TN TDOT Department of Transportation

Materials & Tests Division
Materials & Pavements Section

PAVEMENT DESIGN GUIDE

Rev. July 2026

Contents

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I. INTRODUCTION

This manual outlines the current policies and practices for developing pavement designs in Tennessee. The pavement design procedures presented herein provide for the structural design of pavement structures. This policy is based on the *1993 AASHTO Guide for Design of Pavement Structures*.

II. GENERAL DESIGN POLICY

2.1 Routes Requiring Structural Pavement Design

A structural pavement design is required for any new interstate and state routes with the exceptions of the cases stated below:

- Routes not on the State Highway System or Interstate System with Average Daily Loadings (ADL) of less than 150 Equivalent Single Axle Load (ESALs) are not required to do a structural pavement design and may use the Catalog of Designs provided in Appendix B.
- Utility cuts and/or maintenance/emergency repairs (such as culvert replacements) should replace the pavement with the existing depth of asphalt. See Utility Standard Drawings for details.
- Resurfacing Projects are not required to utilize a complete design. However, it is highly recommended to conduct structural testing on these projects. Therefore, existing structure capacity can be compared to the required structure capacity and considered in line with the project scope and budget when selecting the appropriate treatment or overlay thickness.

2.2 Design Life

The analysis period for the design of the pavement structure will depend on the type of project. The analysis periods will conform to the following:

Route Classification	**Design Life**
New Construction	20 Years
Major Reconstruction	20 Years
Asphalt Rehabilitation	15 Years Minimum
PCC Rehabilitation (CPR)	15 Years Minimum
Temporary Pavement	Anticipated Life of the temporary lane plus one year.

Table 2-1

It is possible that due to project limitations, alternative design life criteria other than the Design Life shown in the table 2-1 may be considered if the Project Team approves.

2.3 Required Information to Get Started

Before starting the pavement design, the following information is required:

- **Geotechnical Report:** this document is provided by the Geotechnical Engineer on the project team. Typically, the Geotechnical Report is to be finalized concurrently as the start of the pavement design process. In some cases, the Geotech Engineer may be able to provide the California Bearing Ratio (CBR) before finalizing the entire report. For projects having schedule time constraints, it is recommended for the Pavement Designer to coordinate with the Geotechnical Engineer to request The CBR prior to finalizing the Geotechnical Report.

- **Traffic Report:** this document is provided by the TDOT Planning Division. This document contains the AADT and traffic loading information discussed later in this document.

- **Typical Sections:** each unique typical section requires a pavement design. The Pavement Designer should stay informed on the project and obtain these typical sections from the Line and Grade plan set.

- **Project-specific considerations:** As a member of the project team, the pavement designer should be aware of the project scope, schedule, and budget. Specific restrictions or other needed considerations will be provided at project meetings and must be incorporated into the design.

III. Flexible Pavement Design Process

3.1 Design Parameters for Determining Required Structural Number

The parameters listed in the following paragraphs are used to calculate the required SN of flexible pavements. These parameters are input into the following equation from the *1993 AASHTO Guide for Design of Pavement Structures* to obtain a required SN. All the values below are applied to new flexible pavement and to calculate the required structural capacity for resurfacing projects.

$$\mathrm{Log}_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}\left(SN_{REQ} + 1\right) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Z_R (Pavement Reliability) is defined as the equivalent Z-score for the chosen probability that a pavement section will perform satisfactorily over the design period. Typical values are given in the table 2-2. Other reliability values can be utilized if justified by the project conditions and agreed to by the Project Team.

Route Classification	Pavement Reliability	Z_R
Interstate	95%	-1.645
Controlled Access State Route	95%	-1.645
State Routes	90%	-1.282
Off System Arterial	85%	-1.037
Temporary Traffic Lane	85%	-1.037
Off System Minor	80%	-0.841

Table 2-2

S_o (Overall Standard Deviation) measures the overall confidence the designer may have in the design inputs; TDOT utilizes **0.45** for new flexible pavement design.

M_R (Subgrade Resilient Modulus) must be calculated for the roadbed soil materials. TDOT uses the equation below to determine the soil modulus based on the CBR. The CBR is provided in the Geotechnical Report.

For soils with CBR less than 4, see Appendix A.

For CBR less than 10, use the equation below to calculate M_R:

$$M_R = 1{,}500 \times \text{CBR}$$

For CBR greater than 10, assume M_R = 15,000.

For projects on existing pavement (e.g., resurfacing projects), M_R may be back-calculated from non-destructive testing outcome (e.g., Falling Weight Deflectometer (FWD) testing). It should be noted that, typically the back-calculated M_R is greater than typical and thus should be capped at 15,000

ΔPSI (The Change in Pavement Serviceability Index) provides a relative measure of the change in the condition of the roadway structure over the design life. A typical change in PSI of 1.7 for most designs is determined from an initial serviceability of 4.2 and a final terminal serviceability of 2.5.

W_{18} (Cumulative Single Axle Load Applications) measures the traffic over the design life. The concept of equivalent single-axle loads (ESAL) represents the accumulation of several standard 18-hip axle loads over the pavement structure. W_{18} is calculated based on the Average Daily Loading (ADL) in the Traffic Report and the Design Life.

$$W_{18} = \text{ADL} \times 365 \times \text{Design Life}$$

When ADL is used, Growth Rate, Lane Distribution, Directional Distribution are not required as they are imbedded in the ADL calculations.

If a Traffic Report is unavailable see appendix C.

<u>SN_{REQ} (Required Structural Number)</u> is the unknown value that needs to be solved for. Direct analytical solving is difficult. An iterative trial and error method or solver is typically utilized. Various online applications are available, such as PaveXpress. All these calculation methods can be used though the pavement designer shall verify the assumption built within these tools (e.g., traffic calculations) as they might differ from TDOT practices.

3.2 Determining the Designed Structural Number

Once the SN_{REQ} has been determined, the pavement design may be chosen such that the Design Structural Number (SN_{DES}) is greater than or equal to SN_{REQ}. SN_{DES} is calculated as shown below.

$$\mathrm{SN}_{\mathrm{DES}} = a_1 D_1 + a_2 D_2 + a_3 D_3 + \ldots . a_n D_n$$

D_X (layer thickness) is the thickness of the pavement layer in inches.

a_X (Structural Layer Coefficient) represents the structural credit assigned to each component of the pavement structure. TDOT values for the Structural Coefficient are given in the table 3-1.

The University of Tennessee research has validated the “a” layer coefficient.[1,2].

[1] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 1 – Hot Mix Asphalt,* Knoxville: The University of Tennessee, March 2008

[2] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 2 – Layer Coefficient and Index Properties of Base Materials,* Knoxville: The University of Tennessee, June 2005 – May 2007

Layer	Structural Layer Coefficient
Surface, Grading D, TL, TLD	0.40
Surface, Grading E, TLE	0.40
Surface, Grading OGFC	0.00**
Leveling, Grading C	0.40
Leveling, Grading CM	0.40
Leveling, Grading C-W	0.40
Binder, Grading B-M2	0.40
Black Base, Grading A	0.40
Black Base, Grading A-S	0.30
Black Base, Grading A-CRL	0.30
Mineral Aggregate Base, Type A	0.14
Mineral Aggregate Base, Type B*	0.10
Aggregate Cement Base	0.23
Lime Fly-Ash Base	0.28
Subgrade Treatment – Lime	0.08
Subgrade Treatment – Cement	0.15

* In Region 4, the pavement designer shall assume unspecified aggregate bases will be constructed as a Type B unless otherwise specified. (See Appendix D)

** OGFC is a non-structural layer

Table 3-1

A description of each of TDOT Pavement Layer is provided in Appendix F.

Each pavement material type shown in the table 3-2 has specific gradations and maximum nominal aggregate sizes that influence the ability to compact each layer to the required densities therefore providing adequate pavement performance. The following table 3-2 illustrates the minimum asphalt layer thicknesses associated with each material type to achieve appropriate layer densities during construction. Do not specify layers thinner than specified in the table 3-2.

Asphalt Minimum Layer Thickness	
Type and Grading	**Minimum Layer Thickness**
Black Base, Grading "A"	3”
Black Base, Grading "A-S"	3”
Black Base, Grading "A-CRL"	3”
Binder, Grading "B-M2"	2”
Binder, Grading “CM”	1.5”
Surface, Grading "D"	1.25”
Surface, Grading “OGFC”	1.25”
Surface, Grading “TLD and TLE”	7/8”
Surface, Grading “TL”	5/8”
Surface, Grading "E"	1.25”

Table 3-2

3.3 Determining Pavement Layers

The designer shall provide a final SN_{DES} greater than or equal to the SN_{REQ}. This is typically an iterative process in which a trial design is assumed and modified until the design requirement is met. The following are general guidelines for a starting point in the iterative process and guidelines on what may and may not be changed.

3.4 Travel Lanes (General)

Standard Starting Assumptions Travel Lanes: The designer shall assume the following layers as the starting point for each new pavement design. This design has an SN of 4.8 with all layers, 3.9 without the A-S, and 2.7 without the A or A-S.

- 1.25" Surface, Grading D
- 2” Binder, Grading B-Mod2
- 3” Black Base, Grading A
- 3” Black Base, Grading A-S (if needed, see below)
- 10” Mineral Aggregate Base, Type A

Guidelines and Limitations:

- D mix is required to provide frictional skid resistance to the structure's surface. Also, increasing the thickness of the D mix is uneconomical and should not be done. Therefore, the designer shall leave the D mix at 1.25 inches. Potentially, a TLD mixture at 7/8” may be utilized for a low-volume route, but the TL and TLD mixes are generally intended for rehabilitation/resurfacing.
- B-Mod2 is required to provide a reasonably smooth intermediate layer to build the smoothest possible surface layer. The designer should always include at least 2” of B-Mod2. If a slight increase in SN is needed, B-Mod2 may be increased up to 2.5 inches. Further increases in structure should be made with more economical layers such as A mix or Mineral Aggregate Base.
- A-S mix serves as a drainage layer. It is typically used on multi-lane highways. Underdrains are used in conjunction with an A-S mix. A 3-inch layer is the minimum thickness, with a maximum layer thickness of 4 inches. The A-S mix shall be placed below the A mix and above the Mineral Aggregate Base.
- Mineral Aggregate Base: The designer should keep the mineral aggregate under the pavement structure between 10-12” in most cases. 4” is the absolute minimum. While the most economical layer, the layer coefficient of mineral aggregate, is a third of asphalt layers, significant increases in SN should be made by increasing the A-mix layer to prevent total pavement thickness from becoming unreasonably deep. For Region 4 see Appendix D.
- A-mix: is the most economical of the asphalt sections. It should be placed at a minimum thickness of 3”. Increasing the A mix thickness is often the most economical method of increasing SN. A mix is not necessarily required. Structural Number can be achieved without A mix on lower volume routes, so it is acceptable to pave the BM2 directly onto the Mineral Aggregate Base. If A-S is utilized, always include a 3” minimum A mix.

Using the proceeding guidelines and limitations, the pavement designer shall adjust the pavement structure until the design Structural Number is greater than the required Structural Number.

3.5 Travel Lanes (Open Graded Friction Course)

Standard Starting Assumptions Travel Lanes: Routes paved with Open-Graded Friction Course (OGFC) are an exception. For these routes, assume the following as a starting point.

- 1.25" Surface, Grading OGFC
- 1.5" Binder, Grading CM
- 3" Black Base, Grading A
- 3" Black Base, Grading A-S (if needed, see below)
- 10" Mineral Aggregate Base, Type A

Guidelines and Limitations:

- OGFC: Increasing the thickness of the OGFC mix is uneconomic and should not be done. Therefore, the designer should leave the OGFC mix at 1.25 inches. This is a non-structural layer. Therefore, this layer should not be included in the structural capacity calculation.
- CM: provides an impermeable layer under the permeable OGFC layer to prevent water from penetrating further into the pavement layer. It is required under all OGFCs. Increasing this layer is also uneconomical and shall not be done. Place it at 1.5"
- A, A-S, Mineral Aggregate: see the previous section.

The pavement designer shall adjust the pavement structure using the above guidelines and limitations until the design Structural Number is greater than the required Structural Number.

3.6 Shoulder Design

Shoulders less than 4' wide will be assumed to be paved in conjunction with the mainline in a single paver pass and not have a separate pavement design. Shoulders wider than 4' will be paved independently and, due to little to no traffic, can utilize a lower SN to provide a more economical pavement design.

The SN_{REQ} of separate pavement designs for shoulders may be assumed to be a fraction of the mainline.

- If shoulders are not expected to carry traffic, shoulders may be designed for 2% of the mainline ESALs.
- For Projects where the shoulder is expected to carry some traffic, such as during construction or wheel wander by heavy trucks, design the shoulders to carry 20% of the mainline ESALs.

Starting Assumptions (not OGFC): The designer shall assume the following layers as the starting point for each new pavement design.

- 1.25" Surface, Grading E
- 10+" Mineral Aggregate Base, Type A

Guidelines and Limitations:

- E mix is utilized on shoulders and is generally more economical than D mix. However, this is not always the case. If local prices show D mix and E mix at roughly equal cost, paving the shoulders with D mix may be done. E mix should be placed at a minimum of 1.25" and may be increased to 1.5".
- Mineral Aggregate Base should be placed to make the total shoulder pavement depth equal to that of the total pavement depth of the adjacent travel lane.
- If necessary, to increase the Structural Number, 2 to 2.5" of B-Mod2 may be used, and 3" or more inches of A mix may be utilized as needed.
- In all cases, the total depth of the shoulder pavement design shall be equal to the total depth of the pavement for the adjacent travel lane.

Standard Starting Assumptions (with OGFC): For all shoulders with OGFC mainlines, assume:

- 1.25" Surface, Grading OGFC
- 1.5" Binder, Grading CM
- 10"+ Mineral Aggregate

Guidelines and Limitations

- OGFC and CM thicknesses shall continue from the mainline across the shoulder. Note on the plans that the OGFC shall end one foot from the edge of the paved shoulder below to daylight the OGFC. This is a non-structural layer. Therefore, this layer should not be included in the structural capacity calculation.
- Mineral Aggregate Base should be placed to make the total shoulder pavement depth equal to that of the total pavement depth of the adjacent travel lane.
- If necessary to increase the Structural Number, 3” or more inches of A mix may be utilized.
- In all cases, the total depth of the shoulder pavement design shall be equal to the total depth of the pavement in the adjacent travel lane.

3.7 Performance Grade Asphalt

The pavement designers shall specify the performance grade for all routes based on the accumulated ESALs over the pavement's life, as per the table 3-3.

Accumulated ESALs over Design Life	Performance Grade Asphalt
30,000,000+ or All Interstates	PG 76-22
3,000,000 to 29,999,999	PG 70-22
<3,000,000	PG 64-22

Table 3-3

Over stiffening the binder, that is using a higher grade binder that necessary, may lead to more durability issues due to cracking. Exceptions to the Table 3-3 and any use of PG 82-22 will be considered on a project by project case with the approval of the State Materials & Pavement Engineering Manager. Consideration should be given to utilizing rigid pavement as an alternative to PG 82-22.

3.8 Tack Coat and Prime Coat

Tack Coat shall be applied between all asphalt pavement layers per TDOT Standard Specifications 403 except above drainable base layers. The Pavement Designer shall note that Tack Coat is required on the Pavement Design submitted to the project team.

Prime Coat is not required in most cases and shall only be applied between the Aggregate base and the lowest asphalt layer if the total asphalt depth of a state highway is less than or equal to 4 inches. If it is required it shall be applied at a rate of 0.35 Gal/SY. The Pavement Designer shall note the Prime Coat application rate on the Pavement Design submitted to the project team.

IV. Rigid Pavement Design Process

4.1 Design Parameters for Determining Required Structural Number

The parameters listed in the following paragraphs are used to calculate the required thickness of rigid pavements. These parameters are input into the following equation from the *1993 AASHTO Guide for Design of Pavement Structures* to obtain a Portland Cement Concrete (PCC) layer thickness (D) thickness. All the values below are applied to new rigid pavement and to calculate the required structural capacity for rehabilitation projects.

$$\log(W_{18}) = Z_R \times S_0 + 7.35\log(D+1) + 0.06 + \frac{\log\left(\frac{\Delta PSI}{4.2-1.5}\right)}{1+\frac{1.624\times 10^7}{(D+1)^{8.46}}} + (4.22-0.32p_t)\log\left[\frac{S'_c \times C_d(D^{0.75}-1.132)}{215.63\times J\left[D^{0.75}-\frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$

Z_R (Pavement reliability) is defined as the equivalent Z-score for the chosen probability that a pavement section will perform satisfactorily over the design period. Typical values for rigid pavements are 95% for Interstates or Controlled Access State Routes and 90% for all others. See **Table 2-2.**

S_O (Overall standard deviation) measures the overall confidence the designer may have in the design inputs; TDOT utilizes **0.35** for new rigid pavement design. The range of S_O values provided can vary between 0.30 – 0.40 as per Part II, Section 2.1.3 of the *1993 AASHTO Guide for Design of Pavement Structures*.

D (Slab Depth) The 1993 AASHTO empirical equation for rigid pavement is usually solved for the slab depth or thickness (D). Typical values can be between **8 – 12 inches**.

ΔPSI (The Change in Pavement Serviceability Index) provides a relative measure of the change in the condition of the roadway structure over the design life. **A typical change in PSI of 2.0** for most designs is determined from an initial serviceability of 4.5 and a final terminal serviceability of 2.5 (p_t).

W_{18} (Cumulative Single Axle Load Applications) measures the traffic over the design life. The concept of equivalent single-axle loads (ESAL) represents the accumulation of several standard 18-hip axle loads over the pavement structure. W_{18} is calculated based on the Average Daily Loading (ADL) in the Traffic Report and the Design Life.

$$W_{18} = \text{ADL} \times 365 \times \text{Design Life}$$

When ADL is used, Growth Rate, Lane Distribution, Directional Distribution are not required as they is imbedded in the ADL calculations.

E_c (Elastic Modulus) is the ration between the stress and strain of concrete in flexure. It is estimated as:

$$E_c = 57{,}000\sqrt{f'c(psi)}$$

Class CP, the class of concrete used for paving, per TDOT Specifications 501.03 has a f'c of 3000 psi. Concrete with a higher strength can be specified as need under special circumstances with the approval by the TDOT State Materials & Pavement Manager. The maximum E_c for the purpose of pavement design shall be 6,000,000 psi.

S'c (Modulus of Repture) represents the flexural strength of concrete. It is to be assumed for the purposes of pavement design to be 650 psi.

J (Load Transfer Coefficient) is a factor that accounts for load transfer across lanes and slabs discontinuity. The load transfer of rigid pavement structures is essential to overall pavement performance. The table 4-1 shows the recommended J values in addition to the allowable ranges.

Pavement Type	Asphalt Shoulder	Tied PCC Shoulder (Wide Lane can also be included)
Plain Jointed and Jointed Reinforced Concrete Pavement	3.2	2.7 (2.5 – 3.1)
Continuously Reinforced Concrete Pavement	3.0 (2.9 – 3.2)	2.6 (2.3 – 2.9)

Table 4-1

C_d (Drainage Coefficient) Rigid pavement designs are assigned a drainage coefficient, which represents the relative loss of base material strength due to the drainage characteristics and the total time it is exposed to near-saturation conditions. Free-draining materials, such as treated permeable bases, have a coefficient of 1.2, while slow-draining base materials often remain saturated and would have a coefficient of 1.0. Slabs for TDOT project shall be placed on Permeable Bases, therefore C_d shall be **1.2**. For resurfacing projects if the quality of drainage is known as well as the levels of saturation of the pavement, C_d can be changed according to Table 2.4 in the *1993 AASHTO Guide for Design of Pavement Structures.*

K_{eff} (Modulus of subgrade Reaction) is used to estimate the support of the PCC slab by the underlying layers. If PCC is placed on the subgrade then k is calculated based on the equation below:

$$k_{eff} = M_R/19.4$$

If the pavement designer is using the standard TDOT slab support of 4" Treated Permeable Base and 4" Granular Base table 4-2 may be used to estimate k_{eff}.

Subgrade CBR	K_{eff} (4" TPB + 4" Stone Base)
2	200
3	275
4	300
5	350
6	400
7	425
8	450
9	500
10	525

Table 4-2

k_{eff} can be calculated from the following website as well. http://apps.acpa.org/applibrary/KValue/

The following inputs (M_R, and base assumptions) are required for the calculator

M_R (Subgrade resilient modulus) must be calculated for the roadbed soil materials. TDOT uses the equation below to determine the soil modulus based on the CBR. The CBR is provided in the Geotechnical Report.

For soils with CBR less than 4, see Appendix A.

For CBR less than 10, use the equation below to calculate M_R:

$$M_R = 1{,}500 \times \mathrm{CBR}$$

For CBR greater than 10, assume M_R = 15,000

For projects on existing pavement (e.g., resurfacing projects), M_R may be back-calculated from non-destructive testing outcome (e.g., Falling Weight Deflectometer (FWD) testing). It should be noted that, typically the back-calculated M_R is greater than should be typical and thus should be capped at 15,000

Base Layer Assumptions: Concrete pavement for TDOT projects should be placed on 4" of Treated Permeable Base(TPB) and 4" Aggregate Base (Unstabilized Granular Base). Use an assumed resilient modulus of 350,000 psi for the TPB and 15,000 psi for the Aggregate Base.

4.2 Rigid Pavement Overlay:

For PCC overlays over existing rigid pavement, unbound PCC over rigid pavement design needs to be considered.

For AC and PCC overlays load transfer efficiency need to be determined using FWD and J factors need to be calculated following the table 4-3.

Load Transfer Efficiency (LTE)	J-Factor
>70%	3.2
70%≥LTE≥50%	-0.05*LTE+6.7
<50%	4.2

Table 4-3

4.3 Travel Lanes & Shoulders

For each new pavement design, the designer shall assume the following layers as the starting point of the design,

- Concrete Slab
- 4.0” Treated Permeable Base
- 4.0” Mineral Aggregate Base, Type A

Guidelines and Limitations:

- Portland Cement Concrete item serves as the PCC layer. The thickness will be solved directly from 1993 AASHTO Guide for Design of Pavement Structures Rigid Pavement Equation. From a practical perspective, the minimum thickness of Portland cement concrete pavements typically constructed for highway pavements ranges from 6 to 12 inches. Always specify concrete pavement by rounding up to the nearest inch.
- Treated base layers may also provide stability or drainability of the pavement structure. The minimum thickness for these layers is typically 4. The pavement designer will call for a 4” treated permeable base under concrete pavements. This item will serve as a drainage layer. Underdrains are used in conjunction with a treated permeable base.
- The Mineral Aggregate Base serves as the unbound aggregate layer. On concrete pavements, the thickness of the mineral aggregate base is a minimum of 4 inches.

4.4 Shoulder Design for Concrete Pavements

Rigid pavements may be designed with tied concrete pavement shoulders or asphalt and aggregate shoulders. The thickness of tied concrete paved shoulders shall equal that of the mainline pavement design.

For asphalt and aggregate shoulders, the pavement design will be based on 2% of the mainline traffic unless the shoulder will be used for maintenance of traffic, in which case the design will be based on 20% of the mainline traffic.

V. PAVEMENT DESIGN PACKAGE

The Pavement Design shall be submitted to the Project Manager and Roadway Designer by the deadline set in the project schedule. The Pavement Design Package shall include the following information:

- Project cover sheet: including county, route, project description, project pin, and Identification of the Pavement Designer and the Quality Control Reviewer.

For each pavement design included in the project, provide:

- Design Calculation Inputs
  - Route/road name Identification
  - Traffic Information:
    - Project Year,
    - Design Year,
    - Design Year ADL,
    - ADT
    - project total ESALs.
    - The date of the traffic Report
    - source of the traffic data.
  - Soil information
    - CBR value
    - calculated soil modulus
    - Geotech Report Number
    - Geotech Report Date
    - Geotech Report Author/Firm.
  - Pavement Design Information
    - Required Structural Number
    - Structural Number of the Designed Pavement
    - % Designed SN is more significant than Required SN
    - Total ESALs the as Designed Pavement SN would support
- Pavement Schedule
  - Mainline and Shoulder Cross Pavement Layers
    - Mix and PG Grade of each layer
    - Depth of each layer
    - TDOT Item Number of each layer (Layers with multiple component item numbers should be listed in the same line and noted.)
  - Direction for Tack and Prime Coats
  - Special Notes such as for underdrains, special breakouts, existing pavement, etc.)

The report shall be prepared under the direction of a Professional Engineer, and the package shall be sealed and signed.

VI. APPENDIX A: WEAK SUBGRADES

If the CBR is less than 4, soil stabilization or undercutting should be considered as part of the pavement design. Undercutting is unlikely to be an economical solution for the design of long sections of roadways. In this case, stabilized soils and stabilized bases should be considered separately or together as part of the pavement design.

Stabilized Soil

- Soil-cement base is in-place or select soil with Portland Cement mixed in, moistened, and compacted to increase its structural capacity. Generally, the depth of treatment is 6”.
- Lime-treated subgrade is in-place subgrade materials treated with lime and compacted to increase their structural capacity. Generally, the depth of treatment is 6” but may go up to 12” for very poor subgrades.
- In either case, consult the Geotechnical Engineering Section for a recommendation before utilizing.

Stabilized Base Courses

- Aggregate-Cement Base is a mineral aggregate base treated with cement to increase its Structural Value. Place 4” to 8” in thickness.
- Aggregate Lime Fly-Ash Base is a mineral aggregate base treated with lime and fly ash to increase its structural value. Place in 4” to 8”. This option has historically not been utilized much in the 21st century. Cement Treated Base is preferred unless project-specific circumstances make Lime Fly-Ash practical.

VII. APPENDIX B: LOW VOLUME ROAD PAVEMENT DESIGN

The following pavement design guidance is intended to design low-volume off-system routes. This method allows the pavement to be designed with assumed county soil conditions; thus, no Geotechnical Report is required. This catalog of designs provides a conservative estimate for routes that are low risk. This method is restricted to routes with Average Daily Loads of less than 150 ESALs.

Select the soil group from table B1 based on the project's county. In the Table B2, intersect the ADL for the route with the soil group to find the pavement design number. In Table B3, see the catalog design for that design number.

COUNTY	GROUP	COUNTY	GROUP	COUNTY	GROUP
Anderson	2	Hamilton	3	Morgan	4
Bedford	3	Hancock	6	Obion	5
Benton	2	Hardeman	3	Overton	6
Bledsoe	6	Hardin	2	Perry	3
Blount	4	Hawkins	6	Pickett	5
Bradley	1	Haywood	4	Polk	5
Campbell	4	Henderson	3	Putnam	6
Cannon	4	Henry	3	Rhea	1
Carroll	4	Hickman	4	Roane	4
Carter	6	Houston	6	Robertson	4
Cheatham	3	Humphreys	5	Rutherford	6
Chester	4	Jackson	6	Scott	2
Claiborne	2	Jefferson	4	Sequatchie	3
Clay	6	Johnson	6	Sevier	1
Cocke	5	Knox	4	Shelby	5
Coffee	4	Lake	3	Smith	3
Crockett	4	Lauderdale	4	Stewart	5
Cumberland	5	Lawrence	5	Sullivan	4
Davidson	3	Lewis	4	Sumner	3
Decatur	3	Lincoln	3	Tipton	5
DeKalb	3	Loudon	6	Trousdale	4
Dickson	6	McMinn	3	Unicoi	6
Dyer	5	McNairy	4	Union	5
Fayette	5	Macon	4	Van Buren	5
Fentress	2	Madison	4	Warren	5
Franklin	4	Marion	3	Washington	4
Gibson	5	Marshall	4	Wayne	5
Giles	5	Maury	5	Weakley	4
Grainger	6	Meigs	3	White	4
Greene	5	Monroe	3	Williamson	3
Grundy	2	Montgomery	4	Wilson	2
Hamblen	2	Moore	3		

Table B-1

FLEX ADLs	COUNTY SOIL GROUP NUMBER					
	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
1 – 19	I	I	III	III	III	IV
20 – 29	I	I	I	I	III	III
30 – 39	I	I	I	I	I	III
40 – 59	II	I	I	I	I	I
60 – 89	II	II	I	I	I	I
90 – 119	II	II	II	I	I	I
120 – 150	II	II	II	II	I	I

Table B-2

MIX TYPE	PAVEMENT DESIGN NUMBER			
	I	II	III	IV
"D"	1.25"	1.25"	1.25"	1.25"
"B-M2"	2.00"	2.00"	2.00"	2.00"
"A"	3.00"	3.00"	----	----
Mineral aggregate	8.00"	10.00"	12.00"	8.00"

Note: Tack Coat should be included on asphalt surfaces.

Note: No prime coat is required if the mineral aggregate is to be covered with asphalt in the same construction season. If the mineral aggregate will be wintered without asphalt, use a Tack coat to seal the mineral aggregate surface. In general, Prime Coat Materials are uneconomical for local projects, and the same material specified for tack coat is sufficient for the needs of these routes.

Table B-3

VIII. APPENDIX C: ESAL CALCULATION

In case the Traffic Report is not available the following calculations can be used to determine the Design ESALs. traffic calculations should be closely monitored by the Project Team:

1. Average Annual Daily Truck Traffic (AADTT) need to be collected (TDOT TCDS can be used https://tdot.public.ms2soft.com/tcds/tsearch.asp?loc=Tdot&mod=TCDS)

2. Growth Factor (GF) needs to be calculated using the equation below:

$$\mathrm{GF}\ (\%) = [\left(\frac{\mathrm{AADT}_{Year\ Y}}{\mathrm{AADT}_{Year\ X}}\right)^{\frac{1}{Y-X}} - 1] * 100$$

Where:

$AADT_{Year\ Y}$ is the AADT for the latest recorded year (Year Y)

$AADT_{Year\ X}$ is the AADT for a previous recorded year (Year X)

Year Y needs to be greater than Year X.

3. Convert the AADTT to ESALs using the table C-1. If no vehicle distribution was available use vehicles categories (3) for Passenger vehicles (PA) and (6-7) for Business/Commercial Vehicles (BC). If the latest traffic record is not calculated at the base design year the base year ESALs need to be calculated using the equation below.

Vehicle Type (Vehicle category)		**18-kip Factor Flexible**	**18-kip Factor Rigid**
Passenger cars and motorcycles (1-2)		0.001	0.001
Pick-up, Panel, Van (3)		0.004	0.004
Buses (4)		0.300	0.300
Single Unit Truck	2-axle, 6-tire (5)	0.260	0.260
	3-axle or more (6-7)	1.000	1.500
Combination Truck	4-axle (8)	0.640	0.800
	5-axle or more (9-13)	1.200	1.900

Table C-1

$$ESALs_{Base\ Year} = \mathrm{ESALs}_{Last\ Recorded\ Year}\ (1 + \frac{\mathrm{GF}}{100})^{Base\ Year\ -\ Last\ Recorded\ Year}$$

4. Assign the lane distribution factor. If the road is composed of 2 lanes or less then the Lane Distribution Factor is equal to 100%. If the road is composed of more than 2 lanes use the table C-2:

ADT	Lane Distribution Factor (L)
<5,000	95%
5,000 to 10,000	90%
10,000 to 15,000	85%
15,000 to 20,000	80%
20,000 to 30,000	75%
30,000 to 40,000	70%
>40,000	60%

Table C-2

5. Assign 50% as Directional Distribution (DD)

6. Calculate the design ESALs based on the equation below:

$$Design\ ESALs = ESALs_{Base\ Year} * 365 * \frac{(1+GF)^{Design\ Life} - 1}{GF} * L * DD$$

IX. APPENDIX D: ALTERNATIVE BASES

In Region 4 and any other area where the project team indicates that gravel may be used as the base the Pavement Designer shall prepare three alternate base designs: an assumed gravel base, a specified limestone aggregate base, and a Cement Treated Base (CTB).

- The first design shall be done utilizing an assumed type A aggregate as the base line. However, to ensure that this design is representative of built conditions the aggregate base shall be designated as 303-01.09 "Mineral Aggregate, Type A Base, Grading D Limestone."

- The assumed gravel bases shall calculate utilizing the type B aggregate base structural coefficient of 0.10. The aggregate base shall also be held to a maximum of 12 inches in depth. Deficiencies in structure after this design change shall be made up with additional A mix in the pavement design.

- The CTB design shall be limited to 8 inches of Cement Treated Base and utilize the asphalt thickness of the baseline design.

The Pavement Designer shall present all options to the Design Team. Due to a lack of readily available limestone across Region 4. The project should not proceed with only the limestone option. In most cases it is preferred to allow bids on at least two of the alternative designs.

X. APPENDIX E: PRELIMINARY DESIGN

For projects in Stage 1 it is often required to provide a pavement design for completing the Line & Grade Estimate. However, this typically falls prior to the Geotechnical Report being available. In this case the designer shall assume a CBR of 4 and complete a preliminary pavement design based on the traffic report provided in the Concept Report.

XI. APPENDIX F: PAVEMENT LAYER DESCRIPTIONS

Surface Layers

Surface layers are defined in section 411 or 501 of the TDOT Specifications Book. These mixes have the smallest aggregate size to provide a smooth riding surface for the driver. These mixes also incorporate a proscribed amount of polish resistant materials to ensure stopping friction is maintained.

- HMA Grading D: Most common surface mix, typically placed 1.25"
- HMA Grading TL: Thin lift surface mix with can be placed as thin as 5/8" used as a pavement preservation lift
- HMA Grading TLD: A thin life surface mix that with a gradation between D and TL. Typically placed around 7/8" of an inch.
- HMA Open Graded Friction Course (OGFC): is a permeable surface that allows for quick removal of water from the pavement surface. Typically utilized on Interstates and other Freeways in Tennessee. Placed at 1.25" in depth.
- HMA C-W: Low volume surface layer, utilized by local agencies primarily. Mix has a higher binder content but often no polish resistant aggregate. Mix is intended for projects with low speed low volume routes where high speed braking and rutting is not a concern. Typical used only as park roads or low volume off system routes for local cities/counties.
- HMA Grading E: Most common shoulder mix, typically placed 1.25 inches. Similar to D mix in gradation but lacking polish resistant aggregate
- HMA Grading TLE: shoulder mix similar in gradation to TLD but without polish resistant aggregate.
- Class CP Concrete: Standard paving concrete for Tennessee. It is a 3000 psi standard mix.
- Class X Concrete: Nonstandard concrete mixtures that can be designated by the pavement designer if needed in an extraordinary condition.

Binder Layers

HMA Binder layers are defined in section 307 of the TDOT Specifications Book. These mixes have aggregate gradations between the surface and base layer, they provide a smoother surface to pave the surface mix on to ensure a smooth finished surface is feasible.

- B-Mod2 (BM2): is the primary binder course used in TDOT projects. Typically placed between 2 and 3" in depth.
- B and B-Mod(BM): Legacy mixes that proceeded BM2, no longer in use.
- CM: is the designated binder layer to be placed below OGFC at 1.5" in depth.
- C: Legacy mix that proceeded CM, no longer in use.

- C-S: Scratch mix used to level after milling, used only in resurfacing. Is not to be used as a structural layer in a pavement design.
- Crack Attenuating Mix (CAM): binder layer intended to slow reflective cracking. Typically utilized in resurfacing on an existing cracked pavement that cannot be economically repaired/replaced with extensive cracking.

Base Layers

Base layers are placed between the subgrade and surface to build the required structure. Base layers generally in two categories bound and unbound. Bound layers are stabilized with either asphalt or cement for greater cohesion while unbound layers are not and are generally added as a first layer to separate the subgrade from the rest of the pavement.

Bound Base Layers since they are stabilized with asphalt include:

- HMA Grading A: Primary base mix for TDOT projects. Makes up the majority of the pavement structure and the most economical layer to increase to add structure.
- HMA Grading A-S: drainable base layer utilized on multilane (4+) highways. Along with underdrains serves to ensure that the pavement and base is well drained.
- HMA Grading A-CRL: Crack relieve base layer, utilized when overlaying existing concrete pavement, rubbilized or crack and seated concrete pavements. The layer replaces A-S mix in the structure and also serves as a drainage layer in this use.
- Treated Permeable Base (TPB): Treated permeable base serves as the drainage layer under concrete pavements. It may utilize either cement or asphalt as the binder to stabilize the base. In practice it is generally asphalt and practically the same as HMA A-S.
- Cement Treated Base (CTB): stabilized aggregate base with a small amount of cement. Serves as a stronger alternative to an aggregate unbound base.

Unbound base layers serve to separate the pavement from the subgrade and to provide a stable construction platform.

- Mineral Aggregate Base: is the primary unbound base layer utilized in Tennessee. In Regions 1, 2 and, 3 it is assumed that mineral aggregate base will be a crushed quarried stone such as limestone. In Region 4 quarried stones are much less common and the default aggregate is most likely to be a dredged gravel. See Appendix D for Designing Mineral Aggregate bases in Region 4.

REVISION NOTES:

July 2026

General: added table numbers

General: Added section Numbers

Table 3 Layer Coefficient Table: Note updated for Region 4 designs.

3.4: Updated A-S policy. A-S to be utilized on all multi-lane state routes (4 or + lanes) regardless of c/g moving forward

3.4: Added reference to Appendix D for Region 4 Aggregate Base.

3.7: Updated PG Binder Selection Policy

3.8: Updated Prime Coat Policy

Added Appendices D, E, F.