COLORADO
Department of Transportation

M-E Pavement Design Manual

2024 Addendum

INTRODUCTION

Purpose of Manual Addendum

The purpose of this 2024 Pavement Design Manual Addendum is to update values contained in the 2021 Pavement Design Manual based on data collected in the last 2 years. The 2021 Pavement Design Manual, accompanied by this 2024 Addendum, shall serve as the uniform and detailed procedure for designing pavements after **July 1, 2023** for all designs in CDOT's right of way**.** We highly recommend using this guide for off-system projects for overall consistency.

Approved Pavement Design Methods

The AASHTO Mechanistic-Empirical (M-E) design procedure using AASHTOWare Pavement M-E Design software (formerly DARWin-ME™) is the recommended method to determine pavement design thickness. CDOT strongly recommends using the 2020 AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice (MOP) and the 2021 AASHTO MEPDG MOP supplement along with the latest CDOT Pavement Design Manual.

Coordinating Designs with Other Agencies

Other agencies should contact either the Region Materials Engineer (RME) or the Pavement Design Program Manager (PDMP) concerning CDOT and Region policies relating to pavement issues.

SUMMARY OF MANUAL REVISIONS FROM 2021 PDM

Section	Major Revisions
Introduction, Acronyms and Definitions	▪ Definitions: The zone of influence to be used in designs is 6 inches beneath the grid
Chapter 1	▪ Table 1.1: Added column for BCOA-ME Design Guide ▪ Section 1.4: Added directions for accessing the Help guide ▪ Section 1.5: Added Working with the M-E Design Database (FOR CDOT EMPLOYEES ONLY) ▪ Section 1.7: Added Using the Optimization Function
Chapter 2	▪ Section 2.7: Added "The reliability of the design shall be determined by the RME." ▪ Table 2.3: Updated reliability ranges ▪ Section 2.7: Added guidance for new design lanes ▪ Updated initial IRI; HMA of 61 inches/mile and PCCP of 72 inches per mile ▪ Tables 2.4, 2.5, 2.6, 2.7: Updated terminal threshold values per the latest AASHTO ME-Design Manual of Practice and Addendum
Chapter 3	▪ Section 3.1.4: Added guidance for jump/bypass lanes ▪ Table 3.3: Added a row for paid express lanes and guidance for deceleration and acceleration lanes ▪ Section 3.2.1: Added "The RME shall approve all weather stations used in the design." ▪ Table 3.14: Added guidance for choosing virtual station locations ▪ Section 3.2: Added new procedure for selecting MERRA weather stations
Chapter 4	▪ Section 4.2: Added reference to the RME prior to performing a soil survey ▪ Sections 4.2.3.1, 4.2.3.2, 4.2.3.4, 4.2.4, 4.2.11, 4.2.12, 4.2.14, 4.2.14.1, 4.3: Added phrase "shall be done per the CDOT Geotechnical Design Manual." ▪ Section 4.3: Added "Rock embankment shall meet all of the following requirements per subsection 203.03(2) of the *CDOT Standard Specifications for Road and Bridge Construction*." ▪ Tables 4.3, 4.4 and 4.5: Changed wording to "M-E Design will estimate these values internally using gradation, plasticity index, liquid limit, and whether or not the layer is compacted," "The RME shall approve the gradation, plasticity index, liquid limit, water content, and whether or not the layer is compacted for all designs," and "The test method used shall be dependent on soil classification. See Section 203 in the CDOT Standards Specifications for Road and Bridge Construction." ▪ Table 4.9: Added "All testing shall be done at 200 psf unless directed otherwise by the RME."

Chapter 5	▪ Section 5.2: Added reference to the CDOT Geotechnical Design Manual ▪ Section 5.6.1: Added guidance for using RAP in designs
Chapter 6	▪ Section 6.4: Changed the initial IRI for HMA to 61 inches/mile ▪ Table 6.7: Removed SG mix and changed to maximum thickness for S mixes to 3.00 inches ▪ Table 6.15: Removed SG mix ▪ Removed sensitivity figures
Chapter 7	▪ Section 7.4: Updated the initial IRI for PCCP to 72 inches/mile ▪ Removed sensitivity figures
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MECHANISTIC-EMPIRICAL (M-E) PAVEMENT DESIGN BASIC DEFINITIONS

These definitions may be slightly different from the definition in the previous section. These basic definitions are to agree with the usage as in the Mechanistic-Empirical (M-E) Pavement Design Guide. Some have been modified to clarify this manual's notation.

Fabric Layers

- **Geosynthetics:** A planar material manufactured from a polymeric material used with soil, rock, earth, or other geotechnical-related materials. It serves six primary functions: filtration, drainage, separation, reinforcement, fluid blockage, and protection. Typical geosynthetics include geotextiles, geomembranes, and geogrids.
- **Geotextiles:** Permeable fabric made of textile materials used as filters to prevent soil migration and soil mixing. Geotextiles also act as reinforcement, adding shear strength to a soil.
- **Geomembranes:** Impermeable polymer sheeting used as fluid barriers to prevent migration of liquid pollutants in the soil.
- **Geogrids:** Polymeric grid material having relatively high tensile strength and a uniformly distributed array of large apertures (openings). The apertures allow soil particles on either side to come in direct contact, increasing the interaction between the geogrid and surrounding soils. Geogrids are used primarily for reinforcement. The zone of influence to be used in designs is 6 inches beneath the grid.

CHAPTER 1
INTRODUCTION

1.1 Introduction

The Colorado Department of Transportation (CDOT) has adopted the *2020 AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice (MOP)* and the *2021 AASHTO MEPDG MOP Supplement* for pavement design and analysis along with the AASHTOWare Pavement M-E Design software, otherwise called the M-E Design software. The pavement design models in the M-E Design software were calibrated and validated using extensive Colorado pavement performance data. **CDOT currently uses version 2.3 of the M-E Design software.**

1.2 Scope and Limitations

1.2.2 Scope

Pavement structure sections, except for experimental construction for research, are to be designed using methods or standards described in **Table 1.1 Recommended Pavement Design Procedures.** Although M-E Design allows pavement design and analysis of seventeen pavement types, not all of these pavement types have been calibrated for Colorado conditions. Furthermore, this design procedure did not include performance prediction models for thin and ultra-thin concrete overlay designs until version 2.6. Designers are advised as much as possible to follow recommendations presented in **Table 1.1 Recommended Pavement Design Procedures** for selecting appropriate pavement design/analysis methodology for a given pavement type.

Table 1.1 Recommended Pavement Design Procedures

Pavement Type	Design Methodology	
	CDOT 2023 Pavement M-E Design Manual	BCOA-ME Design Guide
New HMA	✓	
Flexible Overlays of Existing HMA	✓	
Flexible Overlays of Existing Rigid	✓	
New Rigid	✓	
PCC Overlays of Existing Rigid	✓	
Thin and Ultrathin Concrete Overlays		✓
Concrete Pavement Restoration	✓	
Flexible Pavement for Intersections	✓	
Rigid Pavement for Intersections	✓	

1.3 Overview of AASHTO Pavement Mechanistic-Empirical Design Procedure

The AASHTO Pavement M-E Design Procedure is based on mechanistic-empirical design concepts. This means the design procedure calculates pavement responses such as stresses, strains, and deflections under axle loads and climatic conditions and accumulates the damage over the design analysis period. The procedure empirically relates calculated damage over time to pavement distresses and smoothness based on the performance of actual projects in Colorado. More details are found in the following documents:

- AASHTO, *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*, 2021, Supplement - Third Edition, American Association of State Highway and Transportation Officials, Washington, DC, 2021.
- AASHTO, *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice*, 2020, Third Edition, American Association of State Highway and Transportation Officials, Washington, DC, 2020.
- AASHTO, *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*, November 2010, American Association of State Highway and Transportation Officials, Washington, DC, 2010.
- NCHRP, 1-37A Project. *2002 Design Guide: Design of New and Rehabilitated Pavement Structures*, National Cooperative Highway Research Program, National Academy of Sciences, DC, 2004.

1.4 Overview of AASHTOWare Pavement M-E Design Software

The AASHTOWare Pavement M-E Design software is a production-ready software tool for performing pavement designs using the AASHTO *MEPDG Manual of Practice* methodology. The M-E Design software performs a wide range of analysis and calculations in a rapid, user-friendly format. With its many customized features, the M-E Design software will help simplify the pavement design process and result in improved, cost-effective designs. The following subsections provide a brief overview of the process involved in installing, uninstalling, and running the M-E Design software.

A very detailed and comprehensive user manual for the M-E Design software is available with the software. Since the details of this process are likely to change over time, they are not repeated here. The HELP document can be easily obtained in the following two ways; see Figures 1.2 through 1.7:

Method 1

Step 1: From the Windows File Explorer, go to "This PC". Click "Windows (C:).

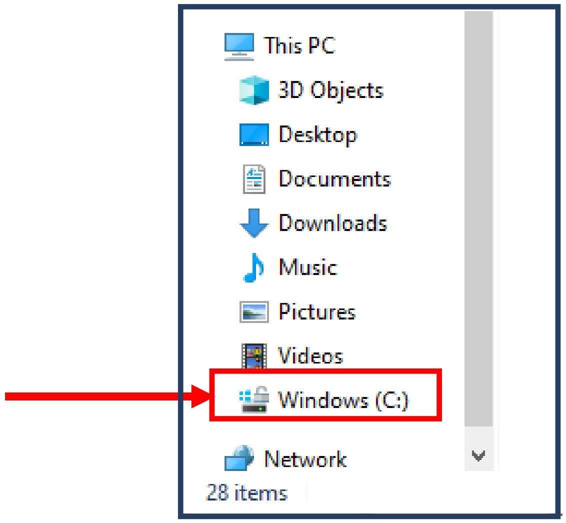


Figure 1.1 Method 1, Step 1

Step 2: Click "Program Files (x86) located in the Documents directory.

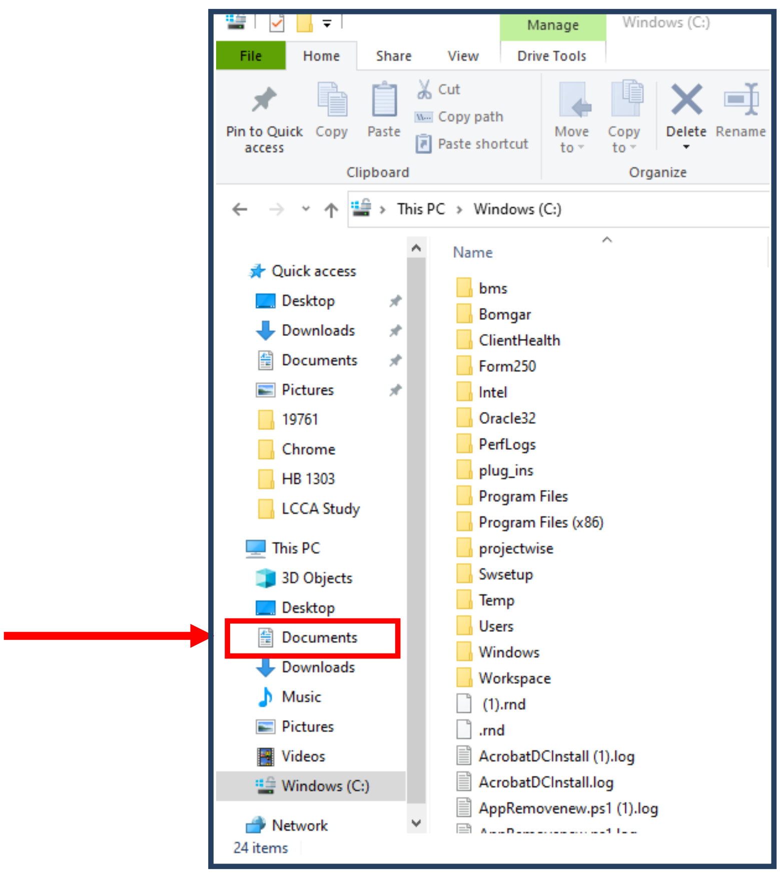


Figure 1.2 Method 1, Step 2

Step 3: Select the “AASHTOWare” folder.

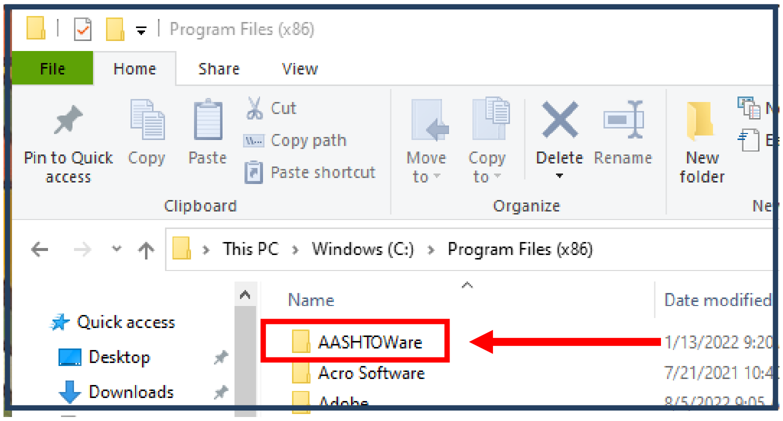


Figure 1.3 Method 1, Step 3

Step 4: Select the “ME Design” folder.

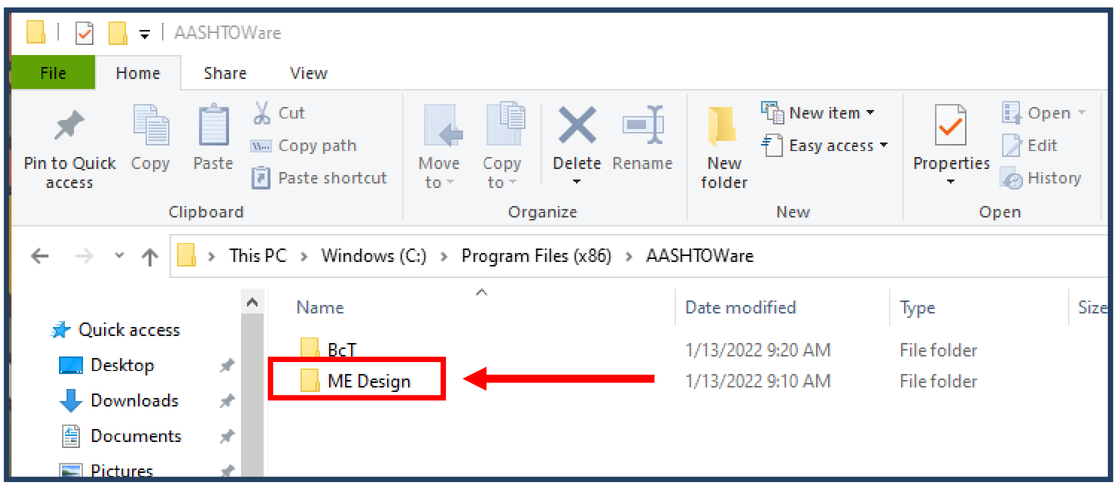


Figure 1.4 Method 1, Step 4

Step 5: Select the “PDF Help” folder. You will find a PDF of the Help System manual in both SI and English units.

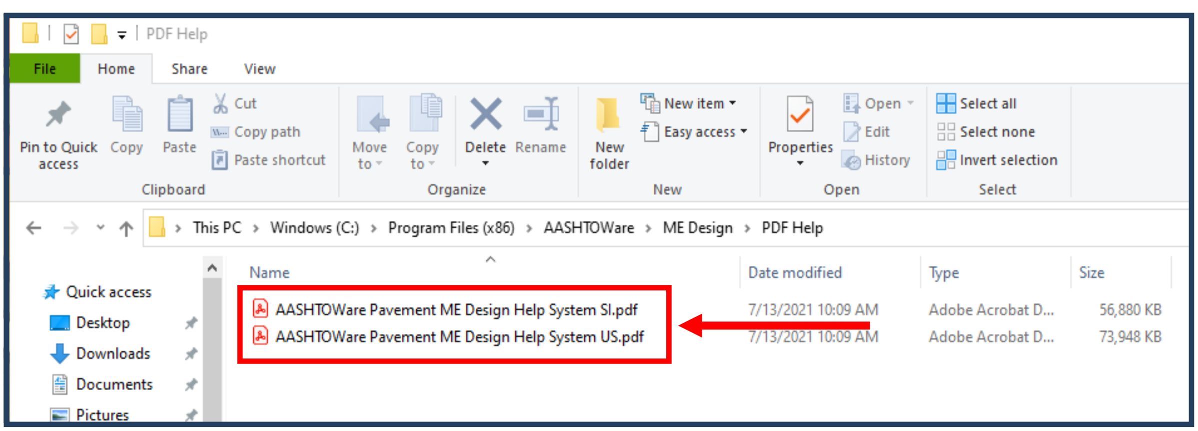


Figure 1.5 Method 1, Step 5

Method 2

Step 1: Press the '*F1 key*' after opening the software.

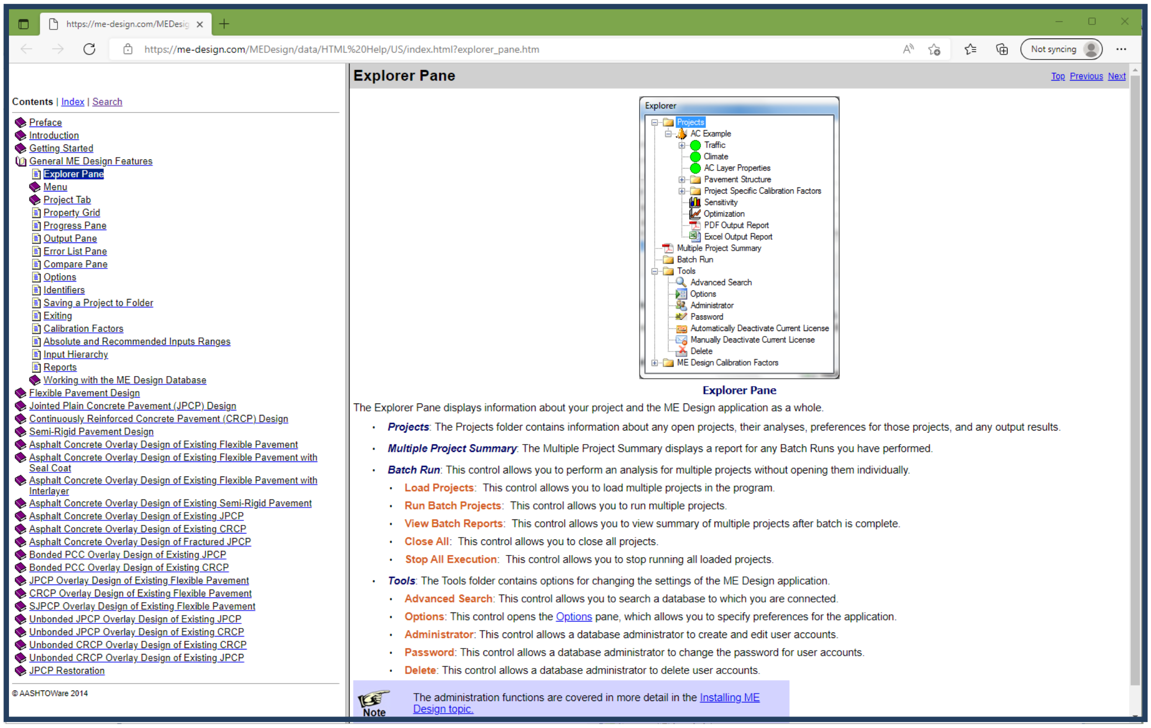


Figure 1.6 Method 2, Step 1

1.5 Working with the M-E Design Database (CDOT EMPLOYEES ONLY)

M-E Design includes an enterprise option for saving, searching, and loading projects utilizing a relational database. This feature allows users to store and retrieve data at varying degrees of granularity, from entire projects to data from individual projects such as pavement layers, materials, traffic, climate, backcalculation, etc. This section briefly describes how to set up the CDOT M-E Design database.

Step 1: Obtain ME-Design Login Credentials

Contact the CDOT Pavement Design Unit to obtain a username and login for ME-Design.

Step 2: CDOT OIT System Administrator to Set Up Database

Contact the CDOT Pavement Design Unit to start a request for entering the necessary database information. The Pavement Design Unit will pass the request to the OIT System Administrator to remote into your device and enter the required information. NOTE: The required information for access to the CDOT database cannot be entered by the Pavement Design Unit or individual users. Once the database is set up, the user will be able to access it through logging into ME-Design and following the instructions contained in this chapter.

1.6 Working with the M-E Design Database (ALL USERS)

Download and Access Instructions

Blank M-E Design databases for MS SQL and ORACLE can be found in the Database Resource Documents section at http://www.me-design.com/. The user must have a valid user name and password to access the website.

Database Installation

The following sections describe the installation process for creating a blank M-E Design database.

Installation Requirements

The requirements for installing and creating a blank M-E Design database are as follows:

- A user with administrative privileges on the target machine will be required to set up the M-E Design database.
- The maximum size of the M-E Design database shall be no greater than 10 GB.
- ORACLE 10g Release 2 or ORACLE Client 10g Release 2 or greater (contains the ORACLE Provider for OLEDB).
- Microsoft SQL Server 2005 or Express (and later versions).

Once the database is installed, the user can open the M-E Design software and select '*Open M-E Design*' with a data base connection check box (see **Figure 1.13 M-E Design Software Splash Screen Showing Database Login Location.**)

Figure 1.7 M-E Design Software Splash Screen Showing Database Login Location

Enter the Login name and Password supplied by the CDOT Pavement Design Unit or AASHTO to access the M-E Design database.

CHAPTER 2
PAVEMENT DESIGN INFORMATION

2.1 Introduction

This chapter provides pavement designers the general information required for conducting pavement design and analysis using the M-E Design software. This section does not include traffic, climate, or material related inputs.

2.7 Design Performance Criteria and Reliability (Risk)

Performance verification is the basis of the acceptance or rejection of a trial design evaluated using the M-E Design software. A successful design is one where all selected performance threshold limits are satisfied at their chosen levels of reliability at the end of the design life.

M-E Design requires the designer to specify the critical levels or threshold values of pavement distresses and smoothness to judge the adequacy of a design. The type of distresses used in performance verification is specific to the pavement type (flexible or rigid) and design (rehabilitation or new design). Additionally, design reliability levels are required to account for the uncertainty and variability expected to exist in pavement design and construction and the application of traffic loads and climatic factors over the design life. The threshold and reliability levels for distresses and smoothness significantly impact construction costs and performance.

The designer must set realistic numerical limits or threshold values for each performance criterion and reasonable reliability levels for a given design life.

Limits on the various performance criteria should be considered along with design reliability and design period. Both performance criteria and reliability factors are determined based on the roadway's functional classification and whether it is in an urban or a rural location. Once selected, the limits should be used consistently throughout the pavement type selection and design calculations. **Consultation of the mix design(s) with the RME shall occur**.

The reliability is a factor of safety to account for the inherent variations in construction, materials, traffic, climate, and other design inputs. **Table 2.3 Reliability (Risk)** provides the pavement structure's recommended values to survive the design period traffic. Reliability values recommended for use in previous editions of the AASHTO Design Guide should not be used with M-E Design. Reliability is not dependent on either type of pavement or type of project. The reliability of the design shall be determined by the RME.

Table 2.1 Reliability (Risk)

Functional Classification	New Construction	Rehabilitation
Interstate	90-95	80-95
Principal Arterials (freeways and expressways)	90-95	80-95
Principal Arterials (other)	85-95	75-95
Minor Arterial	85-95	75-95
Major Collectors	80-95	70-90
Minor Collectors	80-95	70-90
Local	80-95	70-90

Table 2.4 Recommended Threshold Values of Performance Criteria for New Construction or Reconstruction of Flexible Pavement Projects, Table 2.5 Recommended Threshold Values of Performance Criteria for New Construction or Reconstruction Projects of Rigid Pavement, Table 2.6 Recommended Threshold Values of Performance Criteria for Rehabilitation Projects of Flexible Pavements and **Table 2.7 Recommended Threshold Values of Performance Criteria for Rehabilitation Projects of Rigid Pavements** provide the threshold values recommended in M-E Design for pavements. M-E Design also requires the designer to enter the expected initial smoothness (IRI) at the time of construction.

New Design Lane

When a project requires a designer to add a new design lane to an existing pavement, the new design lane should have the same thickness as the existing pavement.

It is recommended to use an initial IRI value of 61 inches/mile for all HMA projects and 72 inches/mile for all PCC projects as they reflect targets that are documented using smoothness data from flexible and rigid pavements constructed between 2017 and 2022. **The same reliability value is recommended for all distresses; any changes should have Region Materials and Staff Materials approval.**

Table 2.2 Recommended Threshold Values of Performance Criteria for New Construction of Flexible Pavement

Flexible Pavement	
Performance Criteria	**Maximum Value at End of the Design Life**
Terminal IRI (inches per mile)	Interstate - 160 Principal Arterial - 200 Minor Arterial - 200 Major Collector - 200 Minor Collector - 200* Local Roadway - 200*
AC Top-Down Fatigue Cracking (feet per mile)	Interstate -2,000 Principal Arterial - 2,500 Minor Arterial -3,000 Major Collector -3,000 Minor Collector - 3,000* Local Roadway - 3,000*
AC Bottom-Up Fatigue Cracking (percent lane area)	Interstate - 10 Principal Arterial - 20 Minor Arterial - 35 Major Collector -35 Minor Collector -35* Local Roadway - 35*
AC Thermal Cracking (feet per mile)	Interstate - 1,500 Principal Arterial - 1,500 Minor Arterial - 1,500 Major Collector - 1,500 Minor Collector - 1,500* Local Roadway - 1,500*
Permanent Deformation (total inches)	Interstate - 0.40 Principal Arterial - 0.50 Minor Arterial - 0.65 Major Collector - 0.65 Minor Collector - 0.65* Local Roadway - 0.65*
Permanent Deformation AC Only (inches)	Interstate - 0.40 Principal Arterial - 0.50 Minor Arterial - 0.65 Major Collector - 0.65 Minor Collector - 0.65* Local Roadway - 0.65*
Additional Thresholds for Chemically Stabilized Layer	
Fatigue Fracture (percent lane area) (For semi-rigid base layer)	Interstate - 10 Principal Arterial - 25 Minor Arterial - 25 Major Collector - 25 Minor Collector - 25* Local Roadway - 25*
AC Total Fatigue Cracking Bottom Up + Reflective (percent lane area) (For semi-rigid base layer)	Interstate - 10 Principal Arterial - 25 Minor Arterial - 25 Major Collector - 25 Minor Collector - 25* Local Roadway - 25*
AC Total Transverse Cracking Thermal + Reflective (feet per mile) (For semi-rigid base layer)	Interstate - 1,500 Principal Arterial - 1,500 Minor Arterial - 1,500 Major Collector - 1,500 Minor Collector -1,500* Local Roadway - 1,500*
Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.	

Table 2.3 Recommended Threshold Values of Performance Criteria for Rehabilitation of Flexible Pavement Projects

Flexible Pavement		
Performance Criteria	**Maximum Value at End of the Design Life (Minimum Age Shall Be 10 Years)**	
Terminal IRI (inches per mile)	Interstate - 160 Principal Arterial - 200 Minor Arterial - 200 Major Collector - 200 Minor Collector - 200* Local Roadway - 200*	
AC Top-Down Fatigue Cracking (feet per mile)	Interstate -2,000 Principal Arterial - 2,500 Minor Arterial - 3,000 Major Collector -3,000 Minor Collector - 3,000* Local Roadway - 3,000*	
AC Bottom-Up Fatigue Cracking (percent lane area)	Interstate - 10 Principal Arterial - 20 Minor Arterial - 35 Major Collector -35 Minor Collector -35* Local Roadway - 35*	
AC Thermal Cracking (feet per mile)	Interstate - 1,500 Principal Arterial - 1,500 Minor Arterial - 1,500 Major Collector - 1,500 Minor Collector - 1,500* Local Roadway - 1,500*	
Permanent Deformation (total inches)	Interstate - 0.40 Principal Arterial - 0.50 Minor Arterial - 0.65 Major Collector - 0.65 Minor Collector - 0.65* Local Roadway - 0.65*	
Permanent Deformation AC Only (inches)	Interstate - 0.40 Principal Arterial - 0.50 Minor Arterial - 0.65 Major Collector - 0.65 Minor Collector - 0.65* Local Roadway - 0.65*	
AC Total Fatigue Cracking Bottom-Up + Reflective (percent lane area)	Interstate - 20 Principal Arterial - 35 Minor Arterial - 35 Major Collector - 35 Minor Collector - 35* Local Roadway - 35*	Use 50% Reliability
AC Total Transverse Cracking Thermal + Reflective (feet per mile)	Interstate - 2,500 Principal Arterial - 2,500 Minor Arterial - 2,500 Major Collector - 2,500 Minor Collector - 2,500* Local Roadway - 2,500*	
Additional Thresholds for Chemically Stabilized Layer		
Fatigue Fracture (percent lane area) (For semi-rigid base layer)	Interstate - 20 Principal Arterial - 35 Minor Arterial - 35 Major Collector - 35 Minor Collector - 35* Local Roadway - 35*	

Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.

Table 2.4 Recommended Threshold Values of Performance Criteria for New Construction of Rigid Pavement

Rigid Pavement (JPCP)	
Performance Criteria	**Maximum Value at End of the Design Life (30 years)**
Terminal IRI (inches per mile)	Interstate - 160 Principal Arterial - 200 Minor Arterial - 200 Major Collector - 200 Minor Collector - 200* Local Roadway - 200*
Transverse Slab Cracking (percent slabs)	Interstate - 10.0 Principal Arterial - 15.0 Minor Arterial - 20.0 Major Collector - 20.0 Minor Collector - 20.0* Local Roadway - 20.0*
Mean Joint Faulting (inches)	Interstate - 0.15 Principal Arterial - 0.20 Minor Arterial - 0.25 Major Collector - 0.25 Minor Collector - 0.25* Local Roadway - 0.25*
Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.	

Table 2.5 Recommended Threshold Values of Performance Criteria for Rehabilitation of Rigid Pavement Projects

Rigid Pavement (JPCP)	
Performance Criteria	**Maximum Value at End of the Design Life (Minimum Age Shall Be 20 Years)**
Terminal IRI (inches per mile)	Interstate - 160 Principal Arterial - 200 Minor Arterial - 200 Major Collector - 200 Minor Collector - 200* Local Roadway - 200*
Transverse Slab Cracking (percent)	Interstate -10.0 Principal Arterial - 15.0 Minor Arterial - 20.0 Major Collector - 20.0 Minor Collector - 20.0* Local Roadway - 20.0*
Mean Joint Faulting (inches)	Interstate - 0.15 Principal Arterial - 0.20 Minor Arterial - 0.25 Major Collector - 0.25 Minor Collector - 0.25* Local Roadway - 0.25*
Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.	

Functional Classification

The appropriate functional classification for a particular roadway can be determined by using one of 2 methods:

Method 1:
CDOT Form #463: Design Data, completed for the specific highway project being designed. A blank CDOT Form #463 is shown in the Appendix of the *CDOT Project Development Manual*.

As an example, CDOT Form #463 identifies a segment of State Highway 83 as a principal arterial; the reliability for this roadway can be obtained from **Table 2.3 Reliability (Risk).** As the table shows, the reliability for this road may range from 85 to 95 percent. This is a high profile road, so the reliability is set at 95 percent.

Method 2:
CDOT Online Transportation Information System (OTIS): Open OTIS in your browser using the following link: https://dtdapps.coloradodot.info/otis

Select "Highway Data" from the OTIS Webpage as shown in **Figure 2.3 - OTIS Webpage - Home.** This will open the Highway Data Explorer as shown in **Figure 2.4 - OTIS Highway Data Explorer.**

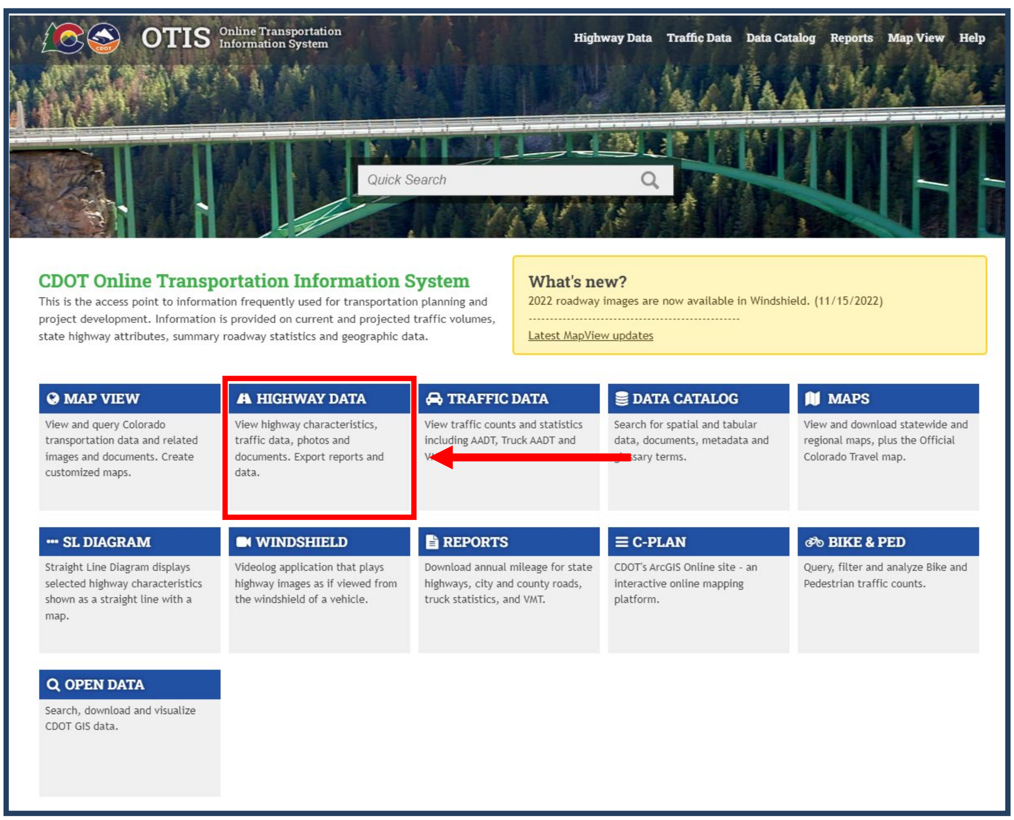


Figure 2.3 OTIS Webpage - Home

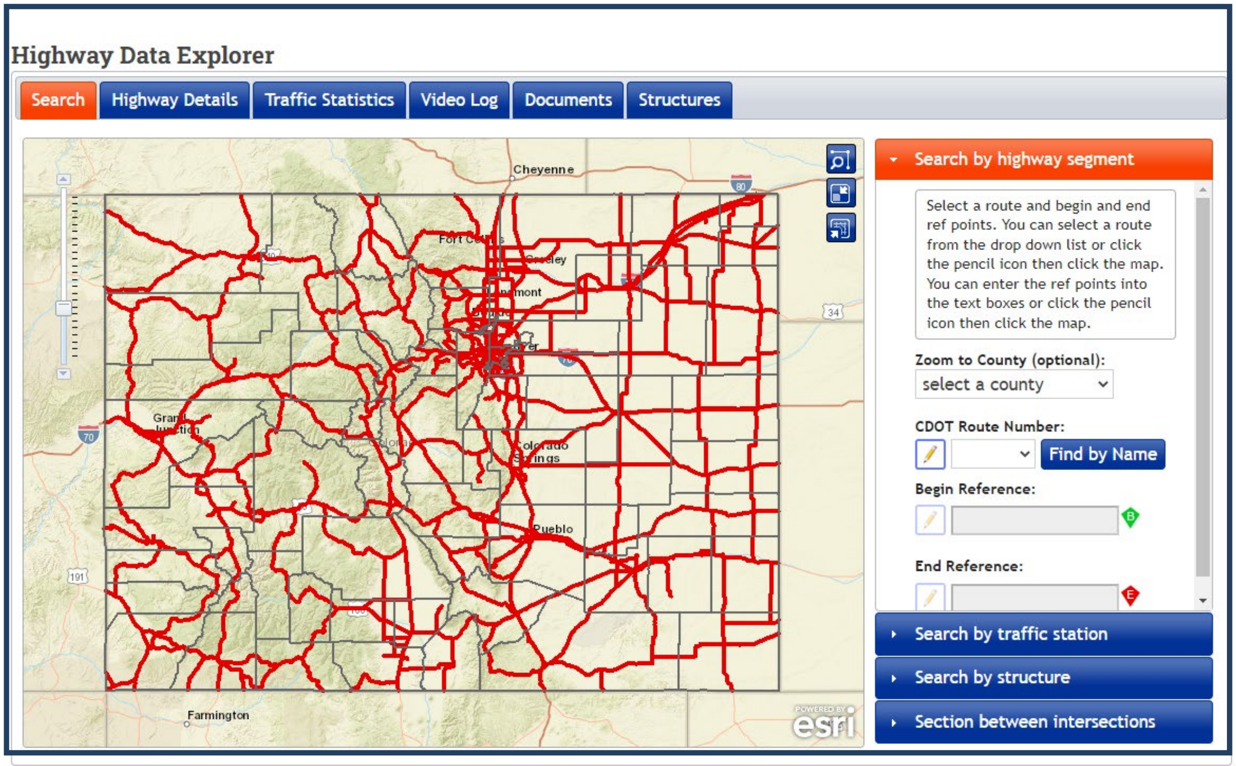


Figure 2.4 OTIS Highway Data Explorer

The Highway Data Explorer allows the user to search using the following criteria:

- Highway Segment
- Traffic Station
- Structure
- Between Intersections

Using one of the above listed search criteria, select the project segment. Once selected, go to the “Highway Details” tab. This will open the screen shown in **Figure 2.5 OTIS Highway Details**.

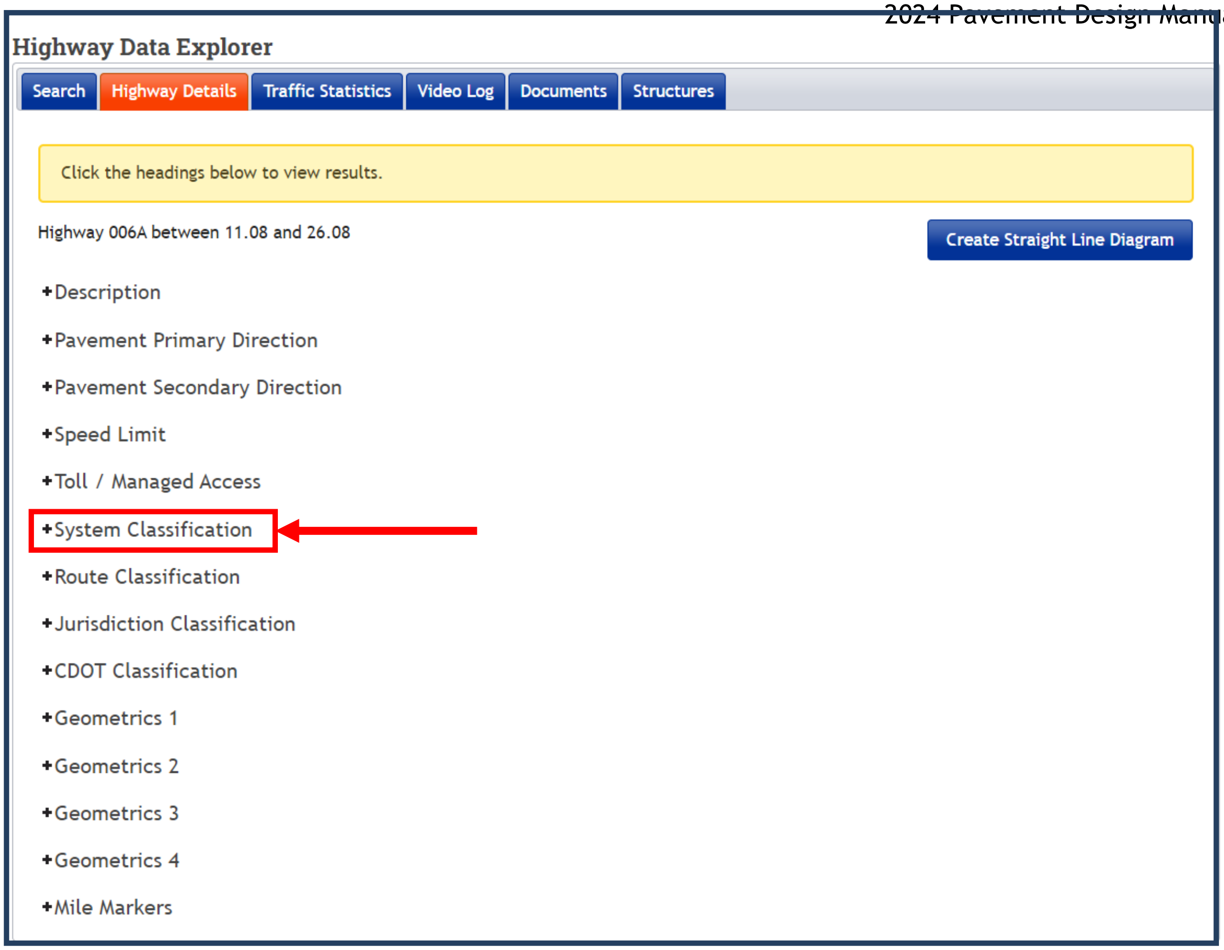
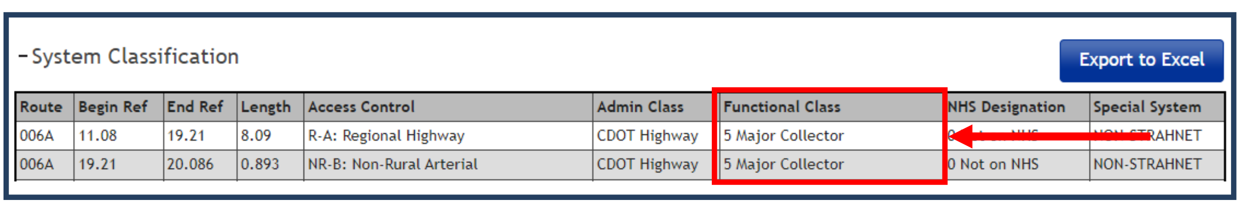


Figure 2.5 OTIS Highway Details

Select the '+' icon for "System Classification. This will open a table with information on the selected segment – use the class shown in the "Functional Class" column shown in **Figure 2.6 OTIS System Classification.**



-System Classification

Export to Excel

Route	Begin Ref	End Ref	Length	Access Control	Admin Class	Functional Class	NHS Designation	Special System
006A	11.08	19.21	8.09	R-A: Regional Highway	CDOT Highway	5 Major Collector	[illegible]	[illegible]
006A	19.21	20.086	0.893	NR-B: Non-Rural Arterial	CDOT Highway	5 Major Collector	0 Not on NHS	NON-STRAHNET

Figure 2.6 OTIS System Classification

CHAPTER 3
TRAFFIC AND CLIMATE

Traffic and climate related inputs required for conducting pavement design and analysis using M-E Design software are discussed in this chapter.

3.1.4 Lane and Directional Distributions

The most heavily used lane is referred to as the design lane. Generally, the outside lanes are the design lanes. Traffic analysis determines a percent of all trucks traveling on the facility for the design lanes. This number is also referred to as a lane distribution factor.

The percent of trucks in the design direction is applied to the two-directional AADT to account for any differences to truck volumes by the direction. The percentage of trucks in the design direction is referred to as the directional distribution factor. Generally, the directional distribution factor is a 50/50 percent split. If the number of lanes and volumes are not the same for each direction, it may be appropriate to design a different pavement structure for each direction of travel.

Recent designs have called for creating a queue jump/bypass lane specifically for busses, however some instances may include trash trucks. Historically these two types of vehicles are considered overweight vehicles per individual axle, so although the daily counts may be low to moderate they need to be considered similar to a Class 5 or Class 9 vehicle to calculate the predicted damage. The jump/bypass lanes should be designed with the same thickness as the primary design lane.

Table 3.1 Design Lane Factor

Type of Facility	Number of Lanes in Design Direction	Design Lane Factor	Percent of Total Trucks in the Design Lane (Outside Lane)	Directional Split (Design Direction/ Non-design Direction)
One Way	1	1.00	100	NA
2-Lanes	1	0.60	100	60/40
4-Lanes	2	0.45	90	50/50
6-Lanes	3	0.309	60	50/50
8-Lanes	4	0.25	50	50/50
Paid Express Lanes	Treated as an extra lane; no special design factors are to be applied.*			50/50
Note: The *Highway Capacity Manual*, 2000 (Exhibit 12-13) recommends using a default value for directional split of 60/40 on a two-lane highway may it be rural or urban ().				
* Deceleration and acceleration lanes are to be treated the same as the rest of the roadway, in particular the adjacent lane.				

3.2 Climate

3.2.1 Creating Project Specific Climate Input Files

Designers can select one or more weather stations based on the proximity to the project location. A single weather station can be set when the project is within reasonable proximity, however a virtual station by selecting at least three surrounding weather stations is recommended. The RME shall approve all weather stations used in the design. A virtual station is recommended to increase the accuracy of weather data for the specific project location. Proximity is defined in terms of longitude, latitude, and elevation. The designer should select the stations that are closest to the project in elevation and distance.

Given Colorado's mountainous terrain, caution should be used if the elevations are significantly different, even if the stations are relatively close to the project. The recommendations for selecting climatic inputs are presented in **Table 3.14 Recommendations for Climatic Inputs**.

Table 3.2 Recommendations for Climatic Inputs

Climate Inputs	Recommendations
Weather Station ≤ 50 Miles and Elevation Difference ≤ 500 feet	Import specific weather station
Weather Station > 50 Miles Elevation Difference > 500 feet	Singular and virtual weather stations consisting of two or more nearby stations shall be in concurrence with the RME. The preferred virtual station will have stations within 50 miles distance and 500 foot elevation of the project.
Depth of Water Table (feet)	Actual depth may be found in County Soil Reports[1], project geotechnical reports, or an estimate based on the area. The depth of the water table typically ranges from 3 to 100 feet. If the water table is encountered within the upper 10 feet the designer should investigate dewatering methods and/or drains to lower the water table's elevation. Separate designs should be made for areas that do not have a high water table versus those that do. If dewatering is not an option, the design will likely result in a thick pavement.

Note:
[1] The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database. Another available resource for estimating depth of water table for a project site is the Colorado Division of Water Resources database and geologic well logs available online at http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/geo/

CHAPTER 4
SUBGRADE

The M-E Design process begins with a preliminary soil survey. Geotechnical investigations are typically required for new construction and reconstruction projects. The CDOT Program Engineer shall work with the Region Materials Engineer to determine the scope of the soil survey and ensure it is completed if requested. Refer to CDOT Geotechnical Design Manual for all geotechnical investigation and design.

Table 4.1 Recommended Subgrade Inputs for New Flexible and JPCP Design

Pavement and Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
New Flexible and JPCP	Resilient modulus	Not available	CDOT lab testing	AASHTO Soil Classification
	Gradation	Not available	Colorado Procedure 21-08	Use CDOT defaults
	Atterberg limit[1]	Not available	AASHTO T 195	Use CDOT defaults
	Poisson's ratio	Not available	Use M-E Design software defaults	Use M-E Design software default of 0.4
	Coefficient of lateral pressure	Not available	Use M-E Design software defaults	Use M-E Design software default of 0.5
	Maximum dry density	Not available	AASHTO T 99 or T 180[3]	M-E Design will estimate these values internally using gradation, plasticity index, liquid limit, and whether or not the layer is compacted.[2]
	Optimum moisture content	Not available	AASHTO T 99 or T 180[3]	
	Specific gravity	Not available	AASHTO T 100	
	Saturated hydraulic conductivity	Not available	AASHTO T 215	
	Soil water characteristic curve parameters	Not available	Not applicable	

Note:
1 For drainage reasons if non-plastic use PI = 1
2 The RME shall approve the gradation, plasticity index, liquid limit, water content, and whether or not the layer is compacted for all designs.
3 The test method used shall be dependent on soil classification. See Section 203 in the CDOT Standards Specifications for Road and Bridge Construction.

Table 4.2 Recommended Subgrade Inputs for HMA Overlays of Existing Flexible Pavement

Pavement and Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
HMA Overlays of Existing Flexible Pavement	Resilient modulus	FWD deflection testing and backcalculated resilient modulus	CDOT lab testing	AASHTO soil classification
	Gradation	Colorado Procedure 21-08		Use CDOT defaults
	Atterberg limit[1]	AASHTO T 195		Use CDOT defaults
	Poisson's ratio	Use software defaults		Use M-E Design software default of 0.4
	Coefficient of lateral pressure	Use software defaults		Use M-E Design software default of 0.5
	Maximum dry density	AASHTO T 99 or T 180[3]		M-E Design will estimate these values internally using gradation, plasticity index, liquid limit, and whether or not the layer is compacted. [2]
	Optimum moisture content	AASHTO T 99 or T 180[3]		
	Specific gravity	AASHTO T 100		
	Saturated hydraulic conductivity	AASHTO T 215		
	Soil water characteristic curve parameters	Not applicable		

Note:
[1] For drainage reasons if non-plastic use PI = 1
[1] The RME shall approve the gradation, plasticity index, liquid limit, water content, and whether or not the layer is compacted for all designs.
[2] The test method used shall be dependent on soil classification. See Section 203 in the CDOT Standards Specifications for Road and Bridge Construction.

Table 4.3 Recommended Subgrade Inputs for Overlays of Existing Rigid Pavement

Pavement and Design Type	Material Property	Input Hierarchy		
		Level 1	Level 2	Level 3
Overlays of Rigid Pavement	Resilient Modulus	FWD deflection testing and backcalculated dynamic k-value[3]	CDOT lab testing	AASHTO soil classification
	Gradation	Colorado Procedure 21-08		Use CDOT defaults
	Atterberg Limit [1]	AASHTO T 195		Use CDOT defaults
	Poisson's ratio	Use software defaults		Use M-E Design software default of 0.4
	Coefficient of lateral pressure	Use software defaults		Use M-E Design software default of 0.5
	Maximum dry density	AASHTO T 99 or T 180[3]		M-E Design will estimate these values internally using gradation, plasticity index, liquid limit, and whether or not the layer is compacted. [2]
	Optimum moisture content	AASHTO T 99 or T 180[3]		
	Specific gravity	AASHTO T 100		
	Saturated hydraulic conductivity	AASHTO T 215		
	Soil water characteristic curve parameters	Not applicable		

Note:
[1] For drainage reasons if non-plastic use PI = 1
[2] The RME shall approve the gradation, plasticity index, liquid limit, water content, and whether or not the layer is compacted for all designs.
[3] The k-value represents the subgrade layer as well as unbound layers including granular aggregate base and subbase layers.

4.4.3 Recommended Inputs for Subgrade/Embankment Materials

4.4.3.1 Inputs for New HMA and JPCP

Level 1 Inputs

Level 1 inputs are not available for new HMA and JPCP designs in this manual since they are project specific values.

Level 2 Inputs

The designer must input a single value of design M_r. Two approaches are available for Level 2 design subgrade M_r:

- **Laboratory Resilient Modulus**: The design M_r may be obtained through laboratory resilient modulus tests conducted in accordance with AASHTO T 307, Determining the Resilient Modulus of Soils and Aggregate Materials.

Subgrade design M_r should reflect the range of stress states likely to be developed beneath flexible or rigid pavements subjected to moving wheel loads. Therefore, the laboratory measured M_r should be adjusted for the expected in-place stress state for use in M-E Design software. Stress state is determined based on the depth at which the material will be located within the pavement system (i.e., the stress states for specimens to be used as base or subbase or subgrade may differ considerably).

- **CDOT Resilient Modulus, R-value Correlation:** The design M_r may be obtained through correlations with other laboratory tested soil properties such as the R-value. Equation **Eq. 4-1** gives an approximate correlation of resistance value (R-value) to M_r. This equation is valid only for AASHTO T 190 procedure. If the R-value of the existing subgrade or embankment material is estimated to be greater than 40, a FWD analysis or resilient modulus by AASHTO T 307 should be performed. CDOT uses Hveem stabilometer equipment to measure strength properties of soils and bases. This equipment yields an index value called the R-value. The R-value is considered a static value and the M_r value is considered a dynamic value.

$$Mr = 3438.6 * R^{0.2753} \qquad \textbf{Eq. 4-1}$$

Where:
M_r = resilient modulus (psi)
R = R-value obtained from the Hveem stabilometer

This equation **should be** used for R-values of 40 or less. Research is currently being done for soils with R-values greater than 40. The Hveem equipment does not directly provide resilient modulus values, rather, it provides the R-value which is then used to obtain an approximation of resilient modulus from correlation formulas.

4.9 Expansive Subgrade Soils

The risk of swell potential is always a concern to the designer. The categories of the “swell damage risk” is shown in **Table 4.9 Probable Swell Damage Risk**. The designer should use **Table 4.9** to decide the risk.

Table 4.9 Probable Swell Damage Risk

Swell (%)	Swell Pressure (psf, at 200 psf surcharge)	Probable Swell Damage Risk
0	0	None
0 - 1	0 - 1,000	Low
1 - 5	1,000 - 5,000	Medium
5 - 20	5,000 - 10,000	High
Over 20	Over 10,000	Very High
Note: All testing shall be done at 200 psf unless directed otherwise by the RME.		

CHAPTER 5
GRANULAR AND TREATED BASE MATERIALS

5.2 Sampling Base Materials During a Soil Survey Investigation

Base and subbase material samples are collected for information and testing during the soil survey investigation per the CDOT Geotechnical Design Manual which supersedes this manual for geotechnical investigations. The purpose of material sampling is to gather information for the design of pavement rehabilitation and/or new pavement structure.

5.6 Reclaimed Asphalt and Concrete Pavement

5.6.1 Reclaimed Asphalt Pavement Base

Recycled asphalt pavement may be used as a granular base or subbase provided it meets gradation and specified in contract documents. Recycled asphalt used as an aggregate base is roto-milled material. The roto-milled consists of recovered, crushed, screened, and blended material with conventional aggregates, and is placed as a conventional granular material. Available studies of recycled asphalt as a base course has shown RAP can exhibit excessive creep when compared to standard aggregate base course which may lead to early or excessive fatigue cracking and/or permanent deformation. Perched or high water tables or areas with poor drainage may allow water to inundate the RAP causing it to prematurely degrade. The potential for excessive creep and early degradation from water infiltration should be considered by the designer prior to submitting a final design. Additionally the design should verify in the field that the product being placed is actual RAP and not a combination of RAP and other deleterious material(s).

CHAPTER 6
PRINCIPLES OF DESIGN FOR FLEXIBLE PAVEMENT

6.4 Select the Appropriate Performance Indicator Criteria for the Project

Table 2.4 Recommended Threshold Values of Performance Criteria for New Construction or Reconstruction Projects presents recommended performance criteria for flexible pavement design. The designer should enter the appropriate performance criteria based on functional class. An appropriate initial smoothness (IRI) is also required, **For new flexible pavements, the recommended initial IRI is 61 inches/mile**.

6.12 Asphalt Materials Selection

Table 6.7 HMA Grading Size and Layer Thickness gives guidance for mix selection and recommended layer thicknesses for various layers and nominal maximum aggregate sizes.

Table 6.1 HMA Grading Size and Layer Thickness

CDOT HMA Grade	Nominal Maximum Aggregate Size (NMAS)	Overlay Layer Thickness (inches)	
		Minimum	Maximum
SX	½ inch	1.50	3.00
S	¾ inch	2.25	3.00
SF	No. 4 sieve	0.75 [1]	1.50
ST	$^{3}/_{8}$ inch	1.125	2.50

Note: [1] Layers of SF mixes may go below 1 inch as needed to taper thin lift to site conditioning (i.e. rut filling).

6.13 Asphalt Mix Design Criteria

6.13.1 Fractured Face Criteria

CDOT's aggregate fractured face criteria requires the aggregate retained on the No. 4 sieve must have at least two mechanically induced fractured faces (2) (see **Table 6.15 Fracture Face Criteria**).

Table 6.2 Fractured Face Criteria

Percent Fractured Faces of 20 Year 18k ESAL in Design Lane	SF	ST	SX	S	SMA
Non-Interstate Highways or Pavements with < 10,000,000 Total 18K ESALs	60%	60%	60%	60%	90%
Interstate Highways or Pavements with > 10,000,000 Total 18K ESALs	70%	70%	70%	70%	90%

CHAPTER 7
PRINCIPLES OF DESIGN FOR RIGID PAVEMENT

7.4 Select the Appropriate Performance Indicator Criteria for the Project

Table 2.6 Recommended Threshold Values of Performance Criteria for New Construction of Rigid Pavement and **Table 2.7 Recommended Threshold Values of Performance Criteria for Rehabilitation of Rigid Pavement Projects** presents recommended performance criteria for a rigid pavement design. The designer should enter the appropriate performance criteria based on functional class. An appropriate initial smoothness (IRI) is also required. **For new rigid pavements, the recommended initial IRI is 72 inches/mile.** This recommendation is for regular paving projects and projects with incentive-based smoothness acceptance; the designer may modify this value as needed.

CHAPTER 9
PRINCIPLES OF DESIGN FOR PAVEMENT REHABILITATION WITH RIGID OVERLAYS

9.1 M-E Introduction

Overlays are used to remedy structural or functional deficiencies of existing flexible or rigid pavements and extend their useful service life. It is important the designer consider the type of deterioration present when determining whether the pavement has a structural or functional deficiency, so an appropriate overlay type and design can be developed.

9.1.1 CDOT Required Procedure for Rigid Overlays

A concrete overlay is the construction of a new PCCP over an existing HMA pavement. It is considered an advantageous rehabilitation alternative for badly deteriorated HMA pavements, especially those that exhibit such distress as rutting, shoving, and alligator cracking (ACPA 1998). The primary concerns with concrete overlays are as follows:

- The thickness design procedure
- Joint spacing
- The use and spacing of dowels and tie bars

In the past, CDOT **did not recommend a thin concrete overlay thickness of less than 5 inches, however there are a few more recent projects that are planning on using 4 inch thick overlays with 4 foot by 4 foot joint spacing. Conventional concrete overlays use a thickness of 8 inches or greater. Ultra-thin concrete overlay, which uses 4 inches or less of PCCP, should be discussed with the RME prior to design.** (see **Table 9.1 Required Concrete Overlay Procedure).**

Table 9.1 Required Concrete Overlay Procedure

Required Thickness	
< 5 inches	Only under the direction of the RME
≥ 5 to < 8 inches	CDOT Thin concrete overlay procedure
≥ 8 inches	AASHTO Overlay design (M-E Design)

CHAPTER 13
PAVEMENT TYPE SELECTION AND LIFE CYCLE COST ANALYSIS

13.4 Discount Rate

All future costs are adjusted according to a discount rate prorated to a present worth. Costs incurred at any time into the future can be combined with initial construction costs to give a total cost over the life cycle. See **Table 13.3 Present Worth Factors for Discount Rates** for a uniform series of deposits, S_n. **The current discount rate is 1.06 percent with a standard deviation 0.562 percent** (6).

The discount rate and standard deviation will be calculated annually. If the new 10-year average discount rate varies by more than two standard deviations from the original discount rate used at the time of the design, in this case 0.54 percent resulting in a discount rate range of 0.0 to 2.18 percent, a new LCCA should be performed. Thus, all projects that have been shelved prior to 2015 and/or not been awarded should rerun the analysis with the new discount rate. The designer is responsible for checking previous pavement designs to ensure an appropriate discount rate was used and the pavement choice is still valid.

The discounting factors are listed in **Table 13.3 Discount Factors for Discrete Compounding** in symbolic and formula form and a brief interpretation of the notation. Normally, it will not be necessary to calculate factors from these formulas. For intermediate values, computing the factors from the formulas may be necessary, or linear interpolation can be used as an approximation.

The single payment present worth P = F(P/F, $i_{\%}$, *n*) notation is interpreted as, "Find P, given F, using an interest rate of $i_{\%}$ over n years". Thus, an annuity is a series of equal payments, A, made over a period of time. In the case of an annuity that starts at the end of the first year and continues for *n* years, the purchase price, P, would be P = A × (P/A, $i_{\%}$, *n*).

Table 13.4 Discount Factors for Discrete Compounding

Factor Name	Converts	Symbol	Formula	Interpretation of Notation
Single Payment Present Worth	F to P (future single payment to present worth)	(P/F, $i_{\%}$, *n*)	$(1+i)^{-n}$	Find P, given F, using an interest rate of $i_{\%}$ over *n* years
Uniform Series Present Worth	A to P (annual payment to present worth)	(P/A, $i_{\%}$, *n*)	$\frac{(1+i)^n-1}{i(1+i)^n}$	Find P, given A, using an interest rate of $i_{\%}$ over *n* years
Note: P = the single payment present worth; F = future single payment; i % = the interest rate percent, and *n* = number of years.				

13.5.2 Asphalt Cement Cost Adjustment (ACCA)

Included in the unit cost of HMA should be an adjustment for the Force Account Item. This item revises the Contactor's bid price of HMA found in the Cost Data book based on the price of crude oil at the time of construction. The data varies from year to year, Region to Region, and by the various binders used by CDOT. The asphalt cement cost adjustment specification was changed in 2020. Normally CDOT uses a 10 year unit cost weighted average, however at this time there are only a limited number of years of data. In 2022 CDOT paid the Contractors an average of $0.07 per ton. Therefore, we recommend a triangular distribution with the minimum value of $0.0, a most likely value of $0.06 and a maximum value of $0.10 per ton of mix.

The processes used to calculate the asphalt cement adjustment consists of collecting yearly unit cost modification data for each year starting January 1 and ending December 31. The data is sorted and vetted by removing any emergency repair work and anomalous data. Anomalous data consists of an invoice which is missing either tonnage or cost modification (force account) information. Once the data is vetted the total cost modification amount is divided by the total tonnage resulting in the average price per ton cost modification paid out for that year. This number, in addition to the total tons and total cost modification amount is added to the ten year running weighted average. The minimum value is selected from the year which had the least amount of unit cost modification, in this case 2020 CDOT paid $0.00 per ton. Similarly, the maximum value is selected from the year which had the most amount of unit cost modification, in this case 2021 CDOT paid $0.10. The most likely value is the 10 year weighted average (currently only have 3 years of data) in which the total unit cost modification is divided by the total tons.

13.5.3 Maintenance Cost

The designer should exercise good judgment in the application of maintenance costs. Inappropriate selection can adversely influence the selection of alternatives to be constructed. Maintenance costs should be based on the best available information. The CDOT Maintenance Management System compiled data on state highway maintenance costs. The data is sorted and vetted by removing any non-work items such as training and equipment cleaning as well as anomalous data. An example of anomalous data is a Maintenance Work Order missing Route or work description information. The annual maintenance cost per lane mile is shown in **Table 13.5 Annual Maintenance Costs**. This data was collected from January 1, 2018 to December 31, 2022 and divided by the number of lane miles maintained for each pavement type. If actual cost cannot be provided, use the following default values:

Table 13.5 Annual Maintenance Costs

Type of Pavement	Average Annual Cost Per Lane Mile	Lane Miles Surveyed
HMA	$979	19,854
PCCP	$447	3,080

13.5.4 Design Cost

The expected Preliminary Engineering (PE) costs for designing a new or rehabilitated pavement including materials, site investigation, traffic analysis, pavement design, and preparing plans with specifications shall be 10 percent.

13.5.5 Pavement Construction Engineering Costs

Included in the pavement construction cost should be the Cost of Engineering (CE).

13.5.6 Traffic Control Costs

Traffic control costs are the costs to place and maintain signs, signals, markings and devices placed on the roadway to regulate, warn, or guide traffic. Traffic control costs shall be 15 percent.

13.5.7 Serviceable Life

The serviceable life represents the value of an investment alternative at the end of the analysis period. The method CDOT uses to account for serviceable life is prorated based on the cost of the final rehabilitation activity, design life of the rehabilitation strategy, and the time since the last rehabilitation. For example, over a 40-year analysis, Alternative A requires a 10-year design life rehabilitation to be placed at year 31. In this case, Alternative A will have 1 year of serviceable life remaining at the end of the analysis (40-31=9 years of design life consumed and 10-9=1 year of serviceable life). The serviceable life is 1/10 of the rehabilitation cost, as shown in equation **Eq. 13.1**.

The Real Cost program performs this calculation internally and will return the same numerical value as **Eq. 13.1** if the "Include Agency Cost Remaining Service Life Value" and "Include User Cost Remaining Service Life Value" boxes are checked. See section 13.X.X for more information on how serviceable life should be accounted for.

$$SL = (1 - (L_A/L_E)) * C \qquad \textbf{Eq. 13.1}$$

Where:

SL = serviceable life
L_A = the portion of the design life consumed
L_E = the design life of the rehabilitation
C = the cost of the rehabilitation

13.7.4 Analysis Options

Generally, analysis options are decided by agency policy rather than the pavement designer. Options defined in the Analysis Options form include the analysis period, discount rate, beginning year, inclusion of residual service life, and the treatment of user costs in the LCCA. The data inputs and analysis options available on this form are discussed in **Table 13.7 Analysis Data Inputs and Analysis Options**, with CDOT and FHWA's recommendations. A checked box equals *"Yes,"* and unchecked box equals *"No"*.

Table 13.7 Analysis Data Inputs and Analysis Options

Variable Name	Probability Distribution (CDOT Default)	Value (CDOT Default)	Source
Analysis Units	Select option	English	CDOT
Analysis Period (Years)	User specified	40	**Sections 13.3.1, 13.3.2,** and **13.3.3**
Discount Rate (%)	Log normal	Mean = 1.06% Standard deviation = 0.562	**Section 13.4** T-bill, inflation rate, and 10-year moving average
Beginning of Analysis Period	User specified	Date (year)	Project start date
Included Agency Cost Remaining Service Life Value	Select option	Yes	**Section 13.5** (serviceable life)
Include User Costs in Analysis	Select option	Yes	**Section 13.5.7**
User Cost Computation Method	Select option (specified/calculated)	Specified	**Section 13.5.7** Use user costs from CDOT WorkZone software*
Traffic Direction	Select option (both/inbound/outbound)	Both	Site specific
Include User Cost RSL	Select option	Yes	**Section 13.5.7**

Note: * When *"Specified"* is selected, the manual calculated user cost from the WorkZone program will be used in the RealCost program.

13.7.5 Traffic Data Options

Pavement engineers use traffic data to determine their design parameters, **Table 13.7 Traffic Data Options**. In RealCost traffic traffic data is used exclusively to calculate WorkZone.

Table 13.7 Traffic Data Options

Variable Name	Probability Distribution (CDOT Default)	Value (CDOT Default)	Source
AADT at Beginning of Analysis Period (total for both directions)	Deterministic	Project-specific data from OTIS	**Section 3.1.3**
Single Unit Trucks as Percentage of AADT (%)	Deterministic	Project-specific data from OTIS	**Section 3.1.3**
Combination Trucks as Percentage of AADT (%)	Deterministic	Project-specific data from OTIS	**Section 3.1.3**
Annual Growth Rate of Traffic (%)	Deterministic	Project-specific data from OTIS	**Section 3.1.3**
Speed Limit Under Normal Operating Conditions (mph)	Deterministic	User input	Project-specific
Lanes Open in Each Direction Under Normal Conditions	Deterministic	User input	Project-specific
Free Flow Capacity (vphpl)	Deterministic	User input	CDOT WorkZone software (normal capacity per lane)
Queue Dissipation Capacity (vphpl)	Deterministic	User input	CDOT WorkZone software (work zone capacity per lane)
Maximum AADT (total for both directions)	Deterministic	User input	Project-specific
Maximum Queue Length (miles)	Deterministic	5 miles	CDOT
Rural or Urban Hourly Traffic Distribution	Select option (urban/rural)	User input	CDOT WorkZone software (functional class)

Table 13.23 Alternative Level Data Options

Variable Name	Probability Distribution (CDOT Default)	HMA Value (CDOT Default)	PCC Value (CDOT Default)	Source
Alternative Description	User input	User input	User input	Site specific
Activity Description	User input	User input	User input	Site specific
Agency Construction Cost ($1,000)	Triangular	User input	User input	**Figure 13.26** to **Figure 13.69** or site specific
Activity Service Life (years)	Triangular	User input	User input	**Section 13.2.3** or **Section 13.3**
User Work Zone Costs ($1,000)	Deterministic	User input	User input	CDOT Work Zone software **Section 13.5.7**
Maintenance Frequency (years)	Deterministic	1 year	1 year	CDOT[1]
Agency Maintenance Cost ($1,000)	Deterministic	$979/lane mile[1]	$ 447/lane mile[1]	CDOT[1]
Work Zone Length (miles)	Deterministic	User input	User input	Site specific
Work Zone Capacity (vphpl)	Deterministic	User input	User input	CDOT Work Zone software **Section 13.5.7**
No of Lanes Open in Each Direction During Work Zone	Deterministic	User input	User input	Site specific
Work Zone Duration (days)	Deterministic	User input	User input	CDOT Work Zone software **Section 13.5.7**
Work Zone Speed Limit (mph)	User input	User input	User input	Site specific

Note:
[1] Use site specific or latest data. Recalculate yearly cost to account for the number of lanes and project length.

APPENDIX E
PAVEMENT TREATMENT GUIDE FOR HIGHWAY CATEGORIES

E.2 Definitions

E.2.2 Treatment Categories

- **Major Rehabilitation:** Pavement treatments that improve the structural life to the highway. These are asphalt pavement treatments typically 4 inches or thicker, and may include, but are not limited to, 4 inches or thicker asphalt overlays, full depth reclamation, recycling treatments with a 4 inch or thicker overlay, and 5 inch or thicker concrete overlays on asphalt. Concrete pavement treatments in this category may include, but are not limited to, 4 inch or thicker asphalt overlays of concrete, slab replacements exceeding 10%, and rubblization with subsequent treatment.

- **Minor Rehabilitation**: Pavement treatments that improve the structural life to the highway. These are asphalt pavement treatments between 2 and 4 inches thick, and may include mill and fills, recycling treatments with an overlay less than 4 inches thick, overlays, and leveling courses with overlays. Concrete pavement treatments in this category may include asphalt overlays (thinner than 4 inches), slab replacements between 1.6% and 10% with diamond grinding or dowel and tie bar repairs.

- **Pavement Maintenance**: Thin functional treatments less than 2 inches in thickness, intended to extend the life of the highway by maintaining the driving surface. Additional treatments in this category include diamond grinding, retexturing, slab replacements less than 1.6%, crack seals, and sawing and sealing of joints.

APPENDIX I
GEOSYNTHETICS IN M-E DESIGN

Definitions

Zone of Influence

The zone of influence is the depth of increased structural strength in the soil layer. The zone of influence for geogrids used in CDOT designs is 6 inches.