Chapter Forty-four

PAVEMENT DESIGN

BUREAU OF LOCAL ROADS AND STREETS MANUAL

Chapter Forty-four
PAVEMENT DESIGN

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44-1   GENERAL

44-1.01   Pavement Design Definitions

1.   Average Daily Traffic (ADT). The total volume during a given time period (in whole days), greater than one day and less than one year, divided by the number of days in that time period.

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

3.   Binder. The asphalt cement used in HMA pavements specified according to the Superpave Performance Graded system.

4.   Class I Roads and Streets. Facilities with 4 or more lanes and one-way streets with a structural design traffic greater than 3500 ADT.

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

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

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

8.   Composite Pavement.   A pavement structure consisting of HMA surface course overlaying a PCC slab of relatively high bending resistance which serves as the principle load-distributing component.

9.   Continuously Reinforced Concrete Pavement.   A rigid pavement structure having continuous longitudinal reinforcement achieved by overlapping the longitudinal steel reinforcement.

10.   Conventional Flexible Pavement.   A flexible pavement structure consisting of a HMA surface course and a combination of aggregate base, and granular subbase or modified soil layers.

11.   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.

12.   Design Lane. The traffic lane carrying the greatest number of single and multiple vehicular units.

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

14.   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.

15.   Extended Lane. A monolithic paved lane, typically 2 ft wider than the marked pavement riding surface, used to reduce PCC pavement edge stresses. Lanes built with integral curb and gutter may be considered extended lanes and designed as such.

16.   Heavy Commercial Vehicles (HCV's). The combination of single and multiple unit vehicles (SU's + MU's). These typically account for the majority of the 18 kip ESAL applications to the design lane anticipated during the design period.

17.   HMA Design Mixture Temperature. Design temperature of HMA mixture in the pavement based on its geographical location.

18.   HMA Design Modulus (E_{AC}). The HMA mixture modulus (E_{AC}) in the pavement corresponding to the "HMA Design Mixture Temperature".

19.   HMA Design Strain. HMA design tensile strain at the bottom of the HMA pavement layer.

20.   Hot Mix Asphalt (HMA). A mixture consisting of coarse and fine mineral aggregate uniformly coated with asphalt binder. Used as a base, surface, or binder course.

21.   Immediate Bearing Value (IBV). A measure of the support provided by the roadbed soils or by unbound granular materials. The field IBV is obtained from the Dynamic Cone Penetrometer (DCP) test, or in the lab from a penetration test (according to AASHTO T193) on a 4 in diameter, molded sample, immediately after compaction.

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

23.   Modified Soil Layer. A subgrade soil layer treated with a modifier such as lime, fly ash, Portland cement, or slag-modified cement, and constructed according to the BDE Special Provision for Soil Modification.

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

25.   Overloads. Loads that are anticipated to exceed the load limits from which the design TF's were developed. Typically, overloads are created from commercial, garbage, construction, and farm trucks; permit loads; buses; and some farm implements.

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

27.   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.

28.   Random Joints. Transverse joint spacing that is randomized to prevent resonant responses in vehicles. Designers must request a written variance from Central BLRS in order to use randomized transverse joint spacing.

29.   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. The following factors may impact the design reliability: materials; subgrade; traffic prediction accuracy; construction methods; and environmental uncertainties.

30.   Single Units (SU). Trucks and buses having either 2 axles with 6 tires or 3 axles.

31.   Skewed Joints. Transverse joints that are not constructed perpendicular to the centerline of pavement. The use of skewed joints is not encouraged.

32.   Stage Construction. The planned construction of the flexible pavement structure in 2 or more phases. A time period of up to 2 years may elapse between the completion of the first stage and the scheduled construction date of the final stage.

33.   Structural Design Traffic. The ADT estimated for the year representing one-half the design period from the year of construction.

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

35.   Subgrade. The prepared and compacted soil immediately below the pavement system and extending to a depth that will affect the structural design.

36.   Subgrade Support Rating. Rating of subgrade support used in full-depth HMA, rigid, and composite pavement designs. There are three ratings — poor, fair, and granular. These ratings are based on the silt, sand, and clay contents of the subgrade.

37.   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. This layer is sometimes called the wearing course.

38.   Three Times Nominal Maximum Aggregate Size.

39.   Tied Curb and Gutter. A PCC curb and gutter that is tied with reinforcing steel to the pavement so 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 curb and gutter, use a No. 6 or larger reinforcement bar to tie the pavement to the curb and gutter.

40.   Tied Shoulder. A PCC stabilized shoulder tied with reinforcing steel to the pavement so that some of the pavement load is transferred to the shoulder. Used to reduce pavement edge stresses. In order to be considered a tied shoulder and to receive the pavement thickness adjustment for tied shoulders, use a No. 6 or larger reinforcement bars to tie the pavement to the PCC shoulder.

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

42.   Untied Shoulder. Any shoulder that does not provide edge support. The shoulder may consist of earth, aggregate, or bituminous stabilized materials. PCC shoulders that are tied with No. 5 or smaller reinforcing steel are considered untied for purposes of determining pavement thickness.

44-1.02   Minimum HMA Lift Thickness

All HMA surface, binder, and leveling binder lifts must comply with the lift thicknesses in Figure 44-1A.

Mixture Superpave	Typical Use[1]	Leveling Course Minimum Lift Thickness [2][3], in (mm)	Surface/Binder Course Minimum Lift Thickness [2], in (mm)
IL-4.75	B/L	3/8 (10)	3/4 (19)
IL-9.5	S/B/L	3/4 (19) [5]	1 1/4 (29)
IL-12.5	S/B/L	1 1/4 (32)	1 1/2 (38)
IL-19.0 [4]	B/L	1 3/4 (44)	2 1/4 (57)
IL-25.0 [4]	B	Not Allowed	3 (76)

Notes: 1.   *S = Surface; B = Binder; L = Leveling Binder*
                       Minimum thicknesses are the nominal thickness of the lift.
                       If the leveling course is placed at or above the minimum thickness specified for surface/binder course, density will be required.
                       This mix may not be used as a surface lift.
                       If the IL-9.5mm leveling binder is being placed over crack and joint sealant, the minimum lift thickness may be 1/2 in (13 mm).

HMA SURFACE, BINDER, AND LEVELING BINDER LIFT THICKNESSES

Figure 44-1A

44-1.03   Skid Resistance on HMA Surface Courses

Aggregates with suitable friction shall be specified for all HMA surface courses on federal-aid projects and local projects on the state letting. Figure 44-1B lists four surface course mixtures that have been developed to provide adequate skid resistance for various Average Daily Traffic (ADT) levels and number of lanes.

Number of Lanes	Frictional Requirements (ADT)			
	Mixture C	Mixture D	Mixture E	Mixture F
≤ 2	≤ 5,000	> 5,000	N/A	N/A
4	≤ 5,000	5,001 to 25,000	25,001 to 100,000	> 100,000
≥ 6	N/A	5,001 to 60,000	60,001 to 100,000	> 100,000

Note: ADT levels are for the expected year of construction.

FRICTIONAL REQUIREMENTS FOR SURFACE MIXES

Figure 44-1B

Designers should consider using the appropriate friction aggregate on projects funded by other sources and on a local letting

44-1.04   Density Testing on HMA Pavements

As the final measure of quality during construction, density is the most critical characteristic of HMA pavements to achieve durability, minimize permeability, and enhance long term resistance to raveling. The department's Manual of Test Procedures for Materials provides the *Standard Test Method for Correlating Nuclear Gauge Densities with Core Densities.* However, a correlated gauge is not always practical. Therefore, for HMA projects designed using Section 46-2 of this manual or for less than 3,000 tons of a given HMA mixture, a nuclear-core correlation for determining density is not required. One of the following alternative methods may be used:

- Core Density Testing (Preferred Alternative);

- Growth Curve (LR1030 is required to be used); or

- Non-correlated Nuclear Gauge Testing.

44-1.05   Accessibility Requirements

All pavements constructed shall meet the accessibility requirements in Section 41-6 of this manual.

44-1.06   Selection of Pavement Type

The local agency must specify pavement type on the design plans; however, for MFT funded projects, "alternative" or "type" bids may be used according to Section 12-1.03. Figure 44-1C provides a decision tree flow chart as a guide for the design of pavements.

The 1993 *AASHTO Guide for Design of Pavement Structures* lists a number of principal and secondary factors that may play a role in the pavement selection process. Some of these include the following:

1.   Principal Factors. These include traffic, soil characteristics, weather, construction considerations, recycling, and cost comparison.

2.   Secondary Factors. Secondary factors may include performance of similar pavement in the area, adjacent existing pavements, conservation of materials and energy, availability of local materials or contractor capabilities, traffic safety, incorporation of experimental features, stimulation of competition, and local agency preference.

START

Special Design? (See Note 1)

YES → Contact Central Bureau of Local Roads & Streets

NO

New Construction/ Reconstruction?

YES → Chapter 44 Pavement Design

NO

Chapter 46 Pavement Rehabilitation

- Structural Overlay
- Functional Overlay
- PCC Inlay/Overlay
- In-Place Recycling
- Rubblization

Rigid, Composite, Flexible? (Note 2)

RIGID

Traffic Factor > 35

YES → BDE Manual: Chapter 54 Continuously Reinforced Concrete (CRC) Pavement

NO → Chapter 44-2 Rigid Pavement Design → Small Quantity? (Note 3)

- Minimum Materials: Class PV Concrete; HMA Surface and Binder Courses; and Type A Granular Subbase
- 20 ft Traverse Joint Spacing
- Stabilized Subbase Not Required with Curb & Gutter Pavement; or on Class III and IV Roads & Streets with TF < 0.7
- Min. Design Thickness: 2.0 in. HMA & 6.5 in. PCC, or 3.0 in. HMA & 6.0 in. PCC
- Dowel Bars Required, TF ≥ 3.0

- Minimum Materials: Class PV Concrete and Type A Granular Subbase
- Traverse Joint Spacing: Min - 10 ft; Max - 15ft
- Stabilized Subbase Not Required with Curb & Gutter Pavement; or on Class III and IV Roads & Streets with TF < 0.7
- Min. Design Thickness ≥ 6.5 in.
- Dowel Bars Required, TF ≥ 3.0

All Pavement Types:
- Design assuming poor subgrade support rating

Rigid or Composite Pavement:
- Duplicate existing pavement structure
- Provide structurally equivalent pavement

Full Depth HMA Pavement:
- Minimum thickness 6.0 in.

Constructed Adjacent to Existing Pavement? (Note 3)

NO → Design Not Required (Note 4)

COMPOSITE → Chapter 44-5 Composite Pavement Design → Small Quantity? (Note 3)

- Minimum Materials: HMA Surface and Binder Courses
- Modified Soil Layer/ Granular Subgrade Not Required on Class III and IV Roads & Streets with suitable subgrade support
- Min. Design Thickness ≥ 6.0 in.

FLEXIBLE

Traffic Factor > 0.25?

YES → Chapter 44-4 Full-Depth HMA Pavement Design → Small Quantity? (Note 3)

NO

DESIGNER OPTION

Chapter 44-3 Conventional Flexible Pavement Design

- Minimum Materials: HMA Surface and Binder Courses Type A Aggregate Base
- Stabilized Subgrade Not Required if Subgrade Modulus (E_{Ri}) ≥ 2 ksi
- Min. Design Thickness: 3 in. HMA & 8 in. Aggregate Base

NOTES:

1. Special designs include, but are not limited to, the following:
   - designs involving whitetopping;
   - designs involving high-stress locations;
   - designs involving the need to accommodate heavily loaded vehicles traveling in one direction;
   - designs involving the need to match existing pavement structure; and
   - designs involving policy exceptions or less than minimum criteria.

2. Selection of the appropriate pavement type is a designer option. Selection should be based on the criteria in Section 37-1.02.

3. Small quantities are defined as follows:
   - less than 1 city block length;
   - less than 3000 yd²; or
   - widening less than 1 lane-width.

4. Must meet minimum design requirements for the pavement type

44-2 RIGID PAVEMENT DESIGN FOR LOCAL AGENCIES

44-2.01 Introduction

44-2.01(a) Types of Rigid Pavements

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

1. Non-Reinforced Jointed. Jointed pavement without steel reinforcement that may or may not use mechanical load transfer devices (e.g., dowel bars).

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

The non-reinforced jointed pavement design procedure is discussed in this Section. Chapter 54 of the *BDE Manual* provides the design procedures for continuously reinforced concrete pavements.

44-2.01(b) Usage of Procedure

Use the pavement design procedures provided in Section 44-2 for all local road and street projects where 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 1 city block in length,

- less than 3000 yd^2, or

- widening less than 1 lane-width.

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

- duplicate the existing total pavement structure,

- provide a structurally equivalent pavement, or

- design assuming a poor subgrade support rating.

44-2.02   Basic Design Elements

44-2.02(a)   Minimum Material Requirements

The minimum requirement for Portland cement concrete is Class PV concrete, as specified in the *IDOT Standard Specifications.* Use Type A granular subbase, according to the *IDOT Standard Specifications*, where granular subbase is specified.

44-2.02(b)   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. These road classifications are defined in Section 44-1.

44-2.02(c)   Design Period

The design period (DP) 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 minimum design period is 20 years.

44-2.02(d)   Structural Design Traffic

The structural design traffic is the estimated 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 10 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 SU and MU counts are not available for Class III and IV roads and streets, an estimate of those counts may be made from the component percentages of the total traffic in Figure 44-2A.

Class of Road or Street	Percentage of Structural Design Traffic		
	PV (%)	SU (%)	MU (%)
III	88	7	5
IV	88	9	3

TRAFFIC PERCENTAGE
(Class III and IV)

Figure 44-2A

44-2.02(e)   Traffic Factors

For Class I, II, and III roads and streets, the design Traffic Factor (TF) for rigid pavements is determined from the 80,000 lb load limit formulas shown in Figures 44-2B. The formulas are based on the state wide 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 (e.g. 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). These cases should be referred to the Central BLRS for special analysis. The local agency must provide the Central BLRS with the structural design traffic; the design period; traffic distribution by PV, SU, and MU; and loading distribution of HCV traffic.

For Class IV rigid pavements, thicknesses are provided in Section 44-2.03(b) based on the daily volume of HCV's; therefore, a design TF is not necessary.

For TF greater than 10.0, the designer should follow the rigid pavement mechanistic design procedure outlined in Chapter 54 of the *IDOT BDE Manual.* Contact the Central BLRS for additional information.

Class I Roads and Streets	
4 or 5 Lane Pavements (Rural and Urban)	$TF = DP \left[\dfrac{(0.047PV + 64.715SU + 313.389MU)}{1,000,000} \right]$
6 or More Lane Pavements (Rural)	$TF = DP \left[\dfrac{(0.029PV + 57.524SU + 278.568MU)}{1,000,000} \right]$
6 or More Lane Pavements (Urban)	$TF = DP \left[\dfrac{(0.012PV + 53.210SU + 257.675MU)}{1,000,000} \right]$
One-way Street Pavements (Rural and Urban)	$TF = DP \left[\dfrac{(0.073PV + 71.905SU + 348.210MU)}{1,000,000} \right]$
Class II Roads and Streets	
2 or 3 Lane Pavements	$TF = DP \left[\dfrac{(0.073PV + 67.890SU + 283.605MU)}{1,000,000} \right]$
Class III Roads and Streets	
2 or 3 Lane Pavements	$TF = DP \left[\dfrac{(0.073PV + 64.790SU + 281.235MU)}{1,000,000} \right]$ TF minimum = 0.5

TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)
Figure 44-2B

44-2.02(f)   Transverse Pavement Joints

For Class I, II, and III pavements, thickness design curves are given for transverse joint spacings of 12.5 ft and 15 ft (Figures 44-2C and 44-2D). Pavement thickness for each of these 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 are given in Figure 44-2E.

Joint spacings in excess of 15 ft or less than 10 ft require a design variance from the Central BLRS. The Central BLRS will provide the thickness designs for pavements granted for these variances.

A number of factors must be carefully considered when selecting transverse joint spacing. 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. In urban areas where there is a higher concentration of pavement discontinuities (e.g., manholes, storm sewer outlets, traffic detector loops), longer joint spacing can be less forgiving, leading to cracking between joints. However, shorter joint spacing can result in unstable slabs that may rock and pump under repeated loadings. Shorter joint spacing also results in more joints, thereby increasing the expense of joint maintenance over the life of the pavement. In no case is a slab length less than 6 ft recommended except as provided in Section 46-5.

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 (e.g., dowel bars) are required on pavements that have a design TF of 3.0 or greater. For pavements with a TF less than 3.0, the designer has the option of using dowel bars or relying on aggregate interlock for load transfer. Shorter joint spacing is recommended when dowel bars are not used.

Designers desiring use of a randomized transverse joint spacing must request a written variance from the Central BLRS. The maximum transverse joint spacing allowed will be 15 ft.

The use of skewed transverse joints is not encouraged. Failure of the portion of the slab where the skewed joint forms an acute angle with the longitudinal joint has been a common occurrence nationwide, and has proven a difficult failure to patch and maintain. Designers desiring use of skewed joints must request a written variance from the Central BLRS.
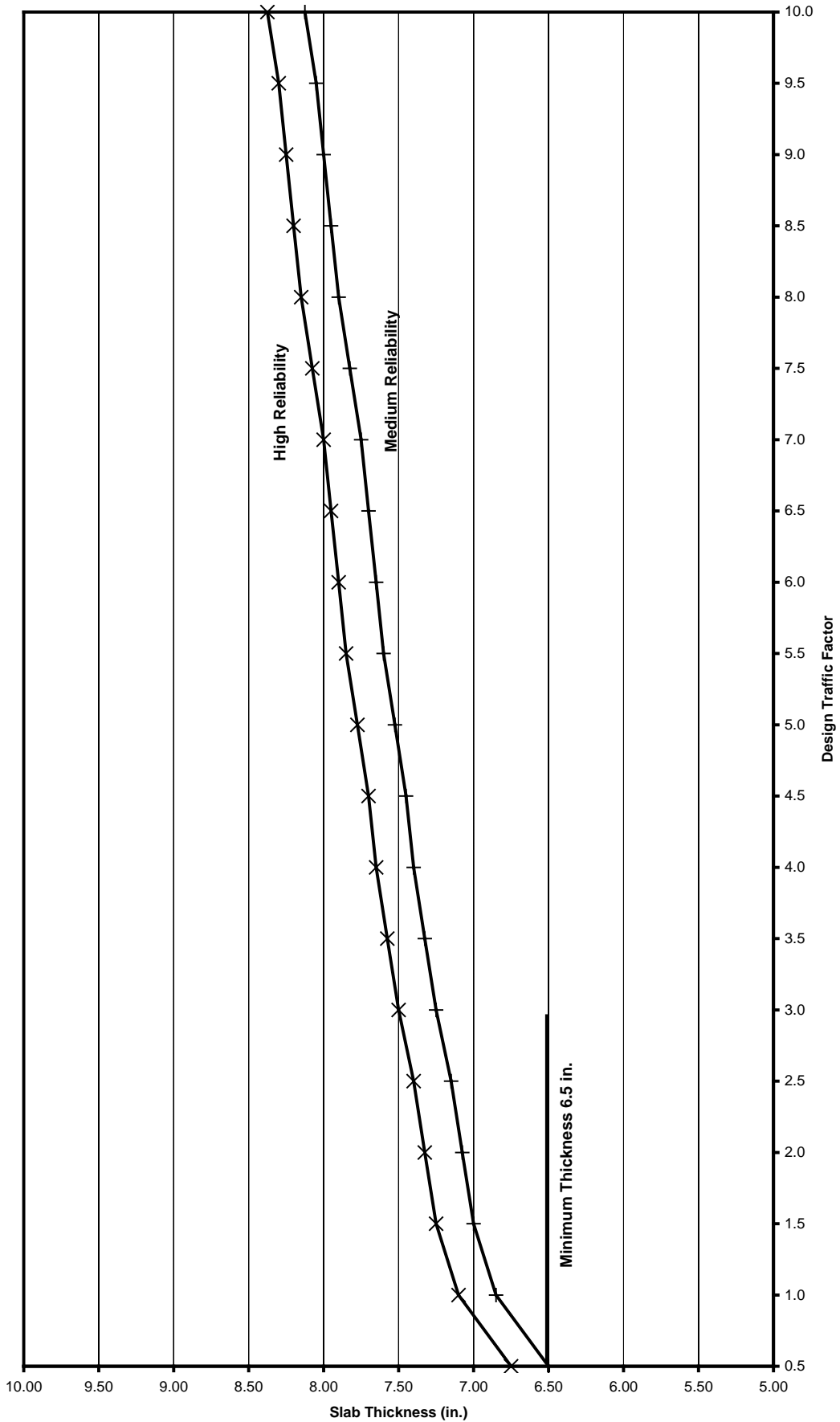
SLAB THICKNESS
(12.5 ft Transverse Joint Spacing; Fair Subgrade)

Figure 44-2C
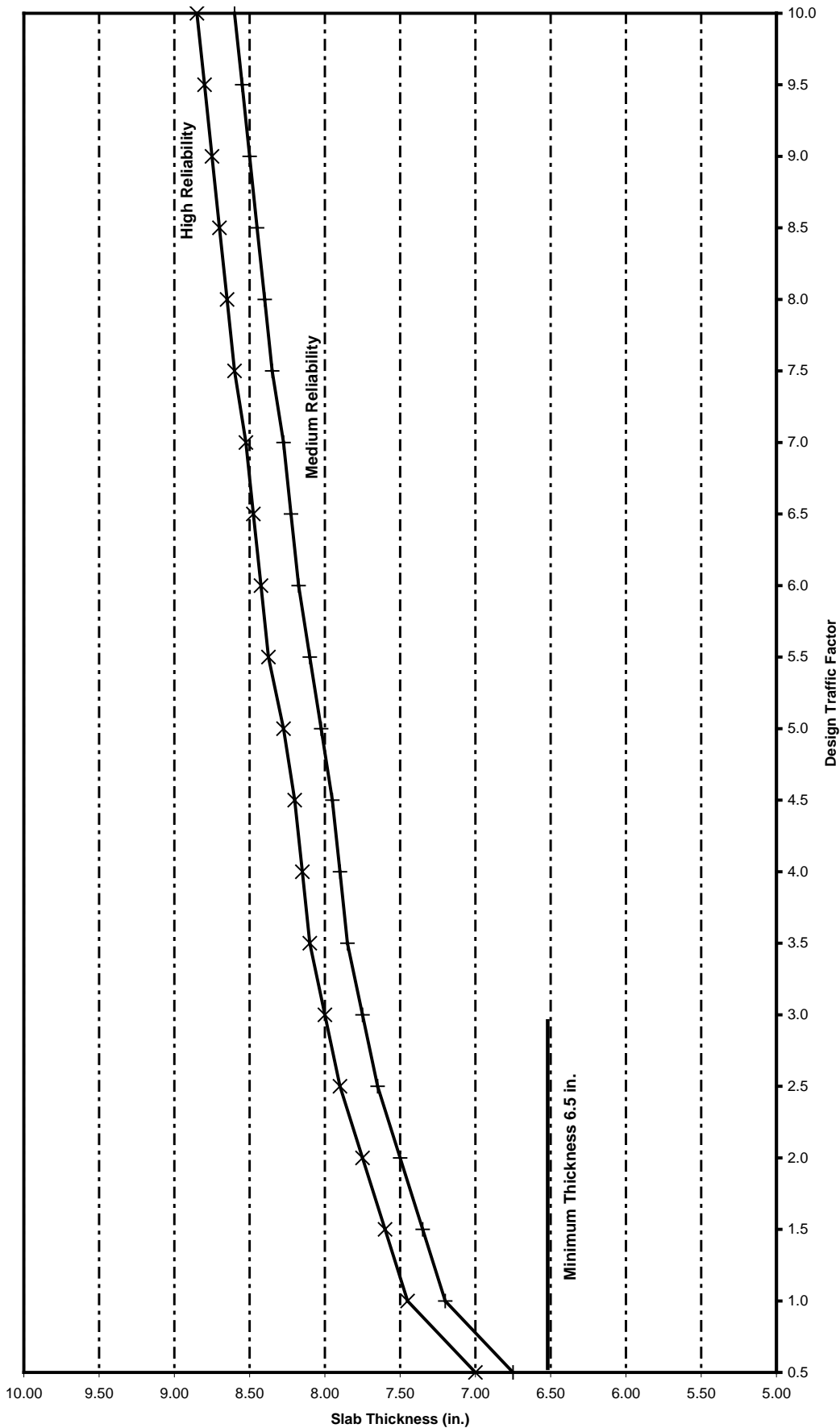
SLAB THICKNESS
(15 ft Transverse Joint Spacing; Fair Subgrade)

Figure 44-2D

Slab Thickness (in)	Maximum Transverse Joint Spacing (ft)
< 8.0	12.5*
≥ 8.0	15.0

* Appropriate for all Class IV pavements.

MAXIMUM TRANSVERSE JOINT SPACING

Figure 44-2E

44-2.02(g)   Longitudinal Pavement Joints

Longitudinal joints run parallel to the pavement length and serve the dual function of separating the pavement into travel lanes and controlling longitudinal cracking. Longitudinal joints may be formed by sawing the slab early in the curing process to form a neat joint before the natural cracking occurs or by limiting the width of the slab being placed. Due to the difficulties of constructing good-performing keyed longitudinal joints, their use is not recommended. Tied longitudinal construction joints should be used in lieu of keyed longitudinal joints.

Typical BLRS practice requires the use of a deformed tie bar at all longitudinal joints. The basic purposes of tying the longitudinal joint are to provide load transfer and prevent lane separation. However, for pavement cross-sections greater than 60 ft wide, including turn lanes, shoulders, and medians, tying the entire width together may promote longitudinal cracking. For pavement cross sections in excess of 60 ft, use of dowel bars in lieu of deformed tie bars at one or more longitudinal joints may be an option. In situations where curb and gutter is present on both sides of the pavement, the confining pressure exhibited may preclude the need for tie bars across all longitudinal joints. In these cases, one or more longitudinal joints should not be tied as appropriate. Local experience may vary in these situations. If it can be determined that lane separation in pavements of similar thickness and cross section has not been a problem, a variance may be requested. The Central BLRS should be consulted for variances to the use of tie bars across longitudinal joints.

44-2.02(h)   Subgrade

Roadbed soils that are susceptible to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave, and/or non-uniform support can affect pavement performance. For Class I and II roads, the designer is required to follow the guidelines found in Section 44-7. Use of Section 44-7 is optional for all Class III and IV roadways. In situ soils that do not develop an IBV in excess of 6.0 when compacted at, or wet of, optimum moisture content, require corrective action. The designer should consider corrective actions (e.g., undercutting, moisture density control, soil modification) in the design plans and specifications. The county soil report can be a useful source of typical soil information (e.g., standard dry density and optimum moisture content (AAHSTO T99), soil classification, percent clay, PI).

Necessary corrective actions as required by Section 44-7 will be in addition to the subbase requirements of the pavement design.

44-2.02(i)   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 3 subgrade support ratings (SSR) — poor, fair, and granular. The SSR is determined by using geotechnical grain size analysis and Figure 44-6A. The SSR should represent the average or majority classification within the design section. Figure 44-6A 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 44-2C and 44-2D) are based on a SSR of fair. Adjustments in the design thickness need to be made for the poor and granular subgrades.

44-2.02(j)   Subbase

A subbase under a pavement serves two purposes. Initially it provides a stable construction platform for the subsequent 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 given in Figure 44-2F.

When placing a PCC pavement directly over a flexible pavement with a HMA surface, consult Central BLRS for design assistance.

Road Class	Subbase Material	Usage[1]	Minimum Thickness (in)
Class I and II	Stabilized Subbase[2]	Required	4
Class III and IV	Granular[3], TF $\geq$ 0.7 Granular[3], TF < 0.7	Required Optional	4 4

Notes:

1.   Subbase will be optional for urban sections having curbs and gutters and storm sewer systems. A 4 in minimum subbase may be used to serve as a working platform where poor soil conditions exist.

2.   Stabilized subbase according to the requirements of the IDOT Standard Specifications *or any applicable special provision.*

3.   Use Type A granular subbase according to the requirements of the IDOT Standard Specifications*.*

SUBBASE REQUIREMENTS

Figure 44-2F

44-2.02(k)   Design Reliability

Design reliability is taken into account through traffic multipliers applied to the design TF. These traffic multipliers are built into the PCC slab thickness design curves in Figures 44-2C and 44-2D. Figures 44-2C and 44-2D contain curves for both high and medium reliability levels. The minimum reliability levels by class of road are given in Figure 44-2G.

Road Class	Minimum Reliability Levels	Reliability (%)
Class I and II	High	90's
Class III	Medium	70's and 80's
Class IV (Figure 44-2H)	Medium	70's and 80's

RELIABILITY LEVELS

Figure 44-2G

44-2.03   Thickness Design

44-2.03(a)   Minimum Design Thickness

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

44-2.03(b)   Preadjusted Slab Thickness

The jointed pavement thickness design procedure is based on determining the preadjusted slab thickness of the rigid pavement, and then adjusting for shoulder type, subgrade support conditions, and anticipated overloads. 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 44-2C and 44-2D for joint spacing of 12.5 ft and 15 ft. If a specific joint spacing is not desired, evaluate slab thicknesses for both potential joint spacings.

For Class IV PCC pavements, Figure 44-2H provides the preadjusted slab thickness for a 12.5 ft joint spacing. Overloads and poor soil conditions have been taken into consideration when developing these thicknesses; therefore, no further overload adjustment is necessary. Do not reduce the pavement thickness below 6.5 in.

Joint spacings of 15 ft are not provided for Class IV pavements because the thicknesses would be less than 8.0 in; therefore, the maximum recommended joint spacing would be 12.5 ft.

44-2.03(c)   Slab Thickness Adjustments

Adjustments to the preadjusted slab thickness should be made based on the shoulder type, subgrade support, and anticipated overloads. The final design thickness is rounded to the next highest 0.25 in. In determining any adjustments, consider the following:

1.   Shoulder Type. The preadjusted rigid pavement thickness is to be adjusted if the PCC pavement has one of the following shoulder types:

    - tied PCC slab, including tied PCC widening;
    - tied curb and gutter;
    - integral curb and gutter; and/or
    - extended lanes.

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Tied PCC slab, tied curb and gutter, and extended lane shoulder types must be tied with No. 6 tie bars or larger in order to receive the pavement thickness adjustment. A No. 6 or larger bar is needed to ensure 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.

Figure 44-2I provides the slab thickness adjustments that are required if a shoulder type listed above is specified.

2. Subgrade Support. Pavement thickness adjustments are based on the subgrade support and whether the pavement structure will have a subbase or not. Figure 44-2J provides the subgrade support adjustment factors.

3. Overloads. The PCC pavement thickness can be adjusted for the number of anticipated overloads per week by using Figure 44-2L. Overloads are those loads that are anticipated to exceed the load limits from which the design TF's were developed. The rigid pavement design procedure is based on 18 kip ESAL's and 80 psi tire pressure conditions. Typical overloads are created from permit loads and commercial, garbage, construction, and farm trucks, as well as, buses and some farm implements. No overload correction is necessary if the TF is greater than 2.0.

Projects adjacent to an industrial site with HCV's entering and leaving the site should be referred to the Central BLRS for special analysis.

Figure 44-2H has already taken overloads into consideration for Class IV pavements and no further overload adjustment is necessary.

After all necessary adjustments to the preadjusted slab thickness have been made, the designer should round the final design thickness to the next highest 0.25 in. The designer should compare the recommended design thicknesses to Figure 44-2E to determine which joint spacing is allowed.

44-2.03(d)   Dowel Bars

Dowel bars must be used in all pavements with a TF of 3.0 or greater. Dowel bar diameter requirements are given in Figure 44-2K.

44-2.03(e)   Typical Sections

Figures 44-2M, 44-2N, and 44-2O illustrate typical local agency rigid pavement designs.

HCV's/day	Slab Thickness for 12.5 ft Joint Spacing (in)
< 40	6.5 [1]
≥ 40	[2]

Notes: 1.   No reduction in thickness will be allowed.

2.   Use the Class III TF equations or a TF of 0.5, whichever is greater, in conjunction with Figures 44-2C and 44-2D.

CLASS IV PAVEMENT PREADJUSTED SLAB THICKNESS

Figure 44-2H

Slab Thickness (in)	Thickness Adjustment (in)
≥ 8.00	- 0.500
7.50 - 7.99	- 0.375
7.00 - 7.49	- 0.250
6.50 - 6.99	- 0.125

Note: *No thickness adjustment is made for flexible or untied PCC shoulders. The designer should be aware of the potential for frost heave if flexible or untied shoulders are used.*

SHOULDER TYPE ADJUSTMENT FACTORS

Figure 44-2I

SSR	Adjustment with Subbase (in)	Adjustment without Subbase* (in)
Poor	0	+0.25
Fair	-0.25	0
Granular	-0.25	-0.25
Existing pavement	-0.25	-0.25

*   *A subbase is optional for all Class III and IV pavements with a TF < 0.7, and for urban sections having curb and gutter and storm sewer systems.*

SUBGRADE SUPPORT ADJUSTMENT FACTORS

Figure 44-2J

Slab Thickness (in)	Dowel Diameter (in)
> 8.00	1.5
7.00 to 7.99	1.25
< 7.00	1.0

DOWEL BAR DIAMETER REQUIREMENTS

Figure 44-2K
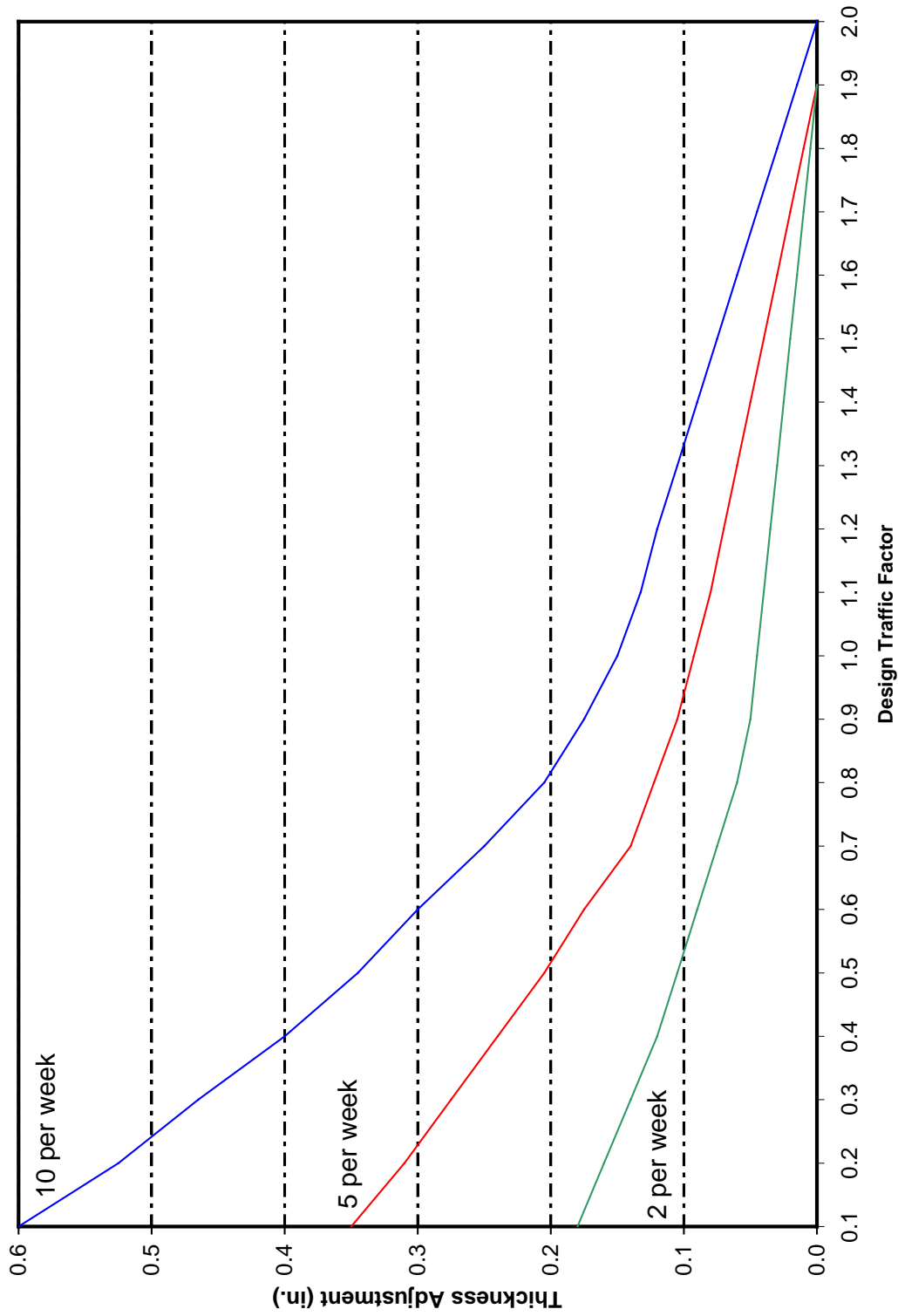
OVERLOAD ADJUSTMENTS
(Number of Vehicles Equivalent to a Heavy Garbage Truck)

Figure 44-2L
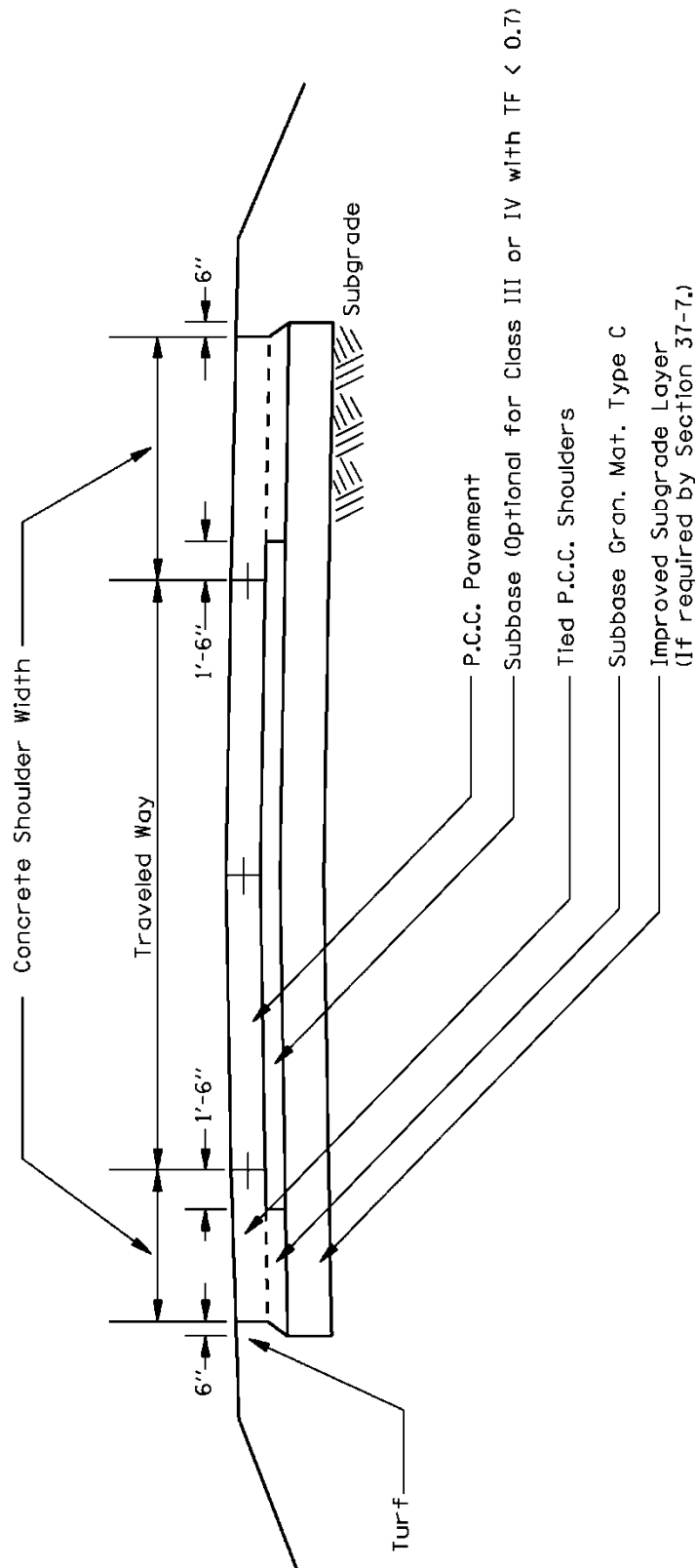
TYPICAL RIGID DESIGN WITH TIED SHOULDERS

Figure 44-2M
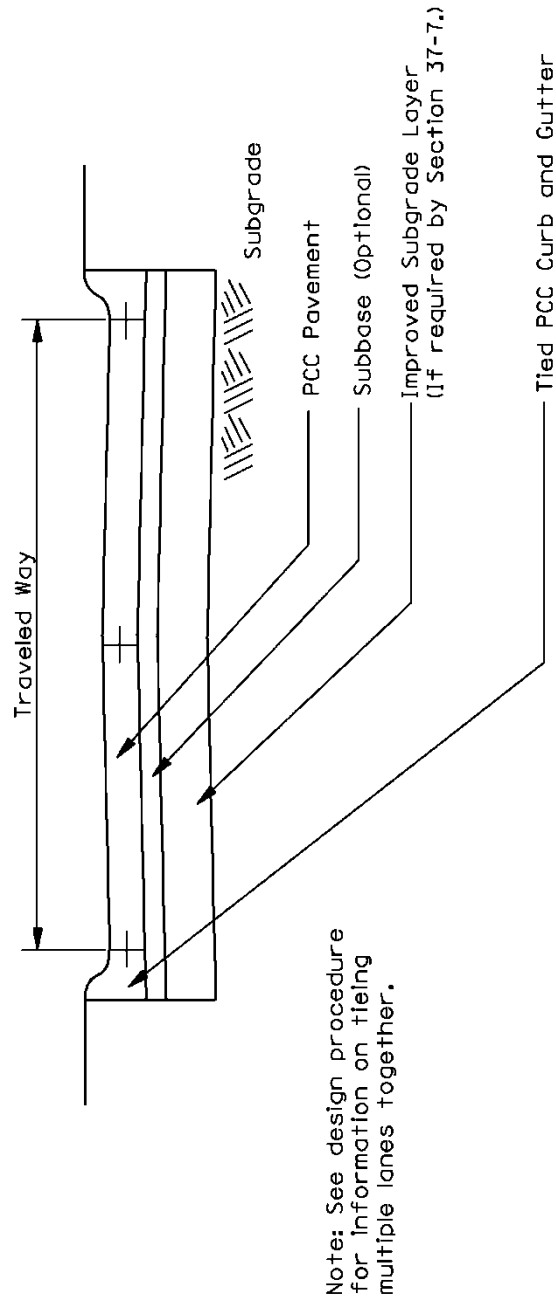
RIGID DESIGN WITH TIED CURB AND GUTTER

Figure 44-2N
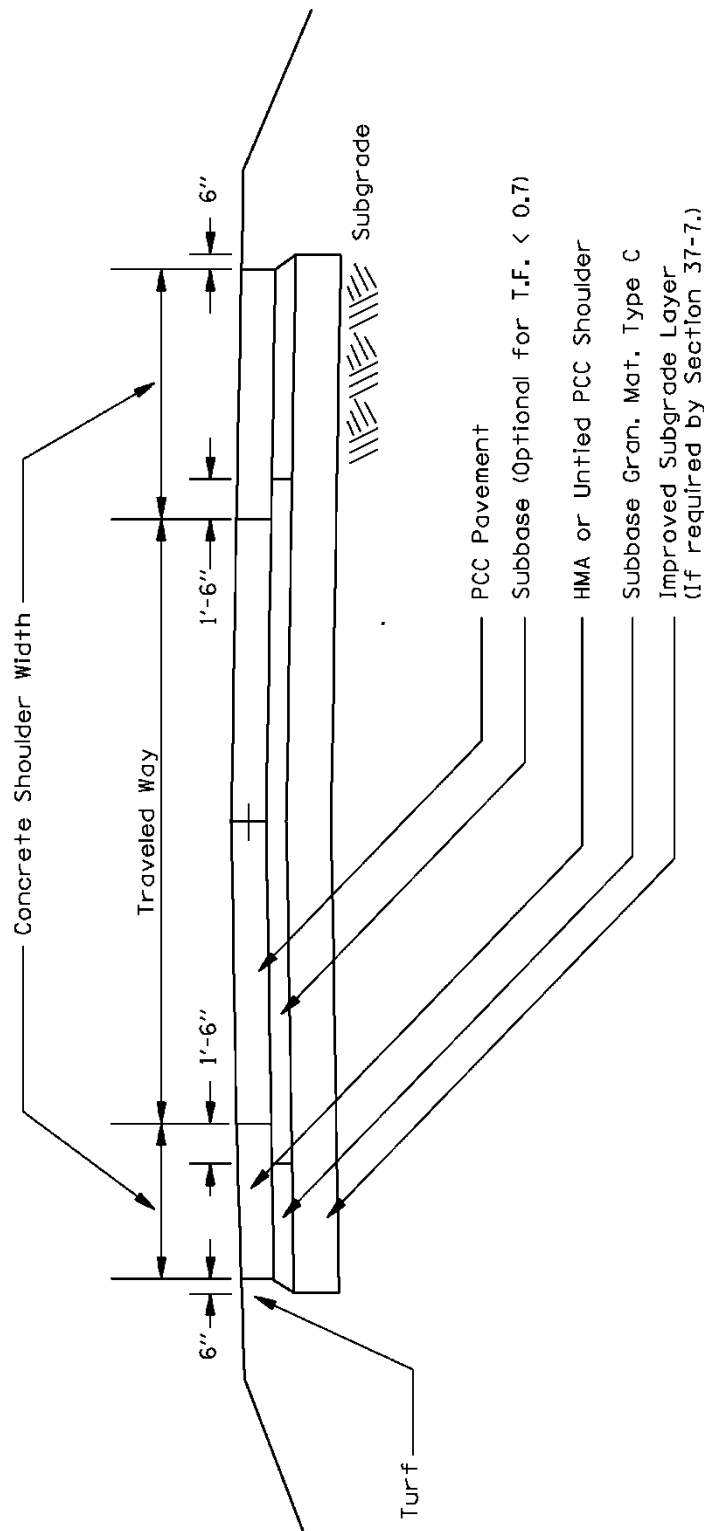
TYPICAL RIGID DESIGN WITH UNTIED SHOULDERS

Figure 44-2O

44-2.04   Example Calculation

* * * * * * * * * *

Example 44-2.1

Given: Class I, one-way urban street
            Design Period: 20 years
            Design Traffic:
            ADT: 8900
            94% PV (8366), 5% SU (445), 1% MU (89)
            Subgrade Support Rating: poor
            Shoulders: tied curb and gutter
            Overload vehicles: 5 per week

Problem*:*   Design a jointed concrete pavement for the given conditions.

Solution:

3.   Use Figure 44-2B and determine the TF equation for a one-way Class I pavement.

        One-way Streets and Pavements (Rural and Urban)

$$TF = DP \left[\frac{(0.073PV + 71.905SU + 348.210MU)}{1,000,000} \right]$$

$$TF = 20 \left[\frac{(0.073 \times 8366 + 71.905 \times 445 + 348.210 \times 89)}{1,000,000} \right]$$

$$TF = 1.27$$

Because the pavement is a Class I road with tied curb and gutter, a subbase is optional; see Figure 44-2F, Note 1. For this example, assume a subbase is used. From Figure 44-2F, the minimum subbase requirement is 4 in. Dowels or aggregate interlock are design options because the TF is less than 3.0; see Section 44-2.03(d).

Because this is a Class I facility, the high-reliability curves of Figures 44-2C and 44-2D should be used. The preadjusted slab thicknesses for fair subgrade support, flexible shoulders, and high reliability are:

Transverse Joint Spacing (ft)	Preadjusted Thickness (in)
12.5	7.25
15.0	7.55

Pavement thickness adjustments for tied curb and gutter are listed below based on the preadjusted pavement thickness determined above and the shoulder adjustment factors; see Figure 44-2I.

Transverse Joint Spacing (ft)	Adjustments for Shoulder Type (in)
12.5	deduct 0.250
15.0	deduct 0.250

Pavement thickness adjustments for subgrade support are based on the SSR and whether the pavement structure will have a subbase or not. Assuming a stabilized subbase, no pavement thickness adjustment is required for a pavement with a poor SSR; see Figure 44-2J.

Note that if the designer had opted not to use a stabilized subbase, a pavement thickness adjustment of plus 0.25 in would be required.

Pavement thickness adjustments (increases) for overloads can be taken directly from Figure 44-2L. An adjustment of +0.07 in is necessary for a pavement structure where five overloaded vehicles per week are anticipated in conjunction with a design TF of 1.27.

Adjustments of the preadjusted pavement thicknesses for the different transverse joint spacing are summarized as follows:

Transverse Joint Spacing	Preadjusted Thickness	Adjustments			Final Thickness
		Shoulder	Subgrade	Overloads	
12.5 ft	7.25 in	- 0.250 in	0 in	+0.07 in	7.07 in
15.0 ft	7.55 in	- 0.250 in	0 in	+0.07 in	7.37 in

The designer should round the final design thicknesses up to the next highest 0.25 in. Therefore, the recommended design thicknesses for the preceding joint spacing are:

Transverse Joint Spacing (ft)	Recommended Thickness (in)
12.5	7.25
15.0	7.50

Because the recommended slab thickness is less than 8.0 in, a maximum transverse joint spacing of 12.5 ft should be used per Figure 44-2E.

* * * * * * * * * *

44-3   CONVENTIONAL FLEXIBLE PAVEMENT DESIGN FOR LOCAL AGENCIES

44-3.01   Introduction

A conventional flexible pavement is a HMA surface in combination with a granular base and, if required, additional subbase layers. Conventional flexible pavements are allowed for traffic factors (TF) up to 0.25.

The design criteria for conventional flexible pavements are HMA 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 ESAL's and 80 psi tire pressure conditions.

44-3.02   Basic Design Elements

44-3.02(a)   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. These road classifications are defined in Section 44-1.

44-3.02(b)   Minimum Material Requirements

HMA binder and surface course are required for conventional flexible pavement design. Use a minimum thickness of 3 in of HMA.

All HMA lifts must comply minimum thicknesses in Section 44-1.02.

Use a minimum thickness of 8 in of Type A aggregate base material. A modified soil layer (8 in minimum) or Type B granular subbase material (4 in minimum) may be used at a 1:1 ratio to satisfy granular layer thickness requirements in excess of 8 in. For example, a 12 in base requirement could be satisfied by using 12 in of Type A aggregate base material or 8 in of Type A and 4 in of Type B aggregate material.

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

44-3.02(c)   Design Period

The design period DP 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 DP allowed is 20 years for Class I and II roads and streets. For Class III roads and streets, a minimum DP of 15 years is allowed. For Class III roads and streets, designers are encouraged to determine thicknesses for both 15 year and 20 year DP'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 in to 1 in of additional HMA.

Class IV pavement thicknesses provided in Section 44-3.03(b) should be satisfactory for DP's of 15 years or 20 years.

44-3.02(d)   Structural Design Traffic

The structural design traffic is the estimated 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 10 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 PV, SU, and MU counts are not available for Class III and IV roads and streets, Figure 44-3A provides an estimate of counts that can be made from the component percentages of the total traffic.

Class of Road or Street	Percentage of Structural Design Traffic		
	PV (%)	SU (%)	MU (%)
III	88	7	5
IV	88	9	3

PERCENTAGE OF STRUCTURAL DESIGN TRAFFIC
(Class III or IV)

Figure 44-3A

44-3.02(e)   Traffic Factors

The maximum allowable Traffic Factor (TF) for conventional flexible pavements is 0.25. For Class I, II, and III roads and streets, the design TF for flexible pavements can be determined for various DP's from the 80,000 lb load limit formulas shown in Figure 44-3B. The formulas 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 (e.g., a highway where HCV's entering and leaving a site generally travel empty in one direction and fully loaded in the other). These cases should be referred to the Central BLRS for special analysis. The local agency must provide the Central BLRS with the structural design traffic; the DP; traffic distribution by PV, SU, and MU; and loading condition of HCV traffic.

For Class IV roads and streets, thicknesses are provided in Section 44-3.03(b) based on the daily volume of HCV's; therefore, a design TF is not necessary.

Class I Roads and Streets	
4 or 5 Lane Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.047PV + 59.625SU + 217.139MU)}{1,000,000}\right]$
6 or More Lane Pavements (Rural)	$TF = DP\left[\dfrac{(0.029PV + 53.000SU + 193.012MU)}{1,000,000}\right]$
6 or More Lane Pavements (Urban)	$TF = DP\left[\dfrac{(0.012PV + 49.025SU + 178.536MU)}{1,000,000}\right]$
One-way Streets and Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.073PV + 66.250SU + 241.265MU)}{1,000,000}\right]$
Class II Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 56.030SU + 192.720MU)}{1,000,000}\right]$
Class III Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 54.570SU + 192.175MU)}{1,000,000}\right]$

TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-3B

44-3.02(f) 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 TF greater than 0.1 and with the approval of the district. 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 HMA (base or surface course) is part of the initial stage, provide a minimum HMA thickness of 3 in. The total HMA thickness resulting from the stages will be the HMA design thickness plus an additional 0.5 in.

If a HMA mixture is not part of the initial stage, place an A-2 or A-3 surface treatment over the aggregate base. The aggregate base thickness will be determined on a project-by-project basis by the Central BLRS.

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.

44-3.02(g)   PG Binder Grade Selection

The PG binder grade may affect the performance of a HMA mixture. The conventional flexible pavement design procedure assumes that HMA rutting and thermal cracking are adequately considered in the material selection and mixture design process. Selection of the appropriate binder grade can impact the ability of the mix to resist rutting at higher temperatures and thermal cracking at lower temperatures. Both high and low temperature levels need to be considered when selecting the appropriate binder grade for conventional flexible pavements.

Conventional flexible pavements should use the grades shown in Figures 44-3C and 44-3D. Most conventional flexible pavements should use the grades shown for a standard traffic level. Areas of slow moving or standing traffic (e.g., intersections, bus stops, city streets) warrant the use of stiffer binders to resist rutting. PG binder grade adjustments should be made according to Figures 44-3C and 44-3D for the corresponding N_{design} number, provided by the district, and/or design ESALs. PG binder grade adjustments, where applicable, should be applied to the surface and top binder lift.

Binder grade adjustments may also be warranted based on the use of reclaimed asphalt pavement (RAP) in the mix. For mixtures containing a minimum of 15% RAP, both the high and low temperature binder grades should be decreased by one grade equivalent (e.g., if use of PG 64-22 is specified for a virgin aggregate mix, a PG 58-28 should be used for a mix containing a minimum of 15% RAP). The appropriate grade of binder should be reported on the plans.

The local agency must request a variance from the Central BLRS to use a different PG binder than that specified in Figure 44-3C.

PG Binder Grade Selection[1] [2]			
	Traffic Loading Rate		
Districts 1-4	Standard [3]	Slow [4]	Standing [5]
Surface[6]	PG 58-28	PG 64-28, SBR PG 64-28[7], or SBS PG 64-28	SBR PG 70-28[7] or SBS PG 70-28
Remaining Lifts[6]	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22
Districts 5 – 9			
Surface[6]	PG 64-22	PG 70-22, SBR PG 70-22[7], or SBS PG 70-22	SBR PG 76-22[7] or SBS PG 76-22
Remaining Lifts[6]	PG 64-22	PG 64-22	PG 64-22

Notes:
1. *The binder grades provided in Figure 44-3C are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*

2. *For mixtures containing a minimum of 15% RAP, both the high and low temperature binder grades should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-28 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in the above table.*

3. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*

4. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*

5. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*

6. *Surface includes the top 2 in (50 mm) of HMA. The remaining lifts of HMA may be the same PG binder grade as surface; however, this may increase or decrease the pavement design thickness. If multiple PG Binder grades are used in a HMA design, the predominant PG Binder grade should be used for determining HMA Modulus on Figure 44-3F.*

7. *SBR modified binders are not available in Illinois at this time.*

PG BINDER GRADE SELECTION FOR CONVENTIONAL FLEXIBLE PAVEMENTS
Figure 44-3C

44-3.02(h)   Subgrade Inputs

The general physical characteristics of the roadbed soils affect the design thickness and performance of the pavement structure. For full-depth HMA pavements, the thickness of the pavement structure is sufficient to reduce the subgrade vertical compression stresses to an acceptable level. An improved subgrade under a full-depth HMA pavement functions primarily as a working platform. However, in conventional flexible pavement design, the roadbed soil plays a critical role in the load-carrying capacity of the pavement. Therefore, a careful examination of the subgrade soil characteristics is necessary.

For the design of conventional flexible pavement, the 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} can be determined using one of the methods outlined in Section 44-6.

E_{Ri} values less than 2 ksi require subgrade stabilization. Subgrade soils suspected of having modulus values this low require a soils investigation.

The designer should take into consideration the susceptibility of the roadbed soil to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave, and non-uniform support. The designer should use Section 44-7 to address these types of issues by recommending corrective actions (e.g., undercutting, moisture density control, soil modification) in the design plans and specifications. The special provision entitled "Soil Modification" should be used in lieu of the "Lime-Modified Soils" section of the *IDOT Standard Specifications*. Necessary corrective measures would be in addition to the subbase requirements of the pavement design.

Pavement thickness adjustments are not necessary for sandy/granular subgrade materials, which typically have a modulus greater than 3 ksi. The designer is cautioned against assuming an E_{Ri} value greater than 3 ksi if there are no test results to support the assumption.

44-3.02(i)   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.

1.   Thickness. Use a minimum thickness of 8 in. of Type A aggregate base material. For granular layer thickness requirements in excess of 8 in, The minimum 8 in Type A aggregate base material would still be required, but additional base thickness requirements could be satisfied by using a minimum 4 in Type B granular subbase material or a minimum 8 in modified soil layer.

      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 required.

2.   Width. Aggregate subbase and base course shall be at least 2 ft wider than the HMA surface course. If curb and gutter is used, this may be reduced to 1 ft.

44-3.02(j)   Design Reliability

Design reliability is taken into account through traffic factor multipliers applied to the design TF. These traffic multipliers are built into the HMA design strain curve in Figure 44-3I. The minimum reliability levels by class of road are given in Figure 44-3D.

Road Class	Minimum Reliability Level	Reliability (%)
Class I, II, III, and IV	Medium	70's and 80's

Note: The estimated percent reliability is based on a representative 9-kip Falling Weight Deflectometer surface deflection coefficient of 25%.

RELIABILITY LEVEL
Figure 44-3D

44-3.03   Thickness Design – HMA Mixtures

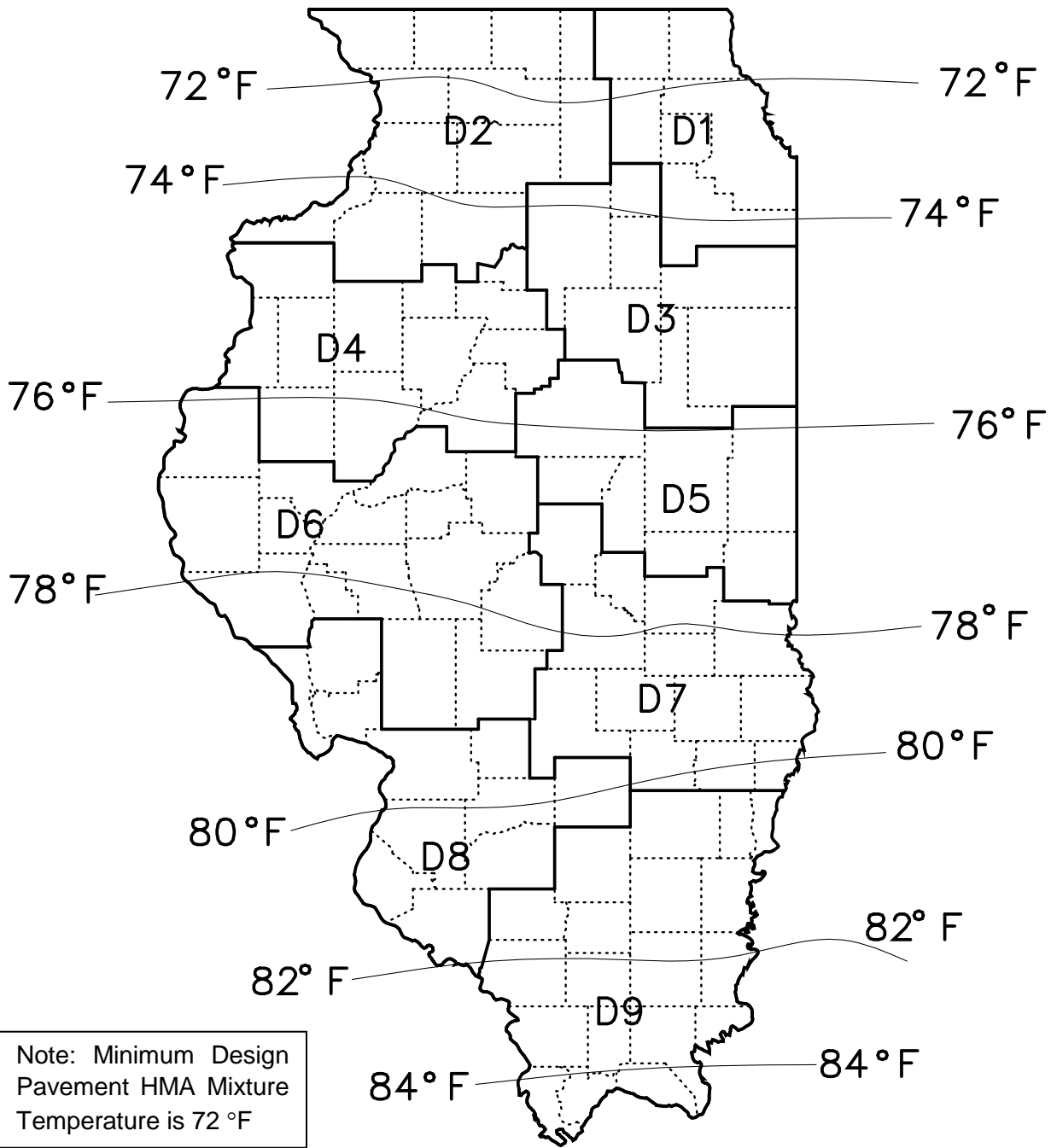### 44-3.03(a)   Class I, II, and III Roads and Streets

The following applies to types of facilities using HMA mixtures:

1.   HMA Design Mixture Temperature. The HMA mixture temperatures are given in Figure 44-3E based on geographic locations in Illinois. The design mixture temperature should be interpolated to the nearest 0.5°F. The minimum design mixture temperature is 72°F.

    Note: Design Time dates are not the same for conventional flexible and full-depth HMA pavements. Conventional flexible design time dates occur earlier in the spring. Therefore, for the same location, the conventional flexible HMA design mixture temperature is lower than the full-depth HMA design mixture temperature. Figure 44-3E of the conventional flexible pavement design is not the same as Figure 44-4F in the full-depth pavement design procedure.

2.   HMA Design Modulus (E_{AC}). The design E_{AC} is the HMA modulus that corresponds to the design mixture temperature. Determine the design E_{AC} value from Figure 44-3F for typical Superpave mixtures with PG 52-XX, PG 58-XX, PG 64-XX, or PG 70-XX.

3.   HMA Design Strain. The HMA design strain is the tensile strain at the bottom of the HMA pavement layer. Use Figure 44-3G in conjunction with the design TF to determine the design strain.

4.   Thickness Requirements. Use Figure 44-3H in conjunction with the HMA design strain from Step 3 to determine the thickness of HMA mixture required. The thicknesses from Figure 44-3H are based on an 8 in minimum Type A 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 in Type A aggregate base is structurally adequate; therefore, 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, Figure 44-3I should be used to determine the appropriate structure enhancement category for the pavement. Subgrades with an E_{Ri} less than 2 ksi must follow Section 43-7.

44-3.03(b)   Class IV Roads and Streets Thickness Requirements

Figures 44-3J and 44-3K provide the HMA 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.

When 4 in or more of HMA are used, 8 in of Type A aggregate base material is satisfactory for all combinations of soil types and traffic levels for all districts.

72°F   72°F

D2   D1

74°F   74°F

D3

D4

76°F   76°F

D5

D6

78°F   78°F

D7

80°F

80°F

82° F

82° F

D9

Note: Minimum Design
Pavement HMA Mixture
Temperature is 72 °F

84° F   84°F

Region Designations:

Region 1 – D1
Region 2 – D2 and D3
Region 3 – D4 and D5
Region 4 – D6 and D7
Region 5 – D8 and D9

HMA MIXTURE TEMPERATURE
(Conventional Flexible)

Figure 44-3E
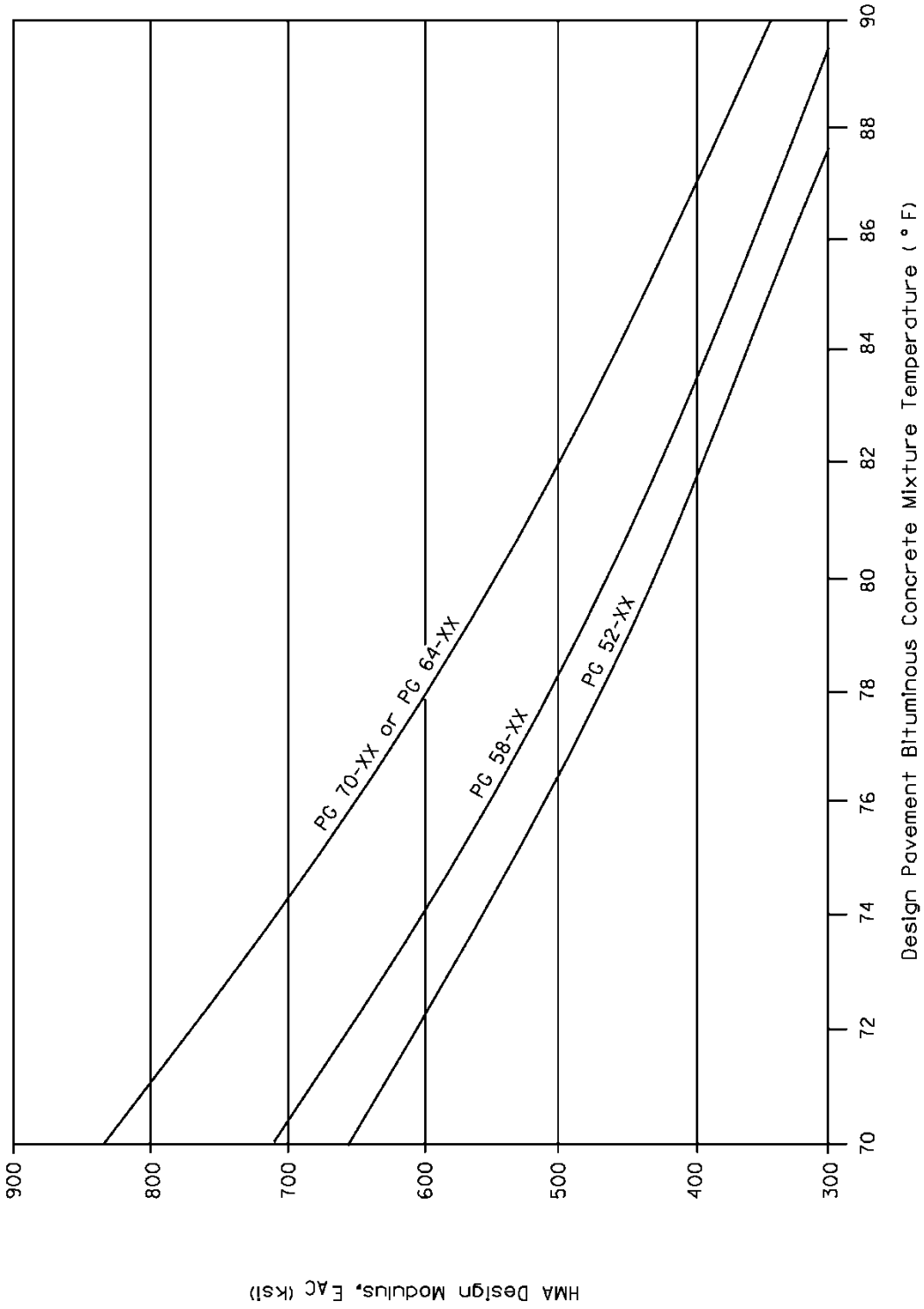
HMA MODULUS
(Mixture Temperature Relations)

Figure 44-3F
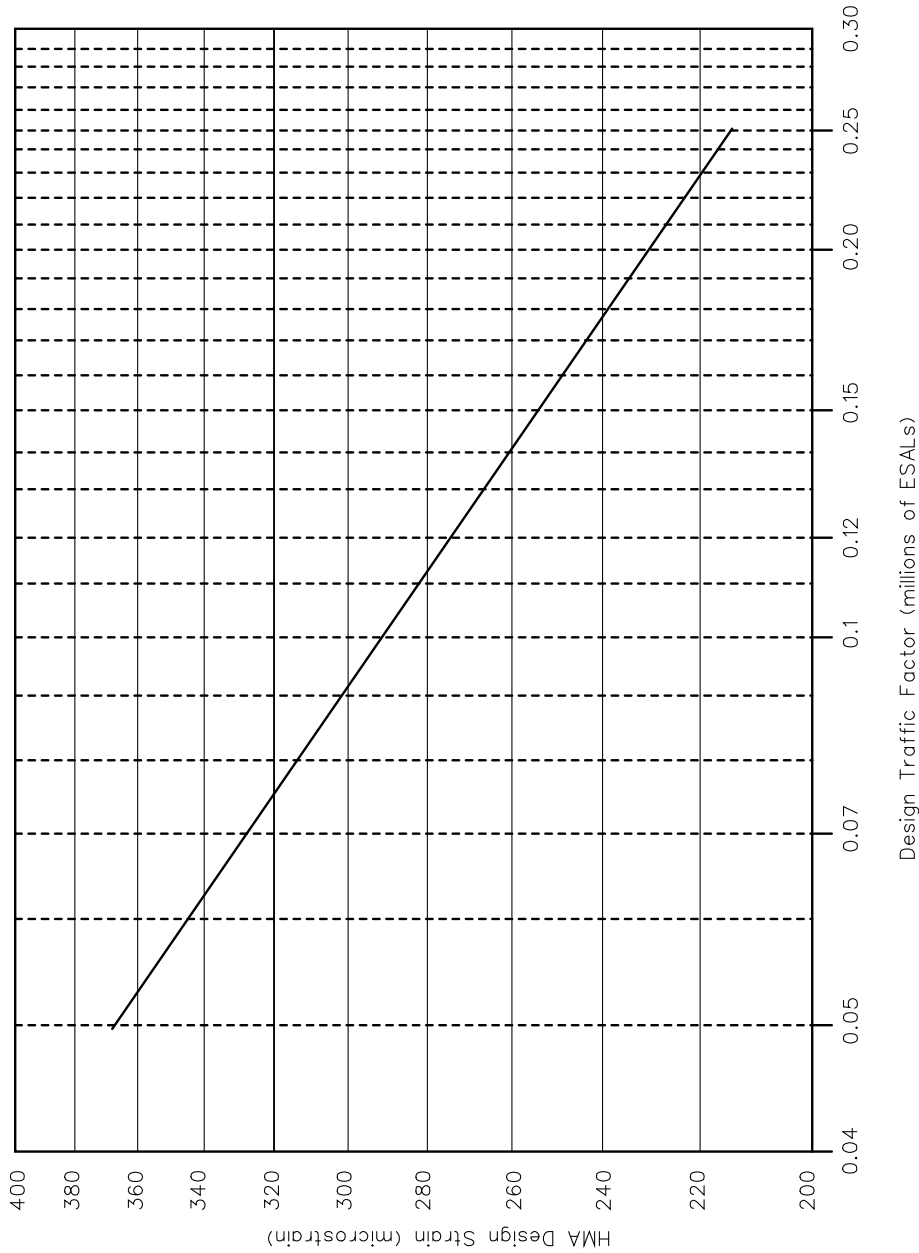
**HMA DESIGN STRAIN
(Traffic Factor Relation for HMA Mixes)
Figure 44-3G**
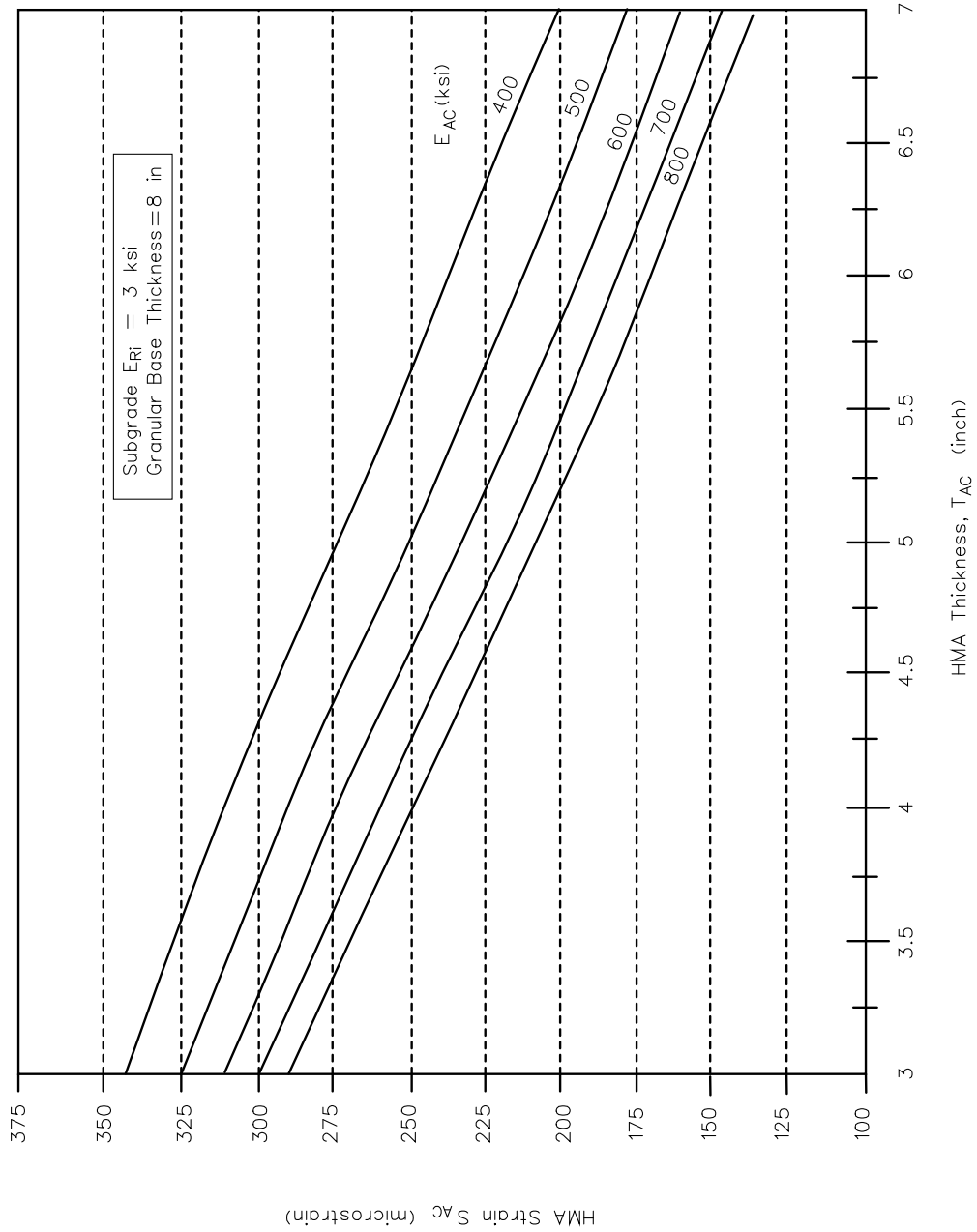
**HMA STRAIN
(Thickness for Superpave Mixtures)**

Figure 44-3H

Original HMA Design Thickness (in)	HMA 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
≥ 4.0	O	O	O	O	O

E: *Enhancement of the pavement structure is required.*

O: *Enhancement of the pavement structure is optional. If no enhancement is desired, an 8 in Type A aggregate base course is required.*

Notes: *If the subgrade E_{Ri} is less than 2 ksi, use Section 44-7 to determine the appropriate subgrade treatment necessary.*

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

1. <u>*E[1]*</u>*. Use one or more of the following:*

    - *Increase the HMA thickness by 0.5 in.*
    - *Increase the Type A aggregate base thickness by 2 in.*
    - *Add a 4 in minimum Type B granular subbase.*
    - *Add an 8-in minimum modified soil layer.*

2. <u>*E[2]*</u>*. Use one or more of the following:*

    - *Increase the HMA thickness by 1.0 in.*
    - *Increase the Type A aggregate base thickness by 4 in.*
    - *Add a 4 in minimum Type B granular subbase.*
    - *Add an 8-in minimum modified soil layer.*

SUPERPAVE HMA — CLASS I, II, AND III ROADS AND STREETS PAVEMENT STRUCTURE ENHANCEMENT (E_{Ri} ≥ 2 ksi and < 3 ksi)

Figure 44-3I

District	1 – 4		5 – 6		7 – 9	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 3	≥ 3	2 – 3	≥ 3	2 – 3	≥ 3
< 10 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
10 – 19 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
20 – 40 HCV's	11 in	8 in	11 in	10 in	14 in	13 in

Note: E_{Ri} values less than 2 ksi require use of Section 44-7.

CLASS IV PAVEMENTS
AGGREGATE BASE THICKNESS NECESSARY FOR A 3.0 IN OR 3.25 IN HMA SURFACE
Figure 44-3J

District	1 – 4		5 – 6		7 – 9	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 3	≥ 3	2 – 3	≥ 3	2 – 3	≥ 3
< 10 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
10 – 19 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
20 – 40 HCV's	8 in	8 in	9 in	8 in	12 in	11 in

Note: E_{Ri} values less than 2 ksi require use of Section 44-7.

CLASS IV PAVEMENTS
AGGREGATE BASE THICKNESS NECESSARY FOR A 3.5 IN OR 3.75 IN HMA SURFACE
Figure 44-3K

44-3.04   Typical Sections

Figures 44-3L and 44-3M illustrate typical local agency conventional flexible pavement designs.

Variable

24"

Variable

24"

Traveled Way

Turf
Shoulder

Superpave Surface Course

Superpave Binder Course

Type A Aggregate Base Course

Improved Subgrade Layer (If Required)
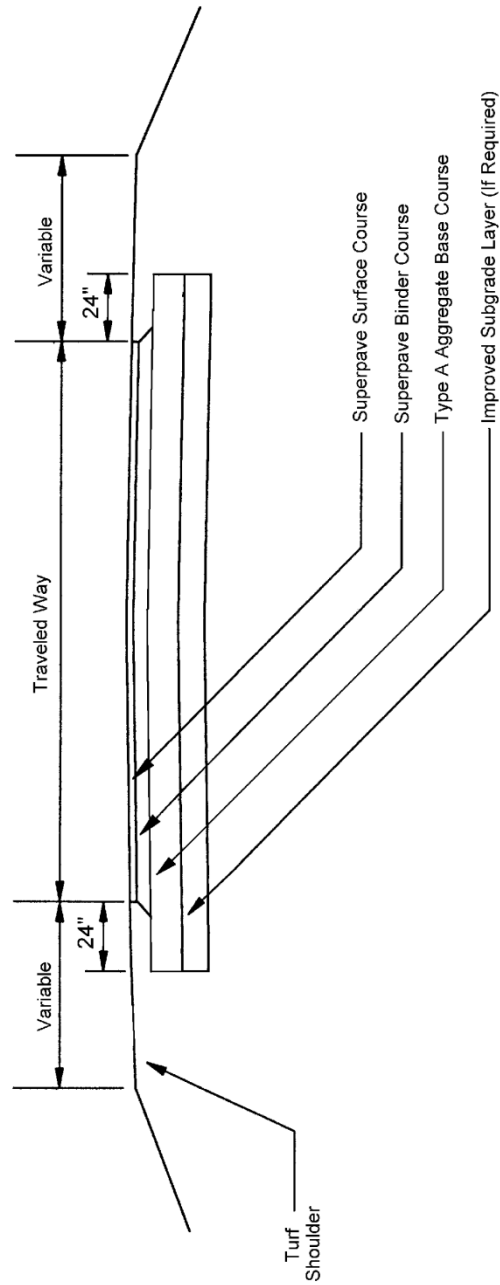
TYPICAL CONVENTIONAL FLEXIBLE RURAL DESIGN

Figure 44-3L

Traveled Way

Superpave Surface Course

Superpave Binder Course

Type A Aggregate Base Course

Improve Subgrade Layer (If Required)

Flush Median (If Required)

Curb & Gutter
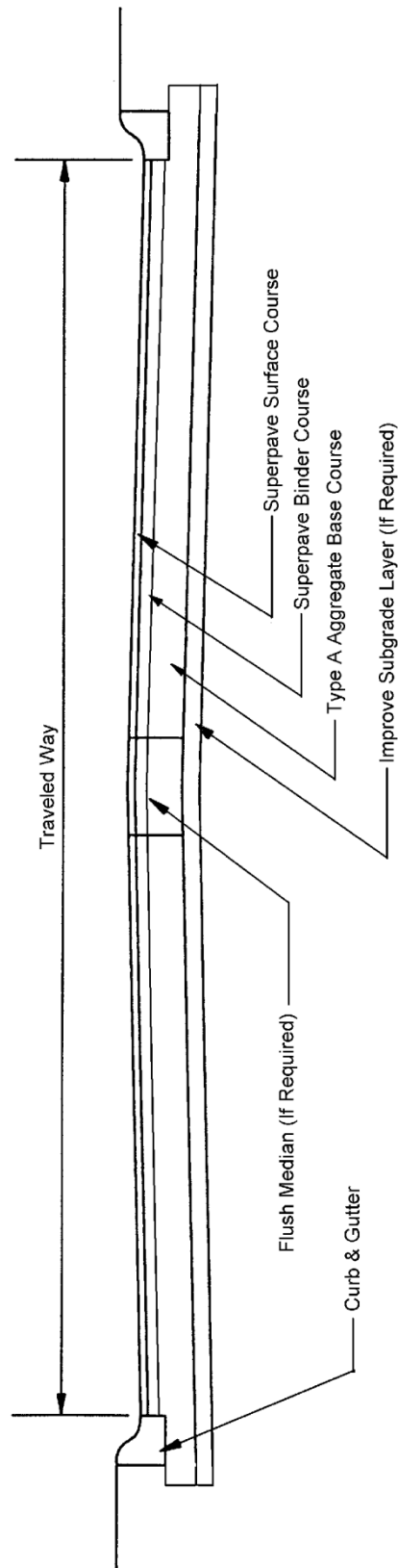
Note: Raised median with curb and gutter may be used in lieu of a flush median.

TYPICAL CONVENTIONAL FLEXIBLE URBAN DESIGN

Figure 44-3M

44-3.05   Example Calculations

Example 44-3.1

Given: Class III, two-lane pavement
         DP: 20 years
         Design Traffic:
             ADT: 420
             85% PV (357), 10% SU (42), 5% MU (21)

         Location: Urbana, IL
         Critical Subgrade E_{Ri}: 3 ksi
         Posted Speed Limit: 45 mph

Problem: Design a conventional flexible pavement with a HMA surface for the given conditions.

Solution:

1.   From Figure 44-3B, use the TF equation for a two-lane Class III pavement.

     2 or 3-Lane Pavements:

$$TF = DP \left[\frac{(0.073PV + 54.570SU + 192.175MU)}{1,000,000} \right]$$

$$TF = DP \left[\frac{(0.073 \times 357 + 54.570 \times 42 + 192.175 \times 21)}{1,000,000} \right]$$

$$TF = 0.127$$

2.   HMA design mixture temperature from Figure 44-3F is 76.5°F.

     From Figure 44-3D, use a PG 64-22 due to a standard traffic loading rate. The HMA design modulus (E_{AC}) from Figure 44-3G would be 640 ksi.

     The HMA design strain from Figure 44-3H would be 265 microstrain.

     HMA thickness from Figure 44-3I is 4.1 in; therefore, round the HMA thickness up to 4.25 in.

     The final design would be 4.25 in HMA surface + 8 in Type A aggregate base (8 in minimum Type A aggregate base is satisfactory because E_{Ri}= 3 ksi.)

Example 44-3.2

Given: Class II, two-lane pavement
DP: 20 years
Design Traffic:
ADT: 3015
97% PV (2925), 2% SU (60), 1% MU (30)
Location: Chicago
Critical Subgrade E_{Ri}: 2 ksi
Posted speed limit: 30 mph (no standing traffic)

Problem: Design a conventional flexible pavement with HMA surface for the given conditions.

Solution:

1. From Figure 44-3B, use the TF equation for a two-lane Class II pavement.

   2 or 3 Lane Pavements:

$$TF = DP \left[\frac{(0.073PV + 56.030SU + 192.720MU)}{1,000,000} \right]$$
$$TF = DP \left[\frac{(0.073 \times 2925 + 56.030 \times 60 + 192.720 \times 30)}{1,000,000} \right]$$

$$TF = 0.187$$

2. A PG 64-28, SBR 64-28, or SBS 64-28 grade of asphalt binder should be used to compensate for the stopping and starting traffic patterns common in urban areas.

3. The HMA design mixture temperature from Figure 44-3E is 73°F.

4. The HMA design modulus (E_{AC}) from Figure 44-3F is 750 ksi.

5. The HMA design strain from Figure 44-3G would be 236 microstrain.

6. HMA thickness from Figure 44-3H is 4.4 in; therefore, round the thickness up to 4.5 in. Figure 44-3I is based on an 8 in Type A aggregate base and an E_{Ri} value of 3 ksi or greater. Because the E_{Ri} value is 2 ksi, Figure 44-3J must be used to determine if any pavement thickness enhancements are necessary.

7. Figure 44-3I designates the pavement thickness adjustment requirement as a category "O" (4.0 in HMA thickness and 700 ksi E_{ac}). Enhancement of the pavement structure is optional.

8. The final design would be 4.5 in of HMA mixture and 8 in of Type A aggregate base material. The designer could opt to enhance the pavement structure by increasing the HMA thickness or the aggregate base thickness or by using a modified soil layer.

Example 44-3.3

Given: Class IV, 2-lane pavement
            DP: 15 years
            Design Traffic:
                ADT: 350
                94.5% PV (331), 3.5% SU (12), 2% MU (7)
            Critical Subgrade E_{Ri}: 2.5 ksi
            Location: District 5

Problem: Design a conventional flexible pavement with a HMA surface for the given
            conditions.

Solution:

Because this is a Class IV street, Figure 44-3J and Figure 44-3K should be used. With 19
HCV's (SU's + MU's) per day and critical subgrade E_{Ri} of 2.5 ksi, the designer will need to
decide if the HMA layer will be constructed using a HMA binder lift and HMA surface lift, or
using 2 surface lifts. The designer decides to use a 19.0 mm binder lift followed by a 9.5 mm
surface lift because this is the preferred cross section for the agencies pavements. Based on
Figure 44-1A, the binder lift must be a minimum of 2.25 in and the surface lift must be a
minimum of 1.25 in. A 3.5 in HMA surface over an 8 in Type A aggregate base is required;
however, because HCV's < 20, Type B aggregate base material may be substituted for Type A
aggregate base material.

* * * * * * * * * *

44-4   FULL-DEPTH HMA PAVEMENT DESIGN FOR LOCAL AGENCIES

44-4.01   Introduction

44-4.01(a)   Design of Full-Depth HMA Pavements

Full-depth HMA pavements are those pavement structures whose surface and principal load-carrying component is HMA. This design procedure assumes that HMA 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 HMA-subgrade interface to an acceptable level. The governing design criteria is the HMA tensile strain. Reduced strain corresponds to increased fatigue life.

44-4.01(b)   Usage of Procedure

Use the pavement design procedure in this Section for all local road and street projects where a full-depth HMA 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 HMA pavements for local agency projects involving MFT and Federal funds. Do not use this procedure 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. Small quantities are considered to be as follows:

- less than one city block in length,

- less than 3000 yd^2, or

- 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, and

- provide a minimum thickness of 6.0 in.

44-4.02   Basic Design Elements

44-4.02(a)   Minimum Material Requirements

HMA surface and binder courses are allowed. Any combination of surface course or binder course may be used to arrive at the total HMA design thickness. However, all HMA lifts must comply minimum thicknesses in Section 44-1.02.

44-4.02(b)   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 and is described in Section 44-1.

44-4.02(c)   Design Period

The design period (DP) is the length of time in years that the pavement is being designed to serve the structural design traffic. For Class I and II roads and streets, a DP of 20 years should be used. For Class III roads and streets, a minimum DP of 15 years is allowed. The pavement thickness provided for Class IV pavements with 40 or less HCV's should be satisfactory for a 15 year or 20 year DP.

44-4.02(d)   Structural Design Traffic

The structural design traffic is the estimated 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 10 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 PV, SU, and MU counts are not available for Class III and IV roads and streets, Figure 44-4A provides an estimate of counts that can be made from the component percentages of the total traffic.

Class of Road or Street	Percentage of Structural Design Traffic		
	PV (%)	SU (%)	MU (%)
III	88	7	5
IV	88	9	3

PERCENTAGE OF STRUCTURAL DESIGN TRAFFIC
(Class III or IV)

Figure 44-4A

44-4.02(e)   Traffic Factors

For Class I, II, and III roads and streets, the design Traffic Factor (TF) for flexible pavements can be determined for various DP's and Classes of roads and streets from the 80,000 lb load limit formulas in Figure 44-4B. The formulas 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 (e.g., a highway where HCV's entering and leaving a site generally travel empty in one direction and fully loaded in the other). These cases should be referred to the Central BLRS for special analysis. The local agency must provide the Central BLRS with the structural design traffic, the DP, traffic distribution by PV, SU, MU, and loading conditions of HCV traffic.

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

Class I Roads and Streets	
4 or 5 Lane Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.047PV + 59.625SU + 217.139MU)}{1,000,000}\right]$
6 or More Lane Pavements (Rural)	$TF = DP\left[\dfrac{(0.029PV + 53.000SU + 193.012MU)}{1,000,000}\right]$
6 or More Lane Pavements (Urban)	$TF = DP\left[\dfrac{(0.012PV + 49.025SU + 178.536MU)}{1,000,000}\right]$
One-way Streets and Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.073PV + 66.250SU + 241.265MU)}{1,000,000}\right]$
Class II Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 56.030SU + 192.720MU)}{1,000,000}\right]$
Class III Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 54.570SU + 192.175MU)}{1,000,000}\right]$

FLEXIBLE TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-4B

44-4.02(f)   Subgrade Support Rating

There are three subgrade support ratings used in this design procedure — poor, fair, and granular. The designer should use Figure 44-6A 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 44-6A 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.

44-4.02(g)   Subgrade Working Platform

Roadbed soils that are susceptible to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave, and/or non-uniform support can affect pavement performance. An improved subgrade layer provides a working platform and uniform support for pavement layer construction. Without the minimum required improved subgrade layer, it may be difficult to ensure adequate density in HMA. A modified soil layer or granular material may be used to satisfy the improved subgrade layer requirement. In urban areas, use of granular material may be more practical than a modified soil layer due to concerns about dust pollution. Subgrade working platform requirements are outlined in Figure 44-4C.

The improved subgrade layer will not be structurally credited in the design procedure. Its purpose is solely to provide a working platform on which to construct a quality pavement structure. A 12 in layer is adequate for this purpose in most, but not all cases. Use of additional improved layer thickness will not reduce the HMA pavement thickness.

Road Class	Improved Working Platform Material	Usage	Minimum Thickness (in)
Class I and II	Modified Soil Layer or Granular Material	Required [1]	12 [3]
Class III and IV	Modified Soil Layer or Granular Material	Optional [2]	12 [3]

Notes:

1. *For Class I and II roads, a 12 in minimum improved subgrade layer is required, unless the existing subgrade is granular. Where an existing granular subgrade is encountered, the local agency may obtain a waiver to the subgrade working platform requirement from Central BLRS by documenting the subgrade suitability.*

2. *For Class III and IV roads, the 12 in minimum improved subgrade layer is optional if documentation can be provided to the district that indicates the subgrade will provide suitable support during construction in accordance with Section 44-7. Because an improved subgrade layer should improve the constructability and possibly the performance of the pavement, its use should be considered.*

3. *In some cases, soft subgrades may require more than 12 in of improved subgrade to provide a stable working platform and uniform support. The designer should review Section 44-7 in order to determine the required thickness of improved subgrade.*

SUBGRADE WORKING PLATFORM REQUIREMENTS

Figure 44-4C

PG Binder Grade Selection [1] [2]			
	Traffic Loading Rate		
Districts 1 – 4	Standard Traffic [3]	Slow Traffic [4]	Standing Traffic [5]
Surface[6]	PG 58-28 [7] [8]	PG 64-28, SBR PG 64-28 [9], or SBS PG 64-28	SBR PG 70-28 [9] or SBS PG 70-28
Remaining Lifts[6]	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22
Districts 5 – 9			
Surface[6]	PG 64-22 [7] [8]	PG 70-22, SBR PG 70-22 [9], or SBS PG 70-22	SBR PG 76-22 [9] or SBS PG 76-22
Remaining Lifts[6]	PG 64-22	PG 64-22	PG 64-22

Notes:
1. *The binder grades provided in this table are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*

2. For *mixtures containing a minimum of 15% RAP, both the high and low temperature binder grades should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-28 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in the above table.*

3. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*

4. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*

5. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*

6. *Consideration should be given to increasing the high temperature grade by one grade equivalent when 10 ≤ T.F. ≤ 30. For example, if use of a PG 64-22 is specified for standard traffic, a PG 70-22, a SBR PG 70-22, or a SBS PG 70-22 should be specified.*

7. *Surface includes the top 2 in (50 mm) of HMA. The remaining lifts of HMA may be the same PG binder grade as surface; however, this may increase or decrease the pavement design thickness. If multiple PG Binder grades are used in a HMA design, the predominant PG Binder grade should be used for determining HMA Modulus on Figure 44-4I.*

8. *The high temperature grade should be increased by one grade equivalent when T.F. > 30. For example, if use of a PG 64-22 is specified for standard traffic, a PG 70-22, a SBR PG 70-22, or a SBS PG 70-22 should be specified.*

9. *SBR-modified binders are not available in Illinois at this time.*

PG BINDER GRADE SELECTION FOR FULL-DEPTH HMA PAVEMENTS
Figure 44-4D

44-4.02(h)   PG Binder Selection

The PG binder grade may affect the performance of a HMA mixture. The full-depth HMA pavement design procedure assumes that HMA rutting and thermal cracking are adequately considered in the material selection and mixture design process. Selection of the appropriate binder grade can impact the ability of the mix to resist rutting at higher temperatures and thermal cracking at lower temperatures. Both high and low temperature levels need to be considered when selecting the appropriate binder grade for full-depth HMA pavements.

Full-depth HMA pavements should use the PG binder grades shown in Figure 44-4E. Most full-depth HMA pavements should use the grades shown for a standard traffic level. Adjustments to the standard traffic level are made if conditions of slow moving traffic or standing traffic warrant. Areas of slow moving or standing traffic, such as intersections or bus stops, warrant the use of stiffer binders to resist rutting and shoving. Adjustments, where applicable, have been applied to the surface and top binder lift. This keeps the same PG grade in these two lifts.

Binder grade adjustments may also be warranted based on extremely high ESALs levels, or the use of reclaimed asphalt pavement (RAP) in the mix. These adjustments should be made according to Note 2 and Note 6 in Figure 44-4E. The appropriate grade of binder should be reported on the plans.

Note: The PG binder grade selection tables for full-depth HMA pavements for local agency pavement design differ from the tables used for the state system. A lower level of reliability is used for local agency design than for the state system.

The local agency must request a variance from the Central BLRS to use a different PG binder than that specified in Figure 44-4D.

44-4.02(i)   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 HMA pavements.

44-4.02(j)   Design Reliability

Design reliability is taken into account through traffic factor multipliers applied to the design TF. These traffic multipliers are built into the HMA design strain curves in Figures 44-4H and 44-4I. The minimum reliability levels by class of road are given in Figure 44-4E.

Road Class	Minimum Reliability Level	Reliability (%)
Class I, II, III, and IV	High	90's

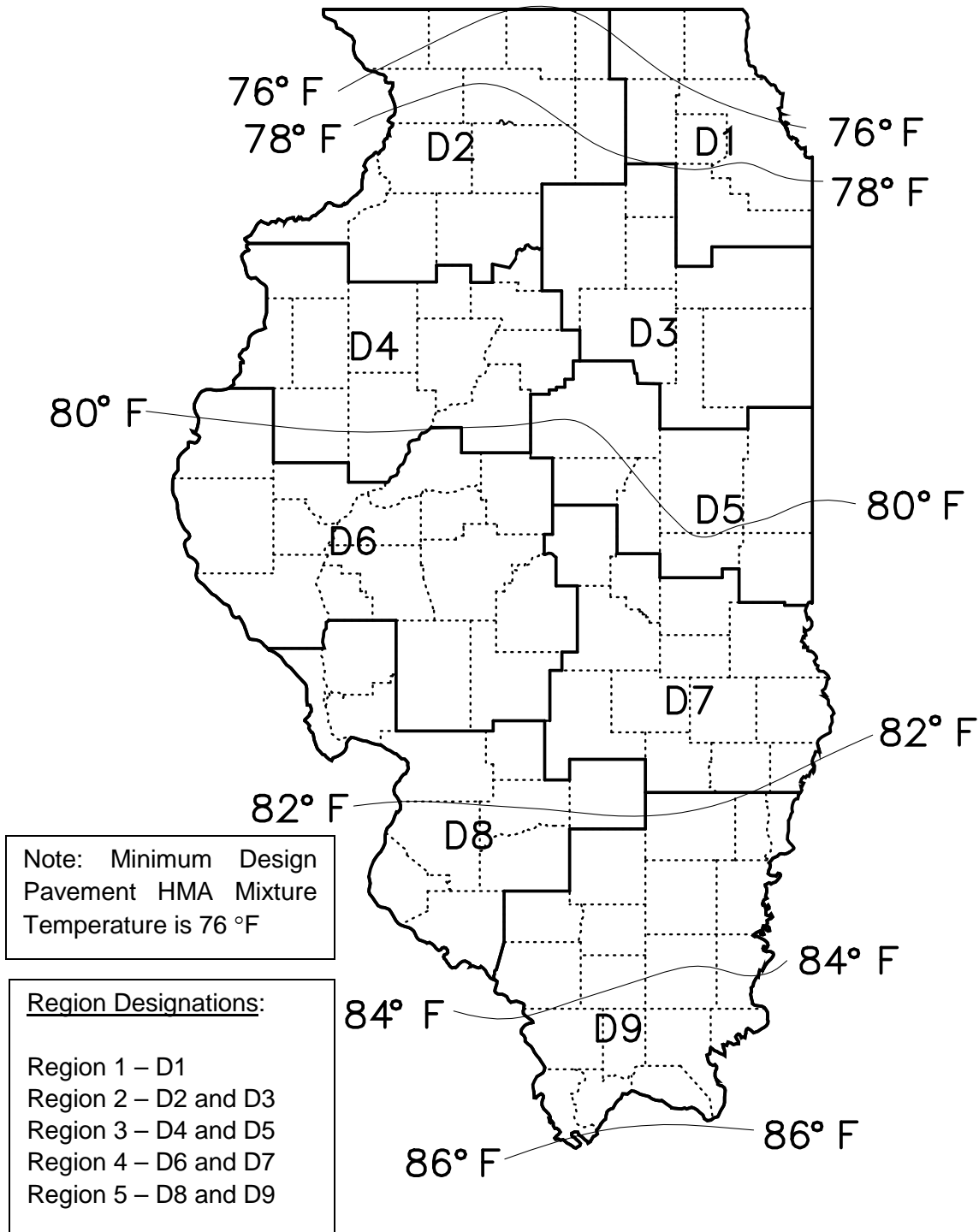**DESIGN RELIABILITY**
Figure 44-4E

44-4.03   Thickness Design

In determining the design thickness, consider the following:

1. <u>Class I, II and III Roads and Streets</u>. The design procedure is as follows:

   - Calculate the TF from the appropriate equation found in Figure 44-4B.

   - Use Figure 44-6A in conjunction with the subgrade soil grain-size analysis to determine the subgrade support rating.

   - Use Figure 44-4D in conjunction with traffic speed and location to determine the PG binder grade.

   - Use Figure 44-4F to determine the HMA 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 HMA and conventional flexible pavements. Full-depth HMA design time dates occur later in the spring. Therefore, for the same location, the conventional flexible HMA design mixture temperature is lower than the full-depth HMA design mixture temperature. Figure 44-3F of the conventional flexible pavement design is not the same as Figure 44-4F in the full-depth pavement design procedure.

   - Use Figure 44-4G (TF < 0.5) or Figure 44-4H (TF ≥ 0.5) to determine the HMA design strain.

   - Use Figure 44-4I to determine the design pavement HMA modulus (E_{AC}).

   - Use Figures 44-4J, 44-4K, or 44-4L, depending on the subgrade support rating, to determine the design HMA thickness. Round the final design thickness to the next highest 0.25 in.

   - The minimum full-depth HMA design thickness is 6 in.

   - A 12 in 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 Section 44-7 during construction.

2. <u>Class IV Roads and Streets</u>. The following procedure applies:

   - If HCV's per day ≤ 40, use a minimum 6 in HMA pavement. A 12 in improved subgrade layer is optional. Class IV pavement subgrades must satisfy the requirements of Section 44-7 during construction.

   - If HCV's per day > 40, use a Class III TF equation and design procedure.

44-4.04   <u>Typical Designs</u>

Figures 44-4M and 44-4N illustrate typical local agency full-depth HMA pavement designs.

76° F
78° F
D2
D1
76° F
78° F

D4
D3

80° F
D6
D5
80° F

D7
82° F

82° F
D8

Note: Minimum Design
Pavement HMA Mixture
Temperature is 76 °F

84° F
Region Designations:
84° F
D9
Region 1 – D1
Region 2 – D2 and D3
Region 3 – D4 and D5
Region 4 – D6 and D7
Region 5 – D8 and D9
86° F
86° F

DESIGN PAVEMENT HMA MIXTURE TEMPERATURE
(Full Depth)

Figure 44-4F
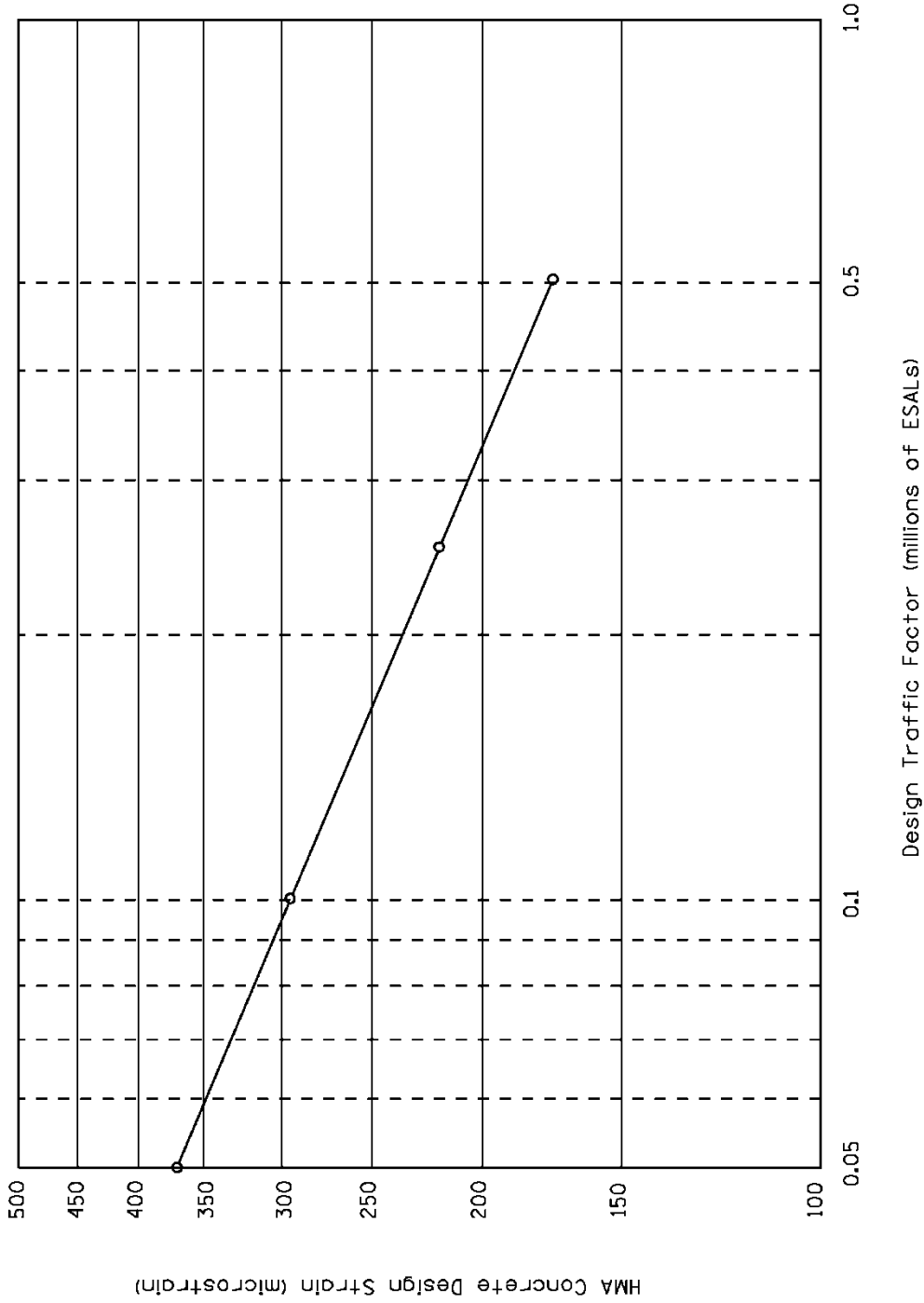
HMA DESIGN STRAIN
(Traffic Factor Relation for Traffic Factor < 0.5)

Figure 44-4G
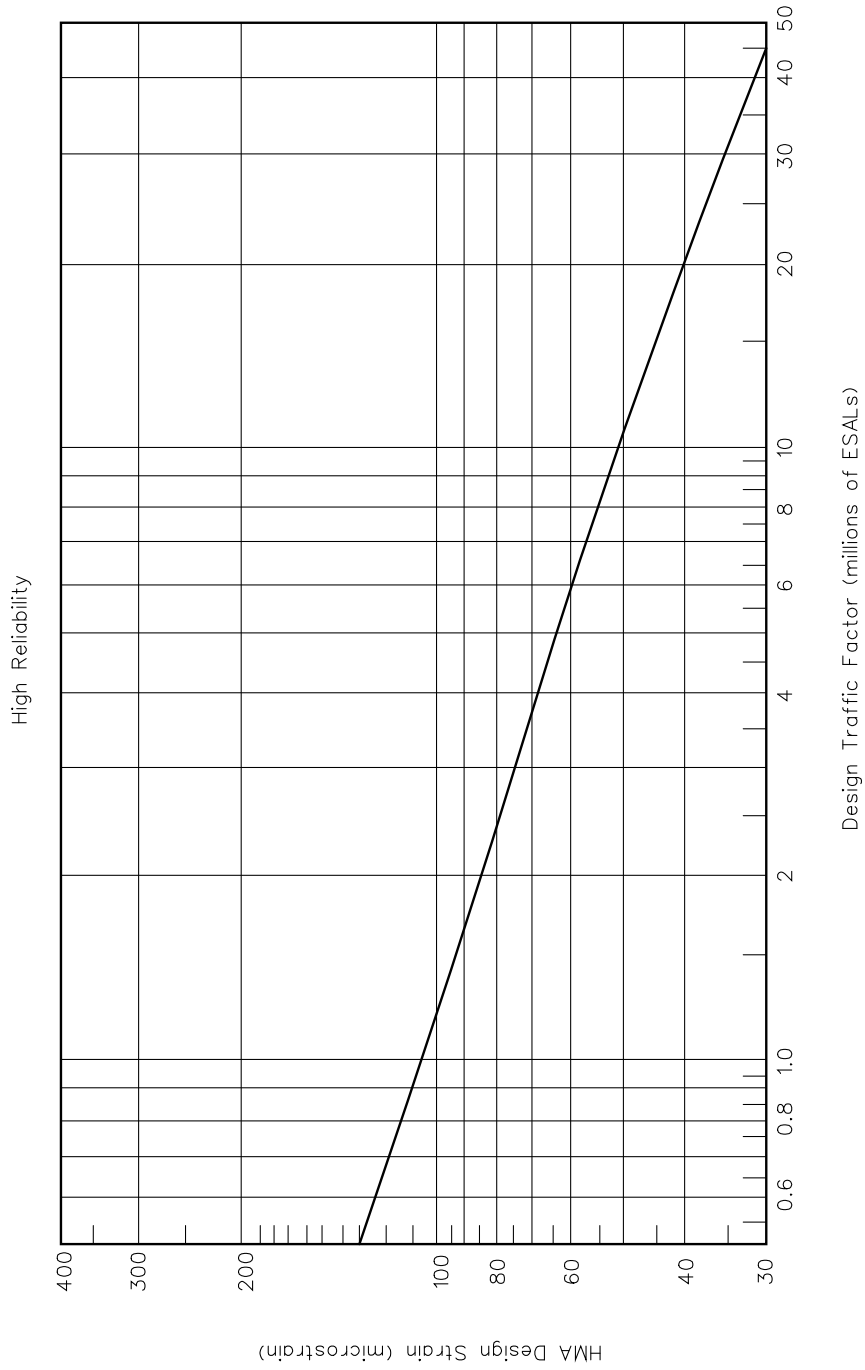
HMA DESIGN STRAIN
(Traffic Factor Relation for Traffic Factor ≥ 0.5)

Figure 44-4H
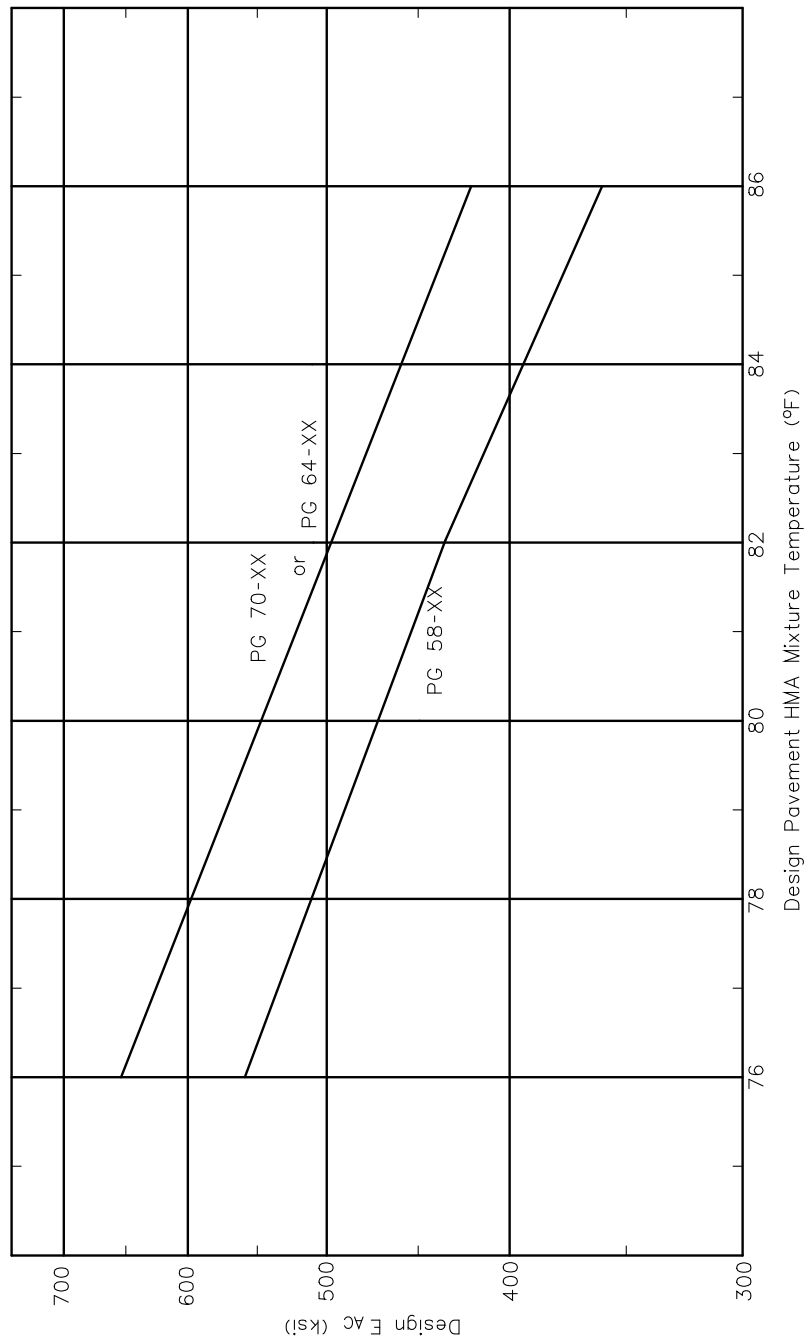
DESIGN PAVEMENT HMA MODULUS

Figure 44-4I

Poor Subgrade

Design $E_{RI} \approx 2ksi$
USDA Textural Class:
Loam
Silt Loam
Silt

Note: High water table conditions are assumed.

$E_{AC} = 300$ ksi
400 ksi
500 ksi
600 ksi
700 ksi
800 ksi

HMA Thickness (Inches)

HMA Design Strain (microstrain)
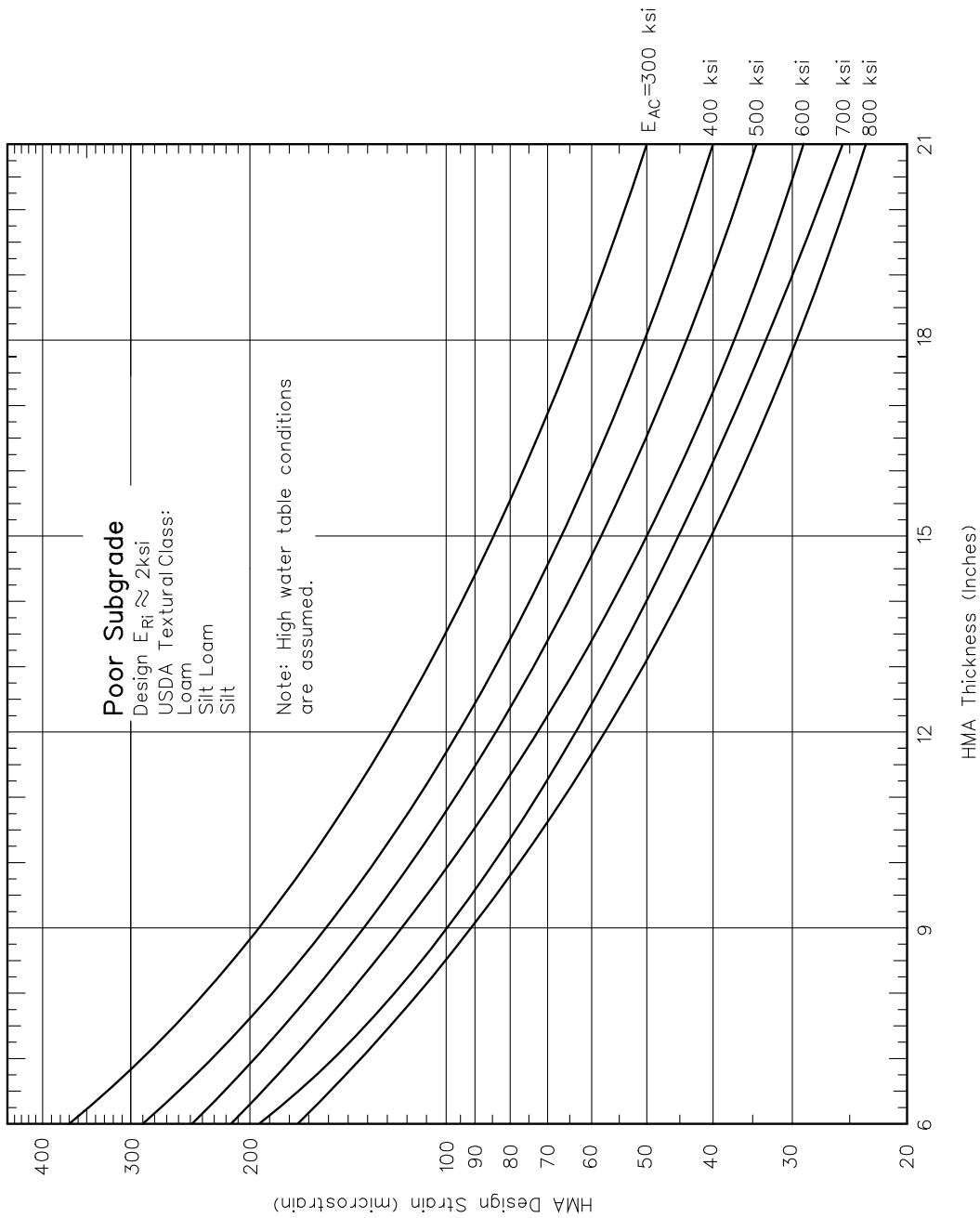
POOR SUBGRADE DESIGN CHART
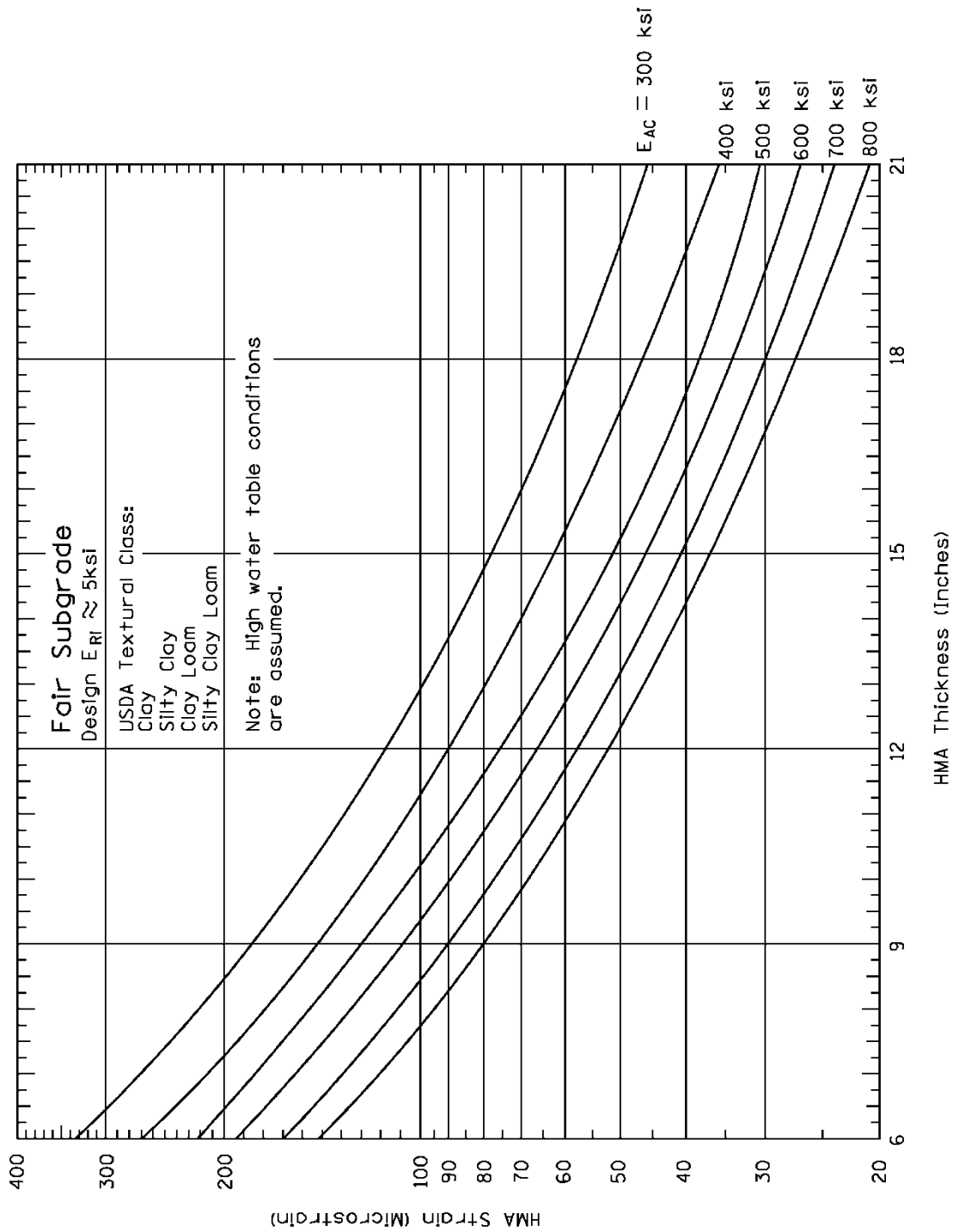
Figure 44-4J

FAIR SUBGRADE DESIGN CHART

Figure 44-4K

Granular Subgrade

USDA Textural Class:
Sand

AASHTO Soil Classification:
A-1
A-3
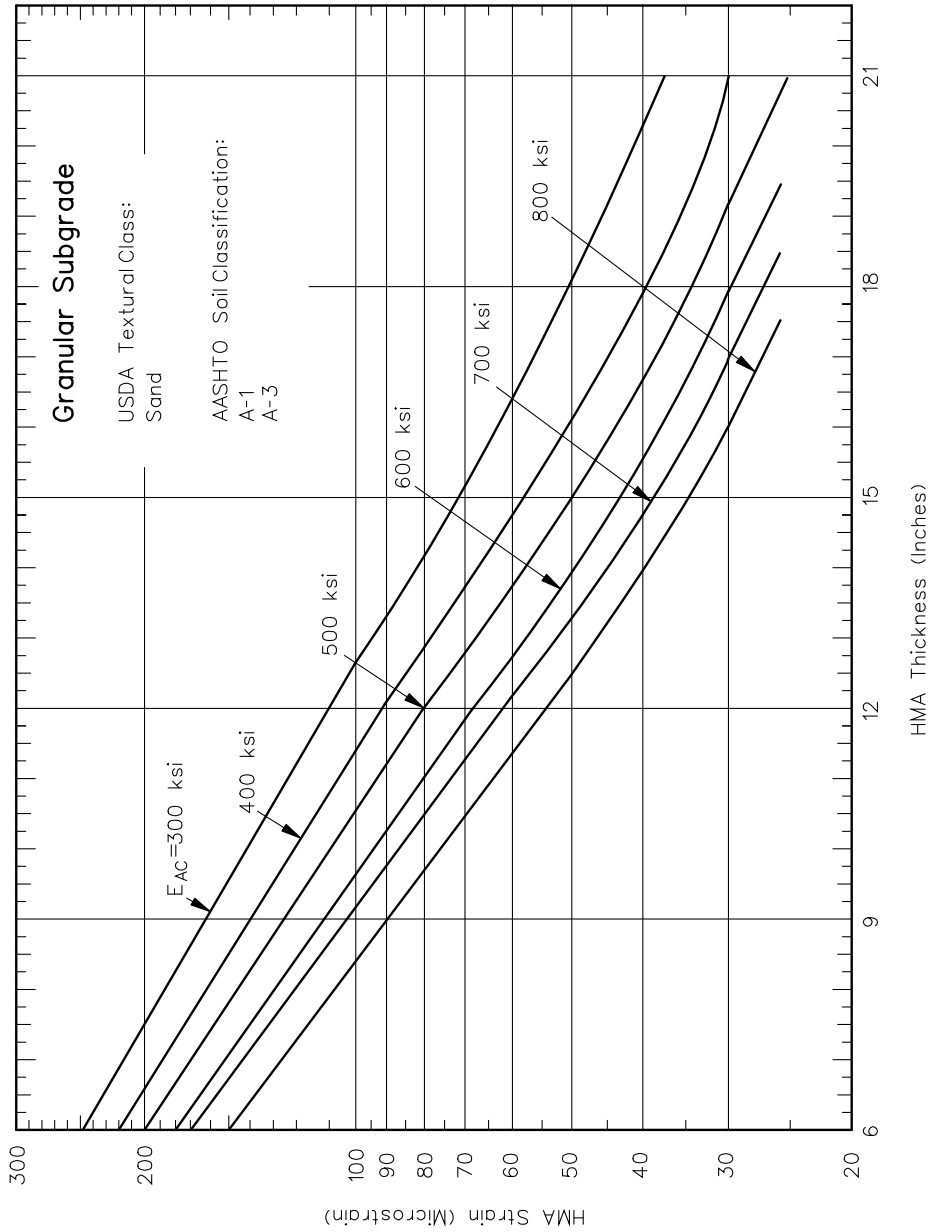
GRANULAR SUBGRADE DESIGN CHART

Figure 44-4L
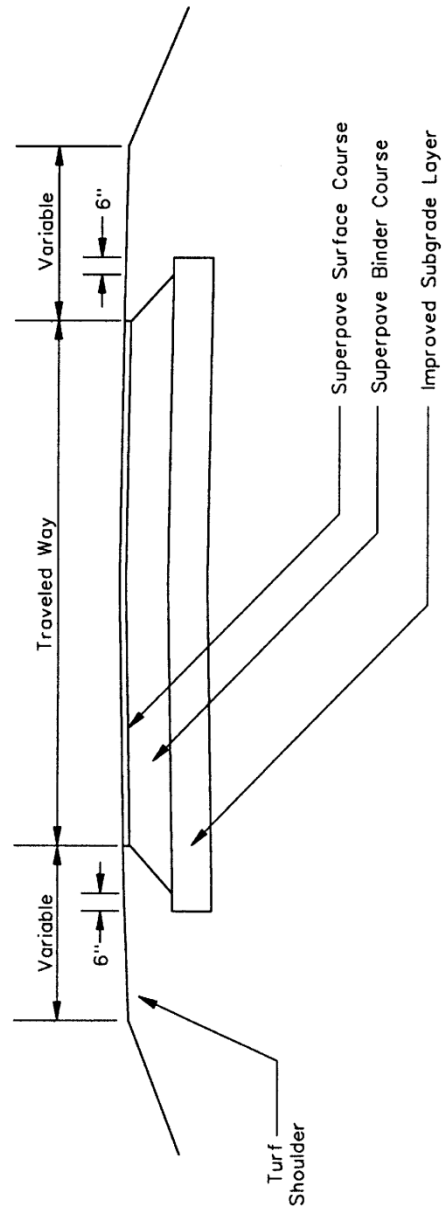
TYPICAL FULL-DEPTH RURAL DESIGN

Figure 44-4M

Traveled Way

Superpave Surface Course

Superpave Binder Course

Improved Subgrade Layer

Flush Median (If Required)

Curb & Gutter
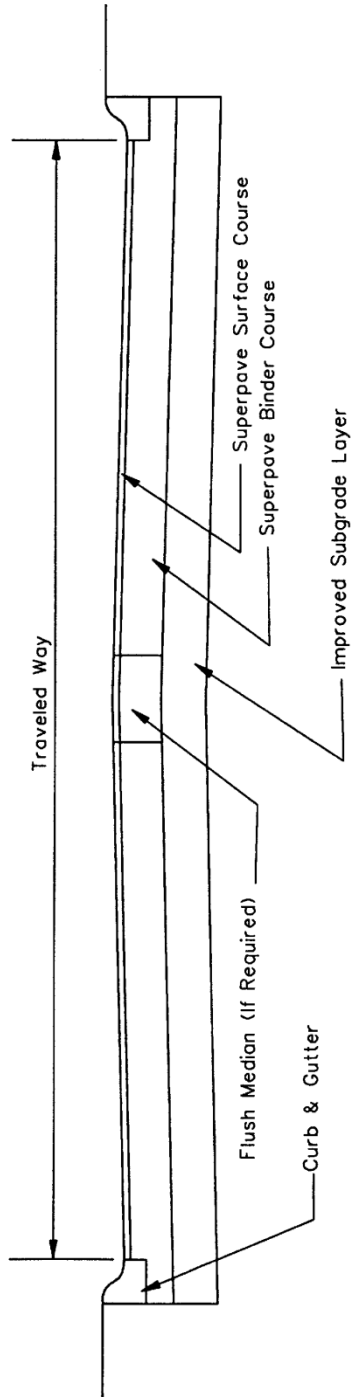
Note: Raised median with curb and gutter may be used in lieu of a flush median

TYPICAL FULL-DEPTH URBAN DESIGN

Figure 44-4N

Date: _____   Route: _____

Calculations by:_____   Section: _____

Checked by: _____   County:_____

Class: _____ Roads and Streets   Location: _____

Limits of Analysis: **Pavement Design:**

Station _____ To   Subgrade Support Rating (SSR):

Station _____   _____ (fair, poor, or granular)

Length: _____Ft _____Miles   Flexible Traffic Factor: _____

Structural Design Traffic: Selected Design PG Binder: _____

ADT: _____   Design Pavement HMA Temp.: _____°F

PV: _____   Design HMA Modulus (E_{AC}): _____ ksi

SU: _____   Design HMA Microstrain: _____

MU: _____   Pavement Thickness: _____ in

          Subgrade: _____

          Comments: _____

FULL-DEPTH HMA PAVEMENT
DESIGN CALCULATIONS FOR LOCAL AGENCIES
Figure 44-4O

44-4.05   Example Calculations

Figure 44-4O provides a chart for design calculations.

* * * * * * * * * *

Example 44-4.1

Given: Class I, 4-lane pavement
            Design Period: 20 years
            Design Traffic:
                ADT: 14,000
                86% PV (12,040), 8% SU (1,120), 6% MU (840)
            Location: Lake County
            Design subgrade support rating: fair
            Posted speed limit: 30 mph (No Standing Traffic)

Problem: Design a full-depth HMA pavement for the given conditions.

Solution:

2.   From Figure 44-4B use the TF equation for a 4-lane Class I pavement.

        4 or 5 Lane Pavement (Rural and Urban):

$$TF = DP\left[\frac{(0.047PV + 59.625SU + 217.139MU)}{1,000,000}\right]$$

$$TF = DP\left[\frac{(0.047 \times 12,040 + 59.625 \times 1,120 + 217.139 \times 840)}{1,000,000}\right]$$

$$TF = 4.99$$

2.   From Figure 44-4D, the binder grade should be PG 64-28, SBR PG 64-28, or SBS PG 64-28 on the surface. A PG64-22 or PG58-22 may be used for binder lifts.

3.   From Figure 44-4F the design pavement HMA temperature would be 76°F.

4.   Use Figure 44-4H (TF ≥ 0.5) in conjunction with the design TF of 4.99 to determine that the HMA design strain is 63 microstrain.

5.   Use Figure 44-4I in conjunction with a design pavement HMA temperature of 76°F to determine that the HMA design modulus is 650 ksi for PG 64-28.

6.   Use Figure 44-4K (subgrade support rating is fair) in conjunction with the HMA strain of 63 microstrain and the design modulus of 650 ksi to determine a design HMA thickness of 12.25 in. This is the thickness after rounding to the next higher 0.25 in.

7.   A 12 in improved subgrade is required for all Class I and II full-depth HMA projects unless built upon a granular subgrade.

Example 44-4.2

Given: Class II, two-lane pavement
          Design Period: 20 years
          Design Traffic:
              ADT: 3000
              95% PV (2850), 3% SU (90), 2% MU (60)
          Location: Springfield, Sangamon County
          The subgrade particle sizes are as follows:
              20% Sand; 55% Silt; 25% Clay
          Posted speed limit: 30 mph (with bus stops)

Problem: Design a full-depth HMA pavement for the given conditions.

Solution:

1.   From Figure 44-4B use the TF equation for a 2-lane Class II.

      2 or 3 Lane Pavement:

$$TF = DP \left[\frac{(0.073PV + 56.030SU + 192.720MU)}{1,000,000} \right]$$

$$TF = DP \left[\frac{(0.073 \times 2,850 + 56.030 \times 90 + 192.720 \times 60)}{1,000,000} \right]$$

$$TF = 0.374$$

2.   From Figure 44-4D, the binder grade should be PG 76-22, SBR PG 76-22, or SBS PG 76-22 on the surface. The bus stops will result in standing traffic. A PG64-22 or PG58-22 may be used for binder lifts.

3.   Based on the subgrade particle sizes and Figure 44-6A, the subgrade support rating is poor.

4.   From Figure 44-4F, the design pavement HMA temperature for Sangamon County would be 80.8°F.

5.   Use Figure 44-4G, TF is less than 0.5, in conjunction with the design TF of 0.336 to determine that the HMA design strain is 190 microstrain.

6.   Use Figure 44-4I in conjunction with the design pavement HMA temperature of 80.8°F to determine that the HMA design modulus is 525 ksi for a PG 76-22.

7.   Use Figure 44-4J, subgrade support rating is poor, in conjunction with the HMA strain of 210 microstrain and the design modulus of 525 ksi to determine a design HMA thickness of 7.00 in. This thickness is after rounding to the next higher 0.25 in.

8.   A 12 in improved subgrade is required for all Class I and II full-depth HMA projects unless built upon a granular subgrade.

Example 44-4.3

Given: Class IV, 2-lane pavement
         Design Period: 20 years
         Design Traffic:
             ADT: 350
             90% PV (315), 6% SU (21), 4% MU (14)
         Location: Marion, Williamson County
         Design subgrade support rating: poor
         Asphalt Binder: PG 64-22
         Fall construction is expected.

Problem: Design a full-depth HMA pavement for the given conditions.

Solution:

1.   There are 35 HCV's per day (21 SU's + 14 MU's).

2.   Because the pavement is a Class IV road with less than 40 HCV's per day, a minimum 6 in HMA pavement is required. A 12 in improved subgrade layer should be included as part of the design.

   Note: A 12 in improved subgrade is optional for Class III and IV full-depth HMA projects. The subgrade still must satisfy the requirements of Section 44-7. In this case, due to the poor subgrade support rating and possible late fall construction with little chance of good drying weather, a 12 in 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.

* * * * * * * * * *

44-5   COMPOSITE PAVEMENT DESIGN FOR LOCAL AGENCIES

44-5.01   Introduction

44-5.01(a)   Design of Composite Pavements

A composite pavement is a pavement with a HMA surface layer over a Portland cement concrete (PCC) slab. Advantages of placing the HMA layer over the PCC slab include a reduced PCC slab thickness due to the structural contribution of the HMA, and a more uniform surface appearance in the event that pavement patches are used to repair utility cuts, or due to widening or otherwise modifying the existing pavement. The HMA surface layer also results in reduced thermal gradients through the PCC slab. These reduced thermal effects also allow for increased spacing between joints in the PCC slab.

Whitetopping, a thin PCC overlay over an existing HMA surfaced pavement, is a special design covered in Section 46-5.

44-5.01(b)   Usage of Procedure

The composite pavement design procedure may be used for new construction, reconstruction (removal and replacement using the same alignment), or add lanes.

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 yd^2, or

- widening less than 1 lane width.

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

- duplicate the existing total pavement structure, or

- provide a structurally equivalent pavement, or

- design assuming a "poor" subgrade support rating.

Stage construction is the planned construction of the pavement structure in 2 or more stages. If stage construction of a composite pavement is planned for separate contracts, the designer should design the PCC slab thickness and joint spacing using the rigid pavement design procedure.

44-5.02   Basic Design Elements

44-5.02(a)   Minimum Material Requirements

The Portland cement concrete must meet the requirements for Class PV concrete, as specified in the *IDOT Standard Specifications*. All HMA lifts must comply minimum thicknesses in Section 44-1.02. Type A granular subbase, according to the requirements of the *IDOT Standard Specifications*, must be used where granular subbase is specified.

44-5.02(b)   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.   These road classifications are defined in Section 44-1.

44-5.02(c)   Design Period

The design period (DP) is the length of time in years that the pavement is being designed to serve the structural design traffic. For all classes of composite pavements, the minimum design period is 20 years.

44-5.02(d)   Structural Design Traffic

The structural design traffic is the estimated 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 10 years after the construction date.

The structural design traffic is estimated from current traffic count data obtained either by visual counts or from traffic maps published by IDOT. If SU and MU counts are not available for Class III and IV roads and streets, an estimate of those counts may be made from the component percentages of the total traffic in Figure 44-5A.

Class of Road or Street	Percentage of Structural Design Traffic		
	PV (%)	SU (%)	MU (%)
III	88	7	5
IV	88	9	3

TRAFFIC PERCENTAGE (CLASS III AND IV)

Figure 44-5A

44-5.02(e)   Traffic Factors

For Class I, II, and III roads and streets, the design Traffic Factor (TF) for composite pavements is determined from the 80,000 lb load limit formulas shown in Figure 44-5B. The formulas 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 (e.g., 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). These cases should be referred to the Central BLRS for special analysis. It will be necessary for the local agency to provide the Central BLRS with the structural design traffic, the design period, and traffic distribution by PV, SU, and MU vehicles.

For Class IV composite pavements, a design TF is not necessary. A preadjusted PCC slab thickness of 6 in should be used for all Class IV composite pavements.

Class I Roads and Streets	
4 or 5 Lane Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.047PV + 64.715SU + 313.389MU)}{1{,}000{,}000}\right]$
6 or More Lane Pavements (Rural)	$TF = DP\left[\dfrac{(0.029PV + 57.524SU + 278.568MU)}{1{,}000{,}000}\right]$
6 or More Lane Pavements (Urban)	$TF = DP\left[\dfrac{(0.012PV + 53.210SU + 257.675MU)}{1{,}000{,}000}\right]$
One-way Street Pavements (Rural and Urban)	$TF = DP\left[\dfrac{(0.073PV + 71.905SU + 348.210MU)}{1{,}000{,}000}\right]$
Class II Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 67.890SU + 283.605MU)}{1{,}000{,}000}\right]$
Class III Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\dfrac{(0.073PV + 64.790SU + 281.235MU)}{1{,}000{,}000}\right]$ TF minimum = 0.5

COMPOSITE PAVEMENT TRAFFIC FACTOR EQUATIONS (80,000 lb Load Limit)

Figure 44-5B

44-5.02(f)   Transverse Pavement Joints

For composite pavements, use 20 ft transverse joint spacing. Use of joint spacing less than 20 ft does not significantly reduce the PCC slab thickness compared with bare PCC jointed pavements. Use of joint spacings in excess of 20 ft can result in intermediate cracking.

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 (e.g., dowel bars) are required on pavements that have a design TF of 3.0 or greater. For pavements with a TF less than 3.0, the designer has the option of using dowel bars or relying on aggregate interlock for load transfer.

Transverse joints in the PCC slab will result in reflective cracking in the HMA surface. Sawed and sealed joints in the HMA surface should be considered over all transverse PCC joints in order to facilitate future maintenance.

44-5.02(g)   Subgrade

Roadbed soils that are susceptible to excessive volume changes, permanent deformation, excessive deflection and rebound, frost heave, and/or non-uniform support can affect pavement performance. For Class I and II roads, the designer is required to follow the guidelines found in Section 44-7. Use of Section 44-7 is optional for all Class III and IV roadways. In situ soils that do not develop an Immediate Bearing Value (IBV) in excess of 6.0 when compacted at, or wet of, optimum moisture content, require corrective action. The designer should recommend corrective actions (e.g., undercutting, moisture density control, modified soil layer) in the design plans and specifications.

Necessary corrective actions as required by Section 44-7 will be in addition to the subbase requirements of the pavement design.

44-5.02(h)   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 3 subgrade support ratings (SSR) — poor, fair, and granular. The SSR is determined by using geotechnical grain size analysis and Figure 44-6A. The SSR should represent the average/majority classification within the design section. Figure 44-6A 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 in Figure 44-5C are based on a fair SSR. Adjustments in the design thickness are made for the poor and granular subgrades.

44-5.02(i)   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 shown in Figure 44-5D.

When placing a composite pavement directly over a flexible pavement with a HMA surface, consult with the Central BLRS for design assistance.
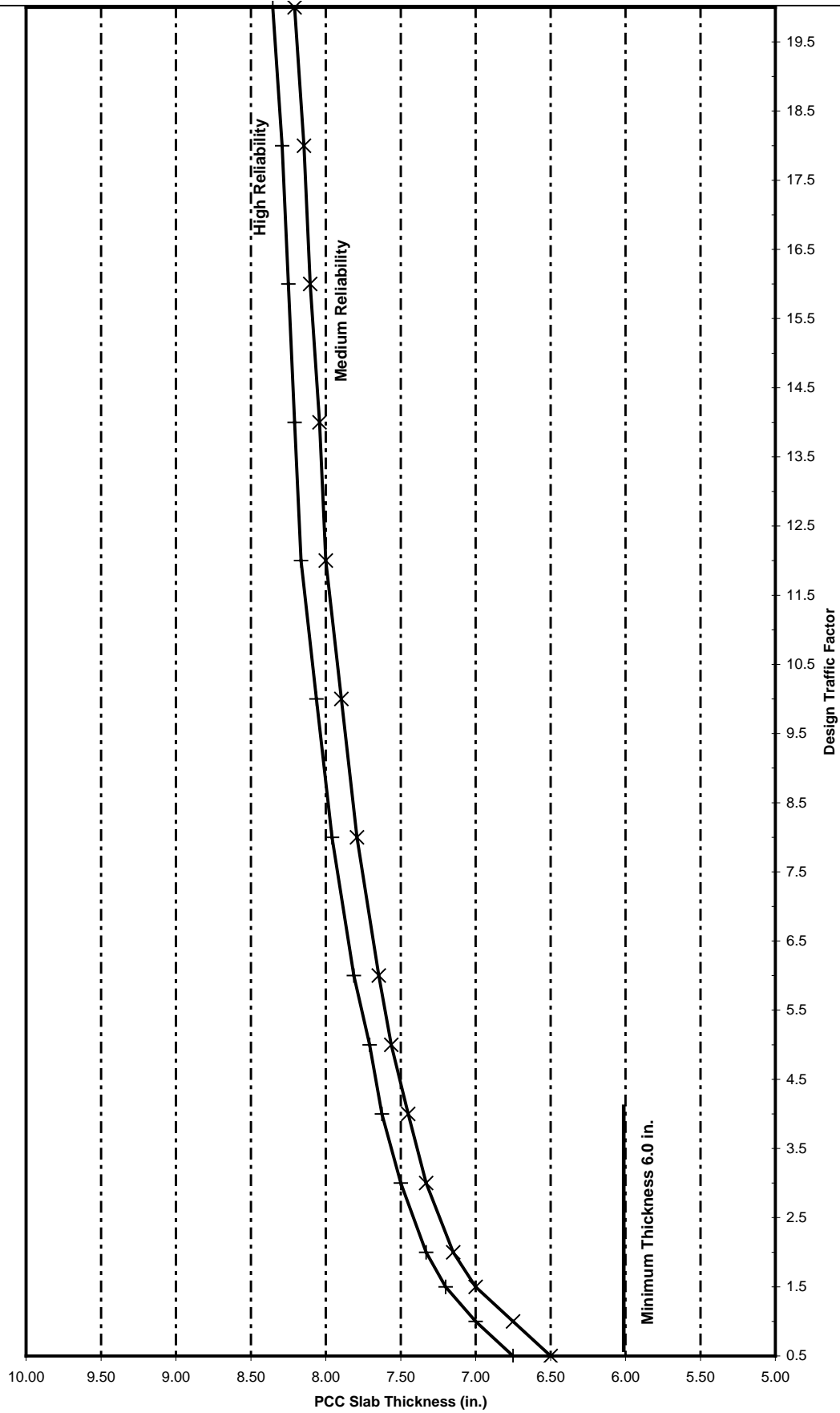
SLAB THICKNESS
(3 in HMA Surface on PCC Slab, Fair Subgrade)

Figure 44-5C

Road Class	Subbase Material	Usage[1]	Minimum Thickness (in)
Class I & II	Stabilized Material	Required	4
Class III & IV	Granular[2], T.F. $\geq$ 0.7 Granular[2], T.F. < 0.7	Required Optional	4 4

Notes:

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

2.   *Use Type A granular subbase according to the requirements of the* IDOT Standard Specifications*.*

SUBBASE REQUIREMENTS

Figure 44-5D

44-5.02(j)   PG Binder Grade Selection

The PG binder grade can affect the performance of a HMA mixture. Rutting or permanent deformation of the HMA surface is a distress common to composite pavements. This design procedure assumes that HMA rutting is considered in the material selection and mixture design process. Because the binder grade can impact the ability of the mix to resist rutting, selection of the appropriate high temperature grade is important. Thermal cracking is not a failure mode for composite pavements, and so the lower temperature grade is not as critical. That is why PG XX-22 binders are specified for composite pavements rather than the PG XX-28 grades appropriate for full-depth HMA pavements, where thermal cracking is of concern.

Composite pavements should use the grades shown in Figures 44-5E and 44-5F. Areas of slow moving or standing traffic (e.g., intersections, bus stops, city streets) warrant the use of stiffer binders to resist rutting. These adjustments should be made according to Figures 44-5E and 44-5F for the corresponding N_{design} number, provided by the district, and/or design ESALs. The appropriate grade of binder should be reported on the plans.

Note that the PG binder grade selection tables for composite pavements for local agency pavement design differ from the tables used for the State system. A lower level of reliability is used for local agency design than for the State system.

The local agency must request a variance from Central BLRS to use a different PG binder than specified in Figure 44-5E and Figure 44-5F.

Illinois N_{design} Number	Flexible Design ESALs, millions[1] (Flexible TF)	PG Binder Grade Selection[2] [3][4]		
		Traffic Loading Rate		
		Standard[5]	Slow[6]	Standing[7]
30	< 0.3	PG 58-22	PG 58-22[8]	PG 64-22[8]
50	0.3 to < 3	PG 58-22	PG 64-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22
70	3 to < 10	PG 58-22	PG 64-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22
90	10 to < 30	PG 58-22[8]	PG 64-22[8]	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22
105	≥ 30	PG 64-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22

Notes:

1.   *Design ESALs are the anticipated project traffic level expected on the design lane over a 20 year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N_{design} level. For N_{design} and PG binder grade selection purposes only, the design ESALs are calculated using the flexible traffic factor equations found in the full-depth pavement design procedure. Rigid traffic factors given in Figure 44-5B and Figure 44-5C are required for the composite pavement thickness design.*

2.   *The binder grades provided in Figure 44-5E are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level".*

3.   *For mixtures containing a minimum of 15% RAP, the high temperature binder grade should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-22 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in Figure 44-5F.*

4.   *Use these grades for composite pavements and all overlays*

5.   *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*

6.   *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*

7.   *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*

8.   *Give consideration to increasing the high temperature grade by one grade equivalent.*

9.   *SBR modified binders are not available in Illinois at this time.*

PG BINDER GRADE SELECTION FOR COMPOSITE PAVEMENTS (DISTRICTS 1-4)

Figure 44-5E

Illinois N$_{design}$ Number	Flexible Design ESALs, millions [1] (Flexible T.F.)	PG Binder Grade Selection [2][3][4]		
		Traffic Loading Rate		
		Standard[5]	Slow[6]	Standing[7]
30	< 0.3	PG 58-22	PG 64-22[8]	PG 64-22[8]
50	0.3 to < 3	PG 64-22	PG 64-22[8]	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22
70	3 to < 10	PG 64-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22
90	10 to < 30	PG 64-22[8]	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22
105	≥ 30	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22

Notes:

1. *Design ESALs are the anticipated project traffic level expected on the design lane over a 20 year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N$_{design}$ level. For N$_{design}$ and PG binder grade selection purposes only, the design ESALs are calculated using the flexible traffic factor equations found in the full-depth pavement design procedure. Rigid traffic factors given in Figure 44-5B and Figure 44-5C are required for the composite pavement thickness design.*

2. *The binder grades provided in Figure 44-5F are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*

3. *For mixtures containing a minimum of 15% RAP, the high temperature binder grade should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-22 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in Figure 44-5G.*

4. *Use these grades for composite pavements and all overlays.*

5. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*

6. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*

7. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*

8. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

9. *SBR modified binders are not available in Illinois at this time.*

PG BINDER GRADE SELECTION FOR COMPOSITE PAVEMENTS (DISTRICTS 5-9)

Figure 44-5F

44-5.02(k) Design Reliability

Design reliability is taken into account through traffic multipliers applied to the design TF. These traffic multipliers are built into the PCC slab thickness design curves in Figure 44-5C. Figure 44-5C contains curves for both high and medium reliability levels. The minimum reliability levels by class of road are shown in 44-5G.

Road Class	Minimum Reliability Levels	Percent Reliability
Class I and II	High	90's
Class III & IV	Medium	70's and 80's

RELIABILITY LEVELS

Figure 44-5G

44-5.03 Thickness Design

44-5.03(a) Minimum Design Thickness

Once all pavement thickness adjustments have been made, the minimum design must have at least:

- 2.0 in of HMA and 6.5 in of PCC, or
- 3.0 in of HMA and 6.0 in of PCC.

44-5.03(b) Preadjusted Slab Thickness

The composite thickness design procedure is based on determining the thickness of the preadjusted pavement assuming a fair SSR, 3 in of HMA surface, 20 ft joint spacing, and a flexible or untied PCC shoulder. Using the level of reliability specified in Figure 44-5G and the design TF, the PCC slab thickness is determined from the curves shown in Figure 44-5C. For Class IV pavements, the preadjusted slab thickness is 6 in. Adjustments to this basic slab thickness can be made for other factors (e.g., pavement support, shoulder type, overloads, and HMA thickness). Adjustments for pavement support conditions must be done prior to other adjustments. The final design thickness should be rounded to the next highest 0.25 in.

44-5.03(c) Slab Thickness Adjustments

In determining any adjustments, consider the following:

1. <u>Pavement Support</u>. Pavement thickness adjustments are based on the subgrade rating and whether or not the pavement structure will have a subbase. The subgrade support adjustments factors are shown in Figure 44-5H.

    Regardless of the decreases indicated in Figure 44-5H, provide a minimum PCC slab thickness for composite pavements of at least 6.0 in.

Subgrade Rating	Subbase Type	Slab Thickness Adjustment (in)
Poor	None	+ 0.25
Poor	Granular	No adjustment
Poor	Stabilized	- 0.25
Fair	None	No adjustment
Fair	Granular	- 0.25
Fair	Stabilized	- 0.25
Granular	None	- 0.25
Granular	Granular	- 0.25
Granular	Stabilized	- 0.25
	Existing Pavement	- 0.25

ADJUSTMENTS FOR PAVEMENT SUPPORT
Figure 44-5H

2.   Shoulder Type.   With flexible or untied PCC shoulders, no adjustments are allowed. Adjustments for tied PCC shoulders, tied curb and gutter, integral curb and gutter, or widened outer lanes will be made according to Figure 44-5I. To receive the thickness reduction, the tied shoulders must be tied with a #6 or larger tie bar at 24 in spacing.   A #6 or larger bar is required to ensure that load transfer is obtained between the pavement and the curb/shoulder. Designers may specify smaller tie bars, but in these cases, no deduction in pavement thickness will be allowed based on shoulder type.

Slab Thickness (in) after adjustment for support conditions	Slab Thickness Adjustment (in)
> 8.0	- 0.50
8.0 in to 7.0	- 0.375
< 7.0	No adjustment

ADJUSTMENTS FOR SHOULDER TYPE
Figure 44-5I

3.   Overloads. Pavement overloads are those loads that are anticipated to exceed the load limits from which the design TF's were developed. These loads are typically created by permit loads and commercial, garbage, construction, and farm trucks, as well as buses and some farm implements. For those pavements for which a significant number of overloads can be anticipated, adjust the pavement thickness as shown in Figure 44-5J.

For pavements designed for a TF of 1.0 and higher, no thickness adjustment is necessary. Care must be taken, however, to ensure the TF selected for design accurately represents the anticipated traffic. A project adjacent to an industrial site with HCV's entering and exiting the site should be referred to the Central BLRS for special analysis.

Design TF	Average No. Overloads Per Week	Slab Thickness Adjustment (in)
≤ 0.50	5	+ 0.15
	10	+ 0.30
.50 to 0.75	5	+ 0.10
	10	+ 0.15
0.75 to 1.0	5	+ 0.05
	10	+ 0.10
> 1.0	5	No Adjustment
	10	No Adjustment

ADJUSTMENTS FOR OVERLOADS
Figure 44-5J

4.   HMA Surface Layer Thickness. The preadjusted slab thickness is based on a HMA surface layer of 3 in placed on the PCC slab. If the HMA layer thickness is other than 3 in, adjust the thickness using Figure 44-5K. In no case should the thickness of the HMA layer be less than 2 in or the PCC slab less than 6 in.

HMA Layer Thickness (in)	Thickness Adjustment for PCC Slab (in)
2	+ 0.50
2.5	+ 0.25
3	No adjustment
4	- 0.25
5	- 0.50

ADJUSTMENTS FOR HMA THICKNESS
Figure 44-5K

44-5.03(d)   Dowel Bars

Dowel bars must be used in all pavements with a TF of 3.0 or greater. Dowel bar diameter requirements are given in Figure 44-5L.

Normal dowel spacing is 12 in; however, with approval from the Central BLRS, the dowels can be clustered in the wheel paths. There are no adjustments in pavement thickness when doweled joints are used.

Slab Thickness (in)	Dowel Diameter (in)
$\geq$ 8.00	1.50
7.00 to 7.99	1.25
$<$ 7.00	1.00

DOWEL DIAMETER
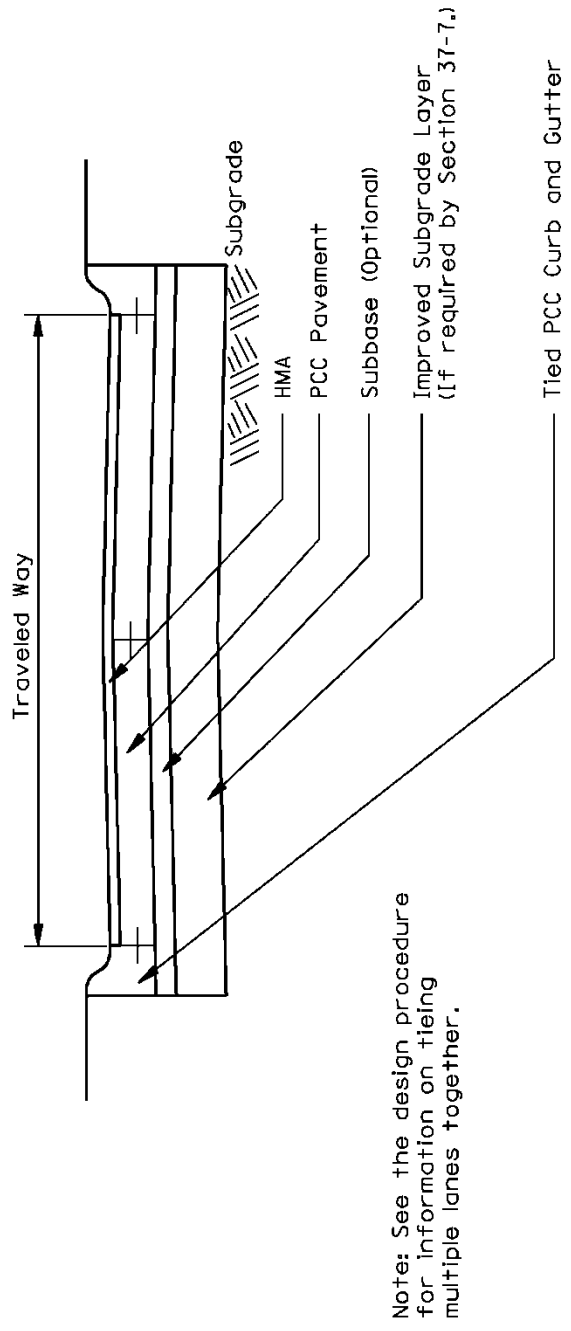
Figure 44-5L

44-5.03(e)   Typical Sections

Figures 44-5M, 44-5N, and 44-5O illustrate typical local agency composite pavement designs.
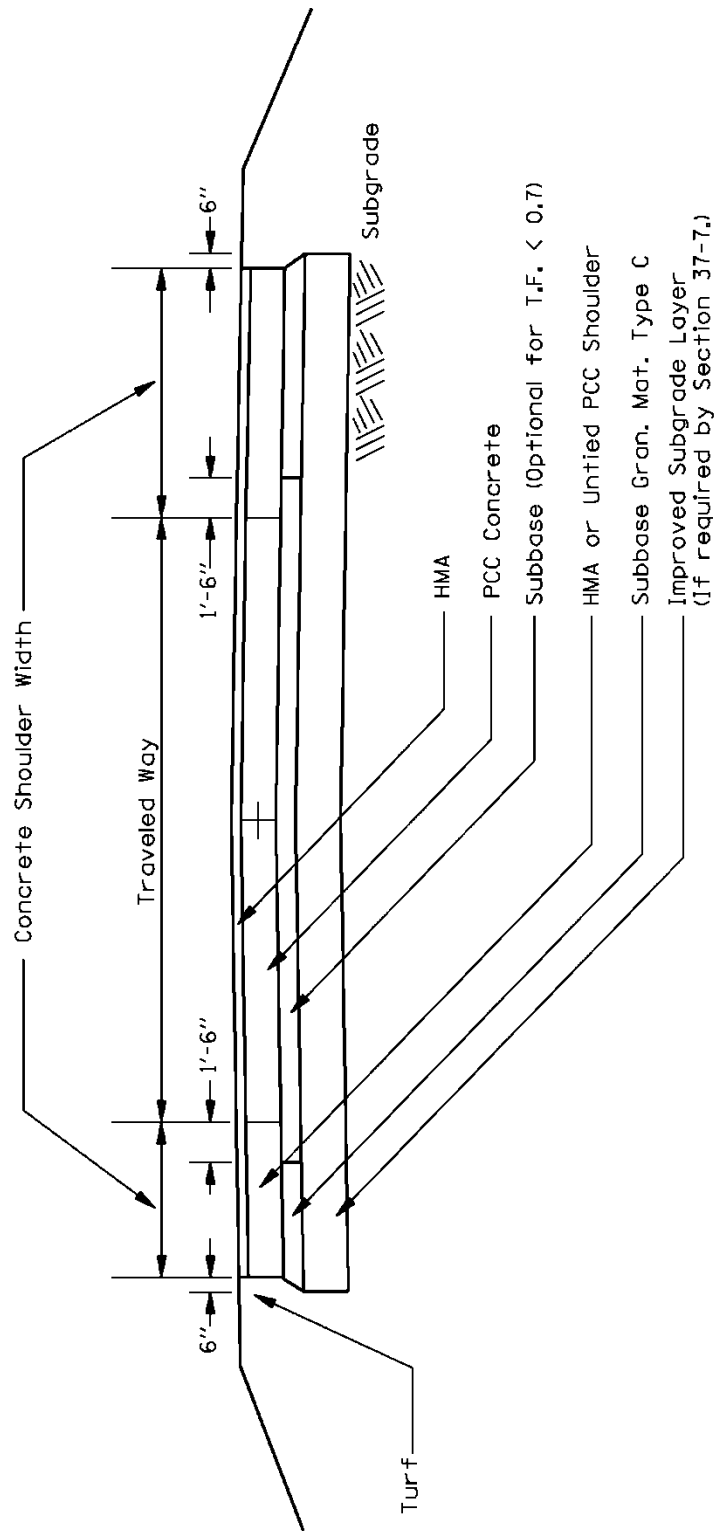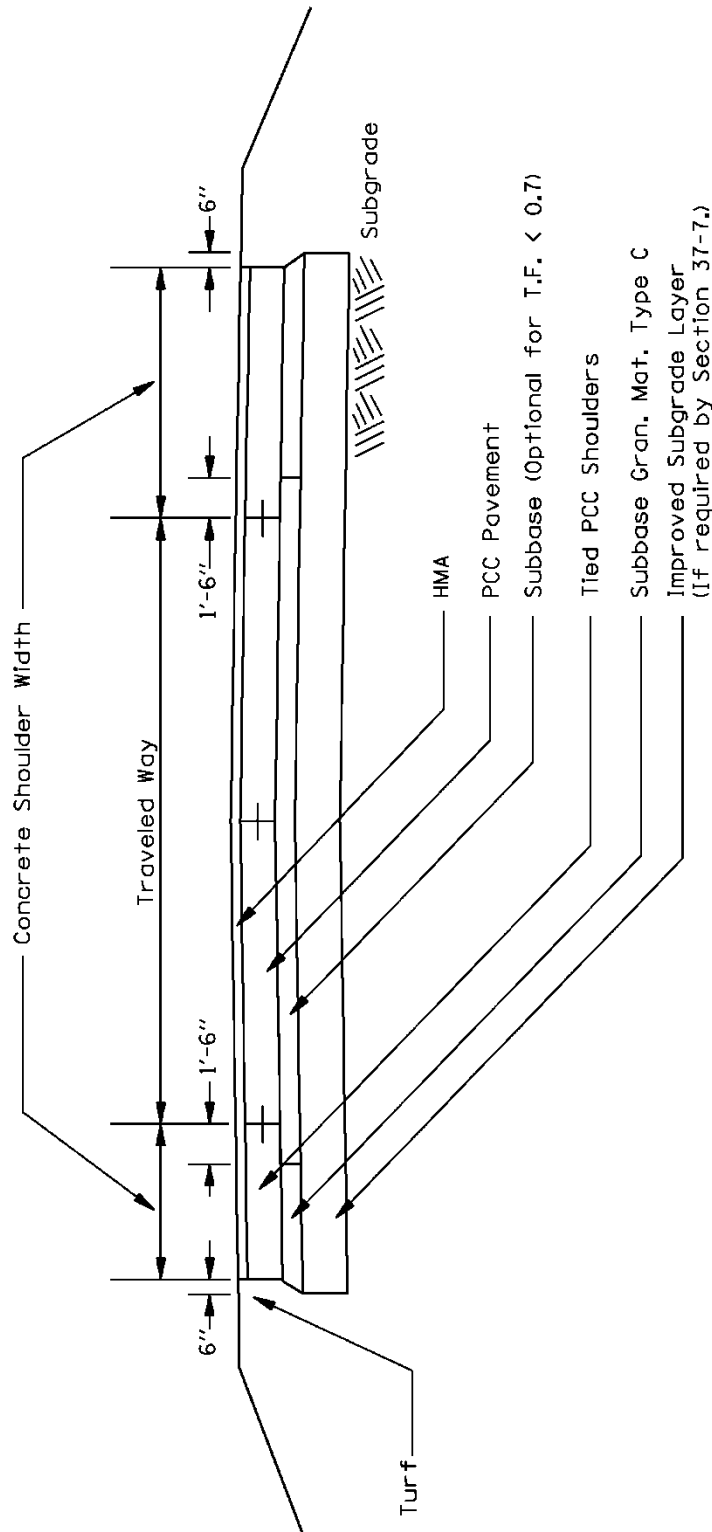
TYPICAL COMPOSITE DESIGN WITH UNTIED SHOULDERS

Figure 44-5M

TYPICAL COMPOSITE DESIGN WITH TIED CURB AND GUTTERS

Figure 44-5N

TYPICAL COMPOSITE DESIGN WITH TIED SHOULDERS

Figure 44-5O

44-5.04   Example Calculation

* * * * * * * * * *

Example 44-5.1

Given: Class I, one-way urban street
                Design period: 20 years
                Design Traffic:
                        ADT: 8900
                        94% PV (8366), 5% SU (445), 1% MU (89)
                Subgrade Support Rating: poor
                Shoulders: tied curb and gutter
                Overloaded vehicles: 5 per week
                3 in HMA surface
                Ndesign level: 50
                District 6, Slow Traffic

Problem: Design a composite pavement for the given conditions.

Solution:

1.   Use Figure 44-5B and determine the TF equation for a one-way Class I pavement.

        One-way Streets and Pavements (Rural and Urban)

$$TF = DP\left[\frac{(0.073PV + 71.905SU + 348.210MU)}{1{,}000{,}000}\right]$$

$$TF = DP\left[\frac{(0.073 \times 8{,}366 + 71.905 \times 445 + 348.210 \times 89)}{1{,}000{,}000}\right]$$

$$TF = 1.27$$

2.   Because the pavement is a Class I facility, a high design reliability is required; see Figure 44-5G. A subbase is optional; see Note #1 in Figure 44-5D. For this example, assume a 4 in stabilized subbase is used. According to Section 44-5.02(f), if the TF is less than 3.0, the designer may choose either dowels or aggregate interlock for load transfer.

3.   From Figure 44-5C, the slab thickness required for high reliability, fair subgrade support, and flexible shoulders is 7.0 in, with a 3 in HMA overlay. From this thickness adjustments can be made for pavement support, shoulder type, overloads, and HMA thickness.

Basic slab thickness (from Figure 44-5C):	7.25 in
Adjustment for poor subgrade with stabilized subbase (Figure 44-5H):	-0.25 in
Slab thickness adjusted for support conditions*:	7.00 in
Adjustment for tied curb and gutter with slab less than 7 in (Figure 44-5J):	No Adjustment
Adjustment for overloads with TF of 1.02 (Figure 44-5K):	No Adjustment
Adjustment for 3 in HMA surface (Figure 44-5L):	No Adjustment
Final thickness:	7.00 in

All other adjustments are made on slab thickness after adjustment for support conditions.

4. Alternative designs may be made by varying the HMA surface thickness. See Figure 44-5K. For example, another possible design could be a 7.25 in PCC slab with 2.5 in of HMA surface.

5. Based on Figure 44-5F, a PG 64-22 binder should be used, assuming slow traffic, with average traffic speeds from 12 to 43 mph, although consideration should be given to specifying a PG 70-22, SBR PG 70-22, or SBS PG 70-22.

44-6   SUBGRADE INPUTS FOR LOCAL ROAD PAVEMENT DESIGN

44-6.01   Introduction

The variability of in situ 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.

44-6.01(a)   Full-Depth Asphalt Concrete, Jointed PCC, and Composite Pavements

A Subgrade Support Rating (SSR) is used as the design subgrade input for full-depth HMA, jointed PCC, and composite pavement designs. The SSR is based on a grain size analysis of the subgrade soil. Figure 44-6A 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.
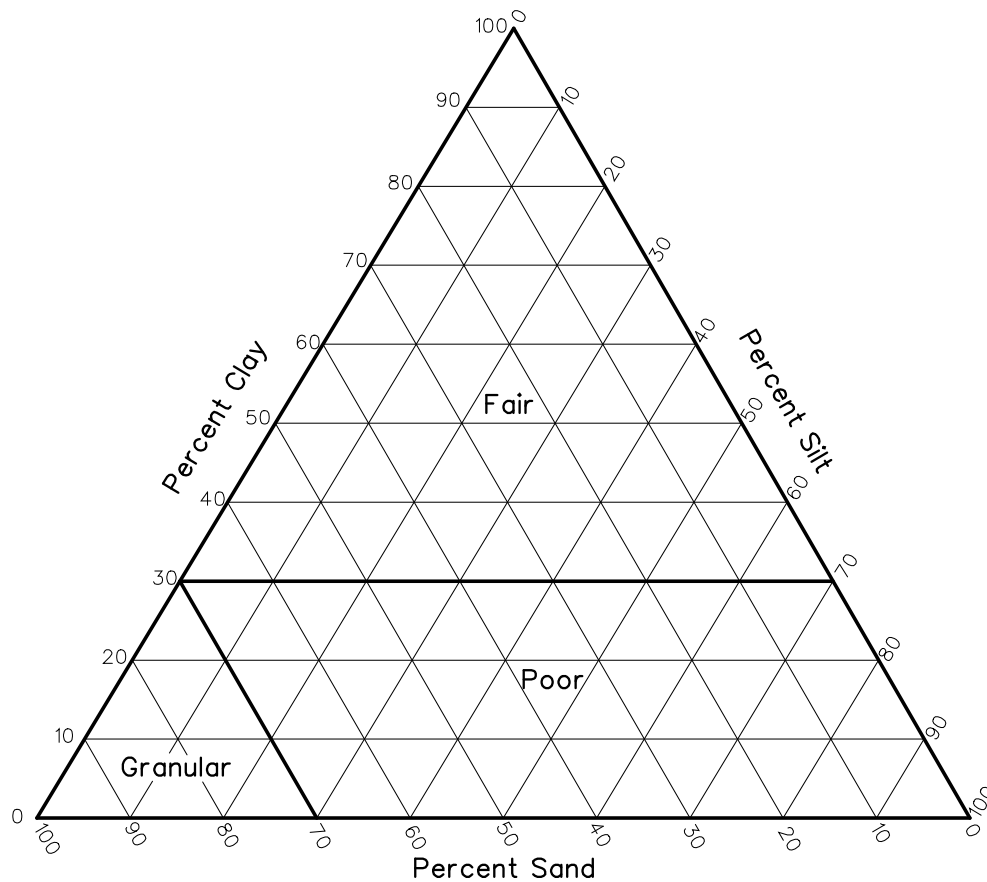
SUBGRADE SUPPORT RATING (SSR)

Figure 44-6A

44-6.01(b)   Flexible Pavement Design

The procedures discussed in this Section do not apply to full-depth HMA pavements.

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 HMA. The E_{Ri} is an indicator of a soil's resilient behavior under loadings. 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.

To determine the subgrade resilient modulus, use the following procedures:

1.   Preliminary E_{Ri} Determination. Listed below are 5 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. The 5 methods are described below:

   a.   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 Central BLRS may be contacted for additional information regarding a resilient modulus testing format.

   b.   Falling Weight Deflectometer (FWD) Testing. Design E_{Ri} values can be back calculated 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 back calculated E_{Ri} if the FWD testing is conducted during other seasons. Contact the Central BLRS if a seasonal adjustment factor is required. The average E_{Ri} back calculated 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. Back calculated 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.

c.   <u>Estimating E_{Ri} from Strength Data</u>. 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 in depth of penetration and a maximum load of 150 lbs (IBV = 7.5). Data obtained from Corps of Engineers hand-held cone penetrometer and DCP testing can be used to estimate the IBV and E_{Ri} through the following equations:

$$IBV = \frac{CI}{40}$$ Equation 44-6.1

Where: IBV = Immediate Bearing Value
                 CI   = Corps of Engineers Cone Index, psi

$$LOG\ IBV = 0.84 - 1.26\ LOG\ (PR)$$ Equation 44-6.2

Where: IBV = Immediate Bearing Value
                 PR   = DCP penetration rate, in/blow

$$Q_u = 4.5\ IBV$$ Equation 44-6.3

Where: Q_u = Unconfined compressive strength, psi
                 IBV = Immediate Bearing Value

$$E_{Ri}* = 0.86 + 0.307\ Q_u$$ Equation 44-6.4

Where: $E_{Ri}*$ = Subgrade resilient modulus, ksi
                 Q_u = 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, this testing should be conducted during the spring. If testing is not conducted during the spring, the E_{Ri} value calculated from Equation 44-6.4 will need to be corrected as discussed in Section 44-6.01(b).

d.   <u>Estimating E_{Ri} from Soil Properties</u>. 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 44-6.5 may be used to predict E_{Ri} at optimum water content and 95% AASHTO T-99 maximum dry density:

$$E_{Ri}(OPT)^* = 4.46 + 0.098\ (\%\ Clay) + 0.119\ (PI)\qquad\text{Equation 44-6.5}$$

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 44-6B is a graphical solution to Equation 44-6.5. 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.
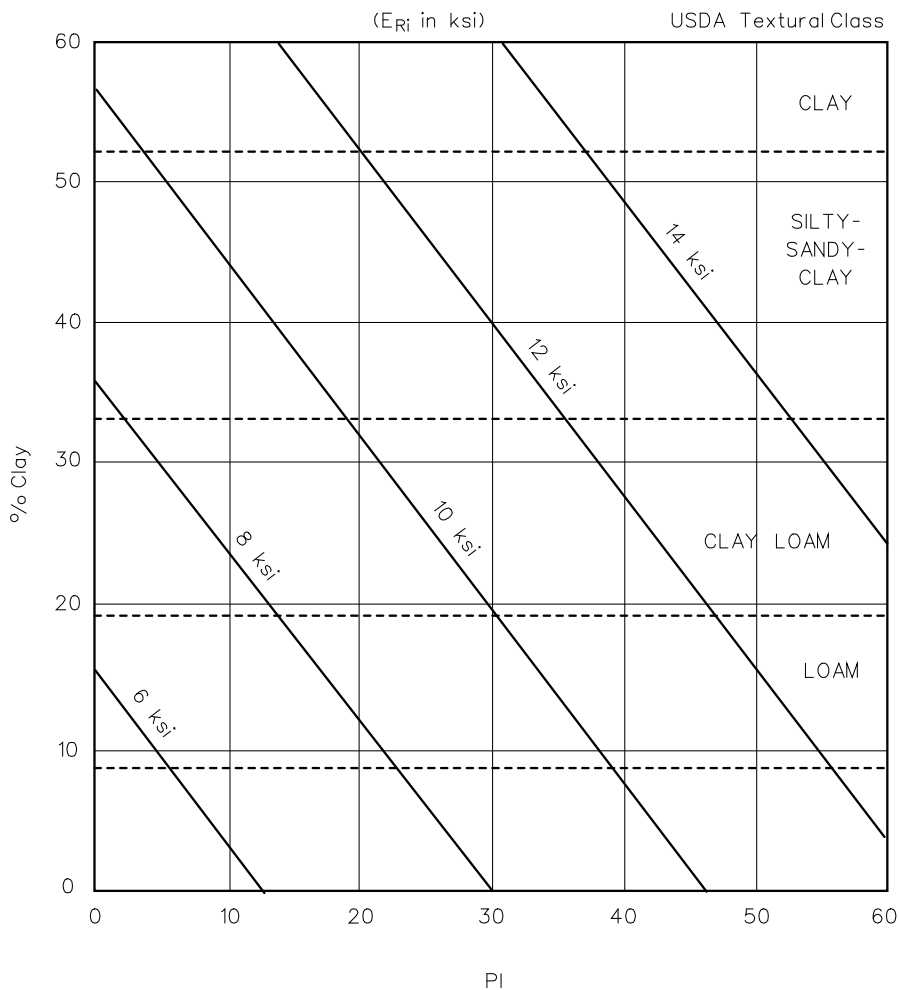
Subgrade E_{Ri} as a Function of %Clay, PI

E_{Ri} in ksi, at w_{opt} and 95% Max γ_d (T-99)

GRAPHICAL SOLUTIONS OF E_{RI} (OPT)

Figure 44-6B

e.   <u>Typical E_{Ri} Values</u>. If data are not available to estimate E_{Ri} values using the previously discussed methods, Figures 44-6C or 44-6D may be used to estimate typical E_{Ri} values. If the water table and frost penetration levels are known, Figure 44-6C may be used to determine typical E_{Ri} values based on the AASHTO soil classification system.

If the frost penetration and water table levels are not known, the designer may use Figure 44-6D to estimate a typical E_{Ri} value. These E_{Ri} values were developed from resilient modulus testing of fine-grained Illinois soils, represent 95% of AASHTO T-99 maximum dry density and moisture contents 2% wet of optimum.

AASHTO Soil Class	High-Water Table[1]		Low-Water Table[2]	
	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 ksi	4.0 ksi	3.0 ksi	6.0 ksi
A-7	2.0 ksi	5.0 ksi	3.5 ksi	7.0 ksi

Notes: 1. *Water table seasonally within 24 in of subgrade surface.*

       2. *Water table seasonally within 72 in of subgrade surface.*

AVERAGE E_{RI} VALUES BASED ON SOIL CLASSIFICATION, WATER TABLE DEPTH, AND FREEZE-THAW CONDITIONS

Figure 44-6C

AASHTO		USDA Textural Class	
Soil Classification	Average E_{Ri} [1] (ksi)	Soil Classification	Average E_{Ri} [2] (ksi)
A-7-6	9.2	Silty Clay, Clay	9.5
A-7-5	6.3	Silty Clay Loam, Clay Loam	7.3
A-6	5.6	Silt Loam, Loam, Silt	6.2
A-4	3.8	Sandy Clay [2]	9.0
A-5 [2]	4.5	Sandy Clay Loam [2]	7.0

95% of AASHTO T-99 maximum dry density and moisture contents 2% wet of optimum.

Notes: 1. *Moisture adjustment necessary.*

       2. *Estimated.*

AVERAGE E_{RI} VALUES FOR VARIOUS SOIL CLASSIFICATIONS

Figure 44-6D

2. <u>Moisture Adjustment Procedure</u>. 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. The following procedure will apply:

a. <u>Known MDD and OMC</u>. 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 44-6.6 can be used to calculate the moisture content for a given degree of saturation and 95% compaction.

$$MC_{\%SR} = \left[\frac{65.7}{MDD} - \frac{1}{G_s} \right] SR \qquad \text{Equation 44-6.6}$$

Where: $MC_{\%SR}$ = Moisture content for a given degree of saturation, %
              MDD = AASHTO T-99 maximum dry density, pcf
              G_s = 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% SR. All other drainage classes should be adjusted to a 90% SR. The drainage classification for a soil series can be found in the County Soil Report.

b. <u>Unknown MDD and OMC</u>. If the MDD and OMC have not been determined, they can be estimated using Equations 44-6.7 and 44-6.8 and then used to solve Equation 44-6.6.

OMC = 1.86 + 0.499 (LL) − 0.354 (PI) + 0.044 (P_{200})   Equation 44-6.7

MDD = 138.96 − 1.10 (LL) + 0.796 (PI) − 0.062(P_{200})   Equation 44-6.8

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.

c.   <u>Adjustment</u>. Once the moisture content for the required degree of saturation is calculated, the field moisture adjustment and design E_{Ri} can be calculated.

$$FMA = MC_{\%SR} - OMC \qquad\qquad\qquad \text{Equation 44-6.9}$$

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

$$\text{Design } E_{Ri} = E_{Ri} \text{ (OPT)} - ((FMA)(MAF)) \qquad\qquad \text{Equation 44-6.10}$$

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 Figure 44-6E based on USDA soil 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

**E_{Ri} MOISTURE ADJUSTMENT FACTORS BASED ON
USDA TEXTURAL CLASSIFICATION**

Figure 44-6E

d.   <u>Minimum Design E_{Ri} Values</u>. A design E_{Ri} of 2 ksi is the lowest allowable design E_{Ri}. If the design E_{Ri} value calculated from Equation 44-6.10 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 IBV values may require remedial subgrade treatments as outlined in Section 44-7. Engineering judgment may also be required to decrease the design E_{Ri} to account for the effect of freeze-thaw cycles on the in situ springtime design condition.

3.   <u>Composite E_{Ri} Estimate</u>. 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% of the subgrade deflection occurs in the upper 60 in 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 in zone should be calculated using Equation 44-6.11.

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

$$\text{Design Composite } E_{Ri} \text{ (ksi)} = \sum_{i=1}^{n} (F_i)(T_i)(E_i) \qquad\qquad \text{Equation 44-6.11}$$

Where: i =   Layer designator; $i = 1$ for the top layer
         n =   Number of layers
         F_i =   Deflection coefficient, see Figure 44-6F
         T_i =   Thickness of soil horizon in 60 in. depth zone, in.
         E_i = E_{Ri} for the soil horizon, adjusted for springtime conditions, ksi

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.

Depth Zone* (in)	F_i
1-12	0.038
12-24	0.015
24-36	0.008
36-60	0.011

Depth measured from surface of subgrade.

DEFLECTION COEFFICIENTS AS A FUNCTION OF DEPTH

Figure 44-6F

44-6.02   Subgrade Design Input Examples

44-6.02(a)   Grain Size Analysis

A grain size analysis shows that the subgrade soil contains 43% clay, 48% silt, and 9% sand. From Figure 44-6A, the Subgrade Support Rating (SSR) is FAIR. An SSR value is necessary for rigid and full-depth HMA pavement design procedures.

44-6.02(b)   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.

44-6.02(c)   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 in Figure 44-6G. IBV, Q_u, and E_{Ri} were calculated using Equations 44-6.2, 44-6.3, and 44-6.4, respectively.

Depth (in)	DCP Penetration Rate (in/blow)	IBV	Q_u (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

ESTIMATING FROM STRENGTH DATA

Figure 44-6G

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 in Section 44-6.02(d).

44-6.02(d)   Estimating E_{Ri} from Soil Properties

The roadway being designed passes through the MIAMI soil series. From the County Soil Report, the information shown in Figure 44-6H 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.*

ESTIMATING FROM SOIL PROPERTIES

Figure 44-6H

From Equation 44-6.5, E_{Ri} (OPT) is calculated for each of the two depths using the midpoint values from the County Soil Report:

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

16 in - 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. Figure 44-6I summarizes the moisture adjustment procedure.

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)[8]

Notes:

1. *From Equation 44-6.5; use midpoint range values from the County Soil Report.*

2. *From Equation 44-6.7; use midpoint range values from the County Soil Report.*

3. *From Equation 44-6.8; use midpoint range values from the County Soil Report.*

4. *From Equation 44-6.6; degree of saturation equals 90%, because Miami soil series is well-drained; estimate Gs as 2.68.*

5. *From Equation 44-6.9.*

6. *From Figure 44-6E.*

7. *From Equation 44-6.10.*

8. *2.0 ksi is the lowest allowable design E_{Ri}.*

MOISTURE ADJUSTMENT PROCEDURE, SPRINGTIME DESIGN CONDITION

Figure 44-6I

The design E_{Ri} values adjusted to reflect springtime design conditions in Figure 44-6I must be combined into a composite E_{Ri} that considers the effect of the 60 in. zone under the load. This can be accomplished using Equation 44-6.11 and Figure 44-6F.

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

44-6.02(e)   Typical E_{Ri} Values

From the County Soil Report, the depth and USDA textural and AASHTO classification data are shown in Figure 44-6J. Average E_{Ri} values based on soil classification are shown.

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.

Soil Series	Depth (in)	USDA Textural Class	AASHTO Class	Average E_{Ri} (ksi) [1]		Average E_{Ri} (ksi) Springtime Conditions
				A	B	C
Tama[2]	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

Notes:

1. *95% of AASHTO T-99 Maximum Dry Density and Moisture Contents 2% Wet of Optimum.*

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

    A.   *From Figure 44-6D, based on USDA textural class.*

    B.   *From Figure 44-6D, based on AASHTO class.*

    C.   *From Figure 44-6C, assuming high-water table and frost penetration.*

AVERAGE E_{RI} VALUES BASED ON SOIL CLASSIFICATION

Figure 44-6J

44-7   SUBGRADE STABILITY REQUIREMENTS FOR LOCAL ROADS

44-7.01   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:

- prevent excessive rutting and shoving during construction,

- provide good support for placement and compaction of pavement layers,

- limit pavement resilient (rebound) deflections to acceptable limits, and

- 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.

44-7.02   Subgrade Stability Procedures

Many typical fine-grained Illinois soils do not develop an Immediate Bearing Value (IBV) in excess of 6.0 when compacted at, or wet of, optimum moisture content. Therefore, the designer must use one of the remedial procedures listed below when the insitu soil does not develop an IBV in excess of 6.0:

- undercut and backfill,

- modified soil layer, or

- moisture-density control.

Moisture-density control is the least permanent remedial procedure.

For pavement design purposes, use the in situ IBV prior to the remedial subgrade treatment.

In situ IBV 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 IBV values are summarized in Figure 44-7A. Central BLRS can be contacted for additional help in determining a field IBV value.

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

Notes:

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

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

SUBGRADE STRENGTH RELATIONSHIPS
Figure 44-7A

44-7.02(a)   Undercut and Backfill

Undercut and backfill involves removing the soft subgrade to a predetermined depth below the grade line 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 44-7B. The use of granular material with good shear strength is recommended. Factors that increase shear strength of a granular material are:

•   using crushed materials;

•   increasing top size;

•   using well-graded materials, as opposed to one-size gradations;

•   reducing PI of fines; and

•   lowering fine content.

A geosynthetic may be used between the subgrade and the granular material to keep the subgrade layer separate from the granular layer, thereby, reducing the required granular thickness. Central BLRS should be contacted for assistance in designing the appropriate granular thickness when geosynthetics are used.
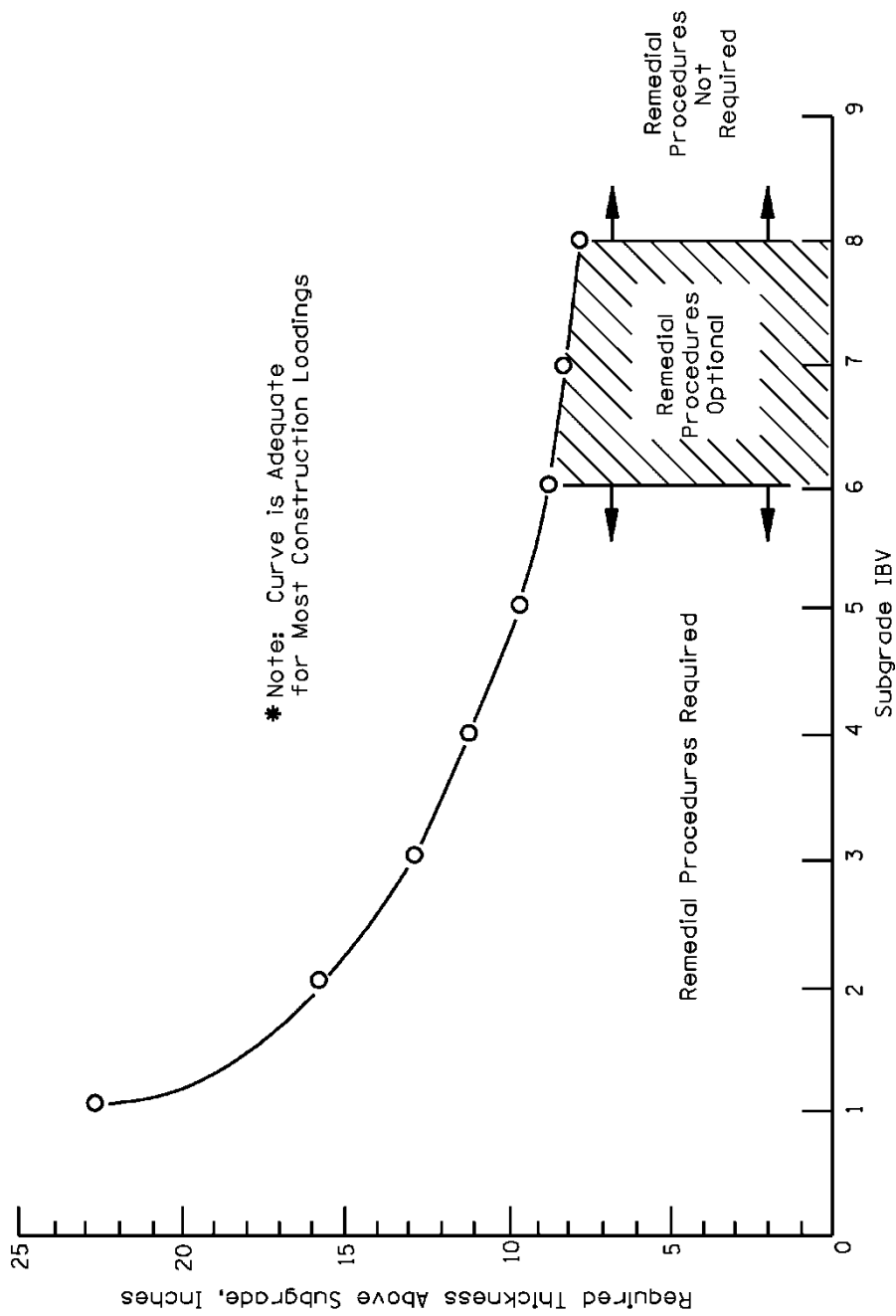
IBV-BASED THICKNESS DESIGN FOR UNDERCUT AND BACKFILL AND MODIFIED SOIL LAYER REMEDIAL PROCEDURES

Figure 44-7B

44-7.02(b)   Soil Modification

Unstable subgrades may be modified (Special Provision "Soil Modification") to improve subgrade stability for new construction or large reconstruction projects. The thickness requirements shown in Figure 44-7B for granular backfill may also be used to determine the thickness of the modified soil layer.

If the soil is to be modified with lime, it is necessary to perform laboratory tests according to the department's "Laboratory Evaluation/Design Procedure for Lime Stabilized Soil Mixtures" to determine if the soil is reactive and to determine the percentage of lime necessary for the soil to develop a minimum IBV of 10.0. The design commonly requires 0.5% percent more lime than the laboratory tests indicate to account for variables in the field.

If the IBV of the modified soil layer is less than 10.0, the engineer has the option of allowing the modified soil layer to field cure in an attempt to obtain an IBV of 10.0, per the department's "Laboratory Evaluation/Design Procedure for Soil Modification". If an IBV of 10.0 is not attainable with a field cure, or if the engineer decides 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 modified soil layer can be combined to meet the required thickness shown in Figure 44-7B. The minimum granular layer thickness should be 4 in. The minimum modified soil layer should be 10 in. Thickness adjustments may be modified to fit field conditions.

The modified soil layer should be covered with the subsequent pavement layer within the same construction season.

44-7.02(c)   Moisture-Density Control

A soil wet of its optimum moisture content may not provide adequate subgrade stability when compacted to 95% 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, according to AASHTO T99, 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.

44-7.03   Treatment Guidelines

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

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

The alternative procedures should be compared by considering construction variability, economics, permanence of treatment, and pavement performance benefits.

The best option should be selected.

More detailed information regarding subgrade stability requirements for local agency pavement design is detailed in *IDOT's Subgrade Stability Manual*.

44-7.04   Subgrade Stability Example

* * * * * * * * * *

Example 44-7.1

Problem: Determine the subgrade treatment alternatives for a soil having an insitu IBV of 4.

Solution:

1.   Requirements.   Based on Figure 44-7B and an IBV of 4, remedial procedures are required.

        Treatments.   The three alternative treatments available are listed below along with specific requirements:

        a.   Undercut and Backfill.   From Figure 44-7B, 11.5 in of granular material is required.

        b.   Modified Soil Layer.   Figure 44-7B shows that 11.5 in of a modified soil layer would be required. If the immediate IBV of the modified soil layer obtained in the field is less than 10.0, the following options are available to the engineer:

        •   field-cure the modified soil layer until an IBV of 10.0 is achieved; or
        •   full- or partial-depth removal and replacement with granular material. In this case, a minimum thickness of 10 in of a modified soil layer and a minimum thickness of 4 in 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, thereby 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.

        Comparison.   The designer should consider the feasibility of these three options, their relative cost, contract time frame, and construction season. The best option should be selected and specified in the project plans. The designer should still use the insitu IBV for pavement design purposes rather than the IBV after remedial treatment.

******

44-8   SURFACE TREATMENTS

A flexible pavement design procedure for bituminous surface treatments, A-2 and A-3, is not included in Chapter 44. Bituminous surface treatments, A-2 and A-3, may be constructed on roads and streets having an estimated ADT, upon completion, of 400 vehicles or less. The minimum thicknesses and widths of base courses for these treatments are as follows:

Type of Base Course	Minimum Thickness (in)	Minimum Width (ft)
Aggregate	8	2 ft wider than surface
Waterbound Macadam	8	
Pozzolanic	6	
Bituminous Stabilized	6	
Cement Stabilized	6	
Lime Stabilized Soil Mixture	8	

**MINIMUM THICKNESSES AND WIDTHS OF BITUMINOUS SURFACE
TREATMENT BASE COURSE
Figure 44-8A**

These minimum thicknesses for base courses are to be supplemented with subbase courses when necessary to compensate for poor subgrade soil conditions. The requirement for subbase may be determined on the basis of the applicable portions of Chapter 44 or some other acceptable method which has proven satisfactory in the past.

A-2 and A-3 bituminous surface treatments may not be placed on roads and streets having estimated ADT of over 400 vehicles upon completion.