Chapter 44

PAVEMENT DESIGN

BUREAU OF LOCAL ROADS AND STREETS MANUAL

Chapter 44
PAVEMENT DESIGN

Table of Contents

Chapter 44
PAVEMENT DESIGN

44-1 GENERAL

Within Chapter 44 there are areas with color (red, blue, or green) added to the text or the figures. The color is based on three example calculations for three different classes of pavement, which are shown through the pavement design procedure for the four types of pavements discussed. The color is only meant to assist in following the criteria used in the examples. There may be duplicate numbers in the figures within Sections 44-1 thru 44-5 to reflect these examples.

44-1.01 Pavement Design Definitions

1. Average Daily Traffic (ADT). The total volume during a given 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 Portland Cement Concrete (PCC) or Roller Compacted Concrete (RCC) 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 spliced longitudinal steel reinforcement.
10. Conventional Flexible Pavement. A flexible pavement structure consisting of a HMA surface course and a combination of aggregate base, 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 HMA Mixture Temperature. Design temperature of HMA mixture in the pavement based on its geographical location.

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

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

15. Design Lane. The traffic lane carrying the greatest number of single and multiple unit vehicles.

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

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

18. Extended Lane. A monolithic paved lane, typically 1 to 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.

19. 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.

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 *IDOT Standard Specifications* 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. 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.

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

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

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

32. Structural Design Traffic. The number of passenger vehicles, single-unit trucks, and multiple-unit trucks estimated for the year representing one-half the design period from the year of construction.

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

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

35. Subgrade Support Rating (SSR). 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.

36. 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.

37. Three Times Nominal Maximum Aggregate Size. The minimum thickness of a HMA course in which the Nominal Maximum Aggregate Size (Superpave) is one size larger than the first sieve that retains more than 10% aggregate.

38. 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, see the *Illinois Highway Standards* for the proper size of reinforcement bar to tie the pavement to the curb and gutter.

39. 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, see the *Illinois Highway Standards* for the proper size of reinforcement bars to tie the pavement to the PCC shoulder.

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

41. 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 smaller reinforcing steel than the size indicated in the *Illinois Highway Standards* are considered untied for purposes of determining pavement thickness.

44-1.02 Accessibility Requirements

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

44-1.03 Basic Mechanistic Design Procedures

Mechanistic pavement design procedures use the actual stresses, strains, and deflections experienced by the pavement to determine its expected fatigue life.

44-1.03(a) Mechanistic Design Factors

Factors that are considered in mechanistic designs include:

- design HMA strain;
- design pavement HMA mixture temperature;
- design HMA mixture modulus (E_{HMA});
- subgrade support rating (SSR);
- design reliability;
- degree of PCC edge support;
- degree of PCC base erosion;
- PCC joint spacing; and
- PCC stresses.

44-1.03(b) Design Period

The level of traffic and type of facility to be constructed affect the selection of the design period. Generally, it is desirable to design highway pavements to carry traffic without necessitating the need for major rehabilitation for a period of 15 to 20 years. However, it may be advantageous to design lesser roadways (e.g., frontage roads, alleys, temporary roads) for shorter periods.

For all pavement types, the minimum design period allowed is 20 years for Class I and II roads and streets. For all pavement types, the minimum design period allowed is 15 years for Class III roads and streets. For Class IV roads and streets with 48 or fewer HCV's, pavement thicknesses provided in each Section 44-2, 44-3, 44-4, and 44-5 should be satisfactory for design periods of 15 years or 20 years.

44-1.03(c) 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.

1. Estimate ADT of PV, SU, and MU. Vehicular classification and traffic volume projections for structural design traffic are based on available traffic data (i.e., ADT). ADT and vehicular classification data for various roadway classes may be obtained from published IDOT traffic maps. If traffic data is unavailable or if published data is dated or does not appear to reflect known conditions or field observations (e.g., land uses, directional distributions), traffic volume and classification studies may be needed to establish a representative base of existing conditions. Factors that compound annual growth typically are used in traffic projections. It is important to consider any future land development or land use changes that may affect the volume or composition of traffic that will use the facility. If vehicular classification data is not available for Class III or Class IV facilities, use the percentages in Figure 44-1A to estimate the number of PV, SU, and MU vehicles from ADT. Also, consider the potential impacts of heavily loaded vehicles, especially in areas near mines, grain elevators, factories, and river ports. It may be necessary to specifically design for such vehicles.

2. Assign Traffic to the Design Lane. Although the sum of the PV, SU, and MU vehicular volumes determined in Step 1 represents the total ADT that will be carried by the highway facility in the year of the projection, the structural design of the pavement will be based on the lane which carries the greatest number of SU and MU vehicles (i.e., the design lane). The distribution factors in Figure 44-1B have been applied to TF equations contained in this chapter. Use the total two-way ADT for multilane facilities when calculating the structural design traffic as the distribution factors account for directional traffic and the percentage of vehicles in the design lane.

   Note that the design lane distribution factors in Figure 44-1B are based on previous traffic studies under average conditions. Unusual traffic control or design features may influence lane usage (e.g., lane restrictions of commercial vehicles, directional influence of major commercial generator). Adjustments may be necessary. Contact the CBLRS for additional guidance.

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 44-1A

Number of Facility Lanes	Percent of Total Vehicular Class Volume (ADT) in Design Lane					
	Rural			Urban		
	PV	SU	MU	PV	SU	MU
2 or 3 *	50%	50%	50%	50%	50%	50%
4 or 5	32%	45%	45%	32%	45%	45%
≥ 6	20%	40%	40%	8%	37%	37%

* *2 or 3 lane facilities include all one-way roads and streets.*

DESIGN LANE DISTRIBUTION FACTORS FOR STRUCTURAL DESIGN TRAFFIC

Figure 44-1B

44-1.04 Selection of Pavement Type

The local public agency (LPA) must specify pavement type on the design plans. For MFT or State funded projects, "alternative" or "type" bids may be used according to Section 12-1 and for federally funded projects see Section 24-1. Figure 44-1E 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 (initial, maintenance, reconstruction, etc.).
2. Secondary Factors. These 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 LPA preference.

44-1.05 Minimum HMA Lift Thickness

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

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*
2. *Minimum thicknesses are the nominal thickness of the lift.*
3. *If the leveling course is placed at or above the minimum thickness specified for surface/binder course, density will be required.*
4. *This mix may not be used as a surface lift.*
5. *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 44-1C

44-1.06 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 44-1D 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.

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

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.

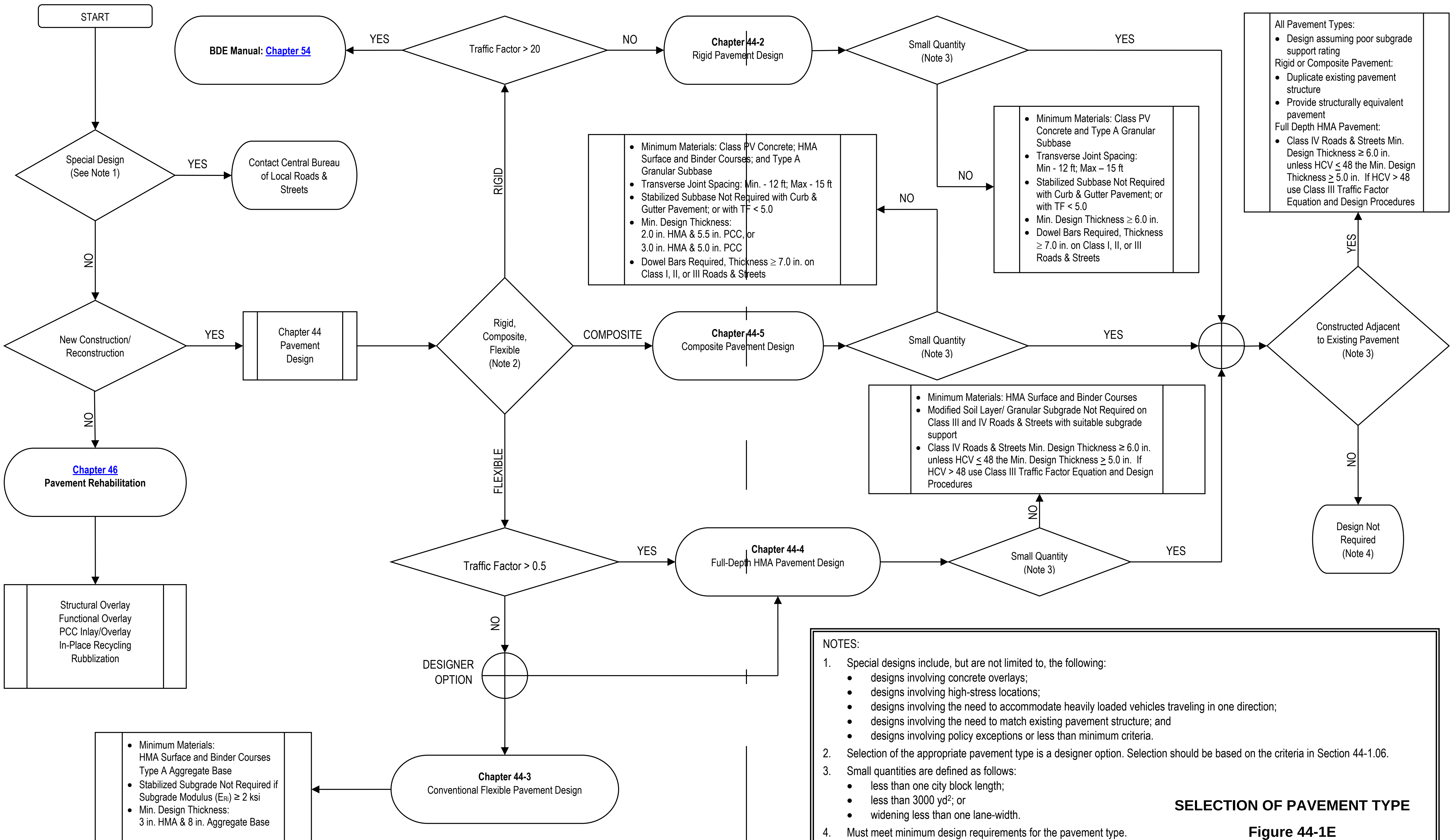
FRICTIONAL REQUIREMENTS FOR SURFACE MIXES

Figure 44-1D

44-1.07 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.



NOTES:

1. Special designs include, but are not limited to, the following:
   - designs involving concrete overlays;
   - 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 44-1.06.
3. Small quantities are defined as follows:
   - less than one city block length;
   - less than 3000 yd^2; or
   - widening less than one lane-width.
4. Must meet minimum design requirements for the pavement type.

SELECTION OF PAVEMENT TYPE

Figure 44-1E

44-1.08 Example Calculations

Chapter 44 provides examples for three classes of roads and streets, showing calculations of the pavement design for rigid pavement, conventional flexible pavement, full-depth HMA pavement, and composite pavement. The same criteria are used for all pavement types. The examples are not to persuade the use of one type of pavement over another. The designer or LPA should refer to Section 44-1.04 to determine which type of pavement to construct.

As the calculations are completed for each example and pavement design, the various figures and text used in each section will be color coordinated with each example to show lines, shaded areas, etc. Section 44-9 provides clean worksheets and figures to use in the submittal of pavement designs. A design period of 20 years is used for all three examples. A design period of 15 years could be used per Section 44-1.03(b).

44-1.08(a) Example Calculation 1 (Red) – Class I Road

Given:

- Class I Road, Four Lane Pavement (Urban) (Section 44-1.01)
- 12 ft Lanes with Concrete Curb and Gutter
- Design Traffic: ADT = 14,000
  - PV's 86%, SU's 8%, MU's 6% (if unknown see Section 44-1.03(c))
- Lake County
- Design Subgrade Support Rating – Fair
- Posted Speed Limit – 30 MPH with Bus Stops

44-1.08(b) Example Calculation 2 (Blue) – Class III Road

Given:

- Class III Road, Two Lane Pavement (Section 44-1.01)
- 11 ft Lanes with Paved HMA Shoulders
- Design Traffic: ADT = 1,800
  - PV's 90%, SU's 6%, MU's 4% (if unknown see Section 44-1.03(c))
- Sangamon County
- Design Subgrade Support Rating – Poor
- Posted Speed Limit – 40 MPH with No Bus Stops

44-1.08(c) Example Calculation 3 (Green) – Class IV Road

Given:

- Class IV Road, Two Lane Pavement (Section 44-1.01)
- 11 ft Lanes with Aggregate Shoulders
- Design Traffic: ADT = 350
  - PV's 88%, SU's 7%, MU's 5% (if unknown see Section 44-1.03(c))
- City of Marion, Williamson County
- Design Subgrade Support Rating – Poor
- Posted Speed Limit – 55 MPH with No Bus Stops

44-2 RIGID PAVEMENT DESIGN FOR LOCAL PUBLIC 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) pavement of relatively high bending resistance. The two types of rigid pavements are as follows:

1. Non-Reinforced Jointed. Jointed pavement without longitudinal 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 man-made 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 LPA intends to transfer jurisdiction following pavement construction, both agencies involved in the jurisdictional transfer should agree on the design.

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

- less than one city block in length,
- less than 3,000 yd^2 (2510 m^2), or
- widening less than one 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) 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 44-2A. 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 CBLRS for special analysis. The LPA must provide the CBLRS 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. However, if the number of HCV's is greater than 48, use the Class III TF equations or a TF of 0.5, whichever is greater, and proceed to design the pavement according to Section 44-2.03.

For TF greater than 20.0, the designer should follow the rigid pavement mechanistic design procedure outlined in Chapter 54 of the *BDE Manual*. Contact the CBLRS for additional information.

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

RIGID PAVEMENT TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-2A

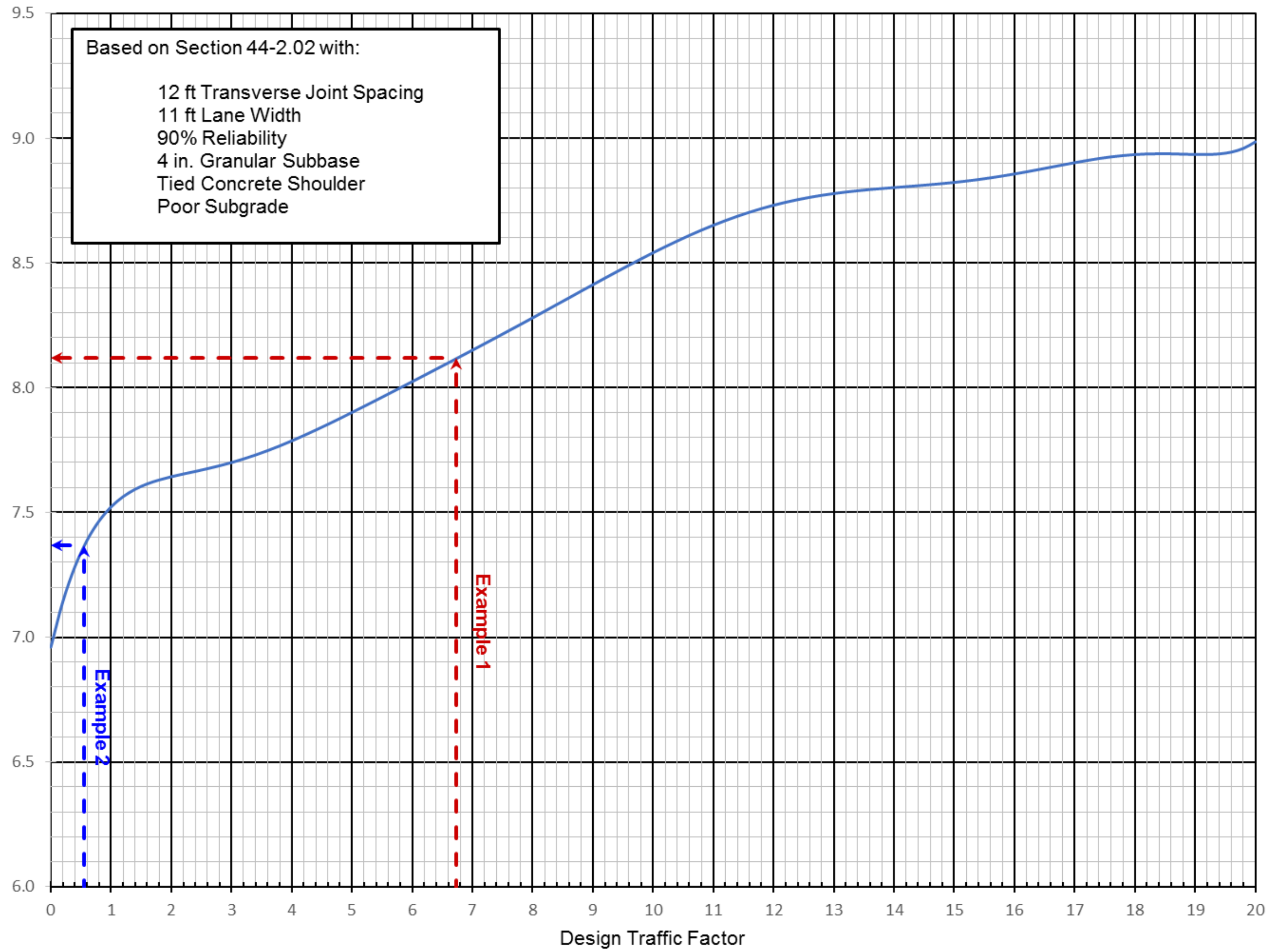
44-2.02(c) Transverse Pavement Joints

For Class I, II, and III pavements, Figure 44-2B provides the thickness design curve for transverse joint spacing of 12 ft, lane width of 11 ft, reliability of 90%, 4 in. granular subbase, tied concrete shoulder, and poor subgrade support. Pavement thickness for this joint spacing may be determined through the pavement design procedure in Section 44-2.03. When alternate joint spacing and pavement design features are desired, the thickness adjustment factor given in Figure 44-2C should be used. The maximum recommended transverse joint spacing for Rigid pavements are given in Figure 44-2D.

Several 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. The maximum transverse joint spacing allowed is 15 ft. The CBLRS will provide the thickness designs for pavements granted variances from the joint spacing in Figure 44-2D. In no case is a slab length less than 6 ft recommended except as provided in Section 46-5.

Designers should not use randomized transverse joint spacing unless matching existing joint spacing of adjacent pavement. The use of skewed transverse joints is not allowed. 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 in Illinois, and has proven a difficult failure to patch and maintain.

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 slab thickness of 7 in. or greater. For slab thickness less than 7 in., 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.



PRE-ADJUSTED RIGID PAVEMENT THICKNESS

Figure 44-2B

Example 3 – Since the HCV's per day ≤ 48, the pre-adjusted thickness is 7.0 in. with adjustments of -0.15 in. providing a final thickness of 7.0 in. which exceeds the minimum of 6.0 in. for rigid pavements.

Adjustment Factor	Rigid Pavement Thickness Adjustment (in.)
75% Reliability	-0.50
15 ft Joint Spacing (0.1 ≤ TF ≤ 5)	+1.00
15 ft Joint Spacing (5 < TF ≤ 20)	+1.25
Untied Shoulder	+0.35
Fair Subgrade	-0.25
Granular Subgrade	-0.50
Stabilized Subbase	-0.25
Existing Pavement as Subbase	-0.50
10 ft Lane Width	+0.25
12 ft Lane Width	-0.25

Note: Thickness adjustment is made for untied shoulders (PCC or flexible). The designer should be aware of the potential for frost heave if untied shoulders are used.

A subbase is optional for all Class III and IV pavements with a TF < 5.0, and for urban sections having curb and gutter and storm sewer systems.

THICKNESS ADJUSTMENT FACTOR

Figure 44-2C

Pavement Thickness (in.)	Maximum Transverse Joint Spacing (ft)
< 10.0	12.0* / 12.0* / 12.0*
≥ 10.0	15.0

** Appropriate for all Class IV pavements.*

MAXIMUM TRANSVERSE JOINT SPACING

Figure 44-2D

44-2.02(d) 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 rigid pavement 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. Keyed longitudinal joints are not recommended because of their difficulty in construction and subsequent poor performance. 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 promote load transfer through tight aggregate interlock joints 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, particularly if excessive steel is used. For pavement cross sections more than 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 or smaller tie bars used than specified in the *Illinois Highway Standards* should be used. 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 CBLRS should be consulted for variances to the use of tie bars across longitudinal joints.

44-2.02(e) 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 more than 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 (AASHTO T 99), soil classification, percent clay, plasticity index (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(f) Subgrade Support Rating (SSR)

The general physical characteristics of the roadbed soil affect the design thickness and performance of the pavement structure. For pavement design purposes, there are three subgrade support ratings (SSR) — poor, fair, and granular. The SSR is determined as discussed in Section 44-6. The SSR should represent the average or majority classification within the design section. The pavement thickness design curve (Figure 44-2B) is based on a SSR of poor. Adjustments in the design thickness need to be made for fair and granular subgrades are shown in Figure 44-2C.

44-2.02(g) Subbase

A subbase under a pavement serves two purposes. Initially, it provides a stable construction platform for the subsequent man-made layers. 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 for subbases are given in Figure 44-2E.

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

Road Class	Subbase Material	Usage [1]	Minimum Thickness (in.)
Class I and II TF ≥ 5.0 TF < 5.0	 Stabilized Subbase [2] Granular [3]	 Required Required	 4 4
Class III and IV TF ≥ 5.0 TF < 5.0	 Granular [3] Granular [3]	 Required Optional / 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 44-2E

44-2.02(h) Design Reliability

Design reliability is considered in the design TF. A reliability of 90% is built into the PCC slab thickness design curve in Figure 44-2B. Adjustments in the design thickness need to be made for medium reliability level as shown in Figure 44-2C. The minimum reliability levels by road classes are given in Figure 44-2F.

Road Class	Minimum Reliability Levels	Reliability (%)
Class I and II	High	90
Class III	Medium	75
Class IV (Figure 44-2G)	Medium	75

RELIABILITY LEVELS

Figure 44-2F

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 in. (15 cm) or greater.

44-2.03(b) Pre-adjusted Rigid Pavement Thickness

The jointed pavement thickness design procedure is based on determining the pre-adjusted thickness of the rigid pavement, and then adjusting for shoulder type, subgrade support conditions, subbase type, joint spacing, reliability, and lane width. The pre-adjusted rigid pavement thicknesses were developed for pavements with tied PCC shoulders, 4 in. granular subbase, and poor subgrade support. For Class I, II, and III pavements, the pre-adjusted rigid pavement thicknesses are determined from Figure 44-2B for joint spacing of 12.0 ft. If a specific joint spacing, shoulder type, reliability, soil support, subbase, or lane width is not desired, adjustments to the slab thicknesses for alternate design features can be made based on recommendations provided in Figure 44-2C.

For Class IV PCC pavements, Figure 44-2G provides the pre-adjusted rigid pavement thickness of 7.0 in. for an 11.0 ft lane width, a 12.0 ft joint spacing, a 90% reliability, with either tied curb or concrete shoulders, and poor soil conditions. Class IV pavements can have a reduced reliability of 75%. Design rigid pavement thickness should never be less than 6.0 in.

Joint spacing of 15 ft are not recommended for Class IV pavements because their thicknesses are typically less than 10.0 in. and the maximum recommended joint spacing is 12.0 ft as shown in Figure 44-2D.

44-2.03(c) Rigid Pavement Thickness Adjustments

Adjustments to the pre-adjusted rigid pavement thickness should be made based on the shoulder type, joint spacing, subgrade support, subbase type, lane width, and reliability. The final design thickness is rounded to the next highest 0.25 in. In determining any adjustments, consider the following:

1. Shoulder Type. The pre-adjusted rigid pavement thickness is valid if the rigid 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.

Tied PCC slab, tied curb and gutter, and extended lane shoulder types must be tied per the *Illinois Highway Standards* in order to avoid a pavement thickness adjustment. The recommended reinforcement bar shown in the *Illinois Highway Standards* is needed to promote load transfer through tight aggregate interlock joints between the pavement and curb/shoulder. Designers may specify smaller tie bars; however, additional pavement thickness will be required based on pavement thickness adjustment factors in Figure 44-2C, since it would be considered as untied.

2. Subgrade and Subbase Support. Rigid pavement thickness adjustments are based on the subgrade support and whether the pavement structure will have a subbase or not. Figure 44-2C provides the subgrade support adjustment factors for fair and granular subgrade. Figure 44-2B provides the slab thickness for 4 in. granular subbase (or none if applicable) with adjustment for stabilized subbase given in Figure 44-2C.

3. Joint Spacing. Joint spacing of 15 ft may be used for rigid pavement thicknesses over 10 in. (Figure 44-2D). Thickness adjustment factors for 15 ft joint spacing are given in Figure 44-2C for TF ≤ 5 and 5 < TF ≤ 20.

4. Lane Width. The standard chart in Figure 44-2B is for an 11 ft lane width. Thickness adjustment can be made for 10 ft and 12 ft lane width as shown in Figure 44-2C.

5. Reliability. Designs for lower reliability can be completed given the criteria in Figure 44-2F and thickness adjustment factor given in Figure 44-2C.

After all necessary adjustments to the pre-adjusted rigid pavement thickness has 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 44-2D to determine which joint spacing is allowed.

44-2.03(d) Dowel Bars

The use of doweled joints will be required for rigid pavement thicknesses that are 7 in. and greater on all Class I, Class II, and Class III roads and streets. Doweled joints will not be required for Class IV roads and streets. Recommended dowel diameters are given in Figure 44-2H.

HCV's/day	Rigid Pavement Thickness for 12 ft Joint Spacing (in.)
≤ 48	7.0 (1)
> 48	(2)

Notes:

1. *Minimum rigid pavement thickness shall not be less than 6 in. after all adjustment factors are applied.*
2. *Use the Class III TF equations or a TF of 0.5, whichever is greater, in conjunction with Figures 44-2B.*

CLASS IV PRE-ADJUSTED RIGID PAVEMENT THICKNESS
(11 ft Lane Width / 90% Reliability / Tied Curb or PCC Shoulders / Poor Soil Conditions)

Figure 44-2G

Rigid Pavement Thickness (in.)	Dowel Diameter (in.)
≥ 10.00	1.50
> 8.00 to 9.99	1.25
≤ 8.00	1.00 / 1.00

DOWEL BAR DIAMETER REQUIREMENTS

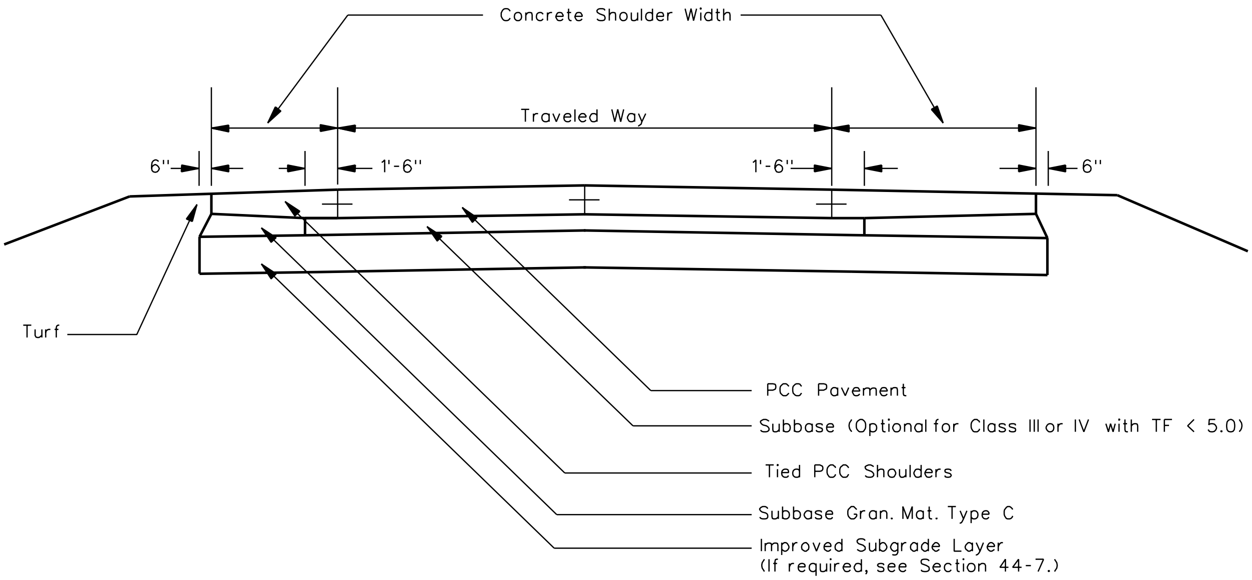
Figure 44-2H

44-2.04 Typical Sections

Figures 44-2I, 44-2J, and 44-2K illustrate typical LPA rigid pavement designs.

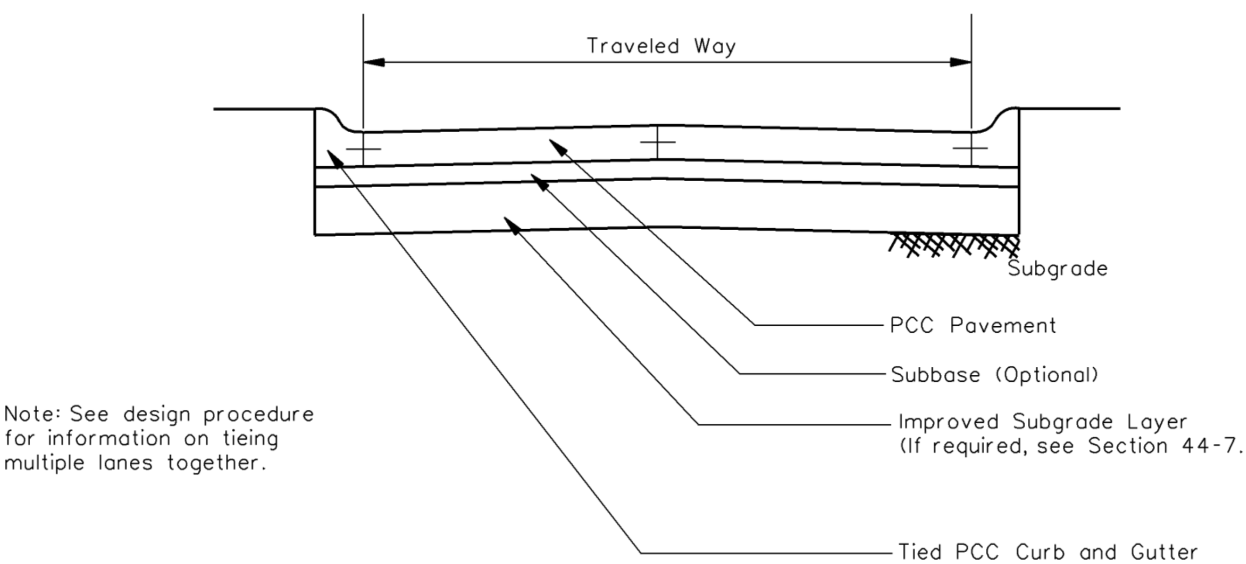
44-2.05 Worksheet

Figure 44-2L represents a worksheet for documenting the rigid pavement design calculations.



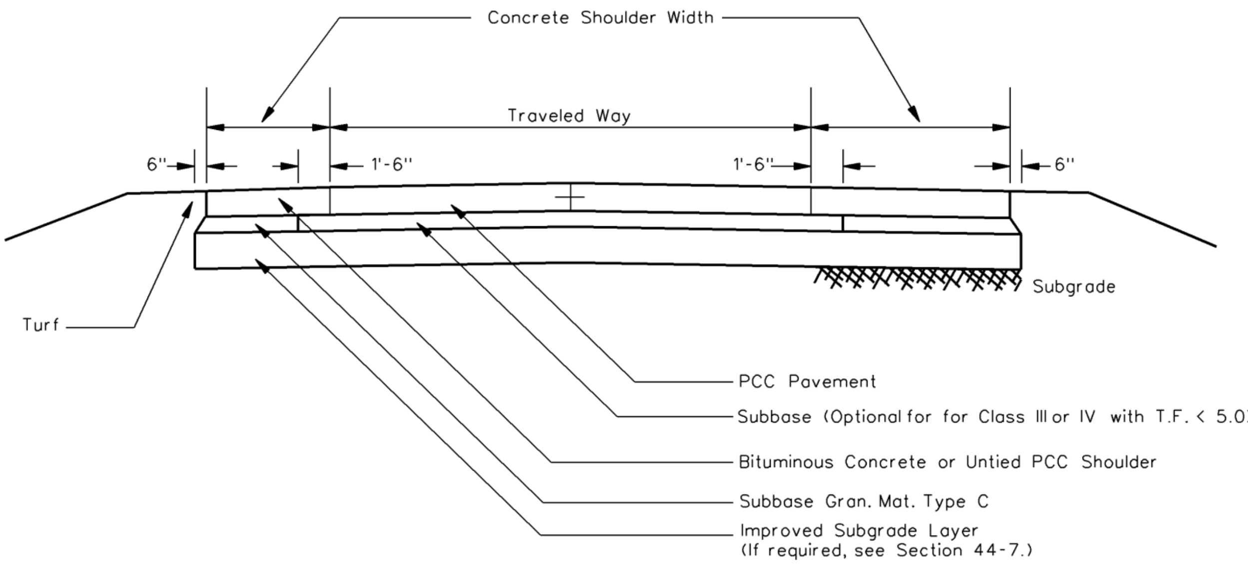
TYPICAL RIGID PAVEMENT DESIGN
WITH TIED SHOULDERS

Figure 44-2I



TYPICAL RIGID PAVEMENT DESIGN
WITH TIED CURB AND GUTTER

Figure 44-2J



TYPICAL RIGID PAVEMENT DESIGN WITH UNTIED SHOULDERS

Figure 44-2K

Date: ______________________ County: ______________________
Calculations by: ______________________ LPA: ______________________
Checked by: ______________________ Section: ______________________
Route: ______________________

Limits of Analysis: Location: ______________________

From: ______________________

To: ______________________

Length: __________ Feet __________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: __________ Width: ______ft

ADT: ______________

Class of Road or Street: _____ *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: __________% / __________

SU: __________% / __________

MU: __________% / __________

HCV: __________

Traffic Factor (Show Calculations)**:** *(Figure 44-2A)*

Traffic Factor: __________

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-2.02(f) and Figure 44-6A)*

Pre-Adjusted Rigid Pavement Thickness: *(Figure 44-2B or Figure 44-2G)* __________in.

Reliability: *(Figure 44-2F)* ☐ 75% or ☐ 90%

Adjustments: *(Section 44-2.03(c) and Figure 44-2C)*

Adjustment	Reference	Value	Applicable Adjustments
75% Reliability	*Section 44-2.02(h)*	-0.50	__________in.
15 ft Joint Spacing (0.1 ≤ TF ≤ 5) / (5 ≤ TF ≤ 20)		+1.00 / +1.25	__________in.
Untied Shoulder		+0.35	__________in.
Fair Subgrade / Granular Subgrade		-0.25 / -0.50	__________in.
Stabilized Subbase / Existing Pavement as Subbase		-0.25 / -0.50	__________in.
☐ 10 ft Lane Width / ☐ 12 ft Lane Width		+0.25 / -0.25	__________in.
		Total Adjustment:	__________in.

Adjusted Rigid Pavement Thickness __________in.

Transverse Joint Spacing *(Figure 44-2D)* ☐ 12 ft or ☐ 15 ft

Final Pavement Thickness *(Rounded to next ¼ in.)* *(Minimum Thickness 6.0 in.)* __________in.

Dowel Bars: ☐ Yes ☐ No *(Section 44-2.03(d))* Size: *(Figure 44-2H)* __________in.

Comments: ____

____

____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

RIGID PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-2L

44-2.06 Example Calculations

44-2.06(a) Example Calculation 1 (Red) – Class I Road

Problem:

Design a jointed concrete pavement for the given conditions.

Given: (Section 44-1.08(a))

Class I Road, Four Lane Pavement (Urban) (Section 44-1.01)
12 ft Lanes with Concrete Curb and Gutter (tied)
Design Traffic: ADT = 14,000
PV's 86%, SU's 8%, MU's 6% (if unknown see Section 44-1.03(c))
Lake County
Design Subgrade Support Rating – Fair
Posted Speed Limit – 30 MPH with Bus Stops

Solution:

Use Figure 44-2A and determine the TF equation for a four-lane Class I road.

4 or 5 Lane Pavements (Rural and Urban)

$$TF = DP\left[\frac{(0.047PV + 64.715SU + 313.389MU)}{1{,}000{,}000}\right]$$

$$TF = 20\left[\frac{(0.047 \times 12040 + 64.715 \times 1120 + 313.389 \times 840)}{1{,}000{,}000}\right]$$

$$TF = 6.73$$

Because the pavement is a Class I road with tied curb and gutter, a subbase is optional (see Figure 44-2E, Note 1). From Figure 44-2E, a stabilized subbase is may be used with a minimum thickness of 4 in.

The pre-adjusted rigid pavement thickness is determined from Figure 44-2B, gives a value of 8.12 in. Based on Figure 44-2C, the thickness adjustment factors are -0.25 in. (fair subgrade), -0.25 in. (stabilized subbase), and -0.25 in. (12 ft lane width). The pre-adjusted rigid pavement thickness is 8.12 in. with adjustments of -0.75 in. for a value of 7.37 in.; this is rounded to the next highest ¼ in. or a final thickness of 7.50 in.

A check of Figure 44-2D, a 12 ft transverse joint spacing is required. Dowels are required because the pavement thickness is greater than 7 in. [Section 44-2.03(d)]. Based on Figure 44-2H, the dowel bar diameter is 1.00 in.

* * * * * * * * * *

Date: ______
Calculations by: ______
Checked by: ______

County: Lake
LPA: ______
Section: ______
Route: ______
Location: ______

Limits of Analysis:

From: ______
To: ______
Length: ______ Feet ______ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 4 Width: 12 ft
ADT: 14,000
Class of Road or Street: I *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

	%	Count
PV:	86 %	12,040
SU:	8 %	1,120
MU:	6 %	840
HCV:	1960	

Traffic Factor (Show Calculations)**:** *(Figure 44-2A)*

$$TF = 20\left[\frac{(0.047 \times 12040 + 64.715 \times 1120 + 313.389 \times 840)}{1,000,000}\right]$$

Traffic Factor: 6.73

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☒ Fair ☐ Granular *(Section 44-2.02(f) and Figure 44-6A)*
Pre-Adjusted Rigid Pavement Thickness: *(Figure 44-2B or Figure 44-2G)* 8.12 in.
Reliability: *(Figure 44-2F)* ☐ 75% or ☒ 90%

Adjustments: *(Section 44-2.03(c) and Figure 44-2C)*

Adjustment	Reference	Value	Applicable Adjustments
75% Reliability	*Section 44-2.02(h)*	-0.50	N/A in.
15 ft Joint Spacing (0.1 ≤ TF ≤ 5) / (5 ≤ TF ≤ 20)		+1.00 / +1.25	N/A in.
Untied Shoulder		+0.35	N/A in.
Fair Subgrade / Granular Subgrade		-0.25 / -0.50	-0.25 in.
Stabilized Subbase / Existing Pavement as Subbase		-0.25 / -0.50	-0.25 in.
☐ 10 ft Lane Width / ☐ 12 ft Lane Width		+0.25 / -0.25	-0.25 in.
		Total Adjustment:	-0.75 in.

Adjusted Rigid Pavement Thickness: 7.37 in.
Transverse Joint Spacing *(Figure 44-2D)* ☒ 12 ft or ☐ 15 ft
Final Pavement Thickness *(Rounded to next ¼ in.)* *(Minimum Thickness 6.0 in.)* 7.50 in.
Dowel Bars: ☒ Yes ☐ No *(Section 44-2.03(d))* Size: *(Figure 44-2H)* 1.00 in.
Comments: A 4 in. stabilized subbase is required.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 1 – RIGID PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-2L

44-2.06(b) Example Calculation 2 (Blue) – Class III Road

Problem:

Design a jointed concrete pavement for the given conditions.

Given: (Section 44-1.08(b))

Class III Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Paved HMA Shoulders
Design Traffic: ADT = 1,800
PV's 90%, SU's 6%, MU's 4% (if unknown see Section 44-1.03(c))
Sangamon County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 40 MPH with No Bus Stops

Solution:

Use Figure 44-2A and determine the TF equation for a two-lane Class III road.

2 or 3 Lane Pavements

$$TF = DP\left[\frac{(0.073PV + 64.790SU + 281.235MU)}{1,000,000}\right]$$

$$TF = 20\left[\frac{(0.073 \times 1620 + 64.790 \times 108 + 281.235 \times 72)}{1,000,000}\right]$$

$$TF = 0.547$$

Because the pavement is a Class III road with a TF < 5.0, a subbase is optional (see Figure 44-2E). From Figure 44-2E, if a subbase is required or desired the minimum thickness is 4 in. For this example the LPA decided to use a 4 in. granular subbase.

The required pre-adjusted rigid pavement thickness is determined from Figure 44-2B, which gives us a value of 7.4 in. Based on Figure 44-2C, the thickness adjustment factors are +0.35 in. (untied shoulders) and no adjustments for poor subgrade or using a 4 in. granular subbase. The LPA decided to use the higher reliability of 90% providing no additional adjustment. The pre-adjusted rigid pavement thickness of 7.4 in. and adjustments of +0.35 in. for a value of 7.75 in.; which does not need to be rounded to the next highest ¼ in.

A check of Figure 44-2D, a 15 ft transverse joint spacing is not allowed, therefore; a 12 ft transverse joint spacing will be used. Dowels are required because the pavement thickness required is greater than 7 in. [Section 44-2.03(d)]. Based on Figure 44-2H, the dowel bar diameter is 1.00 in.

* * * * * * * * * *

Date: ____________
Calculations by: ____________
Checked by: ____________

County: Sangamon
LPA: ____________
Section: ____________
Route: ____________
Location: ____________

Limits of Analysis:

From: ____________
To: ____________
Length: ______ Feet ______ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2 Width: 11 ft
ADT: 1,800
Class of Road or Street: III *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: 90 % / 1,620
SU: 6 % / 108
MU: 4 % / 72
HCV: 180

Traffic Factor (Show Calculations)**:** *(Figure 44-2A)*

$$TF = 20\left[\frac{(0.073 \times 1620 + 64.790 \times 108 + 281.235 \times 72)}{1{,}000{,}000}\right]$$

Traffic Factor: 0.547

Pavement Design:

Subgrade Support Rating (SSR): ☒ Poor ☐ Fair ☐ Granular *(Section 44-2.02(f) and Figure 44-6A)*
Pre-Adjusted Rigid Pavement Thickness: *(Figure 44-2B or Figure 44-2G)* 7.40 in.
Reliability: *(Figure 44-2F)* ☐ 75% or ☒ 90%

Adjustments: *(Section 44-2.03(c) and Figure 44-2C)*

			Applicable Adjustments
75% Reliability	*Section 44-2.02(h)*	-0.50	N/A in.
15 ft Joint Spacing (0.1 ≤ TF ≤ 5) / (5 ≤ TF ≤ 20)		+1.00 / +1.25	N/A in.
Untied Shoulder		+0.35	+0.35 in.
Fair Subgrade / Granular Subgrade		-0.25 / -0.50	0.00 in.
Stabilized Subbase / Existing Pavement as Subbase		-0.25 / -0.50	N/A in.
☐ 10 ft Lane Width / ☐ 12 ft Lane Width		+0.25 / -0.25	N/A in.
		Total Adjustment:	+0.35 in.

Adjusted Rigid Pavement Thickness: 7.75 in.
Transverse Joint Spacing *(Figure 44-2D)* ☒ 12 ft or ☐ 15 ft
Final Pavement Thickness *(Rounded to next ¼ in.)* *(Minimum Thickness 6.0 in.)* 7.75 in.
Dowel Bars: ☒ Yes ☐ No *(Section 44-2.03(d))* Size: *(Figure 44-2H)* 1.00 in.

Comments: ____________

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 2 – RIGID PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-2L

44-2.06(c) Example Calculation 3 (Green) – Class IV Road

Problem:

Design a jointed concrete pavement for the given conditions.

Given: (Section 44-1.08(c))

Class IV Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Aggregate Shoulders
Design Traffic: ADT = 350
PV's 88%, SU's 7%, MU's 5% (if unknown see Section 44-1.03(c))
City of Marion, Williamson County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 55 MPH with No Bus Stops

Solution:

Determine the HCV which is the SU (24) + MU (18) for a value of 42. With the HCV $\leq$ 48, the required pre-adjusted slab thickness is determined from Figure 44-2G, which gives a value of 7.0 in. The minimum rigid pavement thickness is 6.0 in. per Section 44-2.03(a).

Based on Figure 44-2C, the thickness adjustment factors are +0.35 in. (untied shoulders) and the LPA decided to use the lower reliability of 75% providing an adjustment factor of -0.50 in. The pre-adjusted rigid pavement thickness of 7.0 in. and adjustments of -0.15 in. for a value of 6.85 in. This gives a final thickness of 7.00 in.

A check of Figure 44-2D, a 12 ft transverse joint spacing is required. Dowels are not required because it is on a Class IV Road [Section 44-2.03(d)]. If dowel bars were desired the diameter would be 1.00 in. (Figure 44-2H).

* * * * * * * * * *

Date: ______________
Calculations by: ______________
Checked by: ______________

County: Williamson
LPA: City of Marion
Section: ______________
Route: ______________
Location: ______________

Limits of Analysis:

From: ______________
To: ______________
Length: ________ Feet ________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2 Width: 11 ft
ADT: 350
Class of Road or Street: IV *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

	Percent	Count
PV:	88 %	308
SU:	7 %	24
MU:	5 %	18
HCV:	42	

Traffic Factor (Show Calculations)**:** *(Figure 44-2A)*

With the HCV < 48, the required pre-adjusted slab thickness is determined from Figure 44-2G, which gives a value of 7.0 in. The minimum slab thickness is 6.0 in. per Section 44-2.03(a).

Traffic Factor: N/A

Pavement Design:

Subgrade Support Rating (SSR): ☒ Poor ☐ Fair ☐ Granular *(Section 44-2.02(f) and Figure 44-6A)*
Pre-Adjusted Rigid Pavement Thickness: *(Figure 44-2B or Figure 44-2G)* 7.0 in.
Reliability: *(Figure 44-2F)* ☒ 75% or ☐ 90%

Adjustments: *(Section 44-2.03(c) and Figure 44-2C)*

			Applicable Adjustments
75% Reliability	*Section 44-2.02(h)*	-0.50	-0.50 in.
15 ft Joint Spacing (0.1 ≤ TF ≤ 5) / (5 ≤ TF ≤ 20)		+1.00 / +1.25	N/A in.
Untied Shoulder		+0.35	+0.35 in.
Fair Subgrade / Granular Subgrade		-0.25 / -0.50	0.00 in.
Stabilized Subbase / Existing Pavement as Subbase		-0.25 / -0.50	N/A in.
☐ 10 ft Lane Width / ☐ 12 ft Lane Width		+0.25 / -0.25	N/A in.
		Total Adjustment:	-0.15 in.

Adjusted Rigid Pavement Thickness 6.85 in.
Transverse Joint Spacing *(Figure 44-2D)* ☒ 12 ft or ☐ 15 ft
Final Pavement Thickness *(Rounded to next ¼ in.)* *(Minimum Thickness 6.0 in.)* 7.00 in.
Dowel Bars: ☐ Yes ☒ No *(Section 44-2.03(d))* Size: *(Figure 44-2H)* N/A in.

Comments: Dowel bars are not required because it is on a Class IV Road.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 3 – RIGID PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-2L

44-3 CONVENTIONAL FLEXIBLE PAVEMENT DESIGN FOR LOCAL PUBLIC 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 0.50.

The design criteria for conventional flexible pavements are HMA fatigue and subgrade stress. A Subgrade modulus (E_{RI}) is used to accommodate subgrade rutting considerations, see Section 44-3.02(e). 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) 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 with the minimum thicknesses in Section 44-1.05.

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

Class IV pavements with less than 24 HCV's per day may use an aggregate base course, Type B material in place of the aggregate base course, Type A material for the entire base thickness required.

44-3.02(b) Traffic Factors

The maximum allowable Traffic Factor (TF) for conventional flexible pavements is 0.50. 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 44-3A. 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 CBLRS for special analysis. The LPA must provide the CBLRS 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)	$TF = DP\left[\frac{(0.047PV + 59.625SU + 217.139MU)}{1{,}000{,}000}\right]$
6 or More Lane Pavements (Rural)	$TF = DP\left[\frac{(0.029PV + 53.000SU + 193.012MU)}{1{,}000{,}000}\right]$
6 or More Lane Pavements (Urban)	$TF = DP\left[\frac{(0.012PV + 49.025SU + 178.536MU)}{1{,}000{,}000}\right]$
One-way Streets and Pavements (Rural and Urban)	$TF = DP\left[\frac{(0.073PV + 66.250SU + 241.265MU)}{1{,}000{,}000}\right]$
Class II Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\frac{(0.073PV + 56.030SU + 192.720MU)}{1{,}000{,}000}\right]$
Class III Roads and Streets	
2 or 3 Lane Pavements	$TF = DP\left[\frac{(0.073PV + 54.570SU + 192.175MU)}{1{,}000{,}000}\right]$

TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-3A

44-3.02(c) Stage Construction

Stage construction is the planned construction of the pavement structure in two or more stages, such as placing the lower lifts in one construction season and the surface in the next construction season. 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 period that may elapse between the completion of the first stage and the scheduled construction date of the final stage is two years.

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 according to Section 44-8.

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.

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(d) 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 Figure 44-3B. 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 Figure 44-3B. PG binder grade adjustments, where applicable, should be applied to the surface and top binder lift.

The LPA must request a variance from the CBLRS to use a different PG binder than specified in Figure 44-3B.

PG Binder Grade Selection[1]			
Districts 1 – 4	Traffic Loading Rate (Adjustment)		
	Standard [2]	Slow [3]	Standing [4]
Surface[5]	PG 58-28	PG 64-28 or SBS PG 64-28	SBS PG 70-28
Remaining Lifts[5]	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[5]	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
Remaining Lifts[5]	PG 64-22	PG 64-22	PG 64-22

Notes:

1. *The binder grades provided in Figure 44-3B 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. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
3. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
4. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
5. *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 44-3E.*

PG BINDER GRADE SELECTION FOR CONVENTIONAL FLEXIBLE PAVEMENTS

Figure 44-3B

44-3.02(e) 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 pavements, 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. "Soil Modification" should be used in lieu of the "Lime-Modified Soils" section of the *IDOT Standard Specifications* *(Section 302)*. 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(f) 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 aggregate base course, Type A material. A modified soil layer (8 in. minimum) or subbase granular material, Type B (4 in. minimum) may be used at a 1:1 ratio to satisfy granular layer thickness requirements more than 8 in. For example, a 12 in. base requirement could be satisfied by using 12 in. of aggregate base course, Type A material or 8 in. of aggregate base course, Type A and 4 in. of subbase granular material, Type B.

   Class IV pavements with less than 24 HCV's per day may use an aggregate base course, Type B material in place of the aggregate base course, Type A 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(g) Design Reliability

Design reliability is considered through traffic factor multipliers applied to the design TF. These traffic multipliers are built into the design HMA strain curve in Figure 44-3F. The minimum reliability levels by class of road for TF $\leq$ 0.5 are given in Figure 44-3C.

Road Class	Minimum Reliability Level	Reliability (%)
Class I, II, III, and IV	Medium	~ 75%

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

RELIABILITY LEVEL (TF $\leq$ 0.5)

Figure 44-3C

44-3.03 Thickness Design – HMA Mixtures

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

The following applies to facilities using HMA mixtures:

1. Design HMA Mixture Temperature. The HMA mixture temperatures are given in Figure 44-3D 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: The design HMA mixture temperatures for conventional flexible and full-depth HMA pavements are not the same. For the same location, the conventional flexible HMA design mixture temperature is lower than the full-depth HMA design mixture temperature, because conventional flexible design time dates occur earlier in the spring.

2. Design HMA Modulus (E_{HMA}). The design E_{HMA} is the HMA modulus that corresponds to the design mixture temperature. Determine the design E_{HMA} value from Figure 44-3E for typical Superpave mixtures with PG 58-XX, PG 64-XX, PG 70-XX, or PG 76-XX.

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

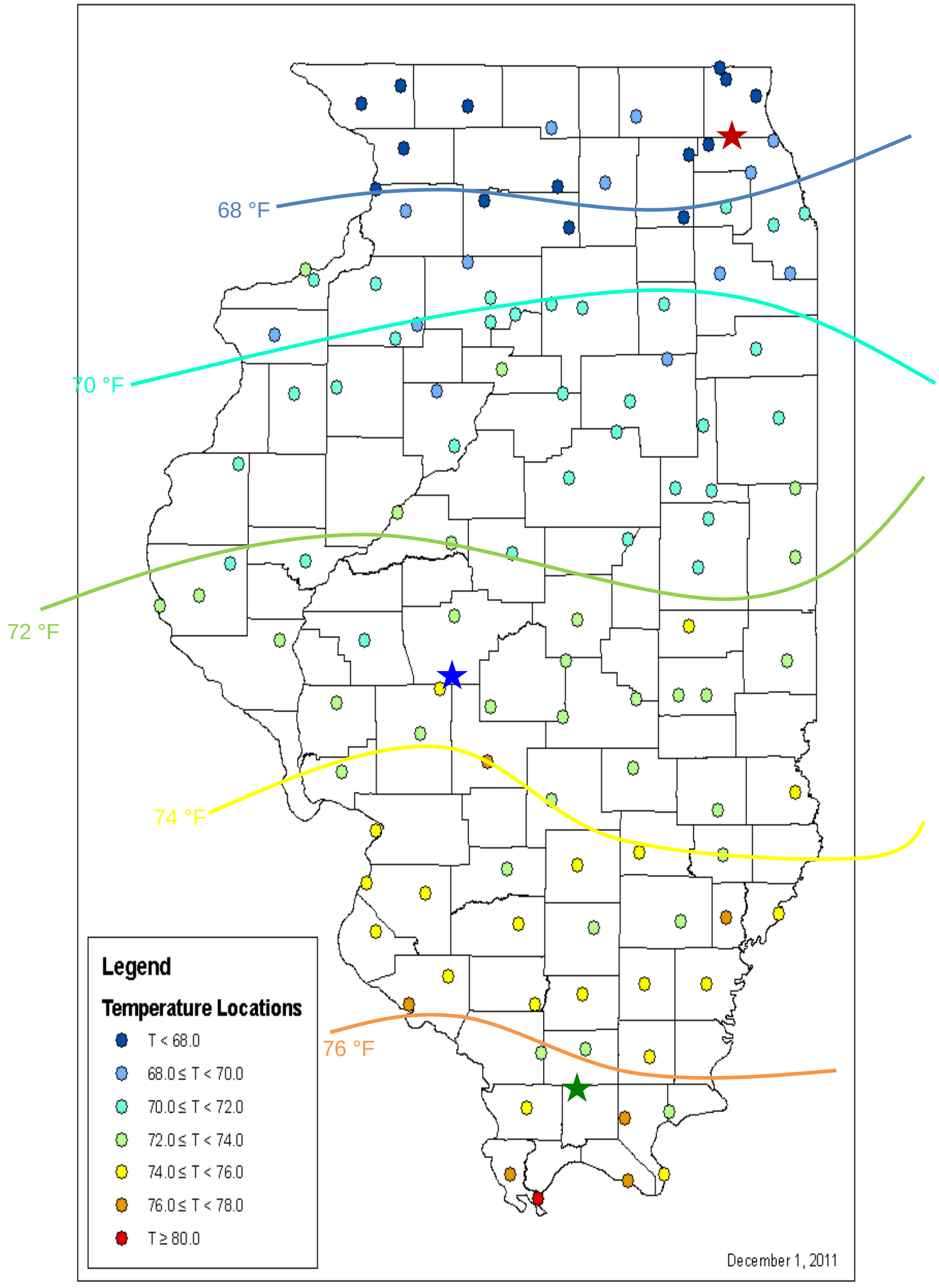
4. Thickness Requirements. Use Figure 44-3G in conjunction with the design HMA modulus from Step 2 and the design HMA strain from Step 3 to determine the thickness of HMA mixture required. The thicknesses from Figure 44-3G are based on an 8 in. minimum Type A aggregate base thickness and an E_{Ri} of 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. aggregate base course, Type A material 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 44-3H 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 44-7.

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

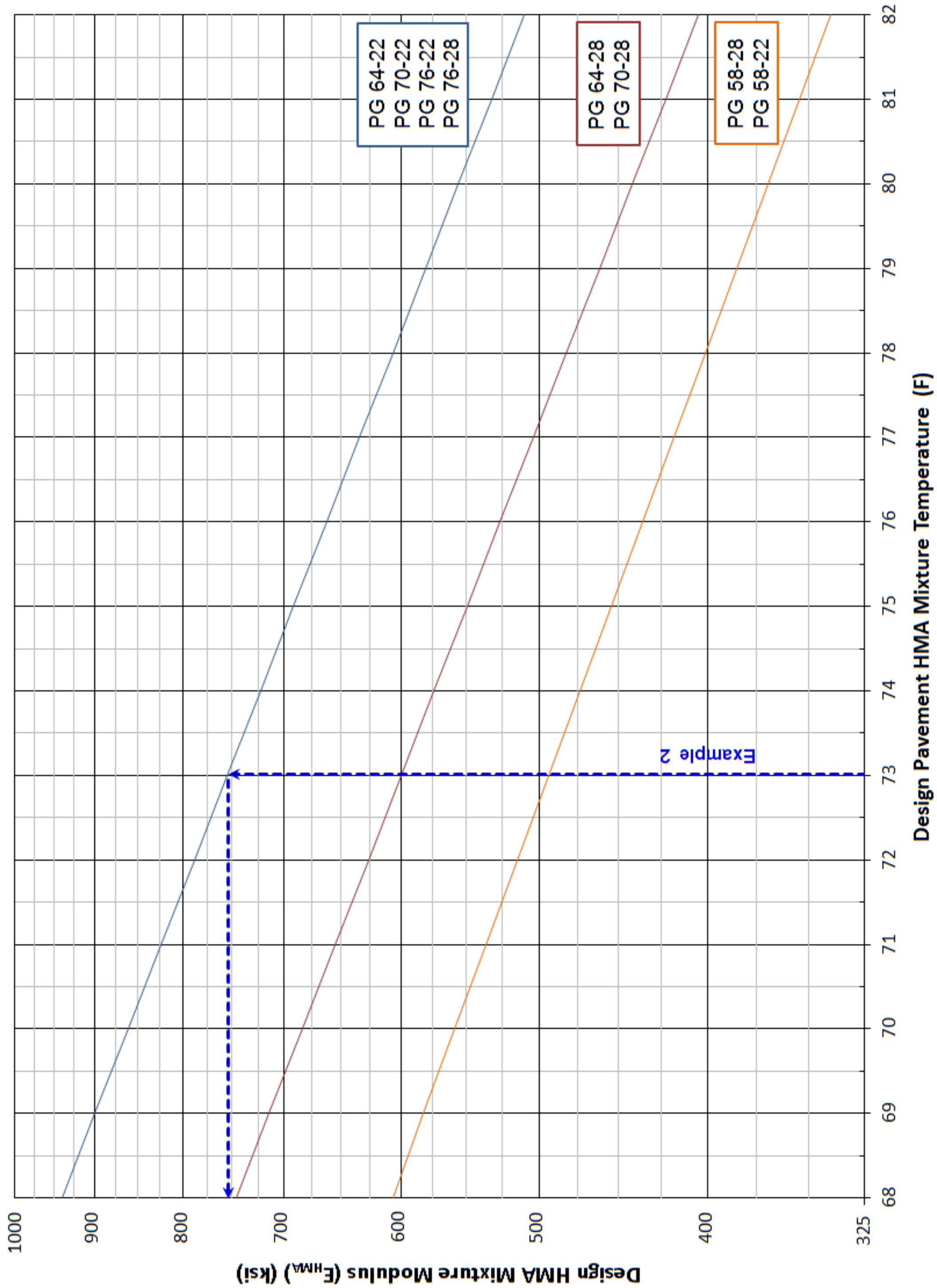
Figures 44-3I and 44-3J provide the HMA and aggregate base thicknesses for various E_{Ri} values and traffic levels. Pavements with less than 24 HCV's per day may use aggregate base course, Type B material in lieu of aggregate base course, Type A material. Pavements with greater than 48 HCV's use a Class III TF equation and design procedure.

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



CONVENTIONAL FLEXIBLE HMA MIXTURE TEMPERATURE

Figure 44-3D



DESIGN HMA MIXTURE MODULUS (E_{HMA}) (ksi)

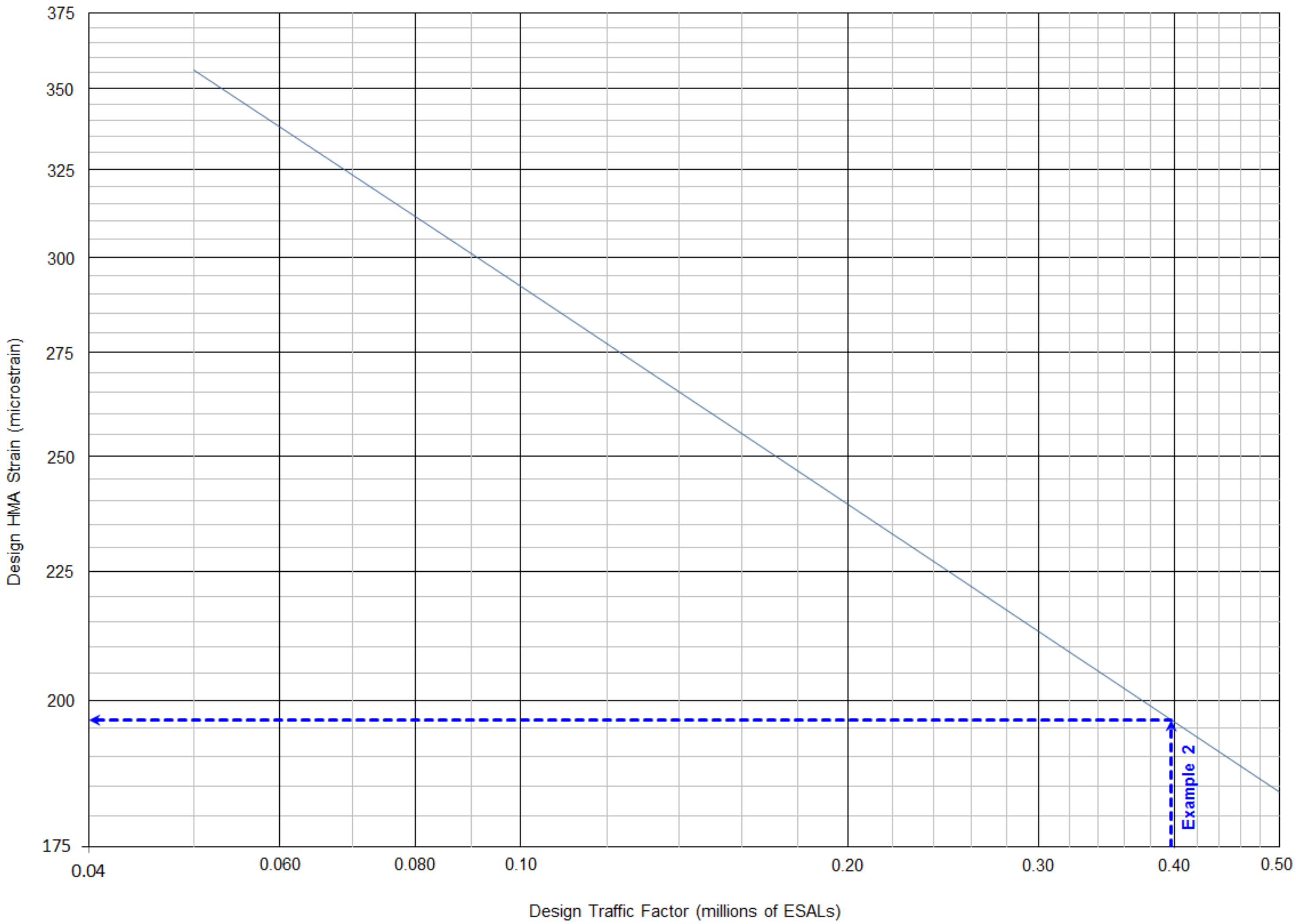
Figure 44-3E

Example 1 – Since the TF > 0.5, Conventional Pavement Design is not allowed.

Example 3 – Since the HCV's per day ≤ 48, Figures 44-3I or 44-3J may be used.

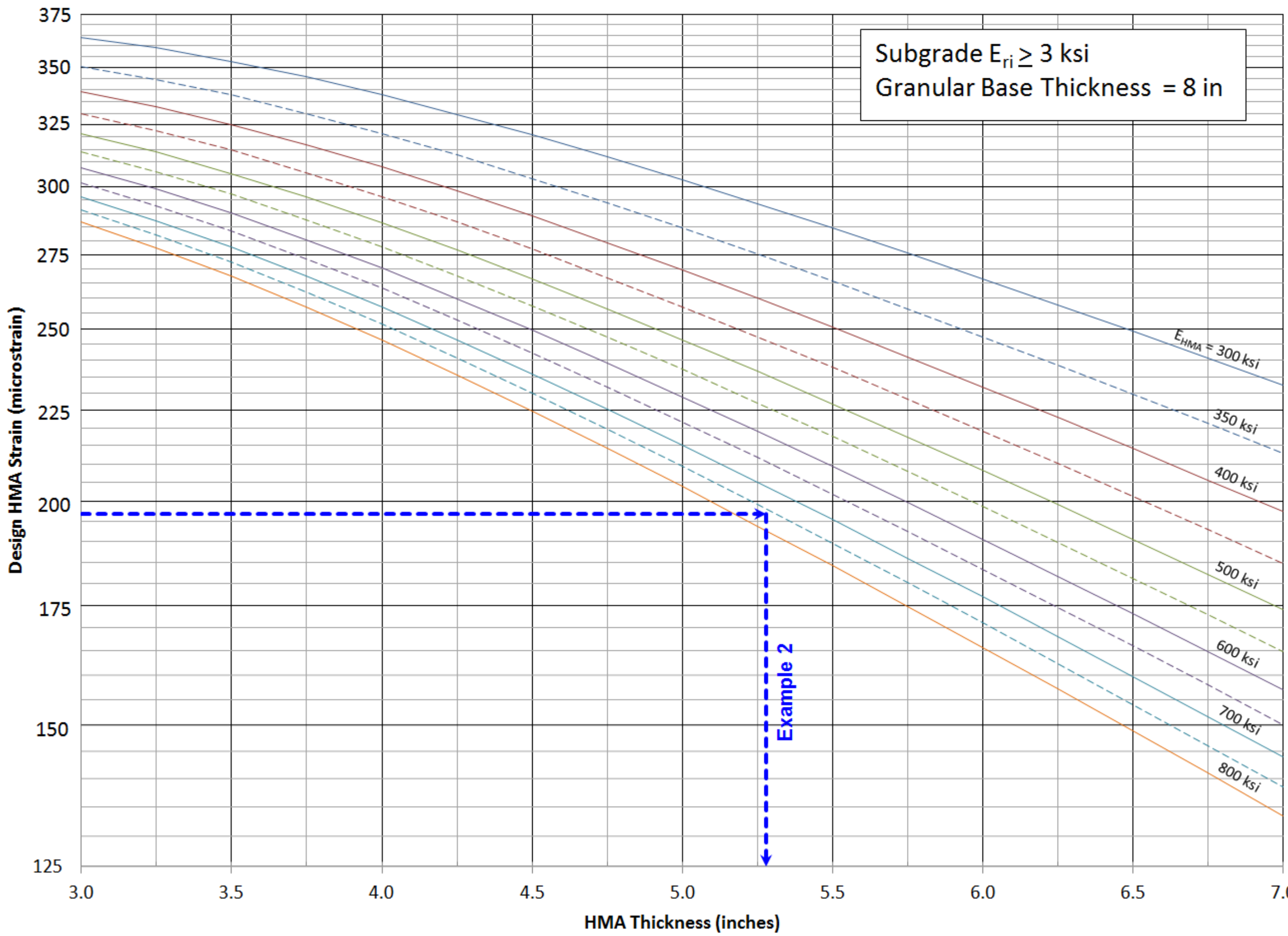
Example 1 – Since the TF > 0.5, Conventional Pavement Design is not allowed.

Example 3 – Since the HCV's per day ≤ 48, Figures 44-3I or 44-3J may be used.



DESIGN HMA STRAIN
(Traffic Factor Relation for HMA Mixes)

Figure 44-3F



CONVENTIONAL FLEXIBLE PAVEMENT DESIGN CHART

Figure 44-3G

Example 1 – Since the TF > 0.5, Conventional Pavement Design is not allowed.

Example 3 – Since the HCV's per day ≤ 48, Figures 44-3I or 44-3J may be used.

Original HMA Design Thickness (in.)	Design HMA Modulus, E_{HMA} (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. aggregate base course, Type A 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. aggregate base course, Type A based on the appropriate category from the above table, can be enhanced by one of the following alternatives:

1. *$E^{(1)}$. Use one or more of the following:*
   - *Increase the HMA thickness by 0.5 in.*
   - *Increase the aggregate base course, Type A thickness by 2 in.*
   - *Add a 4 in. minimum granular subbase course, Type B.*
   - *Add an 8 in. minimum modified soil layer.*
2. *$E^{(2)}$. Use one or more of the following:*
   - *Increase the HMA thickness by 1.0 in.*
   - *Increase the aggregate base course, Type A thickness by 4 in.*
   - *Add a 4 in. minimum granular subbase course, Type B.*
   - *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 44-3H

District	1 – 4		5 – 6		7 – 9	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 2.99	≥ 3	2 – 2.99	≥ 3	2 – 2.99	≥ 3
< 12 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
12 – 23 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
24 – 48 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 44-3I

District	1 – 4		5 – 6		7 – 9	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 2.99	≥ 3	2 – 2.99	≥ 3	2 – 2.99	≥ 3
< 12 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
12 – 23 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
24 – 48 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

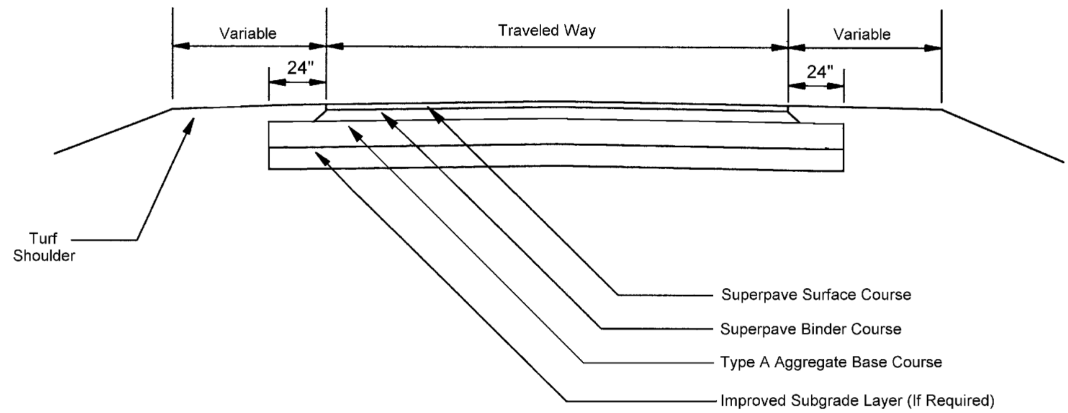
Figure 44-3J

44-3.04 Typical Sections

Figures 44-3K and 44-3L illustrate typical LPA conventional flexible pavement designs.

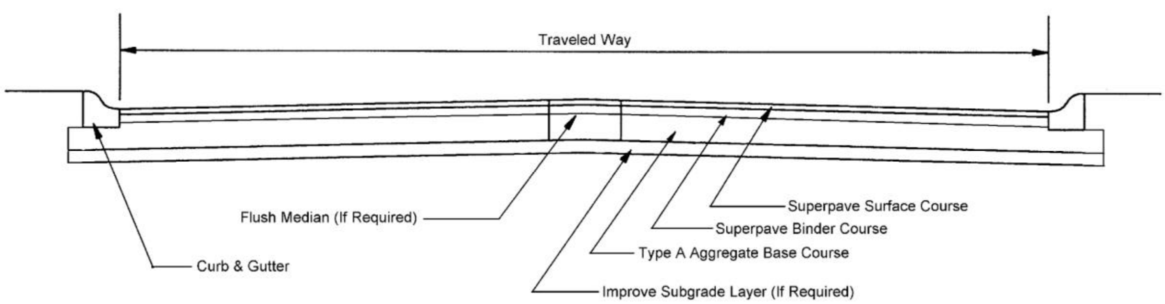
44-3.05 Worksheet

Figure 44-3M represents a worksheet for documenting the conventional flexible pavement design calculations.



TYPICAL CONVENTIONAL FLEXIBLE RURAL DESIGN

Figure 44-3K



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

TYPICAL CONVENTIONAL FLEXIBLE URBAN DESIGN

Figure 44-3L

Date: ______________________ County: ______________________
Calculations by: ______________________ LPA: ______________________
Checked by: ______________________ Section: ______________________
Route: ______________________
Limits of Analysis: Location: ______________________
From: ______________________
To: ______________________
Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: __________
ADT: ______________
Class of Road or Street: _____ *(Section 44-1.01)*

PV: __________% / __________
SU: __________% / __________
MU: __________% / __________
HCV: __________

Traffic Factor (Show Calculations)**:** *(Figure 44-3A)*

Traffic Factor: __________
(Traffic Factor must ≤ 0.50 to qualify for Conventional Flexible Pavement Design Procedures)

Pavement Design:
Subgrade Modulus (E_{RI}): *(Section 44-3.02(e) and Section 44-6)* __________ksi
Selected Design PG Binder *(Figure 44-3B)*
Surface: ______________________
Remaining Lifts: ______________________
Design Pavement HMA Temp: *(Figure 44-3D)* __________ºF
Design HMA Modulus (E_{HMA}): *(Figure 44-3E)* __________ksi
Design HMA Microstrain: *(Figure 44-3F)* __________
Pavement Thickness: *(Figure 44-3G)* __________in.
Pavement Structure Enhancements: *(if 2ksi ≤ E_{RI} < 3 ksi use Figure 44-3H)* ______________________
For Class IV Pavements: *(Figure 44-3I or 44-3J)* ______________________
Minimum Material Requirements *(Section 44-3.02(a))* ______________________
Comments: ______________________

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

CONVENTIONAL FLEXIBLE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-3M

44-3.06 Example Calculations

44-3.06(a) Example Calculation 1 (Red) – Class I Road

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

Given: (Section 44-1.08(a))
Class I Road, Four Lane Pavement (Urban) (Section 44-1.01)
12 ft Lanes with Concrete Curb and Gutter
Design Traffic: ADT = 14,000
PV's 86%, SU's 8%, MU's 6% (if unknown see Section 44-1.03(c))
Lake County
Design Subgrade Modulus (E_{RI}) – 5.0 ksi
Posted Speed Limit – 30 MPH with Bus Stops

Solution:
From Figure 44-3A, use the TF equation for a four-lane Class I road.

4 or 5 Lane Pavements (Rural and Urban:

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

$$TF = 20\left[\frac{(0.047 \times 12040 + 59.625 \times 1120 + 217.139 \times 840)}{1{,}000{,}000}\right]$$

$$TF = 4.99$$

Per Section 44-3.01, conventional flexible pavements are allowed for TF up to 0.50. Since the TF is 4.99 for this example, a conventional flexible pavement is not allowed.

* * * * * * * * * *

Date: ____________________
Calculations by: ____________________
Checked by: ____________________

County: Lake
LPA: ____________________
Section: ____________________
Route: ____________________
Location: ____________________

Limits of Analysis:

From: ____________________
To: ____________________
Length: ________ Feet ________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 4
ADT: 14,000
Class of Road or Street: I *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: 86 % / 12,040
SU: 8 % / 1,120
MU: 6 % / 840
HCV: 1,960

Traffic Factor (Show Calculations)**:** *(Figure 44-3A)*

$$TF = 20\left[\frac{(0.047 \times 12040 + 59.625 \times 1120 + 217.139 \times 840)}{1{,}000{,}000}\right]$$

Traffic Factor: 4.99

(Traffic Factor must ≤ 0.50 to qualify for Conventional Flexible Pavement Design Procedures)

Pavement Design:

Subgrade Modulus (E_{RI}): *(Section 44-3.02(e) and Section 44-6)* ________ ksi

Selected Design PG Binder *(Figure 44-3B)*

Surface: ____________________

Remaining Lifts: ____________________

Design Pavement HMA Temp: *(Figure 44-3D)* ________ ºF

Design HMA Modulus (E_{HMA}): *(Figure 44-3E)* ________ ksi

Design HMA Microstrain: *(Figure 44-3F)* ________

Pavement Thickness: *(Figure 44-3G)* ________ in.

Pavement Structure Enhancements: *(if 2ksi ≤ E_{RI} < 3 ksi use Figure 44-3H)* ____________________

For Class IV Pavements: *(Figure 44-3I or 44-3J)* ____________________

Minimum Material Requirements *(Section 44-3.02(a))* ____________________

Comments: Since the TF is greater than 0.50, a conventional flexible pavement is not allowed.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 1 – CONVENTIONAL FLEXIBLE PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-3M

44-3.06(b) Example Calculation 2 (Blue) – Class III Road

Problem:

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

Given: (Section 44-1.08(b))

Class III Road, Two Lane Pavement (Section 44-1.01)

11 ft Lanes with Paved HMA Shoulders

Design Traffic: ADT = 1,800

PV's 90%, SU's 6%, MU's 4% (if unknown see Section 44-1.03(c))

Sangamon County

Design Subgrade Modulus (E_{RI}) – 2.5 ksi

Posted Speed Limit – 40 MPH with No Bus Stops

Solution:

From Figure 44-3A, use the TF equation for a two-lane Class III road.

2 or 3-Lane Pavements:

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

$$TF = 20\left[\frac{(0.073 \times 1620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

$$TF = 0.397$$

Based on a site investigation an E_{RI} value of 2.5 ksi was determined.

With a posted speed limit of 40 mph, the Traffic Loading Rate is "Slow" and from Figure 44-3B, use a PG 70-22 or SBS PG 70-22 for the surface and a PG 64-22 for the remaining lifts.

The conventional flexible HMA mixture temperature from Figure 44-3D is 73°F.

The design HMA modulus (E_{HMA}) from Figure 44-3E would be 755 ksi.

The design HMA strain from Figure 44-3F would be 197 microstrain.

HMA thickness from Figure 44-3G is 5.3 in; therefore, round the HMA thickness up to 5.50 in. Per Figure 44-3H the 4 in. granular subbase is optional, however; Section 44-3.02(a) requires an 8 in. aggregate base course, Type A.

* * * * * * * * * *

Date: ______________________
Calculations by: ______________________
Checked by: ______________________

County: Sangamon
LPA: ______________________
Section: ______________________
Route: ______________________
Location: ______________________

Limits of Analysis:

From: ______________________
To: ______________________
Length: ________ Feet ________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2
ADT: 1,800
Class of Road or Street: III *(Section 44-1.01)*

	Percent	Count
PV:	90 %	1,620
SU:	6 %	108
MU:	4 %	72
HCV:	180	

Traffic Factor (Show Calculations)**:** *(Figure 44-3A)*

$$TF = 20\left[\frac{(0.073 \times 1620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

Traffic Factor: 0.397

(Traffic Factor must $\leq$ 0.50 to qualify for Conventional Flexible Pavement Design Procedures)

Pavement Design:

Subgrade Modulus (E_{RI}): *(Section 44-3.02(e) and Section 44-6)* 2.5 ksi

Selected Design PG Binder *(Figure 44-3B)*

Surface: PG 70-22 or SBS PG 70-22

Remaining Lifts: PG 64-22

Design Pavement HMA Temp: *(Figure 44-3D)* 73 °F

Design HMA Modulus (E_{HMA}): *(Figure 44-3E)* 755 ksi

Design HMA Microstrain: *(Figure 44-3F)* 197

Pavement Thickness: *(Figure 44-3G)* 5.50 in.

Pavement Structure Enhancements: *(if 2ksi $\leq E_{RI} <$ 3 ksi use Figure 44-3H)* ______________________

For Class IV Pavements: *(Figure 44-3I or 44-3J)* ______________________

Minimum Material Requirements *(Section 44-3.02(a))* An 8 in. Type A base course is required.

Comments: Pavement structure will be 5.50 in. of HMA on an 8 in. aggregate base course, Type A.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 2 – CONVENTIONAL FLEXIBLE PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-3M

44-3.06(c) Example Calculation 3 (Green) – Class IV Road

Problem:
Design a conventional flexible pavement with a HMA surface assuming an E_{RI} value between 2 and 3 with the following given conditions.

Given: (Section 44-1.08(c))
Class IV Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Aggregate Shoulders
Design Traffic: ADT = 350
PV's 88%, SU's 7%, MU's 5% (if unknown see Section 44-1.03(c))
City of Marion, Williamson County
Design Subgrade Modulus (E_{RI}) – 2.5 ksi
Posted Speed Limit – 55 MPH with No Bus Stops

Solution:
Based on a site investigation an E_{RI} value of 2.5 ksi was determined.

Determine the HCV which is the SU (24) + MU (18) for a value of 42. With the HCV $\leq$ 48, Figures 44-3I or 44-3J may be used. With an E_{RI} value between 2 and 3 and the project located in District 9, the designer has the option of:

1) Figure 44-3I resulting in a 3.0 in. or 3.25 in. of HMA surface over a 14 in. aggregate base, or

2) Figure 44-3J resulting in a 3.5 in. or 3.75 in. of HMA surface over a 12 in. aggregate base.

From Figure 44-3B with a standard traffic loading, use a PG 64-22 for the surface and a PG 64-22 for the remaining lifts.

From Section 44-3.02(a), the minimum HMA thickness is 3 in. Since the HCV is > 24, an aggregate base course, Type A material must be used.

* * * * * * * * * *

Date: ______________________
Calculations by: ______________________
Checked by: ______________________

County: Williamson
LPA: City of Marion
Section: ______________________
Route: ______________________
Location: ______________________

Limits of Analysis:

From: ______________________
To: ______________________
Length: ________ Feet ________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2
ADT: 350
Class of Road or Street: IV *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: 88 % / 308
SU: 7 % / 24
MU: 5 % / 18
HCV: 42

Traffic Factor (Show Calculations)**:** *(Figure 44-3A)*

N/A – Class IV Road with HCV ≤ 48

Traffic Factor: N/A
(Traffic Factor must ≤ 0.50 to qualify for Conventional Flexible Pavement Design Procedures)

Pavement Design:

Subgrade Modulus (E_{RI}): *(Section 44-3.02(e) and Section 44-6)* 2.5 ksi
Selected Design PG Binder *(Figure 44-3B)*
Surface: PG 64-22
Remaining Lifts: PG 64-22

Design Pavement HMA Temp: *(Figure 44-3D)* N/A ºF
Design HMA Modulus (E_{HMA}): *(Figure 44-3E)* N/A ksi
Design HMA Microstrain: *(Figure 44-3F)* N/A
Pavement Thickness: *(Figure 44-3G)* N/A in.

Pavement Structure Enhancements: *(if 2ksi ≤ E_{RI} < 3 ksi use Figure 44-3H)* N/A

For Class IV Pavements: *(Figure 44-3I or 44-3J)* With the HCV < 48, Figures 44-3I or 44-3J may be used. The designer decided to use Figure 44-3J resulting in a 3.75 in. HMA over a 12 in. aggregate base.

Minimum Material Requirements *(Section 44-3.02(a))* 3 in. HMA with an 8 in. aggregate base course, Type A.

Comments: Pavement structure will be 3.75 in. of HMA over a 12 in. aggregate base course, Type A.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 3 – CONVENTIONAL FLEXIBLE PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-3M

44-4 FULL-DEPTH HMA PAVEMENT DESIGN FOR LOCAL PUBLIC 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 criterion 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 LPA 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 LPA 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 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 with the minimum thicknesses in Section 44-1.05.

44-4.02(b) 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 44-4A. 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 CBLRS for special analysis. The LPA must provide the CBLRS 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. A design TF is not necessary, if under 48 HCV's per day. However; if the HCV's per day is greater than 48, use a Class III TF equation and design procedure.

44-4.02(c) Subgrade Support Rating (SSR)

There are three subgrade support ratings (SSR) used in this design procedure — poor, fair, and granular. The designer should use Section 44-6 to determine the SSR. The SSR should represent the average or majority rating classification within the design section.

44-4.02(d) 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 44-4B.

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.

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

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

Figure 44-4A

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) 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 LPA may obtain a waiver to the subgrade working platform requirement from CBLRS 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 44-4B

PG Binder Grade Selection [1]			
Districts 1 – 4	**Traffic Loading Rate (Adjustment)**		
	Standard Traffic [2]	Slow Traffic [3]	Standing Traffic [4]
Surface[5]	PG 58-28 [6][7]	PG 64-28 or SBS PG 64-28	SBS PG 70-28
Remaining Lifts[5]	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[5]	PG 64-22 [6][7]	PG 70-22 or SBS PG 70-22	SBS PG 76-22
Remaining Lifts[5]	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. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
3. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
4. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
5. *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 or a SBS PG 70-22 should be specified.*
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 44-4H.*
7. *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 or a SBS PG 70-22 should be specified.*

PG BINDER GRADE SELECTION FOR FULL-DEPTH HMA PAVEMENTS

Figure 44-4C

44-4.02(e) 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 44-4C. 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, should be 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. The appropriate grade of binder should be reported on the plans.

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

The LPA must request a variance from the CBLRS to use a different PG binder than that specified in Figure 44-4C.

44-4.02(f) Stage Construction

Stage construction is the planned construction of the pavement structure in two or more stages, such as placing the lower lifts in one construction season and the surface in the next construction season. Stage construction is not allowed on full-depth HMA pavements.

44-4.02(g) Design Reliability

Design reliability is considered through traffic factor multipliers applied to the design TF. These traffic multipliers are built into the design HMA strain curves in Figures 44-4F and 44-4G. The minimum reliability levels by class of road are given in Figure 44-4D.

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

DESIGN RELIABILITY

Figure 44-4D

44-4.03 Thickness Design

The following processes are used to determine the design thickness:

1. Class I, II and III Roads and Streets. The design procedure is as follows:
   - Calculate the TF from the appropriate equation found in Figure 44-4A.
   - Use Figure 44-6A in conjunction with the subgrade soil grain-size analysis to determine the subgrade support rating.
   - Use Figure 44-4C in conjunction with traffic speed and location to determine the PG binder grade.
   - Use Figure 44-4E to determine the HMA pavement mixture temperature. The design mixture temperature should be interpolated to the nearest 0.5°F.

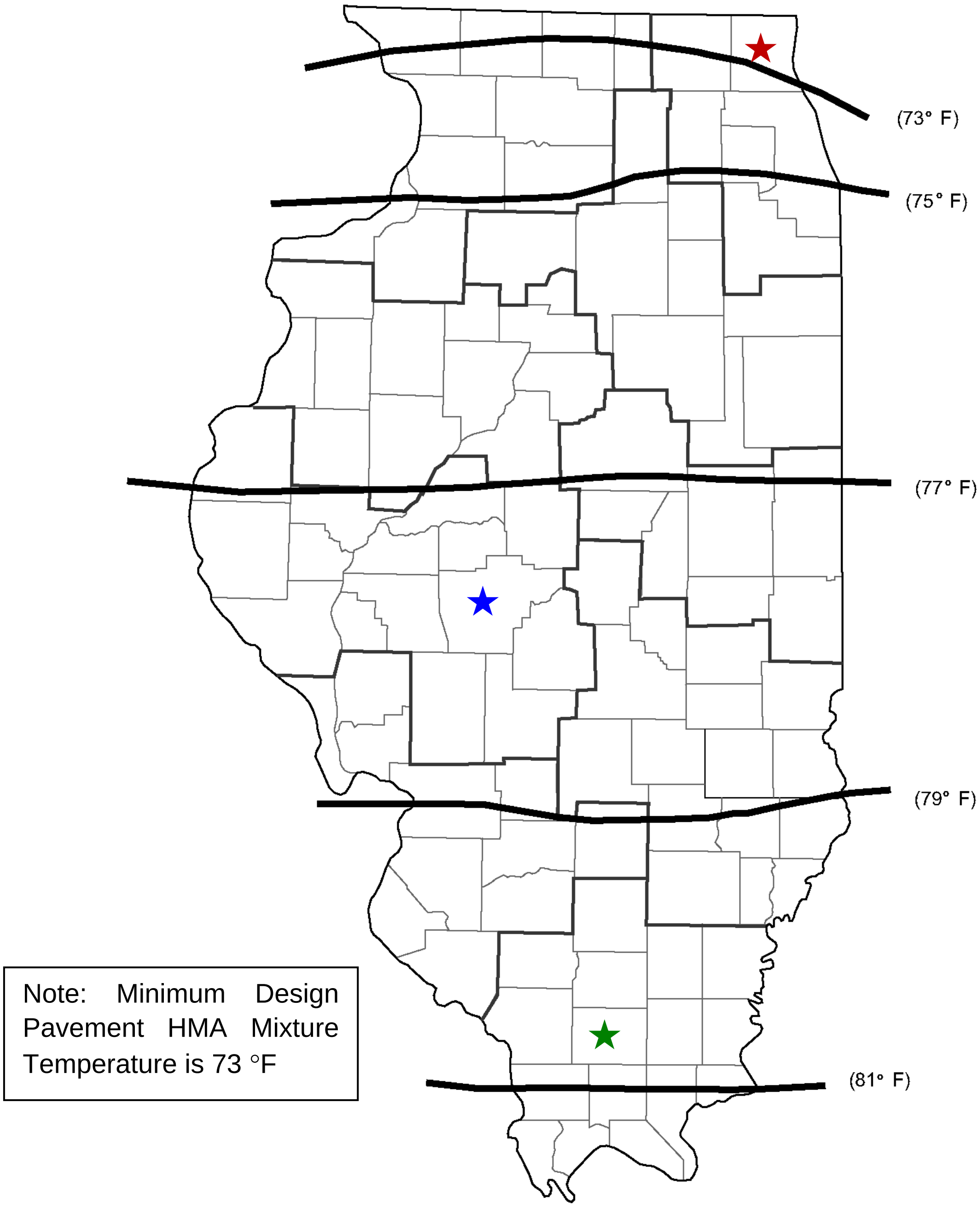
     Note: The design HMA mixture temperatures for conventional flexible and full-depth HMA pavements are not the same. For the same location, the conventional flexible HMA design mixture temperature is lower than the full-depth HMA design mixture temperature, because conventional flexible design time dates occur earlier in the spring.
   - Use Figure 44-4F (TF < 0.5) or Figure 44-4G (TF ≥ 0.5) to determine the design HMA strain.
   - Use Figure 44-4H to determine the design pavement HMA modulus (E_{HMA}).
   - Use Figures 44-4I, 44-4J, or 44-4K, 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. Class IV Roads and Streets. The following procedure applies:
   - If HCV's per day ≤ 48, use a minimum 5 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 > 48, use a Class III TF equation and design procedure.

44-4.04 Typical Sections

Figures 44-4L and 44-4M illustrate typical LPA full-depth HMA pavement designs.

44-4.05 Worksheet

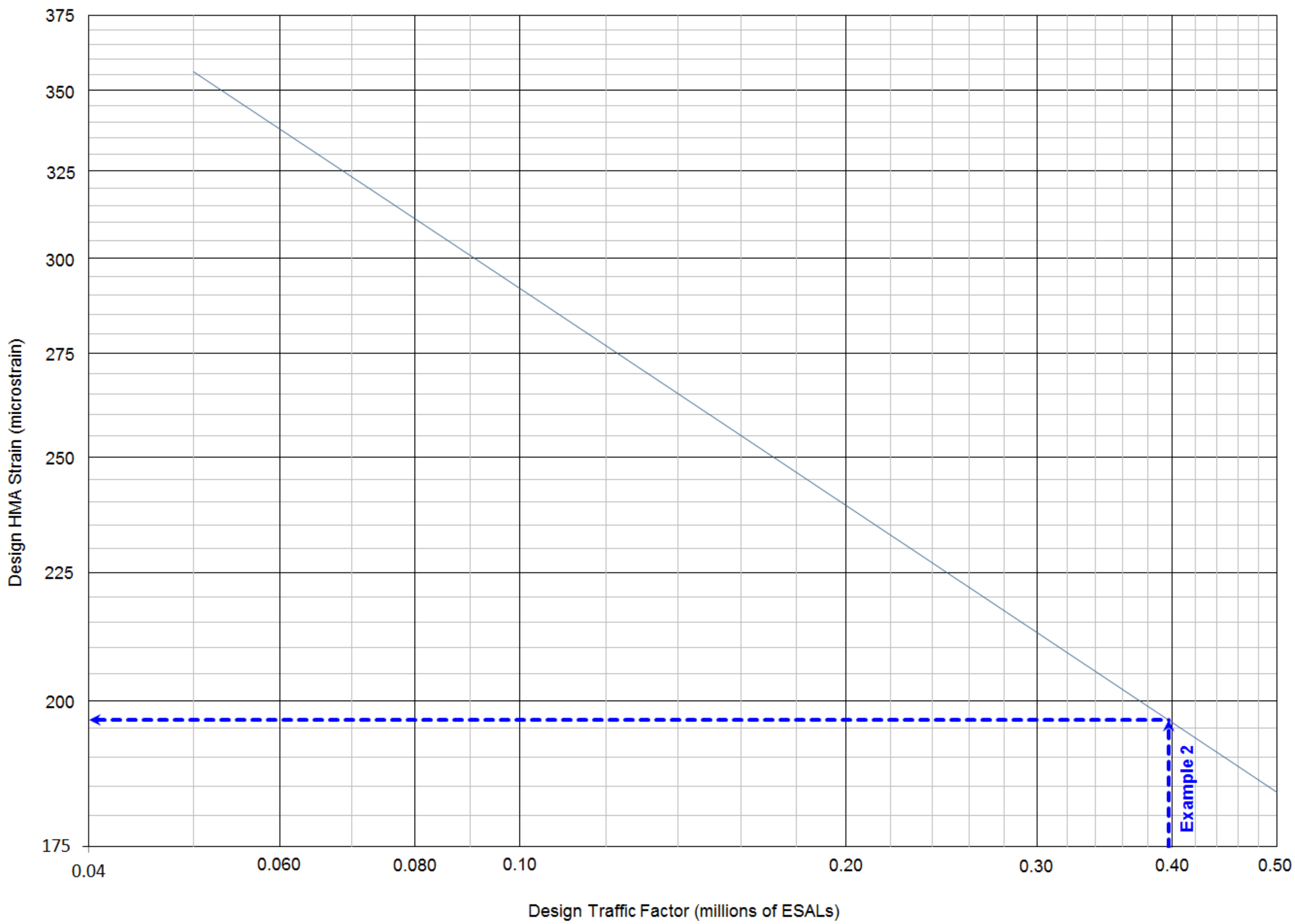
Figure 44-4N represents a worksheet for documenting the full-depth HMA pavement design calculations.



DESIGN PAVEMENT HMA MIXTURE TEMPERATURE
(Full Depth)

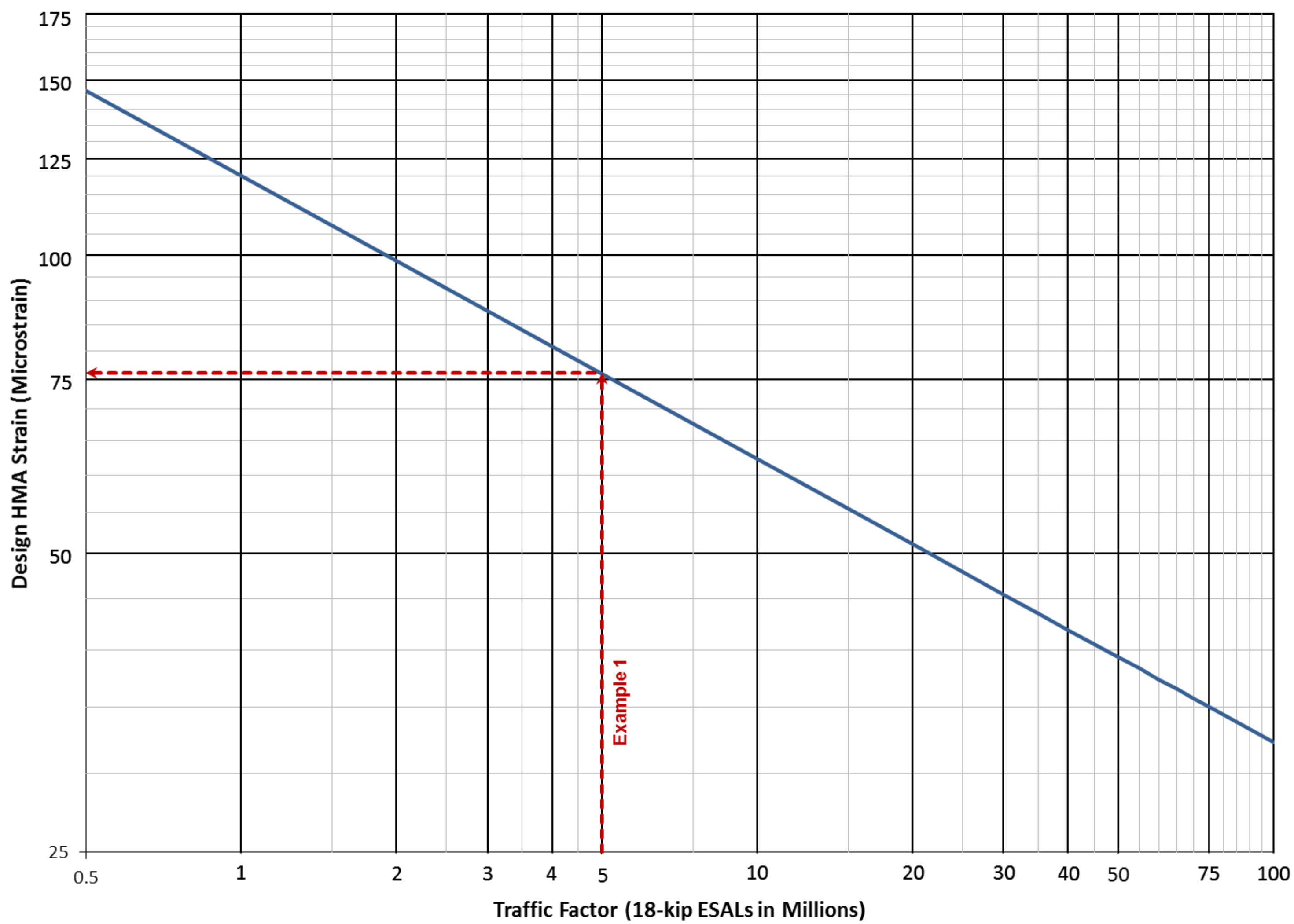
Figure 44-4E

Example 3 – Since the HCV's per day ≤ 48, use a minimum 5 in. HMA pavement.



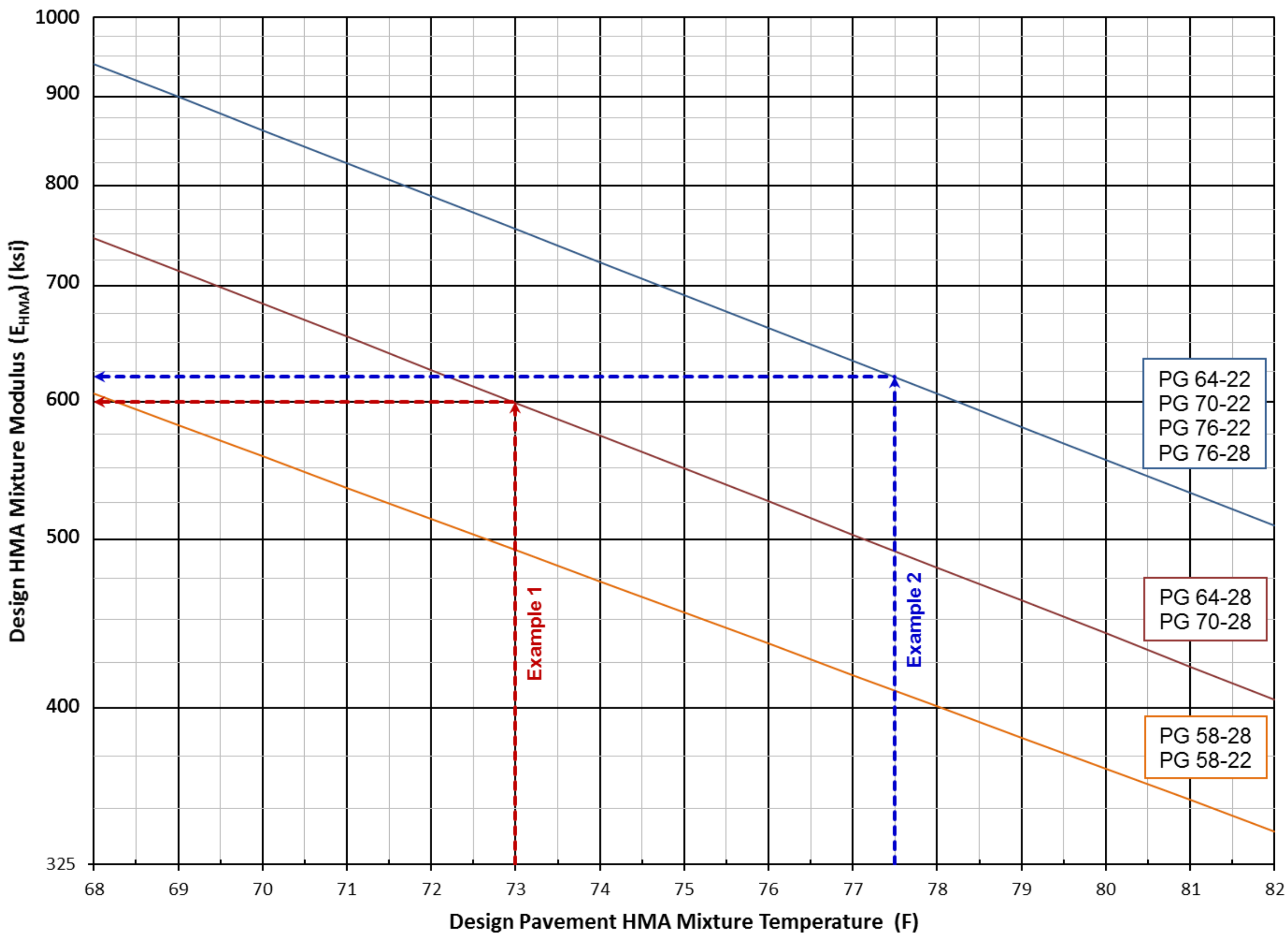
DESIGN HMA STRAIN
(Traffic Factor Relation for Traffic Factor < 0.5)

Figure 44-4F



DESIGN HMA STRAIN
(Traffic Factor Relation for Traffic Factor ≥ 0.5)

Figure 44-4G

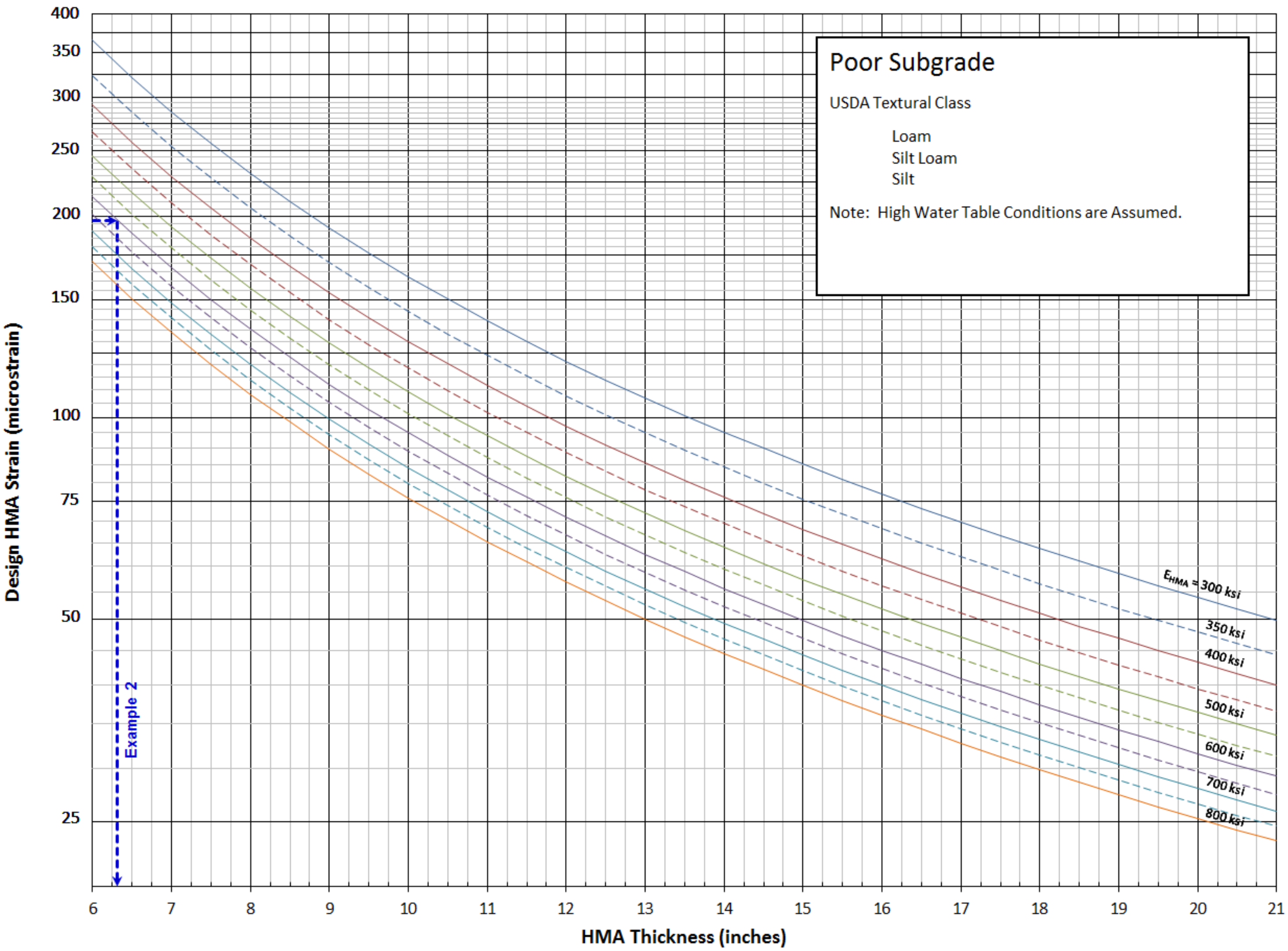


HMA MIXTURE MODULUS (E_{HMA})

Figure 44-4H

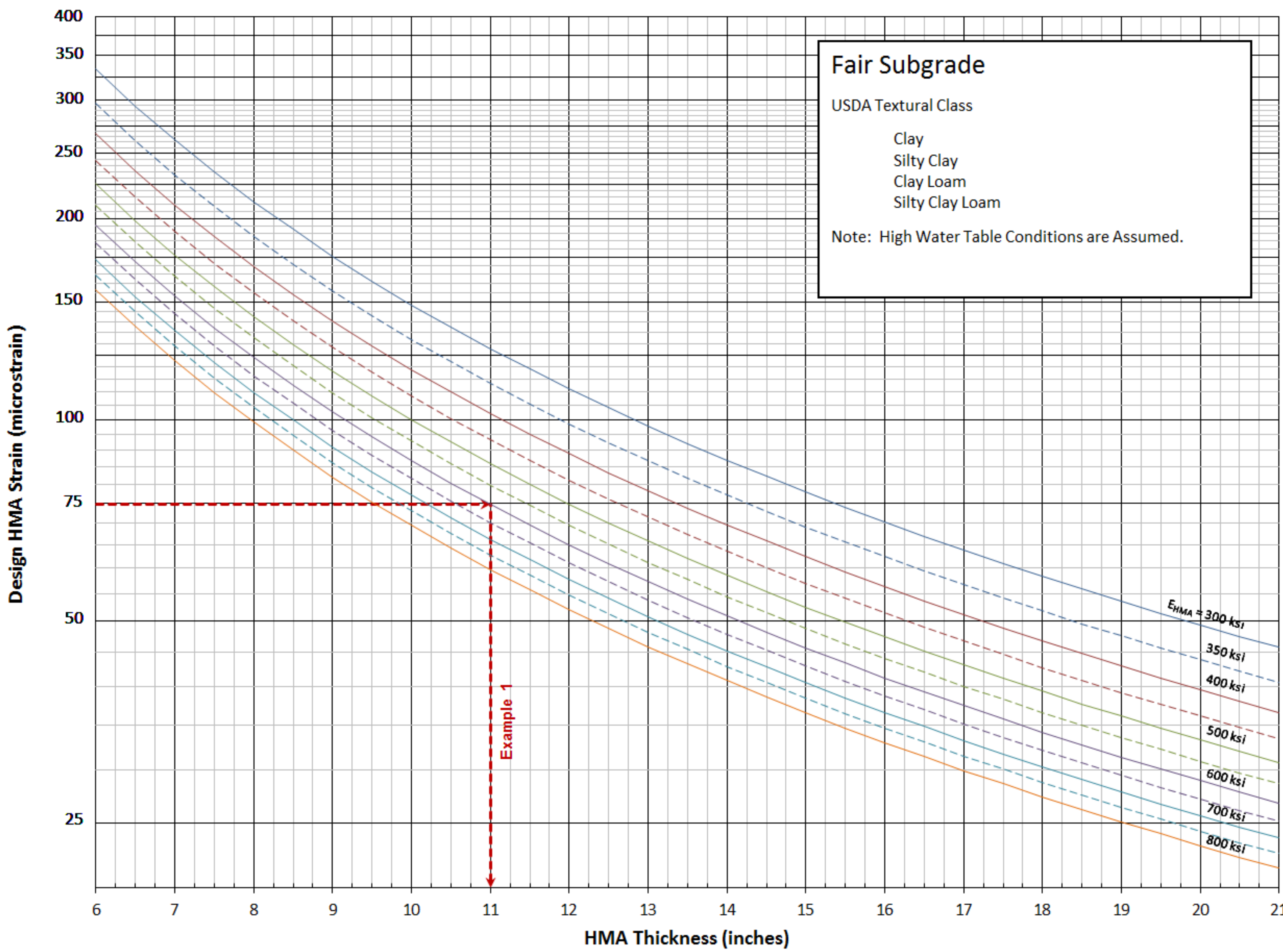
Example 3 – Since the HCV's per day ≤ 48, use a minimum 5 in. HMA pavement.

Example 3 – Since the HCV's per day ≤ 48, use a minimum 5 in. HMA pavement.



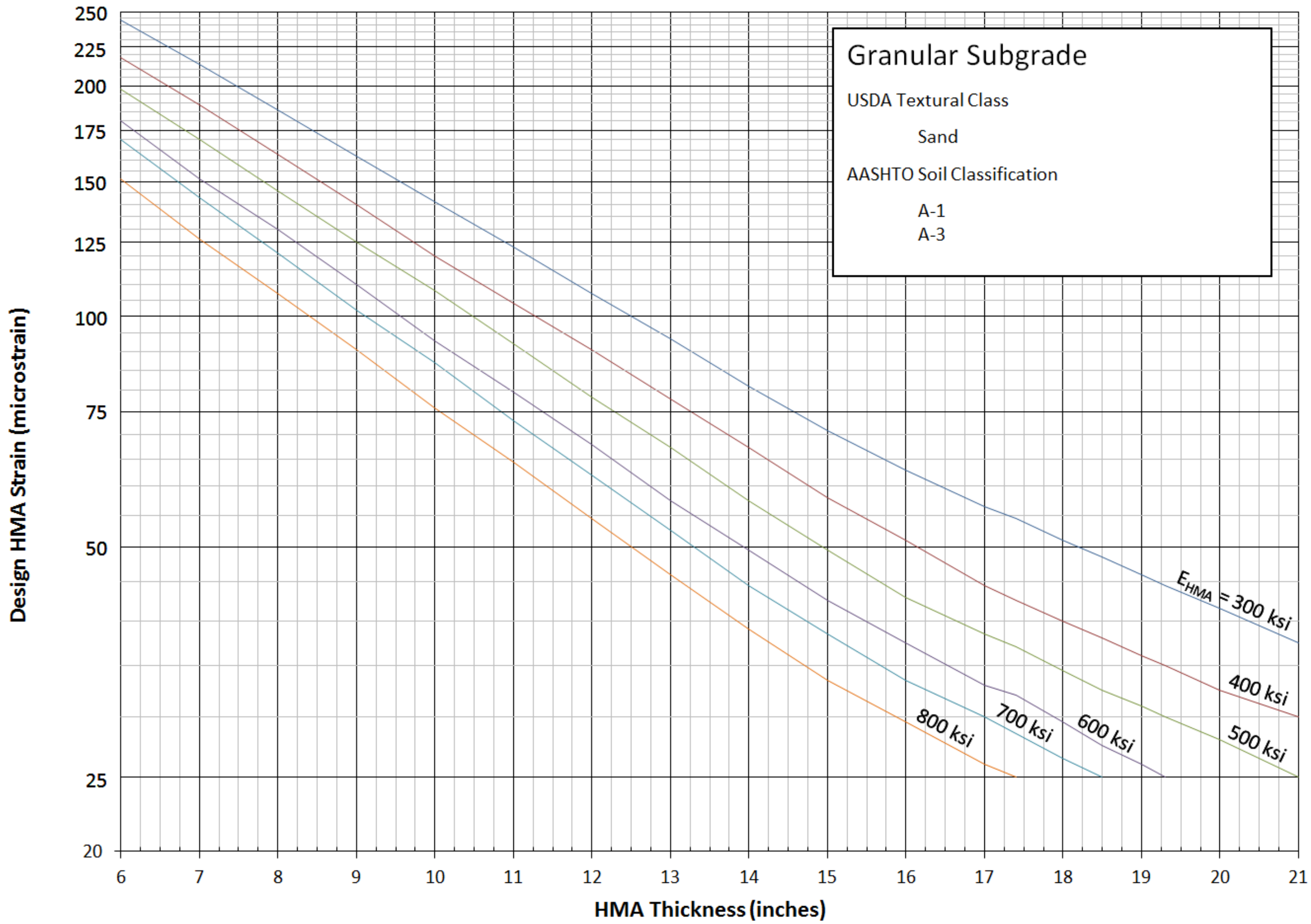
POOR SUBGRADE DESIGN CHART

Figure 44-4I



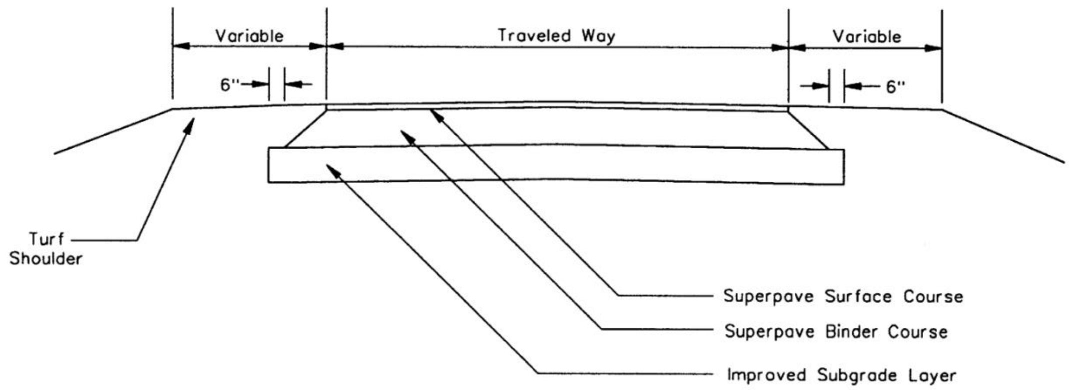
FAIR SUBGRADE DESIGN CHART

Figure 44-4J



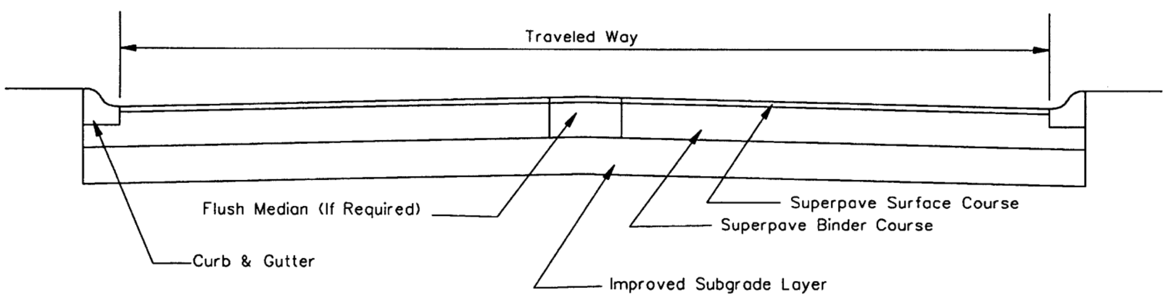
GRANULAR SUBGRADE DESIGN CHART

Figure 44-4K



TYPICAL FULL-DEPTH RURAL DESIGN

Figure 44-4L



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

TYPICAL FULL-DEPTH URBAN DESIGN

Figure 44-4M

Date: ____________________
Calculations by: ____________________
Checked by: ____________________

County: ____________________
LPA: ____________________
Section: ____________________
Route: ____________________
Location: ____________________

Limits of Analysis:
From: ____________________
To: ____________________
Length: ________ Feet ________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: ________
ADT: ________
Class of Road or Street: _____ *(Section 44-1.01)*

PV: ________% / ________
SU: ________% / ________
MU: ________% / ________
HCV: ________

Traffic Factor (Show Calculations)**:** *(Figure 44-4A)*

Traffic Factor: ________

Pavement Design:
Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-4.02(c) and Figure 44-6A)*
Working Platform: *(Figure 44-4B)* ____________________
Selected Design PG Binder *(Figure 44-4C)*
Surface: ____________________
Remaining Lifts: ____________________

Design Pavement HMA Temp: *(Figure 44-4E)* ________ºF
Design HMA Microstrain: *(Figure 44-4F or 44-4G)* ________
Design HMA Modulus (E_{HMA}): *(Figure 44-4H)* ________ksi
Pavement Thickness: *(Section 44-4.03) (Minimum of 6.0 in.)* ________in.

Comments: ____________________
____
____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

FULL-DEPTH HMA PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-4N

44-4.06 Example Calculations

44-4.06(a) Example Calculation 1 (Red) – Class I Road

Problem:

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

Given: (Section 44-1.08(a))

Class I Road, Four Lane Pavement (Urban) (Section 44-1.01)
12 ft Lanes with Concrete Curb and Gutter
Design Traffic: ADT = 14,000
PV's 86%, SU's 8%, MU's 6% (if unknown see Section 44-1.03(c))
Lake County
Design Subgrade Support Rating – Fair
Posted Speed Limit – 30 MPH with Bus Stops

Solution:

From Figure 44-4A use the TF equation for a four-lane Class I road; 4 or 5 Lane Pavement (Rural and Urban):

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

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

$$TF = 4.99$$

From Figure 44-4B, a 12 in. improved subgrade is required for all Class I and II full-depth HMA projects unless built upon a granular subgrade.

Since the road includes bus stops a Traffic Load Rate of "Standing Traffic" and from Figure 44-4C, the surface should be SBS PG 70-28 on the surface. The remaining lifts should be PG 64-22 or PG 58-22.

From Figure 44-4E, the design pavement HMA temperature would be 73°F.

Use Figure 44-4G (TF ≥ 0.5) in conjunction with the design TF of 4.99 to determine that the Design HMA strain is 76 microstrain.

Use Figure 44-4H in conjunction with a design pavement HMA temperature of 73°F to determine that the design HMA modulus is 600 ksi for PG 70-28.

Use Figure 44-4J (subgrade support rating is fair) in conjunction with the HMA strain of 76 microstrain and the design modulus of 600 ksi to determine a design HMA thickness of 11.0 in. This is the thickness after rounding to the next higher 0.25 in.

* * * * * * * * * *

Date: ______ County: Lake
Calculations by: ______ LPA: ______
Checked by: ______ Section: ______
Route: ______

Limits of Analysis: Location: ______

From: ______
To: ______
Length: ______ Feet ______ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 4
ADT: 14,000
Class of Road or Street: I *(Section 44-1.01)*

PV: 86 % / 12,040
SU: 8 % / 1,120
MU: 6 % / 840
HCV: 1,960

Traffic Factor (Show Calculations)**:** *(Figure 44-4A)*

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

Traffic Factor: 4.99

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☒ Fair ☐ Granular *(Section 44-4.02(c) and Figure 44-6A)*
Working Platform: *(Figure 44-4B)* A 12 in. improved subgrade is required.
Selected Design PG Binder *(Figure 44-4C)*
Surface: SBS PG 70-28
Remaining Lifts: PG 64-22 or PG 58-22

Design Pavement HMA Temp: *(Figure 44-4E)* 73ºF
Design HMA Microstrain: *(Figure 44-4F or 44-4G)* 76
Design HMA Modulus (E_{HMA}): *(Figure 44-4H)* 600 ksi
Pavement Thickness: *(Section 44-4.03) (Minimum of 6.0 in.)* 11 in.

Comments: ______

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 1 – FULL-DEPTH HMA PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-4N

44-4.06(b) Example Calculation 2 (Blue) – Class III Road

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

Given: (Section 44-1.08(b))
Class III Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Paved HMA Shoulders
Design Traffic: ADT = 1,800
PV's 90%, SU's 6%, MU's 4% (if unknown see Section 44-1.03(c))
Sangamon County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 40 MPH with No Bus Stops

Solution:
From Figure 44-4A use the TF equation for a two-lane Class IIII road:

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

$$TF = 20\left[\frac{(0.073 \times 1{,}620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

$$TF = 0.397$$

From Figure 44-4B, a 12 in. improved subgrade is optional.

From Figure 44-4C, the surface should be PG 70-22 or SBS PG 70-22 on the surface. The remaining lifts should be PG 64-22.

From Figure 44-4E, the design pavement HMA temperature would be 77.5°F.

Use Figure 44-4F (TF < 0.5) in conjunction with the design TF of 0.397 to determine that the Design HMA strain is 197 microstrain.

Use Figure 44-4H in conjunction with a design pavement HMA temperature of 77.5°F to determine that the design HMA modulus is 621 ksi for PG 70-22 or PG 64-22.

Use Figure 44-4I (subgrade support rating is poor) in conjunction with the HMA strain of 197 microstrain and the design modulus of 621 ksi to determine a design HMA thickness of 6.30 in. After rounding to the next higher 0.25 in, the thickness is 6.5 in. Based on the microstrain of 197, a modulus 621, a poor subgrade support, and the ADT close to a Class II road, it is recommended to improve the subgrade with 12 in. of modified soil or granular layer.

* * * * * * * * * *

Date: ______
Calculations by: ______
Checked by: ______

County: Sangamon
LPA: ______
Section: ______
Route: ______
Location: ______

Limits of Analysis:

From: ______

To: ______

Length: ______ Feet ______ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2

ADT: 1,800

Class of Road or Street: III *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

	Percent	Count
PV:	90 %	1,620
SU:	6 %	108
MU:	4 %	72
HCV:	180	

Traffic Factor (Show Calculations)**:** *(Figure 44-4A)*

$$TF = 20\left[\frac{(0.073 \times 1{,}620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

Traffic Factor: 0.397

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-4.02(c) and Figure 44-6A)*

Working Platform: *(Figure 44-4B)* A 12 in. improved subgrade is optional, however; see below.

Selected Design PG Binder *(Figure 44-4C)*

Surface: PG 70-22 or SBS PG 70-22

Remaining Lifts: PG 64-22

Design Pavement HMA Temp: *(Figure 44-4E)* 77.5°F

Design HMA Microstrain: *(Figure 44-4F or 44-4G)* 197

Design HMA Modulus (E_{HMA}): *(Figure 44-4H)* 621 ksi

Pavement Thickness: *(Section 44-4.03) (Minimum of 6.0 in.)* 6.50 in.

Comments: Based on the microstrain of 197, a modulus 621, a poor subgrade support, and the ADT close to a Class II road, it is recommended to improve the subgrade with 12 in. of modified soil or granular layer.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 2 – FULL-DEPTH HMA PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-4N

44-4.06(c) Example Calculation 3 (Green) – Class IV Road

Problem:

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

Given: (Section 44-1.08(c))

Class IV Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Aggregate Shoulders
Design Traffic: ADT = 350
PV's 88%, SU's 7%, MU's 5% (if unknown see Section 44-1.03(c))
City of Marion, Williamson County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 55 MPH with No Bus Stops

Solution:

Since the HCV's per day is less than 48, use a minimum 5 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. See Section 44-4.03 Item 2.

From Figure 44-4B, a 12 in. improved subgrade is shown as optional. Check the subgrade value with a dynamic cone penetrometer (DCP). If the Immediate Bearing Value (IBV) value is less than 6, an improved subgrade should be provided; see Section 44-7.02.

From Figure 44-4C, the surface should be PG 64-22 on the surface. The remaining lifts should be PG 64-22.

* * * * * * * * * *

Date: ____________________
Calculations by: ____________________
Checked by: ____________________

County: Williamson
LPA: City of Marion
Section: ____________________
Route: ____________________
Location: ____________________

Limits of Analysis:

From: ____________________
To: ____________________
Length: __________ Feet __________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2
ADT: 350
Class of Road or Street: IV *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: 88 % / 306
SU: 7 % / 24
MU: 5 % / 18
HCV: 42

Traffic Factor (Show Calculations)**:** *(Figure 44-4A)*

Since the HCV's per day $\leq$ 48, use a minimum 5 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.

Traffic Factor: N/A

Pavement Design:

Subgrade Support Rating (SSR): ☒ Poor ☐ Fair ☐ Granular *(Section 44-4.02(c) and Figure 44-6A)*

Working Platform: *(Figure 44-4B)* A 12 in. improved subgrade is optional. See Section 44-7.

Selected Design PG Binder *(Figure 44-4C)*

Surface: PG 64-22
Remaining Lifts: PG 64-22

Design Pavement HMA Temp: *(Figure 44-4E)* N/A ºF
Design HMA Microstrain: *(Figure 44-4F or 44-4G)* N/A
Design HMA Modulus (E_{HMA}): *(Figure 44-4H)* N/A ksi
Pavement Thickness: *(Section 44-4.03) (Minimum of 6.0 in.)* 5.0 in.

Comments: Check the subgrade value with a dynamic cone penetrometer (DCP). If the Immediate Bearing Value (IBV) value is less than 6, an improved subgrade should be provided; see Section 44-7.02.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 3 – FULL-DEPTH HMA PAVEMENT DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-4N

44-5 COMPOSITE PAVEMENT DESIGN FOR LOCAL PUBLIC AGENCIES

44-5.01 Introduction

44-5.01(a) Design of Composite Pavements

A composite pavement consists of a HMA surface layer over a Portland cement concrete (PCC) or roller-compacted concrete (RCC) slab. Advantages of placing the HMA layer over the concrete slab include a reduced slab thickness because of the structural contribution of the HMA, and a more uniform surface appearance if pavement patches are used to repair utility cuts, or due to widening or otherwise modifying the existing pavement. The HMA surface layer also reduces the thermal gradients through the concrete slab. These reduced thermal effects also allow for increased spacing between joints in the underlying concrete slab. RCC can only be used for structural designs with TF ≤ 3.0 without prior approval from CBLRS.

Ultra-thin whitetopping or bonded concrete overlay of asphalt, a thin PCC overlay over an existing HMA surfaced pavement, is a not considered a composite pavement, but rather 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 one 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 two or more stages. If stage construction of a composite pavement is planned for separate contracts, the designer should design the concrete 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 with the minimum thicknesses in Section 44-1.05. 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) Traffic Factors

For composite pavements, two Traffic Factors (TF) are required; one to determine the PCC slab thickness and the other to select the PG Binder. For Class I, II, and III roads and streets, the design TF for the PCC slab portion of the composite pavements is determined from the 80,000 lb load limit formulas shown in Figure 44-5A. Use Figure 44-5E to determine the TF for the HMA portion and to select the PG Binder.

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 CBLRS for special analysis. It will be necessary for the LPA to provide the CBLRS 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 to determine the PCC slab thickness. A pre-adjusted PCC slab thickness of 6.5 in. with 2 in. of HMA should be used for all Class IV composite pavements. However, to select the PG Binder a design TF is required using Figure 44-5E.

44-5.02(c) Transverse Pavement Joints

For composite pavements, 12 to 15 ft transverse joint spacings are available to the designer. Joint spacing of 20 ft and greater can result in intermediate slab cracking and/or premature reflective cracking in the HMA surface layer.

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 PCC slab thickness ≥ 7 in. For PCC slab thickness less than 7 in., the designer has the option of using dowel bars or relying on aggregate interlock for load transfer.

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

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

PCC SLAB TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-5A

44-5.02(d) 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) more than 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.

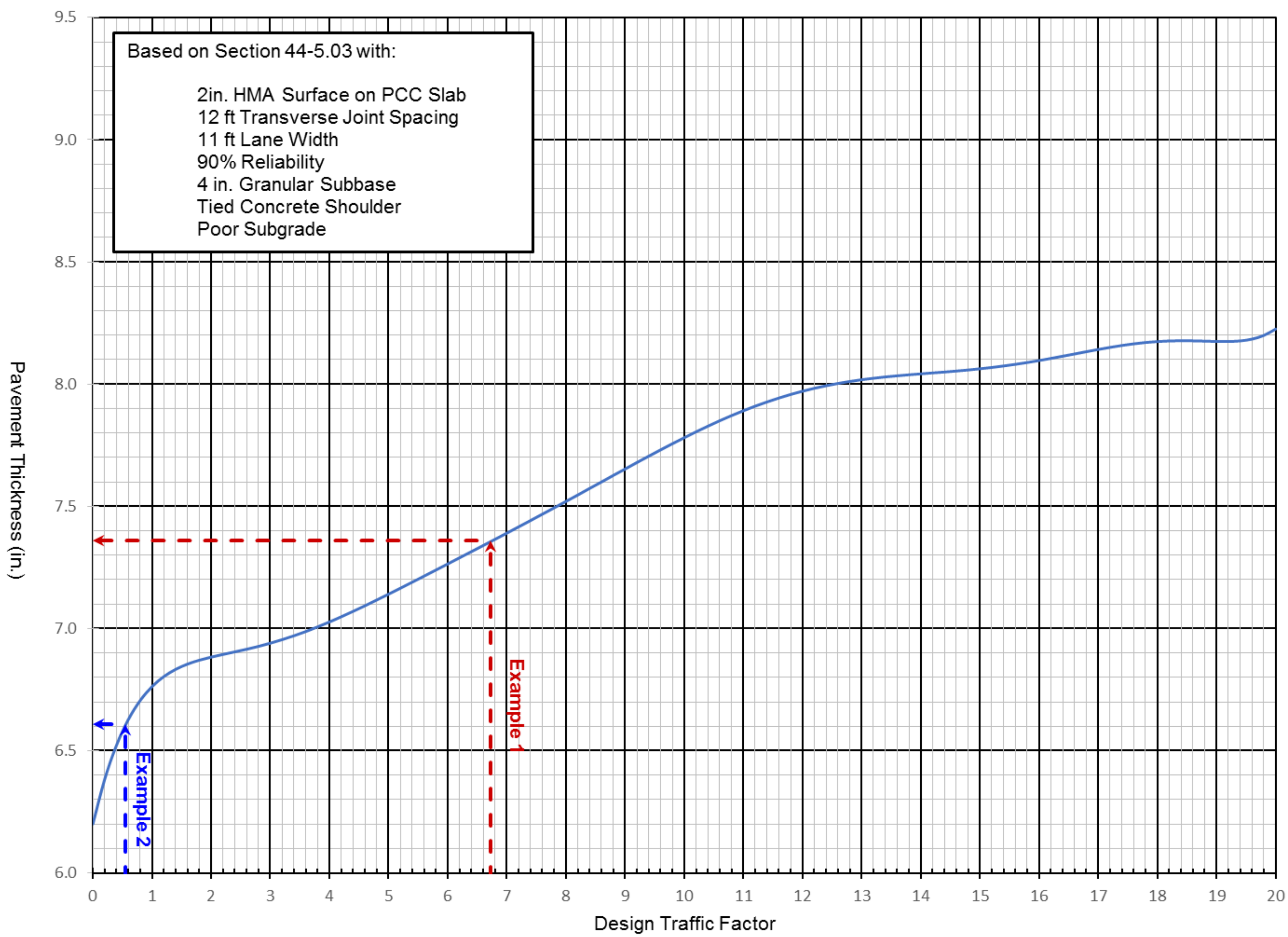
44-5.02(e) Subgrade Support Rating (SSR)

The general physical characteristics of the roadbed soil affect the design thickness and performance of the pavement structure. For pavement design purposes there are three subgrade support ratings (SSR) — poor, fair, and granular. The SSR is determined by using Section 44-6. The SSR should represent the average/majority classification within the design section. The pavement thickness design curves in Figure 44-5B are based on a poor SSR. Adjustments in the design thickness are made for the fair and granular subgrades.

44-5.02(f) 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 44-5E.

When placing a composite pavement directly over a flexible pavement with a HMA surface, consult with the CBLRS for design assistance.



Example 3 – The pre-adjusted slab thickness is 6.5 in. with adjustments of -0.15 in. providing a final thickness of 6.5 in. which exceeds the minimum of 5.5 in. with a 2.0 in. HMA surface for composite pavements.

PRE-ADJUSTED PCC SLAB THICKNESS

Figure 44-5B

Adjustment Factor	PCC Slab Thickness Adjustment (in.)
75% Reliability	-0.50
15 ft Joint Spacing	+1.00
Untied Shoulder	+0.35
Fair Subgrade	-0.25
Granular Subgrade	-0.50
Stabilized Subbase	-0.25
Existing Pavement as Subbase	-0.50
10 ft Lane Width	+0.25
12 ft Lane Width	-0.25
Surface HMA Layer Thickness	See Figure 44-5I

THICKNESS ADJUSTMENT FACTOR

Figure 44-5C

Road Class	Subbase Material	Usage[(1)]	Minimum Thickness (in.)
Class I and II TF ≥ 5.0 TF < 5.0	Stabilized Subbase[(2)] Granular[(3)]	Required Required	4 4
Class III & IV T.F. ≥ 5.0 T.F. < 5.0	Granular[(3)] Granular[(3)]	Required Optional / 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. *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 44-5D

44-5.02(g) 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 44-5F and 44-5G. 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 44-5F and 44-5G 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 LPA pavement design differ from the tables used for the State system. A lower level of reliability is used for LPA design than for the State system.

The LPA must request a variance from CBLRS to use a different PG binder than specified in Figure 44-5F and Figure 44-5G.

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

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

Figure 44-5E

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

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 given in Figure 44-5E. Rigid traffic factors given in Figure 44-5A thru Figure 44-5C are required to determine the PCC slab thickness portion of the composite pavement 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. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

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

Figure 44-5F

Illinois N_{design} Number	Flexible Design ESALs, millions (1) (Flexible T.F.)	PG Binder Grade Selection (2)(3)		
		Traffic Loading Rate (Adjustment)		
		Standard(4)	Slow(5)	Standing(6)
30	< 0.3	PG 58-22	PG 64-22(7)	PG 64-22(7)
50	0.3 to < 3	PG 64-22	PG 64-22(7)	PG 70-22 or SBS PG 70-22
70	3 to < 10	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
90	10 to < 30	PG 64-22(7)	PG 70-22 or SBS PG 70-22	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 given in Figure 44-5E. Rigid traffic factors given in Figure 44-5A thru Figure 44-5C are required to determine the PCC slab thickness portion of the composite pavement 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. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

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

Figure 44-5G

44-5.02(h) Design Reliability

Design reliability is considered through traffic multipliers applied to the design TF. These traffic multipliers are built into the PCC slab thickness design curves in Figure 44-5B, which is for high reliability levels. The minimum reliability levels by road class are shown in 44-5H. The thickness adjustment factor for medium reliability are provided in Figure 44-4C.

Road Class	Minimum Reliability Levels	Percent Reliability
Class I and II	High	90
Class III & IV	Medium	75

RELIABILITY LEVELS

Figure 44-5H

44-5.03 <u>PCC Slab Thickness Design</u>

44-5.03(a) Minimum Design Thickness

Once all PCC slab thickness adjustments have been made, the minimum design must have at least 2 in. of HMA over 5.5 in. of PCC or at least 3 in. of HMA over 5.0 in. of PCC.

44-5.03(b) Pre-adjusted PCC Slab Thickness

The composite thickness design procedure is based on determining the thickness of the pre-adjusted PCC slab assuming a poor SSR, 2 in. of HMA surface, 12 ft joint spacing, 11 ft lane width, a 90% Reliability, 4 in. granular subbase, and a tied PCC shoulder. Using the design TF, the PCC slab thickness is determined from the design curves shown in Figure 44-5B. For Class IV pavements, the pre-adjusted PCC slab thickness is 6.5 in. Adjustments to this basic PCC slab thickness can be made for other factors (e.g., subgrade support, subbase type, joint spacing, shoulder type, reliability, and HMA thickness). The final design thickness should be rounded to the next highest 0.25 in.

44-5.03(c) PCC Slab Thickness Adjustments

In determining any adjustments, consider the following:

1. <u>Pavement Support</u>. PCC slab thickness adjustments are based on the subgrade rating and whether the pavement structure will have a stabilized subbase or no subbase. The subgrade support and stabilized subbase adjustments factors are shown in Figure 44-5C.

2. <u>Shoulder Type</u>. With tied PCC shoulders, tied curb and gutter, integral curb and gutter, or widened outer lanes, no adjustments are required. PCC slab adjustments for untied PCC shoulders should be made according to Figure 44-5C. The tied shoulders must use the proper size of reinforcement bars to tie to the pavement, see the Illinois Highway

Standards to ensure that load transfer is obtained between the pavement and the curb/shoulder. Designers may specify smaller tie bars, but in these cases, additional PCC slab thickness is required.

3. Joint Spacing. Joint spacing of 15 ft instead of 12 ft may be used for composite pavements with the PCC slab thickness adjustment factor given in Figure 44-5C.

4. Lane Width. The standard chart in Figure 44-5B is for an 11 ft lane width. Thickness adjustment can be made for 10 ft and 12 ft lane width as shown in Figure 44-5C.

5. Reliability. Designs for lower reliability can be completed given the criteria in Figure 44-5H and thickness adjustment factor given in Figure 44-5C.

6. HMA Surface Layer Thickness. The pre-adjusted PCC slab thickness is based on a HMA surface layer of 2 in. placed over the PCC slab. If the HMA layer thickness is other than 2 in., adjust the thickness using Figure 44-5I.

HMA Layer Thickness (in.)	PCC Slab Thickness Adjustment (in.)
2	No adjustment
2.5	- 0.25
3	-0.50

ADJUSTMENTS FOR HMA THICKNESS

Figure 44-5I

44-5.03(d) Dowel Bars

The use of doweled joints will be required for pavement thicknesses that are 7 in. and greater on all Class I, Class II, and Class III roads and streets. Doweled joints will not be required for Class IV roads and streets. Dowel bar diameter requirements are given in Figure 44-5J. Normal dowel spacing is 12 in. However, with approval from the CBLRS, the dowels can be placed only in the wheel path area. There is no adjustment in pavement thickness with doweled transverse joints.

PCC Slab Thickness (in.)	Dowel Diameter (in.)
≥ 10.00	1.50
> 8.00 to 9.99	1.25
≤ 8.00	1.00

DOWEL DIAMETER

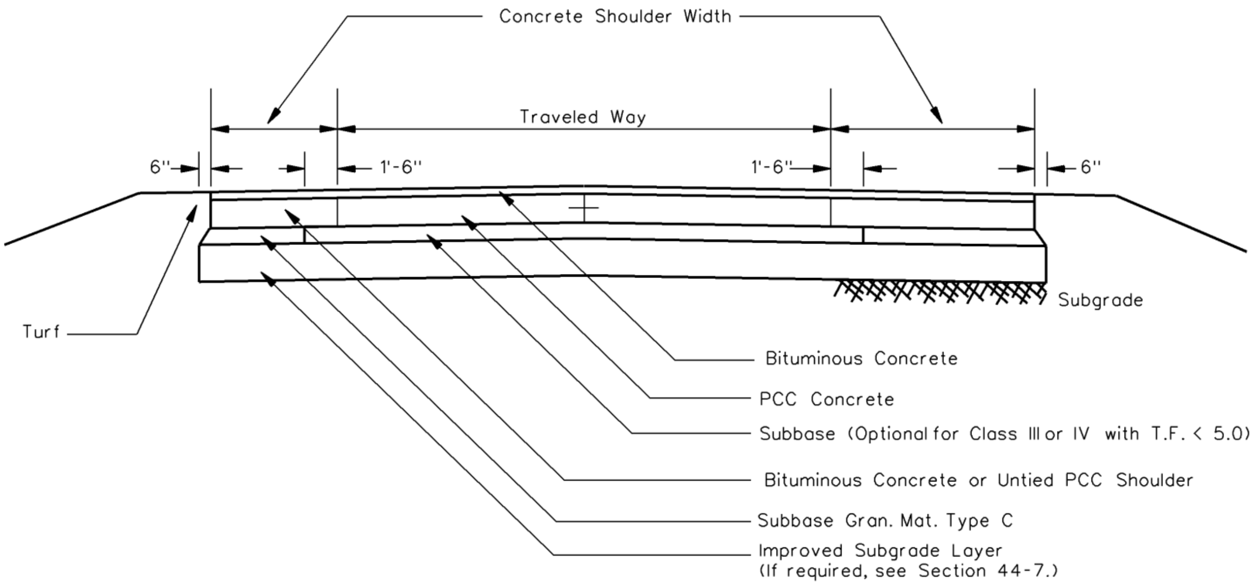
Figure 44-5J

44-5.04 Typical Sections

Figures 44-5K, 44-5L, and 44-5M illustrate typical LPA composite pavement designs.

44-5.05 Worksheet

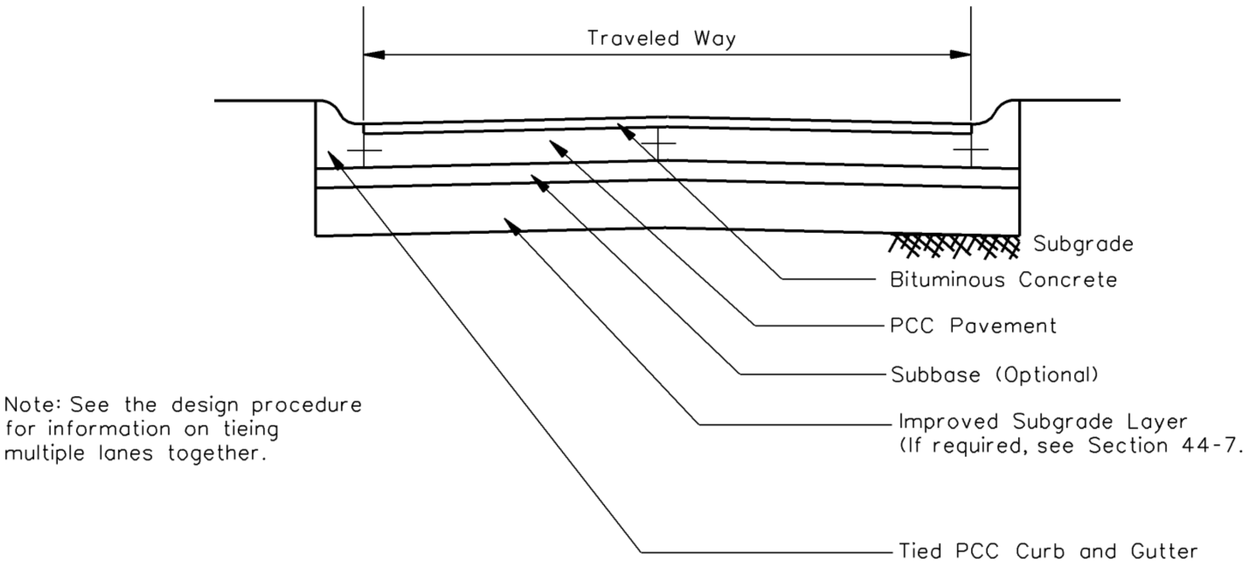
Figure 44-5N represents a worksheet for documenting the composite pavement design calculations.



TYPICAL COMPOSITE DESIGN

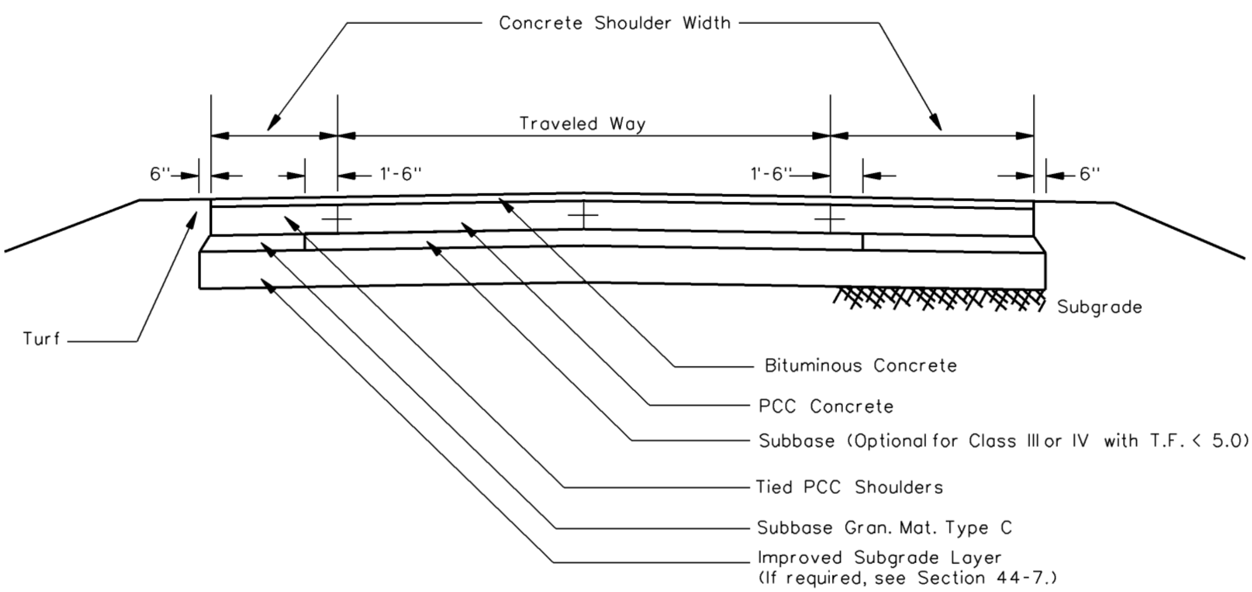
WITH UNTIED SHOULDERS

Figure 44-5K



TYPICAL COMPOSITE DESIGN WITH TIED CURB AND GUTTERS

Figure 44-5L



TYPICAL COMPOSITE DESIGN WITH TIED SHOULDERS

Figure 44-5M

Date: ____________________
Calculations by: ____________________
Checked by: ____________________

County: ____________________
LPA: ____________________
Section: ____________________
Route: ____________________
Location: ____________________

Limits of Analysis:
From: ____________________
To: ____________________
Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: __________
ADT: __________
Class of Road or Street: _____ *(Section 44-1.01)*

PV: __________% / __________
SU: __________% / __________
MU: __________% / __________
HCV: __________

Traffic Factor (Show Calculations)**:**

PCC Slab Traffic Factor: *(Figure 44-5A)* ________

HMA Traffic Factor: *(Figure 44-5E)* ________

Pavement Design:
Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-5.02(e) and Figure 44-6)*
Pre-Adjusted PCC Slab Thickness: *(Figure 44-5B)* *(Class IV use 6.50 in.)* __________in.
Reliability: *(Figure 44-5H)* ☐ 75% or ☐ 90%

Adjustments: *(Section 44-5.03(c) and Figure 44-5C)*

		Applicable Adjustments
75% Reliability *(Section 44-5.02(h))*	-0.50	__________in.
15 ft Joint Spacing	+1.00	__________in.
Untied Shoulder	+0.35	__________in.
Fair Subgrade / Granular Subgrade	-0.25 / -0.50	__________in.
Stabilized Subbase / Existing Pavement as	-0.25 / -0.50	__________in.
10 ft Lane Width / 12 ft Lane Width	+0.25 / -0.25	__________in.
HMA Surface Layer Thickness __________in.	*(See Figure 44-5I)*	__________in.
	Total Adjustment:	__________in.

Adjusted PCC Slab Thickness: *(Section 44-5.03(a))* __________in.
Subbase Requirements: *(Figure 44-5D)* ____________________
Select Binder: *(Figure 44-5F or 44-5G)* ____________________
HMA Layer Thickness: *(Figure 44-5I)* __________in.
Final Pavement Thickness *(Rounded to next ¼ in.)* __________in.
Dowel Bars: ☐ Yes ☐ No *(Section 44-5.03(d))* Size: *(Figure 44-5J)* __________in.
Comments: ____________________

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

COMPOSITE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-5N

44-5.06 Example Calculations

44-5.06(a) Example Calculation 1 (Red) – Class I Road

Problem:

Design a composite pavement for the given conditions.

Given: (Section 44-1.08(a))

Class I Road, Four Lane Pavement (Urban) (Section 44-1.01)
12 ft Lanes with Concrete Curb and Gutter
Design Traffic: ADT = 14,000
PV's 86%, SU's 8%, MU's 6% (if unknown see Section 44-1.03(c))
Lake County
Design Subgrade Support Rating – Fair
Posted Speed Limit – 30 MPH with Bus Stops

Solution:

Use Figure 44-5A and determine the TF equation for a four-lane Class I road; 4 or 5 Lane Pavement (Rural and Urban) to determine the PCC slab thickness:

$$TF = 20\left[\frac{(0.047 \times 12040 + 64.715 \times 1120 + 313.389 \times 840)}{1{,}000{,}000}\right]$$

$$TF = 6.73$$

Because the pavement is a Class I road with tied curb and gutter, a subbase is optional (see Figure 44-5D, Note 1).

The pre-adjusted PCC slab thickness is determined from Figure 44-5B, gives a value of 7.36 in. Based on Figure 44-2C, the thickness adjustment factors are -0.25 in. (fair subgrade) and -0.25 in. (12 ft lane width). The pre-adjusted PCC slab thickness is 7.36 in. with adjustments of -0. 50 in. for a value of 6.86 in; this is rounded to the next highest ¼ in. or a final thickness of 7.0 in. Alternative designs may be made by varying the HMA surface thickness, see Figure 44-5I. For this example, a 2 in. HMA overlay is used.

Dowels are required because the PCC slab thickness required 7 in. or greater [Section 44-5.02(c)]. Based on Figure 44-5J, the dowel bar diameter is 1.00 in.

Based on Figures 44-5E and 44-5F, a TF = 4.99, and bus stops along this road; an Illinois N_{70} will result in specifying the binder as a PG 70-22 or SBS PG 70-22.

$$TF = 20\left[\frac{(0.047 \times 12040 + 59.625 \times 1120 + 217.139 \times 840)}{1{,}000{,}000}\right]$$

$$TF = 4.99$$

* * * * * * * * * *

Date: ____________________
Calculations by: ____________________
Checked by: ____________________

County: Lake
LPA: ____________________
Section: ____________________
Route: ____________________
Location: ____________________

Limits of Analysis:

From: ____________________
To: ____________________
Length: ________ Feet ________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 4
ADT: 14,000
Class of Road or Street: I *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

	Percent	Count
PV:	86 %	12,040
SU:	8 %	1,120
MU:	6 %	840
HCV:	1,960	

Traffic Factor (Show Calculations)**:**

$$TF = 20\left[\frac{(0.047 \times 12040 + 64.715 \times 1120 + 313.389 \times 840)}{1{,}000{,}000}\right]$$

PCC Slab Traffic Factor: *(Figure 44-5A)* 6.73

$$TF = 20\left[\frac{(0.047 \times 12040 + 59.625 \times 1120 + 217.139 \times 840)}{1{,}000{,}000}\right]$$

HMA Traffic Factor: *(Figure 44-5E)* 4.99

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☒ Fair ☐ Granular *(Section 44-5.02(e) and Figure 44-6)*

Pre-Adjusted PCC Slab Thickness: *(Figure 44-5B)* *(Class IV use 6.50 in.)* 7.36 in.

Reliability: *(Figure 44-5H)* ☐ 75% or ☒ 90%

Adjustments: *(Section 44-5.03(c) and Figure 44-5C)*

Adjustment	Value	Applicable Adjustments
75% Reliability *(Section 44-5.02(h))*	-0.50	N/A in.
15 ft Joint Spacing	+1.00	N/A in.
Untied Shoulder	+0.35	N/A in.
Fair Subgrade / Granular Subgrade	-0.25 / -0.50	-0.25 in.
Stabilized Subbase / Existing Pavement as Subbase	-0.25 / -0.50	N/A in.
10 ft Lane Width / 12 ft Lane Width	+0.25 / -0.25	-0.25 in.
HMA Surface Layer Thickness 2.0 in.	*(See Figure 44-5I)*	N/A in.
	Total Adjustment:	-0.50 in.

Adjusted PCC Slab Thickness: *Section 44-5.03(a))* 6.86 use 7.0 in.

Subbase Requirements: *(Figure 44-5D)* A subbase is optional.

Select Binder: *(Figure 44-5F or 44-5G)* PG 70-22 or SBS PG 70-22

HMA Layer Thickness: *(Figure 44-5I)* 2.0 in.

Final Pavement Thickness *(Rounded to next ¼ in.)* 9.0 in.

Dowel Bars: ☒ Yes ☐ No *(Section 44-5.03(d))* Size: *(Figure 44-5J)* 1.00 in.

Comments: ____________________

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 1 – COMPOSITE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-5N

44-5.06(b) Example Calculation 2 (Blue) – Class III Road

Problem:
Design a composite pavement for the given conditions.

Given: (Section 44-1.08(b))
Class III Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Paved HMA Shoulders
Design Traffic: ADT = 1,800
PV's 90%, SU's 6%, MU's 4% (if unknown see Section 44-1.03(c))
Sangamon County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 40 MPH with No Bus Stops

Solution:
Use Figure 44-5A and determine the TF equation for a two-lane Class III road:

$$TF = 20\left[\frac{(0.073 \times 1620 + 64.790 \times 108 + 281.235 \times 72)}{1{,}000{,}000}\right]$$

$$TF = 0.547$$

Because the pavement is a Class III road with a TF < 5.0, a subbase is optional (see Figure 44-5D).

The pre-adjusted PCC slab thickness is determined from Figure 44-5B, gives a value of 6.61 in. Based on Figure 44-2C, the thickness adjustment factors are -0.50 (75% reliability) and +0.35 (untied shoulder). The pre-adjusted PCC slab thickness is 6.61 in. with adjustments of -0.15 in. for a value of 6.46 in; this is rounded to the next highest ¼ in. or a final thickness of 6.50 in. Alternative designs may be made by varying the HMA surface thickness, see Figure 44-5I. For this example, a 3 in. HMA overlay is used, reducing the PCC slab thickness an additional 0.5 in. to a final thickness of 6.0 in.

Dowels are not required because the PCC slab thickness required is less than 7 in [Section 44-5.02(d)].

Based on Figures 44-5E and 44-5G, a TF = 0.397, and a posted speed limit of 40 mph; an Illinois N_{50} will result in specifying the binder as a PG 64-22.

$$TF = 20\left[\frac{(0.073 \times 1620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

$$TF = 0.397$$

* * * * * * * * * *

Date: ____________________ County: Sangamon

Calculations by: ____________________ LPA: ____________________

Checked by: ____________________ Section: ____________________

Route: ____________________

Location: ____________________

Limits of Analysis:

From: ____________________

To: ____________________

Length: __________ Feet __________ Miles

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: 2

ADT: 1,800

Class of Road or Street: III *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

PV: 90 % / 1,620

SU: 6 % / 108

MU: 4 % / 72

HCV: 180

Traffic Factor (Show Calculations)**:**

$$TF = 20\left[\frac{(0.073 \times 1620 + 64.790 \times 108 + 281.235 \times 72)}{1{,}000{,}000}\right]$$

PCC Slab Traffic Factor: *(Figure 44-5A)* 0.547

$$TF = 20\left[\frac{(0.073 \times 1620 + 54.570 \times 108 + 192.175 \times 72)}{1{,}000{,}000}\right]$$

HMA Traffic Factor: *(Figure 44-5E)* 0.397

Pavement Design:

Subgrade Support Rating (SSR): ☒ Poor ☐ Fair ☐ Granular *(Section 44-5.02(e) and Figure 44-6)*

Pre-Adjusted PCC Slab Thickness: *(Figure 44-5B)* *(Class IV use 6.50 in.)* 6.61 in.

Reliability: *(Figure 44-5H)* ☒ 75% or ☐ 90%

Adjustments: *(Section 44-5.03(c) and Figure 44-5C)*

Adjustment	Value	Applicable Adjustments
75% Reliability *(Section 44-5.02(h))*	-0.50	-0.50 in.
15 ft Joint Spacing	+1.00	N/A in.
Untied Shoulder	+0.35	+0.35 in.
Fair Subgrade / Granular Subgrade	-0.25 / -0.50	N/A in.
Stabilized Subbase / Existing Pavement as Subbase	-0.25 / -0.75	N/A in.
10 ft Lane Width / 12 ft Lane Width	+0.25 / -0.25	N/A in.
HMA Surface Layer Thickness 3.0 in.	*(See Figure 44-5I)*	-0.50 in.
	Total Adjustment:	-0.65 in.

Adjusted PCC Slab Thickness: *(Section 44-5.03(a))* 5.96 use 6.0 in.

Subbase Requirements: *(Figure 44-5D)* A subbase is optional.

Select Binder: *(Figure 44-5F or 44-5G)* PG 64-22

HMA Layer Thickness: *(Figure 44-5I)* 3.0 in.

Final Pavement Thickness *(Rounded to next ¼ in.)* 9.0 in.

Dowel Bars: ☐ Yes ☒ No *(Section 44-5.03(d))* Size: *(Figure 44-5J)* N/A in.

Comments: ____________________

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 2 – COMPOSITE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-5N

44-5.06(c) Example Calculation 3 (Green) – Class IV Road

Problem:

Design a composite pavement for the given conditions.

Given: (Section 44-1.08(c))

Class IV Road, Two Lane Pavement (Section 44-1.01)
11 ft Lanes with Aggregate Shoulders
Design Traffic: ADT = 350
PV's 88%, SU's 7%, MU's 5% (if unknown see Section 44-1.03(c))
City of Marion, Williamson County
Design Subgrade Support Rating – Poor
Posted Speed Limit – 55 MPH with No Bus Stops

Solution:

Check the subgrade value with a dynamic cone penetrometer (DCP). If the Immediate Bearing Value (IBV) value is less than 6 an improved subgrade should be provided, see Section 44-7.02. A 4 in. granular subbase is recommended because of a poor subgrade support rating.

Per Section 44-5.02(b), Class IV composite pavements, a design TF is not necessary to determine the PCC slab thickness. A pre-adjusted PCC slab thickness of 6.5 in. should be used for all Class IV composite pavements.

Based on Figure 44-5C, the thickness adjustment factors are -0.50 in. (75% reliability) and +0.35 in. (untied shoulders). The pre-adjusted PCC slab thickness is 6.5 in. with adjustments of -0.15 in. for a value of 6.35 in; providing a final PCC slab thickness of 6.5 in. Alternative designs may be made by varying the HMA surface thickness, see Figure 44-5I. For this example, a 2 in. HMA overlay is used.

Dowels are not required because the PCC slab thickness is less than 7 in. [Section 44-5.03(d)].

Based on Figures 44-5E and 44-5G, a TF = 0.096, and a posted speed limit of 55 mph; an Illinois N_{30} will result in specifying the binder as a PG 58-22.

$$TF = 20\left[\frac{(0.073 \times 308 + 54.570 \times 24 + 192.175 \times 18)}{1{,}000{,}000}\right]$$

$$TF = 0.096$$

* * * * * * * * * *

Date: ____________
Calculations by: ____________
Checked by: ____________

County: Williamson
LPA: City of Marion
Section: ____________
Route: ____________
Location: ____________

Limits of Analysis:
From: ____________
To: ____________
Length: ______ Feet ______ Miles

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: 2
ADT: 350
Class of Road or Street: IV *(Section 44-1.01)*

Percent / Count *(Figure 44-1A as needed)*

	Percent	Count
PV:	88 %	308
SU:	7 %	24
MU:	5 %	18
HCV:	42	

Traffic Factor (Show Calculations)**:**

Per Section 44-5.02(b), Class IV composite pavements; a design TF is not necessary to determine the PCC slab thickness. A pre-adjusted PCC slab thickness of 6.5 in. should be used for all Class IV composite pavements.

PCC Slab Traffic Factor: *(Figure 44-5A)* N/A

$$TF = 20\left[\frac{(0.073 \times 308 + 54.570 \times 24 + 192.175 \times 18)}{1{,}000{,}000}\right]$$

HMA Traffic Factor: *(Figure 44-5E)* 0.096

Pavement Design:

Subgrade Support Rating (SSR): ☒ Poor ☐ Fair ☐ Granular *(Section 44-5.02(e) and Figure 44-6)*

Pre-Adjusted PCC Slab Thickness: *(Figure 44-5B)* *(Class IV use 6.50 in.)* 6.50 in.

Reliability: *(Figure 44-5H)* ☒ 75% or ☐ 90%

Adjustments: *(Section 44-5.03(c) and Figure 44-5C)*

		Applicable Adjustments
75% Reliability *(Section 44-5.02(h))*	-0.50	-0.50 in.
15 ft Joint Spacing	+1.00	N/A in.
Untied Shoulder	+0.35	+0.35 in.
Fair Subgrade / Granular Subgrade	-0.25 / -0.50	N/A in.
Stabilized Subbase / Existing Pavement as Subbase	-0.25 / -0.50	N/A in.
10 ft Lane Width / 12 ft Lane Width	+0.25 / -0.25	N/A in.
HMA Surface Layer Thickness 2.0 in.	*(See Figure 44-5I)*	N/A in.
	Total Adjustment:	-0.15 in.

Adjusted PCC Slab Thickness: *(Section 44-5.03(a))* 6.35 use 6.50 in.
Subbase Requirements: *(Figure 44-5D)* ____________
Select Binder: *(Figure 44-5F or 44-5G)* PG 58-22
HMA Layer Thickness: *(Figure 44-5I)* 2.0 in.
Final Pavement Thickness *(Rounded to next ¼ in.)* 8.50 in.
Dowel Bars: ☐ Yes ☒ No *(Section 44-5.03(d))* Size: *(Figure 44-5J)* N/A in.

Comments: *Check the subgrade value with a dynamic cone penetrometer (DCP). If the Immediate Bearing Value (IBV) value is less than 6 an improved subgrade should be provided, see Section* 44-7.02. A 4 in. granular subbase is recommended because of a poor subgrade support rating.

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

EXAMPLE 3 – COMPOSITE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-5N

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, Rigid, and Composite Pavements

A Subgrade Support Rating is used as the design subgrade input for full-depth HMA, Rigid, 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.

44-6.01(b) Conventional Flexible Pavement Design

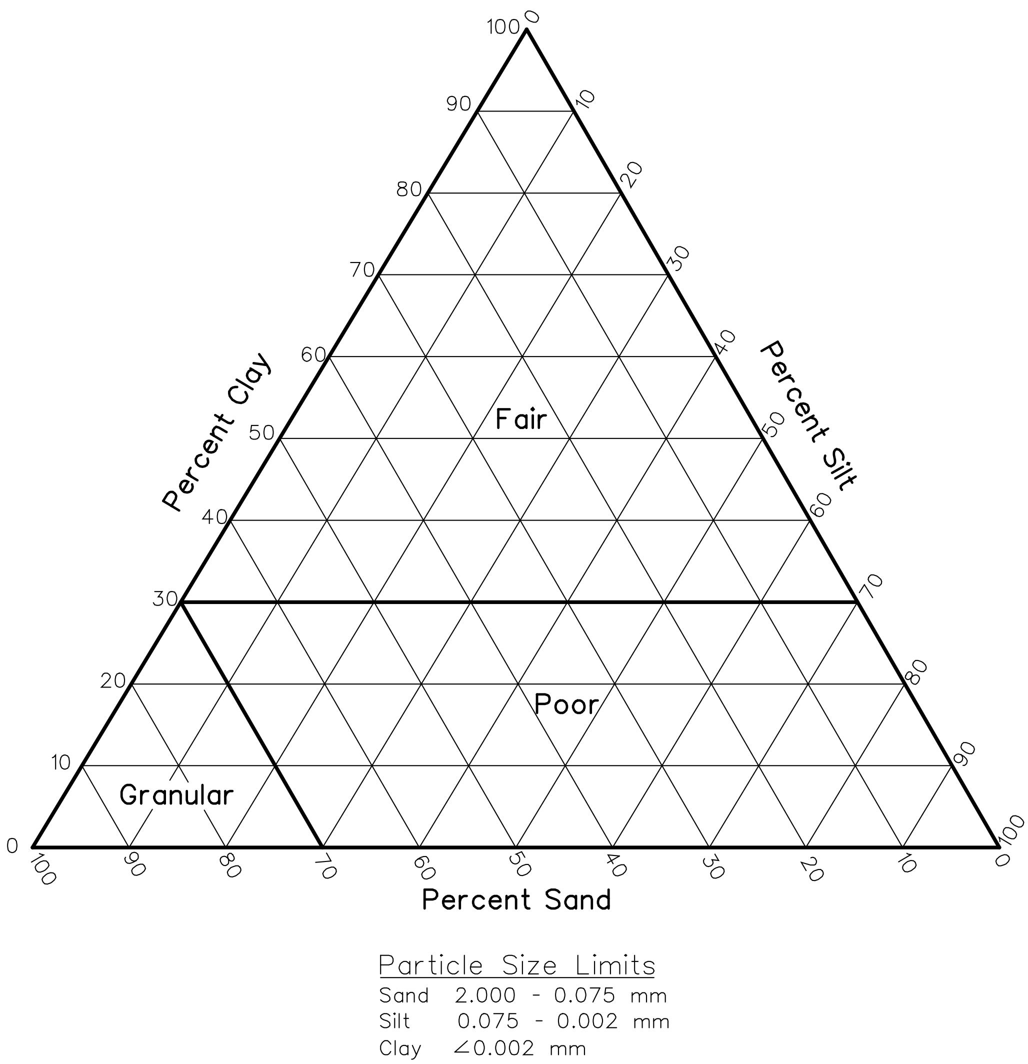
The procedures discussed in this Section do not apply to full-depth HMA pavements.

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.

1. Preliminary E_{Ri} Determination. Listed below are three methods and five procedures 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 five procedures are described below:

    a. Method A. Requires obtaining soil samples to be tested in a laboratory.

        i. Resilient Modulus Testing. The E_{Ri} of a soil may be determined by performing repeated unconfined compression testing in the laboratory. Subgrade specimens from in situ 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 CBLRS may be contacted for additional information regarding a resilient modulus testing format.



SUBGRADE SUPPORT RATING

Figure 44-6A

b. Method B. Requires field testing of soils in situ.

i. 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 CBLRS 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 in situ soil, including the different soil horizons.

ii. Estimating E_{Ri} from Strength Data. An E_{Ri} value can be estimated from strength data obtained with a Corps of Engineers hand-held cone penetrometer, or a dynamic cone penetrometer (DCP). Both the Corps of Engineers hand-held cone penetrometer and the DCP are field-testing devices used to rapidly evaluate the in situ 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).

iii. Estimating E_{Ri} from Soil Properties. Design E_{Ri} values can be estimated based on a soil's clay content (< 2 micron) and plasticity index (PI). These values are easily obtainable from an analysis of the project's soils or the County Soil Report. Equation 44-6.5 may be used to predict E_{Ri} at optimum water content and 95% AASHTO T-99 maximum dry density:

$E_{Ri}(OPT)* = 4.46 + 0.098\ (\%\ Clay) + 0.119\ (PI)$ 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

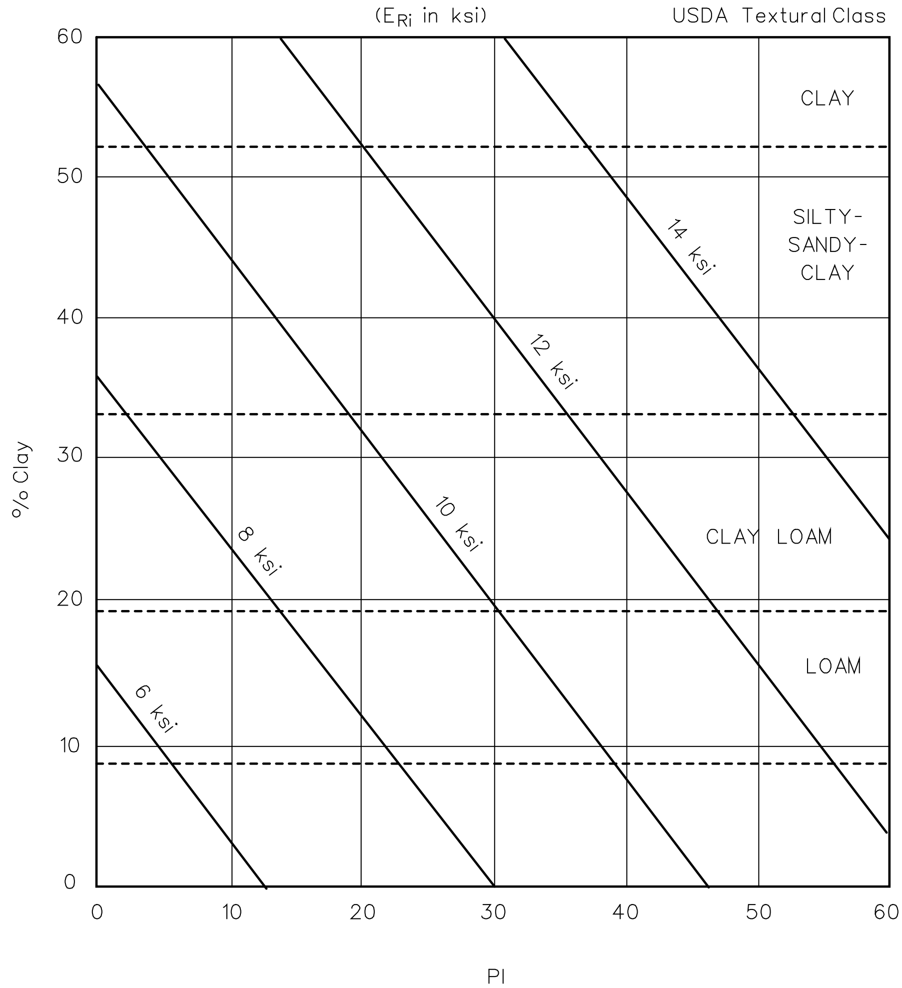
* Moisture adjustment is necessary.

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.

c. Method C. Requires the use of typical values based on AASHTO Soil Classification or USDA Textural Classification.

i. Typical E_{Ri} Values. If data is 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.



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

AASHTO Soil Classification	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. Moisture Adjustment Procedure. The preliminary E_{Ri} determined by one of the above procedures (except for the resilient modulus laboratory or FWD methods) should be corrected to reflect the in situ moisture present under springtime conditions, if the test data reflects conditions other than those of a normal spring. The following procedure will apply:

   a. Known MDD and OMC. 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.

$$MC_{\%SR} = \left[\frac{65.7}{MDD} - \frac{1}{G_s} \right] SR$$ 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. Unknown MDD and OMC. 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. Adjustment. 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 Equation 44-6.9

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

Design E_{Ri} = E_{Ri} (OPT) – ((FMA)(MAF)) Equation 44-6.10

Where: Design E_{Ri} = E_{Ri} for flexible pavement design, corrected for in situ 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. Minimum Design E_{Ri} Values. A design E_{Ri} of 2 ksi is the lowest allowable design E_{Ri}. If the design E_{Ri} value calculated from Equation 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. Composite E_{Ri} Estimate. A soil profile (vertical sections) contains distinct soil layers, called horizons. The County Soil Report contains thicknesses and properties for each horizon in the soil series. In a typical flexible pavement, approximately 70% to 75% 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.

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

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 is FAIR. An SSR value is necessary for rigid, full-depth HMA, and composite 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 in situ 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 in situ 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.)	No. of Blows in the Field	DCP Penetration Rate (in/blow)	IBV	Q_u (psi)	E_{Ri} (ksi)
0 – 16	8 – 9	1.9	3.1	13.9	5.1
16 – 51	29	1.2	5.5	24.7	8.4
51 – 60	5 – 6	1.6	3.8	17.2	6.1

FIELD DATA EXAMPLE FOR
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).

The following are example calculations for estimating subgrade strength from DCP test results. The following calculations pertain to a depth of 16 in. to 51 in., requiring a total of 29 blows in Figure 44-6G.

Equation 44-6.2 for IBV

$$\begin{aligned} \text{LOG IBV} &= 0.84 - 1.26 \times \text{LOG (penetration rate)} \\ &= 0.84 - 1.26 \times \text{LOG } (1.2) \\ &= 0.84 - 1.26 \times 0.079181 \\ &= 0.84 - 0.0998 \\ \text{LOG IBV} &= 0.74023 \end{aligned}$$

$$\text{IBV} = 10^{0.74023} = 5.5$$

Equation 44-6.3 for Unconfined Compressive Strength

$$\begin{aligned} Q_u &= 4.5 \times \text{IBV} \qquad \text{for IBV} = 5.5 \\ &= 4.5 \times 5.5 \end{aligned}$$

$$Q_u = 24.7 \text{ psi}$$

Equation 44-6.4 for Subgrade Resilient Modulus

$$\begin{aligned} E_{RI} &= 0.86 + 0.307 \times Q_u \qquad \text{for } Q_u = 24.7 \text{ psi} \\ &= 0.86 + 0.307 \times 24.7 \end{aligned}$$

$$E_{RI} = 8.4 \text{ ksi}$$

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.

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)
E_{Ri} = 4.9 ksi

Depth (in.)	E_{Ri} (OPT) [1] (ksi)	Optimum Moisture Content [2] (%)	Maximum Dry Density [3] (PCF)	Moisture Content for Given Saturation [4] (%)	Field Moisture Adjustment [5] (%)	Moisture Adjustment Factor [6]	Design E_{Ri} [7] (ksi)
0 – 16	10.2	17.8	106.9	21.7	3.9	0.7	7.6
16 – 60	7.9	15.4	111.2	19.6	4.2	1.5	1.6(2.0)[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

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 Figure 44-6J, Notes 2(a) and 2(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 Note 2(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
				2(a)	2(b)	2(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	6.2	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) more than 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 in situ soil does not develop an IBV more than 6.0:

- undercut and backfill,
- modify 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. CBLRS 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. $IBV = \frac{\text{Cone Index}}{40}$, *psi*

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

SUBGRADE STRENGTH RELATIONSHIPS

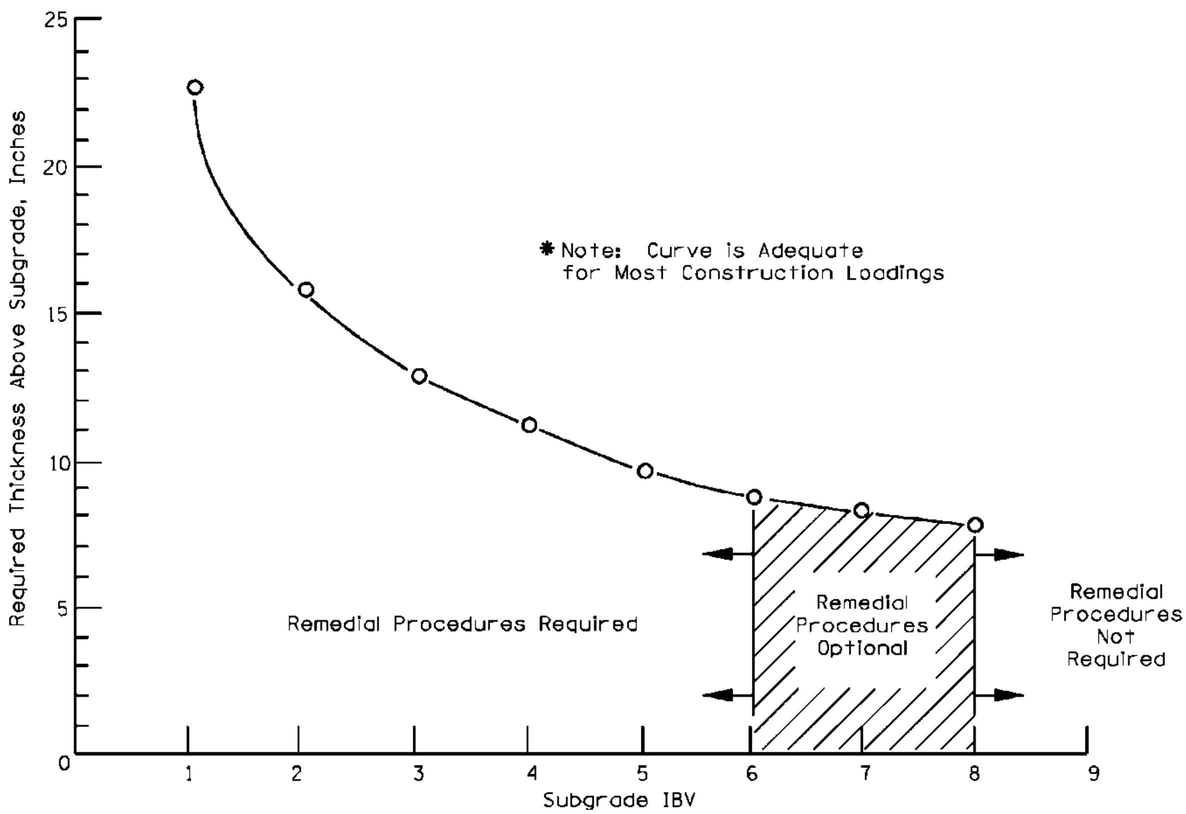
Figure 44-7A

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. CBLRS 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 (*IDOT Standard Specifications* "Soil Modification" section) 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 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 LPA 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 in situ IBV of 4.

Solution:

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 in situ 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.)	*IDOT Standard Specifications*	Minimum Width (ft)
Lime Stabilized Soil Mixture	8	Section 350	2 ft wider than surface
Aggregate Base Course	10 (1)	Section 351	
Soil – Cement Base Course	8	Section 352	

Note:
(1) This may be reduced to 8 in. if located on modified soil (Section 302).

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 based on the applicable portions of Chapter 44 or some other acceptable method which has proven satisfactory in the past.

A-1, 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.

44-9 WORKSHEETS AND FIGURES

The following pages contain the necessary blank pavement design worksheets and various figures from previous sections to assist in the calculation of pavement designs. The submittal of pavement designs shall include the appropriate worksheet, location map, USDA Soil Map (as needed), and completed figures (as needed).

- Section 44-9.01 – Section 44-1 General Figures
- Section 44-9.02 – Section 44-2 Rigid Pavement Design Figures
- Section 44-9.03 – Section 44-3 Conventional Flexible Pavement Design Figures
- Section 44-9.04 – Section 44-4 Full-Depth HMA Pavement Design Figures
- Section 44-9.05 – Section 44-5 Composite Pavement Design Figures

44-9.01 Figures from Section 44-1 (General)

The following figures are to be used as needed for the design of various pavements and submitted, as needed, with the appropriate design calculations.

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

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

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

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

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 44-1A

Number of Facility Lanes	Percent of Total Vehicular Class Volume (ADT) in Design Lane					
	Rural			Urban		
	PV	SU	MU	PV	SU	MU
2 or 3 *	50%	50%	50%	50%	50%	50%
4 or 5	32%	45%	45%	32%	45%	45%
≥ 6	20%	40%	40%	8%	37%	37%

* *2 or 3 lane facilities include all one-way roads and streets.*

DESIGN LANE DISTRIBUTION FACTORS FOR STRUCTURAL DESIGN TRAFFIC

Figure 44-1B

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*
2. *Minimum thicknesses are the nominal thickness of the lift.*
3. *If the leveling course is placed at or above the minimum thickness specified for surface/binder course, density will be required.*
4. *This mix may not be used as a surface lift.*
5. *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 44-1C

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 44-1D

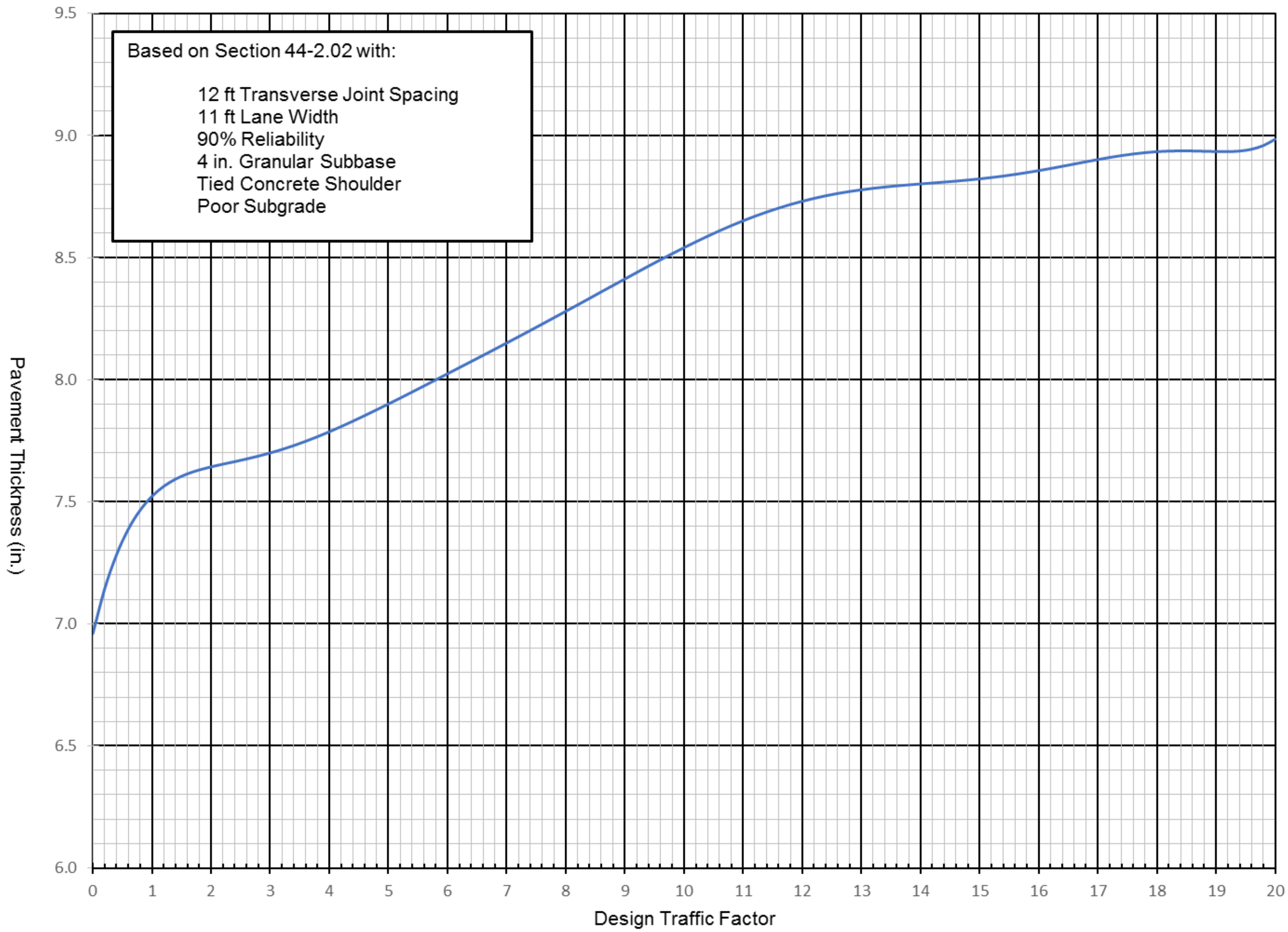
44-9.02 Figures from Section 44-2 (Rigid Pavement Design)

The following figures are to be used for the design of rigid pavements and submitted, as needed, with design calculations (Figure 44-2L).

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

TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-2A



PRE-ADJUSTED RIGID PAVEMENT THICKNESS

Figure 44-2B

Adjustment Factor	Rigid Pavement Thickness Adjustment (in.)
75% Reliability	-0.50
15 ft Joint Spacing (0.1 ≤ TF ≤ 5)	+1.00
15 ft Joint Spacing (5 < TF ≤ 20)	+1.25
Untied Shoulder	+0.35
Fair Subgrade	-0.25
Granular Subgrade	-0.50
Stabilized Subbase	-0.25
Existing Pavement as Subbase	-0.50
10 ft Lane Width	+0.25
12 ft Lane Width	-0.25

Note: Thickness adjustment is made for untied shoulders (PCC or flexible). The designer should be aware of the potential for frost heave if untied shoulders are used

A subbase is optional for all Class III and IV pavements with a TF < 5.0, and for urban sections having curb and gutter and storm sewer systems.

THICKNESS ADJUSTMENT FACTOR

Figure 44-2C

	Maximum Transverse Joint Spacing (ft)
< 10.0	12.0*
≥ 10.0	15.0

** Appropriate for all Class IV pavements.*

MAXIMUM TRANSVERSE JOINT SPACING

Figure 44-2D

Road Class	Subbase Material	Usage [1]	Minimum Thickness (in.)
Class I and II TF ≥ 5.0 TF < 5.0	Stabilized Subbase [2] Granular [3]	Required Required	4 4
Class III and IV TF ≥ 5.0 TF < 5.0	Granular [3] Granular [3]	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 44-2E

Road Class	Minimum Reliability Levels	Reliability (%)
Class I and II	High	90
Class III	Medium	75
Class IV (Figure 44-2G)	Medium	75

RELIABILITY LEVELS

Figure 44-2F

HCV's/day	Rigid Pavement Thickness for 12 ft Joint Spacing (in.)
≤ 48	7.0 (1)
> 48	(2)

Notes:

1. *Minimum rigid pavement thickness shall not be less than 6 in. after all adjustment factors are applied.*
2. *Use the Class III TF equations or a TF of 0.5, whichever is greater, in conjunction with Figure 44-2B.*

CLASS IV PRE-ADJUSTED RIGID PAVEMENT THICKNESS
(11 ft Lane Width / 90% Reliability / Tied Curb or PCC Shoulders / Poor Soil Conditions)

Figure 44-2G

Rigid Pavement Thickness (in.)	Dowel Diameter (in.)
≥ 10.00	1.50
> 8.00 to 9.99	1.25
≤ 8.00	1.00

DOWEL BAR DIAMETER REQUIREMENTS

Figure 44-2H

Figures 44-2I, 44-2J, and 44-2K (Typical Sections) are not included.

Date: ______________________ County: ______________________

Calculations by: ______________________ LPA: ______________________

Checked by: ______________________ Section: ______________________

Route: ______________________

Limits of Analysis: Location: ______________________

From: ______________________

To: ______________________

Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*

Number of Lanes: __________ Width: ______ft

ADT: ______________

Class of Road or Street: _____ *(Section 44-1.01)*

PV: __________% / __________

SU: __________% / __________

MU: __________% / __________

HCV: __________

Traffic Factor (Show Calculations)**:** *(Figure 44-2A)*

Traffic Factor: __________

Pavement Design:

Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-2.02(f) and Figure 44-6A)*

Pre-Adjusted Rigid Pavement Thickness: *(Figure 44-2B or Figure 44-2G)* __________in.

Reliability: *(Figure 44-2F)* ☐ 75% or ☐ 90%

Adjustments: *(Section 44-2.03(c) and Figure 44-2C)*

			Applicable Adjustments
75% Reliability	*Section 44-2.02(h)*	-0.50	__________in.
15 ft Joint Spacing (0.1 ≤ TF ≤ 5) / (5 ≤ TF ≤ 20)		+1.00 / +1.25	__________in.
Untied Shoulder		+0.35	__________in.
Fair Subgrade / Granular Subgrade		-0.25 / -0.50	__________in.
Stabilized Subbase / Existing Pavement as Subbase		-0.25 / -0.50	__________in.
☐ 10 ft Lane Width / ☐ 12 ft Lane Width		+0.25 / -0.25	__________in.
		Total Adjustment:	__________in.

Adjusted Rigid Pavement Thickness __________in.

Transverse Joint Spacing *(Figure 44-2D)* ☐ 12 ft or ☐ 15 ft

Final Pavement Thickness *(Rounded to next ¼ in.)* *(Minimum Thickness 6.0 in.)* __________in.

Dowel Bars: ☐ Yes ☐ No *(Section 44-2.03(d))* Size: *(Figure 44-2H)* __________in.

Comments: ____

____

____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

RIGID PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-2L

44-9.03 Figures from Section 44-3 (Conventional Flexible Pavement Design)

The following figures are to be used for the design of conventional flexible pavements and submitted, as needed, with design calculations (Figure 44-3M).

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

TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-3A

PG Binder Grade Selection[1]			
Districts 1 – 4	Traffic Loading Rate (Adjustment)		
	Standard [2]	Slow [3]	Standing [4]
Surface[5]	PG 58-28	PG 64-28 or SBS PG 64-28	SBS PG 70-28
Remaining Lifts[5]	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[5]	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
Remaining Lifts[5]	PG 64-22	PG 64-22	PG 64-22

Notes:

1. *The binder grades provided in Figure 44-3B 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. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
3. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
4. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
5. *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 44-3E.*

PG BINDER GRADE SELECTION FOR CONVENTIONAL FLEXIBLE PAVEMENTS

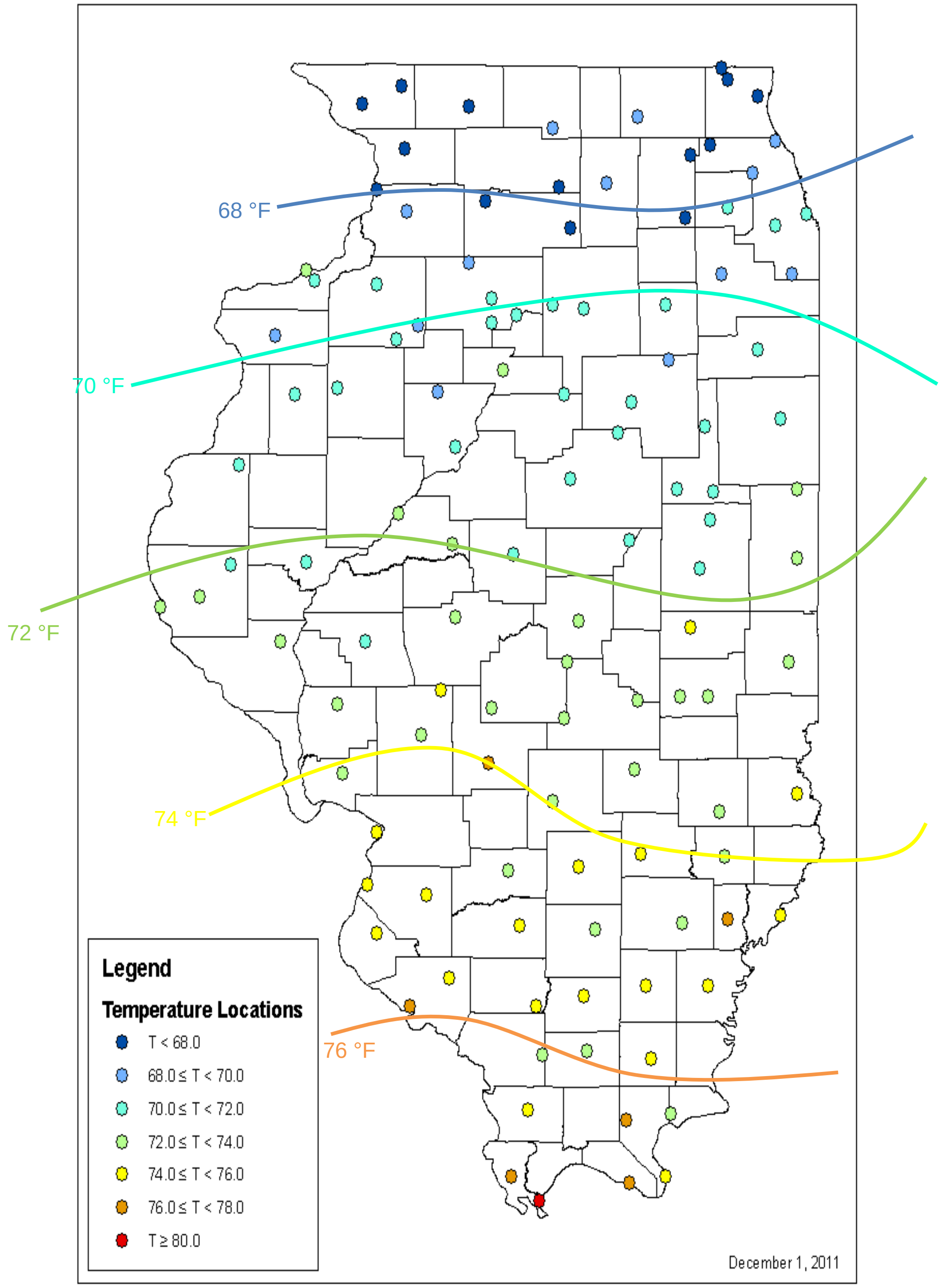
Figure 44-3B

Road Class	Minimum Reliability Level	Reliability (%)
Class I, II, III, and IV	Medium	~75%

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

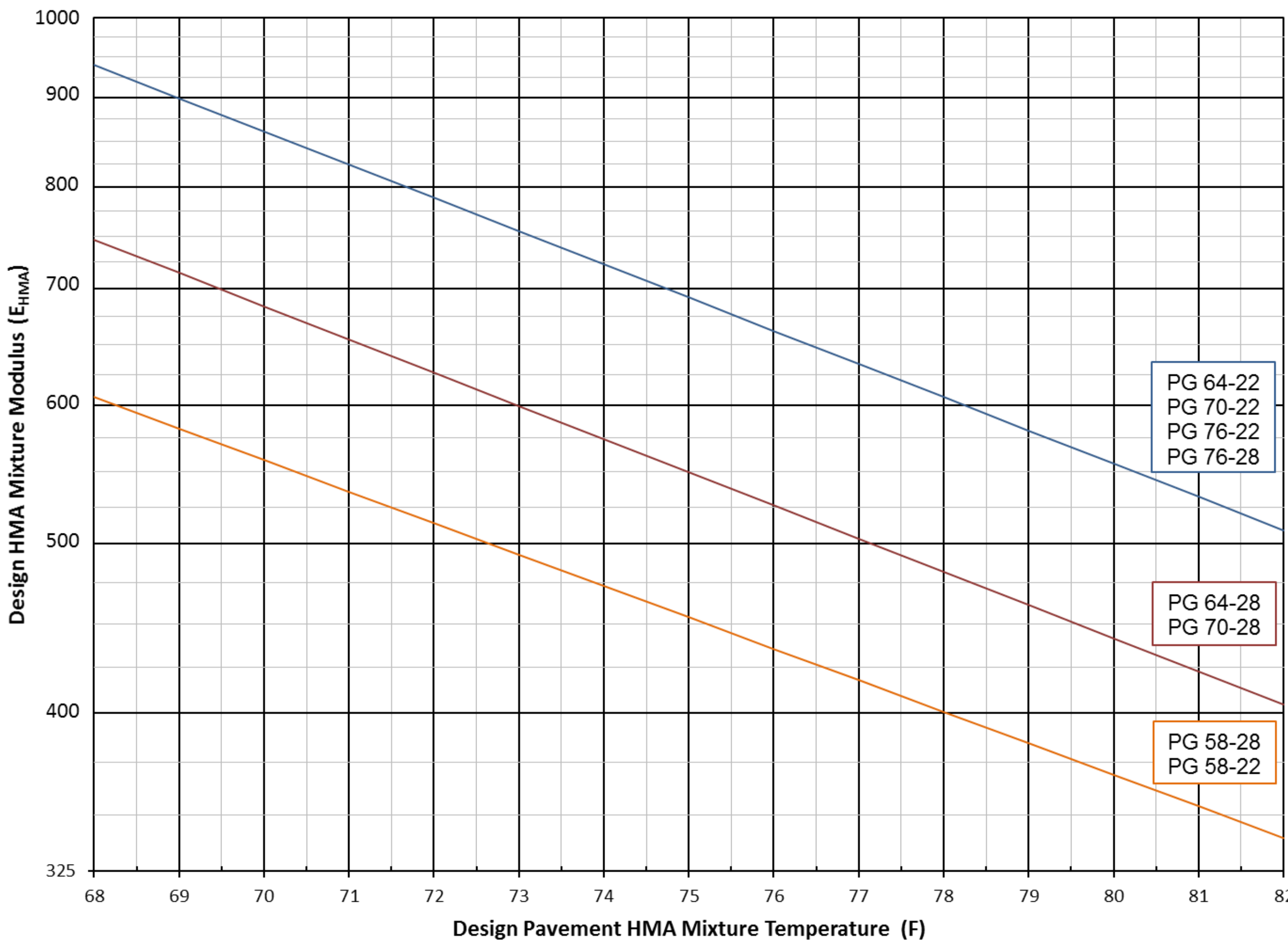
RELIABILITY LEVEL (TF $\leq$ 0.5)

Figure 44-3C



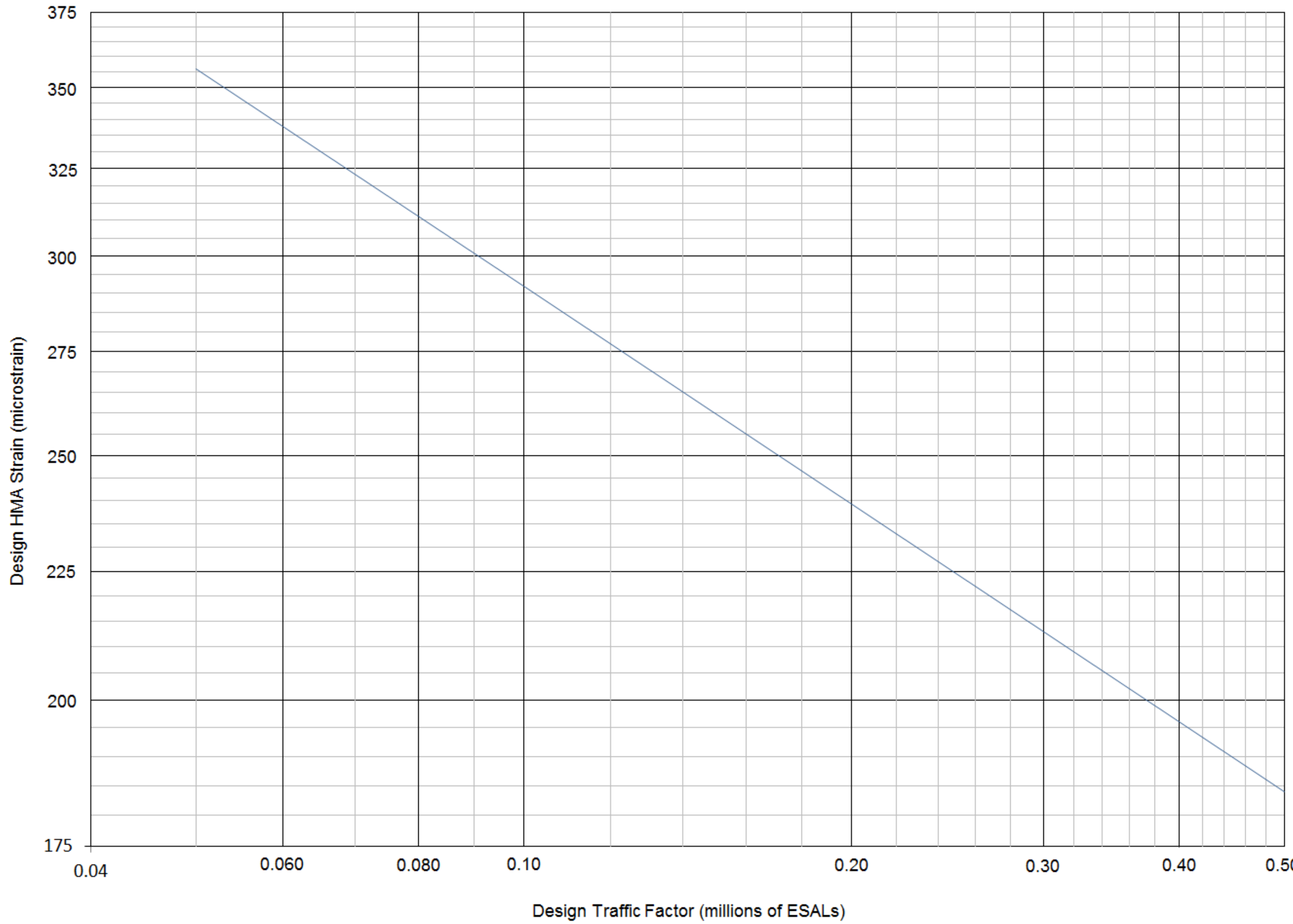
CONVENTIONAL FLEXIBLE HMA MIXTURE TEMPERATURE

Figure 44-3D



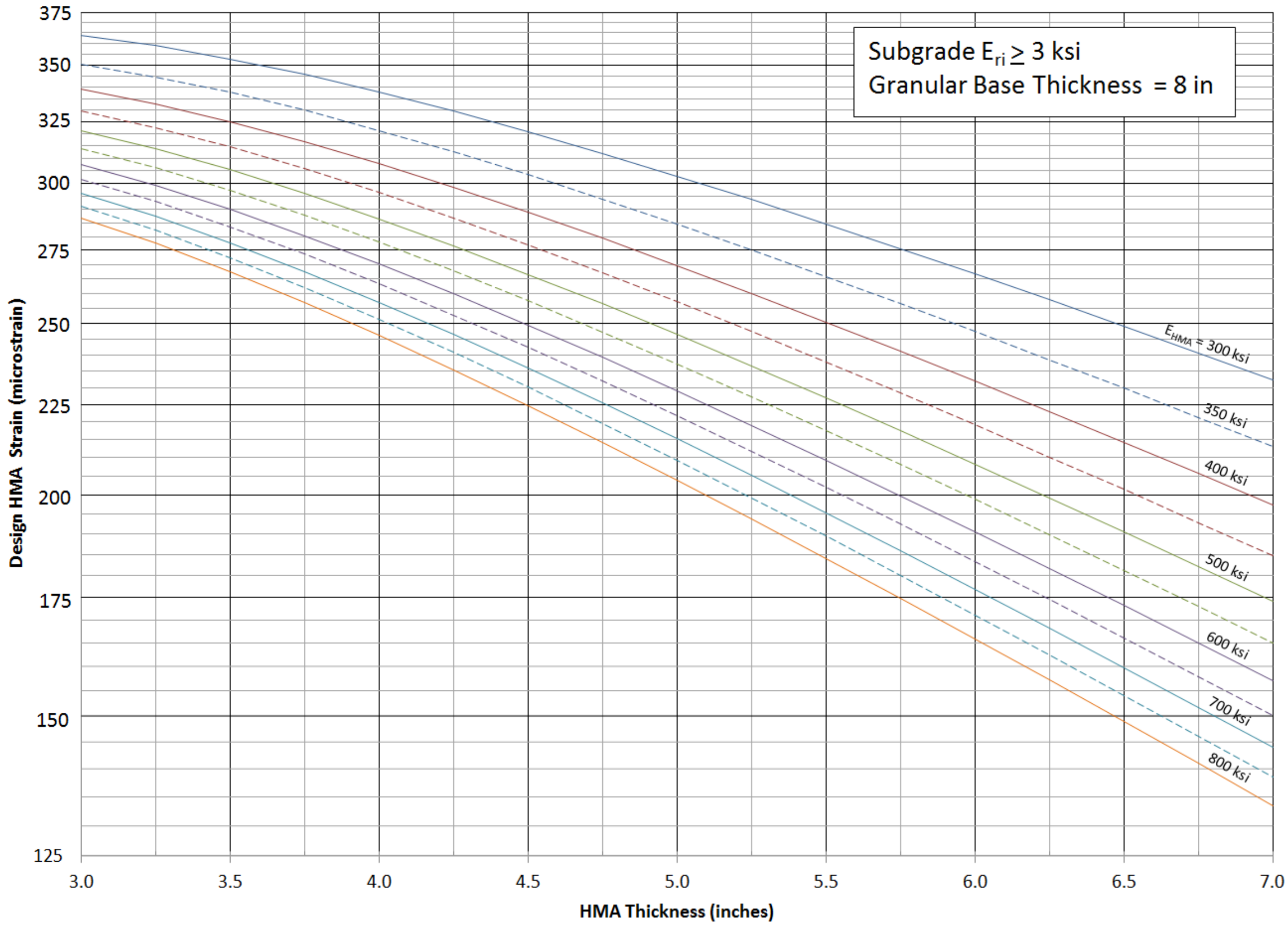
DESIGN HMA MIXTURE MODULUS (E_{HMA}) (ksi)

Figure 44-3E



DESIGN HMA STRAIN
(Traffic Factor Relation for HMA Mixes)

Figure 44-3F



CONVENTIONAL FLEXIBLE PAVEMENT DESIGN CHART

Figure 44-3G

Original HMA Design Thickness (in.)	Design HMA Modulus, E_{HMA} (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. aggregate base course, Type A 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. aggregate base course, Type A based on the appropriate category from the above table, can be enhanced by one of the following alternatives:

1. *$E^{(1)}$. Use one or more of the following:*
   - *Increase the HMA thickness by 0.5 in.*
   - *Increase the aggregate base course, Type A thickness by 2 in.*
   - *Add a 4 in. minimum granular subbase course, Type B.*
   - *Add an 8 in. minimum modified soil layer.*
2. *$E^{(2)}$. Use one or more of the following:*
   - *Increase the HMA thickness by 1.0 in.*
   - *Increase the aggregate base course, Type A thickness by 4 in.*
   - *Add a 4 in. minimum granular subbase course, Type B.*
   - *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 44-3H

District	1 – 4		5 – 6		7 – 9	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 2.99	≥ 3	2 – 2.99	≥ 3	2 – 2.99	≥ 3
< 12 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
12 – 23 HCV's	11 in	8 in	11 in	8 in	12 in	8 in
24 – 48 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 44-3I

District	**1 – 4**		**5 – 6**		**7 – 9**	
Traffic Level	E_{Ri} (ksi)		E_{Ri} (ksi)		E_{Ri} (ksi)	
	2 – 2.99	≥ 3	2 – 2.99	≥ 3	2 – 2.99	≥ 3
< 12 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
12 – 23 HCV's	8 in	8 in	9 in	8 in	10 in	8 in
24 – 48 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 44-3J

Figures 44-3K and 44-3L (Typical Sections) are not included.

Date: ______________________ County: ______________________
Calculations by: ______________________ LPA: ______________________
Checked by: ______________________ Section: ______________________
Route: ______________________
Limits of Analysis: Location: ______________________
From: ______________________
To: ______________________
Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: __________
ADT: __________
Class of Road or Street: _____ *(Section 44-1.01)*

PV: __________% / __________
SU: __________% / __________
MU: __________% / __________
HCV: __________

Traffic Factor (Show Calculations)**:** *(Figure 44-3A)*

Traffic Factor: __________
(Traffic Factor must ≤ 0.50 to qualify for Conventional Flexible Pavement Design Procedures)

Pavement Design:
Subgrade Modulus (E_{RI}): *(Section 44-3.02(e) and Section 44-6)* __________ksi
Selected Design PG Binder *(Figure 44-3B)*
Surface: ______________________
Remaining Lifts: ______________________
Design Pavement HMA Temp: *(Figure 44-3D)* __________ºF
Design HMA Modulus (E_{HMA}): *(Figure 44-3E)* __________ksi
Design HMA Microstrain: *(Figure 44-3F)* __________
Pavement Thickness: *(Figure 44-3G)* __________in.
Pavement Structure Enhancements: *(if 2ksi ≤ E_{RI} < 3 ksi use Figure 44-3H)* ______________________
____
For Class IV Pavements: *(Figure 44-3I or 44-3J)* ______________________
____
Minimum Material Requirements *(Section 44-3.02(a))* ______________________
Comments: ______________________
____
____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

CONVENTIONAL FLEXIBLE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-3M

44-9.04 Figures from Section 44-4 (Full-Depth HMA Pavement Design)

The following figures are to be used for the design of full-depth HMA pavements and submitted, as needed, with design calculations (Figure 44-4N).

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

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

Figure 44-4A

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 LPA may obtain a waiver to the subgrade working platform requirement from CBLRS 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 44-4B

PG Binder Grade Selection [(1)]			
	Traffic Loading Rate (Adjustment)		
Districts 1 – 4	Standard Traffic [(2)]	Slow Traffic [(3)]	Standing Traffic [(4)]
Surface[(5)]	PG 58-28 [(6)(7)]	PG 64-28 or SBS PG 64-28	SBS PG 70-28
Remaining Lifts[(5)]	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[(5)]	PG 64-22 [(6)(7)]	PG 70-22 or SBS PG 70-22	SBS PG 76-22
Remaining Lifts[(5)]	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. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
3. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
4. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
5. *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 or a SBS PG 70-22 should be specified.*
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 44-4H.*
7. *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 or a SBS PG 70-22 should be specified.*

PG BINDER GRADE SELECTION FOR FULL-DEPTH HMA PAVEMENTS

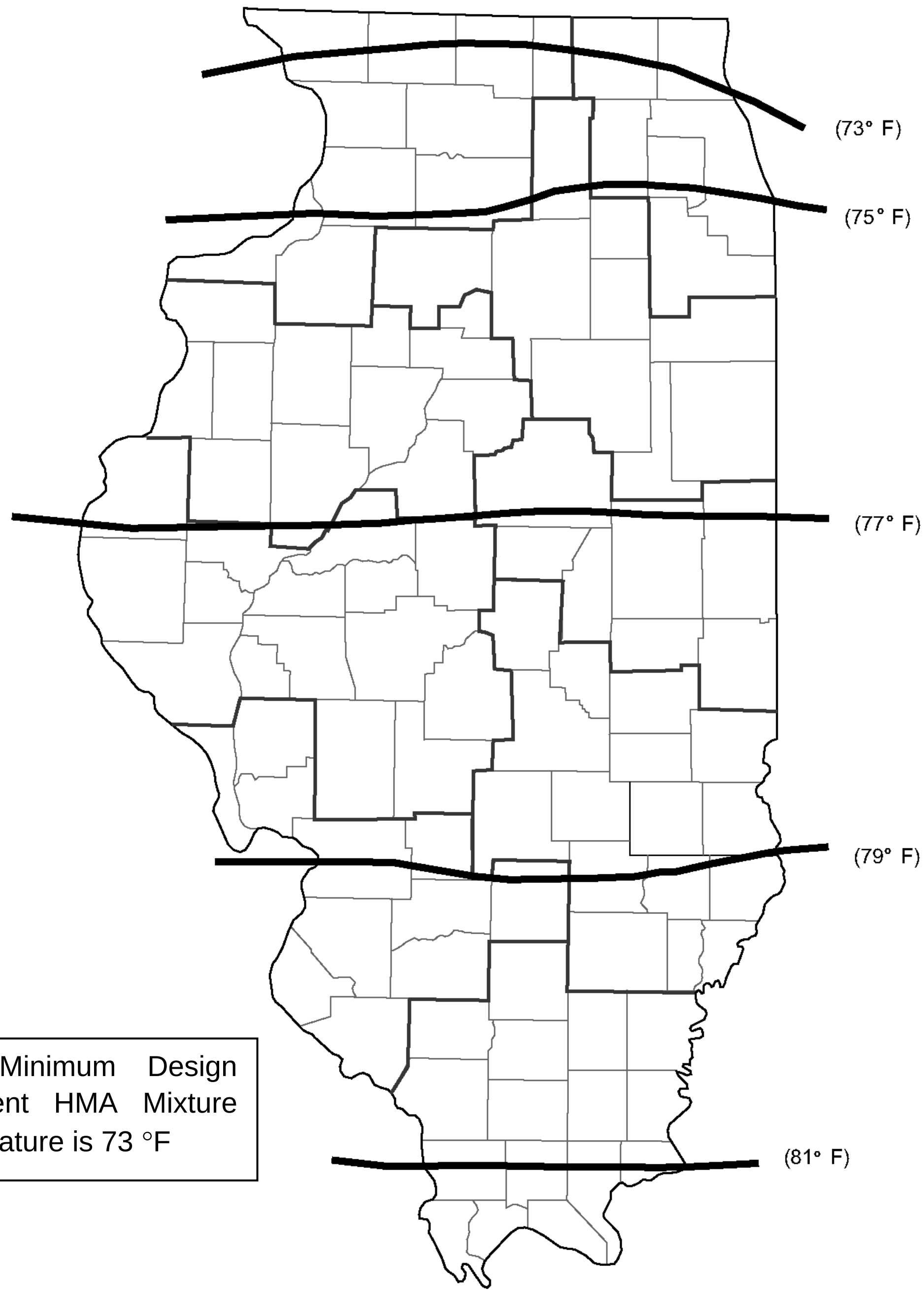
Figure 44-4C

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

DESIGN RELIABILITY

Figure 44-4D

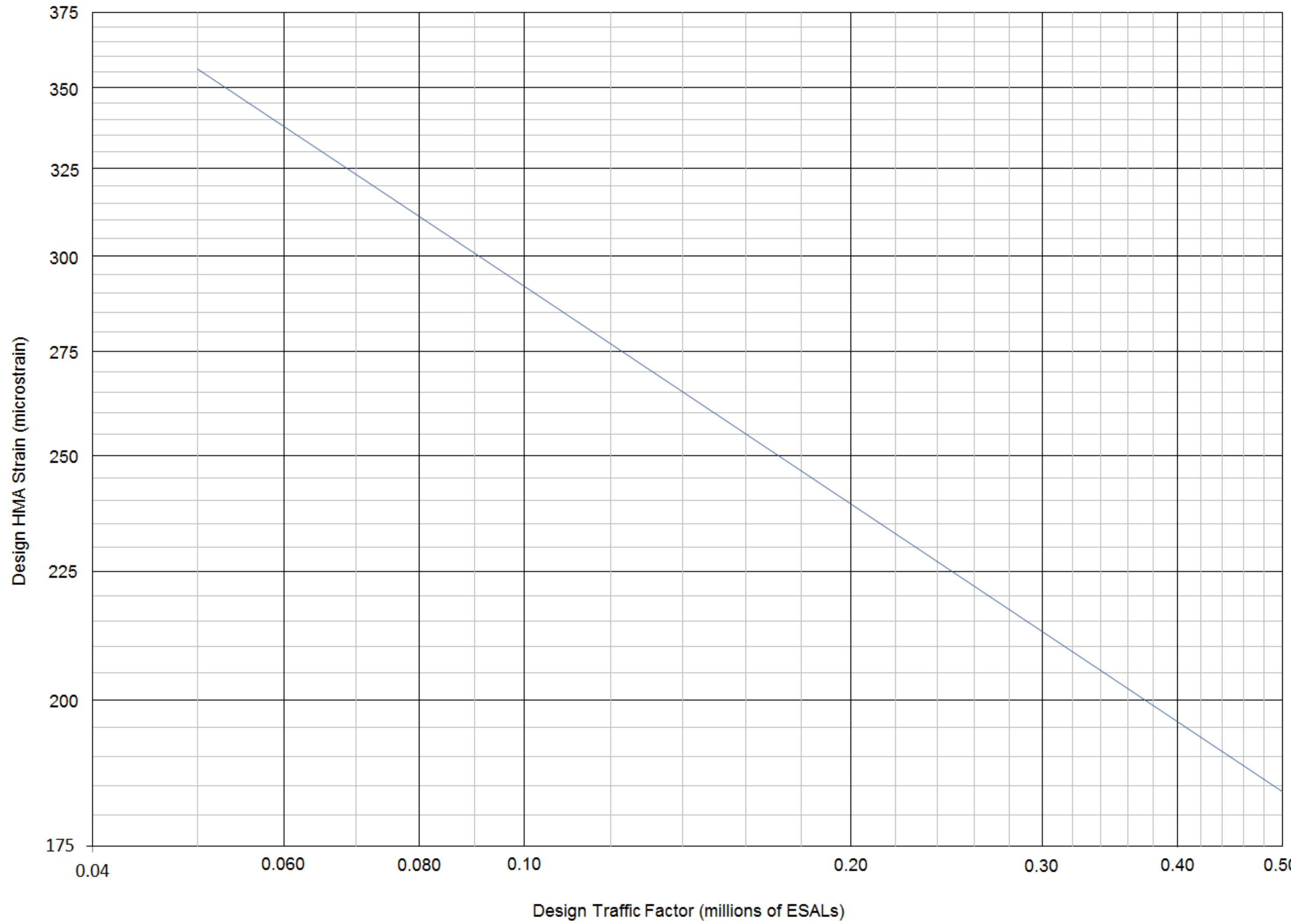
Figures 44-4L and 44-4M (Typical Sections) are not included.



Note: Minimum Design Pavement HMA Mixture Temperature is 73 °F

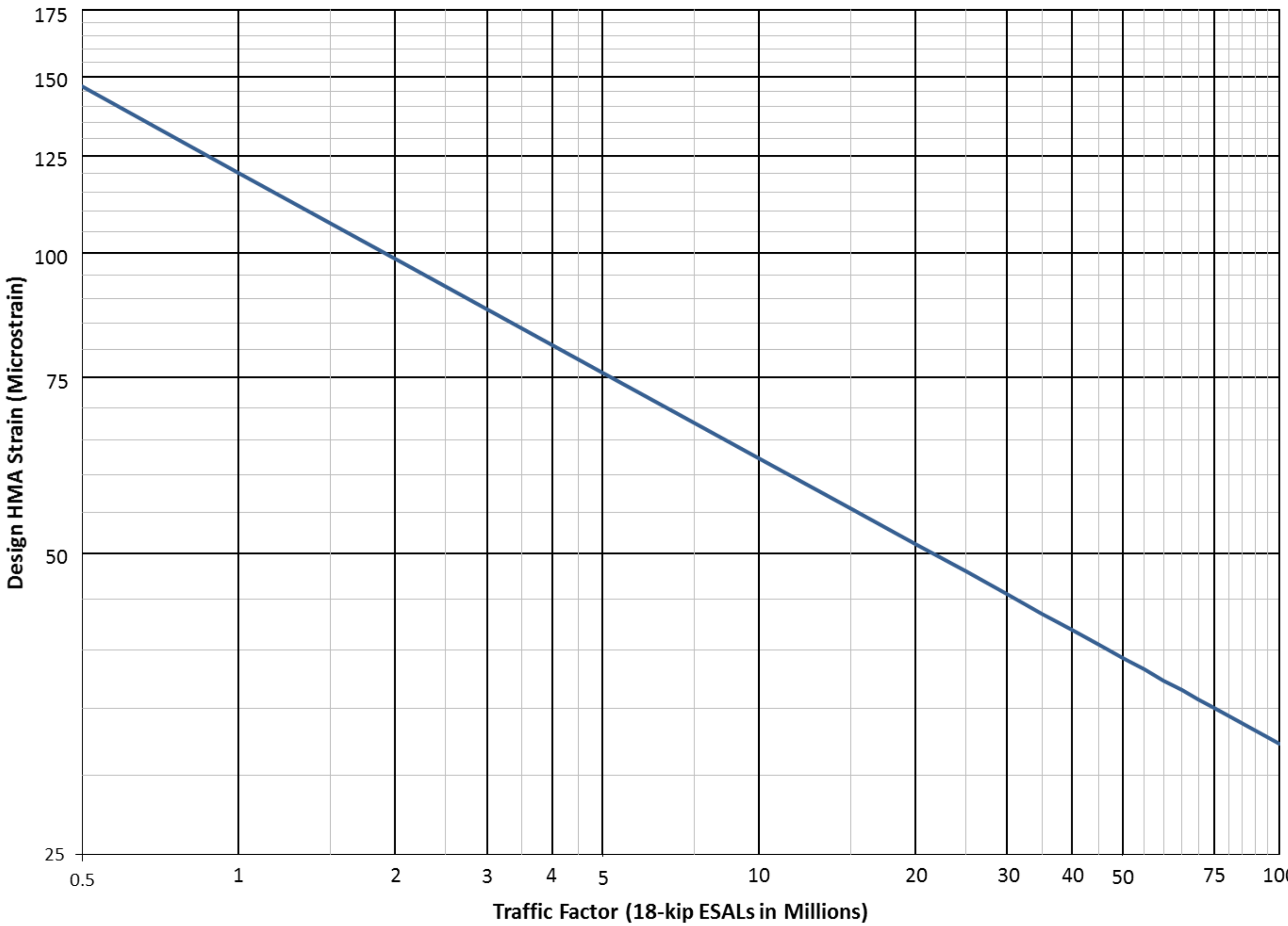
DESIGN PAVEMENT HMA MIXTURE TEMPERATURE
(Full Depth)

Figure 44-4E



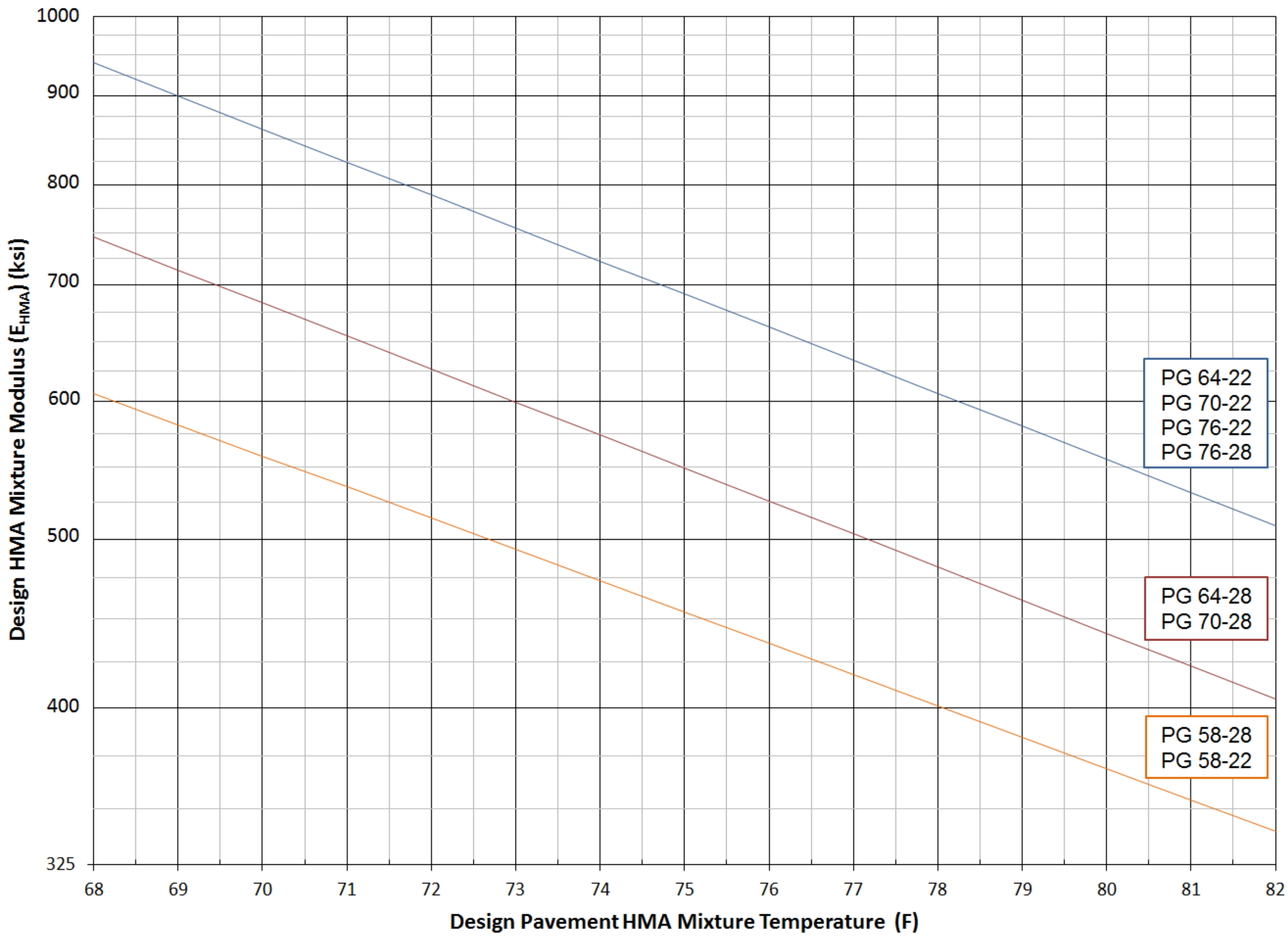
DESIGN HMA STRAIN
(Traffic Factor Relation for Traffic Factor < 0.5)

Figure 44-4F



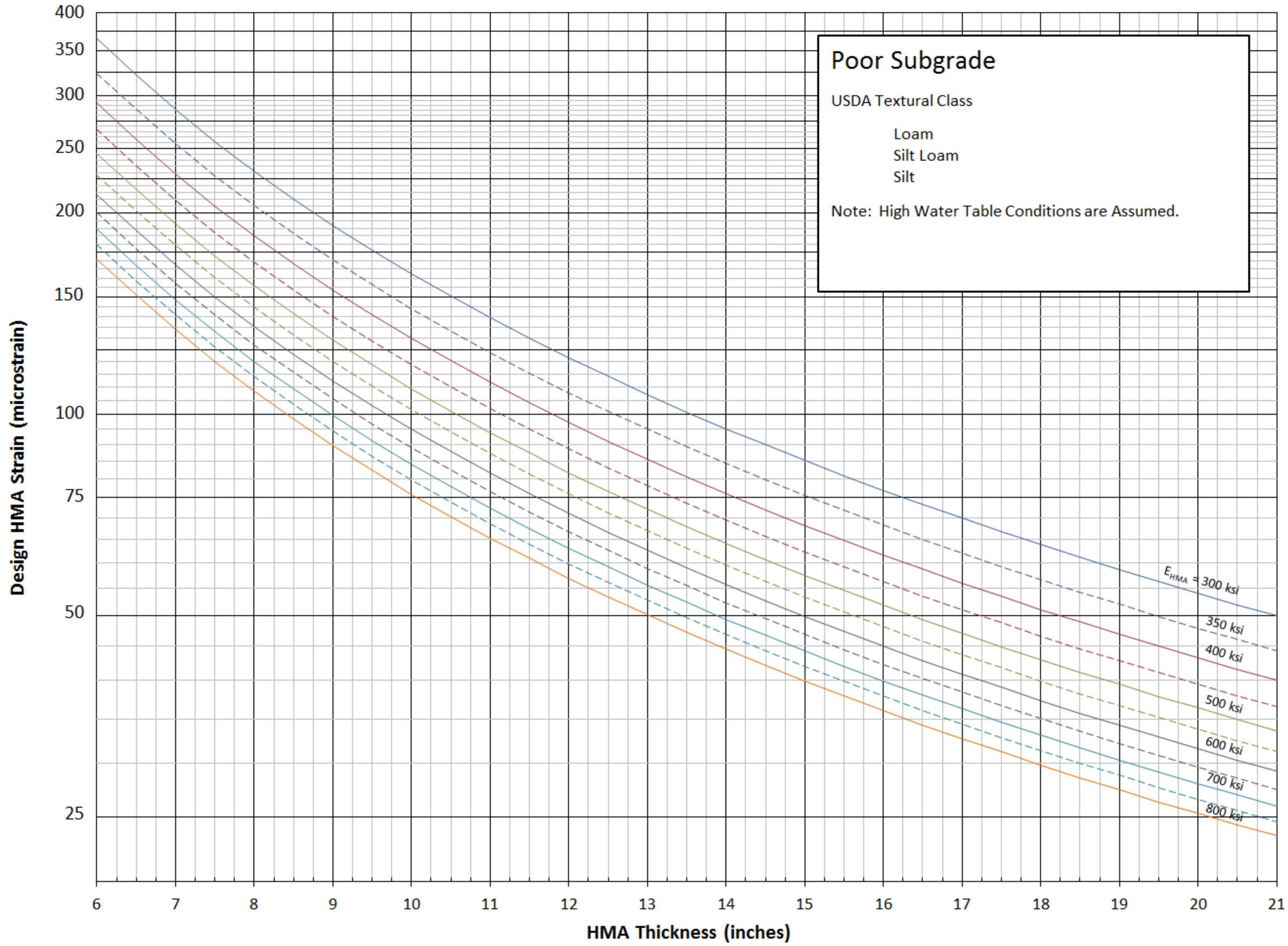
DESIGN HMA STRAIN
(Traffic Factor Relation for Traffic Factor ≥ 0.5)

Figure 44-4G



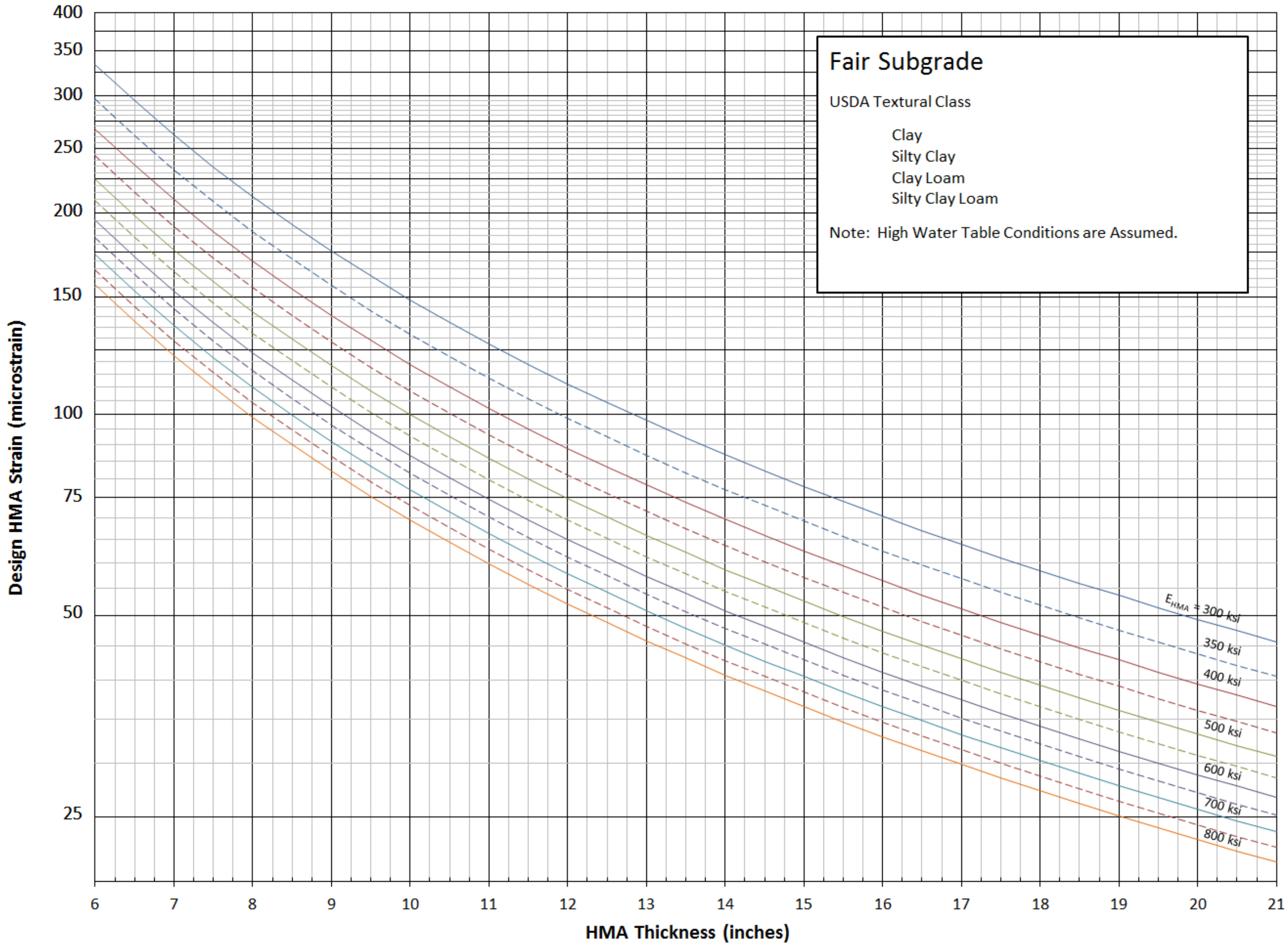
HMA MIXTURE MODULUS (E_{HMA})

Figure 44-4H



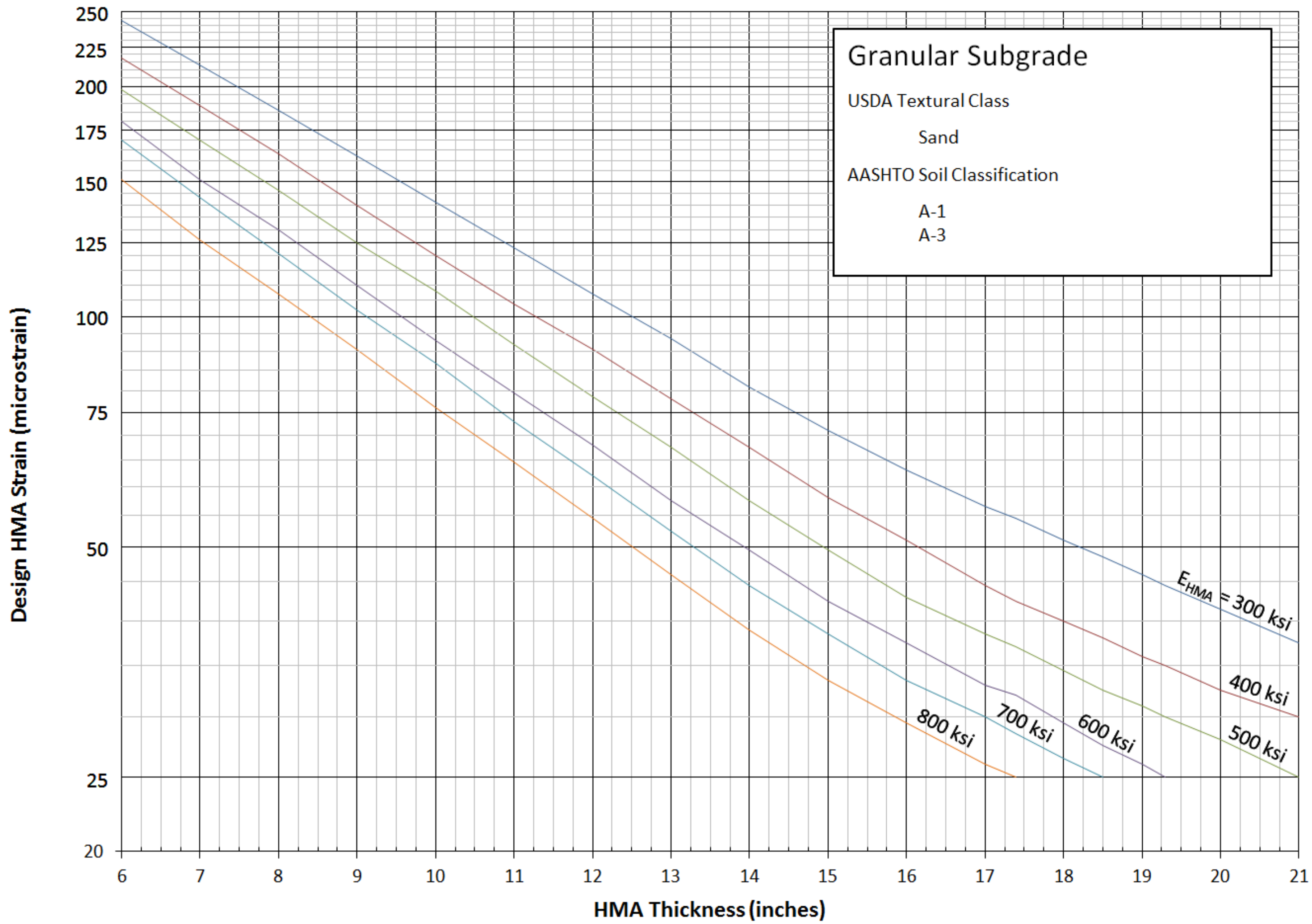
POOR SUBGRADE DESIGN CHART

Figure 44-4I



FAIR SUBGRADE DESIGN CHART

Figure 44-4J



GRANULAR SUBGRADE DESIGN CHART

Figure 44-4K

Date: ______________________ County: ______________________
Calculations by: ______________________ LPA: ______________________
Checked by: ______________________ Section: ______________________
Route: ______________________
Limits of Analysis: Location: ______________________
From: ______________________
To: ______________________
Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*
PV: __________% / __________
SU: __________% / __________
MU: __________% / __________
HCV: __________

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: __________
ADT: __________
Class of Road or Street: _____ *(Section 44-1.01)*

Traffic Factor (Show Calculations)**:** *(Figure 44-4A)*

Traffic Factor: __________

Pavement Design:
Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-4.02(g) and Figure 44-6A)*
Working Platform: *(Figure 44-4B)* ______________________
Selected Design PG Binder *(Figure 44-4C)*
Surface: ______________________
Remaining Lifts: ______________________

Design Pavement HMA Temp: *(Figure 44-4E)* __________ºF
Design HMA Microstrain: *(Figure 44-4F or 44-4G)* __________
Design HMA Modulus (E_{HMA}): *(Figure 44-4H)* __________ksi
Pavement Thickness: *(Section 44-4.03)* *(Minimum of 6.0 in.)* __________in.

Comments: ______________________
____
____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

FULL-DEPTH HMA PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-4N

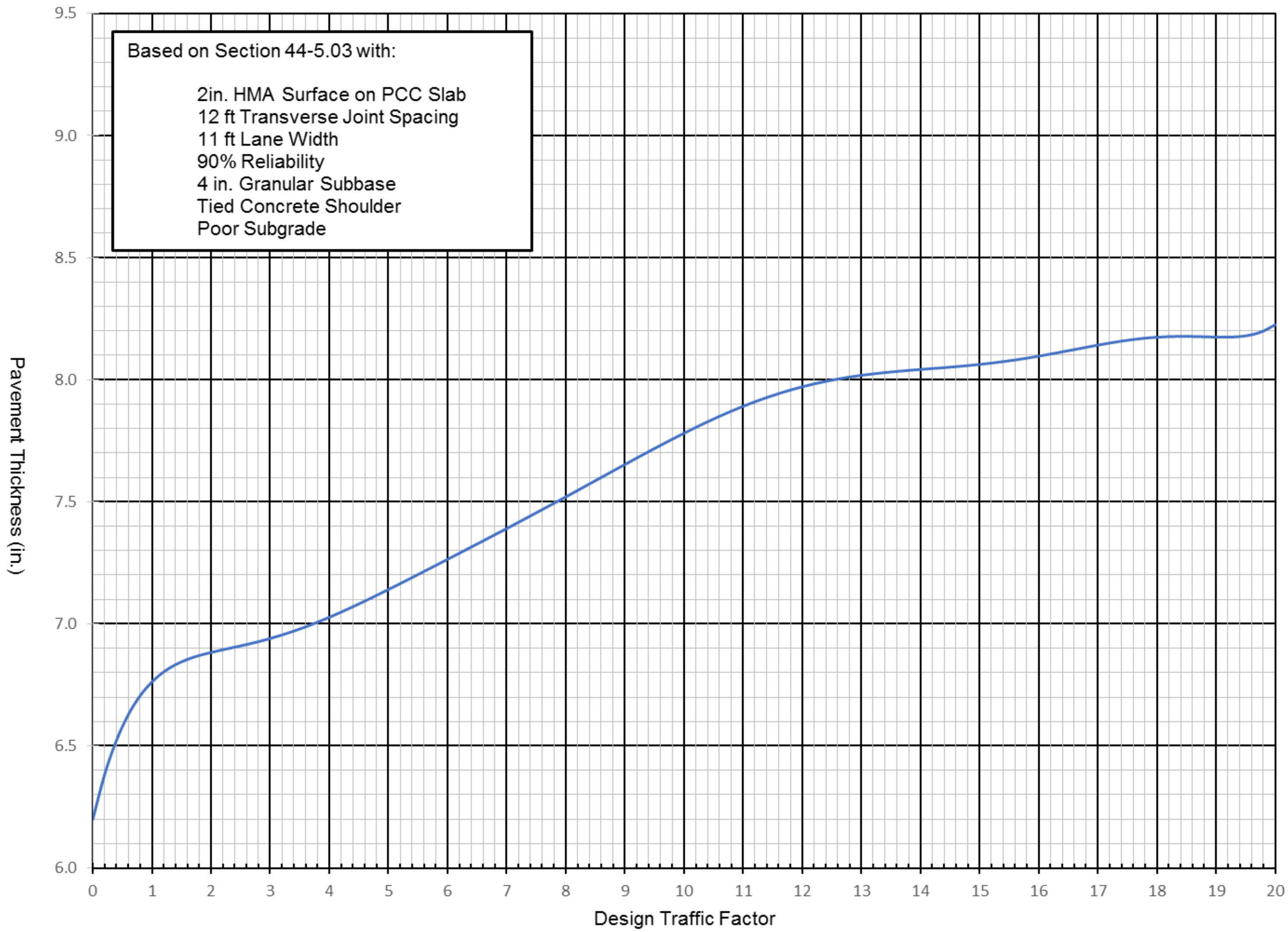
44-9.05 Figures from Section 44-5 (Composite Pavement Design)

The following figures are to be used for the design of composite pavements and submitted, as needed, with design calculations (Figure 44-5N).

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

PCC SLAB TRAFFIC FACTOR EQUATIONS (80,000 LB LOAD LIMIT)

Figure 44-5A



PRE-ADJUSTED PCC SLAB THICKNESS

Figure 44-5B

Adjustment Factor	PCC Slab Thickness Adjustment (in.)
75% Reliability	-0.50
15 ft Joint Spacing	+1.00
Untied Shoulder	+0.35
Fair Subgrade	-0.25
Granular Subgrade	-0.50
Stabilized Subbase	-0.25
Existing Pavement as Subbase	-0.50
10 ft Lane Width	+0.25
12 ft Lane Width	-0.25
HMA Surface Layer Thickness	See Figure 44-5I

THICKNESS ADJUSTMENT FACTOR

Figure 44-5C

Road Class	Subbase Material	Usage(1)	Minimum Thickness (in.)
Class I and II TF ≥ 5.0 TF < 5.0	 Stabilized Subbase(2) Granular(3)	 Required Required	 4 4
Class III & IV T.F. ≥ 5.0 T.F. < 5.0	 Granular(3) Granular(3)	 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. *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 44-5D

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

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

Figure 44-5E

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

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 44-5A and Figure 44-5B 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. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

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

Figure 44-5F

Illinois N_{design} Number	**Flexible Design ESALs, millions (1) (Flexible T.F.)**	**PG Binder Grade Selection (2)(3)**		
		Traffic Loading Rate		
		Standard(4)	Slow(5)	Standing(6)
30	< 0.3	PG 58-22	PG 64-22(7)	PG 64-22(7)
50	0.3 to < 3	PG 64-22	PG 64-22(7)	PG 70-22 or SBS PG 70-22
70	3 to < 10	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
90	10 to < 30	PG 64-22(7)	PG 70-22 or SBS PG 70-22	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 44-5A and Figure 44-5B are required for the composite pavement thickness design.*
2. *The binder grades provided in Figure 44-5G 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. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

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

Figure 44-5G

Road Class	Minimum Reliability Levels	Percent Reliability
Class I and II	High	90
Class III & IV	Medium	75

RELIABILITY LEVELS

Figure 44-5H

HMA Layer Thickness (in.)	PCC Slab Thickness Adjustment (in.)
2	No adjustment
2.5	- 0.25
3	-0.50

ADJUSTMENTS FOR HMA THICKNESS

Figure 44-5I

Slab Thickness (in.)	Dowel Diameter (in.)
≥ 10.00	1.50
> 8.00 to 9.99	1.25
≤ 8.00	1.00

DOWEL DIAMETER

Figure 44-5J

Figures 44-5K, 44-5L, and 44-5M (Typical Sections) are not included.

Date: ____________________ County: ____________________
Calculations by: ____________________ LPA: ____________________
Checked by: ____________________ Section: ____________________
Route: ____________________
Limits of Analysis: Location: ____________________
From: ____________________
To: ____________________
Length: __________ Feet __________ Miles

Percent / Count *(Figure 44-1A as needed)*

Structural Design Traffic: *(Section 44-1.03(c))*
Number of Lanes: __________
ADT: __________
Class of Road or Street: _____ *(Section 44-1.01)*

PV: __________% / __________
SU: __________% / __________
MU: __________% / __________
HCV: __________

Traffic Factor (Show Calculations)**:**

PCC Slab Traffic Factor: *(Figure 44-5A)* ________ HMA Traffic Factor: *(Figure 44-5E)* ________

Pavement Design:
Subgrade Support Rating (SSR): ☐ Poor ☐ Fair ☐ Granular *(Section 44-5.02(e) and Figure 44-6)*
Pre-Adjusted PCC Slab Thickness: *(Figure 44-5B)* *(Class IV use 6.50 in.)* __________in.
Reliability: *(Figure 44-5H)* ☐ 75% or ☐ 90%

Adjustments: *(Section 44-5.03(c) and Figure 44-5C)*

		Applicable Adjustments
75% Reliability *(Section 44-5.02(h))*	-0.50	__________in.
15 ft Joint Spacing	+1.00	__________in.
Untied Shoulder	+0.35	__________in.
Fair Subgrade / Granular Subgrade	-0.25 / -0.50	__________in.
Stabilized Subbase / Existing Pavement as	-0.25 / -0.50	__________in.
10 ft Lane Width / 12 ft Lane Width	+0.25 / -0.25	__________in.
HMA Surface Layer Thickness __________in.	*(See Figure 44-5I)*	__________in.
	Total Adjustment:	__________in.

Adjusted PCC Slab Thickness: *(Section 44-5.03(a))* __________in.
Subbase Requirements: *(Figure 44-5D)* ____________________
Select Binder: *(Figure 44-5F or 44-5G)* ____________________
HMA Layer Thickness: *(Figure 44-5I)* __________in.
Final Pavement Thickness *(Rounded to next ¼ in.)* __________in.
Dowel Bars: ☐ Yes ☐ No *(Section 44-5.03(d))* Size: *(Figure 44-5J)* __________in.
Comments: ____________________
____
____

Attachments: Location Map / USDA Soil Map (as needed) / Completed Figures (as needed)

COMPOSITE PAVEMENT
DESIGN CALCULATIONS FOR LOCAL PUBLIC AGENCIES

Figure 44-5N

44-10 ACRONYMS

This is a summary of the acronyms used within this chapter.

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
BDE	Bureau of Design and Environment
CBLRS	Central Bureau of Local Roads and Streets
DCP	Dynamic Cone Penetrometer
DP	Design Period
HCV	Heavy Commercial Vehicle
HMA	Hot Mix Asphalt
IBV	Immediate Bearing Value
IDOT	Illinois Department of Transportation
LPA	Local Public Agency
MFT	Motor Fuel Tax
MU	Multiple Unit
PCC	Portland Cement Concrete
PI	Plasticity Index
PV	Passenger Vehicle
PG	Performance Grade
RCC	Roller Compacted Concrete
SBS	Styrene-Butadiene Copolymer
SSR	Subgrade Support Rating
SU	Single Unit
TF	Traffic Factor
USDA	United States Department of Agriculture

44-11 REFERENCES

1. *Illinois Highway Standards*, IDOT

2. *Manual of Test Procedures for Materials*, IDOT

3. *Guide for Design of Pavement Structures,* AASHTO, 1993

4. Chapter 54 "Pavement Design", *BDE Manual*, IDOT

5. *IDOT Standard Specifications*, IDOT

6. *"Binder Selection on the Basis of Traffic Speed and Traffic Level", Illinois-Modified AASHTO MP-2, Table 1,* IDOT

7. *Subgrade Stability Manual*, IDOT