RIGID PAVEMENT DESIGN MANUAL

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OFFICE OF DESIGN, PAVEMENT MANAGEMENT SECTION
TALLAHASSEE, FLORIDA
Topic #625-010-006

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CHAPTER 1
INTRODUCTION

1.1 PURPOSE

The objective of this manual is to provide a Pavement Design Engineer with sufficient information so that the necessary input data can be developed and proper engineering principles applied to design a new rigid pavement, or develop a properly engineered pavement rehabilitation project.

It is the responsibility of the Pavement Design Engineer to ensure that the designs produced conform to Department policies, procedures, standards, guidelines, and sound engineering practices.

1.2 AUTHORITY

Sections 20.23(3) (a) and 334.048(3), ***Florida Statutes***

1.3 GENERAL

Chapter 334 of the ***Florida Statutes***, known as the Florida Transportation Code, establishes the responsibilities of the state, counties, and municipalities for the planning and development of the transportation systems serving the people of the State of Florida, with the objective of assuring development of an integrated, balanced statewide system.

The standards in this manual represent minimum requirements, which must be met for rigid pavement design for new construction and rigid pavement rehabilitation of Florida Department of Transportation projects. Any variances should be documented in project files.

Pavement design is primarily a matter of sound application of acceptable engineering criteria and standards. While the standards contained in this manual provide a basis for uniform design practice for typical pavement design situations, precise rules which would apply to all possible situations are impossible to give.

1.4 SCOPE

The principal users of this manual are the District Pavement Design Engineers and their agents (i.e. Consultants). Additional users include other department offices such as Construction, Maintenance, Traffic Operations, etc., and city and county offices.

1.5 RIGID PAVEMENT DESIGN MANUAL ORGANIZATION AND REVISIONS

1.5.1 REFERENCES

The design procedures incorporated in this document are based on the American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide plus numerous National Cooperative Highway Research Program (NCHRP), Transportation Research Board (TRB), and Federal Highway Administration (FHWA) publications.

The specifics addressed in this manual have been tailored to Florida conditions, materials, and policy.

1.5.2 FLORIDA CONDITIONS

A number of coefficients and variables are specified in this manual. They should be considered as standard values for typical Florida projects. There may be instances where a variance from the values would be appropriate. In these instances, the Pavement Design Engineer will stay within the bounds established by the basic AASHTO Design Guide, justify the variance, and document the actions in the Pavement Design File.

1.5.3 APPENDICES

Included with this manual are 3 appendices:

Appendix	Contents
A	Florida Specific Input Variables To Pavement Mechanistic-Empirical Software (AASHTOWare Pavement ME)
B	Rigid Pavement Design Quality Control Plan
C	Estimating Design 18-Kip Equivalent Single Axle Loads ($ESAL_D$)

1.6 DISTRIBUTION

This document is available through the Maps and Publications Section. Manuals may be downloaded from:

Florida Department of Transportation
Maps and Publications
https://www.fdot.gov/publications/publications.shtm

1.7 PROCEDURE FOR REVISIONS AND UPDATES

Rigid Pavement Design Manual holders are solicited for comments and suggestions for changes to the manual by writing to the address below:

Florida Department of Transportation
Pavement Management Section
605 Suwannee Street, M.S.32
Tallahassee, Florida
32399-0450

Each idea or suggestion received will be reviewed by appropriate pavement design staff in a timely manner. Items warranting immediate change will be made with the approval of the State Pavement Design Engineer in the form of a Pavement Design Bulletin.

Pavement Design Bulletins for the Rigid Pavement Design Manual are distributed to the District Design Engineers, District Pavement Design Engineers, and District Consultant Pavement Design Engineers, Federal Highway Administration (FHWA) and posted on the FDOT website.

https://www.fdot.gov/roadway/bulletin/default.shtm

Pavement Design Bulletins will be in effect until the official manual revision.

Statewide meetings of District Roadway Design Engineers will be held quarterly and a statewide meeting of designers may be held annually. A major agenda item at these meetings will be the review of Design Bulletins, planned revisions, and suggestions and comments that may warrant revisions. Based on input from these meetings, official revisions are developed and distributed to the District Design Engineers, District Pavement Design Engineers, Consultant Project Managers, Roadway Design Office, State Materials Office, Federal Highway Administration, industry and other appropriate offices as necessary.

All revisions and updates will be coordinated with the Policy and Process Management Unit prior to implementation to ensure conformance with and incorporation into the Department's Standard Operating System, Procedure No. 025-020-002.

The final revisions and addenda will be distributed to District Pavement Design Engineers and copies provided to Maps and Publications. The date of the latest revision will be posted on the Pavement Management Section and the Maps and Publications Internet Web Pages.

https://www.fdot.gov/publications/publications.shtm

1.8 TRAINING

No mandatory training is required by this procedure. Classes on the manual are available on request by the District Pavement Design Engineer.

1.9 FORMS

No forms are required by this procedure.

CHAPTER 2
DEFINITIONS

2.1 PAVEMENT SYSTEM

The following define the general pavement layers in a rigid jointed plain concrete pavement (JPCP) system. Some of the most important layers are shown in ***Figure 2.1***. The definitions are presented "top-down" through the pavement structure.

Concrete Pavement Slab

This is the main structural element in the rigid JPCP pavement system. It is normally made up of plain cement concrete pavement. Discussion on the design of this layer thickness will be found later on.

The minimum designed thickness should be eight inches (8-in).

Asphalt Base

Asphalt Base provides a uniform, non-erodible and stable construction platform, and contributes to the slab structural performance. Draincrete edgedrains are used to provide subdrainage. Use Optional Base Group 1 Type B-12.5 only. See ***Figure 2.1***. This material is shown in ***Standard Plans***, ***Indexes 446-001*** (Concrete Pavement Subdrainage) and ***120-001*** (Embankment Utilization) for the Asphalt Base option and will be discussed further in ***Chapter 4***.

Special Select Soil

The Special Select Soil is a permeable sandy soil that provides vertical and lateral drainage of infiltrated water through the embankment to the shoulder ditches. The required depth is 60-in. This material is used in the Embankment Utilization of Special Select Soil Option shown in ***Standard Plans***, ***Index 120-001***, typically utilizes draincrete edgedrains to provide additional subdrainage, and will be discussed further in ***Chapter 4***. It is normally bid as embankment material. The Special Stabilized Subbase is a vertically drainable, but stable layer that is 6-in thick and is used with the Special Select Soil Option.

This layer serves as a working platform for the paving machine to permit the efficient construction of the concrete slab while maintaining sufficient vertical permeability of the special select embankment soil. It is constructed by mixing in 3-in of #57 or #89 coarse aggregate into the top 6-in of subgrade and compacted. It is bid as Special Stabilized Subbase and Commercial Stabilizing Material (Special). If the special select soils have sufficient stability for construction, these pay items can be deleted. This should only be done with close coordination and agreement of the District Materials Engineer and District Construction Engineer.

Type B Stabilized Subgrade

The Type B Stabilized Subgrade is a supporting layer that is 12-in thick. This material is only used in the Asphalt Base Option as shown in ***Standard Plans***, Index 120-001. This layer serves as a working platform to permit the efficient construction of the asphalt base. It is bid as Type B Stabilization (LBR-40) with the contractor selecting the approved materials necessary to achieve the LBR 40 value.

Natural Ground or Fill

The Natural Ground or Fill is the natural material or embankment material upon which the Pavement Structure is constructed.

FIGURE 2.1
ASPHALT BASE OPTION

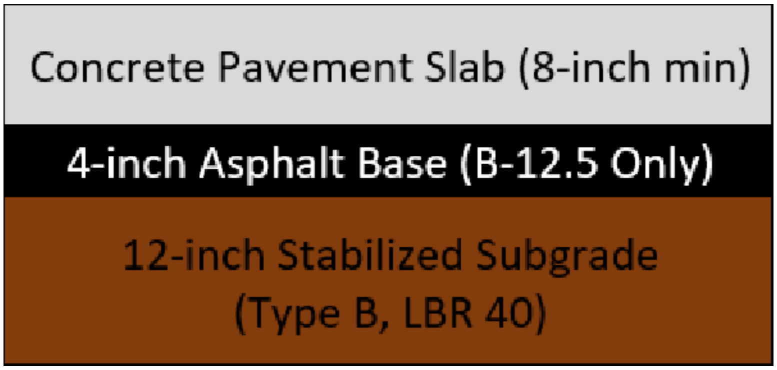
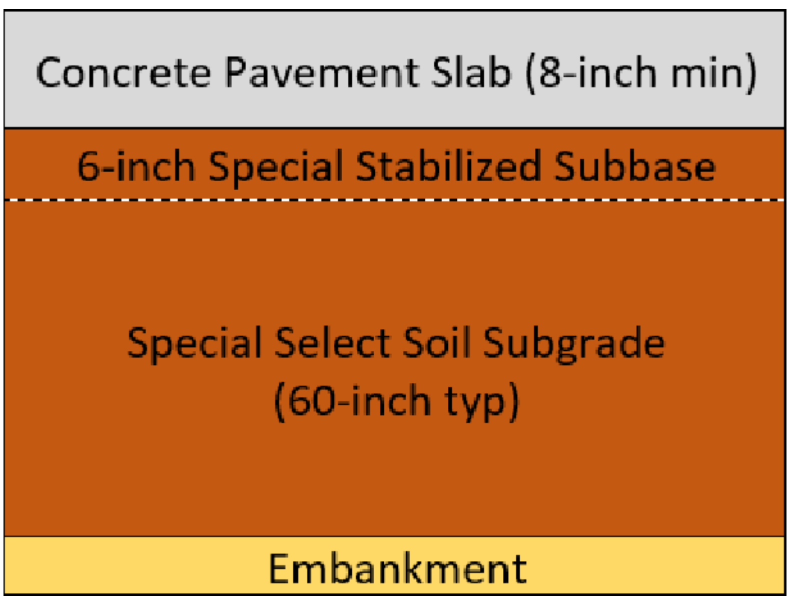


FIGURE 2.2
SPECIAL SELECT SOIL BASE OPTION



2.2 AASHTO MECHANISTIC-EMPIRICAL DESIGN TERMINOLOGY

The following definitions relate to the ***2015 AASHTO Mechanistic-Empirical Pavement Design Guide*** and the AASHTOWare Pavement ME Design software that is used for calculating rigid pavement thickness and is the basis for design tables included in this manual.

2.2.1 VARIABLES

Reliability (%R)

The use of Reliability (%R) allows the Pavement Design Engineer to tailor the design to more closely match the needs of the project. It is the probability of achieving the design life that the Department desires for that facility. The Pavement Design Engineer is cautioned, however, that a high reliability value may increase the slab thickness substantially.

The mechanistic-empirical models are based on smoothness, faulting and transverse cracking failure mechanisms.

Recommended values range from 80% to 95% and can be found in ***Table 3.2***.

Traffic Loading Forecasts (Equivalent Single Axle Loads - ESALs)

The expected truck loadings over the design period are obtained from the District Planning Office for the project location. The number of heavy trucks and the equivalent 18-kip axle loads are forecast for the type of facility and its expected traffic growth.

Climate Region

Temperature gradients through the slab thickness can significantly affect the load induced stresses and performance of concrete pavements in Florida. Analysis using the Pavement ME software has shown there are significant differences in the impact of climate on rigid pavement design through the state. The Rigid Pavement Design Climate Regions determined for Florida are shown in ***Figure 3.1***. The appropriate climate region for the project location being designed must be selected from the design tables in ***Chapter 3*** or the appropriate climate files selected if using the AASHTOWare Pavement ME Design software.

2.2.2 STANDARD INPUTS

Initial Smoothness (IRI)

The initial smoothness (International Roughness Index - IRI) is the smoothness after construction (including standard full diamond grinding). An initial IRI value of 60-in/mile is typical for fully ground new pavements in Florida. Full diamond grinding is required by the standard specifications and ensures a smooth and uniform texture of the pavement surface.

Terminal Smoothness (IRI)

The Terminal Smoothness (IRI) is the smoothness condition of a road when it reaches a point where some type of rehabilitation or reconstruction is warranted. A value of 180-in/mile is used in Florida.

Terminal Faulting

The Terminal Faulting is the mean differential elevation across joints in the wheel path where the condition of a road reaches a point where some type of rehabilitation or reconstruction is warranted. A value of 0.12-in is used in Florida.

Terminal Cracking

The Terminal Cracking value is the percent of transverse slab cracking in the design lane where reconstruction would be warranted. A value of 10% is used in Florida.

28-Day PCC Compressive Strength

For JPCP pavements, a mean 28-Day Portland Cement Concrete (PCC) compressive strength of 4000 psi is used for design in Florida. The Pavement ME Design software uses this value to estimate the elastic modulus and modulus of rupture for the concrete.

Coefficient of Thermal Expansion (CTE)

The CTE describes how the size of an object changes with a change in temperature. A CTE value of 4.5 x 10-6in/in/oF is used as the JPCP pavement design input in Florida based on extensive local calibration testing by the State Materials Office. Below is a table of typical CTE Ranges for common PCC components from the FHWA Portland Cement Concrete Pavements Research.

Typical α Ranges for Common PCC Components

	Coefficient of Thermal Expansion	
Aggregate	**10^{-6}/°C**	**10^{-6}/°F**
Granite	7 – 9	4 – 5
Basalt	6 – 8	3.3 – 4.4
Limestone	6	4.5 *
Dolomite	7 – 10	4 – 5.5
Sandstone	11 – 12	6.1 – 6.7
Quartzite	11 – 13	6.1 – 7.2
Marble	4 – 7	2.2 – 4
Cement Paste (saturated)		
w/c = 0.4	18 – 20	10 – 11
w/c = 0.5	18 – 20	10 – 11
w/c = 0.6	18 – 20	10 – 11
Concrete	7.4 – 13	4.1 – 7.3
Steel	11 – 12	6.1 – 6.7
* Florida uses a Value of 4.5, FHWA uses 3.3		

https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/thermal.cfm

Asphalt Base (See *Figure 2.1*)

Full friction with the slab for the life of the design is assumed for asphalt base. Performance Grade PG 76-22 is used by the software to estimate the Dynamic Modulus of the asphalt base in Florida. An asphalt base aggregate gradation of 100% P3/4-in, 85% P3/8-in, 65% P#4, and 5.7% P#200 is used as typical for Florida.

Stabilized Subgrade Resilient Modulus

A resilient modulus value of 16,000 psi is typical for this layer in Florida.

Road Bed Soil Resilient Modulus (M_R)

The Resilient Modulus (M_R) is a measurement of the stiffness of the roadbed soil. Since rigid concrete pavement is considerably stiffer than flexible asphalt pavement, the rigid designs spread the vehicle loads over a wider area and are not very sensitive to the subgrade modulus. A value of 12,000 psi is typical for Florida select soils and is used to develop the Design Tables in ***Chapter 3***. If evaluation of a significantly different Design M_R value for a specific project site is desired, the Pavement ME software can be run to see if it makes a difference in the concrete thickness.

Joint Spacing

A standard JPCP transverse joint spacing of 15-ft is used in Florida.

Truck Lane Slab Width

A slab width of 13-ft for outside (truck) lanes with striping at 12-ft is standard practice in Florida. If a narrower truck lane is necessary due to constraints, an additional half inch of thickness should be added to the table values or the Pavement ME Design software should be utilized for a revised thickness design.

2.2.3 UNKNOWNS

Required Thickness

The required slab thickness for the design period as determined from the ***Chapter 3*** Design Tables or the AASHTOWare Pavement ME Design software.

2.3 TERMS

The following terms will be used to describe the Department's rigid pavement design options.

New Construction

New construction is the complete development of a pavement system on a new alignment.

Reconstruction

Reconstruction is the extensive removal and replacement of the existing slabs along a significant portion of the project.

Rehabilitation

Rehabilitation is a process to restore the existing rigid pavement to its full serviceability. This could include Concrete Pavement Rehabilitation (CPR) or Crack and Seat or Rubblization of the existing slabs and then an overlay with asphalt.

CHAPTER 3
PAVEMENT THICKNESS DESIGN PROCESS FOR NEW CONSTRUCTION

3.1 MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE (MEPDG)

The Florida Department of Transportation has been using the AASHTO mechanistic-empirical pavement design process as a basis for rigid jointed plain concrete pavement (JPCP) design since 2009. The mechanistic-empirical design process was first adopted by AASHTO with the 2008 Interim Mechanistic-Empirical Pavement Design Guide (MEPDG). This edition of the Florida Rigid Pavement Design Manual is based on the 2015 edition of the AASHTO MEPDG.

Overview of Mechanistic-Empirical Design Process

The mechanistic-empirical design and analysis process calculates pavement responses (stress, strain, and deflections) and uses those responses to compute incremental damage over time. The process then empirically relates the cumulative damage to observed distresses.

AASHTOWare Pavement ME Design software performs these calculations and predicts the smoothness, faulting, and slab transverse cracking performance indicators for JPCP pavements.

3.2 DESIGN PERIODS

The design period in Florida for new rigid construction and total reconstruction is 20 years.

Since concrete pavement rehabilitation (CPR) does not increase the overall slab thicknesses, a rehabilitation design period for calculation purposes is not applicable.

3.3 DESIGN PROCEDURE

In order to design a new rigid pavement, several tasks need to be performed. The first task is to collect all relevant project data, which would include:

- A history of successful construction and performance with concrete pavements.

- The base types which are either Asphalt Base, or Special Select embankment soils as shown in ***Standard Plans***, ***Index 120-001***.
- Traffic loading forecasts (ESALs).

The next task would be to evaluate concrete material properties, which are generally constant for design purposes and include:

- Concrete Compressive Strength (f'c).
- Concrete Modulus of Elasticity (EC).
- Concrete Coefficient of Thermal Expansion (CTE).

The Pavement Design Engineer also needs to work with the roadway design engineer, District Materials Engineer, and District Drainage Engineer to develop preliminary cut and fill typical sections and evaluate the type of subgrade drainage system to be provided.

If there is not a strong history of successful construction, performance, and cost-effectiveness in the project area of using Special Select soils under concrete pavements, then use the Asphalt Base option.

Calculation of the pavement thickness utilizing the design aids provided can be accomplished next.

The Pavement Design Engineer needs to develop pavement details such as:

- Embankment and drainage details.
- Joint details.
- Shoulders details.
- The availability, constructability, and cost-effectiveness of suitable drainable Special Select embankment soils.

The design of the pavement details is just as important as the design of the pavement thickness. Close attention should be paid to their development.

TABLE 3.1
DESIGN PERIODS

The following design periods will be used for rigid pavement design:

New Construction or Reconstruction	20 years
Concrete Pavement Rehabilitation (CPR)	5 to 10 years*

* CPR design life is not calculated, but should be subjectively estimated based on a project's historical deterioration rate and loadings.

3.4 DISTRICT COORDINATION

Early in the design process, the Pavement Design Engineer should closely coordinate with the following offices:

District Design

The District Design Engineer's office should be involved for providing the proposed roadway typical section sheets for such information as pavement widening, side street work and other related information required for the Typical Section Package according to the Department's FDOT Design Manual.

District Drainage

The District Drainage Office should be involved to determine what special drainage considerations need to be addressed. Several areas, which should be addressed include:

- A high-water table that may require the Drainage Engineer to specify the location of outlet pipes.
- Location of edgedrain outlet pipes in an urban area to take advantage of local storm sewers.
- Projects with curb and gutter. Certain curb inlet tops create constructability issues with concrete pavement.

When designing the pavement system, the designer needs to refer to the ***FDOT Design Manual (FDM) Section 210.10.3*** (Vertical Clearances), to determine where the bottom of the pavement slab needs to be in relation to the Base Clearance Water Elevation. The bottom of "roadway base", as referred to in the ***FDM***, for rigid pavement design purposes, is the bottom of the Asphalt Base or the bottom of the concrete slab for the Special Select Soil option.

District Construction

The District Construction Office should be involved to determine if there are any special construction details that need to be included in the plans or issues that need to be addressed. Some of these items may include Maintenance of Traffic (MOT), Constructions Time, etc.

District Materials

The Asphalt Base Option on ***Standard Plans***, ***Index 120-001*** is recommended. If the Special Select Soil option is considered, the District Materials Office should be involved to determine the availability, cost effectiveness, constructability, and history of successful use of suitable permeable special select soils in the construction area and any other special conditions that may exist. One example would include an evaluation of existing soils to determine their AASHTO classifications and lab permeability.

The District Materials Office can also provide recommendations with respect to rehabilitation strategies. Additional coordination of project field reviews and data collection might be needed.

3.5 QUALITY

The Quality Control of a pavement's design is a District responsibility. Upon completion of the design process, an independent design review needs to be performed. A suggested Pavement Design Quality Control Plan is provided in ***Appendix B***.

3.6 DESIGN THICKNESS BASED ON THE 2015 AASHTO GUIDE

This process is applicable to all new construction and reconstruction projects in Florida where the Pavement Design Engineer must determine the concrete pavement depth using the 2015 AASHTO Procedure.

The following is a summary of the steps to be taken to solve for the Required Thickness of the concrete pavement:

- Based on the project location, determine the applicable Florida Rigid Pavement Design Climate Region from Figure 3.1.

- The Accumulated 18-kip Equivalent Single Axle Loads (ESALs) are obtained from the District Planning Office. The process for this procedure can be found in the Project Traffic Forecasting Procedure Topic No. 525-030-120.
- Reliability (%R) value is selected from Table 3.2. Recommended values range from 80% to 95% for new or total reconstruction. For asphalt overlays of concrete pavement, see the Flexible Pavement Design Manual for recommended reliability's and other guidance.

Using these values and the selected base option, the Pavement Design Engineer will calculate the Required Thickness of concrete pavement using the Design ***Tables 3.3*** or ***3.4***, or the AASHTOWare Pavement ME computer program.

Each table uses a different Reliability (%R) value and relates the Accumulated 18-kip Equivalent Single Axle Loads (ESALs) to the Required Thickness for each Climate Region. An example is determined below using ***Table 3.3***. A reduction in slab width from 13-ft to 12-ft (or 11-ft), will cause the slab to crack exponentially more under the same traffic loading thus requiring a thicker slab. A project-specific AASHTOWare Pavement ME design will be required by the Pavement Design Engineer.

3.7 NEW CONSTRUCTION DESIGN EXAMPLE

The following is an example illustrating the mechanics of this procedure. Using the following input:

ESAL = 25,000,000 (from the Planning Office)

Climate Region = D (From ***Figure 3.1*** based on project location)

%R = 90 (from ***Table 3.2***)

Asphalt Base option selected.

The solution is:

Thickness = 10" (from ***Table 3.3***)

TABLE 3.2
RELIABILITY (%R) FOR DIFFERENT ROADWAY FACILITIES

Facility	New or Reconstruction
Limited Access	80 – 95
Urban Arterials	80 – 95
Rural Arterials	80 – 90
Collectors	80 – 90

The type of roadway is determined by the Office of Planning and can be obtained from the Roadway Characteristics Inventory (RCI).

The designer has some flexibility in selecting values that best fits the project when choosing the Reliability (%R).

FIGURE 3.1
FLORIDA RIGID PAVEMENT DESIGN CLIMATE REGIONS

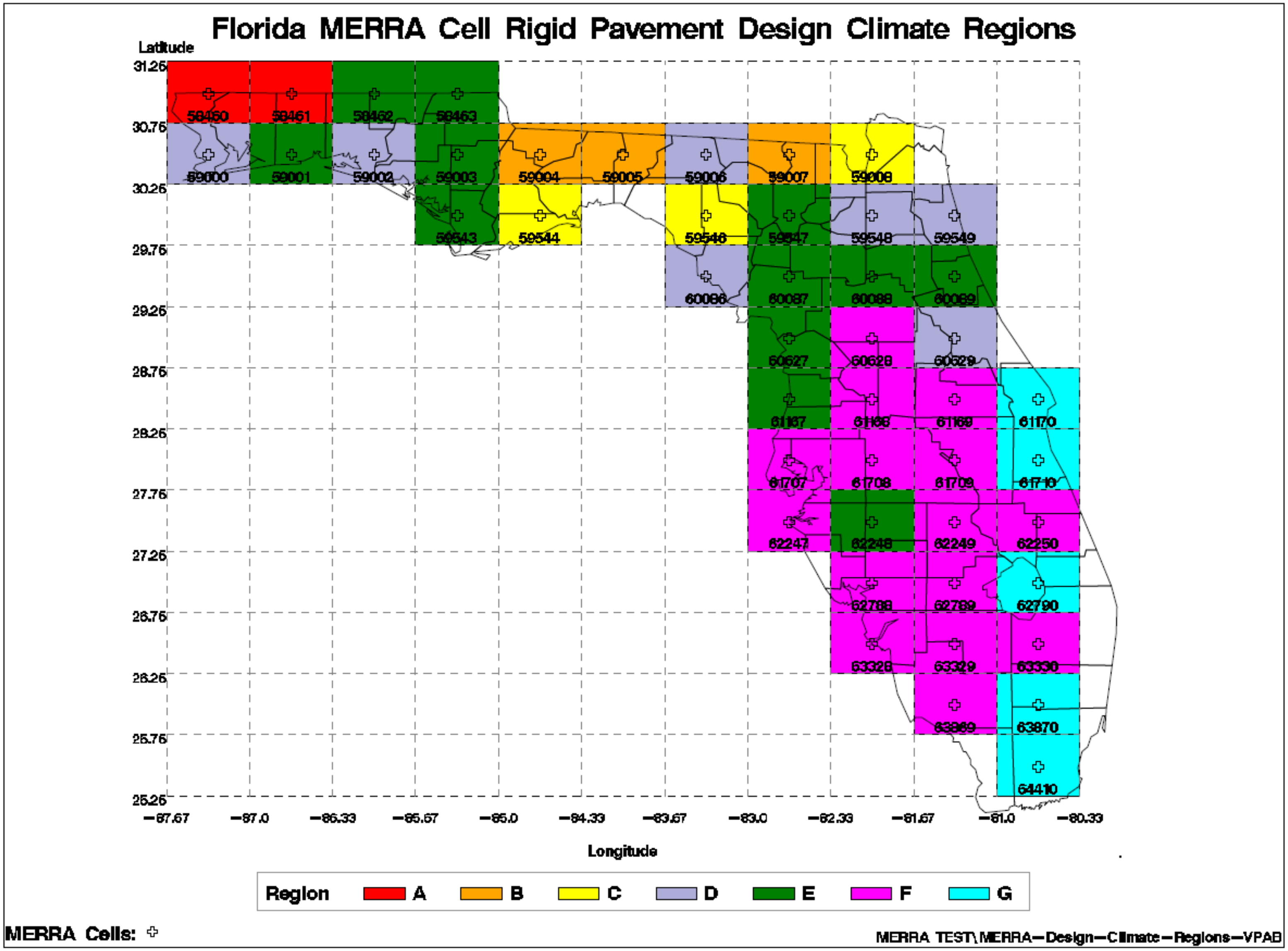


TABLE 3.3
RIGID PAVEMENT DESIGN TABLE
ASPHALT BASE OPTION

Region		A			B			C			D			E			F			G		
Traffic		Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)		
ESALs (millions)	AADTT	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95
1	115	8.0	8.5	8.5	8.0	8.0	8.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
2	230	8.5	8.5	8.5	8.0	8.5	8.5	8.5	8.5	8.5	8.0	8.0	8.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
3	345	9.0	9.0	9.0	8.5	9.0	9.0	8.5	8.5	9.0	8.5	8.5	8.5	8.0	8.0	8.5	8.0	8.0	8.0	8.0	8.0	8.0
4	460	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	8.5	8.5	8.5	8.5	8.5	8.5	8.0	8.0	8.0	8.0	8.0	8.0
5	575	9.0	9.5	9.5	9.0	9.0	9.5	9.0	9.0	9.0	8.5	8.5	9.0	8.5	8.5	8.5	8.0	8.0	8.0	8.0	8.0	8.0
6	690	9.5	9.5	9.5	9.5	9.5	9.5	9.0	9.0	9.5	9.0	9.0	9.0	8.5	8.5	8.5	8.0	8.0	8.5	8.0	8.0	8.0
7	805	9.5	9.5	9.5	9.5	9.5	9.5	9.0	9.5	9.5	9.0	9.0	9.0	8.5	8.5	8.5	8.0	8.5	8.5	8.0	8.0	8.0
8	920	9.5	9.5	10.0	9.5	9.5	9.5	9.5	9.5	9.5	9.0	9.0	9.0	8.5	8.5	9.0	8.5	8.5	8.5	8.0	8.0	8.0
9	1035	9.5	10.0	10.0	9.5	9.5	10.0	9.5	9.5	9.5	9.0	9.0	9.5	8.5	9.0	9.0	8.5	8.5	8.5	8.0	8.0	8.0
10	1150	10.0	10.0	10.5	9.5	10.0	10.0	9.5	9.5	9.5	9.0	9.5	9.5	9.0	9.0	9.0	8.5	8.5	8.5	8.0	8.0	8.5
15	1725	10.5	11.0	11.5	10.5	10.5	11.0	10.0	10.0	10.0	9.5	9.5	9.5	9.0	9.0	9.5	8.5	9.0	9.0	8.5	8.5	8.5
20	2300	11.5	12.0	12.0	11.0	11.5	11.5	10.5	10.5	11.0	9.5	9.5	10.0	9.5	9.5	9.5	9.0	9.0	9.0	8.5	8.5	8.5
25	2875	12.0	12.5	12.5	11.5	12.0	12.0	10.5	11.0	11.5	10.0	10.0	10.0	9.5	9.5	9.5	9.0	9.0	9.0	8.5	9.0	9.0
30	3450	12.5	12.5	12.5	12.0	12.0	12.5	11.0	11.5	11.5	10.0	10.5	10.5	9.5	9.5	9.5	9.0	9.5	9.5	8.5	9.0	9.0
35	4025	12.5	13.0	13.5	12.5	12.5	12.5	11.5	12.0	12.0	10.5	10.5	11.0	9.5	9.5	10.0	9.5	9.5	9.5	9.0	9.0	9.0
40	4600	12.5	13.5	13.5	12.5	12.5	13.0	12.0	12.0	12.5	10.5	11.0	11.5	9.5	10.0	10.0	9.5	9.5	9.5	9.0	9.0	9.0
45	5175	13.0	13.5	14.0	12.5	13.0	13.0	12.0	12.5	12.5	11.0	11.5	11.5	10.0	10.0	10.0	9.5	9.5	10.0	9.0	9.0	9.0
50	5750	13.5	14.0	14.0	13.0	13.0	13.5	12.5	12.5	13.0	11.5	11.5	11.5	10.0	10.0	10.5	9.5	9.5	10.0	9.0	9.0	9.5
60	6900	14.0	14.0	14.5	13.0	13.5	14.0	12.5	13.0	13.0	11.5	12.0	12.5	10.0	10.5	10.5	10.0	10.0	10.5	9.0	9.5	9.5
70	8050	14.0	14.5	15.0	13.5	14.0	14.0	13.0	13.0	13.5	12.0	12.5	12.5	10.5	11.0	11.0	10.5	10.5	10.5	9.5	9.5	9.5
80	9200	14.5	15.0	15.0	14.0	14.0	14.5	13.0	13.5	13.5	12.5	12.5	13.0	11.0	11.0	11.5	10.5	10.5	11.0	9.5	9.5	9.5
90	10350	15.0	15.0	15.5	14.0	14.5	14.5	13.5	13.5	14.0	12.5	13.0	13.0	11.0	11.5	11.5	10.5	11.0	11.5	9.5	9.5	9.5
100	11500	15.0	15.0	15.5	14.5	14.5	15.0	13.5	14.0	14.0	12.5	13.0	13.5	11.5	11.5	12.0	11.0	11.5	11.5	9.5	9.5	9.5

TABLE 3.4
RIGID PAVEMENT DESIGN TABLE
SPECIAL SELECT SOIL OPTION

Region		A			B			C			D			E			F			G		
Traffic		Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)			Reliability (%)		
ESALs (millions)	AADTT	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95	80	90	95
1	115	9.0	9.0	9.5	9.0	9.0	9.5	9.0	9.0	9.0	8.5	8.5	9.0	8.5	8.5	8.5	8.5	8.5	8.5	8.0	8.0	8.0
2	230	10.0	10.0	10.5	10.0	10.0	10.0	9.5	10.0	10.0	9.5	9.5	9.5	9.0	9.0	9.0	9.0	9.0	9.5	8.5	8.5	8.5
3	345	10.5	10.5	10.5	10.5	10.5	10.5	10.0	10.5	10.5	10.0	10.0	10.0	9.0	9.5	9.5	9.5	9.5	10.0	8.5	8.5	9.0
4	460	11.0	11.0	11.0	10.5	11.0	11.0	10.5	10.5	10.5	10.0	10.0	10.5	9.5	9.5	10.0	10.0	10.0	10.0	9.0	9.0	9.0
5	575	11.0	11.0	11.5	11.0	11.0	11.5	10.5	11.0	11.0	10.5	10.5	10.5	10.0	10.0	10.0	10.0	10.0	10.5	9.0	9.0	9.0
6	690	11.5	11.5	11.5	11.0	11.5	11.5	11.0	11.0	11.5	10.5	10.5	11.0	10.0	10.0	10.5	10.0	10.5	10.5	9.0	9.5	9.5
7	805	11.5	11.5	12.0	11.5	11.5	11.5	11.0	11.5	11.5	10.5	11.0	11.0	10.0	10.5	10.5	10.5	10.5	10.5	9.5	9.5	9.5
8	920	11.5	12.0	12.0	11.5	11.5	12.0	11.5	11.5	11.5	11.0	11.0	11.0	10.5	10.5	10.5	10.5	10.5	11.0	9.5	9.5	10.0
9	1035	12.0	12.0	12.5	11.5	12.0	12.0	11.5	11.5	12.0	11.0	11.0	11.5	10.5	10.5	10.5	10.5	10.5	11.0	9.5	10.0	10.0
10	1150	12.0	12.0	12.5	12.0	12.0	12.0	11.5	11.5	12.0	11.5	11.5	11.5	10.5	10.5	11.0	10.5	11.0	11.0	10.0	10.0	10.0
15	1725	12.5	13.0	13.0	12.5	12.5	12.5	12.0	12.0	12.5	12.0	12.0	12.0	11.0	11.0	11.5	11.0	11.5	11.5	10.0	10.0	10.5
20	2300	13.0	13.5	13.5	12.5	13.0	13.0	12.5	12.0	13.0	12.0	12.0	12.5	11.5	11.5	11.5	11.5	11.5	12.0	10.5	10.5	10.5
25	2875	13.5	13.5	14.0	13.0	13.5	13.5	13.0	13.0	13.0	12.5	12.5	12.5	11.5	12.0	12.0	11.5	12.0	12.0	10.5	11.0	11.0
30	3450	13.5	14.0	14.0	13.5	13.5	13.5	13.0	13.0	13.5	12.5	12.5	13.0	12.0	12.0	12.0	12.0	12.0	12.5	11.0	11.0	11.0
35	4025	14.0	14.0	14.0	13.5	13.5	14.0	13.5	13.5	13.5	13.0	13.0	13.0	12.0	12.0	12.5	12.0	12.5	12.5	11.0	11.0	11.5
40	4600	14.0	14.0	14.5	13.5	14.0	14.0	13.5	13.5	14.0	13.0	13.0	13.5	12.0	12.5	12.5	12.5	12.5	12.5	11.0	11.5	11.5
45	5175	14.0	14.5	14.5	14.0	14.0	14.0	13.5	14.0	14.0	13.5	13.5	13.5	12.5	12.5	12.5	12.5	12.5	12.5	11.5	11.5	11.5
50	5750	14.5	14.5	14.5	14.0	14.0	14.5	13.5	14.0	14.0	13.5	13.5	13.5	12.5	12.5	13.0	12.5	12.5	13.0	11.5	11.5	11.5
60	6900	14.5	15.0	15.0	14.0	14.5	14.5	14.0	14.0	14.5	13.5	13.5	14.0	12.5	13.0	13.0	13.0	13.0	13.0	11.5	12.0	12.0
70	8050	15.0	15.0	15.5	14.5	14.5	15.0	14.0	14.5	14.5	14.0	14.0	14.0	13.0	13.0	13.0	13.0	13.0	13.5	12.0	12.0	12.0
80	9200	15.0	15.5	16.0	14.5	15.0	15.0	14.5	14.5	14.5	14.0	14.0	14.0	13.0	13.0	13.5	13.0	13.5	13.5	12.0	12.0	12.5
90	10350	15.5	15.5	16.0	15.0	15.0	15.5	14.5	14.5	15.0	14.0	14.0	14.5	13.0	13.5	13.5	13.5	13.5	13.5	12.0	12.5	12.5
100	11500	15.5	16.0	16.0	15.0	15.0	15.5	14.5	15.0	15.0	14.5	14.5	14.5	13.5	13.5	13.5	13.5	13.5	13.5	12.0	12.5	12.5

CHAPTER 4
EMBANKMENT AND DRAINAGE DETAILS

4.1 GENERAL

The purposes of the embankment and subdrainage system are to support the pavement, provide a construction working platform, and provide subdrainage of infiltrated water with a treated drainage layer.

The subbase and embankment should be designed to prevent pumping. Pumping is the ejection of erodible subbase material due to the presence of free water at the bottom of the slab and the loading of the concrete slabs by heavy trucks. The prevention of pumping is essential to the long-term survivability and good performance of concrete pavement.

All drainage features are designed in the subbase/embankment system. For all pavement options, draincrete edgedrains are recommended, with outfalls extended beyond the shoulder to the roadway front slope. On roadways without open shoulders, (barrier walls, curb & gutter), the outfall connections are to be shown in the Plans, and typically include connections to the drainage system.

In the past, the department has used an unbonded rigid subbase such as cement stabilized subbase or econocrete. These designs have caused significant problems due to their rigidity, lack of permeability, and difficulty in achieving non-erodible properties. These are not recommended for use on department projects.

The Asphalt Base Option is recommended as it uses standard materials and construction methods and provides rapid lateral drainage through draincrete edgedrains. The Asphalt Base Option also contributes to the structural performance of the concrete slab through full slab-base contact friction over the life of the design.

The Special Select Soil Option should only be used when there is a history in the area of successful construction and performance with concrete pavements, and the Special Select Soil, with sufficient permeability, is readily available at a reasonable cost. Although, this typical has been used successfully in the past, construction can be difficult due to the less stable material and problems have been encountered in the field with achieving the proper depth and permeability of the soil. This option also requires a thicker concrete slab than the Asphalt Base Option since it doesn’t contribute to the structural performance of the slab.

Before including the Special Select Soil typical section in the bid documents, the District Materials Engineer must have completed an evaluation of the soils in the project area and recommended in writing that materials meeting the requirements are reasonably available.

4.2 ASPHALT BASE TYPICAL SECTION

This typical section uses Asphalt Base (Type B-12.5 only) Optional Base Group 1 over 12" of Type B Stabilization (LBR 40), which acts as a construction working platform. Draincrete edgedrains are also provided as detailed in ***Standard Plans***, ***Indexes 120-001*** and ***446-001***. Illustration of this typical section is shown in ***Standard Plans***, ***Index 120-001*** with more detail provided in ***Standard Plans***, ***Index 446-001***.

4.3 SPECIAL SELECT SOIL TYPICAL SECTION

The Special Select Soil typical section should only be selected when approved in writing by the District Materials Engineer and shown in the plans. The special select soil typical section is composed of a deep and moderately permeable special select soil that provides for removal of infiltrated water vertically and laterally through the embankment to the shoulder ditches. This is placed in the top 60 inches of embankment. The special select soil must have a minimum average lab permeability of 5×10^{-5} $^{cm}/_{sec}$ with no individual test less than 1×10^{-5} $^{cm}/_{sec}$. It also must be non-plastic with no more than 10% passing the #200 sieve. Due to this moderate permeability requirement, it is necessary to have a minimum of 60-inch depth to provide vertical flow conditions and ensure drainability.

This permeability rate and depth of special select material are based on calculations using Figure 45 of Report No. FHWA-TS-80-224 Highway Subdrainage Design Manual, August 1980. An infiltration rate of 0.7 ft^3/day/ft (28 cc/hr/cm) of joint is assumed, with an average storm duration of 10 hours and an average interval between storms of 100 hours for drainage of the infiltrated water. If any of these assumptions or design details are changed, a new drainage analysis must be done.

To provide a permeable working platform, 3 inches of #57 or #89 stone is placed on top of the special select soil and mixed into the top 6 inches. An illustration of this Special Select Soil drainage alternate can be seen in ***Standard Plans***, ***Index 120-001*** with more detail for the edgedrain provided in ***Standard Plans***, ***Index 446-001***.

To provide extra insurance that water is quickly removed from the critical lower pavement edge, draincrete edgedrains are provided with outfalls located on the roadway front slope. In an urban area, this may be a storm sewer.

The “daylighting” of the embankment (extending the limits of the special select soil out to the roadway front slope) to provide additional drainage is also recommended.

It is recommended that the Cross-Section Sheets show the limits of the concrete slab, the Special Select Soil, and other soils.

The decision to use the Special Select Soil Typical Section is determined based on the history of successful use in the area, the cost-effectiveness and availability of sufficient Special Select Soil material, the permeability of the material, and the consistency of the material throughout the length of the project. If the material on the project has to be blended to bring it up to the permeability requirement, an analysis needs to be done to estimate this cost. The thicker slab requirement for the Special Select Soil Option also needs to be factored in. If these costs substantially exceed the cost of the Asphalt Base Option, or if adequate Special Select Soil is not available, then Asphalt Base should be used.

The District Design Section is responsible for making a Pavement Type Selection Analysis of all major new alignment or base reconstruction projects. The District Design Section should refer to the ***Pavement Type Selection Manual*** (Topic No. 625-010-005) for guidance on this analysis. If the Special Select Soil Option is considered possibly cost-effective and feasible, the District Materials Engineer should work closely with the design section to evaluate the permeability of the existing roadbed soils on the project under consideration.

Based on the soils classification data from the roadway soils survey and the District Materials Engineer’s experience, a recommendation should be made to the District Pavement Design Engineer as to whether the soils on the project are likely to provide adequate permeability for a rigid pavement subgrade.

When the preliminary type selection analysis by the design section indicates that a rigid pavement with Special Select Soil Option may be selected, the District Materials Office should perform laboratory permeability tests in accordance with FM 1-T 215 of the top 60 inches of roadway soils below the proposed roadway grade. This testing is essential to determine if the roadway soils can provide adequate vertical drainage of infiltrated water from the rigid pavement joints.

CHAPTER 5
JOINT DETAILS

5.1 GENERAL

The purpose of joints is to control cracking caused by initial concrete shrinkage due to drops in moisture and temperature, and to reduce in-service stresses as the slabs contract and curl during temperature changes and differentials through the slab.

There are several types of joints. There are transverse joints (sometimes referred to as contraction joints), longitudinal joints, expansion joints and construction joints.

5.2 JOINT SEALING

All joints are to be sealed to keep incompressibles out of the joint and to minimize the inflow of water, to the extent possible, out of the subgrade. It is not possible to totally seal pavement joints against water infiltration, so it is essential to have a good subdrainage system as described in ***Chapter 4***.

For concrete-to-concrete joints use silicone sealant material. For concrete to asphalt joints use self-leveling silicone or hot pour sealant material.

Standard Plans, ***Index 350-001*** gives joint dimension details that are in accordance with sealant industry recommendations.

5.3 TRANSVERSE (CONTRACTION) JOINTS

Transverse joints are perpendicular to the centerline of the roadway. Their purpose is to prevent uncontrolled cracking and reduce curling induced stresses.

5.3.1 TRANSVERSE JOINT DOWEL BARS

While cutting of the slabs helps control random cracking, it also creates weakened locations on the slabs. This could result in high deflections and stresses at the joints. Dowel bars are used across transverse joints to reduce these stresses and deflections, and provide adequate load transfer. This reduces the potential for pumping of the subbase material.

Dowel bars are placed in concrete parallel to the centerline of the roadway and the surface of the pavement.

Spacing of the dowel bars should be 12-inches unless otherwise indicated due to some special reason. The lengths of the dowel bars are 18-inches. The dowel bar diameters are 1 inch, 1¼ inches, and 1½ inches. ***Table 5.1*** shows the dowel bar diameters for different pavement thickness.

Dowel bars are placed in advance of the concrete pouring operation using a dowel bar basket.

TABLE 5.1
LOAD TRANSFER DEVICES

Required Pavement Thickness (inches)	Dowel Bar Diameter (inches)
8	1
8½ - 10½	1¼
≥ 11	1½
Note: Dowel bar spacing should be 12-inches. Dowel bar length should be 18-inches.	

5.3.2 TRANSVERSE JOINT SPACING

Transverse joint spacing shall not exceed 15 feet or twenty-four times the slab thickness, whichever is less.

5.4 LONGITUDINAL JOINTS

The purpose of longitudinal joints is to prevent uncontrolled cracking of slabs. Longitudinal joints are often tied with rebar to maintain the aggregate interlock between slabs.

Longitudinal joints should not be spaced greater than 15-feet. If a lane exceeds 15-feet, such as ramps and weigh stations, a longitudinal joint should be provided in the center of the lane.

5.4.1 TIE BARS

Deformed reinforcing steel tie bars generally tie longitudinal joints together. The purpose of the tie bar is to tie adjacent lanes and/or shoulders tightly together. Tie bars do not significantly assist in the load transfer directly, but does improve aggregate interlock.

Standard tie bar sizes and spacings are shown in ***Standard Plans***, ***Index 350-001***.

5.4.2 DESIGN AND CONSTRUCTION CONSIDERATIONS

Tie bars are implanted into the fresh concrete by mechanical means, or the tie bars are placed in advance of the concrete pouring operation using approved tie bar chairs.

Slab widths are 12-feet or 13-feet, unless otherwise indicated in the plans for special reasons. A 13-foot wide slab is used for the outside design lane to reduce edge stresses. The travel lane is striped at 12 feet.

When a change in the number of through lanes causes the design lane to change, such as at ramps, transitions from 13-feet to 12-feet wide slabs can be made over three slab lengths as shown in ***Standard Plans***, ***Index 350-001*** to avoid unmatched longitudinal joints.

5.5 EXPANSION JOINTS

The purpose of an expansion joint is to provide for the expansion of concrete pavement due to infiltration of incompressible material into the joints and during periods of extreme temperature change.

Expansion joints are also provided in areas where there is an abrupt change in geometry (e.g., "T" intersections, bridges, ramps, and terminals) or an immovable structure (e.g., parking areas, toll plazas, buildings, bridge approach slabs, etc.). Refer to ***Standard Plans***, ***Index 350-001***.

Expansion joints are also included in areas where there are concrete curbs, traffic separators, manholes, and drainage structures (e.g., grates, inlets, etc.). The cost of expansion joints is included in the cost of the concrete pavement.

For expansion joints at bridge approaches, refer to ***Standard Plans***, ***Index 370-001***. These joints are paid for at the contract unit price for Bridge Approach Expansion Joint.

5.6 CONSTRUCTION JOINTS

The purpose of a construction joint is to provide a clean transition from one concrete pouring operation to the next. An example would be fresh concrete against old concrete from one day to the next. These could be both longitudinal and transverse joints.

The transverse construction joint is doweled and is formed using a header.

Longitudinal construction joints are often tied using rebar.

5.7 VENDOR EXPANSION AND CONTRACTION ASSEMBLIES

Vendor expansion and contraction assemblies are used to maintain dowel bar alignment during construction and are shown in ***Standard Plans***, ***Index 350-001***. Manufacturers of vendor expansion and contraction assemblies can be found in the department's Qualified Products List.

5.8 JOINT LAYOUT

The purpose of providing a joint layout is to show non-standard joint geometries to avoid discontinuities that can lead to random cracking.

Types of joint layouts that provide guidance can be found in the ***Standard Plans***, ***Index 350-001*** and include thru Intersections, 'T' Intersections, and ramps. Other irregular areas should have joint layouts carefully detailed in the plans.

- Align New joints with existing joints.
- Construct Traverse Joints perpendicular to the roadway.
- Adjust Transverse Joints to Align with utility manholes or inlets.
- Avoid angles less than 60 degrees by doglegging joints through curve radius points. Use 90 degree angles when possible.
- Provide Transverse joints at all pavement width changes.
- Avoid odd shapes, keep slabs near-square or pie-shaped.

The American Concrete Pavement Association (***ACPA***) link below also provides additional guidance for concrete pavement as well as information for joint layout design.

http://wikipave.org/index.php?title=Joint_Layout

5.9 GRINDING

Grinding for smoothness shall be performed on the entire pavement surface lanes for new and rehabilitation projects.

Grinding ***Specification 352*** is referenced from the 350 Specification, and a grinding pay item is recommended for both new construction and rehabilitated pavement areas.

CHAPTER 6
SHOULDER DESIGN

6.1 GENERAL

The purpose of shoulders is to provide edge support of the mainline pavement, assist off-tracking vehicles, increase safety, provide additional pavement widths for lane shifts during rehabilitation, provide refuge for disabled vehicles, and prevent erosion from pavement runoff.

Several types of shoulders are available for concrete pavement. They are asphalt or concrete. ***Table 6.1*** provides guidance on the use of these different types of materials.

Details for the design of the shoulders are dependent on the type of materials used in the embankment. Embankment alternates are Asphalt Base or Special Select Soil with Special Stabilized Subbase.

On outside shoulders, 1-ft of the marked shoulder is cast with the outside truck lane slab. The rest of the shoulder, when concrete, may be cast integrally with the mainline and saw cut, or cast later on. The pavement will be striped for a 12-ft lane with a saw cut or construction joint offset by 1-ft. The slab width is 13-ft but the pavement marking is at 12-ft.

The offset of the joint has strong advantages of greatly reducing loading stresses at the critical low outside truck lane edge.

TABLE 6.1
SHOULDER TYPE SELECTION

Limited Access (Urban)

Asphalt

Tapered Depth Concrete

Full Depth (Tied) Concrete*

Limited Access (Rural), Non-Limited Access, Arterials, and Collectors

Asphalt

Partial Depth (Tied) Concrete

Notes

* For future Maintenance of Traffic or Widening.

6.2 ASPHALT

Asphalt shoulders can be used for Limited Access facilities, Non-Limited Access Arterials and Collectors.

For additional information on the design of asphalt shoulders please refer to the ***Flexible Pavement Design Manual***, Document # 625-010-002.

6.3 CONCRETE

The following are some of the different types of concrete shoulders that are available:

Tapered Thickness

Tapered thickness shoulder is recommended for use on Limited Access facilities.

Tapered thickness shoulder is a shoulder in which the thickness of the shoulder tapers out depending on the width and slope of the shoulder. The minimum thickness should not be less than 6-in.

Full Depth (Tied)

Full thickness (tied) concrete shoulders may be used on Limited Access (Urban) facilities where use for future Maintenance of Traffic or Widening is likely.

Partial Depth (Tied)

Partial thickness (tied) concrete shoulders may be used on Limited Access (Rural) facilities, Non-Limited Access, Arterials, and Collectors (See Figure 6.4). The design thickness can be based on 3% of a mainline 20 year calculated 18-kip ESAL for truck off tracking on the shoulder.

If the shoulders are likely to be used to carry a substantial amount of traffic as a part of a Maintenance of Traffic (MOT) scheme, the Pavement Design Engineer may design the shoulder in the same manner as a roadway, based on an ESAL estimate of shoulder traffic during Maintenance of Traffic periods.

The minimum thickness is 6-in.

6.3.1 DESIGN AND CONSTRUCTION CONSIDERATIONS

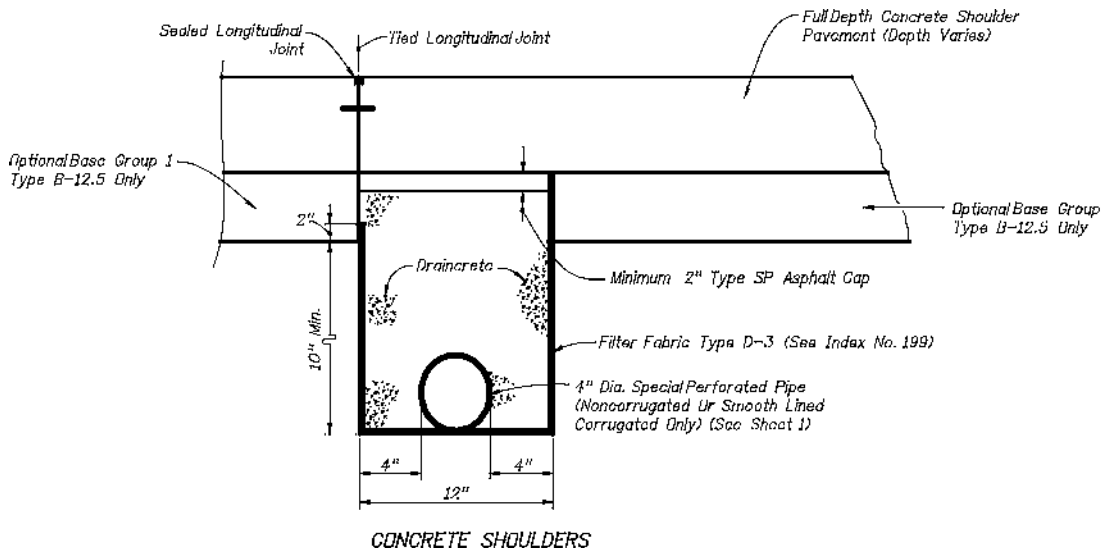
Some design and construction considerations include the following when using concrete shoulders.

- Transverse joints should match the mainline joints.
- Transverse joints should be doweled if likely to be used for maintenance of traffic in the future.

6.4 GRASS

Grass shoulders can be used for non-state low volume roads.

FIGURE 6.1
CONCRETE SHOULDER WITH ASPHALT BASE



Notes:

The above illustration is not to scale.

Thickness for the Asphalt Base is 4-in and Stabilization is 12-in.

CHAPTER 7
PAVEMENT WIDENING

7.1 GENERAL

Pavement widening falls into two different areas, strip widening and lane addition.

Strip widening is where additional width is added to the existing pavement width because the existing width is less than the departments required design lane width criteria. Many times this is generally done for safety considerations. An example would be widening of an existing 10-ft wide lanes facility to provide 12-ft lanes. This is a common need for roads constructed early in the Department's history. To reduce the potential for shrinkage cracking, the minimum practical width of concrete pavement widening should be 3-ft, with special consideration giving to jointing details as later described in ***Section 7.6***, Joint Details.

Lane addition is where full lanes are added. This is a common need when a facility is expanded for capacity considerations.

Intersection improvement is a hybrid of the two, where the roadway may be widened on both sides less than full lane width to accommodate a middle turn lane on a four-lane undivided section. Other improvements could be made which would include the addition of complete turn lanes, which could occur where there is adequate median space.

7.2 EVALUATION

Several questions need to be asked when evaluating the proposal to widen an existing pavement. Two of these questions are:

> Is the existing pavement condition adequate to provide extended life without extensive rehabilitation?
>
> Is the existing location programmed in the future for widening, reconstruction, realignment, etc.?

7.3 REQUIRED DESIGN INFORMATION

For widening, the existing roadway pavement typical section needs to be researched. This could include such information as slab thickness, slab dimensions, embankment soils, and drainage. On older pavements, the thickness needs to be checked in the center of the road and at the roads edge. Some older pavements in service today were built with a thickened edge.

The 18-kip Equivalent Single Axle Loads (ESALs) should be requested for lane addition projects to assist in evaluation of the remaining life of the existing pavement and the thickness desirable for the design lane. For strip widening, the 18-kip Equivalent Single Axle Load (ESALs) calculations are not necessary.

7.4 PAVEMENT THICKNESS DETERMINATION

Before any thickness determination can be done on the proposed concrete pavement for strip widening or lane addition, an analysis on the remaining life of the existing pavement needs to be performed. This analysis should closely examine any deterioration of the existing pavement.

For a strip-widening project, a formal analysis does not need to be done for the pavement thickness. The best solution is to match the existing pavement. Some benefits in matching the existing pavement thickness include:

- Any flow of water between the existing slab and the subgrade will not be disrupted, pooled, or dammed.
- Trenching adjacent to the existing slab below the slab bottom that may cause a weakening of subgrade support along the pavement edge may be avoided.
- Preservation of any existing edgedrains systems may be possible.

For a lane addition project, a formal analysis needs to be done in order to determine the proposed thickness. If the calculated thickness is less than the existing, the thickness of the new lane should match the existing thickness.

If the calculated thickness for a lane addition project is greater than the existing thickness, then the calculated thickness may be used if adequate drainage can be assured. Actual pavement performance may be different than that predicted by the AASHTO Equation. Engineering judgment should be used to evaluate the remaining life and thickness required.

7.5 EMBANKMENT AND DRAINAGE DETAILS

Embankment and drainage details are very critical to the performance of the pavement system (see ***Chapter 4***).

7.5.1 EMBANKMENT CONSIDERATIONS

Several embankment considerations need to be addressed when doing any type of widening. These considerations include:

- Existing utility clearance relative to the depth of excavation could be a concern especially in older urban areas.
- The loss of subgrade support along the pavement edge and settlement of adjacent pavement and structures due to excavation.
- Traffic Control Plans (TCP) in cases where the width of the existing pavement is less than 12-ft. This will affect the selection of barricades.

7.5.2 DRAINAGE

The recommended type of edgedrain system for widening is the draincrete edgedrain system as shown in ***Standard Plans***, ***Index 446-001***. This design is used because the strength of the draincrete material provides lateral support of the existing pavement base and supports heavy loads on the pavement surface over the pipe during and after construction from heavy construction equipment, off-tracking trucks, and other forces.

Project information needs to be obtained on the existing drainage. This is important in the location of edgedrain outfalls. If the outfall is tied into the existing storm water drainage system in an urban area, any normal flows will need to be below the outlet end of the pipe. If no drainage system is available, the outfall end of the pipe will need to be located where it will not cause problems to pedestrians, traffic, and/or maintenance.

7.6 JOINT DETAILS

Joint details are very important to the performance of the concrete pavement. Failure to follow these guidelines can result in slab cracking.

7.6.1 TRANSVERSE JOINT SPACING

Transverse joints should normally match the existing pavement if spacing is 15-ft or less. This includes contraction and expansion joints. Closer joint spacing should be provided when the length of the existing slab is greater than 15-ft or there is a significant number of existing mid slab transverse cracks. An additional dowelled transverse joint should be added at the middle of strip widening slabs that are 6-ft or less wide and greater than 10-ft in length.

7.6.2 LONGITUDINAL JOINTS

It is preferable not to tie a new concrete widening section greater than 6-ft wide to the existing pavement. This is due to the potential for stress build-ups due to differential shrinkage of the new concrete adjacent to the existing. If tying to the existing is desired, then existing transverse joints must be matched in the widening and tie bars offset from the transverse joints by 3-ft.

Joint details should be provided for areas composed of mixed geometry. Examples of this include ramps, intersections, etc. An exception would be widening where the same details for each slab may be repetitive such as lane additions.

7.7 SHOULDER DETAILS

When adding a lane, the shoulders should be appropriate for the type of facility. If concrete is used, it may be best not to tie the lane and the shoulder to the existing pavement in order to avoid any unnecessary stress build up.

CHAPTER 8
DISTRESS

8.1 GENERAL

Factors that can lead to concrete pavement deterioration includes:

- Heavy loads imposed by trucks.
- Stresses induced by temperature changes.
- Free water retained in the pavement structure.
- Loss of subgrade support due to pumping.
- Inadequate maintenance.

8.2 IDENTIFICATION AND CAUSES OF DISTRESS

The tool that the Department uses to maintain system information on distressed pavements is a data base called the "Pavement Condition Survey". The State Materials Office in Gainesville maintains this.

The Pavement Condition Survey includes information on the following signs of distress:

- Pumping
- Faulting
- Cracking, this includes transverse cracking, longitudinal cracking, corner cracking, and shattered slabs
- Joint distress, which includes poor joint condition, and spalling
- Surface defects, which includes surface deterioration, and patching
- Shoulder deterioration (not included in the pavement condition survey)
- Ride quality

8.3 PUMPING

The "pumping" of concrete is a process where the action of a heavy wheel load across a transverse joint will cause the expulsion of water and fine base material in suspension underneath the pavement slabs to escape through the pavement joints at the edge of pavement.

Three conditions that must exist for pumping to occur include:

- Presence of free water.
- Erodible base material.
- Heavy wheel loads.

The mechanism of pumping is as follows:

1. Water enters the base from joints and cracks in the pavement (See ***Figure 8.1A***).

2. As a wheel load approaches a pavement joint (on the approach slab) the water underneath the pavement moves slowly to the next slab. Some fine base material also moves in this direction (See ***Figure 8.1B***).

3. When the wheel load crosses the joint to the other side (on the leave slab), the water underneath the pavement moves rapidly backs to the adjacent slab. This high-speed water causes more erosion of the pavement base. Some water is ejected up through the joint with some of the base material (See ***Figure 8.1C***). Evidence of base material can be seen as stains on the shoulder.

4. The final result is a void under the leave slab and a possible buildup of material under the approach slab. The void creates a cantilevered effect on the concrete pavement. This results in cracking and faulting of the slab (See ***Figure 8.1D***).

The severity of pumping is measured in terms of:

- Light - Visible deposits of material, light stains, shoulder settlement at the transverse joint, or, may include one or all of these
- Moderate - Visible deposits of material, moderate stains, shoulder settlement at the transverse joint, moderate faulting at the shoulders, or may include one or all of these
- Severe - Visible deposits of material, heavy stains, shoulder settlement at the transverse joint, or moderate faulting at the shoulders, or may include one or all of these

Items that also contribute to pumping are poor load transfer, and/or low stiffness subbase.

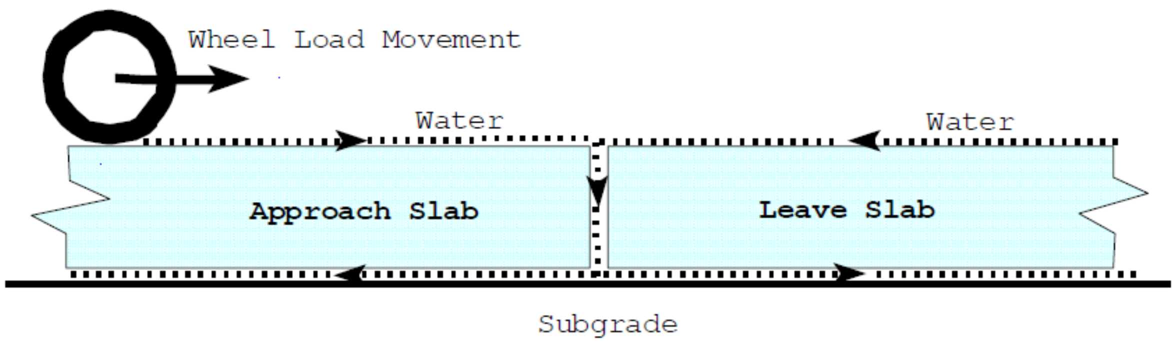
8.4 FAULTING

In new pavement, the elevations of each slab at the transverse joint are the same. In faulted pavement, a difference in the elevation between the slabs at the transverse joint exists.

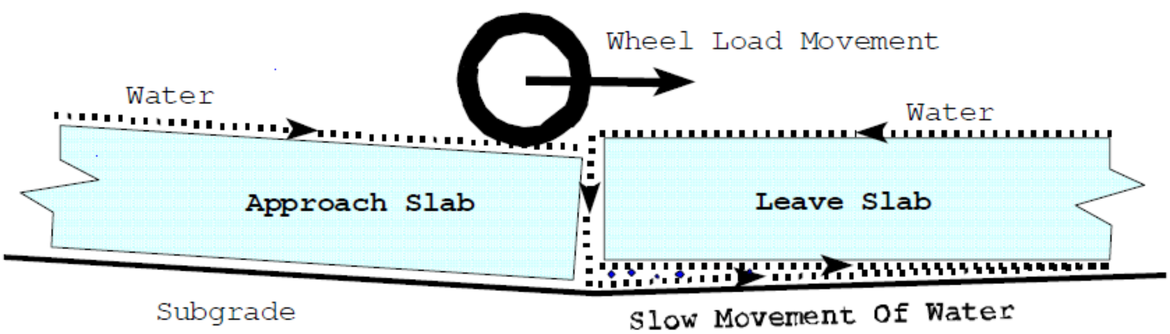
Faulting can be caused by the erosion (on the leave slab) and build up (on the approach slab) of base fines by the action of pumping. A lack of load transfer also contributes to faulting.

The severity of faulting is measured in increments of thirty-seconds of an inch. The larger the fault measurements, the more severe.

FIGURE 8.1
MECHANISM OF PUMPING



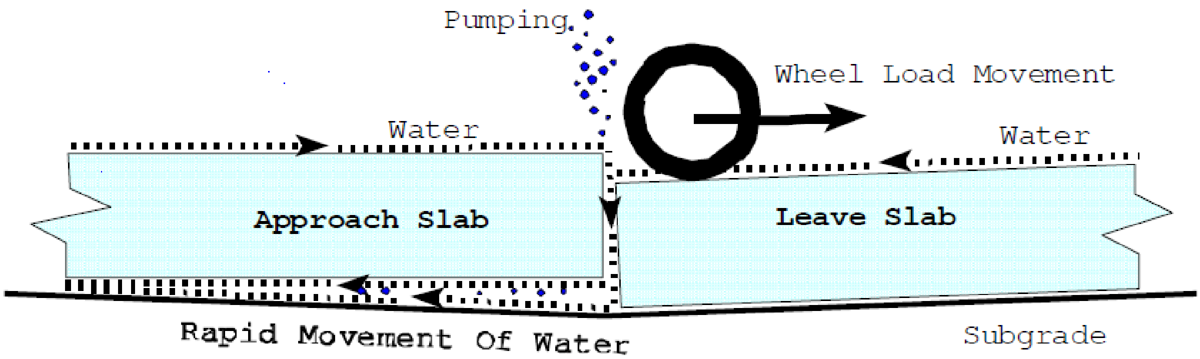
A. Water enters base from joints and cracks.



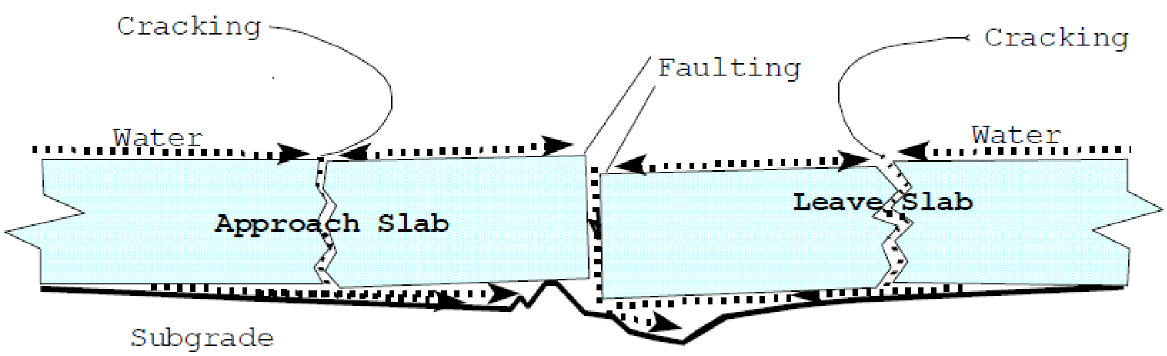
B. Water moves slowly to the leave slab. Some eroded fine material also moves.

FIGURE 8.1
(Continued)

MECHANISM OF PUMPING



C. Water moves rapidly to the Approach Slab with some eroded fine material. Some of this material is ejected out.



D. Void under Leave Slab. Erodable material under Approach Slab. Slab faulting and cracking.

8.5 CRACKING

Cracking occurs when a concrete slab breaks into two or more pieces. The types of cracking are:

- Transverse Cracking - Occurs at right angles to the centerline.
- Longitudinal Cracking - Generally runs parallel to the centerline.
- Corner Cracking - Intersects both longitudinal and transverse joint.
- Intersecting Cracks (Sometimes referred to as a shattered slab) - Occurs when one or more of the different types of cracks connect or cross within a slab.

8.5.1 GENERAL CAUSE

Cracking is generally contributed to by:

- Shrinkage
- Loss of slab support due to voids.
- Settlement of the embankment.
- Misaligned dowels.

8.5.2 TRANSVERSE CRACKING

Transverse cracking is contributed to by:

- Improper joint spacing, installation, depth or dimensions.
- Improper alignment of load transfers assemblies.
- Thermal gradient warping and movement stresses.
- Stiff, unbonded subbase.
- Shrinkage due to rapid moisture loss during construction.
- Heavy trucks loading.
- A combination of any of these.

8.5.3 LONGITUDINAL CRACKING

Longitudinal cracking is contributed to by:

- Sawing joints too late.
- Insufficient cut depth.
- Loss of subgrade support.
- Thermal gradient warping and movement stresses.
- Heavy trucks loadings.
- One or all of the above.

8.5.4 CORNER CRACKING

Corner cracking is caused by:

- The loss of subgrade support due to pumping.
- Stiff unbonded subbase.
- Warping.
- Tie bars placed too close to a transverse joint.
- Heavy truck loadings.
- Combinations of the above.

8.5.5 INTERSECTING CRACKS

Intersecting Cracks (Sometimes referred to as a shattered slab) is caused by the continuing deterioration of one or more or a combination of transverse, longitudinal, and corner cracks.

8.5.6 CRACK SEVERITY

The severity of transverse, longitudinal, and corner cracking is measured in terms of:

- Light - Visible cracks less than 1/8-in wide.
- Moderate - Cracks 1h-in to 1/2-in wide, and/or little faulting, and/or intrusion of debris.
- Severe - Cracks greater than 1/2-in wide, and/or loss of aggregate interlock, intrusion of water and debris, faulting, and/or spalling.

For intersecting cracks:

- Moderate - Slab is broken into several pieces with some interlock remaining. Replacement is necessary.
- Severe - Slab is broken into pieces that are acting independently. Replacement is necessary.

The severity of cracking is of great concern because it is a measure of the degree of distress and it assists in directing the rehabilitation strategy (i.e., slab replacement versus clean and reseal random cracks).

8.6 JOINT DISTRESS

Joint distress is when Poor Joint Condition and/or Spalling occur.

8.6.1 POOR JOINT CONDITION

Poor Joint Condition is the loss or deterioration of joint seals. This condition is due to:

- Cracking which are the most common, splitting, and erosion of the sealant.
- Hardening of the sealant due to age and oxidation.
- Loss of face bond of the sealant material to the reservoir.
- Improper cleaning of the reservoir prior to insulation.
- Moisture condition prior to installation.
- Joint dimensions of reservoir and sealant.

The severity of Poor Joint Condition is measured in terms of:

- Partially Sealed - Joint seal has deteriorated to the extent that adhesion or cohesion has failed and water is infiltrating into the joint.
- Not Sealed - Joint seal is either non-existent or has deteriorated to the extent that both water and incompressible materials are infiltrating the joint.

8.6.2 SPALLING

Spalling is the cracking and disintegration at the slab edges. Spalling may be caused by the intrusion of incompressible material, which restricts slab expansion and contraction. Incompressible materials are usually rocks and sand. Spalling also occurs at cracks due to irregular shape of the cracks and poor load transfer.

The severity of spalling is measured in terms of:

- Light - Spalled areas are less than 1.5-in wide.
- Moderate - Spalled areas are 1.5-in to 3-in wide.
- Severe - Spalled areas are greater than 3-in wide.

8.7 SURFACE DEFECTS

Surface defects are when Surface Deterioration and/or Patching occur.

8.7.1 SURFACE DETERIORATION

Surface Deterioration is the disintegration and loss of the concrete wearing surface. Surface deterioration is due to:

- Poor construction materials such as poor aggregate, cement, additives, mixing operations, etc.
- Poor construction methods such as poor placement, curing, finishing, cutting, etc.
- Traffic such as (tire rims, chains, and metal).
- Chemical reactants.

The severity of Surface Deterioration is measured in terms of:

- Moderate - Some coarse aggregate has been exposed and the wearing surface has disintegrated up to a depth of a 1/2-in
- Severe - Most coarse aggregate has been exposed and some has been removed. The wearing surface has disintegrated to a depth of 1/2-in or greater.

8.7.2 PATCHING

Patches are the corrections made to pavement defects. Patching is due to:

- Maintenance forces correct or improve a section of pavement that has deteriorated and may provide a solution that can perform as well as the existing material.
- The performance of the patching material depends on the correct application and materials (concrete, asphalt, and other), workmanship (preparation, finishing, and curing), traffic conditions, etc.

The severity of Patching is measured in terms of:

- Fair - The patch is providing marginal performance and is expected to serve its function for a few years.
- Poor - The patch has deteriorated to the extent that it no longer serves its function and should be replaced as soon as possible.

8.8 SHOULDER DISTRESS

Each type of shoulder has its own distress mechanism.

8.8.1 FORMS OF SHOULDER DISTRESS

Shoulder distress is when one or all of the following occur:

For Concrete shoulders:

- Pumping.
- Faulting.
- Cracking.
- Joint Distress.
- Surface Defects.

For Asphalt shoulders:

- Irregular movement of shoulder material.
- Drop-off in the elevation between the roadway and the shoulder.

For Grass Shoulders:

- Erosion of the shoulder material.

8.8.2 CAUSE OF SHOULDER DISTRESS

Shoulder Distress is caused by:

For Concrete shoulders:

- Pumping of water under the shoulder.
- Faulting due to loss of slab support.
- Off-tracking of heavy trucks.
- May include one or all of these.

For Asphalt shoulders:

- Pumping of water under the shoulder.
- Off-tracking of heavy trucks.
- Time (environmental deterioration).
- May include one or all of these.

For Grass shoulders:

- Erosion due to pumping and runoff, and/or,
- Off-tracking of heavy trucks.

The severity of Shoulder Distress is not measured in the field, but noted in the survey.

8.9 POOR RIDE QUALITY

Poor ride quality is caused by changes in the longitudinal profile of the road. Poor ride quality is due to:

- Faulting.
- Cracking.
- Surface defects.
- Repair work such as patching, slab replacement, and spall repair.
- Lack of control on the original construction.
- May include one or all of these.

The Ride Quality is reported on a scale of 0 to 10 with 10 being the best. Ride profilers are used by the State Materials Office to measure ride quality. The International Roughness Index (IRI) values from profiler data are converted to a scale of 0 to 10, with 10 being an excellent ride.

CHAPTER 9
PAVEMENT REHABILITATION

9.1 GENERAL

Several items need to be researched before any type of rehabilitation activity is considered. One such issue would include looking at future programming. Would this pavement in the next couple of years undergo any type of widening, reconstruction, etc.? Such research could save needed funds or avoid compromising the design.

Another item for consideration would be to look at the rate of deterioration and what are the mechanisms causing the distress. Each rehabilitation alternative considered must address the cause of the distress such as drainage, and not simply fix the resulting cracking or other visible distress.

Before detailed design activities take place, the designer needs to do a life cycle cost analysis to weigh the long-term possibilities. The Value Engineering Section has a Manual on Life Cycle Cost Analysis for Transportation Projects (July 1990) that can be a helpful tool to assist in the analysis.

9.2 DEPARTMENT RECOMMENDED OPTIONS

Several options are available to the designer as rehabilitation options. One option is Concrete Pavement Rehabilitation (CPR). This alternative can include slab replacement, diamond grinding, installation of edgedrains, cleaning and resealing joints, and routing and sealing random cracks.

This option is used when the life cycle cost of Concrete Pavement Rehabilitation is less than the cost of the other alternatives.

Another alternative involves Crack, Reseat, and Overlay (CRO) Existing Concrete Pavement. This alternative involves cracking and reseating the existing concrete pavement and overlaying it with an Asphalt Membrane Interlayer (AMI), Structural Asphalt, and Asphalt Friction Course.

Rubblization and Overlay is another alternative using specialized equipment which reduces the nominal size of PCC pieces to about 6-in and essentially reduces the slab to a high-strength granular base course and overlaying it with Structural Asphalt, and Asphalt Friction Course.

Other alternatives not discussed in detail here include replacing the existing pavement or reconstruction. These alternatives involve removing or recycling the entire existing pavement and replacing it with a new pavement. This could be concrete or asphalt as determined by the pavement type selection process.

Careful analysis of life cycle costs of these alternatives will determine which is the most cost effective.

CHAPTER 10
CONCRETE PAVEMENT REHABILITATION (CPR)

10.1 GENERAL

Concrete Pavement Rehabilitation (CPR) involves several operations, which must be done, in sequence in order to avoid compromising other operations. An example of sequencing would include performing slab replacement before grinding. Doing this out of order would compromise the ride of the pavement.

10.2 SLAB REPLACEMENT

Slab replacement includes partial slab, full slab, and multiple slab replacement. The purpose of slab replacement is to replace shattered and/or severely broken slabs.

Standard Plans*, *Index 353-001 provides plan views of the layout of concrete pavement replacement and repair criteria. This ***Index*** can be used by the designer to assist in estimating quantities when evaluating the needed rehabilitation. Specific locations and type of pavement repair should be shown on the plans.

Types of slab replacement include:

- Full slab replacement, which includes the slab from joint to joint.
- Multiple slab replacement, which includes several connecting, slabs.
- Partial slab replacement, which includes slabs where a part of the slab has disintegrated, joints have spalled significantly or the corners have cracked.

Minimum recommended Full Depth Repair dimensions are 12-ft wide (or full lane width) by 6-ft long. If less than a full slab is replaced, the remaining slab that is not replaced should also have these minimum dimensions.

One construction concern to be addressed in the Traffic Control Plans is if the removed slabs have to remain open overnight. Normally, it is desirable to replace the slabs as soon as possible. The designers should coordinate with the construction and materials offices and indicate in the plans and specifications the use of High Early Strength Concrete when required. A minimum compressive strength of 1,600 psi is needed prior to opening to traffic. The State Materials Office can be consulted on the use of these materials.

Full slab replacements should be full lane width and a minimum of 6-ft in length. Dowel bars should be retrofitted into each end of the repair. If repairs extend beyond 15-ft, an intermediate, doweled transverse joint is to be provided. The longitudinal joints for slab replacements should not be tied.

Slab replacement and other quantity estimates are to be made in the field in cooperation with construction personnel and carefully documented on a slab by slab basis. If necessary, lanes should be closed and cores taken of representative cracks to determine the depth of cracking and spalling.

Historical rates of deterioration are to be reviewed and plan quantities increased to account for deterioration expected to occur between the field survey and actual construction. A final check of quantities is to be made just prior to finalizing the plans for letting.

10.3 INSTALLATION OF EDGEDRAINS

Draincrete edgedrains are used in projects where edgedrains are non-functioning or nonexistent. This provides excellent structural support for heavy vehicles that may off track from the pavement edge as well as good lateral soil support.

Geocomposites are not recommended in Concrete Pavement Rehabilitation Projects because of the potential for settlement of the backfill under load, and clogging of the filter fabric. See ***Standard Plans***, ***Index 446-001*** for edgedrain details for rehabilitation projects.

10.4 DIAMOND GRINDING

The purpose of diamond grinding is to restore faulted pavement and to improve ride. Grinding is recommended for any concrete restoration project unless there are special reasons not to.

One factor that affects the cost of grinding significantly is the type of aggregate used in the concrete slab. Aggregate that is hard (has a higher hardness number) such as river gravel could cost more to grind compared to a softer material such as limerock. The designer needs to consult with the District Materials Engineer about the type of aggregate used in the existing pavement in making the cost estimate.

10.5 CLEAN AND RESEAL JOINTS

All joints should be cleaned and resealed on any rehabilitation project. The purpose of cleaning and resealing joints is to reduce the intrusion of water into the base and keep incompressible out of the joints. The Pavement Design Engineer should be familiar with ***Standard Plans***, ***Index 350-001***.

10.6 ROUT AND SEAL RANDOM CRACKS

The purpose of routing and sealing random cracks is to reduce the intrusion of water into the base and keep incompressible out of the joints. Using special saws or routers due to the random nature of crack propagation does this.

10.7 OTHER

Restoration of load transfer has been tried in undoweled pavements in Florida, but was not successful. Until further research and demonstrated success is performed in Florida, the general use of load transfer restoration is not recommended.

CHAPTER 11
OTHER RECOMMENDED REHABILITATION ALTERNATIVES

11.1 GENERAL

Several other rehabilitation alternatives are available to the designer. Some of these have been tried several times with good results. These alternatives are usually cost effective only if the existing concrete pavement is significantly deteriorated. If the Pavement Design Engineer decides to use one of these alternatives, information is available that will guide the Pavement Design Engineer during the design process.

11.2 CRACK, RESEAT, AND OVERLAY (CRO) EXISTING PAVEMENT

This alternative involves cracking the existing concrete pavement up, reseating the existing pavement, and overlaying the existing pavement with an Asphalt Membrane Interlayer (AMI), Asphalt Structural Course, and Friction Course.

11.2.1 BREAKING THE EXISTING PAVEMENT

The existing pavement should be broken according to specifications into properly sized pieces to reduce thermal expansion and contraction of the concrete, thereby retarding any reflective cracking.

11.2.2 RESEATING THE CRACKED PAVEMENT

The cracked pavement should be reseated firmly into place using rubber wheeled rollers. The purpose of reseating the existing pavement is to provide the following benefits:

- Eliminate any slab pieces that may rock, slide, or push.
- Remove any jagged edges.

11.2.3 ASPHALT MEMBRANE INTERLAYER (AMI)

The purpose of the Asphalt Membrane Interlayer (AMI) is to retard any reflective cracking that may occur, and provide a waterproofing layer to keep any water remaining under the slabs from pumping into the asphalt layers.

More information about this material as well as information on the design of additional asphalt layers can be found in the ***Flexible Pavement Design Manual*** (Document No. 625-010-002).

11.2.4 ASPHALT OVERLAY

The purpose of the asphalt overlay is to provide additional structural strength to the pavement system and to provide a new riding surface on top of the prepared surface. This should include an Asphalt Structural Course and a Friction Course. Information on the design of these layers can be found in the ***Flexible Pavement Design Manual***.

11.2.5 DESIGN AND CONSTRUCTION CONSIDERATIONS

In designing the project, the cracked and reseated concrete pavement can be treated as a base. Using the ***Flexible Pavement Design Manual***, and from historical project experience, the cracked and reseated pavement layer coefficients that should typically be used include the following:

Structural Coefficients

Material	Good	Fair	Poor
Reseated Concrete	0.23	0.20	0.18

Design details need to be developed for the pavement where there is a transition into a bridge approach slab. It is usually advisable to remove some of the slabs so that thin asphalt feathering is not required, due to its potential to oxidize and delaminate with time. An appropriate thickness transition length should be provided for high-speed facilities.

Another area where design details need to be provided would be in the area of a bridge underpass. Reduction in clearance below standards at an underpass due to the extra asphalt must be avoided. Bridge vertical clearance information can be found in Chapter 260 of the ***FDOT Design Manual*** - Procedure No. 625-000-002.

The solution may be to remove the concrete pavement in advance of the underpass and provide additional base material before placement of the Asphalt Structural Course and Friction Course.

If the pavement system still has a large amount of water in the pavement system, using edgedrains may provide an outlet for the water before the cracking and reseating operation is performed.

11.3 RECYCLING

Another alternative that the department has utilized is the complete recycling of the existing concrete pavement as an aggregate source for a new pavement. This option is desirable when cost effective and where problems with the subbase have been encountered and must be addressed.

This has been tried in some areas of the state successfully where the cost of removing the pavement, crushing the slabs, and sorting out the material, has provided life cycle cost savings.

11.4 RUBBLIZATION

The existing pavement slab is fractured into aggregate–sized particles, which destroys the slab action. Rubblization is usually appropriate when deterioration of the existing pavement renders normal crack/seat or break/seat methods ineffective.

11.5 PATCHING

For isolated or random small spalls and/or corner cracks, a fiber reinforced polymer patching material may be used. Bulking aggregates and final surface aggregates are specified in Developmental Specification 351. The picture below illustrates a typical candidate for patching. This application can be used in conjunction with slab replacements or full depth repair. Additionally, using this patching could result in time and construction cost savings.

FIGURE 11.1 – Spalling

CHAPTER 12
JPCP OVERLAYS OF ASPHALT PAVEMENT

12.1 GENERAL

The construction of a Jointed Plain Concrete Pavement (JPCP) over an existing flexible (asphalt) pavement is called JPCP overlay of Asphalt pavement. The FDOT has limited experience with rigid overlays of flexible pavement, but successful projects have been constructed in 1989 on US-1 and in 2009 on I-95.

Ultra-thin (3 and 4-in thick) concrete overlays were tried on a truck inspection station on I-10 in 1997, but they were not successful (FDOT Research Report BC-354). If other types of overlays are tried, it should be considered experimental and coordinated with the State Materials Office as outlined in ***Chapter 13***.

12.2 STRUCTURAL DESIGN

A rigid pavement overlay of an existing flexible pavement structure is basically designed the same as a new rigid pavement, treating the existing flexible pavement structure as an asphalt base course over granular base. The required overlay thickness is determined using the Asphalt Base design tables in ***Chapter 3*** or with the Pavement ME software.

The following variable and standard design inputs are the same as listed in ***Section 2.2*** of this manual. See ***Section 2.2*** for the recommended input values.

12.3 VARIABLES

Reliability (%R)

Traffic Loading Forecasts (Equivalent Single Axle Loads - ESALs)

Climate Region

12.4 STANDARD INPUTS

(See Appendix A for Florida Standard Input Values)

Initial Smoothness (IRI)

Terminal Smoothness (IRI)

Terminal Faulting

Terminal Cracking

28-Day PCC Compressive Strength

Coefficient of Thermal Expansion (CTE)

Asphalt Base (thickness after milling plus new asphalt overlay)

Limerock Base

Stabilized Subgrade (Type B) Resilient Modulus

Road Bed Soil Resilient Modulus (M_R)

Joint Spacing

Truck Lane Slab Width

12.5 ASPHALT BASE THICKNESS

It is permissible to leave structurally sound existing asphalt pavement for use as a base layer for concrete. However, milling of the existing pavement may be used to minimize grade increases, adjust roadway cross sections, and remove wheel path ruts and to provide a uniform longitudinal profile.

The rigid overlay thickness is very sensitive to the asphalt base thickness due to the bonding condition and relatively high asphalt dynamic modulus, but is not highly sensitive to the limerock and other underlying granular layers.

When milling an existing flexible pavement prior to a rigid overlay, it is usually desirable to leave at least ¾” of asphalt over the base throughout the project to protect it from traffic and rain. The milled surface should then be overlaid with at least one inch of Type SP Traffic Level B (TL B).

The total asphalt base thickness for input to the Pavement ME design software is the thickness of the existing asphalt pavement after any milling and the new asphalt overlay.

It may be feasible to place JPCP overlay directly on a milled surface, but this has not been tried in Florida. If the designer desires to try this, it should be considered experimental and coordinated with the State Materials Office as outlined in ***Chapter 13***.

12.6 SUB-DRAINAGE

The edgedrain system should be as per ***Standard Plans***, Index 446-001 for rehabilitation.

12.7 OTHER DESIGN INPUTS AND DETAILS

Joint Details (Chapter 5)

Shoulder Design (Chapter 6)

Pavement Widening (Chapter 7)

CHAPTER 13
NEW TECHNOLOGIES

13.1 GENERAL

New technology is important to the designer because the Department benefits by the reduction in life cycle costs, the introduction of new materials, and/or improved methods of construction.

13.2 NEW CONSTRUCTION AND REHABILITATION

Construction projects that are experimental in nature may provide the department with valuable design and performance information.

Experimental projects should be carefully coordinated with the State Materials Office Pavement Evaluation Section to set up control and experimental limits so that detailed performance evaluations can be made over time.

Experimental projects should be limited in scope and not used for the first time on major interstate projects.

13.3 NEW PRODUCTS

New products are tested to determine their effectiveness under Florida conditions.

Examples may include components such as joint seals, concrete material additives and curing compounds.

APPENDIX A
FLORIDA-SPECIFIC INPUTS TO PAVEMENT ME SOFTWARE

Jointed Plain Concrete Pavement (JPCP) compressive strength: 4,000 psi

JPCP coefficient of thermal expansion (CTE): 4.5 x 10E-6 in/in/deg F

JPCP joint spacing: 15 ft

Joint sealant type: Other (silicone)

Widened slab: 13 ft

Erodibility index: Erosion resistant (3)

PCC-base contact friction: Full friction, no loss at 240 months

Permanent curl/warp: -10 deg F

Base: 4” Asphalt Base Course (Optional Base Group 1, ABC only)

Non-stabilized base: 12” Type B stabilization LBR 40, Resilient modulus of 16,000 psi, A-2-4 soil

Embankment subgrade: A-2-4 or A-3, Resilient modulus of 12,000 psi

Project Specific (for Florida) Calibration Factors:

PCC Cracking C4: 1.38E-07
PCC Cracking C5: -3.633
PCC Faulting C1: 4.0472
PCC Faulting C6: 0.0790
PCC IRI-JPCP C3: 2.2555

References:

Development of Thickness Design Tables Based on MEPDG; Texas Transportation Institute; Oh, Fernando, June 2008

MEPDG Local Calibration Project; PBS&J Project No. 100011242; Oh, Zollinger, Fernando, March 2011

Calibration of Florida MEPDG Cracking Model; Zollinger, February 2015

APPENDIX B
RIGID PAVEMENT DESIGN QUALITY CONTROL PLAN

B.1 QUALITY CONTROL PLAN

All rigid pavement designs will be reviewed independently for accuracy and constructability. The following quality control plan is provided as a guideline.

B.2 DEFINITIONS

The following definitions are used throughout this section. Quality conformance to policies, procedures, standards, guidelines and above all, good engineering practice is emphasized.

Quality Assurance (QA) - Consists of all planned and systematic actions necessary to provide adequate confidence that a design, structure, system, or component will perform satisfactorily and conform to project requirements. Quality assurance involves establishing project related policies, procedures, standards, training, guidelines, and systems necessary to produce quality pavements.

Quality Control (QC) - This is the checking and review of designs and plans for compliance with policies, procedures, standards, guidelines and good engineering practice.

B.3 RESPONSIBILITY

The district offices and turnpike consultants are responsible for Quality Control. Quality Assurance is the role of the Central Office.

B.4 RIGID PAVEMENT DESIGNS

Pavement designs will be developed in accordance with the ***Rigid Pavement Design Manual*** (Document No. 625-010-006). The approved pavement design and the supporting data will be included in the District Project Design File.

B.4.1 MINIMUM REQUIREMENTS

The Pavement Design Package as a minimum will include the following items:

The Pavement Design Summary Sheet will show the approved pavement design and will be signed and sealed by the District Pavement Design Engineer or the designated responsible Pavement Design Engineer. The District Design Engineer will sign for concurrence with the design. The file copy will show Federal Highway Administration (FHWA) approval, if required, for Federal Aid Projects or Certification Acceptance as appropriate.

Project location and description of the type of work, if not clearly stated on the summary sheet.

The basis for the material properties used in the design, signed and sealed where required, including if applicable for:

New Construction

- Resilient Modulus (M_R).
- Material properties used if different than those in the Design Manual.
- Concrete Pavement Rehabilitation (CPR) and Lane Widening
- Existing pavement layer information (layer types, thickness, and condition).
- A copy of the Pavement Coring and Evaluation Report.
- Drainage recommendations.
- The $ESAL_D$ calculations are normally signed and certified by the Planning Office. The basis for the input data used for these calculations must be stated.
- Required slab thickness calculations.
- Documentation addressing any special features such as cross slope, coordination with adjacent projects, stage construction, drainage considerations, etc.
- Sketch of a possible construction sequence, including any widening and shoulders, to insure constructability in accordance with the standards.
- A drawing of the rigid pavement design typical section or an adequate narrative description.
- Joint Design Details showing Plan View in areas where geometric changes occur (i.e., intersections, ramps, etc.)

B.4.2 DISTRIBUTION

Central Office approval of the pavement design is not required. Designs will be monitored and periodically reviewed, in detail, for quality assurance and for purposes of identifying and improving deficiencies in design policies, procedures, standards and guidelines.

For Federal Aid Projects that are selected under the Federal Highway Administration (FHWA) PODI (Projects of Division Interest) program, two copies of the approved Pavement Design Summary Sheet and one copy of the supporting documentation will be forwarded directly to the appropriate FHWA Engineer for FHWA concurrence (concurrent with the transmittal to the State Pavement Design Engineer).

Only mainline or major elements of a project need formal FHWA pavement design approval. Details such as cross roads and shoulders will be handled as a part of the plans approval process. Do not send these copies to the Central Office for transmittal to FHWA. The District will deal directly with the FHWA to resolve any questions. Central Office Pavement Management will be available for assistance if requested by the District or FHWA. The FHWA will return directly to the District one copy of the summary sheet with signature denoting concurrence. This copy will be filed in the District Project Design file.

B.4.3 REVISIONS

Changes made subsequent to formal distribution will require that a revised summary sheet be prepared, a copy of which shall be signed and sealed, distributed, and filed for permanent record in the Project Design File.

Minor changes may be noted in type or ink on the original Pavement Design Summary Sheet with the responsible Professional Engineer's initials and the date of change. A copy of the revised original should then be signed, dated, sealed and filed for permanent record.

Major changes may require that a complete new Pavement Design Summary Sheet be prepared and processed, in which case it shall note that it supersedes a previous design. Copies of revised pavement designs including backup data documenting why the change is being made will be transmitted to the State Pavement Design Engineer and redistributed as appropriate.

For intersection improvement, short roadway connectors on bridge replacement projects, and roadway widening projects, the Modulus of Subgrade Reaction (K Value), 18-kip (80-kN) Equivalent Single Axle Loads ($ESAL_D$), and computation of slab thickness are normally not required. However, in all cases, a document describing how the pavement design was developed should be prepared, signed and sealed.

B.4.4 DOCUMENTATION

Every attempt should be made to follow written procedures. Situations will occur where following the pavement design procedure will result in a required slab thickness that cannot be met. This could occur when a design is required in a widening area.

The Pavement Design Engineer will have to exercise engineering judgment on what should be done in these cases. When this occurs, the Pavement Design Engineer is advised to document the project, make special note of the problem, and provide additional explanation as to how the recommended design was developed. Consultation with other engineers (Construction, Drainage, Materials, etc.) is highly recommended and should be noted in the design file.

B.5 DISTRICT QUALITY CONTROL

The quality control process will include the three activities listed below:

(1) The checking and review of pavement designs for compliance with policies, procedures, standards, guidelines and good engineering practice.

(2) The checking and review of plans to ensure that the approved pavement designs are correctly incorporated.

(3) Documentation of the Quality Control Process.

An independent qualified Professional Engineer will carry out the Quality Control Process. As a minimum, the documentation will consist of a copy of the QC Checklist filed with the Pavement Design Package, or a Pavement Design Quality Control File maintained by Financial Item Number order consisting of:

- A copy of the signed and sealed Pavement Design Summary Sheet.
- A copy of the QC Checklist signed by the QC Engineer.
- A sample checklist is attached.

B.6 QUALITY ASSURANCE REVIEWS

The State Pavement Design Engineer will be responsible for conducting and/or coordinating all pavement related QA activities within each District and the Turnpike. A QA review of District Pavement Design activities will generally be conducted annually.

RIGID PAVEMENT DESIGN QUALITY CONTROL CHECKLIST

State Proj. No. ___________________ Fed Aid No. _________________

FPID ____________________________ County _____________________

Rigid Pavement Design Review	**Satisfactory Yes / No / NA**
Rigid Pavement Design Summary Sheet	
Project Location and Description	
Traffic Data and $ESAL_D$ Calculations	
Resilient Modulus (M_R)	
Required Slab Thickness Calculations	
Drainage Evaluation	
Shoulder Design	
Coordination with Other Offices	
Other Special Details	
Final Pavement Design Drawing or Narrative	

Rigid Pavement Design Review	**Satisfactory Yes / No / NA**
Rehabilitation	
Field Evaluation of Project	
Pavement Coring and Evaluation	
Distress Evaluation	
Projects that Do Not Require Design Calculations	
Existing Pavement Evaluation	
Structural Evaluation	
Plans Review	
Plans Conform to Pavement Design (Dimensions, etc.)	
Design Details Adequately Covered	
Constructible with the Current Technology	

QA by ____ Date _________________

APPENDIX C
ESTIMATING DESIGN 18-KIP EQUIVALENT SINGLE AXLE LOADS ($ESAL_D$)

C.1 BACKGROUND

One of the products of the AASHO (American Association of State Highway Officials) Road Test conducted near Ottawa, Illinois from 1958 to 1960 was a method for relating the relative damage caused by different axle loadings. This evolved into a procedure that permitted the calculation of the accumulated damage caused by mixed vehicle loadings over a pavement design period. The four tires, single axle, carrying 18,000 lbs (18-kip) Equivalent Single Axle Load or $ESAL_D$ was accepted as the base for these calculations. ***Table C.1*** illustrates the relationship of axle weight to damage.

A detailed write-up, including tabulated damage factors for single, tandem, and triple axles, is given in Appendix D of the 1993 AASHTO (American Association of State Highway and Transportation Officials) Guide for Design of Pavement Structures.

A procedure for calculating a more precise estimate on the Department's projects can be obtained from the Office of Planning, Project Traffic Forecasting Procedure Topic No. 525-030-120, using the ***Project Traffic Forecasting Handbook***. Calculations on Department projects must be signed and certified by the Department's planning section.

The following is a simple procedure for estimating $ESAL_D$ in the design lane. Design periods used in these calculations can be found in the manual. The design lane is the lane where the majority of the trucks can be found. A common example would be a four-lane divided highway where most of the trucks would be found in the travel lane. The basic equation is presented and the variables are defined. Simple input coefficients are tabulated. A computer spreadsheet that performs the necessary computations is available from the Department.

TABLE C.1
RELATIONSHIP OF AXLE WEIGHT TO DAMAGE
(D=12", Pt=2.5)

	Total Axle Load (kip)	Equivalent Damage (ESALs)
Single Axle	14	0.34
	18	**1.00**
	22	2.41
Tandem Axle	30	1.14
	34	1.97
	38	3.18
	44	6.01

C.2 BASIC EQUATION

The $ESAL_D$ required for pavement design purposes can be computed using the following equation:

$$ESAL_D = \sum_{y=1}^{y=x}(AADTxT_{24}xD_FxL_FxE_{18}x365)$$

Where:

$ESAL_D$ = Number of accumulated 18-kip Equivalent Single Axle Loads in the design lane for the design period.

y = The year that the calculation is made for. When y=1, the entire variable applies to year 1. Most of the variables are constant except AADT, which may change from year to year. Others may change when changes in the system occur. Such changes include parallel roads, shopping centers, truck terminals, etc.

x = The Design Year

AADT = Average Annual Daily Traffic.

T_{24} = Percent Heavy Trucks during a 24-hour period. Trucks with 6 tires or more are considered in the calculations.

D_F = Directional Distribution Factor. Use 1.0 if one-way traffic is counted or 0.5 for two-way traffic. This value is not to be confused with the Directional Factor use for planning capacity computations.

L_F = Lane Factor converts directional trucks to the design lane trucks. Lane factors can be adjusted to account for unique features known to the designer such as roadways with designated truck lanes. L_F values can be determined from ***Table C.2***.

E_{18} = Equivalency factor which is the damage caused by one average heavy truck measured in 18-kip Equivalent Single Axle Loads. These factors will be periodically updated based on Weigh-In-Motion (WIM) data. E_{18} values can be determined from ***Table C.3*** or the latest Planning guidance.

TABLE C.2
LANE FACTORS (LF) FOR DIFFERENT TYPES OF FACILITIES

	Number of Lanes in One Direction	
Total AADT	**Two Lanes L_F**	**Three Lanes L_F**
4,000	0.94	0.82
8,000	0.88	0.76
12,000	0.85	0.72
16,000	0.82	0.70
20,000	0.81	0.68
30,000	0.77	0.65
40,000	0.75	0.63
50,000	0.73	0.61
60,000	0.72	0.59
70,000	0.70	0.58
80,000	0.69	0.57
100,000	0.67	0.55
120,000	0.66	0.53
140,000	-	0.52
160,000	-	0.51
200,000	-	0.49

The equation that best defines this Lane Factor (L_F) information is:

$$L_F = (1.56 - 0.0826 \times \text{Ln(One Way AADT)} - 0.12368 \times LV)$$

Where:

L_F = Proportion of all one directional trucks in the design lane.

LV = 0 if the number of lanes in one direction is 2. LV = 1 if the number of lanes in one direction is 3 or more.

Ln = Natural Logarithm.

Source: National Cooperative Highway Research Program Report 277, Portland Cement Concrete Pavement Evaluation System (COPES), Transportation Research Board, September 1986.

TABLE C.3
EQUIVALENCY FACTORS E_{18} FOR DIFFERENT TYPES OF FACILITIES

	Flexible Pavement	Rigid Pavement
Freeways		
Rural	1.05	1.60
Urban	0.90	1.27
Arterials and Collectors		
Rural	0.96	1.35
Urban	0.89	1.22

C.3 SAMPLE PROBLEMS

Several sample problems have been provided that illustrates this process.

C.3.1 SAMPLE PROBLEM #1

The District Planning Engineer has provided the following information about a high volume, urban, arterial; four lanes divided two-way projects that will open in the year 2005. The Pavement Type Selection Process indicates that the best alternative is rigid pavement.

GIVEN:

The following input is provided. Note that other facilities within the urban area become available in the year 2013 thus causing the traffic assignment (AADT) to drop and T_{24} to change.

T_{24} = 12%

2005 Estimated AADT = 12,000

2013 Estimated AADT = 16,000

T_{24} = 8%

2014 Estimated AADT = 12,000

2025 Estimated AADT = 34,000

DATA:

The following data can be determined from information and tables provided.

D_F = 0.50 (for two-way traffic)

E_{18} = 1.22 (from ***Table C.3***)

L_F = 0.85 for AADT = 12,000 (from ***Table C.2***)

L_F = 0.82 for AADT = 16,000 (from ***Table C.2***)

L_F = 0.81 for AADT = 20,000 (from ***Table C.2***)

L_F = 0.77 for AADT = 30,000 (from ***Table C.2***)

L_F = 0.75 for AADT = 40,000 (from ***Table C.2***)

FIND:

The $ESAL_D$ for a 20-year design period beginning in 2005.

SOLUTION:

Using the following equations:

For the years 2005 to 2013:

$$ESAL_D = \sum_{y=2005}^{y=2013} (AADT \times T_{24} \times D_F \times L_F \times E_{18} \times 365)$$

$$ESAL_D = \sum_{y=2005}^{y=2013} (AADT \times 0.12 \times 0.50 \times L_F \times 1.22 \times 365)$$

For the years 2014 to 2025:

$$ESAL_D = \sum_{y=2014}^{y=2025} (AADT \times T_{24} \times D_F \times L_F \times E_{18} \times 365)$$

$$ESAL_D = \sum_{y=2014}^{y=2025} (AADT \times 0.08 \times 0.50 \times L_F \times 1.22 \times 365)$$

CALCULATING:

Year	AADT	L_F	Annual ESAL*	Accumulated ESAL
2005	12,000	0.85	272,524	272,524
2006	12,500	0.84	280,539	553,063
2007	13,000	0.84	291,761	884,824
2008	13,500	0.84	302,981	1,147,806
2009	14,000	0.83	310,463	1,458,269
2010	14,500	0.83	321,551	1,779,820
2011	15,000	0.83	332,639	2,112,459
2012	15,500	0.82	339,586	2,452,045
2013	16,000	0.82	350,540	2,802,585
2014	12,000	0.85	181,682	2,984,267
2015	14,000	0.84	209,469	3,193,736
2016	16,000	0.82	233,693	3,427,429
2017	18,000	0.81	259,699	3,687,128
2018	20,000	0.81	288,554	3,975,682
2019	22,000	0.80	313,491	4,289,173
2020	24,000	0.79	337,716	4,626,889
2021	26,000	0.78	361,227	4,988,116
2022	28,000	0.78	389,014	5,377,130
2023	30,000	0.77	411,457	5,788,587
2024	32,000	0.77	438,888	6,227,475
2025	34,000	0.76	460,262	6,687,737

* Values are rounded for simplicity.

CONCLUSION:

Note that the 20-year accumulated value ($ESAL_D$) is 6,227,475 ESALs or 7,000,000 ESALs.

C.3.2 SAMPLE PROBLEM #2

The District Planning Engineer has provided the following information about a moderate volume, rural arterial four lanes divided two-way project that will open in the year 1990. The Pavement Type Selection Process indicates that the best alternative is rigid pavement.

GIVEN:

The following input is provided:

T24 = 10%

1990 Estimated AADT = 8,000

2010 Estimated AADT = 18,000

DATA:

The following data can be determined from information and tables provided.

D_F = 0.50 (for two-way traffic)

E_{18} = 1.35 (from ***Table C.3***)

L_F = 0.88 for AADT = 8,000 (from ***Table C.2***)

L_F = 0.85 for AADT = 12,000 (from ***Table C.2***)

L_F = 0.82 for AADT = 16,000 (from ***Table C.2***)

L_F = 0.81 for AADT = 20,000 (from ***Table C.2***)

FIND:

The $ESAL_D$ for a 20-year design period beginning in 1990.

SOLUTION:

Using the following equation:

For the year 1990 to 2010.

$$\mathbf{ESAL_D = \sum_{y=1990}^{y=2010} (AADT \times T_{24} \times D_F \times L_F \times E_{18} \times 365)}$$

$$\mathbf{ESAL_D = \sum_{y=1990}^{y=2010} (AADT \times 0.10 \times 0.50 \times L_F \times 1.35 \times 365)}$$

CALCULATING:

Year	AADT	L_F	Annual ESAL*	Accumulated ESAL
1990	8,000	0.88	173,448	173,448
1991	8,500	0.87	182,194	355,642
1992	9,000	0.87	192,912	548,554
1993	9,500	0.86	201,288	749,842
1994	10,000	0.86	211,883	961,725
1995	10,500	0.86	222,477	1,184,202
1996	11,000	0.85	230,361	1,414,563
1997	11,500	0.85	240,832	1,655,395
1998	12,000	0.85	251,303	1,906,698
1999	12,500	0.84	258,694	2,165,392
2000	13,000	0.84	269,042	2,434,434
2001	13,500	0.84	279,389	2,713,823
2002	14,000	0.83	286,288	3,000,111
2003	14,500	0.83	296,512	3,296,623
2004	15,000	0.83	306,737	3,603,360
2005	15,500	0.82	313,143	3,916,503
2006	16,000	0.82	323,244	4,239,747
2007	16,500	0.82	333,345	4,573,092
2008	17,000	0.82	343,447	4,916,539
2009	17,500	0.81	349,237	5,265,776
2010	18,000	0.81	359,215	5,624,991

* Values are rounded for simplicity.

CONCLUSION:

Note that the 20 year (2009) accumulated value is 5,265,776 ESALs (rounding $ESAL_D$ = 6,000,000).

If the project design period delayed one year and the design period reduced to 19 years, the new $ESAL_D$ would be:

5,624,991 - 173,448 = 5,451,543 ESALs (Rounding $ESAL_D$ = 6,000,000).