Chapter Fifty-Four

PAVEMENT DESIGN

BUREAU OF DESIGN AND ENVIRONMENT MANUAL

Chapter Fifty-Four
PAVEMENT DESIGN

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CHAPTER FIFTY-FOUR
PAVEMENT DESIGN

54-1 GENERAL

54-1.01 Scope of Chapter

Following the AASHTO Road Test Project, IDOT assessed the results and performed additional research to develop practical applications of the findings that would be applicable to all marked and all unmarked routes on the State highway system. As a result, the following structural pavement design methodologies were developed and included in Chapter 54:

- mechanistic design of rigid pavements,
- modified AASHTO design of rigid pavements,
- mechanistic design of flexible pavements,
- modified AASHTO design of flexible pavements, and
- design procedures for composite pavements.

A flowchart is presented in Chapter 54 that will assist in determining the appropriate structural pavement design methodology, pavement type, and design criteria. In addition to providing an analytical approach to structural pavement design, Chapter 54 presents an analytical method for selecting the most economical pavement design that can be expected to meet structural design requirements. The pavement design submittal serves as documentation to substantiate the recommendation of pavement type and thickness.

54-1.02 Definitions

The following definitions are typically used in pavement design:

1. Base Course. The layer or layers of specified or selected material (e.g., bituminous aggregate mixture (BAM), cement aggregate mixture (CAM)) of designed thickness placed on a subbase or a subgrade to support the surface course.

2. Class I Roads and Streets. Roads and streets designed as a facility, or as part of a future facility, with four or more lanes, and all one-way streets with structural design traffic greater than 3500 ADT.

3. Class II Roads and Streets. Roads and streets designed as a two-lane facility with structural design traffic greater than 2000 ADT, and all one-way streets with structural design traffic less than 3500 ADT.

4. Class III Roads and Streets. Roads and streets with structural design traffic between 750 ADT and 2000 ADT.

5. Class IV Roads and Streets. Roads and streets with structural design traffic less than 750 ADT.

6. Composite Pavement. A pavement structure having an AC surface overlaying a PCC slab of relatively high-bending resistance that serves as the principal load distributing layer. The PCC slab may be either a newly constructed base course or an existing rigid or composite pavement that is to be resurfaced.

7. Composite Pavement Structural Number (SN_C). An index number derived from an analysis of traffic and roadbed soil conditions that is used to determine the thickness of bituminous surface and PCC base course, if required, for a composite pavement.

8. Construction Year Traffic. Construction year traffic is the ADT for the year the facility is to be opened to traffic.

9. Continuously Reinforced Concrete Pavement (CRCP). A rigid pavement structure having continuous longitudinal reinforcement. The continuous reinforcement is achieved by overlapping the longitudinal steel reinforcing bars.

10. Design AC Strain. The design asphalt concrete (AC) strain is the tensile strain at the bottom of the AC pavement layer used in the design of mechanistic flexible pavements.

11. Design E_{AC} (AC Mixture Modulus). The design E_{AC} is the AC mixture modulus in the pavement that corresponds to the design pavement AC mixture temperature. E_{AC} is selected from Figure 54-5D and is based on the relationship between the design AC mixture temperature and the asphalt cement type (i.e., PG58-xx (AC 10) or PG64-xx (AC 20)) used in the design of mechanistic flexible pavements.

12. Design Lane. The lane carrying the greatest number of SU and MU vehicles.

13. Design Pavement AC Mixture Temperature. The design temperature of the AC mixture to be used in the design of mechanistic flexible pavements is based on the pavement's geographical location. See Figure 54-5C.

14. Design Period. The number of years that a pavement is to carry a specific traffic volume and retain a serviceability level at or above a designated minimum value.

15. Design Subgrade Support Rating (SSR). The design SSR is the rating of the subgrade support under mechanistically designed pavements. There are three classes of SSR: poor, fair, and granular. SSR is determined by the district geotechnical engineer and documented in the project soils report.

16. Equivalency Factor. A numerical factor that expresses the relationship of a given axle load to another axle load in terms of its effect on the serviceability of a pavement structure. In pavement design, all axle loads are equated in terms of an equivalent number of repetitions of an 18-kip, single-axle load (ESAL's).

17. Existing Traffic. Existing traffic is the existing ADT of the facility.

18. Flexible Pavement. An asphalt pavement structure which maintains intimate contact with and distributes loads to the subgrade which depends upon aggregate interlock, particle friction, and cohesion for stability (e.g., Superpave or Class I mixtures).

19. Flexible Pavement Structural Number (SN_F). An index number derived from an analysis of traffic and roadbed soil conditions which may be converted to a flexible pavement thickness for modified AASHTO through the use of suitable factors related to the types and strengths of material being used within the pavement structure.

20. Future Traffic. Future traffic is the ADT of the facility at the end of the design period, typically 20 years.

21. Illinois Bearing Ratio (IBR). The IBR is a measure of the support provided by the roadbed soils or by unbound granular materials under modified AASHTO designed pavements or composite pavements. The IBR test procedure is a modification of the California Bearing Ratio (CBR) procedure and is a soaked laboratory test.

22. Improved Subgrade. A subgrade which has been modified with lime, by-product lime, cement, or other approved material or, alternatively, has been removed and replaced with aggregate.

23. Integral Curb and Gutter. A curb and gutter which is paved monolithically with the pavement. It is used to reduce edge stresses.

24. Jointed Plain Concrete Pavement (JPCP). A rigid pavement structure that utilizes doweled joints at 15 ft nominal intervals.

25. Jointed Reinforced Concrete Pavement (JRCP). A rigid pavement that utilizes distributed steel reinforcement and transverse contraction joints.

26. Mechanistic Pavement Design. A structural pavement design procedure used to determine fatigue life based on actual conditions, including stresses, strains, and deflections. It can be used to suit any local condition and material.

27. Multiple-Unit (MU) Vehicles. MU vehicles include truck tractor semi-trailers, full trailer combination vehicles, and other similar combinations.

28. Passenger Vehicles (PV). PVs include automobiles, pickup trucks, vans, and other similar two-axle, four-tire vehicles.

29. Pavement Performance. The trend of pavement serviceability with respect to repetitive vehicular load applications.

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

31. Present Serviceability Index (PSI). A number derived by formula for estimating the serviceability rating from measurements of certain physical features of the pavement.

32. Present Serviceability Rating (PSR). The mean value of the independent subjective ratings by members of a special panel for the AASHTO Road Test as to the serviceability of a section of the highway.

33. Pumping. The ejection of foundation material through joints or cracks or along edges of rigid slabs due to vertical movements of the slab under traffic.

34. Ramp. A roadway that connects two or more legs at an interchange and includes at least one ramp terminal section. Roadways that connect two legs of freeway, and that are continuations of mainline lanes, or arise from tapers designed for high-speed operation are not considered ramps, but are considered part of the mainline for structural design.

35. Rigid Pavement. A pavement structure whose surface and principal load distributing component is a PCC slab of relatively high bending resistance (e.g., JPCP, CRCP, JRCP).

36. Roadbed. That portion of the highway within the side slopes that is graded and prepared as a foundation for the pavement structure and shoulders.

37. Serviceability. The ability of a pavement, at the time of observation, to serve automobile and truck traffic.

38. Single-Axle Load. The total load transmitted by all wheels whose centers may be included between two parallel transverse vertical planes 40 in apart, extending across the full width of the vehicle.

39. Single-Unit (SU) Vehicles. SU vehicles include two- or three-axle trucks and buses having six tires.

40. Structural Design Traffic. The ADT that is estimated for the year that represents one-half of the design period which is then classified into PV, SU, and MU vehicles and assigned to the design lane to determine a traffic factor.

41. Subbase. The layer, or layers, of specified or selected material (e.g., BAM, CAM) of designed thickness that is placed on the subgrade to support the base course or, in the case of rigid pavements, the PCC slab.

42. Subgrade. The top surface of a roadbed upon which the pavement structure and shoulders are constructed.

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

44. Tandem-Axle Load. The total load transmitted to the road by two or more consecutive axles whose centers may be included between two parallel vertical planes spaced more than 40 in but not more than 96 in apart, extending across the full width of the vehicle.

45. Tied Curb and Gutter. A PCC curb and gutter which is tied with reinforcing steel to the pavement. It is used to reduce edge stresses.

46. Tied Shoulder. A PCC stabilized shoulder tied with reinforcing steel to the pavement. It is used to reduce pavement edge stresses.

47. Time-Traffic Exposure Factor. A numerical factor applied to the pavement design term indicated by the AASHTO Road Test pavement performance equations (rigid and flexible) to modify the equations to be more representative of the behavior of pavements serving under similar conditions but over periods of time more typical of regular service life.

48. Traffic Factor (TF). The total number of 18-kip equivalent single-axle load applications (ESAL's) to the design lane anticipated during the design period, expressed in millions. It is used as an equivalency factor for mixed traffic loads.

49. Untied Shoulder. Any shoulder which does not provide edge support. The shoulder may consist of earth, aggregate, bituminous stabilized, or other materials.

54-1.03 Pavement Design Methodologies

54-1.03(a) Mechanistic

Since the completion of the AASHTO Road Test Project, the Department has developed many new highway materials and procedures to improve pavement construction. This effort has resulted in improved material usage, construction procedures, and pavement designs which, although common practice today, were neither envisioned nor included in design procedures at the time of the AASHTO Road Test. To better address modern pavement design,

mechanistically based structural pavement design procedures have been developed for JPCP and full-depth bituminous concrete (AC) designs.

Mechanistic pavement design procedures use the actual stresses, strains, and deflections experienced by the pavement to determine its expected fatigue life. Factors that are considered in mechanistic designs include:

- design AC strain,
- design pavement AC mixture temperature,
- design AC mixture modulus (E_{AC}),
- subgrade support ratio (SSR), and
- degree of edge support (PCC design).

See Section 54-1.02 for definitions of these factors.

Mechanistic procedures were developed using structural mechanical analysis, computer modeling, and actual performance and response of existing pavement sections. Mechanistic procedures are intended to supplement the procedures of the AASHTO Road Test Project and are applicable to JPCP designs with nominal 15 ft panels and full-depth AC designs with Superpave surface and binder when used to design State-maintained facilities. Electronic spreadsheets to assist in the pavement design and selection process are available from BDE.

54-1.03(b) Modified AASHTO

The modified AASHTO design procedures are based on the AASHTO Road Test pavement performance equations, which correlate performance of test sections with pavement design, the magnitude and configuration of the axle load, and the number of axle-load applications. The AASHTO equations are necessarily limited to the following factors:

- physical environment of the Road Test Project,
- materials used in the test pavements,
- range of pavement thicknesses included in the experiments,
- axle loads used and number of axle-load applications experienced,
- specific times and rates of application of the test traffic,
- construction techniques employed, and
- climatic cycles experienced during construction and testing of the experimental facility.

To apply the AASHTO equations in design, it is necessary to make certain assumptions and extrapolations based on experience and engineering judgment. In developing the design procedures, modifications were made to the AASHTO equations to reflect the effect of the following variations on pavement performance:

- mixed truck and passenger car traffic axle loadings when compared with controlled traffic axle loadings in the AASHTO Road Test,

- pavements subjected to traffic over longer periods of time when compared to the two years of traffic in the AASHTO Road Test, and

- variations in the support strengths of the roadbed soils.

Variations in climatic conditions as they exist from one part of the State to another and particularly between the extreme northern and extreme southern portions undoubtedly affect pavement performance. The relative effects of these variations on pavement performance, however, are not sufficiently distinguishable at the present time to be taken into account in pavement structural design. Therefore, in developing the modified AASHTO structural design procedures, climatic effects were considered only on a State-wide basis.

Initially, procedures were developed for design of rigid and flexible pavements. Continuation of this effort focused on design of bituminous surfacings for both existing PCC pavements and new PCC base courses. This resulted in the composite design procedure, which is based on a modification of the rigid design methodology.

54-1.04 Selection of Design Methodology, Pavement Type, and Design Criteria

Figure 54-1A presents a flowchart that will help to determine the appropriate structural pavement design methodology, pavement type, and design criteria. The mechanistic structural pavement design methodology will be used for all projects on marked and unmarked routes of the State highway system that require a pavement design submittal to the BDE (see Section 54-8.01). This includes complete reconstruction of existing pavements and projects involving widening in excess of 6 ft. However, if a new roadway is to be constructed on the local system and jurisdiction is being transferred to the Local Agency, the Local Agency should concur in the design. In addition, the following will apply:

1. New Construction/Reconstruction Projects. For new pavements, including reconstructed pavements, the pavement selection will be based on an economic analysis using estimated costs of life-cycle activities (see Section 54-7). This procedure utilizes a 40-year life cycle, a 3% discount rate, and a comparison of pavement types based on annualized costs.

2. Widening Projects Involving Resurfacing. For projects involving widening in excess of 6-ft where the existing pavement and widening are to be resurfaced, the following will apply.

    - The thickness of resurfacing over the existing pavement first should be determined.

- The mechanistic pavement design procedure then will be used to determine the total thickness of pavement required for the full-depth AC Superpave pavement widening. The thickness of the resurfacing will be subtracted from the total thickness to determine the thickness of the additional binder required.

- Procedures contained in Section 54-6 will be used to design the PCC base course thickness of the composite pavement alternative and procedures contained in Section 54-5 will be used to design a flexible widening with BAM base course. The thickness of the Superpave surface over the PCC or BAM base course will be equal to that determined for the resurfacing of the existing pavement.

- The selection of the pavement type then will be based on first cost.

3. Widening Projects Not Involving Resurfacing. For projects involving widening in excess of 6 ft where the existing pavement and widening are not to be resurfaced, the following will apply:

    - The mechanistic structural pavement design procedures will be used to determine the required thickness for both the rigid and full-depth AC Superpave pavement alternatives.

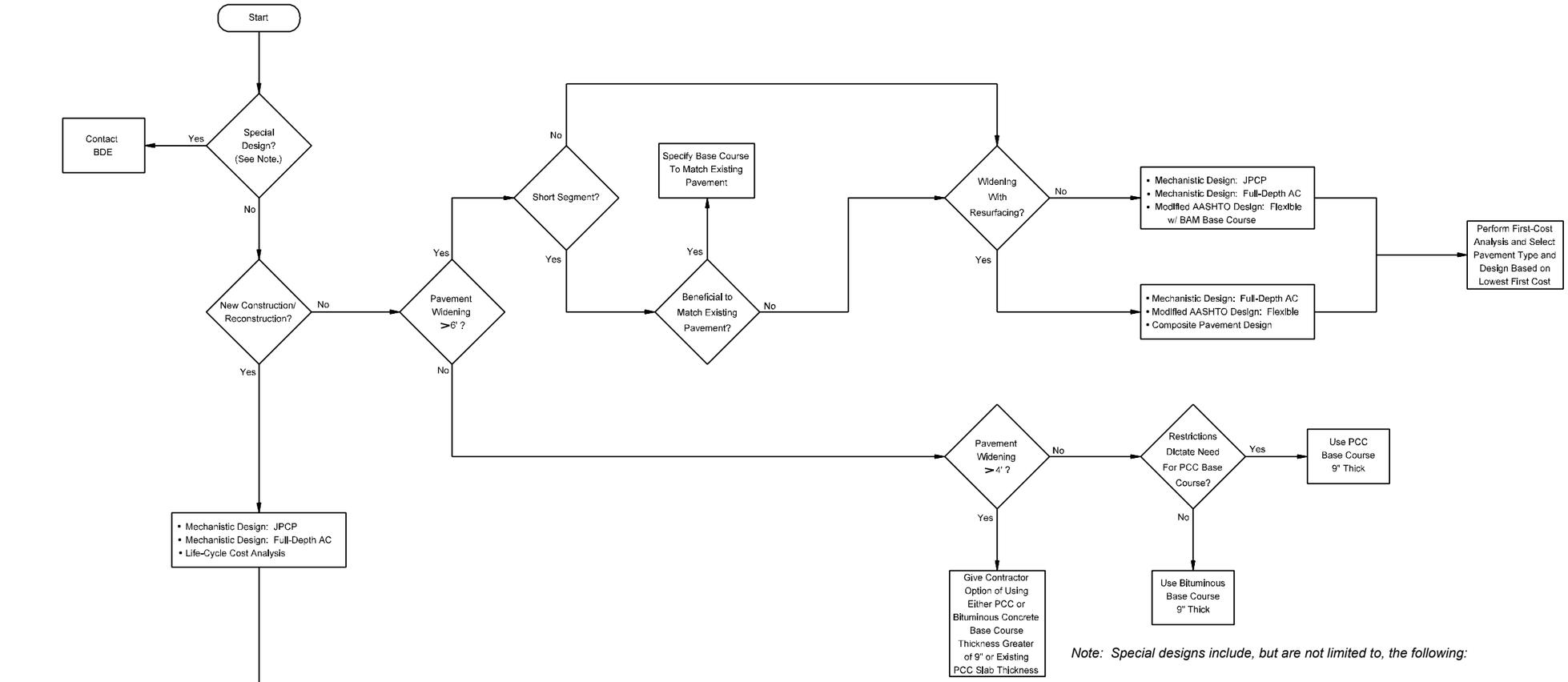
    - Procedures contained in Section 54-5 will be used to design a flexible widening with BAM base course alternative.

    - The selection of the pavement type then will be based on first cost.

4. Special Considerations of Mechanistic Designs. The design charts used in the mechanistic design methodology provide several options for both rigid and flexible pavement designs. The following special considerations apply:

    a. Rigid Pavement Designs. Unless prior approval to use untied shoulders has been granted by the BDE or if stabilized shoulders are not required, the rigid pavement design curve for the 12 ft lane with tied concrete shoulders will be used for determining the design thickness. If the rigid option is selected, plans will be prepared based on the thickness obtained with the 12 ft lane. The criteria for the use of subbase under rigid pavements, as discussed in Section 54-4.01(h), will apply; however, the 12 in modified layer or 12 in granular material layer will still be required on all but granular *in situ* soils.

    b. Flexible Pavement Designs. For flexible pavement designs, the designer will be required to select an appropriate asphalt cement grade (i.e., PG 58-XX (AC 10), PG 64-XX (AC 20), PG 70-XX, or PG76-XX)). The grade selected will be included in the plans.



Note: Special designs include, but are not limited to, the following:

- *designs involving high-stress locations (e.g., high-stress intersections);*
- *designs involving the need to accommodate heavily loaded vehicles;*
- *use of JRCP to match existing pavement structure;*
- *use of CRCP to match existing pavement or at locations where the traffic factor is greater than 35;*
- *designs involving a Jurisdictional Transfer to a Local Agency necessitating the need for a waiver;*
- *designs involving waivers associated with staged construction, short segments, and detours and crossovers;*
- *use of untied shoulder or untied curb and gutter designs or other-than-rigid shoulders with rigid pavement structures;*
- *mechanistic designs that do not require an improvement to the subgrade; and*
- *designs involving policy exceptions or less than minimum criteria.*

FLOWCHART FOR SELECTION OF DESIGN METHODOLOGY, PAVEMENT TYPE, AND DESIGN CRITERIA

Figure 54-1A

54-1.05 Intersections

The type of pavement material selected for intersections will depend upon the existing pavement type and the volume and type of vehicles crossing or turning at the intersection. The following sections discuss the type and application of pavement materials typically used at intersections.

54-1.05(a) High-Stress Intersections

High-stress intersections are defined as those under stop control, either signal or sign, that have one or more of the following conditions:

- The approach grade on any stop-controlled leg of the intersection is greater than or equal to 3.5%.
- The two-way ADT for MU vehicles is greater than or equal to 400 vehicles in rural areas or 800 vehicles in urban areas. For ramps and other one-way facilities, use one-half of this ADT criteria.
- The ADT for turning MU vehicles on any one leg of the intersection is greater than or equal to 200 vehicles in rural areas or 400 vehicles in urban areas. This also applies to sharp turning movements that are not under stop control.

Pavement types for high-stress intersections are limited to either of the following materials:

- PCC; or
- AC Superpave $N_{design} \geq 90$.

Use these materials a minimum of 150 ft back from the location of the stop bar. The maximum length normally will be the length of the turn lane plus the taper. A greater length is permitted if a capacity study indicates a greater queue length.

If an existing intersection exhibits rutting and shoving of the bituminous concrete surface material, consider complete reconstruction rather than resurfacing the intersection.

54-1.05(b) Distress Treatment at Other Intersections

Intersections not meeting the criteria in Section 54-1.05(a) are not considered high-stress intersections. Nevertheless, they may exhibit, or have the potential to exhibit, pavement distress similar to that exhibited at high-stress intersections.

At intersections that do not meet high-stress criteria where the existing pavement type is bare PCC, PCC may be used if the improvement consists of minor widening without resurfacing.

Those intersections that are not considered high-stress but have an AC pavement type exhibiting distress (e.g., rutting, shoving) should be investigated to determine the cause. Examine and test the existing pavement structure to determine where any unstable material exists and if slippage is at PCC/AC interface. If found, remove and replace the unstable material prior to resurfacing. If the investigation indicates a stable mixture but experience indicates a problem with flexible or composite pavements, consider obtaining an exception to the criteria presented in Section 54-1.05(a). Example conditions which may allow an exception include:

- lower urban ADT for MU vehicles if all are required to stop or if the approach speed is greater than 40 mph;
- lower urban and rural ADT for MU vehicles if the majority are fully loaded at intersections near warehouse facilities, landfills, grain elevators, etc.;
- demonstrated problems with shoving of a bituminous overlay related to tight turning movements; and
- including SU trucks in the MU truck count where the SU vehicles are primarily fully loaded hauling vehicles (e.g., grain trucks, concrete trucks, coal trucks).

The above exceptions also apply to intersections not exhibiting distress if the intersection is being constructed or reconstructed. Any exception request needs BDE approval. Requests to use PCC pavement for intersections that are not high stress and do not require an exception will be submitted for approval through the normal pavement selection process.

54-1.05(c) Side Road Approaches

The following will apply to the placement of pavement material at side road approaches:

For side road approaches that have a surface type lower than bituminous concrete, surface the approach with bituminous concrete to the right-of-way line or to 50 ft beyond the edge of the traveled way, whichever is less.

For side road approaches that have a surface equal to or greater than bituminous concrete, surface the approach with bituminous concrete to at least the edge of shoulder.

54-1.06 Interchange Ramps

The following will apply to the structural pavement design of interchange ramps:

1. Design Methodology. Use the mechanistic structural pavement design methodology for interchange ramp projects, regardless of whether or not the ramps are to be newly

constructed, reconstructed, or widened. The minimum traffic criteria are given in Figure 54-1B. Other pavement design methodologies (e.g., modified AASHTO designs, composite pavement designs) are rarely used for interchange ramp designs and will require BDE approval.

2. Pavement Type. Use a pavement type for interchange ramps that is the same as that of the contract being let for the mainline, except that ramps connected to entrance or exit ramp terminals shall be jointed PCC pavement if rigid pavement is used for the mainline.

3. Design Considerations. Typically, it is necessary to perform a structural pavement design for interchange ramps that is independent of that for the mainline pavement. Give adequate consideration to the requirements of high-stress locations (see Section 54-1.05(a)) and heavily loaded vehicles (see Section 54-2.01(e)) during design.

54-1.07 Rest Areas

Design the rest area exit and entrance ramps, roadways, shoulders, and parking areas for the greater of the actual projected traffic in the design year, or for Interstate/supplemental freeways minimums assuming lane distribution of P=32%, S=M=45%. Use a pavement type for rest areas that is the same as that of the contract being let for the mainline, except use jointed PCC pavement if the mainline is a rigid design. The concentration of heavy trucks braking on the ramps and inner roadways and the sharp turning maneuvers to enter parking stalls requires these facilities to be considered high-stress locations. If AC is used for the pavement material, it may require a different asphalt cement grade and/or special mixture designs. See Sections 54-1.05(a) and 54-1.06 for additional information. For PCC pavements, use stabilized subbase. Design shoulders to the same thickness and material as the pavement as shown in Figure 16-1H.

54-1.08 Weigh Stations

Design the weigh station ramps and detention parking area to provide the same structural capacity as the adjacent freeway. Weigh stations are, by definition, “High Stress” locations for pavement design purposes. When flexible or composite pavements are selected, apply modifications to the bituminous mixtures to the driving lane pavements beginning 2500 ft upstation of the exit ramp terminal stub, and downstation to a point 2500 ft beyond the entrance ramp terminal stub, as well as throughout all pavements in the weigh stations and ramps. See Section 54-1.05(a) for additional information.

Crossroad	Design Traffic Criteria		Lane Distribution Criteria	Traffic Factor Equation	
				Rigid	Flexible
Interstate or Supplemental Freeway	Greater of:	Actual Ramp Traffic Projection for Design Year	P = S = M = 100% (100% of Actual Ramp Traffic in Design Lane)	54-4.1	54-5.1
		Interstate/Supplemental Freeway Minimum Traffic (Figure 54-2C)	Same as used for Mainline Design Lane	54-4.1	54-5.1
Other State Marked Route	Greater of:	Actual Ramp Traffic Projection for Design Year	P = S = M = 100% (100% of Actual Ramp Traffic in Design Lane)	54-4.1	54-5.1
		Marked Route Minimum Design Traffic (Figure 54-2C)	Same as used for Crossroad Design Lane	54-4.2	54-5.2
Unmarked Route	Greater of:	Actual Ramp Traffic Projection for Design Year	P = S = M = 100% (100% of Actual Ramp Traffic in Design Lane)	54-4.1	54-5.1
		Marked Route Minimum Design Traffic (Figure 54-2C)	P = S = M = 50% (50% of Marked Route Minimum in Design Lane)	54-4.2	54-5.2

[1] *Use the highest traffic factor of any ramp at a given interchange for all ramps at that interchange.*

DESIGN TRAFFIC CRITERIA FOR INTERCHANGE RAMPS[1]

Figure 54-1B

54-2 BASIC DESIGN PARAMETERS (Mechanistic)

54-2.01 Development of Design Procedures

54-2.01(a) General

See Section 54-1.03(a) for a brief discussion of the mechanistic structural pavement design methodology.

54-2.01(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 20 years. However, it may be advantageous to design lesser roadways (e.g., frontage roads) for shorter periods. Use the following guidelines when selecting an appropriate design period:

1. New Construction/Reconstruction Projects. For new construction/reconstruction projects, see the following sections for the appropriate design period:

   - Rigid Pavement: Mechanistic Design — Section 54-4.01(e).
   - Rigid Pavement: Modified AASHTO Design — Section 54-4.02(b).
   - Flexible Pavement: Mechanistic Design — Section 54-5.01(e).
   - Flexible Pavement: Modified AASHTO Design — Section 54-5.02(b).
   - Composite Pavement Design: Modified AASHTO Design — Section 54-6.02.

2. Widening Projects. Use the following guidelines when selecting the design period for widening projects:

   a. Widening Without Resurfacing. Use a design period of 20 years.

   b. Widening With Resurfacing. Use the Department's policy for the thickness of the resurfacing. Use a design period of 20 years for the base course. For projects with new curb and gutter, design the resurfacing for 15 years and the base course for 20 years.

54-2.01(c) Structural Design Traffic

Structural design traffic is an estimate, based on ADT, of the volume of PV, SU, and MU vehicles that will be in the design lane in the year that is one-half the design period from the established date of construction. For example, if the design period is 20 years, the structural design traffic will be projected for the year which is 10 years from the established date of construction. In all IDOT pavement design procedures, structural design traffic is used to

calculate a traffic factor (i.e., a factor representing the anticipated traffic load in the design lane on the pavement structure). However, the procedures and equations used to calculate the traffic factor differ among pavement design methodologies (e.g., mechanistic design, modified AASHTO design, rigid pavements, flexible pavements). Use the following procedures to determine structural design traffic:

1. Estimate ADT of PV, SU, and MU Vehicles. 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. Contact the district Programming Section for traffic data. 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. Other methodologies may apply. 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 54-2A to estimate the number of PV, SU, and MU vehicles from ADT. Also give consideration to 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 (see Section 54-2.01(e)).

Facility Class	Percent of Total ADT		
	PV	SU	MU
Class III	88%	7%	5%
Class IV	88%	9%	3%

VEHICULAR CLASSIFICATION FOR STRUCTURAL DESIGN TRAFFIC
(Class III and Class IV Facilities)

Figure 54-2A

2. Assign Traffic to 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). Use the distribution factors in Figure 54-2B to estimate the number of PV, SU, and MU vehicles that will be in the design lane. Use the total two-way ADT for multilane facilities as the distribution factors account for this. For example, if the total projected ADT for a rural 4-lane facility determined in Step 1 includes 300 MU vehicles, the estimated number of MU vehicles in the design lane will be 135 (i.e., 300 • 0.45). Note that the design lane distribution factors in Figure 54-2B 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, relatively close interchange spacing). Give consideration to such factors before applying the distribution factors in Figure 54-2B. Adjustments may be necessary.

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	32%	45%	45%	32%	45%	45%
≥ 6	20%	40%	40%	8%	37%	37%

** One-way roads and streets.*

DESIGN LANE DISTRIBUTION FACTORS FOR STRUCTURAL DESIGN TRAFFIC

Figure 54-2B

3. Determine Actual Structural Design Traffic (All Design Methodologies). Steps 1 and 2 above are used to estimate the actual structural design traffic. The actual structural design traffic is used to calculate an actual traffic factor, which is a number representing an estimate of the total ESALs that will be in the design lane on the pavement structure during the design period. Unless other minimum criteria apply (e.g., see Item 4), this traffic factor will be used to design the entire pavement structure. In all IDOT pavement design methodologies it is necessary to calculate an actual traffic factor. There are two different sets of traffic factor equations, one for rigid pavements and one for flexible. Section 54-4.01(g) applies to rigid mechanistic, rigid modified AASHTO, and composite pavement designs. Section 54-5.01(g) applies only to flexible pavement designs using either the mechanistic or modified AASHTO methodologies.

4. Determine Minimum Structural Design Traffic (Mechanistic Design Only). The concept of using minimum structural design traffic to determine a minimum traffic factor applies only to mechanistic pavement designs. The minimum traffic factor is a factor that represents a minimum threshold below which the Department will not permit lesser pavement designs and is based on a set of minimum SU and MU vehicular volumes which are obtained from Figure 54-2C. Figure 54-2C applies to mechanistic designs of both rigid and flexible pavements. To obtain the minimum structural design traffic, enter Figure 54-2C and select the set of minimum SU and MU vehicular volumes for the type of facility being designed regardless of actual design traffic. Use the procedures discussed in Step 2 to distribute the minimum volumes obtained from Figure 54-2C and determine the number of SU and MU vehicles in the design lane. The SU and MU vehicles assigned to the design lane will be used to calculate the minimum traffic factor. The minimum traffic factor is calculated in the same manner as the actual traffic factor calculated in Step 3. The only difference is that minimum, not projected actual, traffic volumes are used. The greater of the two traffic factors, actual or minimum, will be used to perform the mechanistic design of the pavement structure. Note that mechanistic

designs of flexible pavements for unmarked routes have an overriding absolute minimum traffic factor of 0.5. For example, if the actual traffic factor calculated in Step 3 is less than the calculated minimum traffic factor, and the calculated minimum traffic factor is less than 0.5, the absolute minimum traffic factor of 0.5 will be used in the mechanistic design of the flexible pavement.

Facility Type	PV	SU	MU
Interstate and Supplemental Freeways	0	500	1500
All Other Marked State Routes	0	300	900
All Unmarked State Routes	No Minimum Volume Requirements②		

Notes:

1. *The minimum vehicular class volumes presented in Figure 54-2C are given as ADT (i.e., two-way traffic) and must be assigned to the design lane using the procedures described in Step 2 in Section 54-2.01(c).*

2. *Note that mechanistic designs of flexible pavements on unmarked routes have an overriding absolute minimum traffic factor of 0.5. See Step 4 in Section 54-2.01(c).*

MINIMUM VEHICULAR CLASS VOLUMES FOR STRUCTURAL DESIGN TRAFFIC (Mechanistic Design: Rigid and Flexible Pavements)

Figure 54-2C

54-2.01(d) Mixed-Traffic Axle Loadings

To evaluate the effects of mixed-traffic axle loadings on pavement performance, a system was developed to convert these loadings to a traffic factor. The traffic factor represents the total number of 18-kip equivalent single-axle load applications, expressed in millions, that a given pavement may be expected to carry throughout its entire service life.

In developing this system, equivalency factors for various groupings of single-axle and tandem-axle loadings were determined from the AASHTO Road Test equations, statewide weigh survey data, and classification counts at weigh stations. The equivalency factor for any given single-axle or tandem-axle load expresses the number of 18-kip single-axle load applications that is equivalent in effect upon pavement performance to one application of the given axle load.

In determining the number of 18-kip equivalent single-axle loads that represents one application of each of the three classes of vehicles (i.e., PV, SU, and MU), consideration must be given to the differences in average axle weights of both SU and MU trucks operating on various highways (e.g., high volume major highways with heavy commercial truck traffic, low volume farm-to-market highways). Highways were divided into four general classifications to reflect

these differences in average axle loads. Because rigid and flexible pavements respond differently to axle loadings, the equivalency factors reflect these differences. The 18-kip equivalencies per vehicular classification for Class I through Class IV roads and streets are presented in this chapter for each design methodology.

In areas that include mines, grain elevators, factories, river ports, and landfills, the impacts of heavily loaded SU and MU vehicles may become significant. See Section 54-2.01(e) for additional information on designing for heavily loaded vehicles.

54-2.01(e) Heavily Loaded Vehicles

The equivalency factors for SU and MU vehicles that are incorporated in the IDOT pavement design methodologies presented in this chapter assume that traffic on the roadway is a typical mix of fully loaded, partially loaded, and empty vehicles. See Section 54-2.01(d) for additional information on equivalency factors for mixed-traffic axle loadings. Highway sections in some areas of the State provide access to businesses that utilize fully loaded trucks. Using typical SU and MU equivalency factors often will result in an inadequately designed pavement section. It only requires an increase in gross vehicle weight of approximately 10% to double the resulting damage to the pavement. Failure to consider the effects of heavily loaded vehicles can reduce pavement life significantly, in some cases by as much as one-half. It is therefore important to seriously evaluate pavement designs that will accommodate heavily loaded vehicles.

Typically, operations that involve moving commodities and hauling large quantities of materials to and from ports and other locations use heavily loaded vehicles. Such operations may include mining operations, grain terminals, factories, river ports, landfills, etc. In general, designs should be adjusted where heavily loaded vehicles comprise 10% or more of the design truck traffic. Contact the Bureau of Materials and Physical Research for assistance in analysis of traffic and pavement sections.

54-2.01(f) Roadbed Soils

Subsurface exploration is an essential part of the engineering survey for highway location and design. It includes soils investigation, sampling, testing, identification, and distribution with respect to the horizontal and vertical alignment of the highway. USDA county soils reports often are used in preliminary geotechnical investigations and in developing soil sampling surveys. Roadbed soil types, problem areas, recommendations, and corrective measures are compiled by the geotechnical engineer in the project geotechnical report which, after approval by the Soil Committee, will become a project design document for incorporation in the project plans and specifications. Consider the following guidelines when evaluating the need for subgrade improvements:

1. Importance of Subgrade Stability. Subgrade stability plays a critical role in the construction and performance of a pavement. Pavement performance is directly related

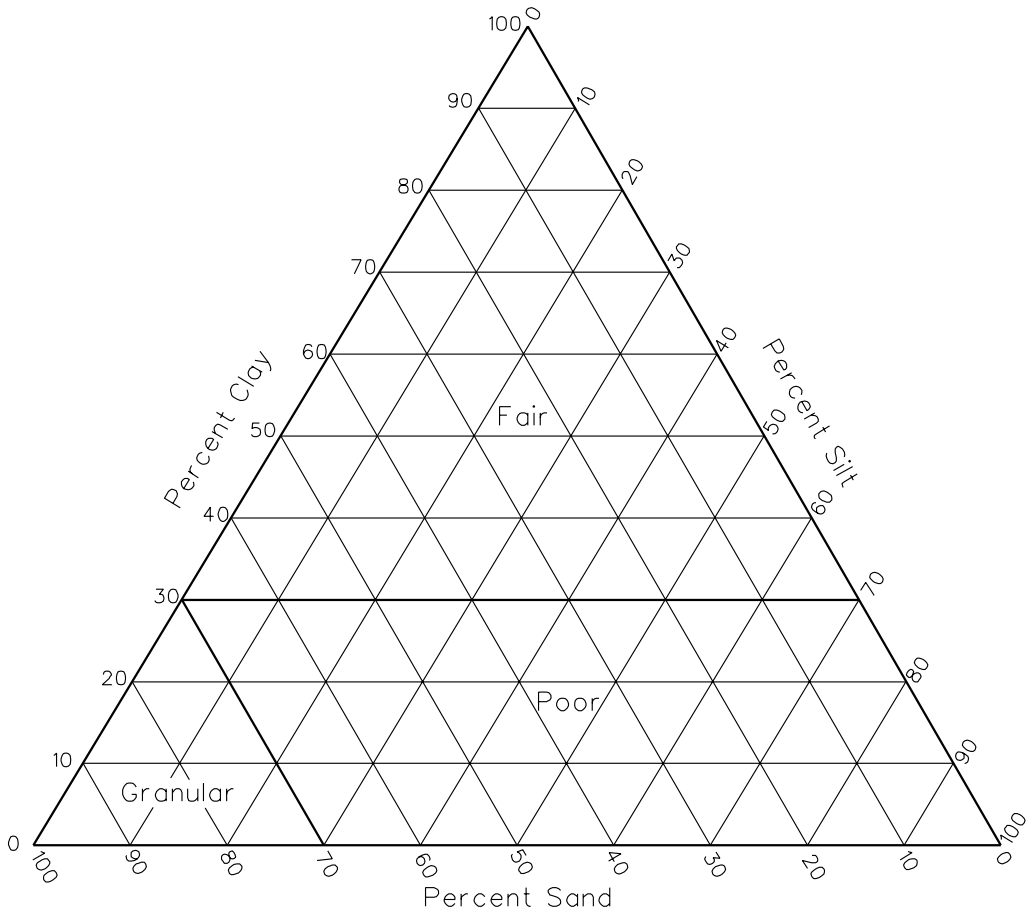
to the physical properties of the roadbed soils and the materials used in the pavement structure. Subgrade stability is a function of a soil's strength and its behavior under repeated traffic loadings. Both properties significantly influence pavement construction operations and the long-term performance of the pavement structure. The pavement subgrade should be sufficiently stable to:

- prevent excessive rutting and shoving during construction;
- provide uniform support for placement and compaction of pavement layers;
- minimize impacts of excessive volume change and frost;
- limit pavement resilient (i.e., rebound) deflections to acceptable limits; and
- restrict permanent deformation during pavement service life.

2. Department Policy. A subgrade that provides a stable working platform will minimize rutting and moisture related problems resulting in effective construction and a smoother pavement. Department policy was established to ensure that the pavement subgrade, *in situ* or improved, will provide a stable working platform for all pavement construction. Most Illinois soils are not capable of providing a subgrade that meets the criteria for a stable working platform. Although the negative effects of less satisfactory soils can, to some degree, be reduced by increasing pavement structure thickness, it usually is necessary to treat *in situ* soils to ensure adequate subgrade support for construction equipment operations and for the placement and compaction of pavement layers. Where *in situ* soils are found to be inadequate to provide a stable working platform, it is required that a minimum 12 in thick improved subgrade layer be provided.

3. Design Considerations. Mechanistic structural pavement designs will provide structurally adequate pavements that are suited to local conditions and material selection. The mechanistic design methodology for both rigid and flexible pavement types assumes that a stable subgrade is present (*in situ* or improved) and that, if improved, the subgrade is constructed with the highest quality material. The subgrade, however, is not given additional credit during design nor is the cost of providing an improved subgrade included in the pavement selection process. If it is determined that an improved subgrade layer is needed to provide a stable working platform, no change will be made to the subgrade support rating that is used during design (see Item 4). For additional design guidance, see the IDOT *Subgrade Stability Manual*.

4. Soils Evaluation (Subgrade Support Rating — SSR). Mechanistic pavement design procedures require that subgrade support ratings be determined for the project's *in situ* soils. These SSR valuations will be used to design the pavement structure. SSRs are based on information provided in the project geotechnical report. There are three SSR categories (i.e., poor, fair, and granular). Based on the percent clay, silt, and sand found in the *in situ* soil, SSR valuations are obtained from Figure 54-2D (Note that Figure 54-2D already assumes a high water table and appropriate frost penetration). All project soils will be evaluated by the district geotechnical engineer to determine and verify what, if any, subgrade treatment is needed. It also is the responsibility of the geotechnical



SUBGRADE SUPPORT RATING (SSR)
(Mechanistic Design)

Figure 54-2D

engineer to provide the designer with SSRs and their application limits within the project. Each SSR in the soils report will represent the average soil conditions within the specified limits of the project. For small projects, in the absence of laboratory tests, SSR valuations may be estimated using USDA county soils reports.

5. Policy Deviations. Typical Illinois soils have poor to fair SSR valuations and require an improved subgrade layer. Although infrequent, an *in situ* soil (e.g., granular) may be found at a project location that will provide a stable working platform without improvement. Where marginally adequate soils are found, the district geotechnical engineer may recommend something less than a 12 in thick improved subgrade layer. On the other hand, the geotechnical report may recommend a thicker improved subgrade layer. Where an improved subgrade layer is needed to provide a stable working platform, any deviation from the 12 in thickness criteria must be supported by the geotechnical engineer, documented in the project geotechnical report, and approved by the BDE. In such cases, ensure that supporting conclusions and recommendations are adequately documented in the pavement design submittal.

6. Subgrade Improvement Alternatives. Where it is determined that the subgrade soil needs improvement, use one of the following alternatives to provide the required depth of the improved subgrade layer:

- soils modification (e.g., lime, by-product lime, cement);
- undercut and backfill with granular material; or
- moisture-density control.

Consider the following when selecting from the above alternatives:

a. Typical Treatment. Where required, lime modification typically is used for the improved subgrade layer.

b. Non Lime-Reactive Soils. Where *in situ* soils are found to not react with lime or by-product lime (e.g., organic and sandy soils), cement modification typically is used for the improved subgrade layer.

c. Urban Areas. For dust control in urban areas, granular material may be specified for the improved subgrade layer.

d. Granular Material Availability. If granular material is readily available, the district may elect to specify granular material for the improved subgrade layer in lieu of typical treatments. This decision will be made on a case-by-case basis.

e. Alternatives Analysis. For the subgrade treatments being considered, determine the appropriate construction parameters for the subgrade alternatives analysis. This may include the following:

- required thickness of the improved subgrade layer;
- percentage of lime, by-product lime, or cement required;
- required depth of undercut and granular backfill; and/or
- moisture-density levels required to achieve the needed stability.

Base the decision for selecting the subgrade treatment on factors that include material availability, constructibility, economics, permanence of treatment, and pavement performance benefits. Select the alternative for the improved subgrade layer that is best suited for the project.

7. Embankment Settlement. Underlying soils can settle under the weight of a newly constructed embankment resulting in differential settlement and/or embankment failures. The settlements are expensive to fix and can result in pavement dips. For all classes of roads and streets, construction should be sequenced to assure that earthwork is completed during one construction season and that paving is initiated the next. If this cannot be accomplished with some degree of certainty, include special provisions in the contract that will assure adequate embankment settlement prior to subsequent pavement layers being placed. Consult the district geotechnical engineer for guidance in preparing such special provisions.

54-2.02 Structural Design

To select the proper type and thickness of mainline pavement for a particular project, first determine the following:

- the volume and composition of traffic to be carried by the pavement,
- the length of time the pavement is to service this traffic,
- the strength characteristics of the subgrade soils and pavement materials, and
- the minimum quality of service to be provided by the pavement during its lifetime.

See Section 54-1.06 for information on pavement designs for interchange ramps. Pavement designs for rest areas and weigh stations are discussed in Sections 54-1.07 and 54-1.08, respectively.

54-2.03 Limitations and Requirements

54-2.03(a) General

The procedures that are presented in this chapter will allow the designer to select an economically optimal pavement design that is most capable of carrying the anticipated traffic. To ensure that the selected design is both practical and adequate, the following sections present policy limitations and requirements that must be considered.

54-2.03(b) Adherence to Specifications

The design procedures that are presented in this Chapter are based on the assumption that material requirements, mixture designs, and construction procedures and controls will be in accordance with current IDOT specifications and practices. To ensure satisfactory performance, the strengths of structural components that are assumed during design must be achieved during construction. These strengths should be shown on the cover sheet or typical cross sections of the plans, along with the structural design traffic, the percentage breakdown of the structural design traffic for PV, SU, and MU vehicles, the percentage of these vehicles in the design lane, and the SSR or IBR valuations of the roadbed soils. See Section 63-4.05 for additional information on placing structural design traffic on plans.

54-2.03(c) Structural Design Traffic

The equations used to convert structural design traffic into 18-kip equivalent single-axle load applications are based on an average distribution of vehicle types and axle loadings and are directly applicable to most roads and streets. However, cases will arise in which these equations should not be used, and a special analysis will be necessary. One such case would be that involving a highway adjacent to an industrial site where the commercial vehicles entering and leaving the site generally travel empty in one direction and fully loaded in the other. Contact the Bureau of Materials and Physical Research for assistance. It will be necessary for the district to furnish the structural design traffic and weight and classification count data in sufficient detail to permit a determination of the distribution of commercial vehicle types and the single-axle and tandem-axle loadings within each type. See Section 54-2.01(e) for additional information on designing for heavily loaded vehicles.

54-2.03(d) Terminal Service Level

At the end of the design period, the serviceability level of the pavement can be expected to have been reduced to a value of 2.5 for Class I roads and streets and to 2.0 for Class II, Class III, and Class IV roads and streets, and the pavement should be considered eligible for rehabilitation. The design period may or may not be the actual service life of the pavement. The actual service life may be longer or shorter than the design period depending upon the conditions under which the pavement actually serves and the conditions assumed for the design. Highly significant are the differences between the structural design traffic and the actual traffic carried by the pavement, and the difference between the design terminal serviceability level and the actual serviceability level at which the pavement is structurally upgraded.

54-3 BASIC DESIGN PARAMETERS (Modified AASHTO)

54-3.01 Development of Design Procedures

54-3.01(a) General

See Section 54-1.03(b) for a brief description of the modified AASHTO design procedures.

54-3.01(b) Design Period

Section 54-2.01(b) applies to the modified AASHTO design procedures.

54-3.01(c) Structural Design Traffic

Section 54-2.01(c) applies to the modified AASHTO design procedures except for the requirement of calculating a minimum traffic factor based on minimum structural design traffic.

54-3.01(d) Mixed-Traffic Axle Loadings

Section 54-2.01(d) applies to the modified AASHTO design procedures.

54-3.01(e) Heavily Loaded Vehicles

Section 54-2.01(e) applies to the modified AASHTO design procedures.

54-3.01(f) Roadbed Soils

Section 54-2.01(f) does not apply to the modified AASHTO design procedures. The following material specifically relates to the modified AASHTO design methodology.

An A-6 (9-13) type of roadbed soil was used throughout the entire embankment of the AASHTO Road Test Project. Because only one soil type was taken into consideration in the AASHTO Road Test, it was necessary to modify the AASHTO Road Test equations so that pavement thicknesses could be developed for other soil types. The modification makes use of the Illinois Bearing Ratio (IBR) of the soil, which is the only soil support value normally determined by the Department for modified AASHTO designs. Other soil strength test procedures can be used provided that the test results can be directly correlated with those obtained by the IBR test procedure.

The IBR selected for use in design should represent a minimum value for the soil to be used. Preferably, laboratory tests should be made on four-day soaked samples of the soils to be used

in construction. It is recommended that a soil survey be made prior to all construction; however, when test data are not available, use the values presented in Figure 54-3A.

Soil Classification	IBR
A-1	20
A-2-4, A-2-5	15
A-2-6, A-2-7	12
A-3	10
A-4, A-5, A-6	3
A-7-5, A-7-6	2

SUGGESTED IBR VALUES FOR VARIOUS SOIL CLASSIFICATIONS
Figure 54-3A

Pavement performance is directly related to the physical properties and the support capacity of the materials used in the pavement structure and of the roadbed soils. The effect of less satisfactory soils, to some degree, can be reduced by increasing the thickness of the pavement structure, but it may be necessary to take other steps to ensure adequate pavement performance. The problems that can be encountered because roadbed soils are subject to permanent deformation, excessive volume changes, excessive deflection and rebound, frost susceptibility, and non-uniform support from wide variations in soil types within the State should be recognized in the design stage. Corrective measures should be included in the plans and in the special provisions for any and all small isolated areas of unsatisfactory soils. If such areas contain soils that are unsatisfactory for roadbed construction, the soils should be either removed and replaced with satisfactory soils or granular material or improved in place with a suitable stabilizing agent. If such soils are unsatisfactory only from the standpoint of having an IBR less than the minimum selected for design, consider the following treatments:

- remove and replace with soils or granular material at or above the minimum value,
- remove and replace with additional subbase material to a depth that will compensate for the deficiency in support strength, or
- improve the material in-place with a suitable stabilizing agent.

See the Bureau of Materials and Physical Research *Subgrade Stability Manual* for further guidance.

54-3.02 Structural Design

Section 54-2.02 applies to the modified AASHTO design procedures.

54-3.03 Limitations and Requirements

54-3.03(a) General

Section 54-2.03(a) applies to the modified AASHTO design procedures.

54-3.03(b) Adherence to Specifications

Section 54-2.03(b) applies to the modified AASHTO design procedures.

54-3.03(c) Structural Design Traffic

Section 54-2.03(c) applies to the modified AASHTO design procedures.

54-3.03(d) Terminal Service Life

Section 54-2.03(d) applies to the modified AASHTO design procedures.

54-4 STRUCTURAL DESIGN OF RIGID PAVEMENTS

54-4.01 Mechanistic

54-4.01(a) Limitations

Thickness designs may be obtained for thicknesses ranging from 6 in to 12 in and for traffic factors up to approximately 60. For traffic factors above 35, CRCP may be used, see Section 54-4.02 for design procedures. The use of doweled joints will be required for pavement thicknesses that are 7 in and greater. Recommended dowel diameters are given in Figure 54-4A. If designs for traffic factors greater than 60 or for pavement thicknesses greater than 12 in are desired, contact the BDE.

Pavement Thickness (T) (inches)	Nominal Dowel Diameter (inches)
≥ 8	1.5
$7 \leq T < 8$	1.25
< 7	1

RECOMMENDED DOWEL DIAMETERS
Figure 54-4A

54-4.01(b) Application of Design Method

The mechanistic design procedures for rigid pavements enable the designer to determine the type and thickness of PCC pavement that are required to carry a specified volume and composition of traffic for a designated period of time while retaining minimum serviceability. Use the procedures presented in Section 54-4.01(j) to determine pavement type and thickness and provide a subbase in accordance with Section 54-4.01(h).

54-4.01(c) Edge Support Conditions

The mechanistic design methodology gives the designer the option of selecting from the following two edge support conditions:

1. Tied Shoulder. The tied shoulder condition consists of a 12 ft paved lane that is tied with reinforcing steel to a PCC shoulder or curb and gutter.

2. Untied Shoulder. Any 12 ft pavement which is not positively tied with reinforcing steel to the shoulder or curb and gutter is considered an untied shoulder condition. An untied shoulder may consist of earth, aggregate or bituminous stabilized materials.

The selection of edge support has a pronounced effect on edge stresses and pavement thickness. Department policy dictates exclusive use of tied shoulders, unless otherwise approved by the BDE.

54-4.01(d) Joint Spacing Limitations

Joint spacing between panels may need to vary to accommodate adjacent pavements, drainage structures, etc. See the *Highway Standards* for typical designs. The mechanistic design procedures may be used to design pavement thickness for panel lengths of 12 ft to 18 ft with a nominal length of 15 ft. If designs for longer panel sections are required to match existing pavements, contact the BDE.

54-4.01(e) Design Period

The design period for all rigid pavements usually will be 20 years.

54-4.01(f) Equivalency Factors

Section 54-2.01(d) describes the use of equivalency factors to convert mixed-traffic loadings to 18-kip ESAL applications. Equivalency factors for rigid pavements are presented in Figure 54-4B. The factors in Figure 54-4B were used to develop the traffic factor equations discussed in Section 54-4.01(g).

54-4.01(g) Traffic Factor

The traffic factor is the projected total 18-kip equivalent single-axle load, expressed in millions, to be carried by the design lane during the design period. Based on the class of the facility, select the appropriate equation from Figure 54-4C to calculate the traffic factor for rigid pavement designs. See Section 54-2.01(c) for information on structural design traffic.

Facility Class	18-kip ESAL Applications Per Vehicle		
	PV	SU	MU
Class I	0.0004	0.394	1.908
Class II	0.0004	0.372	1.554
Class III	0.0004	0.355	1.541
Class IV	0.0004	0.350	1.523

EQUIVALENCY FACTORS
(Rigid Pavements)

Figure 54-4B

Facility Class	Traffic Factor Equation	Equation Number
Class I	$TF = DP\left[\frac{(0.15 \bullet P \bullet PV) + (143.81 \bullet S \bullet SU) + (696.42 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-4.1
Class II	$TF = DP\left[\frac{(0.15 \bullet P \bullet PV) + (135.78 \bullet S \bullet SU) + (567.21 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-4.2
Class III	$TF = DP\left[\frac{(0.15 \bullet P \bullet PV) + (129.58 \bullet S \bullet SU) + (562.47 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-4.3
Class IV	$TF = DP\left[\frac{(0.15 \bullet P \bullet PV) + (127.75 \bullet S \bullet SU) + (555.90 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-4.4

Where:

PV, SU, MU = structural design traffic expressed as the number of PV, SU, and MU vehicles.
P, S, M = percent of PV, SU, and MU in the design lane expressed as a decimal.
DP = design period — usually 20 years.

TRAFFIC FACTOR EQUATIONS
(Rigid Pavements)

Figure 54-4C

54-4.01(h) Subbase Type and Thickness

The subbase serves two purposes. Initially, it provides a stable working platform for construction of the rigid pavement. After construction is complete, the subbase improves pavement performance by minimizing pumping of fine-grained roadbed soils. Provide a 4 in stabilized subbase under all rigid pavements on Class I and Class II roads and streets and on all Class III and IV roads and streets having a traffic factor of 0.7 or greater. On Class III roads and streets (other than State primary highways) and Class IV roads and streets having a traffic factor of less than 0.7, the designer has the option of designing the pavement structure with or without a subbase. Exceptions to this policy are:

- Those streets having curb and gutter and storm sewers, for which the designer may omit the subbase.

- Those Class III or IV roads and streets where the existing roadbed soils have a quality equal to the standard subbase requirements.

A stabilized subbase will not be required for urban sections having curbs and gutters and storm sewer systems. However, at the designer's option, a granular subbase may be used to serve as a working platform where poor soil conditions exist. The thickness of the subbase will be determined by the designer.

54-4.01(i) Designating Structural Information on Plans

See Section 63-4.05 for information on designating structural information on plans.

54-4.01(j) Thickness Design Procedure

For a mechanistic design of a rigid pavement, use the following steps to determine thickness:

1. Determine Traffic Factor. Use the following procedures to determine the traffic factor:

    a. Determine the facility class (e.g., Class I, II, III, or IV).

    b. Determine the actual structural design traffic as described in Section 54-2.01(c).

    c. Determine the minimum structural design traffic as described in Section 54-2.01(c) and Figure 54-2C.

    d. Based on the facility class, select the appropriate traffic factor equation from Figure 54-4C.

    e. Calculate the actual traffic factor.

    f. Calculate the minimum traffic factor.

    g. Compare the actual traffic factor to the minimum traffic factor and use the greater of the two as the traffic factor for design.

2. Determine the Subgrade Support Rating. Determine the subgrade support rating as described in Section 54-2.01(f) (e.g., poor, fair, granular).

3. Determine the Edge Support. Determine the edge support condition to analyze as discussed in Section 54-4.01(c) (e.g., tied shoulder).

4. Determine the PCC Thickness. Use the following procedures to determine the PCC thickness:

a. Based on the subgrade support rating (e.g., poor, fair, granular) determined in Step 2, select the appropriate rigid pavement mechanistic design chart from the following:

- SSR = Poor; use Figure 54-4D
- SSR = Fair; use Figure 54-4E
- SSR = Granular; use Figure 54-4F

b. Within the design chart, select the curve that represents the edge support condition, either tied or untied.

c. Enter the chart along the horizontal axis with the traffic factor determined in Step 1.

d. Move up vertically until the curve selected in Step 4b is intersected.

e. From the point of intersection, move left horizontally until the vertical axis is intersected.

f. Read the thickness from the chart's vertical axis.

g. Round the thickness up to the nearest 0.25 in.

54-4.01(k) Shoulder Type/Design

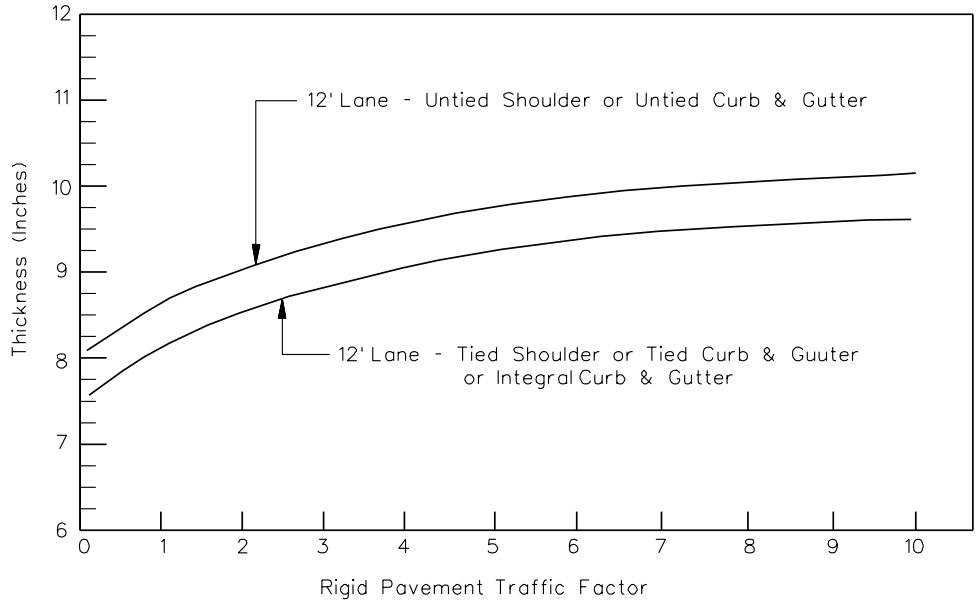
For newly constructed or reconstructed rural projects, use a tied rigid shoulder with all mechanistic rigid pavement designs. The thickness of the shoulder will vary uniformly from the pavement thickness to 6 in minimum at the outside edge.

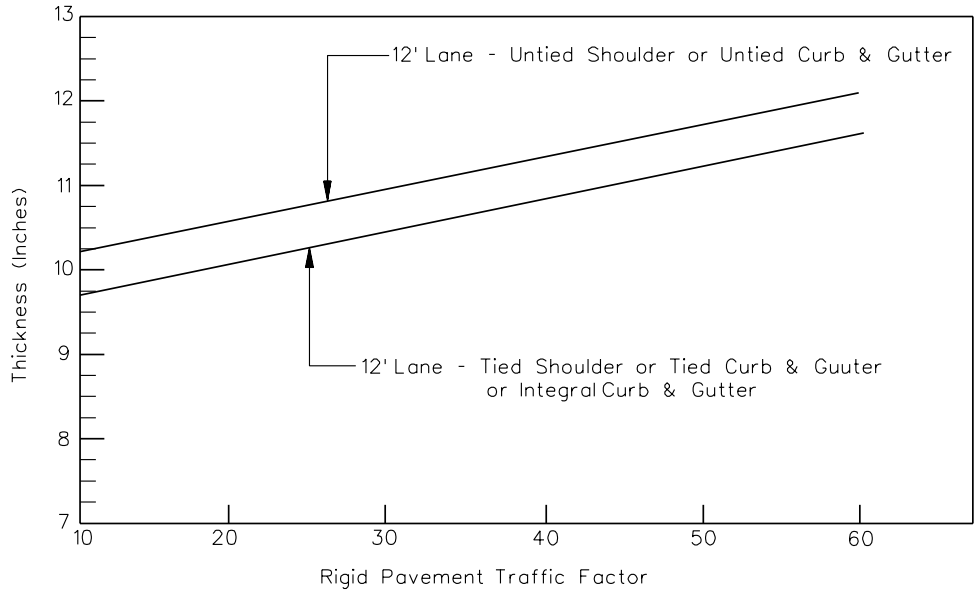
54-4.01(l) Design Example

See Section 54-9 for a design example.

54-4.01(m) Typical Sections

Figures 54-4G through 54-4I illustrate typical rural and urban pavement sections of rigid designs for various types of highway facilities.

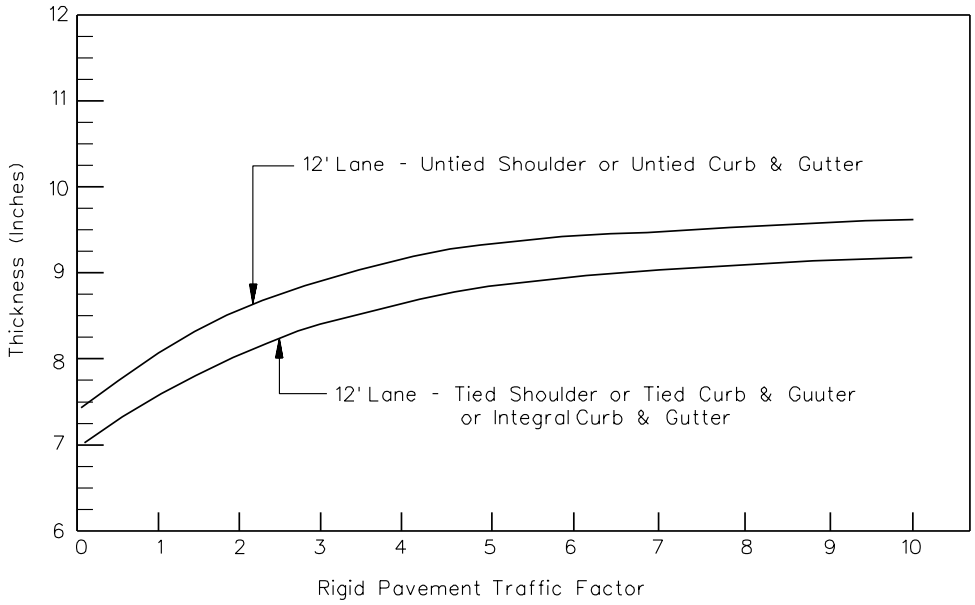


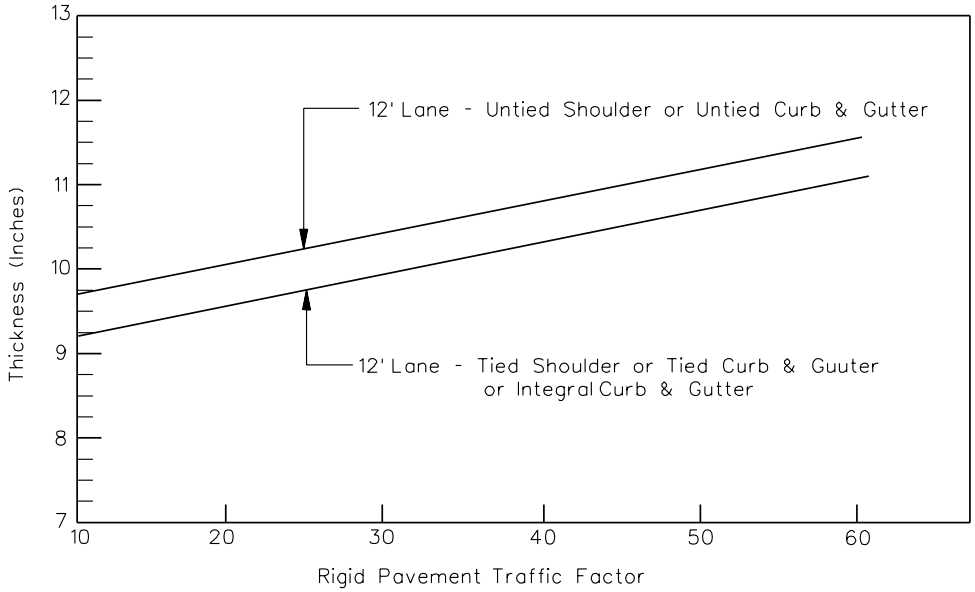


Note: Use of untied shoulder design requires BDE approval.

RIGID PAVEMENT DESIGN CHART
(Mechanistic Design: SSR = Poor)

Figure 54-4D

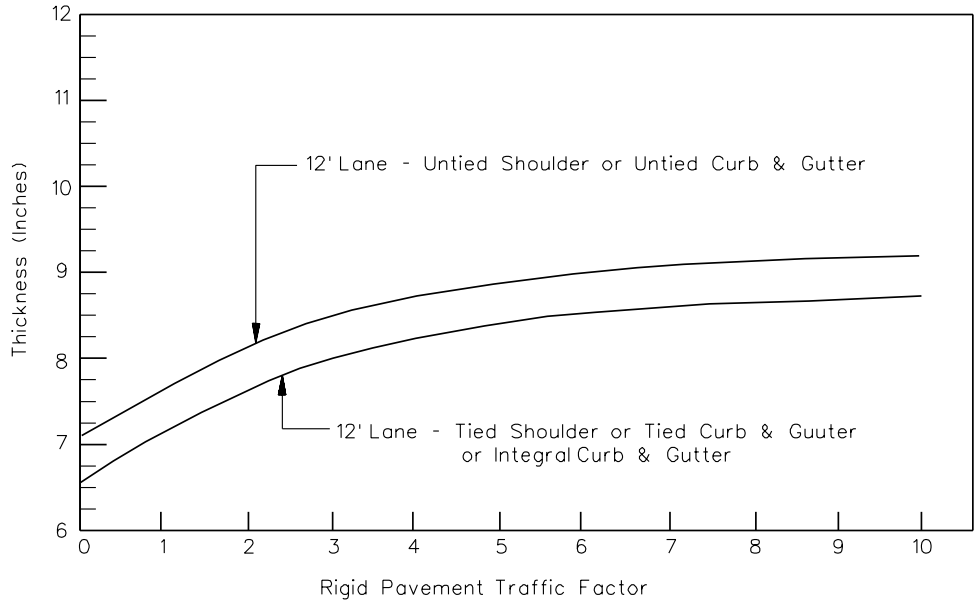


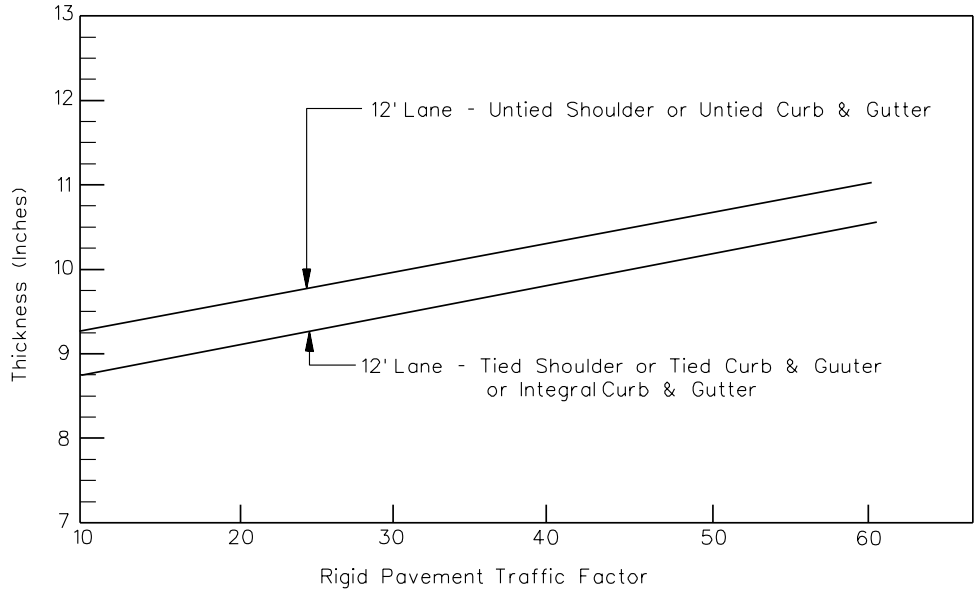


Note: Use of untied shoulder design requires BDE approval.

RIGID PAVEMENT DESIGN CHART
(Mechanistic Design: SSR = Fair)

Figure 54-4E

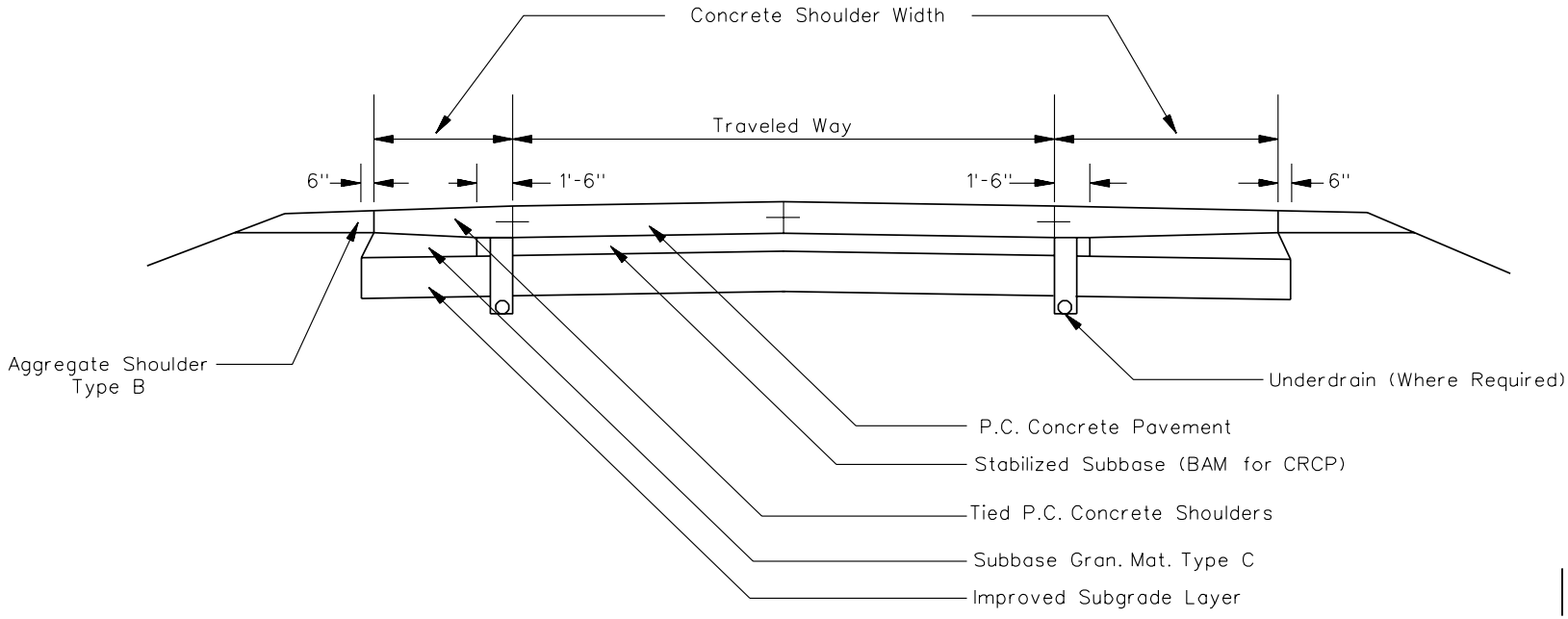




Note: Use of untied shoulder design requires BDE approval.

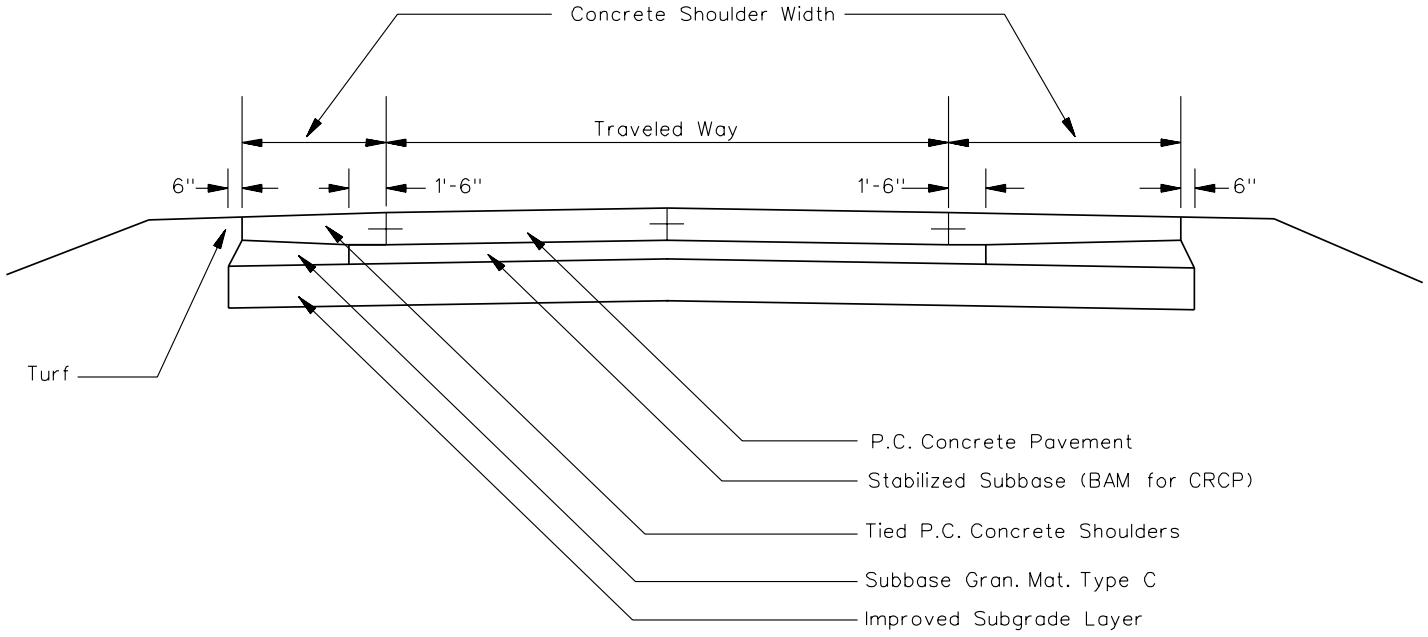
RIGID PAVEMENT DESIGN CHART
(Mechanistic Design: SSR = Granular)

Figure 54-4F



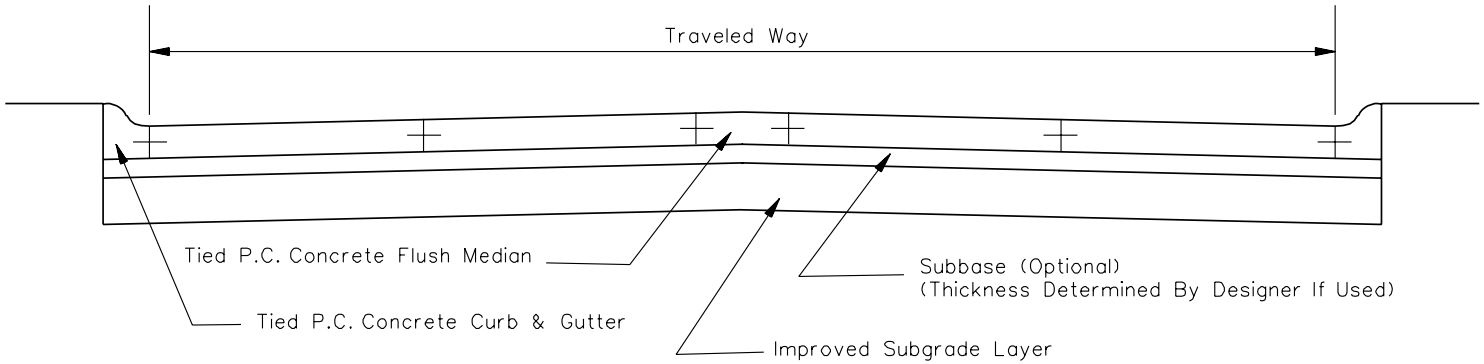
TYPICAL RURAL SECTION: RIGID DESIGN WITH TIED SHOULDER
(Trunk, Major Highways, Area Service Highways)

Figure 54-4G



TYPICAL RURAL SECTION: RIGID DESIGN WITH TIED SHOULDER
(Collectors, Land Access Highways)

Figure 54-4H



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

TYPICAL URBAN SECTION: RIGID DESIGN WITH TIED CURB AND GUTTER

Figure 54-4I

54-4.01(n) Joint Placement

The proper placement of pavement joints greatly affects the overall performance of the pavement. Where joints are not properly designed, uncontrolled cracking can occur. Features that can affect joint spacing are turn lanes, drainage blockouts, medians, intersecting side streets, etc. This is especially true at large intersections. It is imperative that the designer and the construction engineer pay particular attention to joint placement in these areas.

Designers should provide jointing details in the plans, and construction engineers should make every effort to follow the joint layout. In many cases, it will be necessary to adjust the normal 15 ft spacing used by IDOT to accommodate other features. Joints in the intersection may need to be placed at 11 ft or 12 ft centers to match the lane lines of the intersecting side street. In some cases, it also may be possible to adjust the location of drainage castings so that they are located at a normal joint position. The American Concrete Pavement Association has published a bulletin entitled *Intersection Joint Layout*. Although this bulletin should not be construed as an IDOT policy or standard, it does contain helpful information on jointing intersections and can serve as a design reference.

The designer and construction engineer also must be aware of planned staged construction and its effect on joint layout. Where adjacent lanes are to be constructed in stages, it is important to plan the layout of the joints before any pavement is placed. Occasionally, new pavement is constructed adjacent to existing pavement that was designed using a different joint type and spacing. When this occurs, the designer must make provisions in the plans to match existing joints. A detailed joint survey prior to plan preparation can help eliminate problems during construction and throughout the life of the pavement.

54-4.02 <u>Modified AASHTO</u>

54-4.02(a) Application of Design Method

The modified AASHTO design procedures for JRCP and CRCP rigid pavements enable the designer to determine the type and thickness of PCC pavements that are required where it is necessary to match existing bare PCC pavements which were constructed using these designs. Use the procedures presented in Section 54-4.02(e) to determine pavement type and thickness and provide a subbase in accordance with Section 54-4.02(f). For JRCP, the maximum joint spacing will be 50 ft. CRCP designs should not be used unless the traffic factor is greater than 35.

54-4.02(b) Design Period

Section 54-4.01(e) applies to modified AASHTO designs for rigid pavements.

54-4.02(c) Equivalency Factors

Section 54-4.01(f) applies to modified AASHTO designs for rigid pavements.

54-4.02(d) Traffic Factors

Section 54-4.01(g) applies to modified AASHTO designs for rigid pavements.

54-4.02(e) Pavement Type and Thickness

For a modified AASHTO design of a rigid pavement, use the following steps to determine thickness:

1. Determine Traffic Factor. Use the following procedures to determine the traffic factor:

    a. Determine the facility class (e.g., Class I, II, III, or IV).

    b. Determine the actual structural design traffic as described in Section 54-3.01(c). Note that the minimum traffic as described in Section 54-2.01(c) does not apply to the modified AASHTO design.

    c. Based on the facility class, select the appropriate traffic factor equation from Figure 54-4C.

    d. Calculate the actual traffic factor for design.

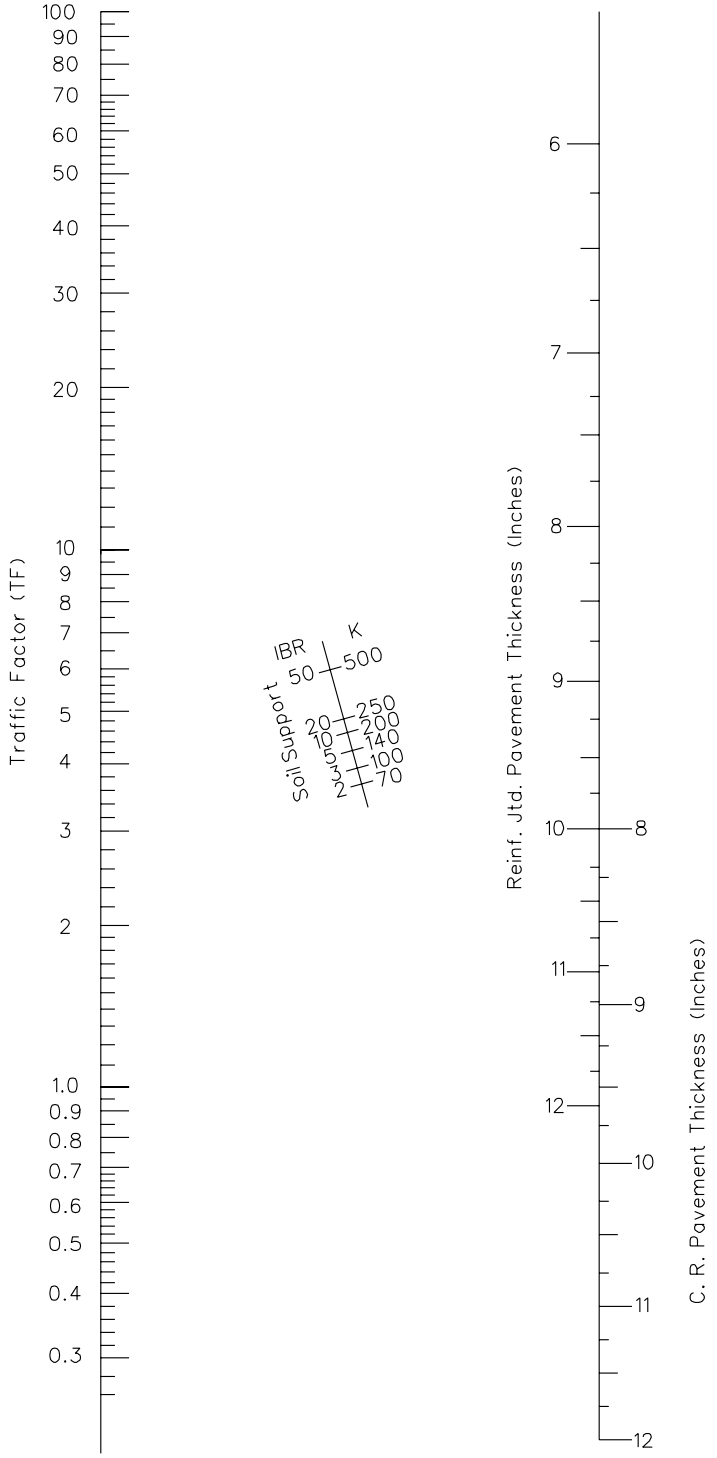
2. Determine the Illinois Bearing Ratio. Determine the Illinois Bearing Ratio as discussed in Section 54-3.01(f).

3. Determine the PCC Thickness. Use the following procedures to determine the PCC thickness:

    a. Based on the facility class determined in Step 1a, select the appropriate design nomograph from the following:

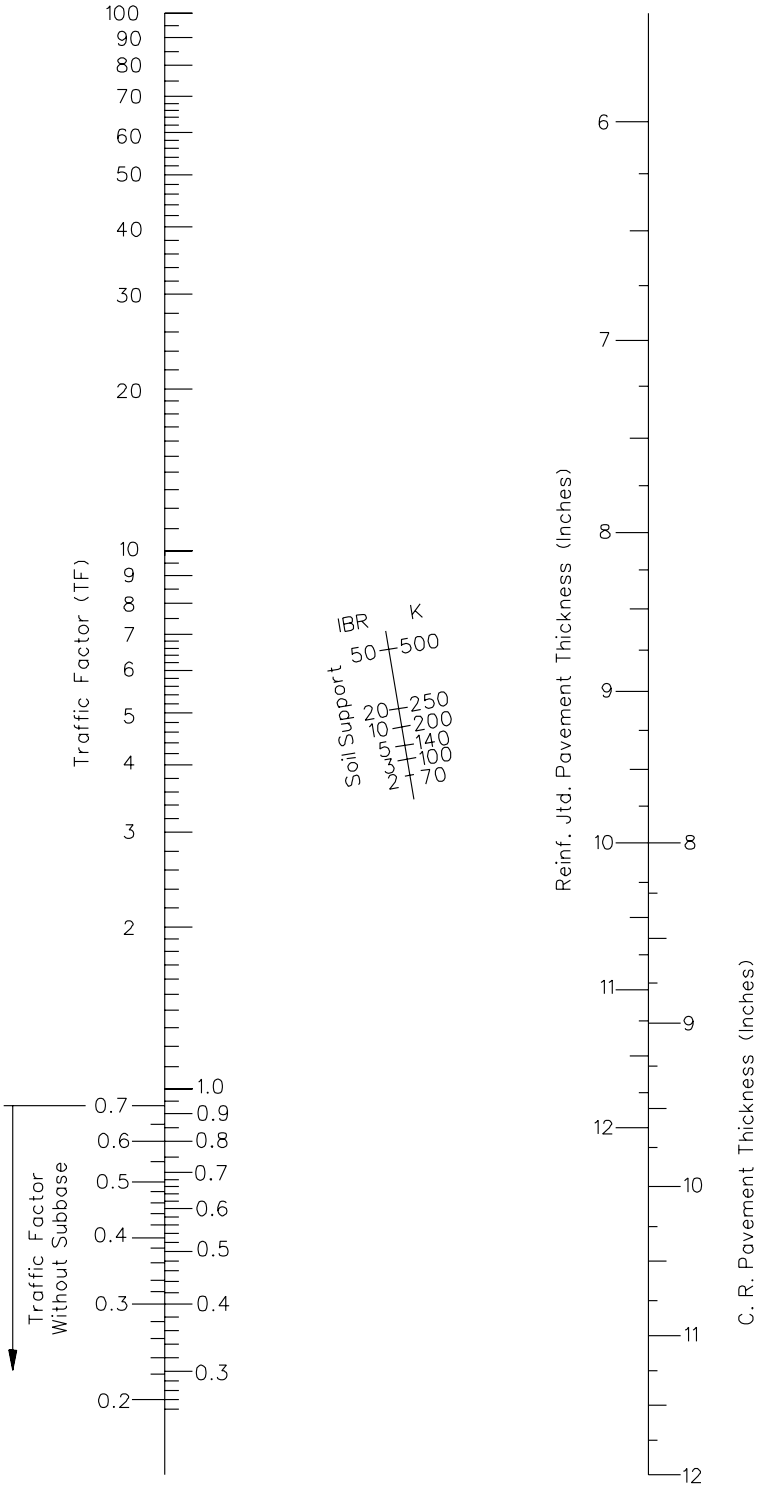
        - Class I Facilities: use Figure 54-4J
        - Class II, III, and IV Facilities: use Figure 54-4K

    b. Within the nomograph, project a line from the traffic factor determined in Step 1 through the IBR of the roadbed soil determined in Step 2 and intersect the pavement type and thickness axis of the nomograph.



RIGID PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class I Facilities: JRCP and CRCP)

Figure 54-4J



RIGID PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class II, III, and IV Facilities: JCRP and CRCP)

Figure 54-4K

c. Read the pavement type from the point of intersection on the nomograph (i.e., either JRCP or CRCP). Note that CRCP is used only if the traffic factor is greater than 35.

d. Read the PCC thickness from the point of intersection on the nomograph and round the thickness up to the nearest 0.25 in.

e. If design inputs produce values which exceed the chart's, the design's parameters should be forwarded to BDE for design.

54-4.02(f) Subbase Type and Thickness

Section 54-4.01(h) applies to modified AASHTO designs for rigid pavements, except the stabilized subbase shall be constructed of BAM for CRCP.

54-4.02(g) Minimum Structural Design Requirements

To ensure that practical and adequate designs are developed, the minimum structural design requirements presented in Figure 54-4L have been established. This minimum criteria will govern in all cases where the calculated pavement thickness is less than the desired minimum.

54-4.02(h) Designating Structural Information on Plans

See Section 63-4.05 for information on designating structural information on plans.

54-4.02(i) Joints and Concrete Lug End Anchorages

The following guidelines should be used when CRCP is placed between structures that are in close proximity to each other.

Where the slab length of CRCP between bridges or other pavement types is less than 1500 ft, use a doweled expansion joint. Where the slab length is between 1500 ft and 2000 ft, contact BDE. For sections of CRCP longer than 2000 ft, use a lug system. A wide flange beam terminal may be used in place of a lug system.

54-4.02(j) Design Example

See Section 54-9 for a design example.

Facility Type	PCC Pavement		Subbase⑤	
	Type①	Minimum②③ Thickness (inches)	Type	Minimum Thickness (inches)
Class I	JRCP④	10	Stabilized Granular Material	4
Class II	JRCP	8	Stabilized Granular Material	4
Class III State Primary All Others	JRCP	8 7	Stabilized Granular Material Granular Material⑥	4
Class IV	JRCP	6	Granular Material⑥	4

Notes:

① *JRCP should be used only to match existing pavement.*

② *For municipal streets having curb and gutter and storm sewer system, and for which maintenance responsibility is borne entirely by the Municipality, the minimum pavement thickness will be 6 in. In no case will the design thickness be less than that provided by Figures 54-4J and 54-4K.*

③ *Where the design thickness equals 6 in or 7 in, standard reinforcement may be omitted at the option of the designer provided sawed transverse contraction joints are spaced no greater than 20 ft apart.*

④ *A structurally equivalent CRCP may be used if the traffic factor is greater than 35. If CRCP is used, provide a BAM subbase.*

⑤ *A subbase will not be required for urban sections having curb and gutter and storm sewer system. However, at the designer's option, a granular subbase may be used to serve as a working platform where poor soil conditions exist. The thickness of the subbase will be determined by the designer.*

⑥ *Pavement for Class III facilities (other than State primary highways) and for Class IV facilities may be designed with or without a subbase, at the designer's option, provided that the traffic factor is less than or equal to 0.7.*

MINIMUM STRUCTURAL DESIGN REQUIREMENTS
(Rigid Pavement: Modified AASHTO Design)

Figure 54-4L

54-4.02(k) Typical Sections

See Section 54-4.01(m) for typical rural and urban pavement sections of rigid designs for various types of highway facilities, except that the improved subgrade layer is not required.

Because the modified AASHTO design procedure for flexible pavements allows for a variety of solutions, no typical sections are provided.

54-5 STRUCTURAL DESIGN OF FLEXIBLE PAVEMENTS

54-5.01 Mechanistic

54-5.01(a) Limitations

Thickness designs may be obtained for traffic factors from 0.5 minimum to approximately 50 and for pavement thicknesses ranging from 6 in to 21 in. Although the mechanistic design procedures will allow full-depth AC pavements to be designed 6 in thick, the absolute minimum 0.5 traffic factor will control the design thickness of flexible pavements at the lower limits. If designs for a traffic factor greater than 50 or for a pavement thickness greater than 21 in are desired, contact the BDE.

54-5.01(b) Minimum Material Quality

The mechanistic full-depth AC design procedures require, and are limited to, the use of Superpave surface and binder courses with 4 percent air voids. Superpave (4 percent voids, $N_{design} \geq 90$) mixtures will be specified for Interstate and supplemental freeways. Superpave (4 percent voids, $N_{design} \leq 70$) mixtures may be specified for all other highway classifications. Any combination of surface course and binder course may be used to total the design AC thickness. However, for the purpose of providing the most economical design, a surface course thickness of 2 in should be used for new construction (see Section 54-5.01(h)). If there is any question as to the use of any Superpave mixture in the procedure, contact the Bureau of Materials and Physical Research. Superpave mixture design criteria must be met as outlined in Section 53-4.08.

54-5.01(c) Asphalt Cement Selection

The mechanistic design procedures give the designer the option of selecting an appropriate asphalt cement type within the limits of current IDOT policy. The designer should be aware that in northern Illinois the use of a softer asphalt cement will reduce the effects of thermal cracking. On lower volume roads, a softer asphalt cement may be desired to reduce weathering and raveling and improve durability. On high volume roads and in areas of slower moving or standing loads, a stiffer asphalt cement should be used. In some cases, it may be desirable to use one asphalt cement grade for the binder course and another asphalt cement grade for the surface course. Where more than one asphalt cement grade is used, the design thickness for the binder asphalt cement grade will be used. Information on design asphalt cement grade selection is provided in Section 53-4.02(c). The design asphalt cement grade will be provided by the district and will be noted on the plans.

Project location and traffic volume are the main factors affecting the performance of AC pavements. Consult with the district materials engineer to determine the proper asphalt cement grade.

54-5.01(d) Application of Design Method

The mechanistic design procedures enable the designer to determine the material types and thicknesses for the various layers of a flexible pavement which are required to carry a specified volume and composition of traffic for a designated period of time while retaining a serviceability level at or above a selected minimum value. Use the procedures presented in Section 54-5.01(h) to determine the thickness design for full-depth AC pavement.

54-5.01(e) Design Period

The design period for all Class I and Class II roads and streets and for Class III State primary highways normally will be 20 years. Other Class III and all Class IV roads and streets may be designed for less than 20 years.

54-5.01(f) Equivalency Factors

Section 54-2.01(d) describes the use of equivalency factors to convert mixed-traffic loadings to 18-kip ESAL applications. Equivalency factors for flexible pavements are given in Figure 54-5A. These equivalency factors have been used to develop the equations presented in Section 54-5.01(g).

Facility Class	18-kip ESAL Applications Per Vehicle		
	PV	SU	MU
Class I	0.0004	0.363	1.322
Class II	0.0004	0.307	1.056
Class III	0.0004	0.299	1.053
Class IV (ADT > 400)	0.0004	0.299	1.053
Class IV (ADT ≤ 400)	0.0004	0.027	0.216

EQUIVALENCY FACTORS
(Flexible Pavements)

Figure 54-5A

54-5.01(g) Traffic Factor

The traffic factor is the projected total 18-kip equivalent single-axle load, expressed in millions, to be carried by the design lane during the design period. Figure 54-5B presents the traffic factor equations that should be used for flexible pavement designs.

Facility Class	Traffic Factor Equation	Equation Number
Class I	$TF=DP\left[\frac{(0.15 \bullet P \bullet PV)+(132.50 \bullet S \bullet SU)+(482.53 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-5.1
Class II	$TF=DP\left[\frac{(0.15 \bullet P \bullet PV)+(112.06 \bullet S \bullet SU)+(385.44 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-5.2
Class III and Class IV (ADT > 400)	$TF=DP\left[\frac{(0.15 \bullet P \bullet PV)+(109.14 \bullet S \bullet SU)+(384.35 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-5.3
Class IV (ADT ≤ 400)	$TF=DP\left[\frac{(0.15 \bullet P \bullet PV)+(9.86 \bullet S \bullet SU)+(78.84 \bullet M \bullet MU)}{1x10^6}\right]$	Equation 54-5.4

Where:
DP = design period in number of years.
PV, SU, MU = structural design traffic expressed as the number of PV, SU, and MU vehicles.
P, S, M = percent of PV, SU, and MU in the design lane expressed as a decimal.

TRAFFIC FACTOR EQUATIONS
(Flexible Pavements)
Figure 54-5B

54-5.01(h) Thickness Design Process for Full-Depth AC

For a mechanistic design of a flexible pavement, use the following steps to determine thickness:

1. Determine Traffic Factor. Use the following procedures to determine the traffic factor:

   a. Determine the facility class (e.g., Class I, II, III, or IV) and the design period (see Section 54-5.01(e)).

   b. Determine the actual structural design traffic as described in Section 54-2.01(c).

   c. Determine the minimum structural design traffic as described in Section 54-2.01(c) and shown in Figure 54-2C.

   d. Based on the facility class, select the appropriate traffic factor equation from Figure 54-5B.

   e. Calculate the actual traffic factor.

   f. Calculate the minimum traffic factor.

g. Compare the actual traffic factor to the minimum traffic factor and select the greater of the two. Compare the resulting traffic factor to 0.5. If less than 0.5, use 0.5 as the absolute minimum traffic factor for design.

2. Determine the Subgrade Support Rating. Determine the subgrade support rating as described in Section 54-2.01(f) (e.g., poor, fair, granular).

3. Determine the Asphalt Cement Grade. Determine the asphalt cement grade as discussed in Section 54-5.01(c).

4. Determine the AC Mixture Temperature. Use the following steps to determine the AC mixture temperature:

   a. On Figure 54-5C, identify and mark the location where the pavement section will be constructed.

   b. Using the temperature contours on Figure 54-5C, interpolate the temperature to the nearest 0.1°F at the marked location, except that the minimum AC mixture temperature will be 76°F.

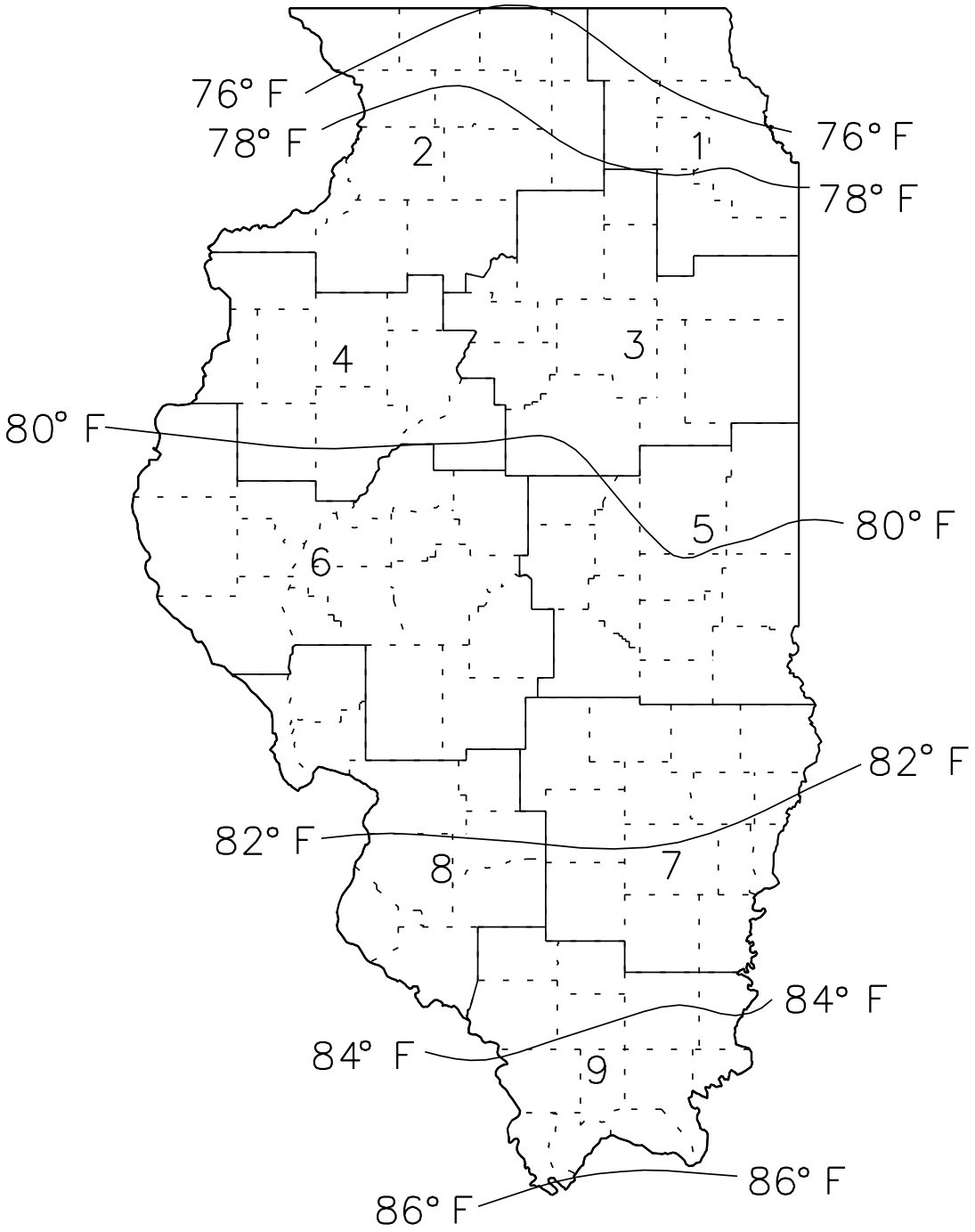
5. Determine AC Mixture Modulus (E_{AC}). Use the following procedures to determine the AC mixture modulus (E_{AC}) for pavement design:

   a. Along the horizontal axis of Figure 54-5D, locate the value of the AC mixture temperature determined in Step 4.

   b. Move up vertically and intersect the curve that represents the asphalt cement grade determined in Step 3.

   c. Move left horizontally from the point of intersection on the asphalt cement grade curve and intersect the vertical axis of the AC mixture modulus (E_{AC}).

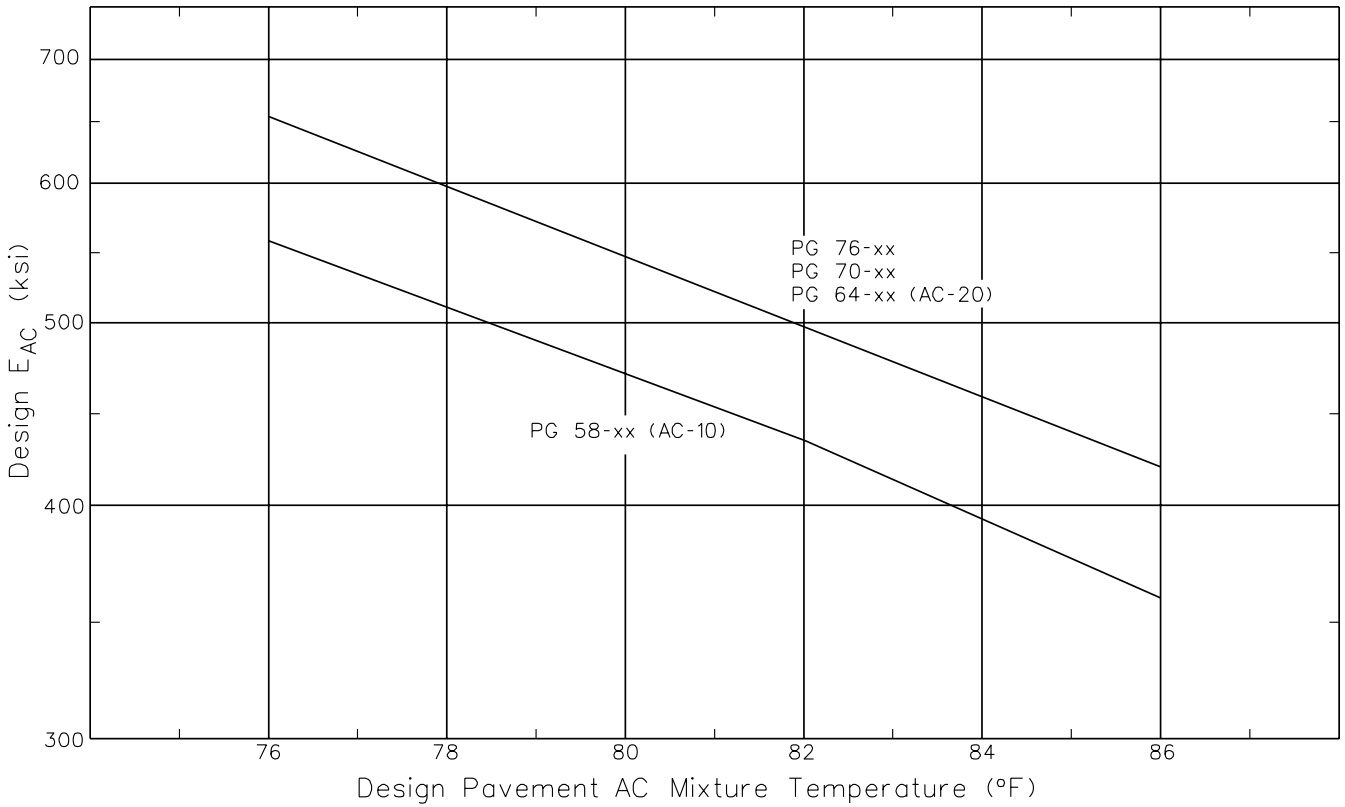
   d. At the point of intersection with the vertical axis, read the AC mixture modulus (E_{AC}) and round the value to the nearest 10 ksi. This will be the AC mixture modulus for use in the design of the flexible pavement thickness (see Figures 54-5F, 54-5G or 54-5H).



Note: The minimum design AC mixture temperature will be 76°F.

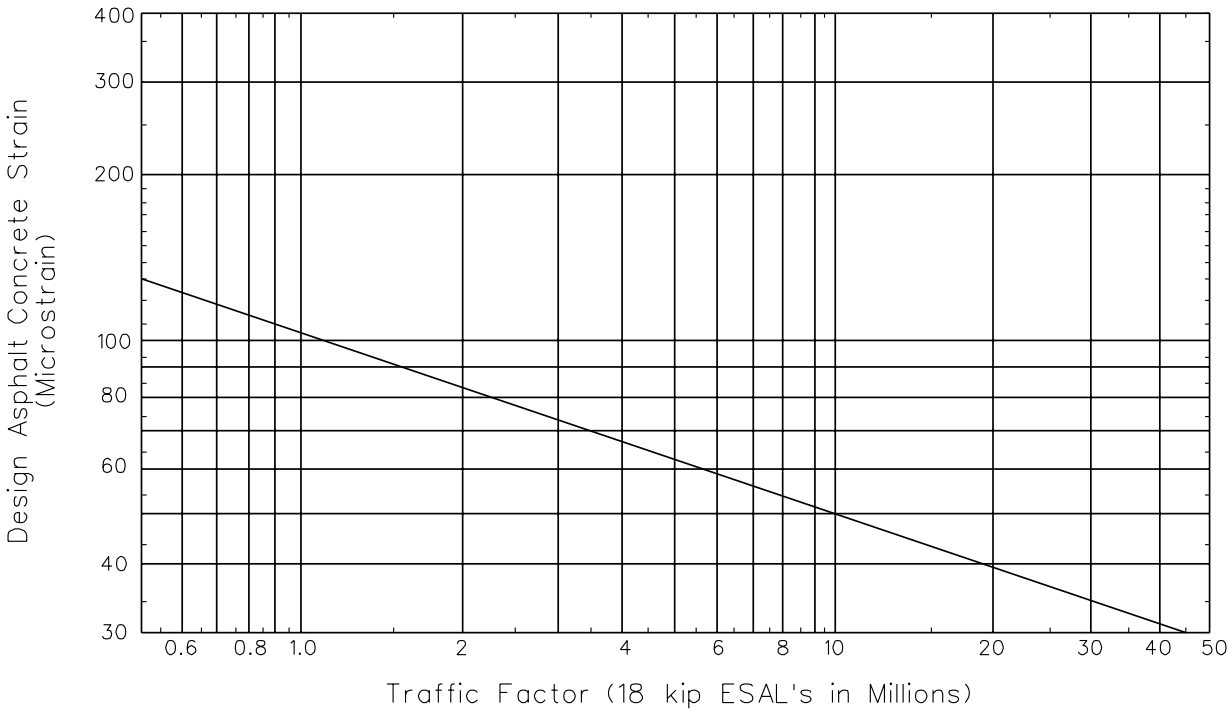
AC MIXTURE TEMPERATURE
(Mechanistic Design: Flexible Pavement)

Figure 54-5C



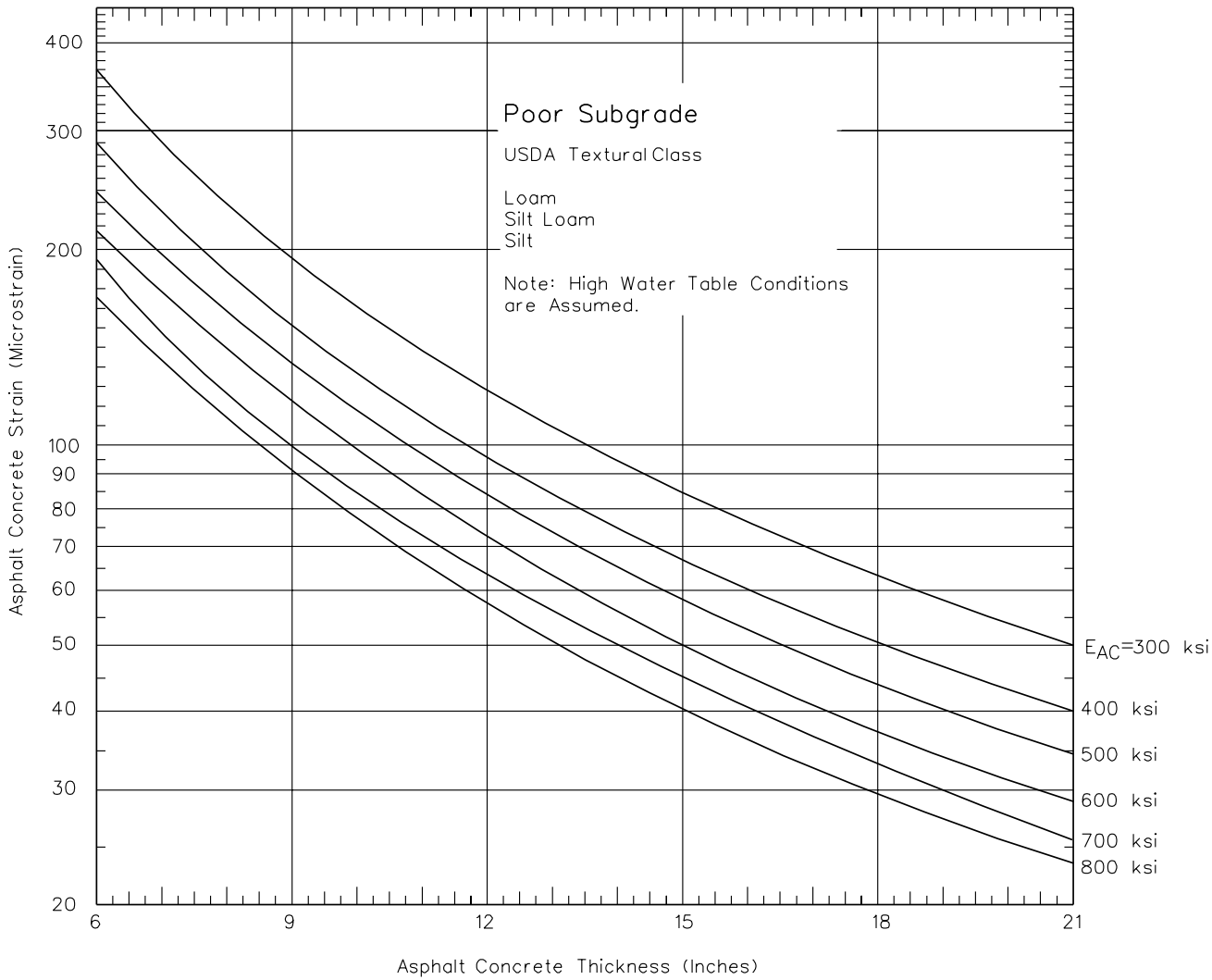
AC MIXTURE MODULUS (E_{AC})
(Mechanistic Design: Flexible Pavement

Figure 54-5D



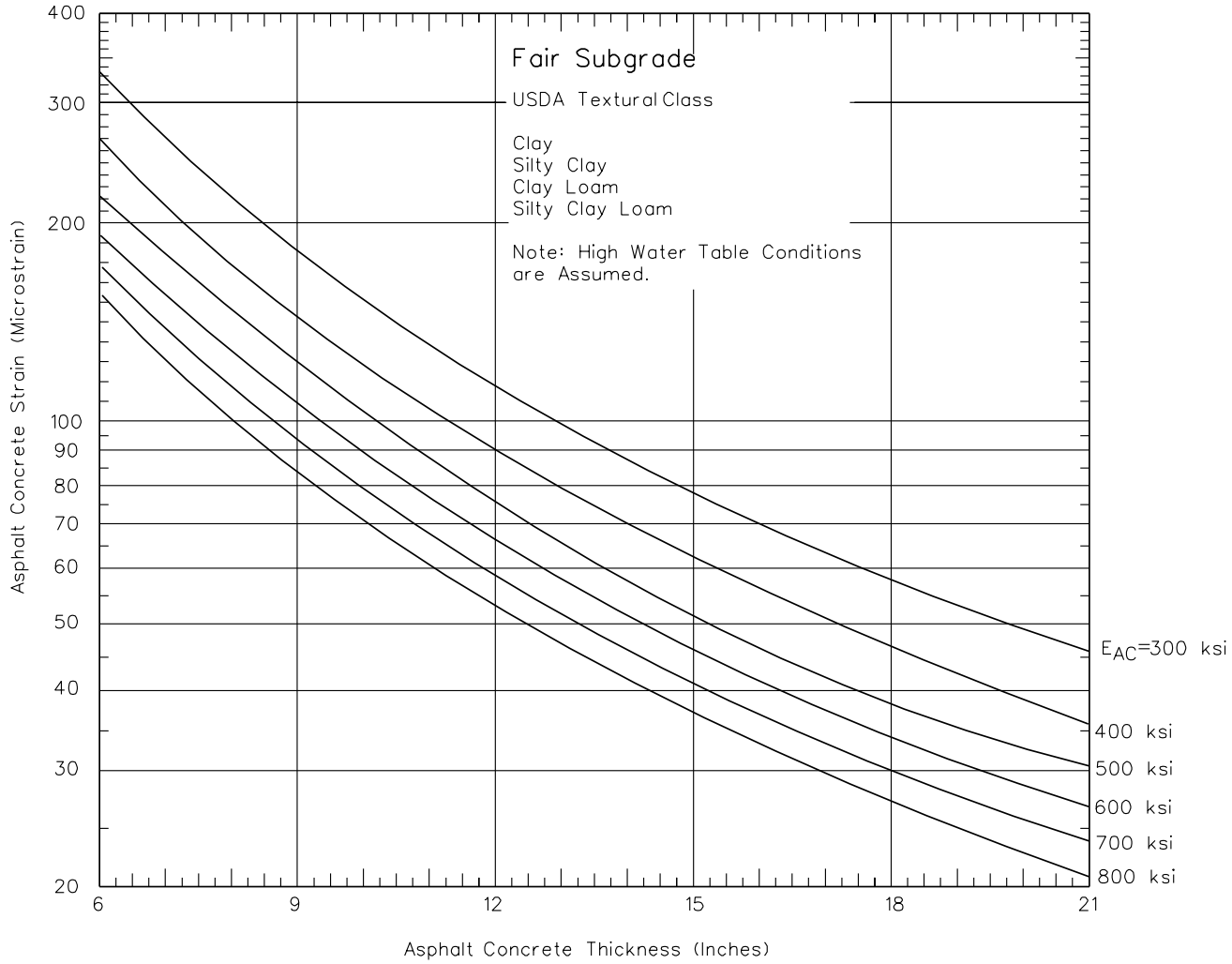
DESIGN AC STRAIN
(Mechanistic Design: Flexible Pavement)

Figure 54-5E



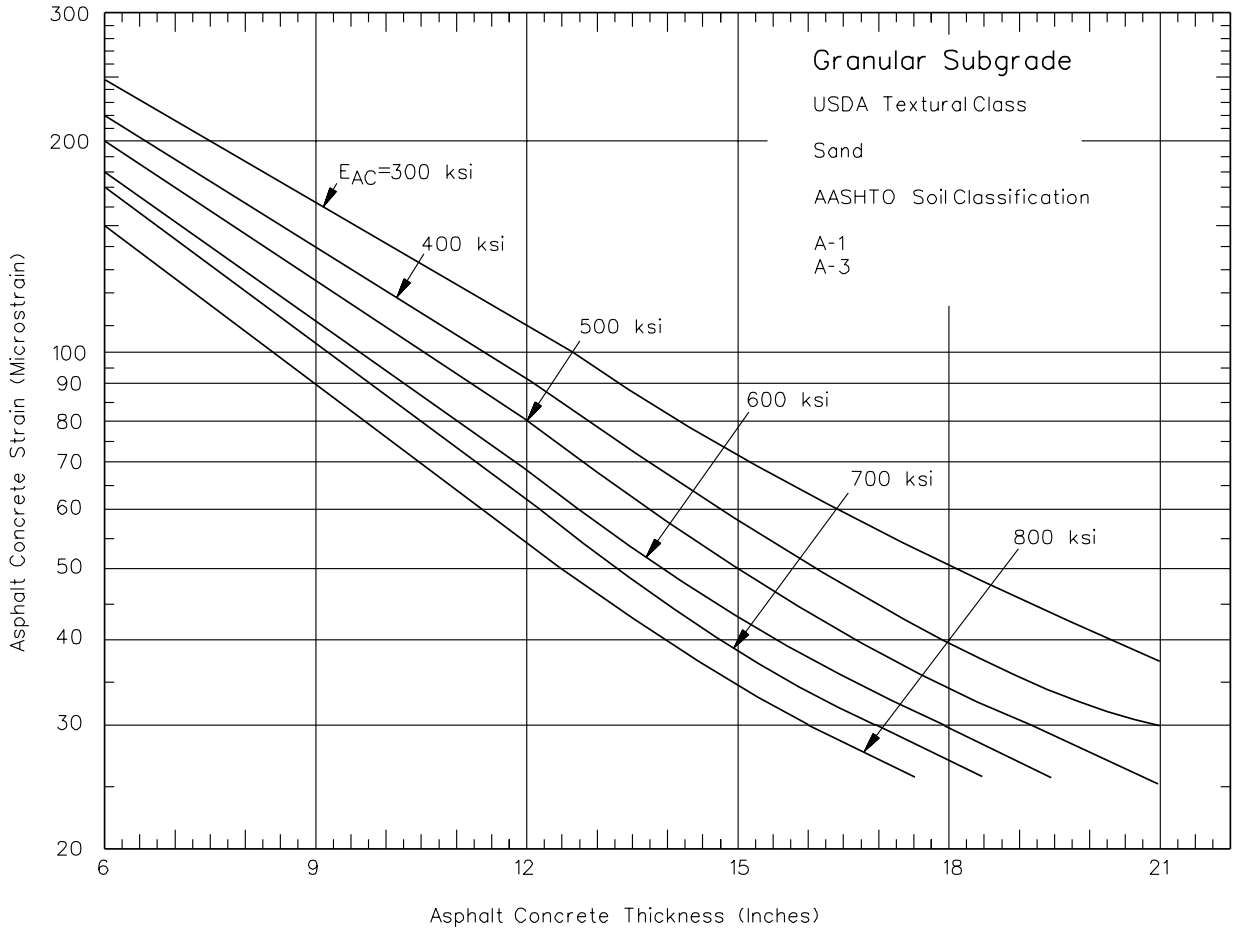
AC THICKNESS DESIGN CHART
(Mechanistic Design: Flexible Pavement: SSR = Poor)

Figure 54-5F



AC THICKNESS DESIGN CHART
(Mechanistic Design: Flexible Pavement: SSR = Fair)

Figure 54-5G



AC THICKNESS DESIGN CHART
(Mechanistic Design: Flexible Pavement: SSR = Granular)

Figure 54-5H

6. Determine Design AC Strain. Use the following procedures to determine the design AC strain:

   a. Along the horizontal axis of Figure 54-5E, locate the value of the traffic factor determined in Step 1.

   b. Move up vertically and intersect the curve.

   c. Move left horizontally from the point of intersection on the curve and intersect the vertical axis of the design AC strain (i.e., microstrain).

   d. At the point of intersection with the vertical axis, read the design AC strain and round the value to the nearest unit microstrain. This will be the AC strain to use in the design of the flexible pavement thickness (see Figures 54-5F, 54-5G or 54-5H).

7. Determine Pavement Thickness. Use the following procedure to determine the pavement thickness:

   a. Using the subgrade support rating determined in Step 2 (e.g., poor, fair, granular), select from Figures 54-5F, 54-5G, and 54-5H, the one chart that represents the subgrade support rating for use in design.

   b. On the chart selected in Step 7a, there will exist a set of six curves that represents AC mixture moduli (E_{AC}) from 300 ksi to 800 ksi. Using the value of E_{AC} that was determined in Step 5, interpolate and draw a parallel curve that will represent the AC mixture modulus for use in design.

   c. Along the left vertical axis of the selected chart, locate the value of the design AC strain determined in Step 6.

   d. Move right horizontally and intersect the design E_{AC} curve interpolated and drawn in Step 7b.

   e. Move down vertically and intersect the horizontal axis of the selected chart.

   f. Read the thickness from the point of intersection on the horizontal axis and round this value up to the nearest 0.25 in. This will be the total thickness for the pavement design.

   g. Use the following guidelines to determine the proper surface course thickness for full-depth pavements:

- New or reconstructed pavements where the pavement selection is based on life-cycle costs will have a surface course thickness of 2 in.

- Additional lanes, pavement widening, and short reconstruction segments where the pavement selection is based on first cost will have a surface course thickness equal to the surface course thickness of the resurfacing if the adjacent pavement is being resurfaced. Otherwise, the surface course will be 2 in.

8. Surface Friction Aggregate. See Section 53-4.08(e) for guidance on the selection of the appropriate surface friction aggregate.

54-5.01(i) Designating Structural Design Information on Plans

See Section 63-4.05 for information on designating structural design information on plans.

54-5.01(j) Shoulder Type/Design

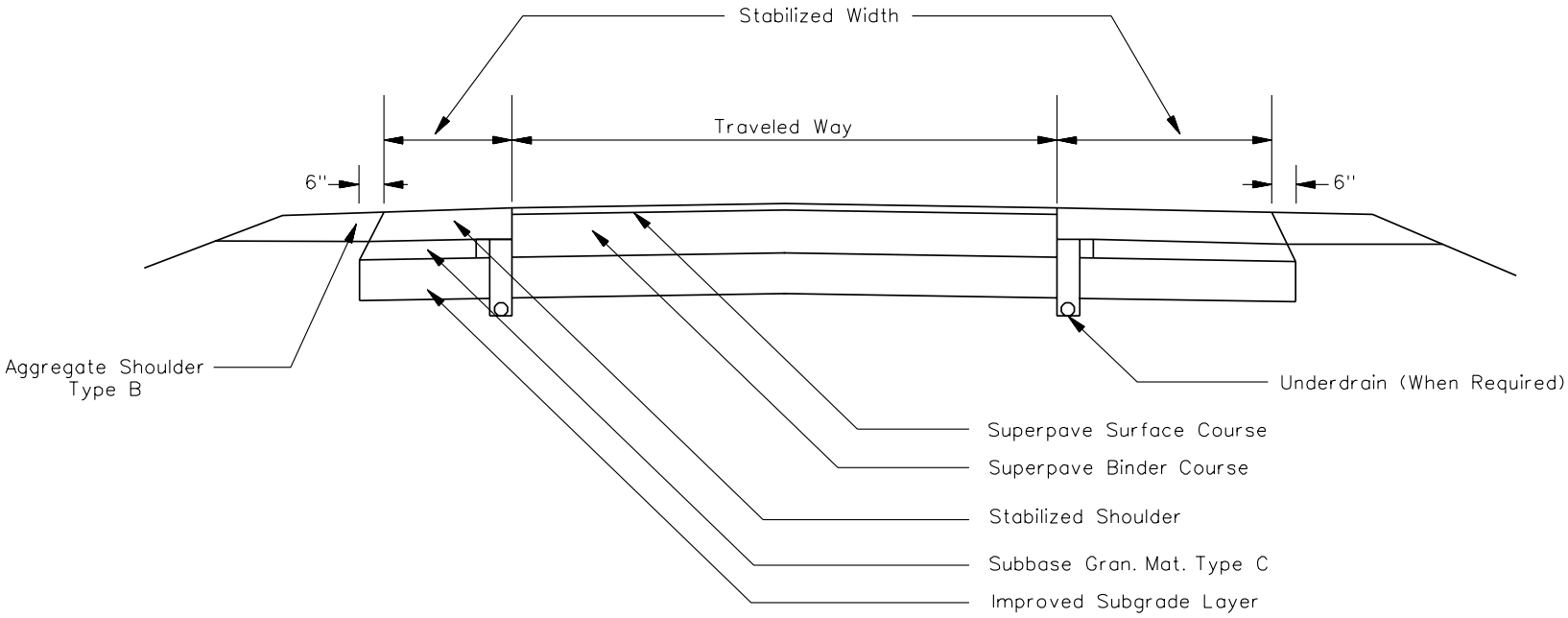
Use flexible shoulders with flexible pavement designs. The shoulder should be of constant thickness to a depth determined by the designer, but should not be less than 8 in. Give particular consideration to the need to provide a greater-than-minimum shoulder thickness along heavily traveled truck routes.

54-5.01(k) Design Example

See Section 54-9 for a design example.

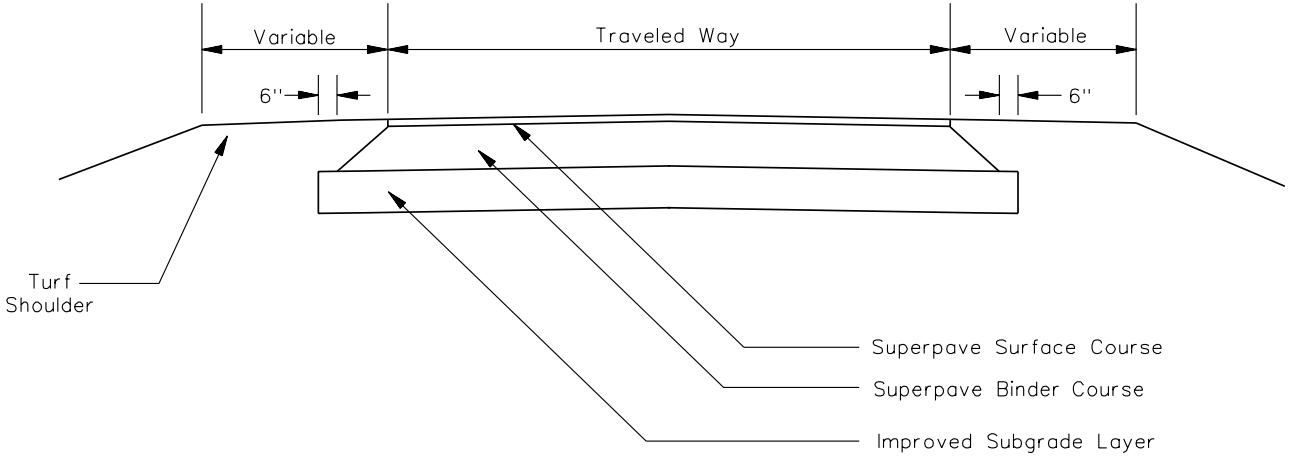
54-5.01(l) Typical Sections

Figures 54-5I through 54-5K illustrate typical rural and urban pavement sections of flexible designs for various types of highway facilities.



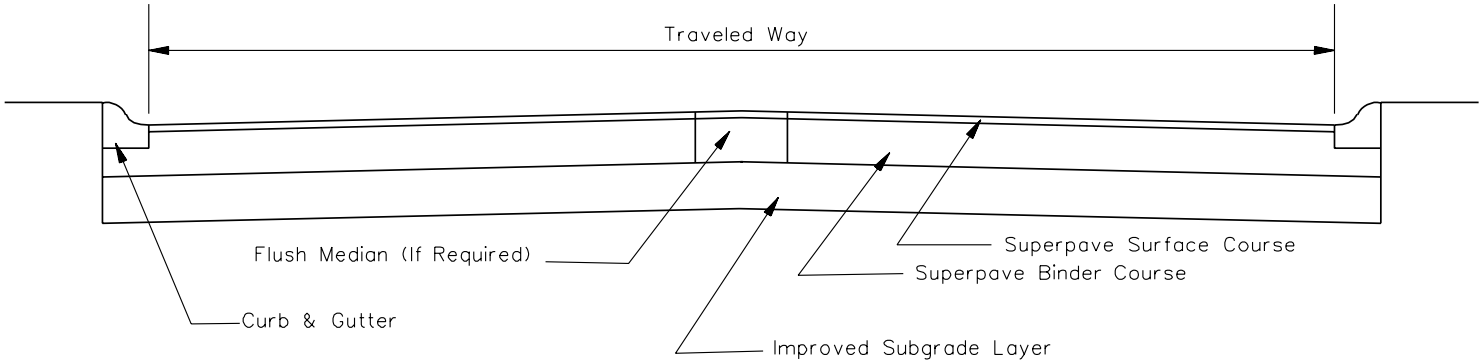
TYPICAL RURAL SECTION: FULL-DEPTH AC DESIGN
(Trunk, Major Highways, Area Service Highways)

Figure 54-5I



TYPICAL RURAL SECTION: FULL-DEPTH AC DESIGN
(Collectors, Land Access Highways)

Figure 54-5J



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

TYPICAL URBAN SECTION: FULL-DEPTH AC DESIGN

Figure 54-5K

54-5.02 Modified AASHTO

54-5.02(a) Application of Design Method

The modified AASHTO design procedures for flexible pavements enable the designer to determine the material types and thicknesses for the various layers of a flexible pavement which are required to carry a specified volume and composition of traffic for a designated period of time while retaining a serviceability level at or above a selected minimum value. Application of this design method involves the following steps:

1. Determine Traffic Factor. Use the following procedures to determine the traffic factor:

    a. Determine the facility class (e.g., Class I, II, III, or IV) and the design period (see Section 54-5.02(b)).

    b. Determine the actual structural design traffic as described in Section 54-3.01(c). Note that the minimum traffic as described in Section 54-2.01(c) does not apply to the modified AASHTO design.

    c. Based on the facility class, select the appropriate traffic factor equation from Figure 54-5B.

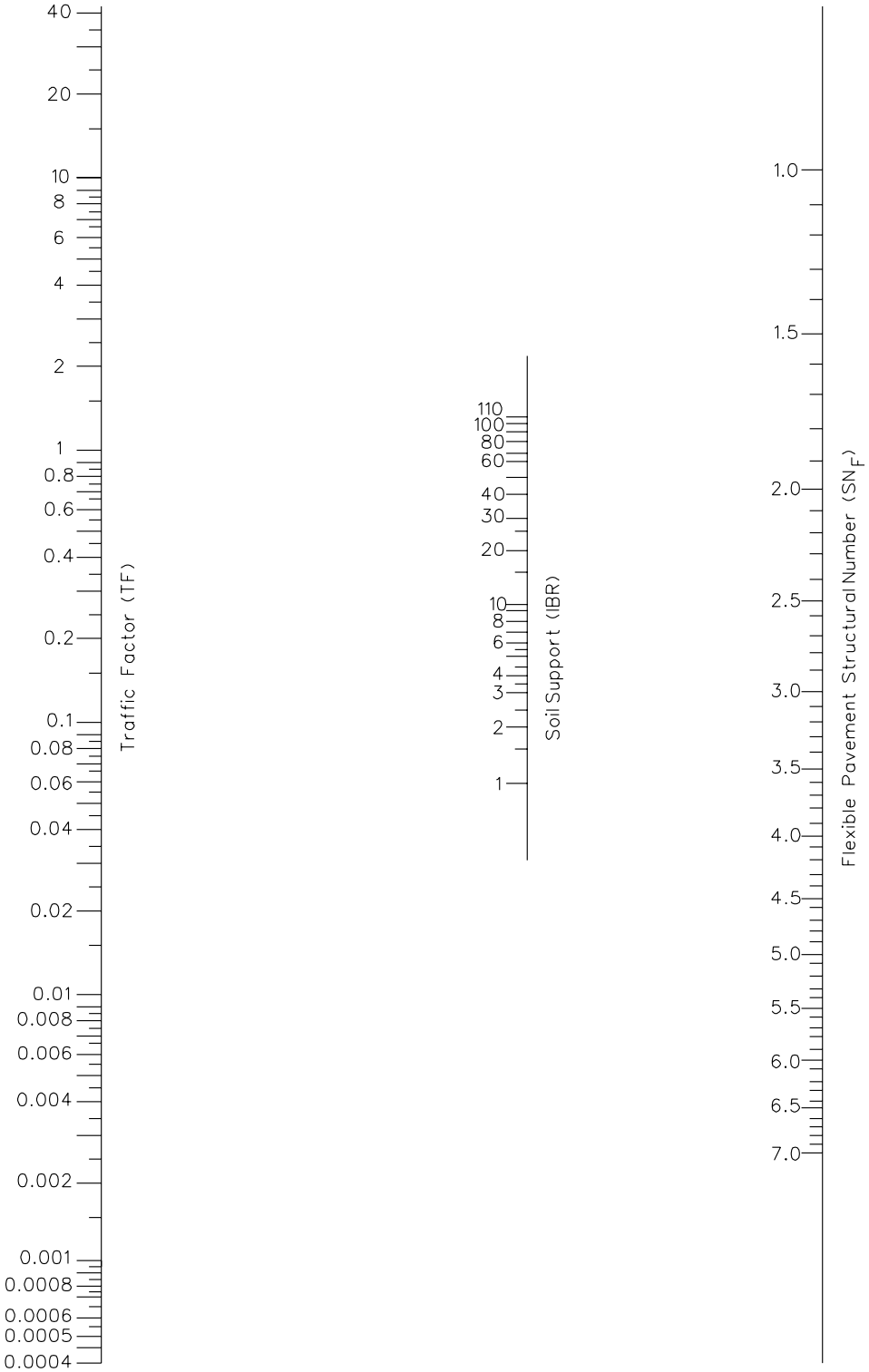
    d. Calculate the actual traffic factor for use in design.

2. Determine the Illinois Bearing Ratio. Determine the Illinois Bearing Ratio of the roadbed soil (see Section 54-3.01(f)).

3. Determine the Structural Number (SN_F). Determine the flexible pavement structural number (SN_F) using the appropriate design nomograph for the facility class (i.e., Figure 54-5L for Class I facilities or Figure 54-5M for Class II, III, and IV facilities). See Section 54-5.02(e). Check Figure 54-5R for the minimum thickness, minimum structural number, and material requirements. See Section 54-5.02(h).

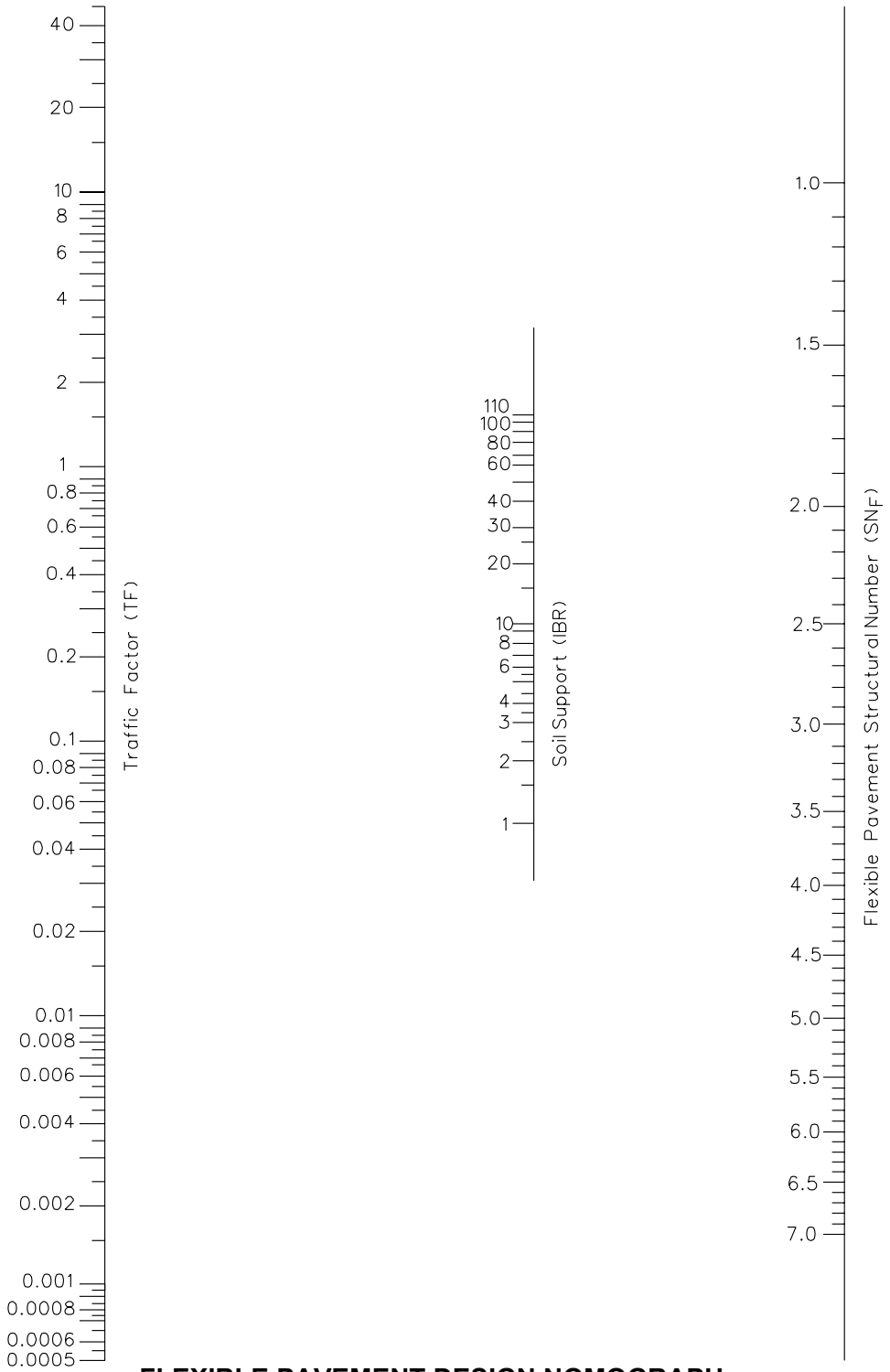
4. Determine Types and Thicknesses of Materials. Using Equation 54-5.5 in Section 54-5.02(f) and the appropriate strength coefficients obtained from Figure 54-5N, select the types and thicknesses of materials which will satisfy the structural number at minimum cost. See Section 54-5.02(g). The various layers will be rounded up to the nearest 0.25" increment of thickness.

5. Compare with Minimum Criteria. Compare the selected design with the minimum requirements presented in Figure 54-5R to ensure that the minimum design requirements have been met. See Section 54-5.02(h).



FLEXIBLE PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class I Facilities)

Figure 54-5L



FLEXIBLE PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class II, III, and IV Facilities)

Figure 54-5M

STRUCTURAL MATERIALS	MINIMUM STRENGTH REQUIREMENTS			COEFFICIENTS③		
	MS①	IBR	CS②	a_1	a_2	a_3
Bituminous Surface						
Road Mix (Class B)				0.20		
Plant Mix (Class B)						
Liquid Asphalt				0.22		
Asphalt Cement	900			0.30		
Superpave Bituminous Concrete (4% voids)				0.40		
Base Course						
Aggregate, Type B						
Uncrushed		50			0.10	
Crushed		80			0.13	
Aggregate, Type A		80			0.13	
Waterbound Macadam		110			0.14	
Bituminous Stabilized Granular Material	300				0.16	
	400				0.18	
	800				0.23	
	1000				0.25	
	1200				0.27	
	1500				0.30	
	1700				0.33	
Superpave Binder (4% voids)					0.33	
Pozzolanic, Type A			600		0.28	
Lime Stabilized Soil			150		0.11	
Select Soil Stabilized			300		0.15	
with Cement			500		0.20	
Cement Stabilized Granular Material			650		0.23	
			750		0.25	
			1000		0.28	
Subbase						
Granular Material, Type B		30				0.11
Granular Material, Type A						
Uncrushed		50				0.12
Crushed		80				0.14
Lime Stabilized Soil			100			0.12

Notes:

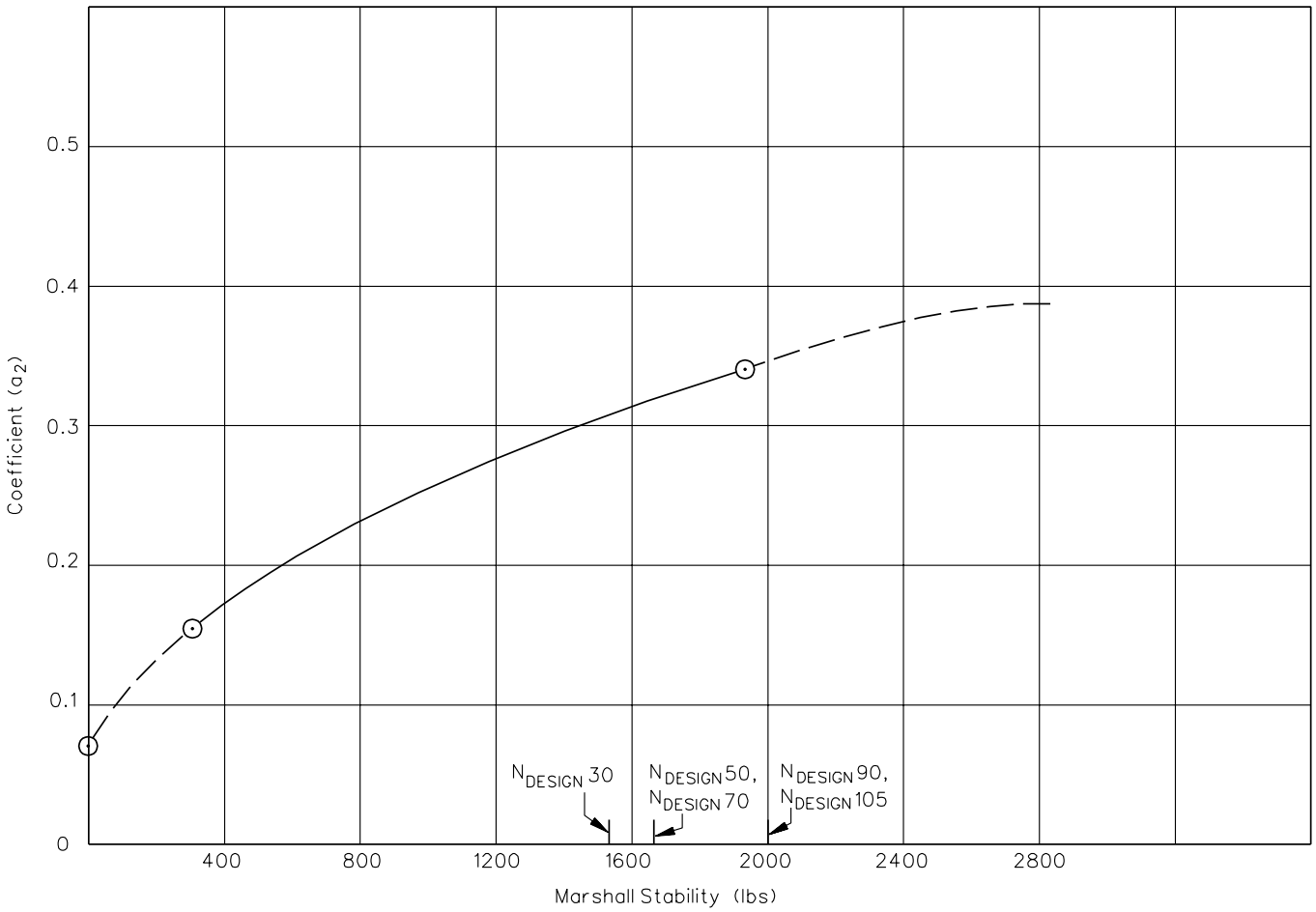
① *Marshall Stability (MS) index or equivalent.*

② *Compressive strength (CS) in pounds per square inch (psi). For cement stabilized soils and granular materials, use the 7 day compressive strength that can be reasonably expected under field conditions. For lime stabilized soils, use the accelerated curing compressive strength at 120°F for 48 hours. For Pozzolanic, Type A, use the compressive strength after a 14 day curing period at 72°F.*

③ *For materials with strengths other than those shown, the coefficients may be determined from Figures 54-5O, 54-5P, and 54-5Q. Other approved materials of similar strengths may be substituted for those presented in Figure 54-5N.*

COEFFICIENTS FOR MATERIALS IN NEW FLEXIBLE PAVEMENT STRUCTURES
(Modified AASHTO Design)

Figure 54-5N

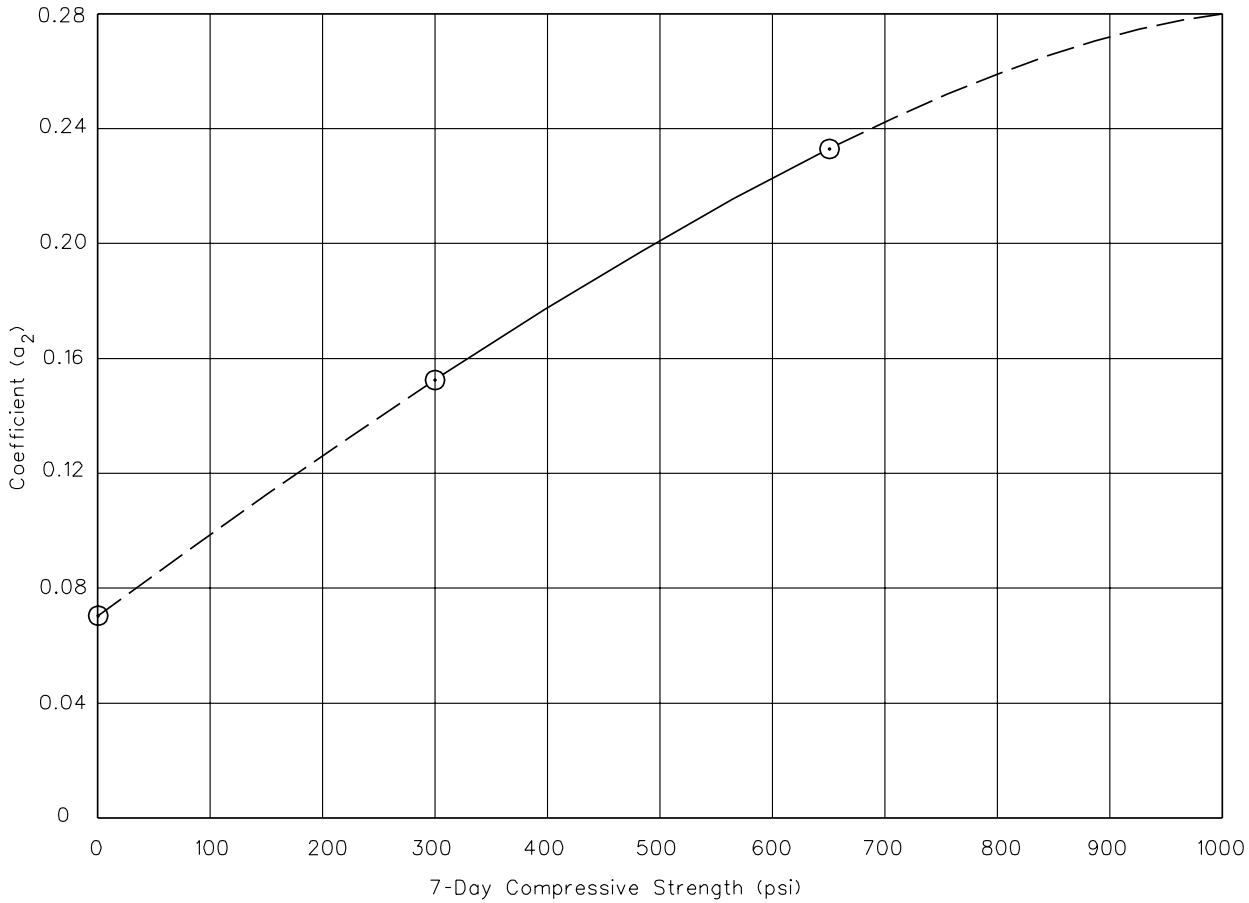


Note: The following Marshall stabilities can be assumed:

- *1500 lbs for Superpave N_{Design}30 mixes.*
- *1700 lbs for Superpave N_{Design}50 and N_{Design} 70 mixes; and*
- *2000 lbs for Superpave N_{Design} 90 and N_{Design} 105 mixes.*

COEFFICIENTS FOR BITUMINOUS SURFACE COURSE MATERIALS
(Modified AASHTO Design)

Figure 54-5O

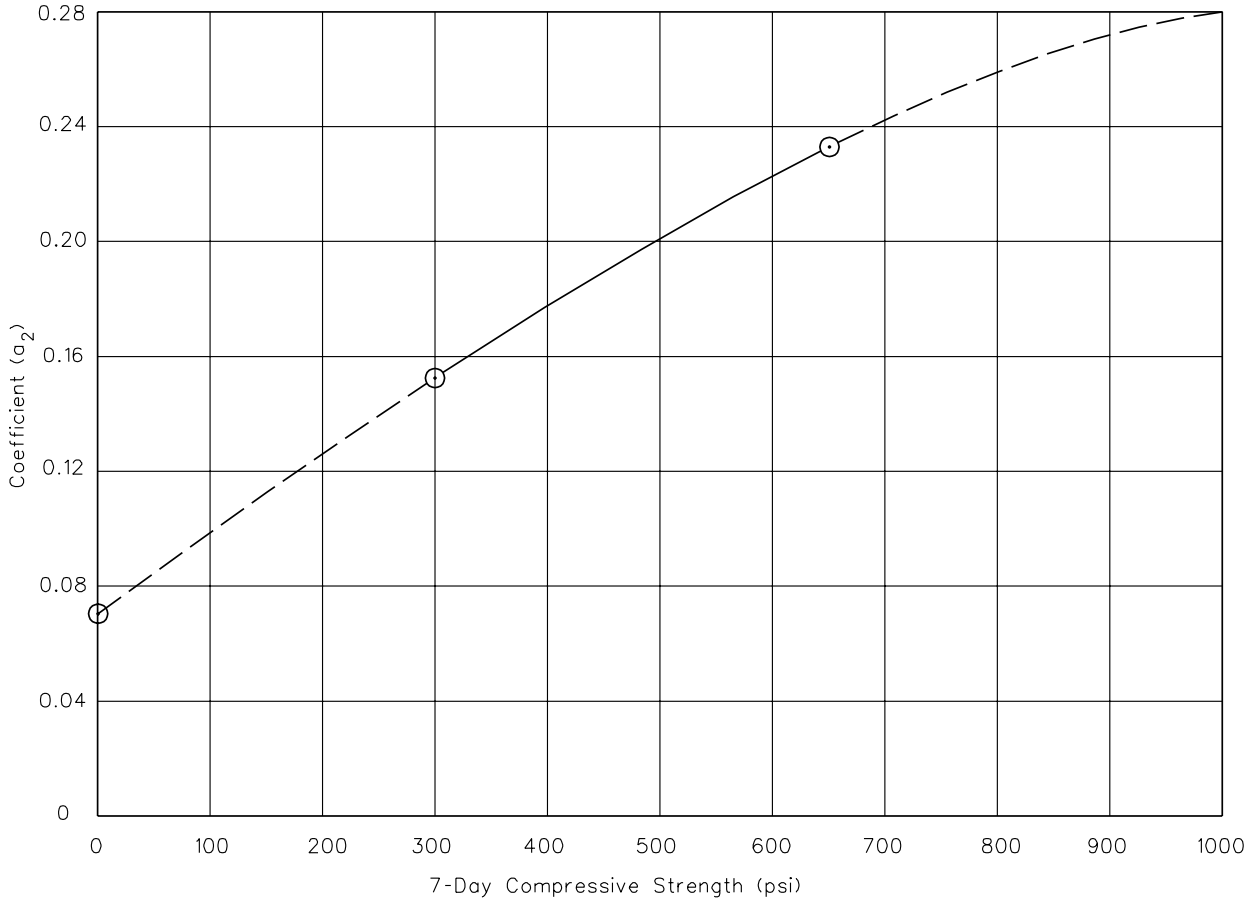


Note: The following Marshall stabilities can be assumed:

- *1500 lbs for Superpave N_{Design}30 mixes.*
- *1700 lbs for Superpave N_{Design}50 and N_{Design} 70 mixes; and*
- *2000 lbs for Superpave N_{Design} 90 and N_{Design} 105 mixes.*

COEFFICIENTS FOR BITUMINOUS STABILIZED GRANULAR MATERIALS
(Modified AASHTO Design)

Figure 54-5P



COEFFICIENTS FOR CEMENT STABILIZED GRANULAR MATERIALS
(Modified AASHTO Design)

Figure 54-5Q

STRUCTURAL NUMBER (D_t)①		MINIMUM THICKNESS (inches)			MINIMUM MATERIAL⑤		
From	To	Surface	Base②	Subbase③ (optional)	Surface	Base⑥	Subbase⑧ (optional)
1.00	1.99	2	8	4④	Class B Road Mix	Aggregate, Type B⑦	Granular Material, Type B④
			6			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
2.00	2.49	2	8	4④	Class B Plant Mix (asphalt cement)	Aggregate, Type B⑦	Granular Material, Type B④
			6			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
2.50	2.99	⑨	9	4	Class B Plant Mix (asphalt cement)	Aggregate, Type A	Granular Material, Type B
			7			Stabilized Granular Material (MS_{min} = 300 or CS_{min} = 300)	
3.00	3.49	⑨	11	4	Superpave (4% voids)	Aggregate, Type A	Granular Material, Type B
			8			Stabilized Granular Material (MS_{min} = 400 or CS_{min} = 400)	
3.50	3.99	⑨	8	4	Superpave (4% voids)	Stabilized Granular Material (MS_{min} = 800 or CS_{min} = 650)	Granular Material, Type B
4.00	4.49	⑨	8	4	Superpave (4% voids)	Stabilized Granular Material (MS_{min} = 1000 or CS_{min} = 750)	Granular Material, Type B
4.50	4.99	⑨	9	4	Superpave (4% voids)	Stabilized Granular Material (MS_{min} = 1200 or CS_{min} = 1000)	Granular Material, Type B
			9			Pozzolanic, Type A	
5.00	5.99	⑨	10	4	Superpave (4% voids)	Stabilized Granular Material (MS_{min} = 1500)	Granular Material, Type A
≥ 6.00		⑨	12	4	Superpave (4% voids)	Stabilized Granular Material (MS_{min} = 1700)	Granular Material, Type A

Notes:

① ***The minimum allowable structural number for Interstates and supplemental freeways will be 5.6; for multi-lane State primary highways, 5.0; and for two-lane State primary highways, 4.0.***

② *Where bituminous stabilized granular material with a strength greater than the minimum required above is used, a reduction in the minimum required thickness, up to a maximum of 1 in, will be allowed.*

③ *The minimum thickness of a lime stabilized soil subbase will be 6 in.*

④ *If an uncrushed Aggregate Base Course, Type B is used, a subbase will not be used.*

⑤ *Other approved materials having equal or greater strengths may be substituted for those listed above.*

⑥ *MS = Marshall Stability (lbs.) or equivalent, CS = 7-day compressive strength (psi) that can be reasonably expected under field conditions.*

⑦ *Lime stabilized soil may be used, provided the minimum thickness is not less than 8 in.*

⑧ *The use of a granular subbase is not mandatory.*

⑨ *Use Policy Resurfacing Thickness (see Chapter 53), unless prior BDE approval is received.*

MINIMUM THICKNESS AND MATERIAL REQUIREMENTS FOR FLEXIBLE PAVEMENTS
(Modified AASHTO Design)
Figure 54-5R

54-5.02(b) Design Period

Section 54-5.01(e) applies to modified AASHTO designs of flexible pavements.

54-5.02(c) Equivalency Factors

Section 54-5.01(f) applies to modified AASHTO designs of flexible pavements.

54-5.02(d) Traffic Factors

Section 54-5.01(g) applies to modified AASHTO designs of flexible pavements.

54-5.02(e) Structural Number

Having calculated the traffic factor, only the IBR of the roadbed soil (see Section 54-3.01(f)) is needed to determine the structural number of the flexible pavement. The flexible pavement structural number (SN_F) is obtained by projecting a line through the traffic factor and the IBR on the appropriate design nomograph, either Figure 54-5L for Class I facilities or Figure 54-5M for Class II, III, and IV facilities. Check the structural number (SN_F) to see that it meets or exceeds the minimum structural numbers given to Note (1) of Figure 54-5R for the type of facility being designed.

54-5.02(f) Structural Number Equation

The structural number (SN_F), an abstract number related to the strength required of the total pavement structure, is the summation of the layer thicknesses multiplied by their corresponding strength coefficients. Use the following equation to determine the structural number:

$$SN_F = a_1D_1 + a_2D_2 + a_3D_3 \qquad \text{Equation 54-5.5}$$

Where:

SN_F	=	flexible pavement structural number
a_1, a_2, and a_3	=	coefficients of relative strength of the surface, base, and subbase materials, respectively
D_1, D_2, and D_3	=	thickness, in inches, of the surface, base, and subbase layers, respectively

54-5.02(g) Trial Designs

The structural number equation discussed in Section 54-5.02(f) allows the designer to develop trial designs using various combinations of materials. By applying current bid prices or labor and material quotes to the trial designs, it is possible to select the most economical alternative.

Certain practical restrictions limit the designer's freedom in developing trial designs. A flexible pavement consists of a two or three layer structure, including a surface course and base course or a surface course, base course, and subbase course. Each layer must have sufficient strength and thickness to sustain the load imposed upon it and to distribute it over a sufficient area so as not to exceed the structural strength of the underlying layer. Thus, the composition of the pavement structure must be such that the strength characteristics of the surface course material are higher than those of the base or subbase, and the strength characteristics of the base course materials are higher than those of the subbase.

The above guidelines must be considered when selecting the materials to be used in the pavement structure. For example, if two granular materials having different strength characteristics are selected for use, the higher strength material must be used as the base course and the lower strength material as the subbase. If only one material is to be used for both subbase and base courses, the pavement structure then must be considered as a two-layer system consisting only of a surface course and a base course.

Values of coefficients for various materials that are typically used in flexible pavement structures are presented in Figure 54-5N. These coefficients are consistent with the minimum strength values that can be expected throughout the State and may be used in determining the structural design of flexible pavements using modified AASHTO procedures for any class of road or street.

54-5.02(h) Minimum Thickness and Material Requirements

To ensure practical and adequate designs, the minimum design requirements presented in Figure 54-5R have been established. Surface, base, and subbase materials having strength characteristics greater than those shown for the various structural number groups may be selected, but in no case may an inferior quality of surface, base, or subbase material be selected. Note that increasing the quality of material will reduce the required layer thickness and will tend to increase the level of performance that can be expected by the pavement during its design life, provided the minimum thickness requirements contained in Figure 54-5R are met. Figure 54-5R also serves as an aid in developing trial designs (see Section 54-5.02(g)). Thicknesses for two layers of the pavement first may be selected from the minimums in Figure 54-5R and then the third layer thickness computed.

54-5.02(i) Designating Structural Design Information on Plans

See Section 63-4.05 for information on designating structural design information on plans.

54-5.02(j) Design Example

See Section 54-9 for a design example.

54-5.02(k) Typical Sections

Because the modified AASHTO design procedure for flexible pavements allows for a variety of solutions, no typical sections are provided.

54-6 STRUCTURAL DESIGN OF COMPOSITE PAVEMENTS

54-6.01 Application of Design Method

The design procedures for composite pavements enable the designer to select:

- the thickness of bituminous surface needed to structurally rehabilitate an existing rigid or composite pavement, or

- the thicknesses of both bituminous surface and PCC base course for a new composite pavement.

The resulting composite pavement will be capable of carrying a specified volume and composition of traffic for a designated period of time while retaining a serviceability level at or above a selected minimum value. The composite design method assumes that the existing rigid or composite pavement has reached the end of its design life and is in need of structural rehabilitation. If the existing pavement has not reached the end of its design life, as may be the case when a resurfacing is being designed in conjunction with a lane addition, higher strength coefficients than those discussed in Section 54-6.06 may be appropriate. Such cases should be referred to the BDE or the Bureau of Materials and Physical Research. Application of the composite design method involves the following steps:

1. Determine Traffic Factor. Use the following procedures to determine the traffic factor:

    a. Determine the facility class (e.g., Class I, II, III, or IV).

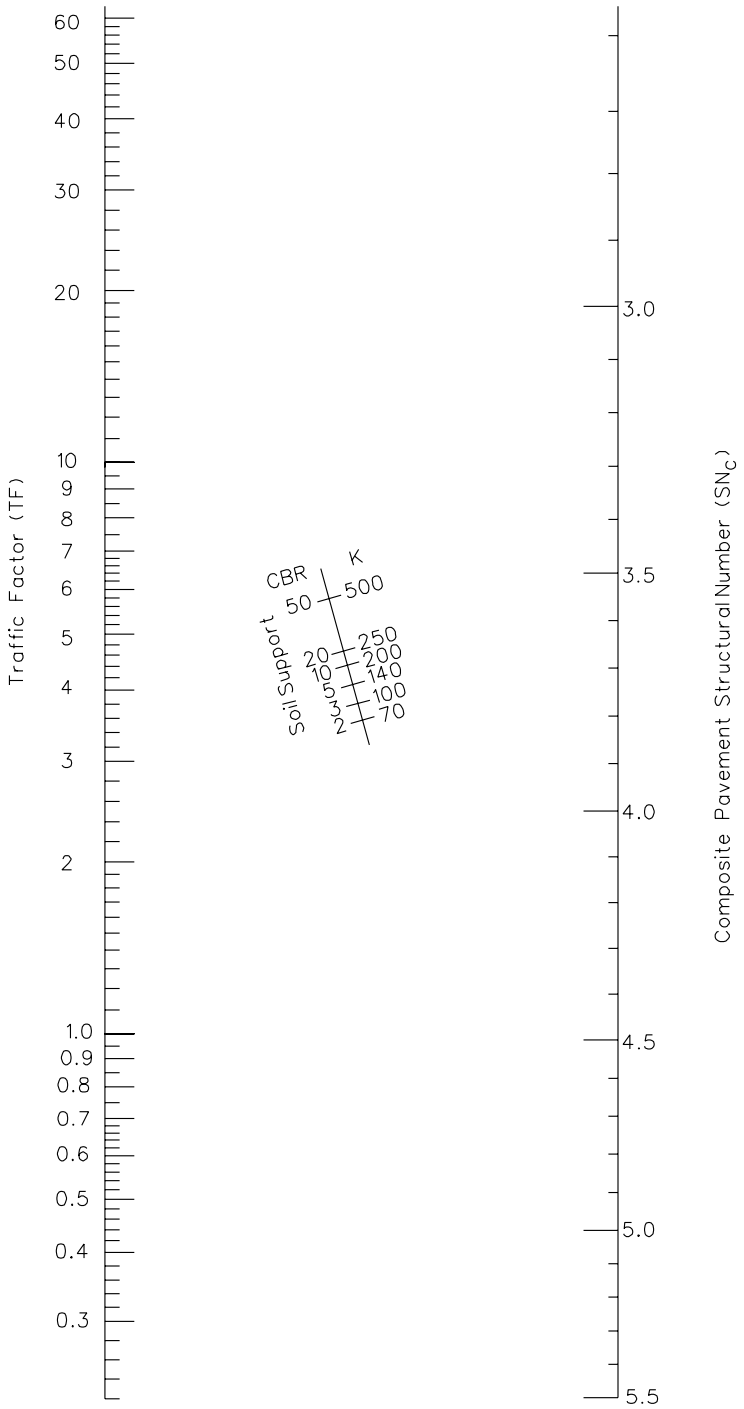
    b. Determine the actual structural design traffic as described in Section 54-3.01(c).

    c. Based on the facility class, select the appropriate traffic factor equation from Figure 54-4C.

    d. Calculate the actual traffic factor to use in design.

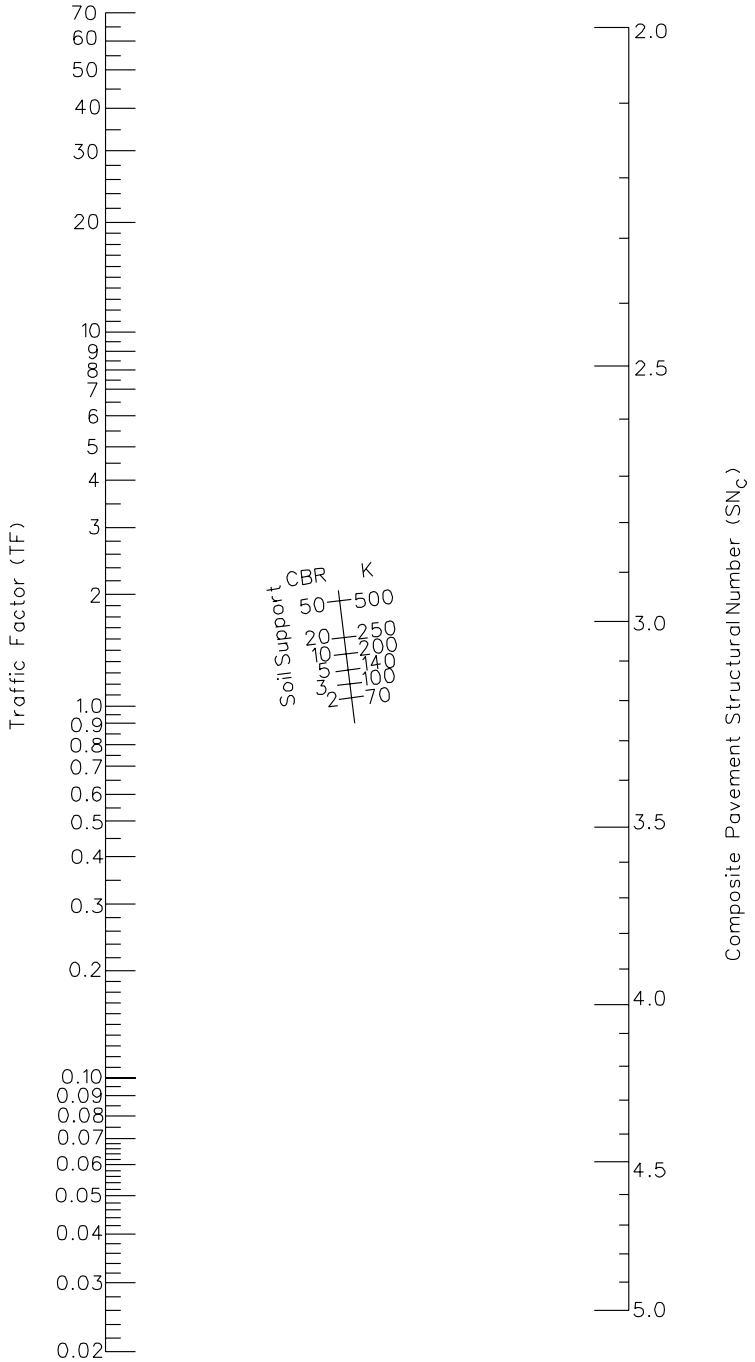
2. Determine the Illinois Bearing Ratio. Determine the Illinois Bearing Ratio of the roadbed soil (see Section 54-3.01(f)).

3. Determine the Structural Number (SN_C). Determine the composite pavement structural number (SN_C) using the appropriate design nomograph for the facility class (i.e., Figure 54-6A for Class I facilities or Figure 54-6B for Class II, III, and IV facilities).



COMPOSITE PAVEMENT DESIGN NOMOGRAPH
(Class I Facilities)

Figure 54-6A



COMPOSITE PAVEMENT DESIGN NOMOGRAPH
(Class II, III, and IV Facilities)

Figure 54-6B

4. Determine Thickness. Select the appropriate equation from Section 54-6.06 as follows:

- First Resurfacing: use Equation 54-6.1
- Second Resurfacing: use Equation 54-6.2
- New Composite Pavement: use Equation 54-6.3

Using the appropriate equation and Figure 54-6C, calculate the thickness of surface and base course, if applicable. Round the thickness(es) up to the nearest 0.25 in. For pavements that are in need of a third resurfacing, see Section 54-6.06.

5. Compare with Minimum Criteria. Compare the calculated thickness(es) with the minimum requirements presented in Figure 54-6D. Use the larger of the values for design.

54-6.02 Design Period

The design period for all composite pavements usually will be 20 years. See Section 54-3.01(b).

54-6.03 Equivalency Factors

Section 54-3.01(d) describes the use of equivalency factors to convert mixed-traffic loadings to 18-kip ESAL applications. Because the main structural layer of a composite pavement is a rigid slab, the equivalency factors are the same as for rigid pavement (see Section 54-4.02(c)). These equivalency factors have been used to develop the traffic factor equations discussed in Section 54-6.04.

54-6.04 Traffic Factors

The traffic factor is the projected total 18-kip equivalent single-axle load, expressed in millions, to be carried by the design lane during the design period. Because the main structural layer of a composite pavement is a rigid slab, the equivalency factors are the same as for rigid pavement (see Section 54-6.03). The traffic factor equations discussed in Section 54-4.02(d) also apply to composite pavement designs.

54-6.05 Composite Pavement Structural Number

Having calculated the traffic factor, only the IBR of the roadbed soil (see Section 54-3.01(f)) is needed to determine the composite pavement structural number. The composite pavement structural number (SN_C) is obtained by projecting a line through the traffic factor and the IBR of

the roadbed soil on the appropriate design nomograph, either Figure 54-6A for Class I facilities or Figure 54-6B for Class II, III, and IV facilities.

Pavement Cross Section (inches)	Equivalent Thickness (D_C) (inches)
10 - 10 - 8 - 10 - 10	9.75
9 - 9 - 7 - 9 - 9	8.75
9 - 7 - 9	7.71
9 - 9 - 6.5 - 9 - 9	8.50
9 - 6 - 9	7.06
8 - 8 - 6 - 8 - 8	7.75
7 - 8 - 7	7.00

EQUIVALENT THICKNESS (D_C) FOR EXISTING NON-UNIFORM PCC PAVEMENTS (Composite Pavement Design)

Figure 54-6C

Facility Class	Superpave Surface Course	PCC Base Course Minimum Thickness (inches)
Class I	Use Policy Thickness unless otherwise approved by BDE. See Chapter 53.	8
Class II		7
Class II State Primary All Others		 7 6
Class IV		6

MINIMUM DESIGN REQUIREMENTS FOR COMPOSITE PAVEMENTS (Composite Pavement Design)

Figure 54-6D

54-6.06 Thickness Design Equations

The composite pavement structural number (SN_C), an abstract number related to the strength required of the total pavement structure, is a summation of layer thicknesses multiplied by their corresponding strength coefficients. Three design equations incorporate the composite pavement structural number as follows:

1. First Resurfacing. For the initial bituminous concrete surfacing over an existing rigid pavement, use the following equation:

$$D_S = \frac{SN_C - 0.26D_C}{0.40} \qquad \text{Equation 54-6.1}$$

2. Second Resurfacing. For a second bituminous concrete surfacing over an existing resurfaced rigid pavement, use the following equation:

$$D_S = \frac{SN_C - 0.25D_E - 0.17D_C}{0.40} \qquad \text{Equation 54-6.2}$$

3. New Composite Pavement. For the design of a new composite pavement, use the following equation:

$$N_C = 0.40\ D_S + 0.33\ D_B \qquad \text{Equation 54-6.3}$$

Where:

SN_C = Composite pavement structural number
D_S = thickness of new bituminous concrete surface (inches)
D_C = equivalent thickness of existing PCC slab (inches)
D_E = thickness of existing bituminous concrete surface (inches)
D_B = thickness of new PCC base course (inches)

Note that the above equations do not include provisions for a third resurfacing. Pavements that are in need of a third resurfacing for structural reasons often are badly deteriorated and may no longer be functioning as a rigid pavement. Contact the BDE or the Bureau of Materials and Physical Research for guidance in selecting the appropriate strength coefficients for such pavements.

In the case of an existing jointed reinforced PCC pavement of uniform thickness, the equivalent thickness of the PCC slab (D_C) is the actual slab thickness. For a CRC pavement, D_C is the slab thickness multiplied by 1.25. Figure 54-6C presents the equivalent thickness (D_C) of the non-uniform PCC pavements formerly constructed by the Department.

Use Equation 54-6.3 to develop designs for totally new composite pavements composed of a bituminous surface and a PCC base course. The application of this pavement design procedure is restricted as follows:

- to changes in horizontal or vertical alignment for short segments of rural pavement,
- to lane additions,
- to reconstruction of short segments of urban pavement, and
- as an option to flexible base materials.

Equation 54-6.3 requires determination of two unknowns (i.e., the surface and the base course thicknesses). To develop a design, it becomes necessary, therefore, to assume the thickness of one pavement component and compute the required thickness of the other. In most cases, it will be best to initially assume the surface course thickness. The surface course thickness selected should be the standard policy resurfacing thickness or the thickness of the resurfacing being placed on the adjacent pavement.

54-6.07 Minimum Design Requirements

The composite design procedures are used to analyze PCC slabs that are surfaced with high-type bituminous concrete and are therefore limited to bituminous concrete surfacing materials that meet the requirements of the *Standard Specifications* for Superpave bituminous concrete. To ensure practical and adequate designs, adhere to the minimum criteria presented in Figure 54-6D for composite pavements.

54-6.08 Designating Structural Design Information on Plans

See Section 63-4.05 for information on designating structural design information on plans.

54-6.09 Design Example

See Section 54-9 for a design example.

54-7 PAVEMENT SELECTION ANALYSIS

54-7.01 Introduction

The life-cycle activities for mechanistically designed pavements that are presented in this section were developed by a panel of Department experts who have experience in the areas of design, construction, materials, and maintenance of Illinois pavements. The expert group established rehabilitation, patching, and maintenance strategies for a 40-year analysis period for typical rigid and flexible pavements.

A framework for data collection has been established to gather actual data on maintenance activities and costs. As these data are collected, appropriate modifications to the life-cycle strategies will be made where needed.

54-7.02 Selection Basis

The selection of pavement design alternatives is based on the following criteria:

1. Widening Projects. Pavement design alternatives for widening projects are evaluated based on a first-cost analysis. The alternative with the lowest first cost is selected for construction.

2. New Construction/Reconstruction Projects. Pavement design alternatives for new or reconstructed pavements are evaluated based on a life-cycle cost analysis. If the difference in life-cycle costs between alternatives is greater than 10%, the alternative with the lowest life-cycle cost is selected for construction. However, if the difference in life-cycle costs is 10% or less, the selection is determined by the Pavement Selection Committee.

3. Waivers. Although the guidelines presented in Item 1 and Item 2 will apply in most cases, a waiver based on issues related to policy, Local Agency requests, or constructibility may need to be considered. Such cases will be referred to the BDE for approval.

54-7.03 Life-Cycle Activities

Figures 54-7A through 54-7E present the maintenance and rehabilitation activities during 40 years of service. Figure 54-7A illustrates the activities for mechanistically designed jointed plain concrete pavements under all traffic levels, and Figures 54-7B through 54-7E present the activities for mechanistically designed full-depth AC pavements for specific ranges of rural and urban flexible traffic factors.

ITEMIZED CONSTRUCTION COST — YEAR 0 • 100% Shoulder Joint Seal
REHABILITATION ACTIVITY — YEAR 7 • 0.5% Full-Depth PCC Pavement Patching (6 ft Doweled Patch)
REHABILITATION ACTIVITY 2 — YEAR 10 • 1.0% Full-Depth PCC Pavement Patching (6 ft Doweled Patch) • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing • 100% Transverse Joint Routing and Sealing • 1% Full-Depth PCC Shoulder Patching
REHABILITATION ACTIVITY 3 — YEAR 15 • 1.5% Full-Depth PCC Pavement Patching (6 ft Doweled Patch)
REHABILITATION ACTIVITY 4 (CPR) — YEAR 20 • Undersealing Holes Drilled (70% of Joints) (2 holes/Joint/Lane) • Undersealing Grout Solids (1.75 ft^3/hole) • 4% Full-Depth PCC Pavement Patching (6 ft Doweled Patch) • 4% Full-Depth PCC Shoulder Patching • 100% Pavement Surface Grinding • 100% Transverse Joint Routing & Sealing • 100% Longitudinal/Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing
REHABILITATION ACTIVITY 5 — YEAR 25 • 1.5% Full-Depth PCC Pavement Patching (6 ft Doweled Patch) • 1.0% Full Depth PCC Shoulder Patching
REHABILITATION ACTIVITY 6 —YEAR 30 • 2.5% Full-Depth PCC Pavement Patching (6 ft Doweled Patch) • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing • 100% Transverse Joint Routing and Sealing • 1.5% Full-Depth PCC Shoulder Patching
REHABILITATION ACTIVITY 7 — YEAR 35 • 3.5% Full-Depth PCC Pavement Patching (6 ft Doweled Patch) • 2.0% Full-Depth PCC Shoulder Patching
ROUTINE MAINTENANCE ACTIVITY — ANNUAL • $505/Lane-Mile/Year

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
JOINTED PLAIN CONCRETE PAVEMENT
(All Traffic Levels)

Figure 54-7A

REHABILITATION ACTIVITY 1 — YEAR 3 • 15% Thermal Crack Routing & Sealing • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving)
REHABILITATION ACTIVITY 2 — YEAR 5 • 0.5% Full-Depth Bituminous Pavement Patching
REHABILITATION ACTIVITY 3 — YEAR 6 • 50% Thermal Crack Routing & Sealing
REHABILITATION ACTIVITY 4 — YEAR 10 • 3.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 5 — YEAR 12 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 6 — YEAR 20 • 0.75 in Surface Milling • Policy Thickness Bituminous Overlay • 4.0% Full-Depth Bituminous Pavement Patching • 4.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 7 —YEAR 21 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 8 — YEAR 23 • 100% Centerline Joint Routing & Sealing (Dual-Lane Paving)
REHABILITATION ACTIVITY 9 — YEAR 31 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-lane and dual-lane paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 10 — YEAR 32 • 3.0% Full-Depth Bituminous Pavement Patching • 3.0% Full-Depth Bituminous Shoulder Patching
ROUTINE MAINTENANCE ACTIVITY — ANNUAL • $505/Lane-Mile/Year

Notes:

1. *For thermal crack routing and sealing, assume 100 ft spacing.*
2. *For random crack routing and sealing, assume 100 ft/station.*
3. *For policy overlay activities, exclude milling on the shoulder and include an overlay thickness on the shoulder equal to the policy thickness surface overlay minus 0.75 in.*
4. *Single lane paving and dual lane paving refers to the placement of the original pavement only.*

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: TF < 15.0 / Urban: TF < 10.0)

Figure 54-7B

REHABILITATION ACTIVITY 1 — YEAR 3 • 15% Thermal Crack Routing & Sealing • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving)
REHABILITATION ACTIVITY 2 — YEAR 5 • 0.5% Full-Depth Bituminous Pavement Patching
REHABILITATION ACTIVITY 3 — YEAR 6 • 50% Thermal Crack Routing & Sealing
REHABILITATION ACTIVITY 4 — YEAR 10 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 3.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 5 — YEAR 11 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 6 — YEAR 13 • 100% Centerline Joint Routing & Sealing (Dual-Lane Paving)
REHABILITATION ACTIVITY 7 — YEAR 20 • 0.75 in Surface Milling • Policy Thickness Bituminous Overlay • 4.0% Full-Depth Bituminous Pavement Patching • 4.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 8 —YEAR 21 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 9 — YEAR 32 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 3.0% Full-Depth Bituminous Pavement Patching • 3.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 10 — YEAR 33 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
ROUTINE MAINTENANCE ACTIVITY — ANNUAL • $505/Lane-Mile/Year

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: 15.0 ≤ TF < 24.5 / Urban: 10.0 ≤ TF < 16.3)

Figure 54-7C

Notes:

1. *For thermal crack routing and sealing, assume 100 ft spacing.*
2. *For random crack routing and sealing, assume 100 ft/station.*
3. *For surface correction activities, exclude milling on the shoulder and include an overlay thickness of 0.75 in on the shoulder.*
4. *For policy overlay activities, exclude milling on the shoulder and include an overlay thickness on the shoulder equal to the policy thickness surface overlay minus 0.75 in.*
5. *Single lane paving and dual lane paving refers to the placement of the original pavement only.*

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: 15.0 ≤ TF < 24.5 / Urban: 10.0 ≤ TF < 16.3)

Figure 54-7C
(Continued)

REHABILITATION ACTIVITY 1 — YEAR 3 • 15% Thermal Crack Routing & Sealing • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving)
REHABILITATION ACTIVITY 2 — YEAR 5 • 0.5% Full-Depth Bituminous Pavement Patching
REHABILITATION ACTIVITY 3 — YEAR 7` • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 3.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 4 — YEAR 8 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving) • 50% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 5 — YEAR 10 • 100% Centerline Joint Routing & Sealing (Dual-Lane Paving)
REHABILITATION ACTIVITY 6 — YEAR 12 • 50% Thermal Crack Routing & Sealing
REHABILITATION ACTIVITY 7 — YEAR 15 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing • 50% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing,
REHABILITATION ACTIVITY 8 — YEAR 20 • 0.75 in Surface Milling • Policy Thickness Bituminous Overlay • 4.0% Full-Depth Bituminous Pavement Patching • 4.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 9 — YEAR 21 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 10 — YEAR 30 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 3.0% Full-Depth Bituminous Pavement Patching • 3.0% Full-Depth Bituminous Shoulder Patching

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: 24.5 ≤ TF < 34.0 / Urban: 16.3 ≤ TF < 22.7)

Figure 54-7D

REHABILITATION ACTIVITY 11 — YEAR 31
• 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
ROUTINE MAINTENANCE ACTIVITY — ANNUAL
• $505/Lane-Mile/Year

Notes:

1. *For thermal crack routing and sealing, assume 100 ft spacing.*

2. *For random crack routing and sealing, assume 100 ft/station.*

3. *For surface correction activities, exclude milling on the shoulder and include an overlay thickness of 0.75 in on the shoulder.*

4. *For policy overlay activities, exclude milling on the shoulder and include an overlay thickness on the shoulder equal to the policy thickness surface overlay minus 0.75 in.*

5. *Single lane paving and dual lane paving refers to the placement of the original pavement only.*

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: 24.5 ≤ TF < 34.0 / Urban: 16.3 ≤ TF < 22.7)

Figure 54-7D
(Continued)

REHABILITATION ACTIVITY 1 — YEAR 3 • 100% Longitudinal Shoulder Joint Routing & Sealing • 15% Thermal Crack Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving)
REHABILITATION ACTIVITY 2 — YEAR 5 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 0.5% Full-Depth Bituminous Pavement Patching • 1.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 3 — YEAR 6` • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane Paving) • 50% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 4 — YEAR 8 • 100% Centerline Joint Routing & Sealing (Dual-Lane Paving)
REHABILITATION ACTIVITY 5 — YEAR 13 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 2.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 6 — YEAR 14 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 7 — YEAR 20 • 0.75 in Surface Milling • Policy Thickness Bituminous Overlay • 4.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 8 — YEAR 21 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 9 — YEAR 28 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 2.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: TF ≥ 34.0 / Urban: TF ≥ 22.7)

Figure 54-7E

REHABILITATION ACTIVITY 10 — YEAR 29 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
REHABILITATION ACTIVITY 11 — YEAR 36 • 0.75 in Surface Milling • 1.5 in Surface Correction Bituminous Overlay • 2.0% Full-Depth Bituminous Pavement Patching • 2.0% Full-Depth Bituminous Shoulder Patching
REHABILITATION ACTIVITY 12 — YEAR 37 • 100% Longitudinal Shoulder Joint Routing & Sealing • 100% Centerline Joint Routing & Sealing (Single-Lane and Dual-Lane Paving) • 100% Thermal Crack Routing & Sealing • 50% Random Crack Routing & Sealing
ROUTINE MAINTENANCE ACTIVITY — ANNUAL • $505/Lane-Mile/Year

Notes:

1. *For thermal crack routing and sealing, assume 100 ft spacing.*

2. *For random crack routing and sealing, assume 100 ft/station.*

3. *For surface correction activities, exclude milling on the shoulder and include an overlay thickness of 0.75 in on the shoulder.*

4. *For policy overlay activities, exclude milling on the shoulder and include an overlay thickness on the shoulder equal to the policy thickness surface overlay minus 0.75 in.*

5. *Single lane paving and dual lane paving refers to the placement of the original pavement only.*

MAINTENANCE AND REHABILITATION ACTIVITY SCHEDULE
FULL-DEPTH AC PAVEMENT
(Rural: TF ≥ 34.0 / Urban: TF ≥ 22.7)

Figure 54-7E
(Continued)

54-7.04 Cost Analysis

The costs of all major pay items will be based upon the anticipated quantities for the contract. Computations that are used to develop costs will be documented for each major pay item. Contact the BDE for the Department's computer analysis procedures for life-cycle cost estimation.

54-7.05 Selection Process

Pavement selection will be based on the annual costs of initial construction and life-cycle activities amortized over the 40-year service life of the pavement. A discount rate of 3% will be used to determine annual costs and no adjustment for inflation will be required. Use the following equation to determine annual costs of alternatives during the selection process:

$$A = D + M + CRF_n\,[C + R_1(PWF_{n1}) + R_2(PWF_{n2}) + \ldots + R_n(PWF_{nn})] \qquad \text{Equation 54-7.1}$$

Where:

A = total annual cost per mile

D = *annual administrative and overhead cost per mile (assumed to be equal for all pavement types)*

M = *total annual maintenance cost per mile (assumed to be $505/lane-mile/year)*

CRF_n = capital recovery factor for year n calculated as follows (see Figure 54-7F):

$$= \frac{i(1+i)^n}{(1+i)^n - 1} \qquad \text{Equation 54-7.2}$$

i = discount rate (assumed to be 0.03 (i.e., 3%))

n = year within analysis period in number of years after initial construction

C = initial construction cost per mile

R_1 = first rehabilitation cost per mile

R_2 = second rehabilitation cost per mile

R_n = n^{th} rehabilitation cost per mile

PWF_{nn} = present worth factor for the nth number of years after initial construction that the nth rehabilitation activity is performed calculated as follows (see Figure 54-7F):

$$= \frac{1}{(1+i)^{nn}} \qquad \text{Equation 54-7.3}$$

n1 = number of years after initial construction that the first rehabilitation activity is performed

n2 = number of years after initial construction that the second rehabilitation activity is performed

nn = number of years n after initial construction that the nth rehabilitation activity is performed

If the cost difference between rigid and flexible pavement designs is 10% or greater, select the alternative with the lowest life-cycle cost. However, if the cost difference is less than 10%, the pavement type will be determined by the Pavement Selection Committee.

The Pavement Selection Committee consists of five Department personnel (i.e., three from the Central Office and two from the district). District Engineers, Deputy Directors, and other high-ranking personnel are excluded from the Committee. Committee meetings usually are held by conference calls. Factors that are considered by the Committee during the selection process are documented in the AASHTO *Guide to Design of Pavement Structures*. Committee deliberations are considered confidential and only the Committee's recommendation as to the final pavement selection is recorded.

n	CRF_n②	PWF_n③	n	CRF_n②	PWF_n③
1	1.0300	0.9709	21	0.0649	0.5375
2	0.5226	0.9426	22	0.0628	0.5219
3	0.3535	0.9151	23	0.0608	0.5067
4	0.2690	0.8885	24	0.0591	0.4919
5	0.2184	0.8626	25	0.0574	0.4776
6	0.1846	0.8375	26	0.0559	0.4637
7	0.1605	0.8131	27	0.0546	0.4502
8	0.1425	0.7894	28	0.0533	0.4372
9	0.1284	0.7664	29	0.0521	0.4243
10	0.1172	0.7441	30	0.0510	0.4120
11	0.1080	0.7224	31	0.0500	0.4000
12	0.1005	0.7014	32	0.0491	0.3883
13	0.0943	0.6810	33	0.0482	0.3770
14	0.0885	0.6611	34	0.0473	0.3660
15	0.0838	0.6419	35	0.0465	0.3554
16	0.0796	0.6232	36	0.0458	0.3450
17	0.0760	0.6050	37	0.0451	0.3350
18	0.0727	0.5874	38	0.0445	0.3252
19	0.0698	0.5703	39	0.0438	0.3158
20	0.0672	0.5537	40	0.0433	0.3066

Notes:

1. *Factors in Figure 54-7F are applicable only for a discount rate of 3% (i.e., i = 0.03).*
2. *See Equation 54-7.2.*
3. *See Equation 54-7.3.*

CAPITAL RECOVERY AND PRESENT WORTH FACTORS

Figure 54-7F

54-8 PAVEMENT DESIGN SUBMITTALS

54-8.01 Submittal Requirement

Pavement design submittals are required if there are more than 4750 yd^2 involved or if the design involves any special designs or waiver requests. Submittals will be sent to the Central Office for BDE approval.

54-8.02 Submittal Content

All pavement design submittals that are forwarded to the BDE will include the following:

1. Transmittal Memorandum. Include a memorandum of transmittal with the submittal. The memorandum should include information such as the route, section, county, district, and recommendation.

2. Sketch Map. Include a sketch map showing the location of the subject improvement and the limits of the analysis.

3. Typical Sections. Include typical cross sections for standard pavement types and for any special or unusual pavement treatment. Typical sections should include information detailing the number of lanes, shoulders, curbs and gutters, and other information as appropriate. Usually, only one typical section is required.

4. Subgrade Stability Chart. If the soil condition is found to be fair or granular, include the subgrade stability chart used in the analysis. Also include documentation for any unusual soil conditions that affect pavement design (e.g., laboratory test results). Because a majority of Illinois soils exhibit poor subgrade stability, it is not necessary to include detailed information to substantiate this fact.

5. Design Calculations. Include all design calculations and assumptions (e.g., traffic factor calculations, thickness calculations, thickness nomographs and related charts, temperature location map). Clearly illustrate how the pavement thickness was determined.

6. Economic Analysis. Include all calculations and assumptions related to the economic analysis (e.g., first-cost analysis, life-cycle cost analysis, total annual cost per mile, maintenance and rehabilitation activities, capital recovery and present worth factors, discount rate). Clearly illustrate how the economic analysis was performed.

7. Unit Cost Sheets. Provide unit cost computation sheets that document the unit costs used for each major pay item involved in each of the alternative designs. The unit cost sheets may be based on assumed material quotes which are comparable to those received in the same general area, or they may be based on actual average bid prices.

If bid prices are used, care should be taken to use prices from projects with quantities nearly equal to those being used for the design. The unit costs must be based on the total anticipated quantities of the major pay items involved for the entire contract section.

8. Other Information. Include adequate documentation that describes any unusual factors affecting design or that influenced the pavement selection (e.g., construction staging, high-stress locations, Local Agency requests, unusual traffic volumes, traffic count summary sheets, memoranda from District Bureaus of Planning, references to current Interstate cost studies).

9. Recommendation. Clearly identify and describe the recommended design and the basis for pavement selection.

54-9 DESIGN EXAMPLES

The following examples illustrate typical IDOT pavement designs:

* * * * * * * * * *

Example 54-9.1

Given: New rural 4-lane State highway in central Sangamon County
ADT (Design Year Traffic) PV = 17,225 SU = 360 MU = 360
Subgrade Support Rating (SSR) = Poor
Asphalt Cement Type = PG58-xx (AC 10)

Because this involves new construction, it will be necessary to perform both a rigid and flexible mechanistic design. See Figure 54-1A.

Solution:

Step 1: Determine the actual traffic factor using Equations 54-4.1 and 54-5.1.

TF_R (Actual)

$$TF_{R(A)} = 20\frac{(0.15 \bullet 0.32 \bullet 17{,}225) + (143.81 \bullet 0.45 \bullet 360) + (696.42 \bullet 0.45 \bullet 360)}{1x10^6}$$

$$= 2.74$$

TF_F (Actual)

$$TF_{F(A)} = 20\frac{(0.15 \bullet 0.32 \bullet 17{,}225) + (132.50 \bullet 0.45 \bullet 360) + (482.53 \bullet 0.45 \bullet 360)}{1x10^6}$$

$$= 2.01$$

Step 2: Check minimum traffic factor.

TF_R (Minimum)

$$TF_{R(M)} = 20\frac{(143.81 \bullet 0.45 \bullet 300) + (696.42 \bullet 0.45 \bullet 900)}{1x10^6}$$

$$= 6.03$$

TF_F (Minimum)

$$TF_{F(M)} = 20\frac{(132.50 \bullet 0.45 \bullet 300) + (482.53 \bullet 0.45 \bullet 900)}{1x10^6}$$

$$= 4.27$$

Because the minimum traffic results in a higher traffic factor, use the minimums.

Step 3: Determine the pavement AC mixture temperature from Figure 54-5C and round to the nearest 0.1°. See Figure 54-9A.

AC Mix Temperature = 80.7°

Step 4: Determine Design E_{AC} from Figure 54-5D and round to nearest 10. See Figure 54-9B.

Design E_{AC} = 460

Step 5: Determine the Design AC strain using the $TF_{F(M)}$ and Figure 54-5E. See Figure 54-9C.

Design AC strain = 66

Step 6: Using the Design E_{AC} and the Design AC strain, determine the flexible thickness from Figure 54-5F for a poor subgrade and round up to the nearest 0.25 in. See Figure 54-9D.

Thickness = 14.50 in (i.e., 14.35 in rounded up to 14.50 in)

Step 7: Using the $TF_{R(M)}$ and Figure 54-4D for a poor subgrade, determine the rigid thickness. Round up to the nearest 0.25 in. See Figure 54-9E.

Thickness = 9.5 in for tied shoulder (i.e., 9.4 in rounded up to 9.5 in)
= 10 in for untied shoulder (i.e., 9.9 in rounded up to 10 in)

Results: For the design thickness, use a 14.50 in full-depth AC pavement or a 9.5 in jointed PCC pavement with tied PCC shoulders. A 40-year life-cycle economic analysis must be performed to determine the pavement type.

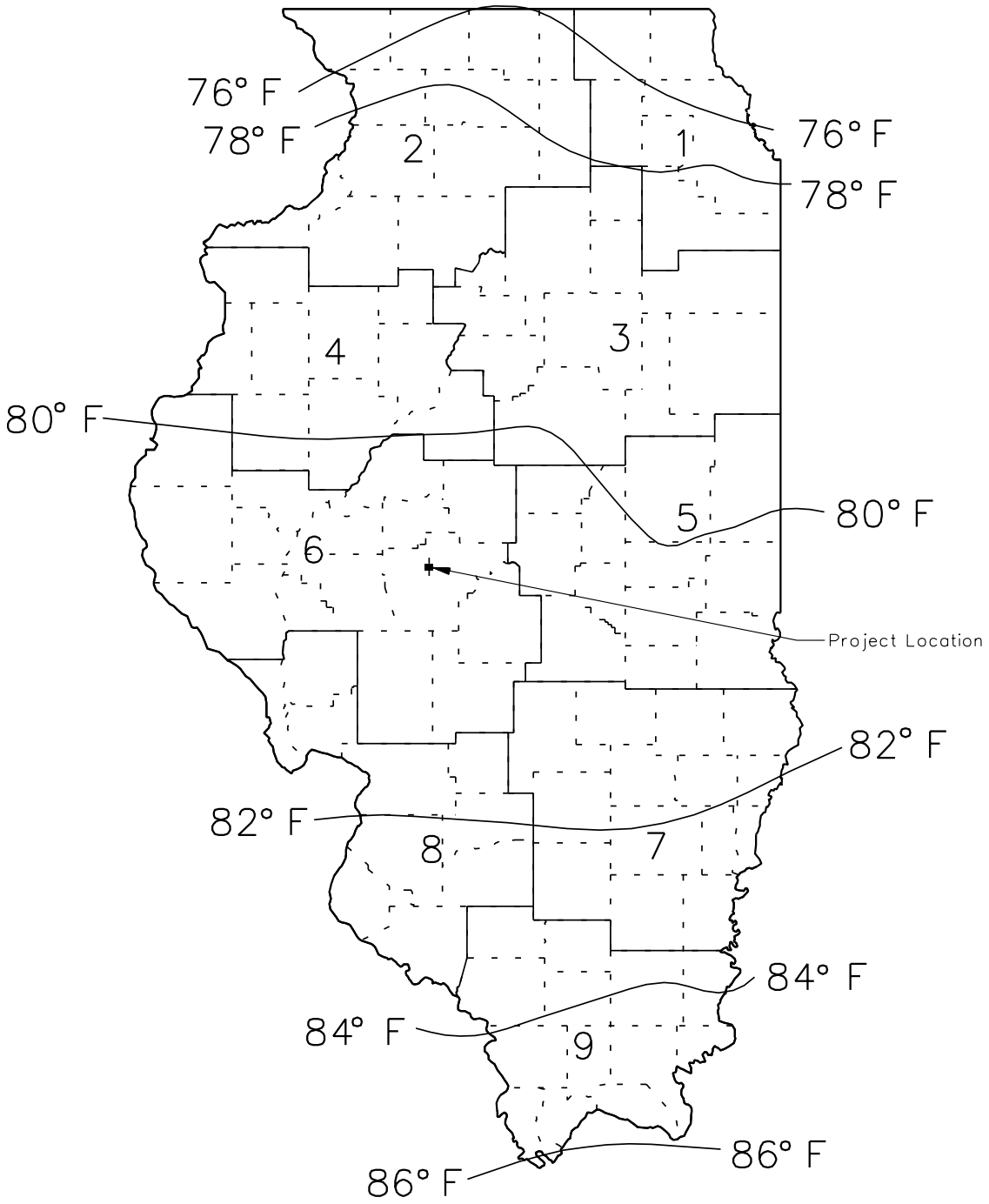
If a modified AASHTO rigid pavement design thickness was required to match an existing pavement using the above given factors, the following solution would apply:

Given: IBR = 3

Solution:

Step 1: The actual TF_R applies.

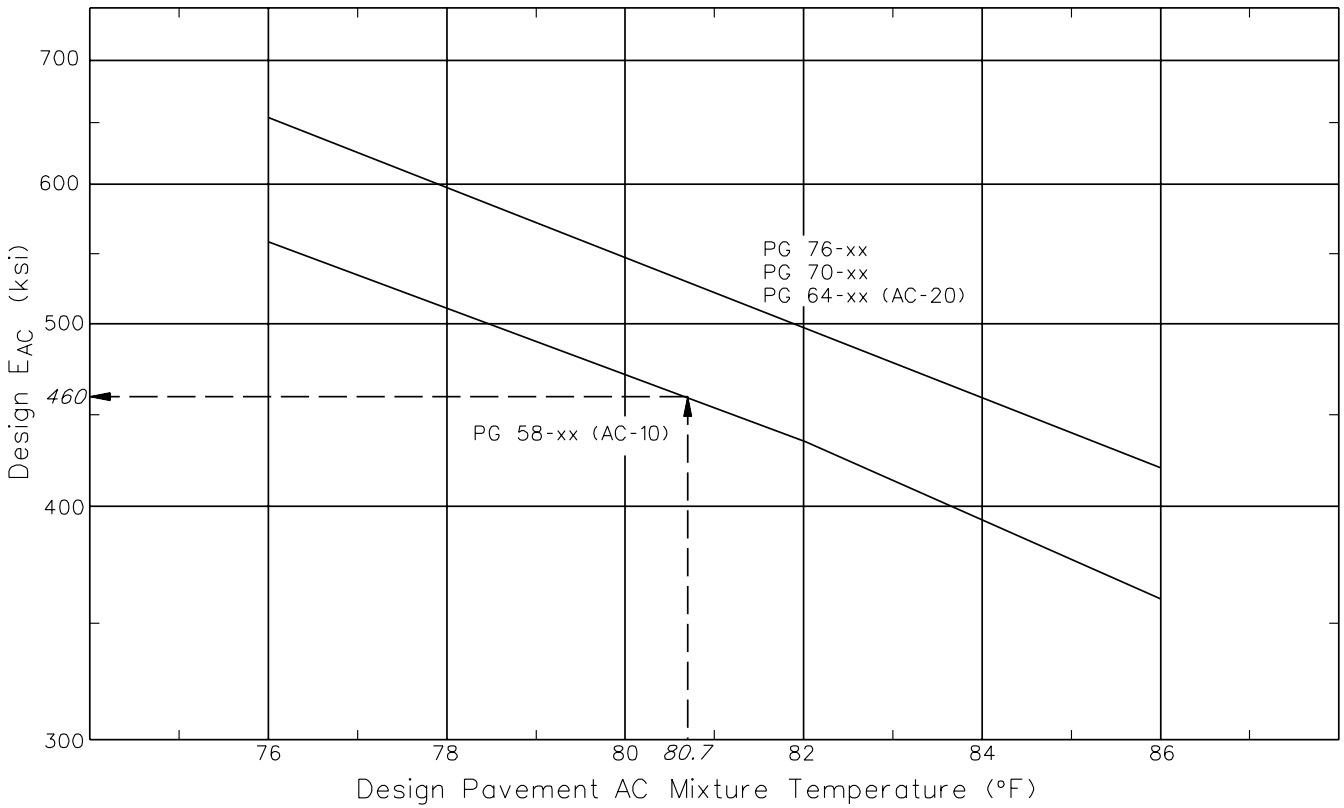
$TF_{R(A)}$ = 2.74



Note: The minimum design AC mixture temperature will be 76°F.

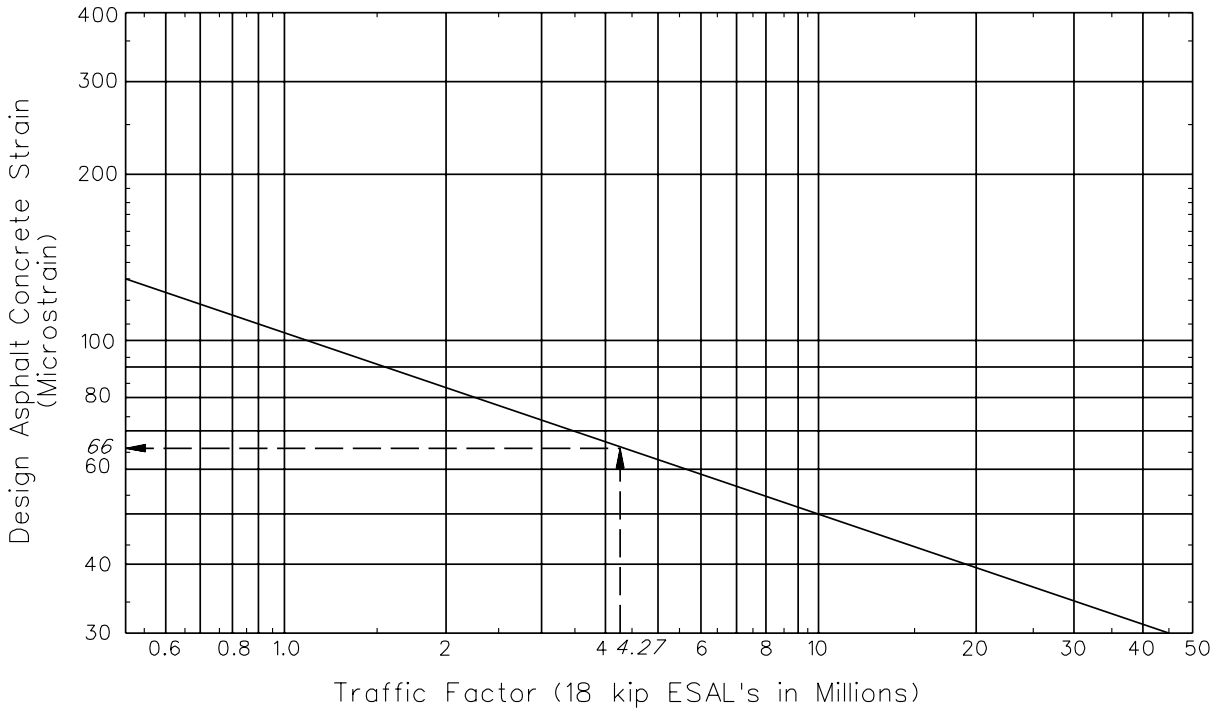
AC MIXTURE TEMPERATURE
(Mechanistic Design: Flexible Pavement)

Figure 54-9A



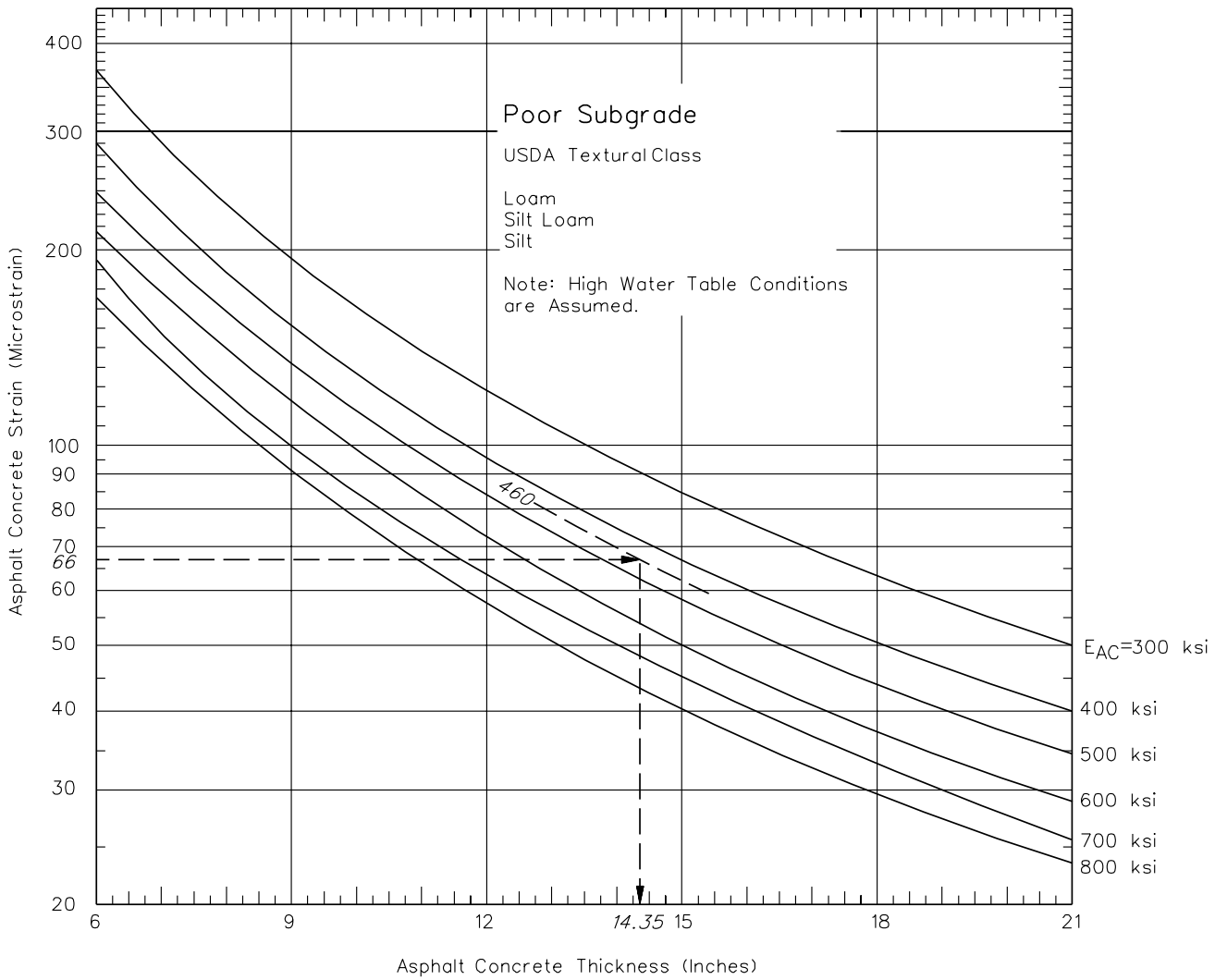
AC MIXTURE MODULUS (E_{AC})
(Mechanistic Design: Flexible Pavement)

Figure 54-9B



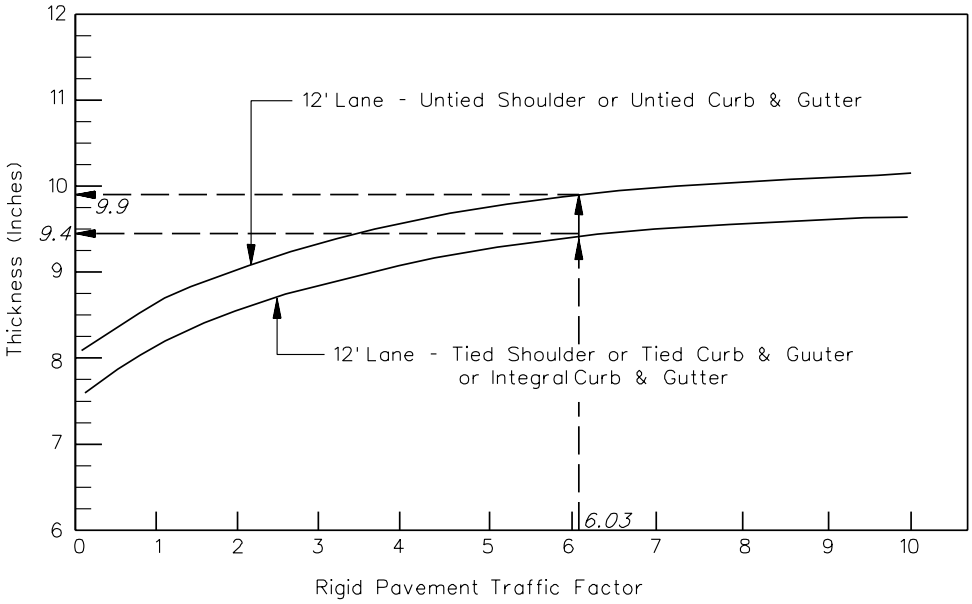
DESIGN AC STRAIN
(Mechanistic Design: Flexible Pavement)

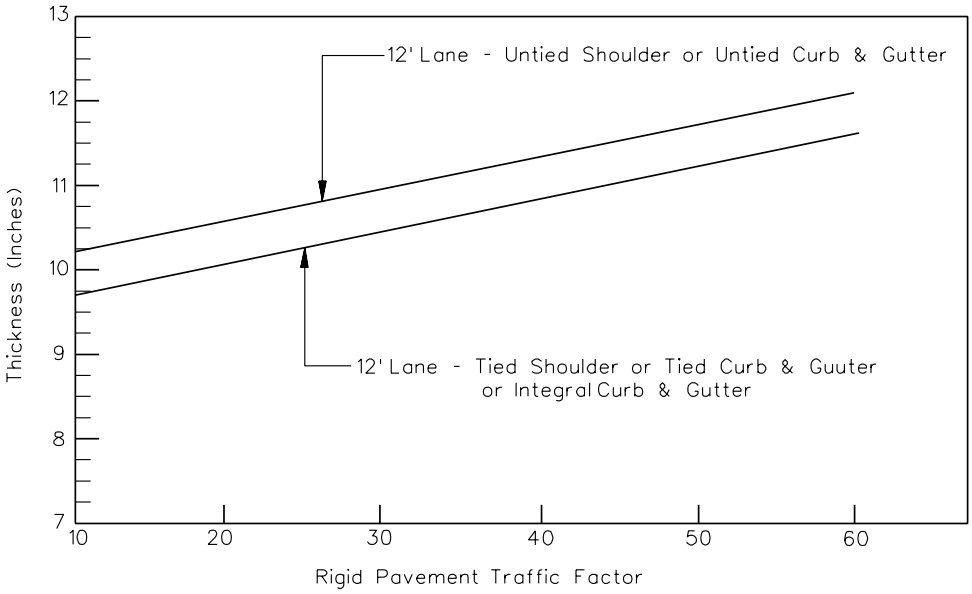
Figure 54-9C



AC THICKNESS DESIGN CHART
(Mechanistic Design: Flexible Pavement: SSR = Poor)

Figure 54-9D

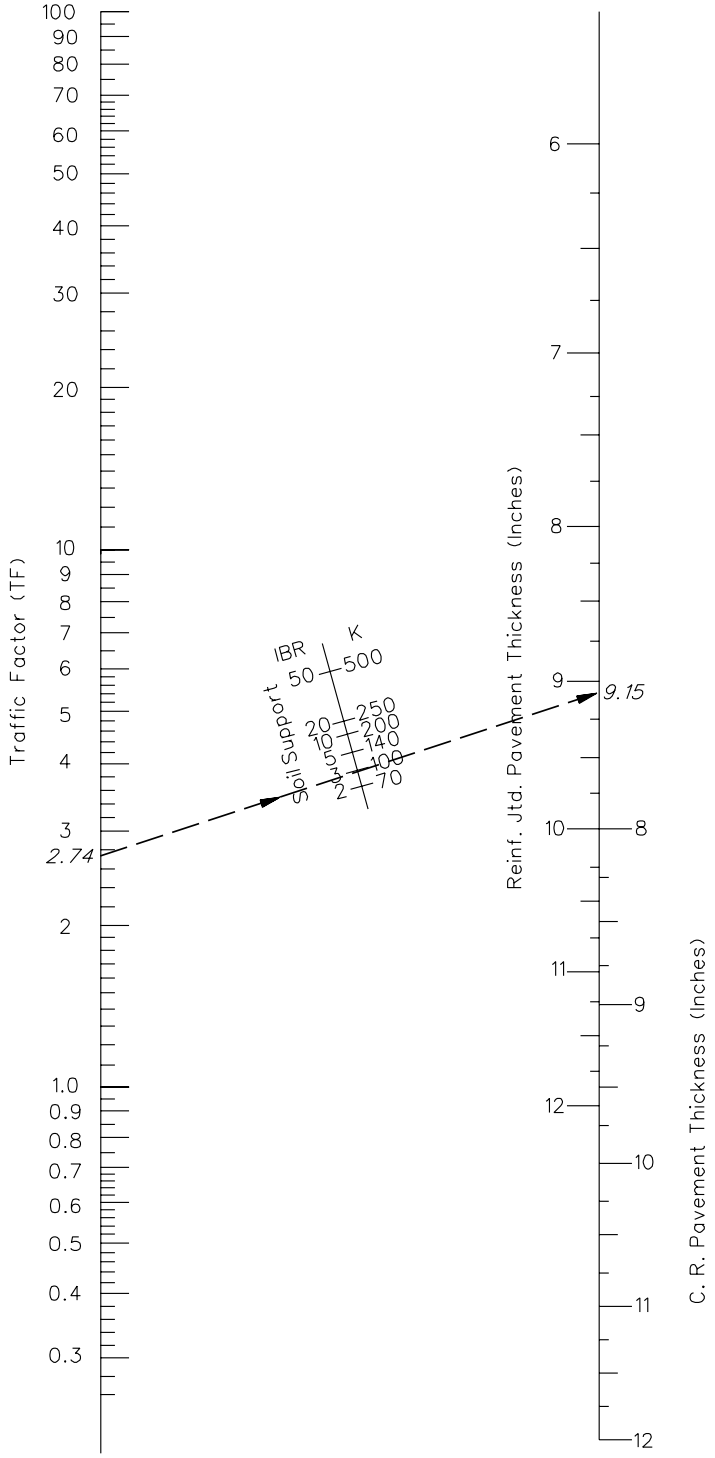




Note: Use of untied shoulder design requires BDE approval.

RIGID PAVEMENT DESIGN CHART
(Mechanistic Design: SSR = Poor)

Figure 54-9E



RIGID PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class I Facilities: JRCP and CRCP)

Figure 54-9F

Step 2: Using the $TF_{R(A)}$ and Figure 54-4J and an IBR of 3, determine the rigid pavement thickness. Round up to the nearest 0.25 in. See Figure 54-9F.

Thickness = 9.25 in (i.e., 9.15 in rounded up to 9.25 in)

Step 3: For a conventional flexible pavement, see Example 54-9.2.

Example 54-9.2

Given: Existing 2-lane rural State highway in central Sangamon County
being widened to 4 lanes – 12 ft widening each side (with resurfacing)
ADT (Design Year Traffic) PV = 17,225 SU = 360 MU = 360
Subgrade Support Rating = Poor IBR = 4
Asphalt Cement Type = PG58-xx (AC 10)

Because the design requires widening with resurfacing, the solution will involve preparing a mechanistic flexible, a modified AASHTO flexible, and a composite design. See Figure 54-1A.

Solution:

Step 1: The mechanistic flexible design will be the same as in Example 54-9.1.

Step 2: Determine the modified AASHTO flexible design. The actual flexible traffic factor will be used.

$TF_{F(A)}$ = 2.01 (from Example 54-9.1)

From Figure 54-5L, determine the flexible pavement structural number (SN_F).

SN_F = 4.4 (See Figure 54-9G)

From Note 1 in Figure 54-5R, the minimum SN_F for a multilane State highway is 5.0.

Using Equation 54-5.5, determine the layer thickness of the surface course, base course, and subbase course.

$$SN_F = a_1 D_1 + a_2 D_2 + a_3 D_3$$

From Figure 54-5N:

a_1 = 0.40 (Superpave Bituminous Concrete)
a_2 = 0.30 (Assumes Bituminous Stabilized Granular Material 1500 MS)
a_3 = 0.11 (Assumes Granular Material, Type B)

D_1 = 2.5 in (Policy resurfacing with widening)
D_3 = 4 in (Assumed)

$5.0 = (2.5 \bullet 0.4) + (0.3\ D_2) + (4 \bullet 0.11)$

$$D_2 = \frac{5.0 - (1.0) - (0.44)}{0.30} = 11.86 \text{ in use 12 in}$$

Check:

$2.5 \bullet 0.4 = 1.00$
$12 \bullet 0.3 = 3.60$
$4 \bullet 0.11 = \underline{0.44}$
$5.04 > 5.0$ — OK

From Figure 54-5R, minimum D_2 = 10 in — OK

Step 3: Determine the composite design. The actual traffic factor will be used.

$TR_{R(A)}$ = 2.74 (from Example 54-9.1)

From Figure 54-6A, determine the composite pavement structural number (SN_C).

SN_C = 3.55 (See Figure 54-9H)

Using Equation 54-6.3, determine the layer thickness:

$SN_C = 0.40\ D_S + 0.33\ D_B$

$$D_B = \frac{3.55 - (0.4 \bullet 2.5)}{0.33}$$

D_B = 7.72 in. From Figure 54-6D, minimum thickness is 8 in.

Results:

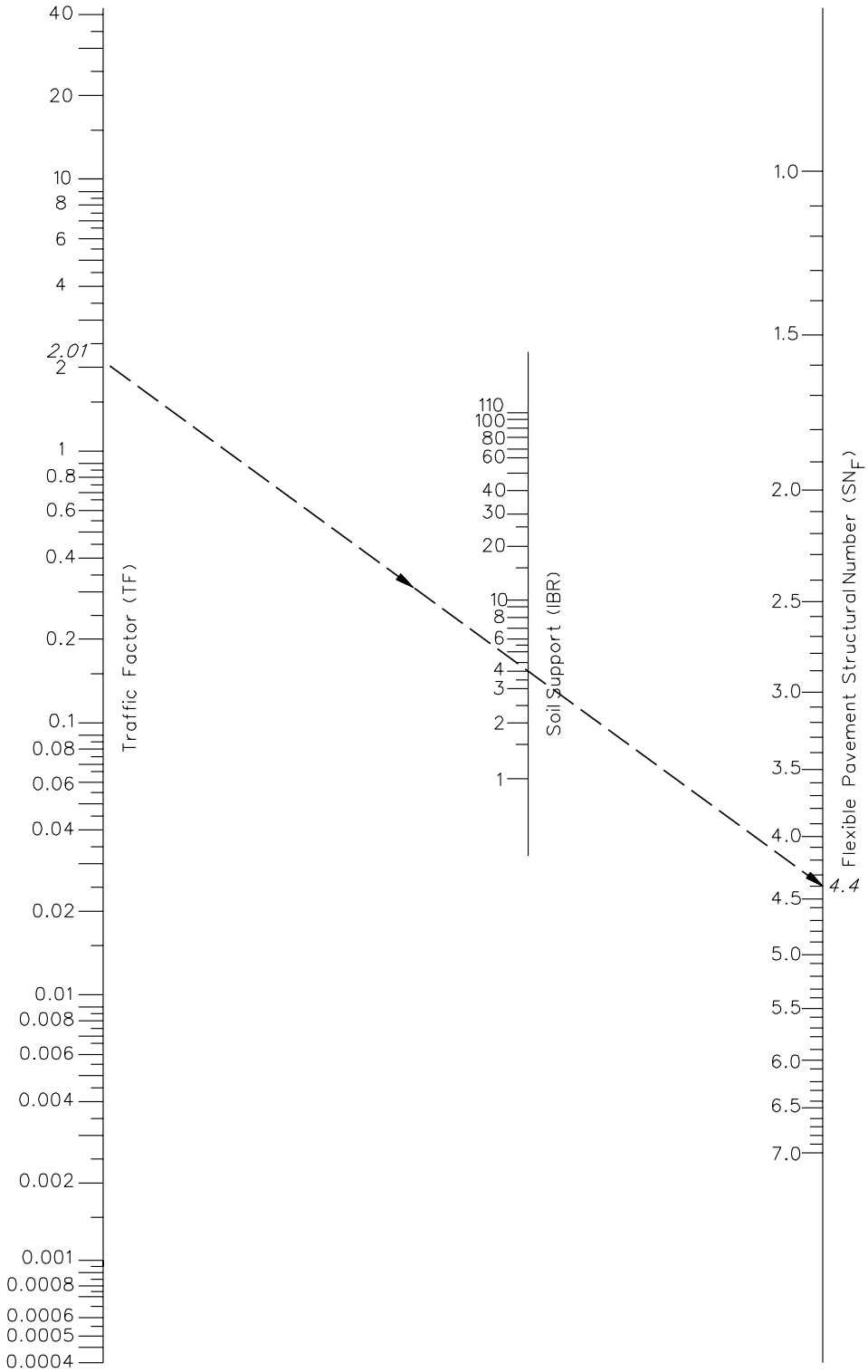
Mechanistic Flexible: 14.50 in Full-Depth Flexible using PG58-xx (AC 10)
12 in Lime-Modified Subgrade

Modified AASHTO Flexible: 2.5 in Superpave Surface Course
12 in Stabilized Base Course
4 in Aggregate Subbase

Composite Design: 2.5 in Superpave Surface Course
8 in PCC Base Course

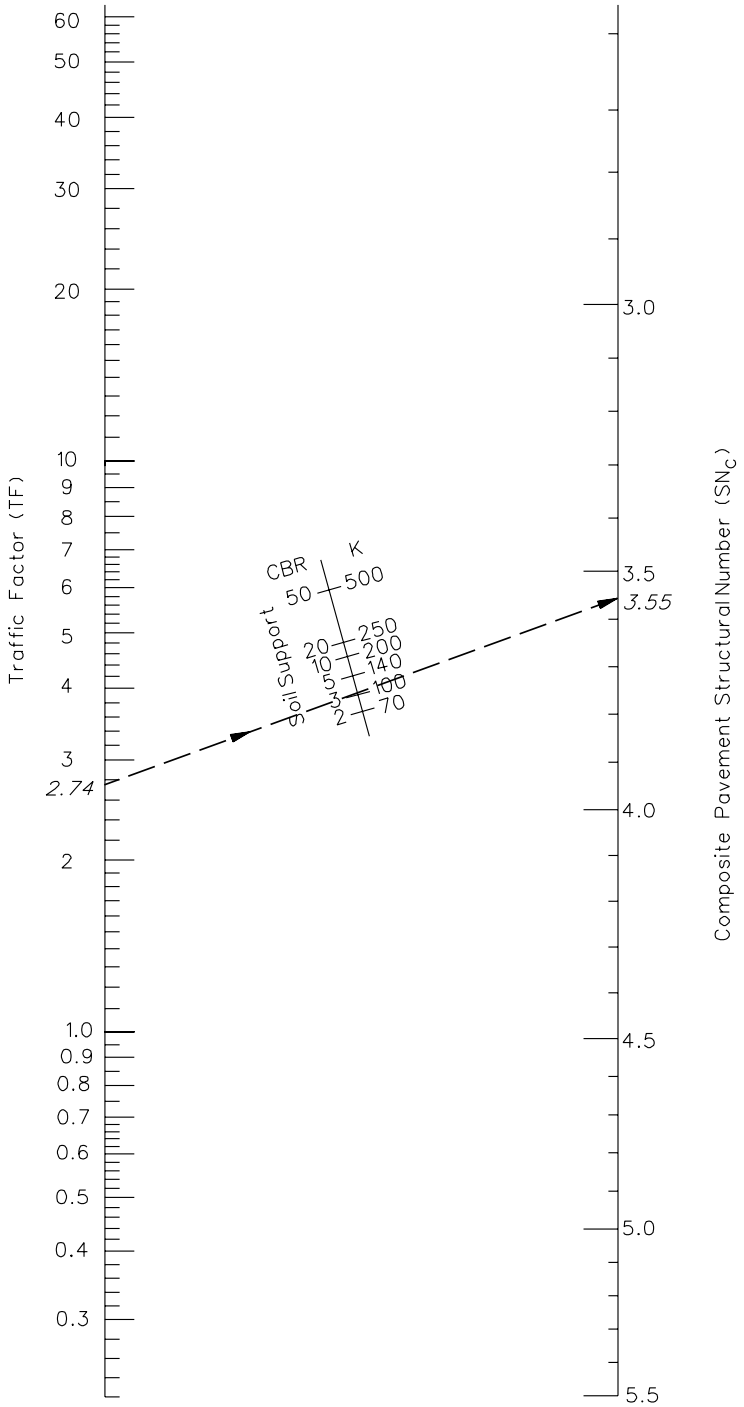
A first-cost economic analysis must be performed to determine the pavement type.

* * * * * * * * * *



FLEXIBLE PAVEMENT DESIGN NOMOGRAPH
(Modified AASHTO Design: Class I Facilities)

Figure 54-9G



COMPOSITE PAVEMENT DESIGN NOMOGRAPH
(Class I Facilities)

Figure 54-9H