VIRGINIA DEPARMENT OF TRANSPORTATION
MATERIALS DIVISION
PAVEMENT DESIGN AND EVALUATION SECTION

GUIDELINES FOR 1993 AASHTO PAVEMENT DESIGN

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Materials Division

Planning Today, For Tomorrow's Challenges

PURPOSE

These guidelines are intended to aid professional staff knowledgeable in the field of pavement design and evaluation. Persons using these guidelines are responsible for their proper use and application in concert with the AASHTO "Guide for Design of Pavement Structures – 1993". The 1993 AASHTO Guide may be ordered by phone (800-231-3475) or via the internet (www.asshto.org). Virginia Department of Transportation and individuals associated with the development of this material cannot be held responsible for improper use or application.

Criticisms or suggestions for improvements in Materials Division Policies and Procedures are invited. These should be made preferably in writing directly to the State Materials Engineer or directed to the State Materials Engineer through the District Materials Engineer.

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FLEXIBLE PAVEMENT DESIGN

Design Variables

Pavement Design Life

Highway Classification	Initial Construction Design (Years)	Initial Overlay Design (Years)
Interstate	30	12
Divided Primary Route	30	12
Undivided Primary Route	20	10
High Volume Secondary Route	20	10
Farm to Market Secondary Route	20	10
Residential/Subdivision Street	20	10

Traffic Factors

Lane Distribution Factors

Number of Lanes Per Direction	VDOT Value for Pavement Design (%)
1	100
2	90
3	70
4 or more	60

Traffic Growth Rate Calculation

$$GR = [((ADT_f / ADT_i)^{(1/(F-I))})-1] \times 100$$

Where:

GR = Growth Rate (%)

ADT_f = Average daily traffic for future year

ADT_i = Average daily traffic for initial year

I = Initial year for ADT

F = Future year for ADT

Future ADT Calculation

If an ADT and growth rate is provided, then a future ADT can be calculated using the following equation:

$$ADT_f = ADT_I (1+GR)^{(F-I)}$$

Where:

GR = Growth Rate (%)

ADT_f = Average daily traffic for future year

ADT_i = Average daily traffic for initial year (year traffic data is provided)

I = Initial year for ADT

F = Future year for ADT

ESAL Factors

When no Weigh in Motion (WIM) or vehicle classification data are available to determine actual Equivalent Single Axle Loads (ESAL) Factors, use the following values:

Vehicle Classification	**ESAL Factor**
Cars/Passenger Vehicles	0.0002
Single Unit Trucks	0.37
Tractor Trailer Trucks	1.28

If traffic classification or WIM data are available, use Appendix D of the *1993 AASHTO Design Guide for Pavement Structures* to determine ESAL factors.

ESAL Calculation

For the ESAL Calculation, use Compound Growth Factors. Assume Truck Growth ESAL Factor is 0%.

Reliability

	VDOT Value for Pavement Design	
Highway Classification	**Urban**	**Rural**
Interstate	95	95
Divided Primary Route	90	90
Undivided Primary Route	90	85
High Volume Secondary Route	90	85
Farm to Market Secondary Route	85	75
Residential/Subdivision Street	75	70

Serviceability

	VDOT Value for Pavement Design	
Highway Classification	**Initial**	**Terminal**
Interstate	4.2	3.0
Divided Primary Route	4.2	2.9
Undivided Primary Route	4.2	2.8
High Volume Secondary Route	4.2	2.8
Farm to Market Secondary Route	4.0	2.5
Residential/Subdivision Street	4.0	2.0

Standard Deviation

For flexible pavements, the standard deviation of 0.49 shall be used.

Stage Construction

This is an option in the Darwin pavement design program, select Stage 1 construction.

Material Information

Structural Layer Coefficients (New Design and Overlay)

Material	VDOT Value for Pavement Design (a_i)
SM-9.0	.44
SM-9.5	.44
SM-12.5	.44
IM-19.0	.44
BM-25.0	.40
BM-37.5	.37
SMA 9.5, SMA 12.5, SMA 19.0	.44
Graded Aggregate Base – 21A or 21B	.12
Cement Treated Aggregate Base	.20
Rubblized Concrete	.18
Break and Seat/Crack and Seat	.25
Soil Cement	.18
Lime Treated Soil	.18
Gravel	.10
Open Graded Drainage Layer – Bound	.10
Open Graded Drainage Layer – Unbound	0 – .10
All other soils	No Layer Coefficient

AC Material Layer Thickness

Material	Minimum Lift Thickness (in.)	Maximum Lift Thickness (in.)
SM-9.0	0.75	1.25
SM-9.5	1.25	1.5
SMA 9.5	1.25	1.5
SM-12.5	1.5	2
SMA 12.5	1.5	2
SMA 19.0	2	3
IM-19.0	2	3
BM-25.0	2.5	4
BM-37.5	3	6

Drainage Coefficients (m)

For most designs, use a value of 1.0. If the quality of drainage is known as well as the period of time the pavement is exposed to levels approaching saturation, then refer to Table 2.4 in the *1993 AASHTO Guide for the Design of Pavement Structures.*

Design Subgrade Resilient Modulus

Caution must be used when selecting a design resilient modulus. An analysis of all the soils data should be conducted prior to selecting a value. An average Resilient Modulus (Mr) should not be used as the design Mr if the coefficient of variance (Cv) is greater than 10%. If the Cv is greater than 10%, then the Pavement Designer should look at sections with similar Mr values and design those section based on that average Mr. If no sections clearly exist, then use the average Mr times 67% to obtain the design Mr. For those locations with an actual Mr less than the design Mr, then the pavement designer should consider a separate design for that location or undercutting the area.

If resilient modulus results are not available, then use the following correlations:

For fine-grained soils with a soaked CBR between 5 and 10 , use the following equation to correlate CBR to resilient modulus (Mr):

$$\text{Design Mr (psi)} = 1{,}500 \times \text{CBR}$$

For non fine-grained soils with a soaked CBR greater than 10, use the following equation:

$$\text{Mr} = 3{,}000 \times \text{CBR}^{0.65}$$

Typical values for fine-grained soils are 2,000 to 10,000 psi.
Typical values for course-grained soils are 10,000 to 20,000 psi.

When FWD testing is conducted and the backcalculated resilient modulus is determined, use the following equation:

$$\text{Design Mr} = C \times \text{Backcalculated Mr}$$

Where C = 0.33

If CBR and backcalculated Mr results are available, use the smaller Design Mr for pavement design purposes.

If the Design Mr based on CBR is greater than 15,000 psi or if the Design Mr from backcalculation is greater than 15,000 psi, then use a Design Mr value of 15,000 psi.

Shoulder Design

Typically, paved shoulders have a pavement structural capacity less than the mainline; however, this is dependent on the roadway. For Interstate routes, the pavement shoulder shall have the same design as the mainline pavement. This will allow the shoulder to support extended periods of traffic loading as well as provide additional support to the mainline structure. A full-depth shoulder (same design as the mainline pavement) is also recommended for other high-volume non-interstate routes.

Where a full-depth shoulder is not necessary, the shoulder's pavement structure should be based on 2.5% of the design ESALs (minimum) for the project following the AASHTO pavement design methodology. A minimum of two AC layers must be designed for the shoulder in order to provide edge support for the mainline pavement structure. The AC layers must be placed on an aggregate or cement stabilized aggregate layer, not directly on subgrade, to provide adequate support and drainage for the shoulder structure. To help ensure positive subsurface drainage, the total pavement depth of the shoulder should be equal to the mainline structure (i.e. mainline pavement structure thickness above the subgrade is 20 inches, shoulder pavement structure thickness above the subgrade is 20 inches).

Pavement Drainage Considerations

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

1. Standard UD-2 underdrains and outlets are required on all raised medians to prevent water infiltration through or under the pavement structure. Refer to the current VDOT Road and Bridge Standards for installation details.
2. When Aggregate Base Material, Type I, Size #21-B is used as an untreated base or subbase, it should be connect to a longitudinal pavement drain (UD-4) with outlets or daylighted (to the face of the ditch) 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. When the design ADT is less than a 1,000 vehicles per day, the Engineer must assess the potential for the presence of water and determine if sub-surface drainage provisions should be made.
3. 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.
4. Standard CD-1 and CD-2 should be considered for use with all types of unstablized aggregates, independent of the traffic levels.
5. For roadways with a design ADT of 20,000 vehicles per day or greater, a drainage layer should 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.

RIGID PAVEMENT DESIGN

Design Variables

Pavement Design Life

Highway Classification	Initial Construction Design (Years)	Initial AC Overlay Design (Years)	Initial PCC Overlay Design (Years)
Interstate	30	10	30
Divided Primary Route	30	10	30
Undivided Primary Route	30	10	30
High Volume Secondary Route	30	10	30

Traffic Factors

Lane Distribution Factors

Number of Lanes Per Direction	VDOT Value for Pavement Design (%)
1	100
2	90
3	70
4 or more	60

Traffic Growth Rate Calculation

$$GR = [((ADT_f / ADT_i)^{(1/(F-I))}) - 1] \times 100$$

Where:

GR = Growth Rate (%)

ADT_f = Average daily traffic for future year

ADT_i = Average daily traffic for initial year

I = Initial year for ADT

F = Future year for ADT

Future ADT Calculation

If an ADT and growth rate is provided, then a future ADT can be calculated using the following equation:

$$ADT_f = ADT_I (1+GR)^{(F-I)}$$

Where:

GR = Growth Rate (%)

ADT_f = Average daily traffic for future year

ADT_i = Average daily traffic for initial year (year traffic data is provided)

I = Initial year for ADT

F = Future year for ADT

ESAL Factors

When no Weigh in Motion (WIM) or vehicle classification data are available to determine actual Equivalent Single Axle Loads (ESAL) Factors, use the following values:

Vehicle Classification	ESAL Factor
Cars/Passenger Vehicles	0.0003
Single Unit Trucks	0.56
Tractor Trailer Trucks	1.92

ESAL Calculation

For the ESAL Calculation, use Compound Growth Factors. Assume Truck Growth ESAL Factor is 0%.

Reliability

	VDOT Value for Pavement Design (%)	
Highway Classification	**Urban**	**Rural**
Interstate	95	95
Divided Primary Route	90	90
Undivided Primary Route	90	85
High Volume Secondary Route	90	85

Serviceability

	VDOT Value for Pavement Design	
Highway Classification	**Initial**	**Terminal**
Interstate	4.5	3.0
Divided Primary Route	4.5	2.9
Undivided Primary Route	4.5	2.8
High Volume Secondary Route	4.5	2.8

Standard Deviation

For rigid pavements, the standard deviation of 0.39 shall be used.

Material Information

28-Day Mean PCC Modulus of Rupture (psi)

Typical Range – 600 to 800 VDOT Value for Pavement Design – 650

Use default value if actual value is not available. Where possible, use value base on historical data.

28-Day Mean PCC Modulus of Elasticity (psi)

Typical Range – 3,000,000 to 8,000,000 VDOT Value for Pavement Design – 5,000,000

Use default value if actual value is not available. Where possible, use value base on historical data.

Mean Effective k-value (psi/inch)

Typical Range – 50 to 500 VDOT Value for Pavement Design – 250

If the subgrade resilient modulus is known or obtained from the CBR, then use the following equation:

k-value = Mr / 19.4

Caution must be used when selecting a design k-value based on resilient modulus and CBR. An analysis of all the soils data should be conducted prior to selecting a value. An average Resilient Modulus (Mr) should not be used as the design Mr if the coefficient of variance (Cv) is greater than 10%. If the Cv is greater than 10%, then the Pavement Designer should look at sections with similar Mr values and design those section based on that average Mr. If no sections clearly exist, then use the average Mr times 67% to obtain the design Mr. For those locations with an actual Mr less than the design Mr, then the pavement designer should consider a separate design for that location or undercutting the area.

If the k-value is obtained from backcalculation, then use this value.

If k-value (based on backcalculation or subgrade resilient modulus) is larger than 500, then use 500 as the design value.

Subdrainage Coefficient

Use a value of 1.0 for design purposes.

Load Transfer Factors

New Pavement Designs and Unbonded PCC Overlays with Load Transfer Devices

	VDOT Value for Design	
Pavement Type	**Asphalt Shoulder**	**Tied PCC Shoulder or Wide Lane**
Jointed Plain	3.2	2.8
Jointed Reinforced	3.2	2.8
Continuously Reinforced	3.0	2.6

Overlays Designs on Existing Pavements

For AC overlays on existing PCC pavements and bonded PCC overlays, determine the appropriate J-Factor based on the load transfer efficiency determined from joint/crack testing.

Pavement Type	**Load Transfer Efficiency**	**VDOT Design J-Factor**
Jointed Plain	> 70%	3.2
	50 – 70%	3.5
	< 50%	4.0
Jointed Reinforced	> 70%	3.2
	50 – 70%	3.5
	< 50%	4.0
Continuously Reinforced		2.4 (working cracks repaired with CRCP)

Shoulder Design

Two types of shoulders are designed for Portland cement concrete highways – full-width concrete shoulders, narrow-width concrete section with an asphalt concrete extension, or an asphalt shoulder. For full-width concrete shoulders, the pavement shoulder shall have the same design as the mainline pavement. This will allow the shoulder to support extended periods of traffic loading as well as provide additional support to the mainline structure.

A narrow-width concrete section with an asphalt concrete extension shoulder is constructed when a wide concrete lane (14 feet) is part of the mainline pavement. Twelve feet of the fourteen-foot wide slab is part of the outside travel lane, the remaining two feet is striped and designated as part of the shoulder. The two-foot section of concrete has the same structure as the twelve-foot section; therefore, no separate pavement design is necessary. For the asphalt concrete portion of the shoulder and other asphalt concrete shoulders, the shoulder's pavement structure should be based on 2.5% of the design ESALs (minimum) for the project following the AASHTO pavement design methodology. A minimum of two AC layers must be designed for the shoulder. The AC layers must be placed on an aggregate or cement stabilized aggregate layer, not directly on subgrade, to provide adequate support and drainage for the shoulder structure. To help ensure positive subsurface drainage, the total pavement depth of the shoulder should be equal to the mainline structure (i.e. mainline pavement structure thickness above the subgrade is 20 inches, shoulder pavement structure thickness above the subgrade is 20 inches).

Pavement Drainage Considerations

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

1. Standard UD-2 underdrains and outlets are required on all raised medians to prevent water infiltration through or under the pavement structure. Refer to the current VDOT Road and Bridge Standards for installation details.
2. When Aggregate Base Material, Type I, Size #21-B is used as an untreated base or subbase, it should be connect to a longitudinal pavement drain (UD-4) with outlets or daylighted (to the face of the ditch) 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. When the design ADT is less than a 1,000 vehicles per day, the Engineer must assess the potential for the presence of water and determine if sub-surface drainage provisions should be made.
3. 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.
4. Standard CD-1 and CD-2 should be considered for use with all types of unstablized aggregates, independent of the traffic levels.
5. For roadways with a design ADT of 20,000 vehicles per day or greater, a drainage layer should 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.