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Virginia Department of Transportation

Pavement Design Guide for Subdivision and Secondary Roads

In Virginia

A companion reference to the Subdivision Street Requirements

Prepared by
Materials Division
Virginia Transportation Research Council
And
Secondary Roads Division

We Keep Virginia Moving VDOT

First Printing ~ October 1973
Revised March 1993
Revised January1996
(Revised 8/1/2000 for Superpave Mix)

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DISCLAIMER
AND
PRECEDENCE OF LOCAL JURISDICTION ORDINANCES

This guide is intended to aid professional personnel knowledgeable in the field of pavement design. Persons using this guide are responsible for its proper use and application. The Virginia Department of Transportation and individuals associated with the development of this material cannot be held responsible for improper use or application.

The pavement design procedures presented in this guide are for flexible pavements only and establish minimum requirements. However, acceptable methods are referenced for the design of rigid pavement. Where the subdivision ordinance of a locality has established a pavement design requirement that exceeds the pavement design obtained by these procedures, that design process shall govern. However, these procedures shall govern the design of pavements for roadways under Department jurisdiction.

ACKNOWLEDGMENTS

The Pavement Design Guide revision of May 1, 2000 introduces Superpave mix designations to the revision released in January 1996 that was completed by Dr. Mohamed K. Elfino, Mr. Roger C. Riner and Mr. David Shiells in cooperation with Mr. Kenneth M. Smith and Mr. David L. Camper of the Secondary Roads Division.

Comments and reviews were also received from the Land Development Section of the Northern Virginia District Office.

This document replaces three earlier documents designated VHRC 73-R18, VHRC 73-R21, and the 1993 and 1996 revisions for secondary and subdivision pavement design manuals, respectively.

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Introduction

The flexible pavement design method presented in this guide was developed by Dr. N. K. Vaswani, who based it on the original AASHO Road Test Results of 1962 and reflects Virginia's design experience. This guide is intended for the design of roadway pavements for new subdivision streets and for secondary roads.

Two design methods are included in this guide:

A. Conventional Pavement Design Method, which requires a rigorous pavement design procedure.

   The conventional flexible pavement design procedure may be divided into two parts:

   1. The evaluation of design variables:
      a. the traffic in terms of projected Average Daily Traffic (ADT)
      b. the soil support value of the subgrade.
   2. Design considerations:
      a. determination of the required Thickness Index of the pavement
      b. the selection of paving materials based on the sum of the products of their thickness and thickness equivalencies equaling or exceeding the required Thickness Index value.

B. Alternative Pavement Design Method, which allows use of predetermined pavement designs for qualifying, new subdivision streets.

Specifications And Additional Resources

Specifications for all materials, testing, construction, and installation can be found in the following Virginia Department of Transportation documents:

- Road and Bridge Specifications and appropriate supplemental specifications
- Virginia Test Methods Manual
- Road and Bridge Standards.

Metric Conversions

The following metric conversion factors shall be used throughout this document.

1 inch = 25 mm	1 pound mass = 454 grams
1 foot = 300 mm	1 pound Force = 4.448 Newton
1 mile = 1.6 km	1 pound/in sq. = 6.895 Pascal

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Discussion of Design Variables

Projected Traffic in Terms of Average Daily Traffic (ADT)

The method used to determine the Design ADT varies based on the project considered. Essentially, the methods are as follows:

A. New Subdivision Streets

The traffic volume for subdivision streets shall be developed as specified in the department's "Subdivision Street Requirements," subject to further adjustment as outlined in the "Flexible Pavement Design Worksheet for New Subdivision Streets" of Appendix IV.

B. Secondary Roads

Pavement design for existing Secondary Roads shall be based on the projected traffic volume for the midpoint of the 20 year design period (i.e. 10 years) after completion of roadway construction. A more complete discussion regarding this factor is found under the section "Design Procedures."

Soil Support Value (SSV) of the Roadway Subgrade Soil

The Soil Support Value of the subgrade soil is the product of the Design CBR and the soil resiliency factor for the soil encountered, as expressed in Equation 1. SSV is used in conjunction with the design traffic volume (Design ADT) to determine the minimum strength requirement (Required Thickness Index) for the pavement.

SSV = Design CBR x RF **Equation 1**

A. **California Bearing Ratio (CBR) of the Roadway Subgrade Soil**

The California Bearing Ratio (CBR) is the ratio of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed stone base material. The resistance of the crushed stone under standardized conditions is well established. The objective of a CBR test is to determine the relative resistance of the subgrade material under the same conditions.

The CBR of the subgrade soils is the principle component of the soil support value (SSV) used in flexible pavement design to determine the required pavement thickness index.

1. Test method

All CBR values are to be determined in accordance with "The Virginia Test Method for Conducting California Bearing Ratio Tests" (Designation VTM-8). For each roadway, a sufficient number of CBR tests must be conducted to determine the average CBR value for the various soil types anticipated to be in the subgrade.

2. Soil Sampling

Representative soil samples for CBR tests shall be taken from the top 12 inches of the finished subgrade by a qualified soils technician or engineer. If the subgrade soil has been identified as fine grained (i.e. more than 35% passing the 200 sieve according to AASHTO Classification System), Atterberg tests (Liquid and Plastic limits) shall be run in addition to the normal sieve analysis and CBR tests, so that an assessment of the potential need of subgrade stabilization or undercut can be made. If indications of unstable conditions for construction equipment are present, natural moisture content determinations should also be made to aid in determining the appropriate method of stabilization/undercut by comparison with the Atterberg Limits of the soils.

a. Soil Sample Frequency and CBR Tests for Design of New Subdivision Streets

1) For streets less than 200 feet in length, one soil sample for conducting AASHTO soil classification and CBR test is required.

2) For streets 200 to 500 feet in length, at least two soil samples for conducting AASHTO soil classification and CBR tests is required, which includes one at each intersection of an existing state road.

3) For longer streets, one soil sample shall be taken at each intersection with an existing state road plus one test sample every 500 feet in length, or portion thereof, is required for conducting AASHTO soil classification and CBR tests.

b. Soil Sample Frequency and CBR Tests for Design of Secondary Road Projects

The District Materials Engineer should assure that sufficient CBR tests are made to represent the various soils encountered on the project. This is to assure that a reasonable estimate of the average subgrade CBR is determined. Frequency of soil samples for secondary road projects shall be determined by the District Materials Engineer.

3. Relationship of Design CBR to Number of Tests Performed

Design CBR is a factor of the number of CBR test results available.

a. For five tests or less, the design CBR shall be the mathematical average of these tests multiplied by two-thirds, rejecting any obviously extreme value.

b. For more than five tests, the highest and lowest CBR values are rejected and the Design CBR value shall be the mathematical average of remaining CBR test values multiplied by a factor of two-thirds.

The two-thirds factor provides the necessary safety margin to compensate for any non-uniformity of the soil, and for any low test results not considered when computing the average of the CBR sample values.

Furthermore, four days of soaking, as specified in the CBR test method, does not necessarily give the minimum CBR strength of some soils. Thus, the two-thirds factor would compensate for all such variations.

4. Construction Factors

The design CBR determination process assumes that the properly compacted subgrade soil will produce a stable platform for pavement construction. If an unstable subgrade is encountered, it should be undercut to a firm foundation and be replaced with adequately compacted soil or aggregate materials or otherwise be stabilized by lime, cement, or the use of a geotextile to produce a stable platform for construction equipment.

Subgrade compaction should be verified every 1000 feet before placement of the subbase/base layer, with a minimum of two compaction tests per roadway. The compaction shall be 100 percent of standard proctor for all but gravely soils. Refer to Section 305.03 of The Road and Bridge Specification for compaction requirements for gravely soils.

B. **Resiliency Factor (RF)**

1. When soil is repeatedly loaded, it undergoes both recoverable (elastic) and permanent (plastic) deformation. The Resiliency Factor is a relative value that reflects a soil's elastic deformation characteristics and its ability to withstand repeated loading.

2. The smaller the elastic deformation the higher the degree of resiliency, and the better the subgrade support. The subgrade soils in Virginia are divided into five load support characteristics based on their degree of resiliency (see Table 1). The resiliency factor of a given soil can be obtained most precisely if the soil classification is known.

   Predicted regional resiliency factors are shown in Appendix I. These factors are valid only when the in-situ moisture content of the subgrade soil is at or near optimum moisture content.

   The optimum moisture content is determined by AASHTO Test Method Designation T-99, Method A, as modified by VTM-1. Additional moisture content testing should be conducted during construction if visual observations dictate. Soils with a moisture content of 20 percent above optimum may need special treatment or may need to be undercut and replaced.

3. Evaluation of Soil Resiliency Factors

   Three primary factors are considered in the evaluation of Soil Resiliency Factors:

   a. Soil Classification (based on AASHTO Designation M-145)

   b. Sand content (percent retained on #200 sieve)

   c. Mica content

      Determination of the mica content is to be done by visual observations. Borderline cases of low or high mica content will be decided by the District Materials Engineer of the Virginia Department of Transportation.

      Use Table 1 to determine the soil resiliency factor, proceeding from the top to the bottom and obtain the correct resiliency factor by the process of elimination.

Table 1
Classification, Load Support Characteristic, and Resiliency Factor
of
Common Soils in Virginia

Mica Content	Soil Classification	Load Support Characteristic	Resiliency Factor
Without Mica	a) A-1 & A-3 Soils b) A-4, A-5 and A-7 soils having a sand content greater than 60%	Excellent	3.0
	A-2, A-4, A-5, A-6 and A-7 soils having a sand content between 40% and 60%.	Good	2.5
	A-2, A-4, A-5, A-6 and A-7 soils having a sand content less than 40%	Average	2.0
With Mica	a) A-7-5 soil. b) soil with low or trace mica content and having an average group index (GI) below 5 c) A-2, A-5, A-6, and A-7-6 soils with low or trace mica content	Poor	1.5
	Soils not within the category of Medium Low Resiliency Soils and also contain mica.	Very Poor	1.0

Discussion of The Flexible Pavement Design Method

Subdivision and Secondary roads in Virginia usually consist of two or three layers of different materials of varying depth over the subgrade. The two-and three-layer systems are shown in Figure 1.

Figure 1 - Illustration of 2 and 3 layer pavement systems.

2 Layer System		
Pavement Layer	Thickness (inches)	Thickness Equivalency
Surface	h_1	a_1
Base	h_2	a_2
Subgrade		

3 Layer System		
Pavement Layer	Thickness (inches)	Thickness Equivalency
Surface	h_1	a_1
Base	h_2	a_2
Subbase	h_3	a_3
Subgrade		

The soil support value (SSV) and the design traffic volume (Design ADT) are used with the nomograph (Appendix II) to determine the minimum strength requirement of the pavement, termed the Required Thickness Index, expressed as D_R. This minimum strength requirement is satisfied by providing materials of known strength indices, termed Thickness Equivalencies (a), sufficient thickness (h) to develop a Pavement Thickness Index (D_P), which will equal or exceed D_R. These variables are discussed in the following sections.

A. **Thickness Equivalency Value (a_x)**

The thickness equivalency value of a given material (a_x, where x is the identity of the pavement layer) is the relative index of strength per inch of depth contributed by the material to the strength of the pavement. Its value depends on the type of the material and its location in the pavement structure. The thickness equivalency values of paving materials are shown in Appendix III.

The thickness equivalencies of some materials differ depending on their location in the pavement structure; higher when used in the base than when used in the subbase. For example, untreated crushed aggregate has a thickness equivalency value of 0.6 when used in the subbase course and 1.0 when used in the base course. Cement treated aggregate and select materials types I and II are considered similarly, see Appendix III.

Investigation and experience has shown that the strength of cement treated native soils or borrow materials (e.g., select materials type II and select borrow) vary depending upon their physical and chemical properties. For consistency and simplicity, the thickness equivalencies of such materials are assumed to be the same whether they are placed in the base or in the subbase.

In 2-layer pavement systems, if the thickness of the lower layer is 8 inches or less, the lower layer is designated the base layer. However, if the thickness is greater than 8 inches, that portion which exceeds 8 inches in thickness is considered a subbase layer and the pavement structure computed as a 3-layer system, with the subbase layer thickness being the thickness of the lower layer reduced by 8 inches.

Example: In a 2-layer system having 12 inches of aggregate in the lower layer, the Base is treated as 8" with an equivalency of 1.0 and a Subbase of 4" with an equivalency of 0.6
(i.e. $h_2 = 8$ inches, $a_2 = 1.0$ and $h_3 = 4$ inches , $a_3 = 0.6$).

The thickness equivalency values of new paving materials must be evaluated relative to established thickness equivalencies as each material is introduced.

Note: Subgrade soils that are very weak or have a very low resiliency factor (i.e. SSV ≤ 2) should be stabilized or under cut.

B. **Thickness Index Value (D)**

The Thickness Index (D) is the total strength of the pavement based on its resistance to a deflection caused by a wheel load. The minimum thickness index required, based on the SSV of the subgrade and design traffic volume (Design ADT), is denoted with the symbol D_R and is obtained from the nomograph (Appendix II). The thickness index value of a pavement design is denoted by the symbol D_P and is obtained by Equation 2 below. A potentially acceptable pavement design is derived when D_P equals or exceeds D_R (i.e. $D_P \geq D_R$).

$$D_P = a_1h_1 + a_2h_2 + a_3h_3 + \ldots + a_xh_x \qquad \textbf{Equation 2}$$

Where: a_1, a_2, and a_3 are the thickness equivalencies of the surface, base and subbase layers, and h_1, h_2, and h_3 represent the thickness in inches of the surface, base, and subbase layers, respectively. In the case of a two-layer system a subbase may not be provided; in this instance, $a_3h_3 = 0$.

Figure 2 - Illustration of a 3-layer pavement design using values from Appendix III in Equation 2.

Pavement Layer	Material	Thickness inches (h_x)	Thickness Equivalency Value (a_x)	(h_x) x (a_x)
Surface	**165 #/SY Asphalt Concrete SM-9.5A**	1.5	2.25 [1]	3.38
Base	**330 #/SY Asphalt Concrete BM-25.0**	3.0	2.25	6.75
Subbase	**Untreated Aggregate (21B)**	6.0	0.60	3.6
Subgrade		$D_P = a_1h_1 + a_2h_2 + a_3h_3 =$		13.73

[1] Note: The higher thickness equivalency value is used for the surface and base material because the combined thickness of the asphalt concrete equals 4.5 inches. Refer to footnote, Appendix III

Design Procedures

New subdivision street pavement designs are to be developed using the “Flexible Pavement Design Worksheet for New Subdivision Streets” (Appendix IV), which the developer shall submit with the design documents for each new subdivision street. Certain new subdivision streets (with a low traffic volume) may qualify to use the Alternative Pavement Design Method.

Pavement designs for secondary road projects, including developer projects augmenting, realigning, or relocating secondary roads, are to be developed using the Conventional Pavement Design Method.

Conventional Pavement Design Method

A. **Determination of Design Traffic (Design ADT)**

The Design ADT used to determine D_R from the nomograph in Appendix II, assumes the traffic volume is equally distributed in both directions. In addition the lane distribution shall be considered as follows:

a. The Design ADT factor shall be the full value determined in this section for all new subdivision streets and two-lane secondary road facilities (one lane in each direction), including the initial two lane phase of a four lane facility when that phase is expected to sustain two-way traffic for an appreciable length of time.

b. The Design ADT factor, except as restricted in paragraph a, shall be 80% for 4-lane and 70% for 6-lane facilities of the Design ADT value.

For traffic volumes exceeding 10,000 ADT, the actual truck count and classification needs to be determined and serious consideration shall be given to designing the pavement as a primary road facility rather than as a secondary road or new subdivision street. A truck equivalency factor may be used to convert the truck traffic to an 18 Kip Equivalent Single Axle Load (ESAL), using 0.37 for each single unit truck and 1.28 for each tractor trailer truck. Designers should check with the District Materials Engineers for updated equivalency factors.

Once the ESAL's are available, the pavement can be designed using the ”1993 AASHTO Guide for Pavement Structures."

1. **Design ADT for New Subdivision Streets**

Design ADT for new subdivision streets shall be determined as described in the current edition of the department’s Subdivision Street Requirements, subject to any adjustment as may be indicated in Step 1 of the “Flexible Pavement Design Worksheet for New Subdivision Streets” (Appendix IV) and as further explained in paragraph 3, “Design ADT When Percent Heavy Commercial Vehicles (%HCV) Exceeds 5.0%.” Therein, the term ‘present traffic’ shall be synonymous with the term ‘projected traffic’ when new subdivision streets are considered.

2. Design ADT for Secondary Roads

The Design ADT for an improvement to the secondary roads system shall be determined by Equation 3:

Design ADT $_{(n)}$ = Present ADT x $[1 +(GR.)]^n$ Equation 3

Where: Design ADT is the Average Daily Traffic volume projected for the design volume year (typically the 10th year after construction is complete) and "n" is the number of years between the design volume year and the year of the present traffic volume (ADT).

The Present ADT is the current traffic volume (ADT) in both directions, determined from an actual traffic count or from preliminary engineering estimates, provided/approved by VDOT's Traffic Engineering or Transportation Planning Divisions.

GR. is the Growth Rate percentage expressed as a decimal (i.e. 5% GR. = 0.05), which may be based on actual historical traffic data or from estimates made by Traffic Engineering Division. The expression $[1 +(GR.)]^n$ yields the "Growth Factor" based on the anticipated annual rate of growth of traffic.

Example: If the Present ADT = 700 for Year 1995, the GR. = 3.6%, and the Roadway Construction is to be completed in Year 1998.

Then: 10th Year after Construction = 1998 + 10 = 2008;

Thus, n = 2008 - 1995 = 13 and Equation 3 yields:

Design ADT_{13} = 700 x $[1 +(0.036)]^{13}$ = 700 x $(1.036)^{13}$
= 700 x (1.584) = 1109 ADT in Year 2008

3. **Design ADT When Percent Heavy Commercial Vehicles (%HCV) Exceeds 5.0%**

The nomograph in Appendix II assumes the number of Heavy Commercial Vehicles (HCV), defined as trucks, buses, etc., having 2 or more axles and 6 or more tires, does not exceed 5.0% of the total traffic volume (ADT). When the design traffic volume includes more than 5.0% HCV, each heavy commercial vehicle above the 5.0% level is considered equal to twenty (20) typical (i.e. non-HCV) vehicles. An Equivalent Present Traffic volume (EPT) representing this adjustment is calculated by Equation 4, the results of which are to be substituted for the Present ADT value used in Equation 3.

EPT = Pres. ADT + (20 x Number of HCV over 5.0%) Equation 4

{Note: Number of HCVs over 5.0% = (% HCV - 5.0%) x Present ADT, where (% HCV - 5.0%) is expressed as a whole number without units.}

Example: If Present Traffic Volume = 1000 ADT, Percent Trucks = 8 %
Using Equation 4:
EPT = 1000 + {20 x [1000 x (0.08-0.05)]}
= 1000 + [20 x (1000 x 0.03)]
= 1000 + (20 x 30)
= 1000 + 600 = 1600 ADT

B. **Determination of Design CBR, Resiliency Factor (RF), and Soil Support Value (SSV)**

1. The Design CBR, as discussed earlier, is the product of the average values of the CBR test results and a safety factor of 2/3, expressed as Equation 5.

Design CBR = Average CBR x 2/3 **Equation 5**

2. Determination of Resiliency Factor (RF)

   The Resiliency Factor (RF) may be determined by one of the following methods:

   a. Table 1
   b. Appendix I - Predicted Regional Resiliency Factors, which are shown graphically for the state and in a listing by county. These values are to be considered maximum values unless otherwise approved by the District Materials Engineer.
   c. Obtained from the District Materials Engineer.

3. Determination of Soil Support Value (SSV)

   The Soil Support Value (SSV) is the product of the Design CBR and RF, as expressed in Equation 1 (SSV = Design CBR x RF), and has a maximum value of 30.

4. Preliminary pavement designs may use the predicted SSV values from Appendix I. However, when the soil moisture content exceeds the plastic limit, and approaches the liquid limit, the predicted values in Appendix I should not be used and a maximum SSV of 2 should be used. Pavement designs for new subdivision streets shall be considered preliminary designs, **not approved for construction**, until substantiated by acceptable test results of the subgrade soil. Approval of the final design shall be obtained prior to construction of the pavement.

C. **Determination of Required Thickness Index (D_R)**

The required thickness index (D_R) is determined from the nomograph in Appendix II, by projecting a straight line from the Soil Support Value (SSV), through the Design ADT value, to intersect the Required Thickness Index scale, from which the minimum required Thickness Index (D_R) is read.

D. **Choice of Materials and Pavement Layer Thickness**

After D_R is determined, the pavement structure design can be derived, as earlier discussed and illustrated in Figure 2, subject to the factors discussed in the sections "Design Considerations" and "Drainage Considerations for Flexible and Rigid Pavements."

Alternative Pavement Design Method

Acceptable, pavement designs for low traffic volume (Design ADT $\leq$ 400), new subdivision streets are shown in Appendix IV (Tables A and B). These predetermined pavement designs may only be used in conjunction with the "Flexible Pavement Design Worksheet for New Subdivision Streets" (Step 3A) provided in Appendix IV.

For new subdivision streets and secondary road projects having a Design ADT greater than 400, pavement designs must be determined using the Conventional Pavement Design Method, which is accommodated in Step 3B of the "Flexible Pavement Design Worksheet for New Subdivision Streets."

DESIGN CONSIDERATIONS

After the Required Thickness Index (D_R) of the pavement has been determined, the choice of materials and the thickness of the layers for the pavement design are primarily at the discretion of the pavement designer. These decisions are usually based on dollar value, structural adequacy, pavement serviceability, historical data, experience, availability of materials, ease of construction, maintenance of traffic, etc.

A. Practical Consideration for Thickness of Layers

The thickness of layers are related to practical considerations. The following are some of the physical characteristics of materials to be considered:

1. The maximum obtainable density of aggregates and asphalt concretes.
2. The stability of asphalt concrete mixes.
3. The preparation of the subgrade (by providing a stabilized subgrade layer).
4. The weakness of thin layers of fairly rigid materials like asphalt concrete, and stabilized soil layers.
5. Nominal aggregate size of the asphalt mix.

B. Recommended Minimum and Maximum Limits

The recommended minimum and maximum limits for the thickness of pavement layers are shown in Appendix III, however, not less than 4 inches of asphalt concrete must be placed over CTA base/subbase material as the surface/intermediate layer(s). In addition, the following criteria shall be considered:

1. Maximum thickness of an asphalt concrete surface shall be 2 inches, except as follows:
   a. When staged surfacing is required, a maximum of 2½ inches of surface is allowable, provided the thickness of the final layer is not less than one inch.
   b. A maximum thickness of 3 inches is allowable when using Type IM-19.0, A.
   c. Six inches of full-depth asphalt concrete pavement is the minimum recommended allowable thickness (surface mix and base mix) when placed directly on the prepared subgrade, except as may be permitted by Tables A and B in Appendix IV for qualifying new subdivision streets.
2. The maximum thickness of aggregate material used as the base layer shall be 8 inches before considering any additional thickness as a subbase material.
3. Maximum combined thickness of the base & subbase aggregate layers is 12 inches.

General Notes and Specifications

The following recommendations are based on the department's design and construction experience.

A. Subgrade, subgrade treatment, or subbase

1. The preparation of the subgrade should be in accordance with the current Virginia Department of Transportation's Road and Bridge Specifications.
2. Local materials, free of organic matter that normally would be considered unsatisfactory for use in construction, may be acceptable when stabilized with a stabilizing agent, such as cement or lime. Lime or cement stabilized subgrades provide a rigid foundation that is a good investment when the traffic is likely to increase considerably. Additionally, this practice may prove to be the most economical.
3. For soils having a high moisture content, treatment with lime (1% to 2% by weight), in lieu of undercutting, may be appropriate. However, such lime treatment is not to be considered part of the pavement structure.
4. When cement stabilized subgrade is recommended, approximately 10% by volume should be used. When lime is the subgrade stabilizing agent, approximately 5% by weight should be used. If Select Material, Type II is used, cement stabilization is required.

   In all cases, representative samples of the soil should be submitted for testing in accordance with the appropriate Virginia Test Method.

   If soil stabilization (cement or lime) is used, verification of the quantity of stabilizing agent actually used will be required through the District Materials Engineer.
5. Cement stabilized aggregate, when used over very weak soils (SSV $\leq$ 2), should be placed over a minimum of 4 inches of untreated aggregate.
6. Soil stabilization should be completed before the temperature drops below 40 degrees Fahrenheit and, for best results, covered immediately with an untreated aggregate course (provided that construction equipment does not damage the stabilized course) or an asphalt cure.
7. Geotextiles should be considered for subgrade stabilization, when the areas in question represent a relatively small amount of the subgrade soils. This may prove more economically feasible, in isolated cases, than the alternatives discussed above. Refer to VDOT special provisions regarding geotextiles for subgrade stabilization to select the proper strength requirements.

B. Aggregate Courses

1. Aggregate Base Materials are of two types and various sizes as shown below:

   a. Type I - Aggregate base material (crushed material only) using #21-A, #21-B or #22 size aggregate.

   b. Type II Aggregate base material (crushed or uncrushed material) using #21-A, or #22 size aggregate.

   When aggregate base material Type I is specified, the coarser graded aggregate, size #21-B, is preferable.

2. All untreated aggregate used in base or subbase courses shall be #21-B gradation, except on roads with an ADT of 1000 or less; where #21-A or #21-B may be used. When the #21-B gradation is used, drainage concerns must be addressed. Use #21-A gradation if the aggregate is cement stabilized.

3. When a local aggregate material is stabilized with cement, approximately 8% by volume should be used. When lime is used as the stabilizing agent, approximately 4% by weight should be used.

   In all cases, however, representative samples of the material should be submitted for testing to determine the correct percentage of stabilizing agent. A minimum stabilized depth of 6 inches is required.

C. Surface course

An asphalt concrete surface course of 165 pounds per square yard (1½ inches thick), placed over a covered prime coat, may be used in lieu of a Class "C" or Class "D" blotted seal or a prime and double seal surface treatment (as specified in all current L&D I&I memoranda).

D. Minimum Designs (Limited to Secondary Road Improvement Projects with ADT ≤ 50.)

1. The base should consist of a minimum of 6 inches aggregate base material, Types I or II, yielding a thickness index of 6.

2. The following minimum recommended design shall only be used when the road is to be surface treated.

   As an alternative, in areas containing borderline local materials but not meeting the specifications for Type I or II base materials, the base may consist of a minimum depth of 6 inches of select borrow having a minimum CBR value of 20. The select borrow base should be stabilized with cement, 8% to 10% by volume, or approximately 40 pounds of cement per square yard. The cement stabilized borrow should be surfaced with a curing agent and double seal.

DESIGN METHODS FOR RIGID PAVEMENT

The following rigid pavement design methods are acceptable: PCA, ACPA, AASHTO. Stabilized aggregate material or stabilized soil should be used under plain jointed concrete pavement when the support soils are weak and truck traffic (%HCV) exceeds 5% of the total traffic volume.

In case of very weak or very low resiliency soils having a CBR values less than 2, the soil should be stabilized for a depth of six inches with cement, 10% to 12% by volume. Concrete shall be Class A-3 paving concrete according to the current Virginia Department of Transportation's Road and Bridge Specifications and appropriate supplemental specifications. The concrete pavement shall be plain Portland cement concrete with a maximum transverse joint spacing of 20 feet (recommended joint spacing: 15 feet) or jointed reinforced concrete with maximum transverse joint spacing of 40 feet. Continuously reinforced concrete is considered an acceptable option.

DRAINAGE CONSIDERATIONS FOR FLEXIBLE AND RIGID PAVEMENTS

The presence of water within the pavement structure has a detrimental effect on pavement performance under anticipated traffic loads. The following are guidelines to minimize these effects:

a) Standard UD-2 underdrains and outlets are required on all raised grass medians to prevent water infiltration through or under the pavement structure. Refer to the current VDOT Road and Bridge Standards for installation details.

b) When Aggregate Base Material, Type I, Size #21-B is used as an untreated aggregate base or subbase, it should connected to a longitudinal pavement edge drain (UD-4) with outlets to provide for positive lateral drainage on all roadways with a design ADT of 1,000 vehicles per day or greater. (Refer to the current VDOT Road and Bridge Standards for installation details). Other drainage layers can also be used.

c) Undercutting, transverse drains, stabilization, and special design surface and subsurface drainage installations should be considered whenever necessary to minimize the adverse impacts of subsurface water on the stability and strength of the pavement structure.

d) Standard CD-1 & 2 should be considered for use with all types of unstabilized aggregates.

e) For roadways with a design ADT of 20,000 vehicles per day or greater, an Open Graded Drainage Layer (OGDL) shall be used, placed on not less than 6-inches of stabilized material and connected to a UD-4 edge drain.

For additional information see Report Number FHWA-TS-80-224, Highway Sub-drainage Design from the US Department of Transportation, Federal Highway Administration.

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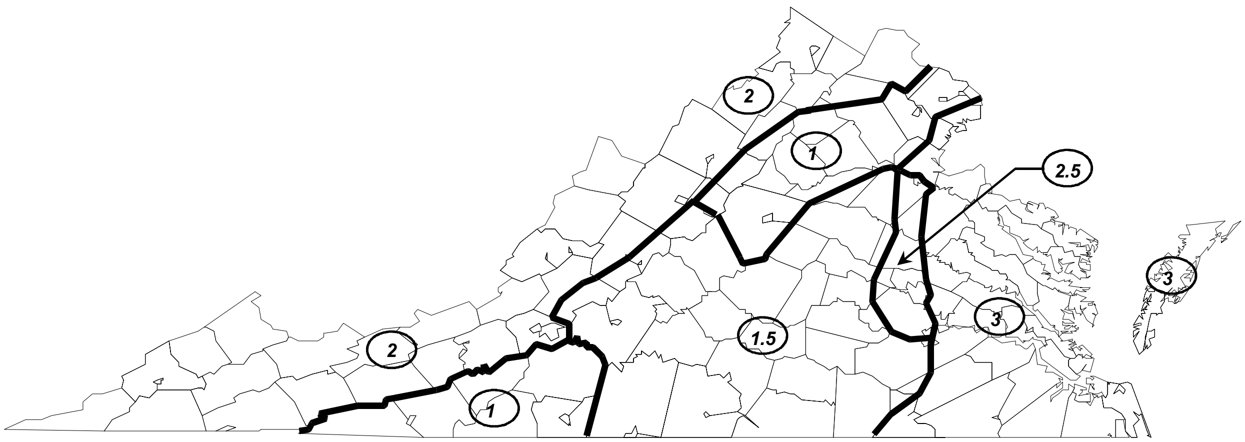
APPENDIX I
Predicted Resiliency Factors, CBR and Soil Support Values

Values may be used for preliminary pavement design only. Final designs must be based on soil tests.

NOTE

Appendix I shall not be used and SSV shall not exceed a value of 2 when the moisture content of the soil exceeds the plastic limit, approaching the liquid limit (e.g. high water table or other reasons).



Regional Chart of Soil Resiliency Factors

Table of Values by County

County Code	County		RF	CBR	SSV
00	Arlington	W. of Rt. 95	1.0	7	7
		E. of Rt. 95	3.0	10	30
01	Accomack		3.0	7	21
02	Albemarle	E. of Rt. 29	1.0	4	4
		W. of Rt. 29	1.0	5	5
03	Alleghany		2.0	5	10
04	Amelia		1.5	6	9
05	Amherst		1.5	5	7.5
06	Appomattox		1.5	5	7.5
07	Augusta		2.0	6	12
08	Bath		2.0	5	10
09	Bedford		1.5	5	7.5
10	Bland		2.0	6	12
11	Botetourt.	From the western base of the Blue Ridge Mountains to the east	1.5	4	6
		Remainder of county.	2.0	4	8
12	Brunswick		1.5	7	10.5

APPENDIX I continued

Table of Values by County					
County Code	**County**		**RF**	**CBR**	**SSV**
13	Buchanan		2.0	6	12
14	Buckingham		1.5	5	7.5
15	Campbell		1.5	5	7.5
16	Caroline	W. of Rt. 2	2.5	10	25
		E. of Rt. 2	3.0	10	30
17	Carroll		1.0	8	8
18	Charles City		3.0	10	30
10	Charlotte		1.5	5	7.5
* 131	Chesapeake		3.0	6	18
20	Chesterfield	SW of a line from Mosley to Colonial Heights	1.5	6	9
		Remainder of County	2.5	9	22.5
21	Clarke		2.0	6	12
22	Craig		2.0	4	8
23	Culpeper	E. of Rts. 229 and 15S	1.0	4	4
		W. of Rts. 229 and 15S	1.0	5	5
24	Cumberland		1.5	6	9
25	Dickenson		2.0	6	12
26	Dinwiddie		1.5	6	9
28	Essex		3.0	10	30
29	Fairfax	E. of Rt. 95	3.0	7	21
		W. of Rt. 95	1.0	4	4
30	Fauquier	N. of Rt. 211	2.0	4	8
		S. of Rt. 211	1.0	4	4
31	Floyd		1.0	8	8
32	Fluvanna		1.5	4	6
33	Franklin		1.0	8	8
34	Frederick		2.0	6	12
35	Giles		2.0	7	14
36	Gloucester		3.0	10	30
37	Goochland	W. of Rt. 522	1.5	7	10.5
		E. of Rt. 522	2.5	7	17.5
38	Grayson		1.0	5	5

APPENDIX I continued

Table of Values by County

County Code	County		RF	CBR	SSV
39	Greene		1.0	5	5
40	Greensville	E. of Rt. 95	3.0	9	27
		W. of Rt. 95	1.5	9	13.5
41	Halifax		1.5	8	12
* 114	Hampton		3.0	9	27
42	Hanover	E. of Rt. 95	3.0	10	30
		W. of Rt. 95 and E. of Rt. 715	2.5	6	15
		W. of Rt. 715	1.5	6	9
43	Henrico	W. of Rt. 95	2.5	7	17.5
		E. of Rt. 95	3.0	7	21
44	Henry		1.0	8	8
45	Highland		2.0	6	12
46	Isle of Wight		3.0	9	27
47	James City		3.0	6	18
48	King George		3.0	10	30
49	King and Queen		3.0	10	30
50	King William		3.0	10	30
51	Lancaster		3.0	10	30
52	Lee		2.0	6	12
53	Loudoun	W. of Rt. 15	2.0	4	8
		E. of Rt. 15	1.0	4	4
54	Louisa		1.5	5	7.5
55	Lunenburg		1.5	5	7.5
56	Madison		1.0	5	5
57	Mathews		3.0	10	30
58	Mecklenburg		1.5	7	10.5
59	Middlesex		3.0	10	30
60	Montgomery		2.0	5	10
61	City of Suffolk		3.0	9	27
62	Nelson		1.5	5	7.5
63	New Kent		3.0	9	27
* 121	Newport News		3.0	9	27
* 122	Norfolk		3.0	9	27

APPENDIX I continued

Table of Values by County

County Code	County		RF	CBR	SSV
65	Northampton		3.0	7	21
66	Northumberland		3.0	10	30
67	Nottoway		1.5	8	12
68	Orange	N. of Rt. 20 & E. of Rt. 522	1.0	6	6
		N. of Rt. 20 & W. of Rt. 522	1.0	5	5
		S. of Rt. 20 & E. of Rt. 522	1.5	6	9
		S. of Rt. 20 & W. of Rt. 522	1.5	5	7.5
69	Page	W. Alma	2.0	6	12
		E. Alma	1.0	6	6
70	Patrick		1.0	8	8
71	Pittsylvania		1.5	8	12
72	Powhatan	W. of Rt. 522 & of Rt. 609	1.5	7	10.5
		E. of Rt. 522 & of Rt. 609	2.5	7	17.5
73	Prince Edward		1.5	5	7.5
74	Prince George		3.0	8	24
76	Prince William	W. Rt. 95	1.0	4	4
		E. Rt. 95	3.0	7	21
77	Pulaski		2.0	5	10
78	Rappahannock	N. Flint Hill	2.0	5	10
		S. Flint Hill	1.0	5	5
79	Richmond		3.0	10	30
80	Roanoke		2.0	7	14
81	Rockbridge	W. of the James, Maury and South Rivers	2.0	5	10
		E. of the James, Maury and South Rivers	1.5	5	7.5
82	Rockingham	W. of Rt. 81	2.0	6	12
		E. of Rt. 81	1.0	6	6
83	Russell		2.0	6	12
84	Scott		2.0	6	12
85	Shenandoah		2.0	6	12
86	Smyth		2.0	6	12
87	Southampton		3.0	9	27

APPENDIX I continued

Table of Values by County					
County Code	**County**		**RF**	**CBR**	**SSV**
88	Spotsylvania	W. of Rt. 95	1.5	6	9
		E. of Rt. 95	2.5	10	25
89	Stafford	W. of Rt. 95	1.0	6	6
		E. of Rt. 95	3.0	10	30
90	Surry		3.0	9	27
91	Sussex	W. of Rt. 95	1.5	9	13.5
		E. of Rt. 95	3.0	9	27
92	Tazewell		2.0	6	12
* 134	Virginia Beach	N. of Rt. 44	3.0	9	27
		S. of Rt. 44	3.0	6	18
93	Warren		2.0	6	12
95	Washington		2.0	6	12
96	Westmoreland		3.0	10	30
97	Wise		2.0	6	12
98	Wythe		2.0	6	12
99	York		3.0	7	21

* Note: Arlington County, Henrico County, and independent cities identified with a "County Code" greater than 99 have administrative jurisdiction over their own transportation facilities. Consequently, for the development of new subdivision streets, the provisions of this guide may not apply in those jurisdictions and developers are encouraged to seek the guidance of appropriate authorities in those areas. However, these provisions shall apply in those jurisdictions for all department managed projects.

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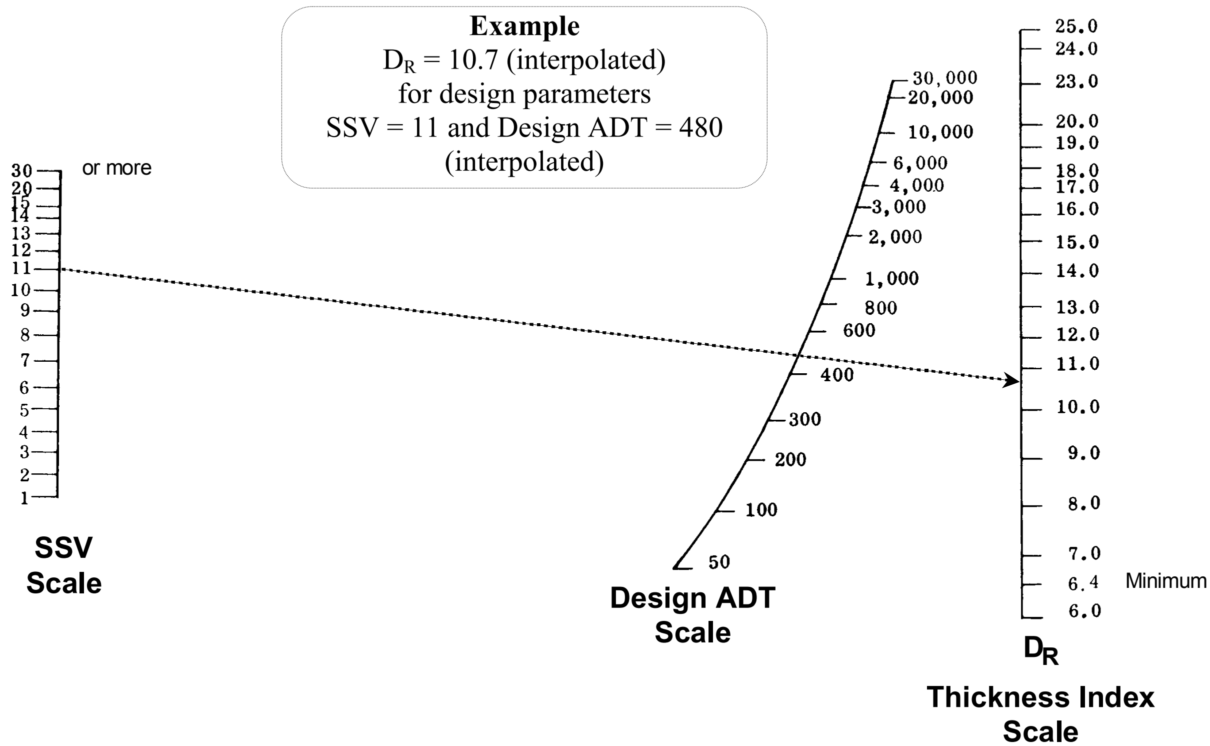
Appendix II
Nomograph for Determining Required Pavement Thickness Index D_R

(Note: An enlarged version of this nomograph is provided on the last page of this reference.)

Final pavement design must be based on the results of appropriate soil tests.

Preliminary designs may be based on values established in Appendix I.



To determine D_R, project a line from the value for SSV through the value for the Design ADT.

The nomograph depicted correlates the soil support value of the subgrade (SSV = Design CBR x RF), the traffic volume (Design ADT), and the minimum required pavement design thickness index (D_R) for subdivision streets and secondary road pavement, based on AASHO design equations. This nomograph assumes the following:

1. Use of Design ADT for two way traffic, equally distributed, thereby deriving the thickness index (D_R) required for any portion of the pavement to support one-half of the design ADT.
2. For D_R greater than 20, staged construction providing an initial stage D_R value of 20 may be permitted.
3. The District Materials Engineer may consider reducing the minimum D_R value of 6.4 for secondary system facilities having a Design ADT <50.

APPENDIX III

Paving Materials & Allowable Values

Location & Notation	Material	Material Notation	Thickness Equivalency Value	Lift Thickness Min. inches	Lift Thickness Max. inches
Surface **a_1**	Asphalt Concrete (SM-9.0A, D)[1]	A.C.	1.67 *	1	1.5
	Asphalt Concrete (SM-9.5A, D)[1]			2 [2]	3
	Prime & Double Seal or Class “C” or D” Blotted Seal Coat Surface Treatments [3]	D.S.	0.84	—	—
Intermediate **a_1**	Asphalt Concrete (IM-19.0) [1]	A.C.	1.67 *	2	3
Base a_2	Asphalt Concrete (BM-2537.5) [1]	A.C.	1.67 *	3	—
	Full Depth Asphalt Concrete (BM-25.0 or BM 37.5) over Subgrade[1]	A.C.	1.60 **	6	—
	Untreated Aggregate [4]	Agg.	1.00	6	8 [4]
	Cement Treated Aggregate [4]	CTA	1.67		
	Cement Treated Select Material, Type II, min. CBR = 20	Sel. Mat. C	1.50		
	Select Material Type I & II, non-plastic, min. CBR = 30	Sel. Mat.	0.84		
	Select Material, Type II, non-plastic, min. CBR = 20	Sel. Mat.	0.60		
	Soil Cement	S.C.	1.00		
	Cement Treated Select Material, Type II	Sel. Mat. C	1.17		
	Cement Treated Select Borrow	Sel. Bor. C	1.00		
	Open Graded Drainage Layer	OGDL	0.60	3	3
Subbase a_3	Untreated Aggregate [4]	Agg.	0.60	4	8 [4]
	Cement Treated Aggregate [4]	CTA	1.33		
	Select Material Type I, non-plastic, min. CBR = 30	Sel. Mat.	0.50		
	Select Material Type II, non-plastic, min. CBR = 20	Sel. Mat.	0.40		
	Soil Cement	S.C.	1.00	6	8
	Soil Lime	S.L.	0.92		
	Cement Treated Select Material, Type II	Sel. Mat. C	1.17		
	Cement Treated Select Borrow	Sel. Bor. C	1.00		

Footnotes for Appendix III

[1] When 4½ inches or more of any combination of Asphalt Concrete (surface + intermediate + base) is called for, the following thickness equivalency values should be used * = 2.25 and ** = 2.15

[2] 1½ inches is acceptable when placed on an asphalt concrete base material.

[3] Prime and Double Seal Surface Treatment, in lieu of blotted seal coat surface treatment, may only be used as outlined in Appendix IV (for new subdivision streets) and the current Location and Design Division I&I Memorandum (for secondary road projects).

[4] For aggregate materials, the maximum combined thickness of base and subbase layers considered for the purpose of calculating the thickness index value shall be 12 inches.

[5] An intermediate mix is required between the surface and base mix when BM-37.5 is used.

Appendix IV

Flexible Pavement Design Worksheet for New Subdivision Streets

This sheet is intended for use and submission in conjunction with VDOT's Subdivision Street Requirements

County		Date:
Subdivision		
Street Name		
Developer		Phone:

ADT	Projected traffic for the street segment considered, as defined in the Subdivision Street Requirements.
CBR_D	Design CBR = Average of CBR_T x 2/3 and modified only as discussed in the Pavement Design Guide.
CBR_T	CBR value of the subgrade sample, taken and tested as specified in the Pavement Design Guide
DME	VDOT District Materials Engineer
EPT	Equivalent projected traffic
HCV	Number of Heavy Commercial Vehicles (e.g. trucks, buses, etc., with 2 or more axles and 6 or more tires).
%HCV	Percentage of the total traffic volume composed of Heavy Commercial Vehicles.
RF	Resiliency Factor = Relative value of the subgrade soil's ability to withstand repeated loading.
SSV	Soil support value of subgrade (SSV = CBR_D x RF)
D_P	Thickness index of proposed pavement design computed by the Conventional Pavement Design Method
D_R	Thickness index required, based on Design ADT and SSV, determined by Appendix II.

Step 1: Determine Design ADT

ADT	
%HCV = 100 x HCV x ADT) or 20 x HCV Note: For %HCV ≤ 5%, use ADT	______ Note: For %HCV>5%, EPT>ADT
Design ADT Use greater of ADT or EPT	

Step 2: Determine Design Values CBR, RF, and SSV

Sample	DBR_T
# 1	
# 2	
# 3	
#	
#	
#	

Resiliency Factor (RF) Source	Value
Table 1	
Appendix I	
DME approved RF	

For preliminary designs, use the lowest RF value in the equation

CBR_D	x	RF	=	**SSV**
(_______)	x	(_______)	=	

Step 3: Pavement Design (Check appropriate box and show proposed pavement design below.)

❑ (A) Limited to Design ADT ≤ 400 - Show pavement material notations and thickness from Appendix IV Tables A and B.

❑ (B) Show pavement section as developed in the Pavement Design Guide.
(See Appendix III for material notations and thickness equivalency values (a)).

D_R = _________
from Appendix II

Description of Proposed Pavement Section

Material Notation		Thickness, h	**a**	**(a x h)**
Surface				
Base				
Subbase				

D_P must equal or exceed the value of D_R. $D_P = \Sigma$**(a x h)** =

Appendix IV - Table A Alternate Pavement Design Selection Chart

This table is to be used only in conjunction with the Flexible Pavement Design Worksheet for New Subdivision Streets.

DESIGN ADT		SUBBASE	BASE	SURFACE
Up to 250 ADT	1		8" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D (See Note A)
	2		8" Soil Cement Stabilized (Native Soil or Borrow)	Blotted Seal Coat - Type C-1 (See Note A)
	3	4" Select Material, Type I, II or III, Minimum CBR 30	6" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D (See Note A)
	4	4" Cement or Lime Stabilized Subgrade	4" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D (See Note A)
	5	6" Aggregate Base Material Type I, Size #21-B	7" Plain Jointed Portland Cement Concrete	
	6 – Option shall only be used when SSV ≥ 10		3" Asphalt Concrete, Type BM-25.0	165 # psy Asphalt Concrete, Type SM-9.5A or SM-12.5A
251 - 400 ADT	1	6" Select Material Type I or III, Minimum CBR 30	6" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D
	2		6" Local or Select Material, Minimum CBR 20, Stabilized With Cement	Blotted Seal Coat - Type C-1
	3		10" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D
	4	6" Cement Stabilized Subgrade	4" Aggregate Base Material, Type I, Size #21-A	Blotted Seal Coat - Type D
	5	6" Aggregate Base Material, Type I, Size #21-B	7" Plain Jointed Portland Cement Concrete	
Design option 6 shall only be used when SSV ≥ 10	6		4" Asphalt Concrete, Type BM-25.0	165 # psy Asphalt Concrete, Type SM-9.5A or SM-12.5A

Note A. For projected traffic volumes (Design ADT) up to 250 only, a prime and double seal surface may be used in lieu of a blotted seal coat.

Appendix IV - Table B Alternative Pavement Design Selection Adjustments

This table may only be used in conjunction with Appendix IV, Table A and its intended purpose.

SSV Under 10	SSV 10 to 20	SSV Over 20 (Maximum 30)
For each 5 SSV units under 10, the pavement design in Table A shall be increased by 0.5 inches of asphalt concrete or 1 inch of aggregate base material.	The pavement designs in Table A may be used as shown without adjustment.	The pavement designs in Table A may be decreased by 0.5 inches of asphalt concrete or 1.0 inch of aggregate base material.

APPENDIX V - Sample Pavement Design

A two lane road is proposed for construction in Prince William County, east of I-95, and will sustain a traffic count of 2500 with a growth rate of 3%, based on a September 1995 traffic count. Heavy commercial vehicles account for 6% of the traffic volume. Construction is expected to be finished in 2003. Soils tests yielded a classification of A-5 with 45% sand with no mica and a Design CBR of 6.3. The following designs might be considered.

Compute Design ADT = Present ADT x $[1 + (GR.)]^n$

Since %HCV > 5%, compute EPT and substitute result for the "Present ADT"

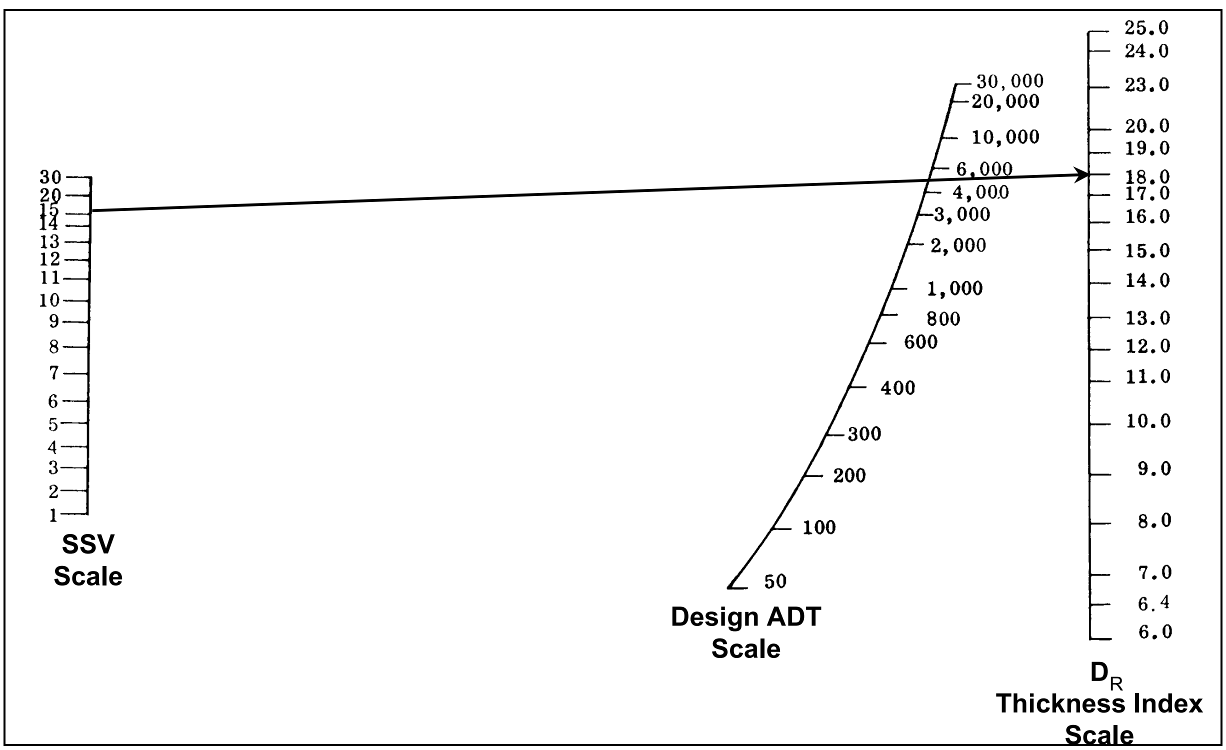
EPT = 2500 + 20 [2500(0.06 - 0.05)] = 2500 + 20 [25] = 3000

∴ USE ***Design ADT*** = $3000\ [\ 1 + (0.03)\ ]^{(10+2003-1995)}$

= $3000\ [1.03]^{18}$ = 3000 [1.70] = 5100 ADT

Compute SSV from Equation 1 SSV = 6.3 x 2.5 (ref. Table 1) = 15.75

Required Design Thickness Index (D_R) from nomograph, Appendix II, is 18.



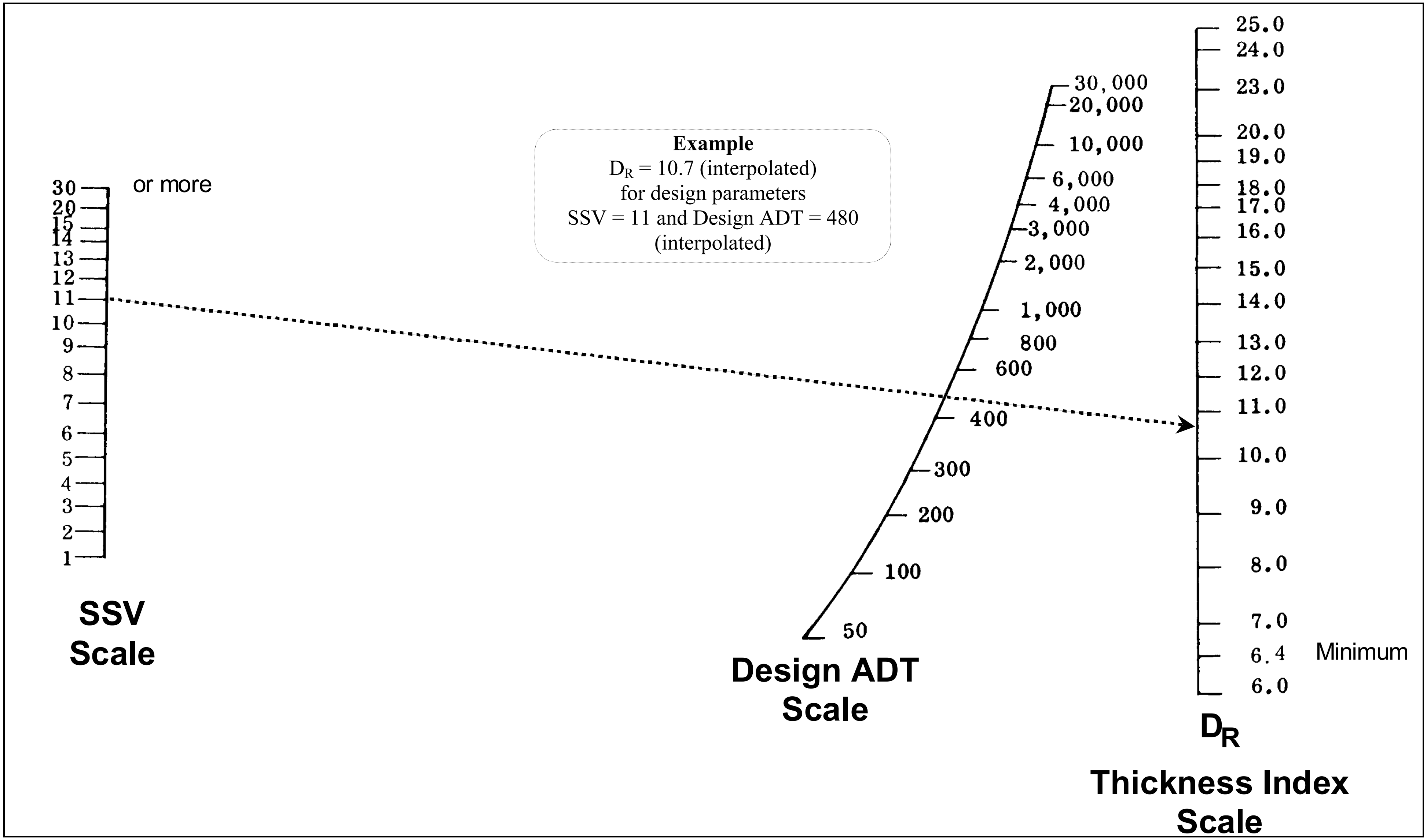
(Sample pavement designs appear on the next page.)

Appendix V - continued
Sample Pavement Design Selection Alternatives
From nomograph, Appendix II, required pavement design Thickness Index D_R = 18

Trial	Pavement Layer	Materials Notation	Thickness (h), inches	Equivalency Value (a)	Layer Thickness Index (h x a)
1	Surface	Asphalt Concrete (SM-9.5A)	1.50	2.25	3.38
	Base	Asphalt Concrete (BM-25.0)	5.00	2.25	11.25
	Subbase	Aggregate Base Material	6.00	0.60	3.60
		D_R = Total of "Layer Thickness Index Values" =			18.23
		Comment: Proposed trial pavement design is			**adequate.**
2	Surface	Asphalt Concrete (SM-9.5A)	1.50	2.25	3.38
	Base	Asphalt Concrete (BM-25.0)	4.00	2.25	9.00
	Subbase	Soil Cement	6.00	1.00	6.00
		D_R = Total of "Layer Thickness Index Values" =			18.38
		Comment: Proposed trial pavement design is			**adequate.**
3	Surface	Asphalt Concrete (SM-9.5A)	1.50	2.15	3.23
	Base	Asphalt Concrete (BM-25.0)	7.00	2.15	15.05
	Subbase	(Note: This is full depth asphalt.)			0.00
		D_R = Total of "Layer Thickness Index Values" =			18.28
		Comment: Proposed trial pavement design is			**adequate.**
4	Surface	Asphalt Concrete (SM-9.5A)	1.50	2.25	3.38
	Base	Asphalt Concrete (BM-25.0)	3.50	2.25	7.88
	Subbase	2 Component Subbase: CTA	4.00	1.00	4.00
		plus Select Material, Type I	4.00	0.84	3.36
		D_R = Total of "Layer Thickness Index Values" =			18.61
		Comment: Proposed trial pavement design is			**adequate.**
5	Surface	Asphalt Concrete (SM-9.5A) @ 2 inches plus (IM-19.0) @ 2 inches	4.00	1.67	6.68
	Base	CTA	7.00	1.67	11.69
	Subbase				0.00
		D_R = Total of "Layer Thickness Index Values" =			18.37
		Comment: Proposed trial pavement design is			**adequate.**
6	Surface	Asphalt Concrete (SM-9.5A)	2.00	1.67	3.34
	Base	Aggregate Base Material	7.00	1.00	7.00
	Subbase	Soil Cement	8.00	1.00	8.00
		D_R = Total of "Layer Thickness Index Values" =			18.34
		Comment: Proposed trial pavement design is			**adequate.**

Note: The trial designs depicted in this example are for illustration purposes only.

Since several "adequate" pavement design options are available, selection of a pavement design depends on the availability and cost of materials, underdrain requirements, ease of construction, and other potential factors.



Please refer to Appendices II and V for the application of this diagram in the design of pavement.