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, and material related inputs.

2.2 Site and Project Identification

Site/project location information is used to identify the project under design. This input has no bearing on design but is very helpful in documenting a design for review and record keeping. The M-E Design software provides the ability to enter site or project identification information such as the location of the project, jurisdiction, identification numbers, beginning and ending milepost, direction of traffic, date created, and date approved.

2.3 Project Files/Records Collection and Review

2.3.1 Project Data Collection

Information gathered should include such items as "As Built" plans from previous projects, pavement design data, materials and soil properties, climate conditions, determination of traffic inputs, and any information relevant to major maintenance.

2.3.2 Field Survey

A pavement evaluation should be conducted to determine the cause of the pavement deterioration. Information gathered in this survey includes review items such as distress, drainage conditions, roughness, traffic control options, safety considerations, any other overall project conditions, and assessments including an estimate of remaining service life. For new alignments, the soil survey investigation records are reviewed.

2.3.3 Initial Selection

Preliminary alternate designs are developed to repair the existing distress and prevent future problems. Based on an evaluation of various candidate alternatives, the first cuts are made at this time, as is a determination if additional data is needed.

2.3.4 Physical Testing

Testing includes collection of additional information such as coring, deflection testing, resilient modulus, permeability, moisture content, etc.

2.3.5 Evaluation and Selection

The selection of new construction and rehabilitation techniques includes identifying the various constraints associated with the project, such as:

- Funding (first cost consideration)
- Traffic control
- Design period
- Geometric problems
- Right of way
- Utilities
- Vertical clearance problems (i.e. overhead clearance)

2.3.6 Historic M-E Design Software Files

Pavement design/analysis projects created in M-E Design software are saved as .dgpx files. After a design/analysis run has been successfully completed, the application will generate a pdf file and Microsoft Excel spreadsheet containing input summary and output results of the trial design. There are several project or CDOT specific input files for traffic, climate, and material characterization associated with the pavement design/analysis projects.

The M-E Design software includes a database option that facilitate enterprise level data management for archiving and searching projects, comparing inputs of any two projects, and creating input data libraries. Each object (i.e. any discrete item such as pavement material layer data, axle load distribution factors, climate and design features, or the project itself) has a unique informational tag called identifiers. The designers can use identifiers to identify, search, filter, save, and retrieve information in a database environment.

The designer should review the data files available with the software system and the database. Project records including the project files, input files, calibration factors, and the output records should be stored in the appropriate data storage systems specified by CDOT. For reasons of software update and input changes, the designer should keep track of the software version, project time stamps, and input modifications using the identifiers of M-E Design software objects.

2.3.7 Records Review

Review of historic and current project files and/or records is an important aspect of pavement design/analysis. A review of these records may reveal key details of interest and significance to the pavement designer. Reviewing the project files and/or records will be the most beneficial to the pavement designer who has not been with the project since its original construction. In reviewing the project files and/or records, the pavement designer should be on the alert for any information relating to pavement design and construction. The Regions should keep copies of the information in the original report for 5 to 8 years.

Records review typically comprises of the following activities:

- Review construction and maintenance files.
- Review previous distress surveys and pavement management records. If possible, establish performance trends and deterioration rates.
- Review previous Falling Weight Deflectometer (FWD) deflection test data.
- Review previous pavement borings and laboratory test results of pavement materials and subgrade soils.
- For existing pavements, perform a windshield survey or an initial surveillance of the roadway's surface, drainage features, and other related items.
- Identify roadway segments with similar or different surface and subsurface features. As much as possible, isolate each unique factor that will influence pavement performance.
- Identify the field testing/material sampling requirements for each segment and the associated traffic control requirements.
- Determine if the pavement performed better or worse than similar designs.

The information gathered in records review can be used to divide a new alignment or existing pavement into units with similar site conditions. Existing pavements may be further divided into units with similar design features and performance characteristics.

2.4 Site Investigation

It may be advantageous to visit the proposed project site a few times during the development of a pavement or rehabilitation design. The pavement designer may find it desirable to make a brief visit to the project site as the first step in the scoping process. As the investigation proceeds, events may develop which will make it desirable to revisit the project site. The following are some of the items that should be determined during visits to the project site.

2.4.1 Abutting Land Usage

The abutting land usage will have an effect on the selection of a pavement type or rehabilitation design procedure. If the abutting land is rural, then a note should be made of its use such as farming, ranching, or other with descriptive details as needed. If the property is urban, a record of usage in terms of residential or commercial is helpful. Additional details on type of residences or commercial usage are also helpful.

2.4.2 Existing/Proposed Project Geometrics

Notes should be made as to the type and typical section including the vertical and horizontal alignment characteristics. Data concerning the typical section should indicate the average and maximum 'cut and fill' heights and extent over the project. Items such as the number of travel lanes, shoulders, type and extent of curb and gutter, and vertical clearances at structures should be recorded.

2.3.4 Geotechnical Investigations

Geotechnical investigations are performed to determine the subgrade soil properties needed for pavement structural design considerations and if subgrade stabilization/modification is needed. While pavement design is based on the response of the soil to short-term loads, long-term soil response may dramatically affect the roadway. For example, roadways constructed over soft soils may experience long-term settlements. Important subgrade parameters obtained through a geotechnical investigation not limited to the soil classification include the following: Atterberg limits, sulfate content, stabilization requirements, test for expansive soils, and other design considerations. Geotechnical investigations are typically required for new construction and reconstruction projects. Contact the Regional Materials Engineer or CDOT Materials and Geotechnical Branch to request a geotechnical investigation. See **Section 4.2 Soil Survey Investigation** of this manual for more information, as well as, Chapter 200 of the *Field Materials Manual*.

2.4.4 Condition Survey

Pavement condition is a key input required for the determination of feasible rehabilitation alternatives. The CDOT Pavement Management System (PMS) provides network-level pavement condition data for use in the preliminary evaluation of the project. If there is no PMS data for a roadway section of interest, one should conduct a manual distress survey of the project to assess the pavement condition and establish the causes of distresses/failure.

2.4.5 Drainage Characteristics

Drainage characteristics should be noted during the visit to the project. Items such as the general terrain drainage, existing pavement drainage, and bridge drainage structures need to be noted. The number of bridges, how the existing pavement terminates at the bridge ends, and if the bridges have bridge approach slabs is important to note. The condition of the bridge end/approach slab and the approach slab/pavement interface conditions are of special interest when concrete pavement exists.

Distresses can be related to particular moisture properties of the materials in the pavement. If the existence of these properties is not recognized and corrected where possible, the rehabilitation work will be wasted by allowing the same type of moisture-related distress to reoccur. The recognition of the amount, severity, and cause of moisture damage also plays an important role in the selection of the rehabilitation scheme to be utilized on the pavement. This information will help in the structural evaluation of the pavement.

Moisture-related distresses develop from external and internal factors that influence the moisture condition in a pavement. An example of external factors are the climatic factors in an area that regulate the supply of moisture to the pavement. Internal factors are pavement material properties whose interaction with moisture influences pavement performance.

The recognition of each distress and the mechanism causing that distress are necessary if the correct rehabilitation procedures are to be selected. Each distress type that develops within a

pavement will be load, environment-related, or a combination of the two. Moisture will serve to accelerate this deterioration when it is environment-related. Moisture problems must be recognized and corrected to prevent future deterioration.

The fact that moisture problems may appear in any layer emphasizes the necessity of having a logical procedure for examining the pavement in order to determine the cause of the problem. Non-Destructive Testing (NDT) will indicate the overall structural level of the pavement. However, NDT alone cannot identify which component of the pavement is responsible for the strength loss. Distress analysis must be utilized in conjunction with the NDT analysis to identify potential moisture-related problems. If the subgrade has moisture problems that caused the distress, it may do no good to overlay, recycle, rework the pavement, or stabilize the base without also addressing the subgrade. If the base or subbase has moisture problems one may need to rework or stabilize the base and/or rework the drainage of the granular layer. **Table 2.1 Moisture-Related Distress in Flexible Pavements** and **Table 2.2 Moisture Related Distress in Rigid Pavements** contains a breakdown of the more common moisture-related distresses for flexible and rigid pavements.

2.5 Construction and Maintenance Experience

On any given project, there are always construction and maintenance experiences with pavement structures that were never entered into the permanent records relating to the project. Usually, it was not realized that information such as this would be useful in the future. The Program Engineers, Resident Engineers, Project Engineers, Construction Inspectors, and other personnel involved with the project may have useful information if interviewed. The Region Maintenance Superintendent and other maintenance personnel may have pavement performance data that do not appear elsewhere in the records. Frequently, maintenance forces have repaired substantial sections of the project and this information is not always readily available in the records.

2.6 Pavement Management System (PMS) Condition Data

The PMS provides network-level pavement condition information for planning and programming purposes. PMS data are used to help select reconstruction, rehabilitation, preventive maintenance projects, and evaluate performance trends. It also provides pavement condition information useful for performing a preliminary evaluation of a project.

For M-E Design, site-specific or project-specific past performance data is used to characterize the existing pavement's condition for use in rehabilitation design. The specifics of how PMS condition data is used is presented in **Chapter 8 Principles of Design for Pavement Rehabilitation with Flexible Overlays** and **Chapter 9 Principles of Design for Pavement Rehabilitation with Rigid Overlays** for rehabilitation designs using flexible and rigid overlays.

CDOT collects and reports pavement performance data on a tenth mile basis, in only one direction of all two-lane highways. CDOT PMS data of relevance to the M-E Design are the following:

- International Roughness Index (IRI)
- Rutting
- Faulting
- Cracking distress

For more information about PMS data, contact the PMS unit or the Region Pavement Manager.

Table 2.1 Moisture-Related Distress in Flexible Pavements

Type	Distress Manifestation	Moisture Problem	Climatic Problem	Materials Problem	Load Associated	Structural Defect Begins In		
						Asphalt	Base	Subgrade
Surface Defect	Bleeding	No	Accentuated by high temp	Bitumen	No	Yes	No	No
	Raveling	No	No	Aggregate	Slightly	Yes	No	No
	Weathering	No	Humidity and light dried bitumen	Bitumen	No	Yes	No	No
Surface Deformation	Bump or Distortion	Excess moisture	Frost Heave	Strength moisture	Yes	No	Yes	Yes
	Corrugation or Rippling	Slight	Climatic and suction relations	Unstable mix	Yes	Yes	Yes	Yes
	Shoving	No	-	Unstable mix loss of bond	Yes	Yes	No	No
	Rutting	Excess in granular layers	Suction and materials	Compaction properties	Yes	Yes	Yes	Yes
	Depression	Excess	Suction and materials	Settlement fill material	Yes	No	No	Yes
	Potholes	Excess	Frost heave	Strength moisture	Yes	No	Yes	Yes
Cracking	Longitudinal	Yes	Spring thaw strength loss	-	Yes	Faulty construction	Yes	Yes
	Alligator	Yes drainage	-	Possible mix problems	Yes	Yes, Mix	Yes	Yes
	Transverse	Yes	Low-temp. freeze thaw cycles	Thermal properties	No	Yes temperature susceptible	Yes	Yes

Table 2.2 Moisture-Related Distress in Rigid Pavements

Type	Distress Manifestation	Moisture Problem	Climatic Problem	Materials Problem	Load Associated	Structural Defect Begins In		
						Asphalt	Base	Subgrade
Surface Defect	Spalling	Possible	No	-	No	Yes	No	No
	Crazing	No	No	Rich mortar	No	Yes weak surface	No	No
Surface Deformation	Blow-up	No	Temp.	Thermal properties	No	Yes	No	No
	Pumping	Yes	Moisture	Fines in base moisture sensitive	Yes	No	Yes	Yes
	Faulting	Yes	Moisture suction	Settlement deformation	Yes	No	Yes	Yes
	Curling	Possible	Moisture and temp.	-	No	Yes	No	No
Cracking	Corner	Yes	Yes	Follows pumping	Yes	No	Yes	Yes
	Diagonal Transverse Longitudinal	Yes	Possible	Cracking follows moisture build-up	Yes	No	Yes	Yes
	Punch-out	Yes	Yes	Deformation following cracking	Yes	No	Yes	Yes
	Joint	Produces damage later	Possible	Proper filler and clean joints	No	Joint	No	No

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 the 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 uncertainty and variability that is expected to exist in pavement design and construction, as well as, in 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 functional classification of the roadway 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 <u>shall</u> occur**.

Recommended Range for Reliability

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 recommended values for the pavement structure 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.

Table 2.3 Reliability (Risk)

Functional Classification	Value for Reliability
Interstate	80-95
Principal Arterials (freeways and expressways)	75-95
Principal Arterials (other)	75-95
Minor Arterial	70-95
Major Collectors	70-90
Minor Collectors	50-90
Local	50-80

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. **It is recommended to use an initial IRI value of 50 inches/mile for all HMA projects and 75 inches/mile for all PCC projects** as they reflect targets that are documented using smoothness data from flexible and rigid pavements constructed between 2005 and 2013. **It is recommended the same reliability value be used for all distresses; any changes should have Region Materials and Staff Materials approval.**

Figure 2.1 Performance Criteria and Reliability in the M-E Design Software for a Sample Flexible Pavement Design presents the M-E Design software screenshot showing performance criteria and the corresponding design reliability values selected for the design/analysis of a sample flexible pavement design.

Figure 2.2 Performance Criteria and Reliability in the M-E Design Software for a Sample JCPC Design presents the M-E Design software screenshot showing performance criteria and the corresponding design reliability values selected for the design/analysis of a sample rigid pavement design.

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

Flexible Pavement		
Performance Criteria	**Maximum Value at End of the Design Life**	**Determines the Years to First Rehabilitation (Minimum Age Shall be 12 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 – 25 Minor Arterial – 25 Major Collector – 25 Minor Collector – 25* Local Roadway – 25*	
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 – 0.55 Principal Arterial – 0.65 Minor Arterial – 0.80 Major Collector – 0.80 Minor Collector – 0.80* Local Roadway – 080*
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 2.5 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 – 25 Minor Arterial – 25 Major Collector – 25 Minor Collector – 25* Local Roadway – 25*
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 – 0.55 Principal Arterial – 0.65 Minor Arterial – 0.80 Major Collector – 0.80 Minor Collector – 0.80* Local Roadway – 0.80*
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 (feet per mile)	Interstate – 20 Principal Arterial – 35 Minor Arterial – 35 Major Collector – 35 Minor Collector – 35* Local Roadway – 35*
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 2.6 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**	**Determines the Year to First Rehabilitation (Minimum Age Shall Be 27 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 – 7.0 Principal Arterial – 7.0 Minor Arterial – 7.0 Major Collector – 7.0 Minor Collector – 7.0* Local Roadway – 7.0*
Mean Joint Faulting (inches)	Interstate – 0.12 Principal Arterial – 0.14 Minor Arterial – 0.20 Major Collector – 0.20 Minor Collector – 0.20* Local Roadway – 0.20*	
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 2.7 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 – 7.0 Principal Arterial – 7.0 Minor Arterial – 7.0 Major Collector – 7.0 Minor Collector – 7.0* Local Roadway – 7.0*
Mean Joint Faulting (inches)	Interstate – 0.12 Principal Arterial – 0.14 Minor Arterial – 0.20 Major Collector – 0.20 Minor Collector – 0.20* Local Roadway – 0.20*
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.	

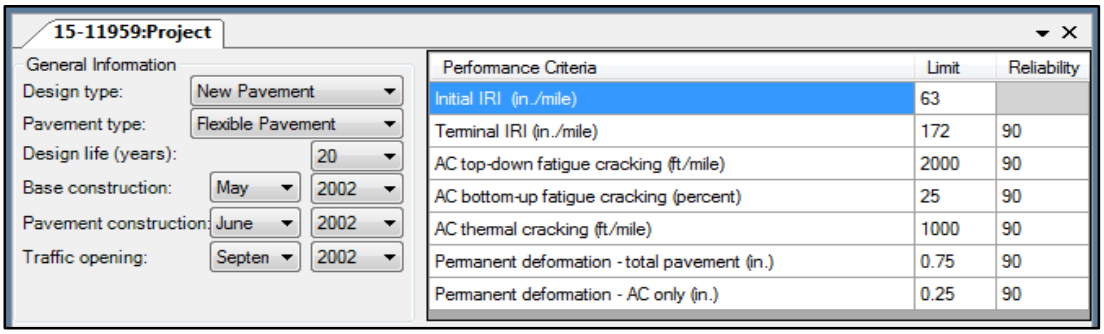

Figure 2.1 Performance Criteria and Reliability in the M-E Design Software for a Sample Flexible Pavement Design

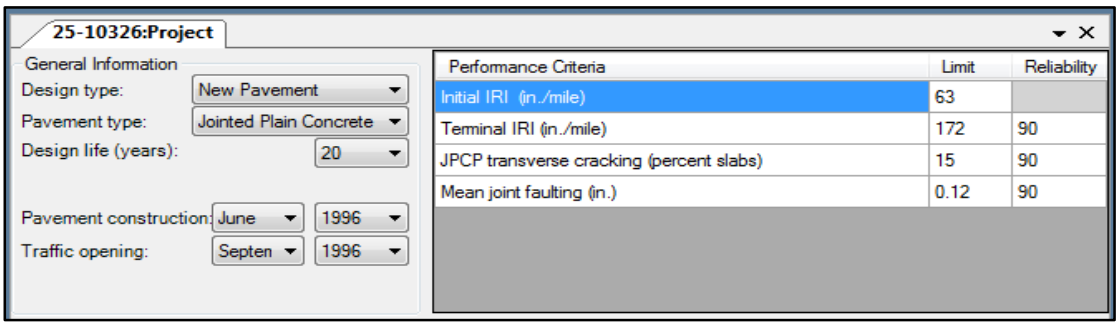

Figure 2.2 Performance Criteria and Reliability in the M-E Design Software for a Sample JPCP Design

The appropriate functional classification for a certain roadway can be determined from the information on 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* and **APPENDIX B: FORMS** of this 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 75 to 95 percent. This is a high profile road, so the reliability is set at 95 percent.

CDOT has a map available designating highway functional classifications, see **Figure 2.3 Functional Classification Map**. The map may be downloaded from the following website: http://alphainternal.dot.state.co.us/App_DTD_DataAccess/Downloads/StatewideMaps/func_class_pdf.pdf

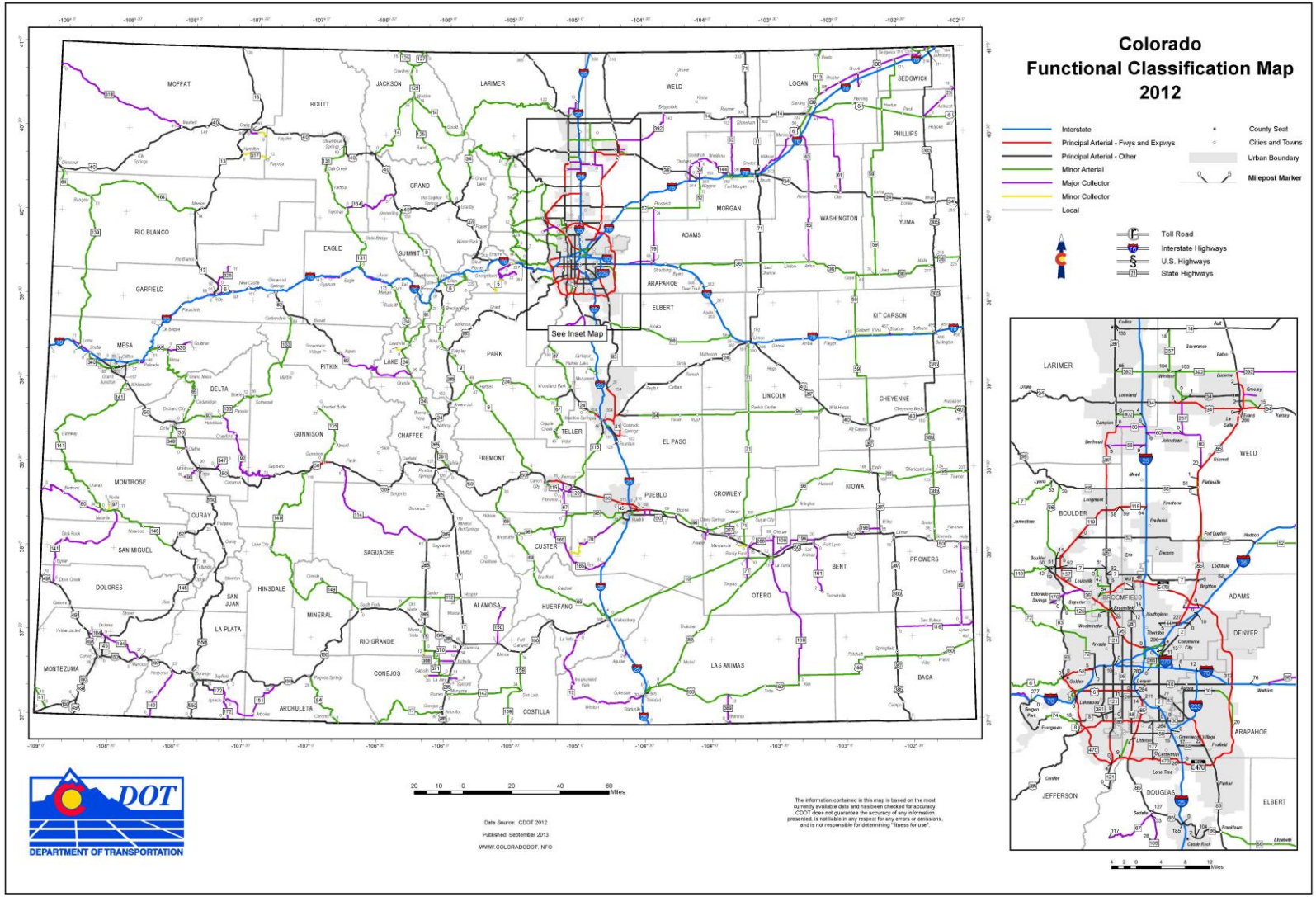

Figure 2.3 Function Classification Map

2.8 Defining Input Hierarchy

M-E Design employs a hierarchical approach to input parameters with regard to traffic, material, and condition of existing pavement. This approach provides the designer with a lot of flexibility in obtaining the design inputs for a project based on the criticality of the project and available resources.

For many of the design inputs, M-E Design allows the designer to select any of three levels of inputs:

- **Level 1:** Project-specific or site-specific inputs are obtained from direct testing or measurements. Obtaining Level 1 inputs requires more resources and time than other levels. Level 1 input would typically be used for designing heavily trafficked pavements or wherever there is dire safety or economic consequences of early failure. Examples include measuring dynamic modulus of hot mix asphalt (HMA) using laboratory testing, measuring PCC elastic moduli using laboratory testing, or using on-site measured traffic classification data.

- **Level 2:** Inputs are estimated from correlations or regression equations derived from a limited testing program or obtained from the agency database. This level could be used when resources or testing equipment are not available for tests required for Level 1. Examples include estimating resilient modulus of unbound materials and subgrade from R-values, estimating PCC elastic moduli from compressive strength tests, or using traffic classification data based on the functional class of the roadway.

- **Level 3:** Inputs are based on "best-estimated" or typical values for the local region. This level might be used for design where there are minimal consequences of early failure (i.e. lower volume roads). Examples include using default resilient modulus values for unbound materials, estimating PCC elastic moduli from 28-day compressive or flexural strength tests, or using default traffic classification data.

The designer can also select a mix of input levels for a given project. For instance, the designer can select the HMA creep compliance at Level 1, subgrade resilient modulus at Level 2, and traffic load spectra at Level 3 for analyzing a flexible pavement trial design. The computational algorithms, procedures, and performance models for predicting distress and smoothness are exactly the same irrespective of the input level used in the design; however, the accuracy of the inputs as defined by the input level may affect the accuracy of performance prediction results.

The input hierarchy provides a powerful tool to show the advantages of good engineering design (using Level 1 inputs) in improving the reliability of the design, and the possibility to reduce pavement construction and rehabilitation costs. It is recommended the designer obtain the inputs that are appropriate and practical for the magnitude of the project under design. Larger, more significant projects require more accurate design inputs.

The selection of the hierarchical level for a specific input depends on several factors, including:

- Sensitivity of the pavement performance to a given input
- The criticality of the project
- The information available at the time of design
- The resources and time available to the designer to obtain the inputs

The designer should consider the above mentioned factors and select a predominant level of input hierarchy based on the recommendations presented in **Table 2.8 Selection of Input Hierarchical Level. Note:** The term "Predominant input hierarchy" implies the designer should, as much as possible, provide inputs at the selected input level.

Table 2.8 Selection of Input Hierarchial Level

Criticality/Sensitivity of Design	Description	Predominant Input Hierarchy
Very Critical	High volume interstates, urban freeways, and expressways	Level 1
Critical	Principal arterials, rural interstates, heavy haul (i.e. mining, logging routes)	Level 1 or Level 2
Some What Critical	Minor arterial and collectors	Level 2 or Level 3
Not Critical	Local roads	Level 3

2.9 Drainage

Water is a fundamental variable in most problems associated with pavement performance and is directly or indirectly responsible for many of the distresses found in pavement systems. A well-drained pavement section is required to maintain the strength coefficients assigned to individual components of a hot mix asphalt pavement section. Edge drains, cross drains, and drainage layers all must tie into a collection system or some other means to carry collected water away from intersections and the pavement section. Installing drainage systems that collect and impound water rather than diverting it away from the pavement section should never be allowed.

The M-E Design procedure does not consider the effects of drainage directly in pavement design/analysis methodology. Drainage effects are considered indirectly through seasonal adjustments of unbound material, subgrade moisture, and related impacts on the strength/modulus.

As good drainage is a prerequisite to any good design, designers must always consider strategies for combating the effects of water in a pavement system such as:

- Preventing water from entering the pavement
- Providing drainage to remove excess water quickly
- Building the pavement strong enough to resist the combined effect of load and water

It is preferable to exclude water from the pavement and provide for rapid drainage. The cost of improving the drainage should be compared to the cost of building a stronger pavement. It is more likely drainage improvements will outperform a stronger pavement. To obtain adequate pavement drainage, the designer should consider providing three types of drainage systems that may include surface, groundwater, and structural drainage.

It is important to understand the roadway geometry, particularly the drainage gradients in the roadway prism, when selecting the type of base. As long as the base will be able to carry drainage away from the pavement structure, a gravel base will perform adequately. It is also important to note that these values apply only to the effects of drainage on untreated base and subbase layers.

2.9.1 Subdrainage Design

Subdrainage is an important consideration in new construction or reconstruction and in the resurfacing, restoration, and rehabilitation of pavement systems. Detailed procedures for pavement subsurface design are provided in several publications, including:

- *CDOT Drainage Design Manual*
- *Guidelines for the Design of Highway Internal Drainage System*, AASHTO 1986 Guide's Appendix AA
- FHWA's DRIP software
- *MEPDG 2004 Design Documents Part 3*, Chapter 1

If necessary, the pavement designer should coordinate with the respective Region Hydraulics Engineer and/or Staff Hydraulics Engineer where a pavement drainage problem is anticipated. The pavement designer may consult the references provided above.

References

1. *AASHTO Mechanistic-Empirical Pavement Design Guide, A Manual of Practice, Interim Edition, July 2008*, American Association of State Highway and Transportation Officials, Washington, DC, 2008.

2. DRIP 2.0 Software Program < http://isddc.dot.gov/OLPFiles/FHWA/010942.pdf >