soil are given below. CBR, Qu, and E_{Ri} were calculated using Equations 2, 3, and 4 respectively.

Depth, Inches	DCP Penetration Rate, In./Blow	CBR	Qu, psi	E_{ri}, ksi
0 - 16	1.9	3.1	13.9	5.1
16 - 51	1.2	5.5	24.7	8.4
51 - 60	1.6	3.8	17.2	6.1

Corrections for springtime conditions (if DCP testing was done other than in springtime) and the composite influence of the soil layers should be made as shown in the Estimating E_{Ri} from Soil Properties example (below).

IV. ESTIMATING E_{Ri} FROM SOIL PROPERTIES

The roadway being designed passes through the MIAMI soil series. From the County Soil Report, the following information is obtained.

Soil Series	USDA Textural Class	Depth from top of Subgrade, In.	Clay, %	PI	Liquid Limit	Percent Passing #200 Sieve
MIAMI*	Clay Loam, Silty Clay Loam,	0-16	25-35	17-31	35-50	64-95
	Loam, Clay Loam Sandy Loam	16-60	15-28	2-20	20-40	50-64

* Assumes that A horizon material has been stripped; remaining material is representative of B and C horizons.

From Equation 5, E_{Ri} (OPT) is calculated for each of the two depths using the midpoint values from the County Soil Report.

0 - 16 in. E_{Ri} (OPT) = 4.46 + 0.098 (30) + 0.119 (24)
E_{Ri} (OPT) = 10.2 ksi

16 -60 in. E_{Ri} (OPT) = 4.46 + 0.098 (22) + 0.119 (11)
E_{Ri} (OPT) = 7.9 ksi

These values must be corrected to reflect the springtime design condition. The following Table summarizes the moisture adjustment procedure.

The design E_{Ri} values adjusted to reflect springtime design conditions in the following Table must be combined into a composite E_{Ri} which considers the effect of the 60-inch zone under the load. This can be accomplished using Equation 11 and Table 4.

Design Composite E_{ri} = (0.038)(12)(7.6) + (0.015)(4)(7.6) + (0.015)(8)(2.0) + (0.008)(12)(2.0) + (0.011)(24)(2.0)
= 4.9 ksi

DEPTH, IN.	E_{Ri}(OPT)[1] KSI	OPTIMUM MOISTURE CONTENT,[2] %	MAXIMUM DRY DENSITY,[3] PCF	MOISTURE CONTENT FOR GIVEN SATURATION[4] %	FIELD MOISTURE ADJUSTMENT,[5] %	MOISTURE ADJUSTMENT FACTOR [6]	DESIGN E_{RI},[7] KSI
0-16	10.2	17.8	106.9	21.7	3.9	0.7	7.6
16-60	7.9	15.4	111.2	19.6	4.2	1.5	1.6(2.0)*

[1]From Equation 5; use midpoint range values from the County Soil Report
[2]From Equation 7; use midpoint range values from the County Soil Report
[3]From Equation 8; use midpoint range values from the County Soil Report
[4]From Equation 6; degree of saturation equals 90 percent since Miami soil series is well-drained; estimate Gs as 2.68
[5]From Equation 9
[6]From Table 3
[7]From Equation 10
*2.0 ksi is the lowest allowable design E_{Ri}

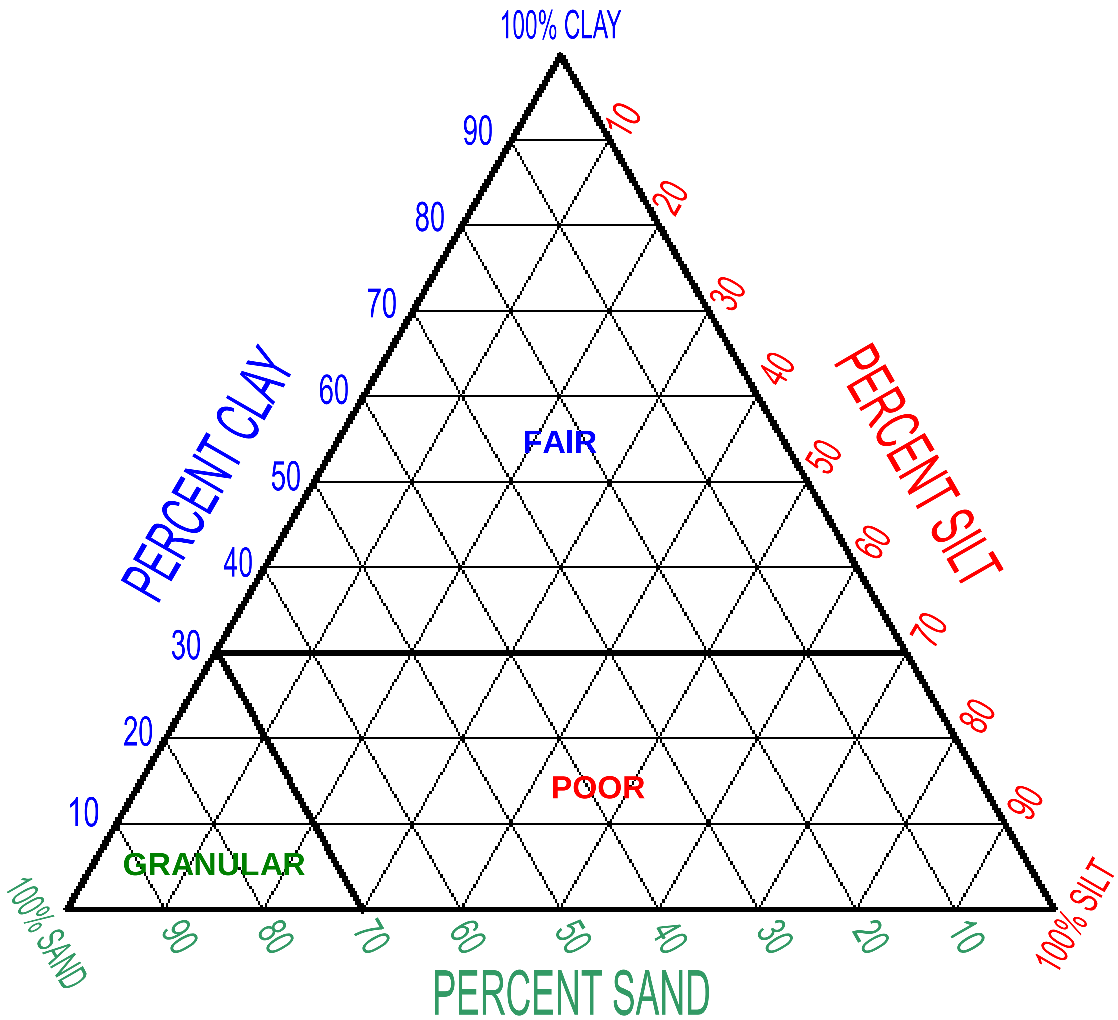
V. TYPICAL E_{Ri} VALUES

From the County Soil Report, the following depth and USDA textural and AASHTO classification data are found. Average E_{Ri} values based on soil classification are shown.

Soil Series	Depth, Inches	USDA Textural Class	AASHTO Class	AVERAGE E_{Ri},ksi (95 % OF AASHTO T-99 MAXIMUM DRY DENSITY AND MOISTURE CONTENTS 2 % WET OF OPTIMUM) A	B	AVERAGE E_{Ri},ksi Springtime Conditions C
Tama*	0-35	Silty Clay Loam	A-7	7.3	6.3	2.0
	35-60	Silty Clay Loam, Silt Loam	A-6	7.3	5.6	2.0

*: Assumes that A horizon has been stripped; remaining material is representative of the B and C horizons.
A: From Table 2, based on USDA textural class
B: From Table 2, based on AASHTO class
C: From Table 1, assuming high water table and frost penetration

Note: Average E_{Ri} values calculated using methods A and B need to be corrected for springtime testing conditions (if necessary) and the composite influence of the soil layers. Average E_{Ri} values calculated with method C reflect springtime testing conditions, but still need to be adjusted to reflect the composite influence of the soil layers.



<u>Particle-Size Limits</u>

Sand	2.000 – 0.075 mm
Silt	0.075 – 0.002 mm
Clay	< 0.002 mm

Figure 1. Subgrade Support Rating (SSR) for Full-Depth Asphalt Concrete and Rigid Pavement Designs

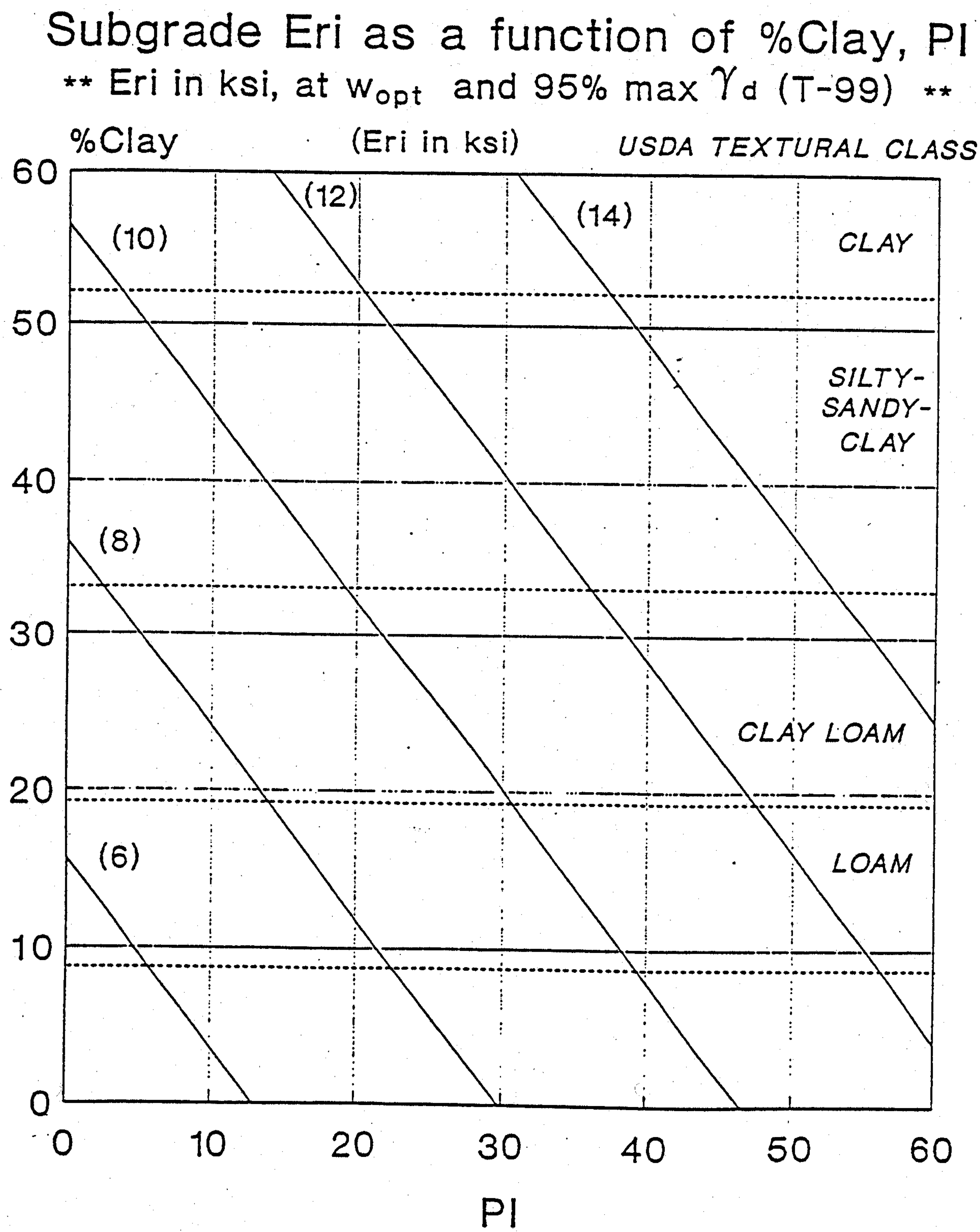


Figure 2: Graphical Solution of E_{Ri} (OPT)

SUBGRADE STABILITY REQUIREMENTS
FOR LOCAL ROADS

INTRODUCTION

This is a condensation of IDOT's Subgrade Stability Manual and has been prepared to give the designer guidance on identifying and treating unsuitable subgrade material. The designer is required to use it for all Class I and II roadways. Its use is optional for all Class III and IV roadways.

Subgrade stability plays a critical role in the construction and performance of a pavement. A pavement's performance is directly related to the physical properties of the roadbed soils as well as the materials used in the pavement structure. Subgrade stability is a function of a soil's strength and its behavior under repeated loading. Both properties significantly influence pavement construction operations and the long-term performance of the subgrade. The subgrade should be sufficiently stable to:

1) Prevent excessive rutting and shoving during construction;

2) Provide good support for placement and compaction of pavement layers;

3) Limit pavement resilient (rebound) deflections to acceptable limits; and

4) Restrict the development of excessive permanent deformation accumulation (rutting) in the subgrade during the service life of the pavement.

While the effect of less satisfactory soils can be reduced by increasing the thickness of the pavement structure, it may be necessary to take other steps to ensure adequate support for the operation of construction equipment and placement and compaction of the pavement layers.

SUBGRADE STABILITY PROCEDURES

Many typical fine-grained Illinois soils do not develop a California Bearing Ratio (CBR) in excess of 6 to 8 when compacted at, or wet of, optimum moisture content. (Note: The Department's Illinois Bearing Ratio (IBR) is considered equal to CBR.) Thus the designer must use one of the three remedial procedures listed below when the insitu soil does not develop a CBR in excess of 6 to 8:

1) Undercut and backfill;

2) Soil-lime mixture; or

3) Moisture-density control.

NOTE: For pavement design purposes, the insitu CBR prior to the remedial subgrade treatment should be used.

Insitu CBR may be determined by use of a Corps of Engineers hand-held cone penetrometer, or a dynamic cone penetrometer (DCP). Correlations relating Corps of Engineers cone penetrometer and DCP test results to CBR values are summarized in Table 1. The Bureau of Local Roads and Streets can be contacted for additional help in determining a field CBR value.

TABLE 1

Subgrade Strength Relationships

CBR	Corps of Engineers Cone Index, psi [1]	DCP Penetration Rate, in./blow [2]
1	40	4.6
2	80	2.7
3	120	1.9
4	160	1.5
5	200	1.3
6	240	1.1
7	280	1.0
8	320	0.9
9	360	0.8

1. $\text{CBR} = \dfrac{\text{Cone Index, psi}}{40}$

2. LOG CBR = 0.84 - 1.26 LOG (Penetration Rate, in./blow)

I. Undercut and Backfill

Undercut and backfill involves removing the soft subgrade to a predetermined depth below the gradeline and replacing it with granular material. This option is appropriate for localized area base repairs as well as for new construction. The granular material helps distribute the load over the unstable subgrade and serves as a working platform for construction equipment. The required removal and backfill depth can be determined from Figure 1. The use of granular material with good shear strength is recommended. Factors that increase shear strength of a granular material are:

1. Using crushed materials;
2. Increasing top size;
3. Using well-graded materials (as opposed to one-size gradations);
4. Reducing PI of fines; and
5. Lowering fine content.

A geotextile may be used between the subgrade and the granular material to keep the subgrade layer separate from the granular layer, thus reducing the required granular thickness. The Bureau of Local Roads and Streets should be contacted for assistance in designing the appropriate granular thickness when geotextiles are used.

II. Soil-Lime Mixture

Unstable subgrades may be treated with a “soil-lime mixture” (LR 302) to improve subgrade stability for new construction or large reconstruction projects. The thickness requirements shown in Figure 1 for granular backfill may also be used to determine the thickness of the soil-lime mixture layer.

If a soil-lime mixture is to be used, it is necessary to perform laboratory tests to determine if the soil is “reacitve” and to determine the percentage of lime necessary for the soil to develop a minimum CBR of 8 to 10.. The designer commonly requires 0.5 percent more lime than the laboratory tests indicate to account for variables in the field.

If the CBR immediately upon completion of the soil-lime mixture is less than 8 to 10, the engineer has the option of allowing the soil-lime-mixture to field cure in an attempt to obtain a CBR of 8 to 10. If a CBR of 8 to 10 is not attainable with a field cure, or if the engineer opts not to wait for a field cure, addition of a granular layer will be required. (Undercutting may be necessary prior to placing the granular layer in cases of grade restrictions.) The thickness of the granular layer and the soil-lime mixture layer can be combined to meet the required thickness shown in Figure 1. The minimum granular layer thickness should be 4 inches. The minimum soil-lime mixture layer should be 10 inches. (Thickness adjustments may be modified to fit field conditions.)

Alternative stabilizing agents such as cement, cement kiln dust, or fly ash may also improve subgrade stability. The effectiveness of these stabilizing agents should be evaluated by analysis of strength and stiffness modifications, curing requirements, thickness requirements, and permanency of treatment. Alternate stabilizing agents must be approved by the Bureau of Local Roads and Streets.

III. Moisture-Density Control

A soil at or wet of its optimum moisture content may not provide adequate subgrade stability when compacted to 95 percent of the standard laboratory density, as required by current IDOT specifications. Moisture controls as well as density controls may be required to ensure the proper compaction necessary to obtain a stable subgrade. Quantitative values of permissible compaction moisture content can be added to the compaction specifications to accomplish this. Laboratory testing is required to determine appropriate compaction densities and moisture contents.

Draining the grade and drying the top portion of the subgrade by disking or tilling may control excess moisture at the time of construction, but it may be difficult to maintain that moisture condition throughout the pavement's life. This method of remedial treatment is the least permanent of the three discussed.

TREATMENT GUIDELINES

The designer should use the following guidelines to determine which of the three remedial treatments is appropriate.

1. Specific details for each subgrade stability alternative should be determined. The required depth of undercut and backfill, the lime percentage and layer thickness required, and the moisture and density levels required to achieve the needed stability levels should be determined.

2. The alternate procedures should be compared by considering construction variabilities, economics, permanence of treatment, and pavement performance benefits.

3. The best option should be selected.

More detailed information regarding subgrade stability requirements for local agency pavement design are detailed in the Department's Subgrade Stability Manual. The designer is referred to this manual for additional information.

SUBGRADE STABILITY EXAMPLE

Determine the subgrade treatment alternatives for a soil having an insitu CBR of 4.

1. Based on Figure 1 and a CBR of 4, remedial procedures are required.

2. The three alternate treatments available are listed below along with specific requirements.

   a. Undercut and Backfill: From Figure 1, 11.5 inches of granular material are required.

   b. Soil-Lime Mixture: Figure 1 shows that 11.5 inches of soil-lime mixture would be required. If the immediate CBR of the soil-lime mixture obtained in the field is less than 8 to 10, the following options are available to the engineer:

      - Field-cure the soil-lime mixture until a CBR of 8 to 10 is achieved or;

      - Full- or partial-depth removal and replacement with granular material. In this case, 10 inches (minimum thickness) of soil-lime mixture and 4 inches (minimum thickness) of granular material would be suitable.

   c. Moisture-Density Control: Moisture and density specifications can be added to the contract documents to control compactive efforts, thus assisting in obtaining a stable subgrade. Laboratory testing can determine the appropriate compaction densities and moisture contents. Disking or tilling may be necessary to control excess moisture.

After comparing these three options, the best option should be selected and specified in the project plans. The designer should still use the insitu CBR for pavement design purposes rather than the CBR after remedial treatment.

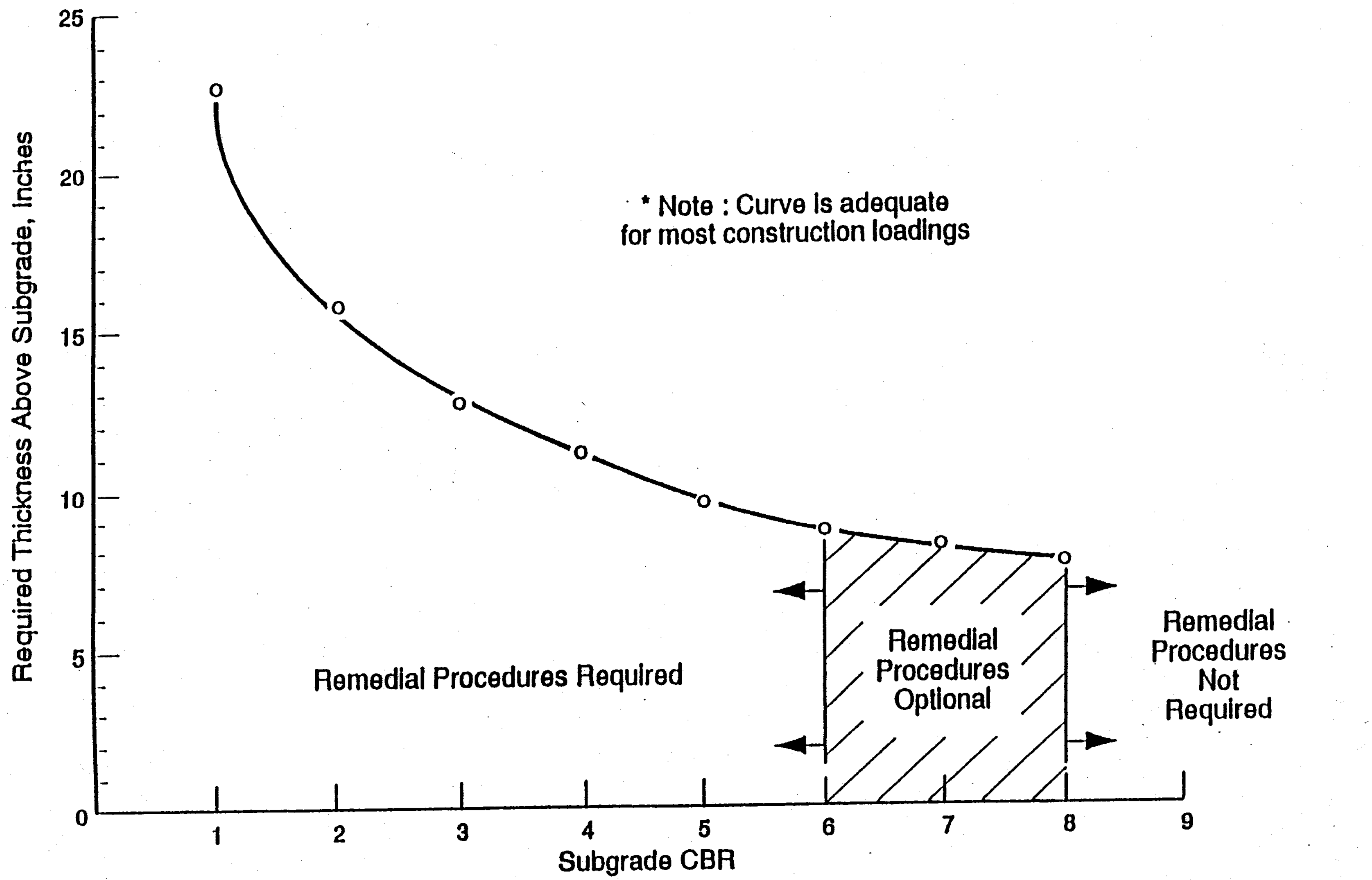


Figure 1: CBR-Based Thickness Design for Undercut and Backfill and Lime-Modified Soil Remedial Procedures

Bureau of Local Roads and Streets
DEFINITION OF TERMS
For Pavement Design

Base Course - The layer used in a pavement system to reinforce and protect the subgrade or subbase.

Bituminous Concrete - A mixture consisting of course and fine mineral aggregate uniformly coated with asphalt cement. Used as a base, surface or binder course.

Bituminous Concrete Design Mix Temperature - Design temperature of bituminous concrete mixture in the pavement based on its geographical location.

Bituminous Concrete Design Modulus (E_{AC}) - The bituminous concrete mixture modulus (E_{AC}) in the pavement corresponding to the “Design Pavement Bituminous Concrete Mixture Temperature”.

Bituminous Concrete Design Strain - Bituminous concrete design tensile strain at the bottom of the bituminous concrete pavement layer.

Class I Roads and Streets- Facilities with four or more lanes, and one-way streets with a structural design traffic greater than 3500 ADT.

Class II Roads and Streets - Two- or three-lane streets with a structural design traffic greater than 2000 ADT and all one-way streets with a structural design traffic less than 3500 ADT.

Class III Roads and Streets - Roads and streets with structural design traffic between 400 and 2000 ADT.

Class IV Roads and Streets - Roads and streets with structural design traffic less than 400 ADT.

Composite Pavement - A pavement structure consisting of bituminous concrete surface course overlaying a Portland Cement concrete slab of relatively high bending resistance which serves as the principle load distributing component.

Continuously Reinforced Concrete Pavement - A rigid pavement having continuous longitudinal reinforcement being achieved by lapping the steel reinforcement.

Conventional Flexible Pavement - A conventional flexible pavement is a Class I or Class B bituminous concrete plant mix surface course and a combination of aggregate base and granular or lime-treated subbase layers.

Design E_{ri} - Resilient modulus is the repeated deviator stress divided by the recoverable (resilient) strain. For the fine-grained subgrade soils that predominate in Illinois, E_{ri} is the resilient modulus for a repeated deviator-stress of approximately 6 ksi.

Design Period (D.P.) - The number of years that a pavement is to carry a specific traffic volume and retain a minimum level of service.

Equivalent Single Axle Loads (ESAL's) - A numeric factor that expresses the relationship of a given axle load in terms of an 18-kip single axle load.

Extended Lane - A monolithic paved lane, typically two feet wider than the marked pavement riding surface, used to reduce pavement edge stresses. Lanes built with integral curb and gutter may be considered extended lanes and designed as such.

Heavy Commercial Vehicles (HCV's) - The combination of single- and multiple-unit vehicles (S.U.'s + M.U.'s). Typically account for the majority of the 18-kip ESAL applications to the design lane anticipated during the design period.

Hinge Joint - A sawed and sealed joint which is held closed by deformed reinforcing bars and intended to prevent mid-panel cracks with a maintainable joint.

Illinois Bearing Ratio (**IBR)** - A measure of the support provided by the roadbed soils or by unbound granular materials. The IBR test procedure is a slight modification of the CBR (California Bearing Ratio) procedure.

Integral Curb & Gutter - A curb and gutter which is paved monolithically with the pavement. Used to reduce edge stresses and provide a means of surface drainage.

Multiple Units (MU) - Truck tractor semi-trailers, full trailer combination vehicles, and other combinations of a similar nature.

Overloads - Loads that are anticipated to exceed the load limits from which the design T.F.'s were developed**.** Typical, overloads are created from commercial, garbage, construction, and farm trucks, permit loads, as well as buses and some farm implements.

Passenger Vehicles (PV) - Automobiles, pickup trucks, vans and other similar two-axle, four-tire vehicles.

Pavement Structure - The combination of subbase, base course and surface course placed on a subgrade to support the traffic loads and distribute the load to the roadbed.

Random Joints - Transverse joint spacing which is randomized to prevent resonant responses in vehicles. When randomized joint spacing is used, spacings of 9-, 11-, 13-, and 15-feet are recommended.

Reliability - The reliability of a pavement design-performance process is the probability that a pavement section designed using the process will perform satisfactorily for the anticipated traffic and environmental conditions for the design period.

Pavement design reliability is incorporated through traffic multipliers. If the traffic factor (T.F.) is 1.0 for the design period of the pavement, designing the pavement for a T.F. of 2.0 would provide a medium level (70's and 80's when expressed as a percentage) of reliability that the pavement would sustain a T.F. of 1.0 without failure.

Factors such as materials, subgrade, traffic prediction accuracy, construction methods and environmental uncertainties impact the design reliability.

The traffic multipliers and corresponding design reliability levels for the pavement design procedures are listed below.

Traffic Multiplier	Reliability, (percent)	Pavement Type
1	50 (Average)	• Conventional Flexible, Class B Mix • Surface Treatments
2	70's - 80's (Medium)	• Conventional Flexible, Class I Mix • Composite, Class III and IV Roads • Rigid, Class III and IV Roads • Full-Depth Bituminous Concrete, T.F. $\leq$ 0.5
$\geq$3	90's (High)	• Composite, Class III and IV Roads • Rigid, Class I and II Roads • Full-Depth Bituminous Concrete, T.F. > 0.5

Single Units (SU) - Trucks and buses having either two axles with six tires or three axles.

Skewed Joints - Transverse joints which are not constructed perpendicular to the centerline of pavement. The skewing should be such that wheel loads of each axle cross the joint one at a time. The obtuse angle at the outside pavement edge should be ahead of the joint in the direction of traffic.

Soil-lime Subgrade - A subgrade which contains a "reactive" soil in which lime and water have been mixed to obtain a strength gain. The Local Roads special provision entitled "soil-lime treated subgrade" should be used in lieu of the "lime-modified soils" section of the Standard Specifications for Road and Bridge Construction

Stage Construction - The planned construction of the flexible pavement structure in two or more phases. A time period of up to two years may elapse between the completion of the first stage and the scheduled construction date of the final stage.

Structural Design Traffic - The average daily traffic (ADT) estimated for the year representing one-half the design period from the year of construction.

Subbase - The layer used in the pavement system between the subgrade and the base course.

Subgrade - The prepared and compacted soil immediately below the pavement system and extending to such depth as will affect the structural design.

Subgrade Support Rating - Rating of subgrade support used in the pavement design. There are three ratings: "poor", "fair" and "granular". These ratings are based on the silt, sand and clay contents of the subgrade.

Surface Course - One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer is sometimes called "wearing course".

Tied Curb & Gutter - A PCC curb and gutter which is tied with reinforcing steel to the pavement such that some of the pavement load is transferred to the curb and gutter. Used to reduce pavement edge stresses and provide a means of surface drainage. In order to be considered a “tied curb and gutter” and to receive a pavement thickness adjustment for “tied shoulders”, a number 6 or larger reinforcement bar must be used to tie the pavement to the curb and gutter.

Tied Shoulder - A PCC stabilized shoulder tied with reinforcing steel to the pavement such that some of the pavement load is transferred to the shoulder. Used to reduce pavement edge stresses. In order to be considered a “tied curb and gutter” and to receive a pavement thickness adjustment for “tied shoulders”, a number 6 or larger reinforcement bars must be used to tie the pavement to the PCC shoulder.

Traffic Factor (T.F.) - The total number of 18 kip equivalent single axle load applications to the design lane anticipated during the design period, expressed in millions.

Untied Shoulder - Any shoulder which does not provide edge support. The shoulder may consist of earth, aggregate or bituminous stabilized materials. (Shoulders that are tied with number 5 or smaller reinforcing steel may be considered untied for purposes of determining pavement thickness.)