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**Database Support for the  
Mechanistic-Empirical Pavement Design  
Guide (MEPDG)**

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**Database Support for the Mechanistic-Empirical Pavement Design Guide (MEPDG)**

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## **TRC-0702**

### **Database Support for the New Mechanistic-Empirical Pavement Design Guide**

#### **(MEPDG)**

The Mechanistic Empirical Pavement Design Guide (MEPDG) developed under the NCHRP 1-37A initiative is a significant advancement in pavement design. However, it is substantially more complex than the 1993 AASHTO Design Guide and it requires significantly more inputs from designers. Some of the required data are either not available or are stored in locations not familiar to designers. In addition, many data sets need to be pre-processed before their use in the MEPDG procedure, such as Weigh-In-Motion (WIM) traffic data. Currently there is no satisfactory software available to accomplish these challenges. Therefore there was a need to study the MEPDG data requirements and produce a centralized database system to aid designers. This report describes the development of a comprehensive database to store and process climate, traffic, material, and performance data for the state of Arkansas. The tasks undertaken were to: (1) identify all the required inputs and analysis parameters, (2) develop algorithms and procedures to locate the available data sets, pre-process raw data, check data quality, and import the traffic and other data sets to the designed database tables, (3) implement database algorithms for uploading, data checking, and generating the require data files for the MEPDG software, and (4) develop a user friendly software interface, PrepME, to generate the required input files for the MEPDG software. The PrepME software will assist all data preparation and improve the management and workflow of the MEPDG input data and be a critical tool for calibrating and implementing the MEPDG.

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## CHAPTER 1 INTRODUCTION

### 1.1 Pavement Design Approaches

The empirical based and the mechanistic-empirical based pavement structural design approaches are the two principal methods widely studied and used in the United States today (1 and 2).

#### 1.1.1 Empirical Method

An empirical approach is based on the results of experiments or engineering experience. This approach requires a number of observations in order to obtain the relationships between input variables and outcomes. During the development of the empirical model, it is not necessary to firmly establish the scientific basis for the model. However, the empirically derived relationships can only be used within the range of the original conditions when the model was developed.

Many pavement design procedures adopt an empirical approach. The relationships among design inputs, such as loads, materials, layer configurations and environment, and pavement failure were obtained through engineering experience, experimental observations, or a combination of both. Empirical design methods can be extremely simple or quite complex. The simplest pavement structural design approaches can be based on the past engineering experience only. For example, some local highway agencies may often design city streets with their preferable pavement structures: 4 inches of Hot Mixture Asphalt (HMA) surface course over 6 inches of crushed stone

base. The reason of this preference is because these structures have produced adequate pavements in the past. More complex pavement design approaches can be based on empirical equations derived from a well designed pilot road and a comprehensive testing scheme, such as the *AASHTO Guide for Design of Pavement Structures* (refer to as the AASHTO Guide) (1).

The AASHTO Guide is the primary document used to design new and rehabilitated highway pavements in the United States today. All versions of the AASHTO design guide are based on empirical models drawn from field performance data measured at the AASHO road test in the late 1950s along with some theoretical support for layer coefficients and drainage factors. The overall serviceability of the pavement is quantified by the Present Serviceability Index (PSI), a composite performance measure combining cracking, patching, rutting, and other distresses. Roughness is the dominant factor governing PSI and is therefore the principal component of performance under this measure. The various versions of the AASHTO guide have served well for several decades. However, the low traffic volumes, antiquated vehicle characteristics, short test duration, limited material types and climate conditions, and other deficiencies of the original AASHO road test challenge the continued use of the AASHTO design guide as the primary pavement design procedure in the United States. These limitations are identified and summarized in the NCHRP 1-37A report (2).

### *1.1.2 Mechanistic-Empirical Method*

A mechanistic approach seeks to explain phenomena or responses only by reference to physical causes. In pavement design, the responses can be the stresses, strains and deflections within a pavement structure, and the physical causes are the loads (both environmental and traffic) and material properties of the pavement structure. The relationships among these phenomena and their physical causes are typically described using mathematical models. Various models are used in pavement design, among which the layered elastic theory is the most commonly used.

Along with this mechanistic approach, empirical models are used when defining the relationships among the calculated stresses, strains and deflections, and pavement failure. As a result, the number of loading cycles to failure can be derived. This kind of approach is called a mechanistic empirical based design method. There are many advantages of a mechanistic-empirical pavement design method over a purely empirical one (2):

- It can be used for both existing pavement rehabilitation and new pavement construction,
- It accommodates changing of load types,
- It can better characterize materials allowing for:
  - Better utilization of available materials,
  - Accommodation of new materials,
  - An improved definition of existing layer properties.
- It uses material properties that relate better to actual pavement performance,
- It provides more reliable performance predictions,
- It better defines the role of construction,

- It accommodates environmental and aging effects on materials,
- It has the ability to accurately characterize in situ material (including subgrade and existing pavement structures) for a more realistic design for the given conditions, by using a portable device (such as a FWD) to make actual field deflection measurements on a pavement structure and to determine existing pavement structural support and the approximate remaining pavement life.

Some typical mechanistic-empirical based design approaches include the 2002 *AASHTO Mechanistic-Empirical Design Guide (MEPDG)* (2), the Washington State Department of Transportation (*WSDOT Pavement Guide*) (3), and the MnPAVE computer program adopted in Minnesota Department of Transportation (MN/DOT) (4).

### *1.1.3 The Mechanistic-Empirical Pavement Design Guide (MEPDG)*

The deficiencies of the empirical design approach were the motivation for the mechanistic-empirical methodology developed in NCHRP Project 1-37A (2). Structural responses (i.e., stresses, strains, and deflections) are mechanistically calculated using multilayer elastic theory or finite element methods on the basis of material properties, environmental conditions, and loading characteristics. Thermal and moisture distributions are mechanistically determined using the Enhanced Integrated Climate Model (EICM). These responses are used as inputs in empirical models to individually predict permanent deformation, fatigue cracking (including bottom-up and top-down), thermal cracking, and roughness. The models were calibrated by using data from the LTPP database for conditions representative of the entire United States. A pavement

structural design is obtained through an iterative process in which predicted performance is compared against the design criteria for the multiple predicted distresses until all design criteria are satisfied to the specified reliability level.

The design approach provided in MEPDG consists of three major stages, shown in Figure 1.1 (2).

Stage 1 of this procedure is to develop input values. In this stage, potential strategies are identified and foundation analysis is conducted. The investigation of distress types in the existing pavements and the causes of those distresses are considered. The strength/stiffness of the existing pavement is evaluated based on deflection testing data. Also, pavement materials inputs and traffic characterization data are developed. The EICM model considers hourly climatic data (temperature, precipitation, solar radiation, cloud cover, and wind speed) from weather stations across the United States, which are used to estimate material properties for the foundation and pavement layers throughout the design life. The frost depth is determined, and the proper moduli are estimated above and below this depth. In addition, an approach for the use of sub-drainage is included in MEPDG.

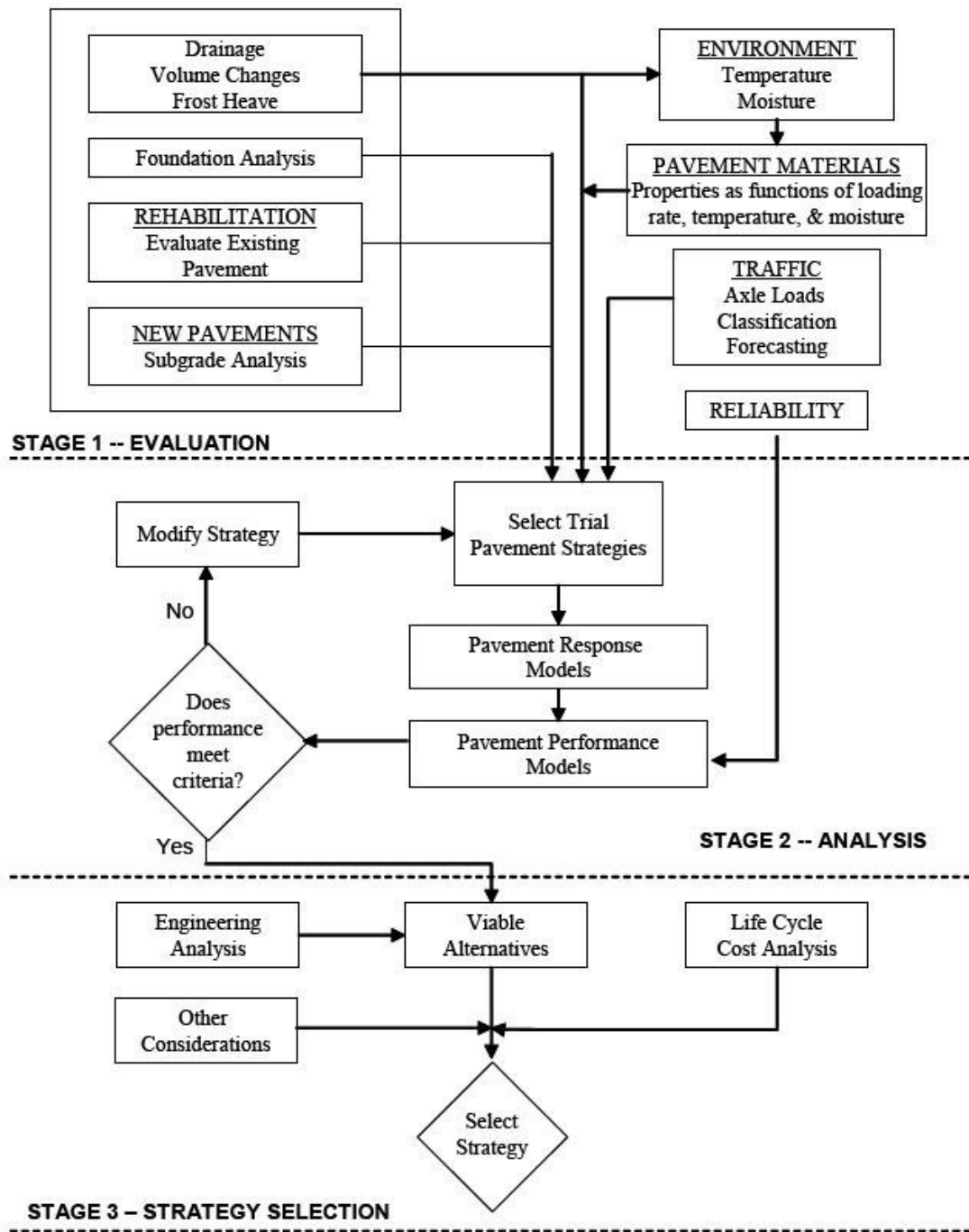


Figure 1.1 The Three-Stage Schematic of the MEPDG Process (2)

Stage 2 consists of the structural/performance analysis. The analysis approach is an iterative process that begins with the selection of an initial trial design. The trial



design requires initial estimates of layer thickness, geometric features, initial smoothness, required repairs to the existing pavements, pavement materials characteristics, and other inputs. The trial section is analyzed incrementally over time using the pavement response and distress models, and the outputs of the analysis are accumulated damage amount of distress and smoothness over time. If the trial design does not meet the performance criteria, modifications need to be made and the analysis re-run until a satisfactory result is obtained.

Stage 3 of the process includes the evaluation of the structurally viable alternatives, such as an engineering analysis and life cycle cost analysis.

The hierarchical approach to design inputs is a feature of MEPDG not found in existing versions of the *AASHTO Guide for the Design of Pavement Structures*. This approach provides the designer with flexibility in obtaining the design inputs for a design project based on the criticality of the project and the available resources. The hierarchical approach is employed with regard to traffic, materials, and environmental inputs. Three levels of inputs are provided (2).

**Level 1** inputs provide for the highest level of accuracy and would have the lowest level of uncertainty or error. Level 1 inputs would typically be used for designing heavily trafficked pavements or wherever there are dire safety or economic consequences of early failure. Level 1 material input require laboratory or field testing, such as the dynamic modulus testing of hot-mix asphalt concrete, site-specific axle load spectra data collections, or nondestructive deflection testing.

**Level 2** inputs provide an intermediate level of accuracy. Level 2 inputs typically would be user-selected, possibly from an agency database, could be derived from a limited testing program, or could be estimated through correlations.

**Level 3** inputs provide the lowest level of accuracy. This level might be used for design where there are minimal consequences of early failure, such as lower volume roads. Inputs typically would be user-selected values or typical averages for the region. In MEPDG software, national default values are provided and could be used as level 3 inputs.

## **1.2 Related Research for MEPDG Implementation in Arkansas**

In order to implement the MEPDG procedure into state highway agencies, the NCHRP 1-37A report identifies several challenges and issues as follows which need to be tackled in advance (2):

- Design input data needed: how the agency will collect the inputs, and establish a database for inputs,
- Performance and reliability design criteria,
- Existing and new testing equipment required,
- Computer hardware and software requirements,
- Local calibration and validation of distress models:
  - Establishing a database of projects,
  - Input guidelines for local conditions, materials, and traffic,

- Adjusting distress and pavement performance models to fit local performance in State,
- Training requirements for staff doing pavement design.

To solve the abovementioned challenges, the Arkansas Highway and Transportation Department (AHTD) has invested significant research funding in projects related to the implementation of MEPDG in Arkansas. These research projects include *Measurement of Design Inputs for AASHTO 2002 Guide* (TRC0302) (5), *Projected Traffic Loading for AASHTO 2002 Guide* (TRC-0402) (6), *ACHM Mix Stiffness and Static Creep Behavior* (TRC-0304) (7), *PCC Materials Input Values for Mechanistic Empirical Pavement Design Guide* (TRC-0708) (8), *Development of a Master Plan for Calibration and Implementation of the M-E Design Guide* (TRC-0602) (9), and related research projects on the resilient modulus of pavement soils.

The primary objective of the research on *Measurement of Design Inputs for AASHTO 2002 Guide* (TRC-0302) was to provide Arkansas design professionals guidance in selecting realistic design inputs for the MEPDG procedure (5). MEPDG requires much more inputs from pavement designers than the currently used 1993 AASHTO Guide. Many designers may lack specific knowledge of the data required. A sensitivity study was performed to assess the relative sensitivity of the models used in MEPDG to inputs relating to Portland cement concrete (PCC) materials in the analysis of jointed plain concrete pavements (JPCP) and to inputs relating to Hot Mix Asphalt (HMA) materials in the analysis of flexible pavements. Based on the studies of sensitivity of various input parameters, the significance levels of inputs can be determined. The finding of this research may aid designers in focusing on those inputs

having the most effect on desired pavement performance. If results show that certain input does not significantly influence the performance models, the designer can accept the default value offered in the MEPDG software with confidence. On the other hand, if an input is "critical" to a successful design, further research will be needed to determine appropriate input values for this parameter. In addition, the results of sensitivity analysis can be used to make recommendations about what parameter may need more quality control attention based on their significant levels.

The primary objective of project TRC-0402 titled with *Projected Traffic Loading for Mechanistic Empirical Pavement Design Guide (MEPDG)* was to provide Arkansas design professionals guidance in selecting realistic traffic inputs (6, 10, and 11). MEPDG requires traffic load spectra inputs for estimating the magnitude, configuration and frequency of the loads that are applied throughout the pavement design life. In this study, traffic inputs for initial implementation of MEPDG and a procedure for updating these inputs in the future were developed. Classification and weight data collected at 55 WIM stations in Arkansas were used in this study. Quality control checks were performed to ensure accurate interpretation of the data. It was found that several stations had substantial missing data, unexpected changes in vehicle class distribution were found in some stations, and some of the WIM scales were not working properly. A sensitivity analysis performed in this study showed that the effects of "bad" data on the pavement design were significant. Therefore, only "good" traffic data were used to develop statewide traffic inputs for MEPDG. The research recommended that statewide vehicle class distribution factors and axle load spectra should be used instead of default values in the MEPDG software. Default or user-

defined values for other traffic inputs, except for annual average daily truck traffic, should be used unless specific information is obtained. It is also recommended that the statewide traffic inputs be updated every three years unless no significant changes are observed in the future.

The dynamic modulus ( $E^*$ ) of hot-mix asphalt (HMA) is one of the fundamental inputs in MEPDG. To provide the laboratory measured  $E^*$  inputs for AHTD, a comprehensive research effort, project TRC 0304 (7), was completed at the University of Arkansas. The research included a study evaluating different  $E^*$  testing protocols, derived by varying combinations of the number of test replicates and the number of measurement instruments affixed on each test specimen recommended in AASHTO TP 62-03 (12). The total research effort included three replicate specimens from each of four aggregate types (MCA, GMQ, ARK, and JET), three nominal maximum aggregate sizes (12.5, 25, and 37.5 mm), two PG binder grades (PG 70-22 and PG 76-22), and two air-void levels (design and 7 percent). The  $E^*$  tests were conducted using five test temperatures (-10, 4, 21, 38, and 54<sup>0</sup>C) and six loading frequencies (0.1, 0.5, 1, 5, 10, 25 Hz). The analysis showed that the variability of the average dynamic modulus for each set of four replicates was acceptable. The master curve comparison of measured and predicted values also confirmed that the Witczak predictive equation fitted the test data in this study very well. The testing procedure and results of this study are recommended for preparing input data for the MEPDG.

Studies (5, 8, 13, 14, and 15) have identified the Coefficient of Thermal Expansion (CTE) of concrete materials as a very sensitive parameter affecting rigid pavement distress predictions within the MEPDG software. However, many state

agencies, including AHTD, currently do not routinely determine the CTE of concrete materials. AHTD has sponsored a research project *PCC Materials Input Values for Mechanistic Empirical Pavement Design Guide* (Project TRC-0708) (8), where the CTE measuring equipment was developed in accordance with the AASHTO TP 60 (16). A testing plan including typical aggregates and cement types used for concrete mixture constructed in Arkansas was conducted to develop the typical CTE inputs. The interaction effect of aggregate and cement types on CTE and pavement performance predictions were evaluated. Three replicate specimens were prepared for each of 24 concrete and cement paste mixtures and tested at 7 and 28 days. The range of CTE determined in this study was in agreement with the range of values reported by other studies, and the variability of test results was favorably comparable. Analysis of variance and sensitivity analyses were performed to evaluate the influence of mixture properties on CTE and the effect on pavement performance predictions of using Level 1- and 3-CTE inputs. It was concluded that the type of coarse aggregate used in Portland Cement Concrete (PCC) mixtures significantly influenced CTE and pavement performance predictions. The proportion of coarse aggregates in the PCC mixture could significantly affect the CTE depending on the types of aggregates used in the mixture. It was recommended that Level-3 CTE input be used for PCC mixtures with limestones and sandstones. In addition, the corresponding testing of the PCC mechanical properties (Young's modulus, modulus of rupture, compressive strength, and poisson's ratio) were also conducted in this project.

The resilient modulus ( $M_R$ ) parameter is another important input in MEPDG software. However, it is not currently measured by AHTD, but rather it is typically

estimated from R-Value test results. This convention was accepted primarily to avoid equipment and labor expenses associated with the resilient modulus test. Several previous researches were conducted in the early 1990s (17 and 18). In recent years, two research projects sponsored by the Mack-Blackwell Rural Transportation Center (MBTC) (19 and 20) aimed to provide tools needed to effectively estimate the resilient modulus of subgrade soils throughout Arkansas for MEPDG design procedure. Project MBTC 2007 (19) aimed to improve the resilient modulus prediction method by developing a material model for subgrade soil based on correlation of soil index properties with the resilient modulus parameter instead of the resilient modulus or R-Value. Twenty soils that contribute a broad aerial coverage (approximately 80%) of the surface soils in the state of Arkansas were selected and tested for simple index and repeated load testing by Qiu, Neo, and Zhao (21). Project MBTC 2032 (20) aimed to correlate results of the simplified triaxial tests, resilient modulus derived from back-calculation of FWD deflection basins, surface wave method to laboratory measured resilient modulus results, and establish the appropriate testing protocol for determining subgrade resilient modulus using a potential combination of FWD, laboratory and seismic methods for Arkansas subgrade soils.

In order to ensure a smooth transition to a working MEPDG Guide for AHTD, the *Development of a Master Plan for Calibration and Implementation of the M-E Design Guide* was initiated (TRC-0602) (9). The master plan can put the MEPDG design procedure to routine use through the preparation of all activities related to the implementation activities – pulling together all the pieces, knowledge, and experience

attained thus far, plus identifying and planning for future required activities, such as local calibration for Arkansas.

### **1.3 Problem Statements**

MEPDG is a significant advancement in pavement design. However, it is substantially more complex than the 1993 AASHTO Guide, which is currently used in Arkansas and many other states, and it requires significantly more inputs from designers. Among them are many parameters with which today's pavement designers are not familiar. Some of the required data are not currently measured or tracked in the 1993 AASHTO Guide. Many data sets need to be pre-processed before their use for MEPDG. In addition, MEPDG provides methodologies for the analysis and performance prediction of different types of flexible and rigid pavements for the specific climatic and traffic conditions. However, the models were developed using available Long Term Pavement Performance (LTPP) national wide data sets. These models require local calibration before MEPDG can be used by highway agencies efficiently.

Based on the review of the related MEPDG research projects conducted in Arkansas, it is apparent that many data set preparation activities have been completed, and it is time to move forward with the local calibration process. However, the data sets required for the implementation of MEPDG are stored in different locations which are not familiar to pavement designers. Many data sets need to be pre-processed before they can be used in the MEPDG design procedure. In particular, the load spectra approach



adopted in MEPDG is much more complex than the existing ESAL based approach and several challenges exist. First, for a long time there has been a gap between traffic and pavement engineers in understanding the needs for traffic data in pavement design. Pavement and traffic engineers need to share their knowledge and experience together when using MEPDG. Secondly, NCHRP Project 1-37A researchers (2) found that roadways within the same Highway Functional Classification (HFC) had significant variability in truck distribution and introduced the Truck Traffic Classification (TTC) system in MEPDG to describe the distribution of trucks traveling on the roadway. This TTC classification is brand new to both traffic and pavement engineers. The third challenge is that the traffic data collected from the automated traffic collection sites often have errors, especially the data collected from the Weigh-In-Motion (WIM) sites which use temperature-dependent piezoelectric sensors (6, and 22). It consumes large amount of resources to process the data by using currently available methods to conduct the data check (23). Fourth, the sizes of the raw traffic data files are huge. For example, the size of truck weight data collected in Arkansas can be 200MB to 300 MB in text file format per month for a single WIM station. With several years of monitoring data, the processing of the raw data becomes tedious and time consuming. It is impractical to manually process those data files even with computer assistance. In addition, there will be tens of thousands of traffic data sets needed to be prepared to characterize traffic load for a particular design. This process needs to be automated with software, which was not available before this research. Although several existing software programs process data and generate reports, the resultant reports do not provide all axle load spectra data required in MEPDG analysis software (23). It would take additional resources to

conduct further analysis for MEPDG. For example, *Traflow*, a computer program developed under NCHRP Project 1-39 (24) for generating traffic inputs for MEPDG, still cannot fulfill many of the requirements for MEPDG. In 2004 AHTD sponsored a research project TRC-0402 titled with *Projected Traffic Loading for Mechanistic-Empirical Pavement Design Guide* (6, 10, and 11). In the research, Excel<sup>®</sup> spreadsheets were developed to reduce raw vehicle classification data and weight data, and to generate volume adjustment factors and axle load spectra for MEPDG. However, the updating procedure needs to be repeated manually if new traffic monitoring data are available.

Therefore, it is very critical and important to support the local calibration effort by concurrently developing a database platform for calibration data collection, storage, and analysis. The completed database will improve the management and accessibility of the MEPDG input data and is a critical step before calibrating and implementing the MEPDG.

#### **1.4 Research Objectives**

The primary objectives of this research are to develop a centralized database of input data sets and to incorporate database feature that can be directly used by AHTD pavement designers in their efforts to implement MEPDG in Arkansas with the following specific goals:

- To identify all the necessary inputs and analysis parameters required;

- To develop the database structures for uploading, preprocessing the required data sets;
- To initiate the collection of pavement design, construction, and performance data required to calibrate the MEPDG procedure;
- To develop a data interface for the MEPDG software to provide input and output utilities for designers.

A final product of the research is the software, PrepME, to be used for preparation of all input data sets for MEPDG.

## **1.5 Report Organization**

The database developed integrates six categories of data sets for MEPDG: climatic, traffic, material, construction, performance and maintenance data. Chapters 2, 3, and 4 describe the environmental effects, traffic characterization and material characterization in MEPDG respectively and their required data inputs for the MEPDG procedure. The database tables designed to store all the necessary information are also presented.

Chapter 5 presents the data sets required for MEPDG local calibration process, including construction, performance, and maintenance data. Accordingly the database tables are designed to store these data sets.

Chapter 6 presents the overall structural database design and the capabilities of the developed database software PrepME.

Chapter 7 presents the work conducted and the significant findings in this study. This chapter also includes recommendations for future research efforts for PrepME.

The data file formats of climatic, traffic inputs are attached in the appendix of this report. In addition, a detailed software user's guide is included in Appendix D to assist users when using the database software PrepME.

## CHAPTER 2 CLIMATIC INPUTS

### 2.1 Environmental Effects

Environmental conditions have a significant effect on the performance of both flexible and rigid pavements. External factors such as precipitation, temperature, freeze-thaw cycles, and water table depth play a key role in defining the bounds of the impact the environment can have on pavement performance. Internal factors such as the susceptibility of the pavement materials to moisture and freeze-thaw damage, drainability of the paving layers, infiltration potential of the pavement, and others define the extent to which the pavement will react to the external environmental conditions (2).

In a pavement structure, moisture and temperature are the two variables that can significantly affect the pavement layer and subgrade properties and, hence, its load carrying capacity. Changing temperature and moisture profiles in the pavement structure and subgrade over the design life of a pavement are considered in MEPDG through the Enhanced Integrated Climatic Model (EICM). The EICM is a one-dimensional coupled heat and moisture flow program that simulates changes in the behavior and characteristics of pavement and subgrade materials in conjunction with climatic conditions over several years of operation. It is fully linked to the software accompanying the MEPDG software and internally performs all the necessary computations. The user inputs to the EICM are entered through interfaces provided as part of the MEPDG software. The EICM processes these inputs and feeds its outputs to the three major components of the MEPDG framework — materials, structural

responses, and performance prediction. The following information throughout the entire pavement/subgrade profile are predicted: temperature, resilient modulus adjustment factors, pore water pressure, water content, frost and thaw depths, frost heave, and drainage performance (2).

## **2.2 Climatic Inputs**

The inputs required by the climatic model fall under the following broad categories (2):

- General information
- Weather-related information
- Ground water related information
- Drainage and surface properties
- Pavement structure and materials

The general information, such as pavement structure construction dates, traffic opening time, is required to initialize the moisture model in the EICM. Because new Thornthwaite Moisture Index (TMI) model is used in the MEPDG software, it makes the entry of drainage path and infiltration unnecessary. The pavement structure and materials related climate data will be further discussed in this report. Only weather-related information and ground water table depth are addressed here.

### *2.2.1 Weather-Related Data*

To accomplish the climatic analysis required for incremental damage accumulation, MEPDG requires five weather-related parameters on an hourly basis over the entire design life for the design project (2):

- Hourly air temperature
- Hourly precipitation
- Hourly wind speed
- Hourly percentage sunshine (used to define cloud cover)
- Hourly relative humidity

In MEPDG, the weather-related information is primarily obtained from weather stations located near the project site. The MEPDG software provides over 800 weather stations containing hourly data across the United States from the National Climatic Data Center (NCDC) database. All the data sets for each station are saved in a file with “hcd” extension and can be downloaded from the website for NCHRP 1-37A project: <http://www.trb.org/mepdg> (25).

The climatic database can be tapped into by simply specifying the latitude, longitude, and elevation of the project site in MEPDG software. Once the GPS coordinates and elevation are specified for the design project site, the MEPDG software will highlight the six closest weather stations to the site from which the user may select any number of stations to generate a virtual project weather station. After selecting the climate stations and inputting the water table depth for the design, click “generate” button and all the climatic data sets required are saved in a file with an “icm” extension through the EICM numerical engine. The climate generating screen window is shown in Figure 2.1.

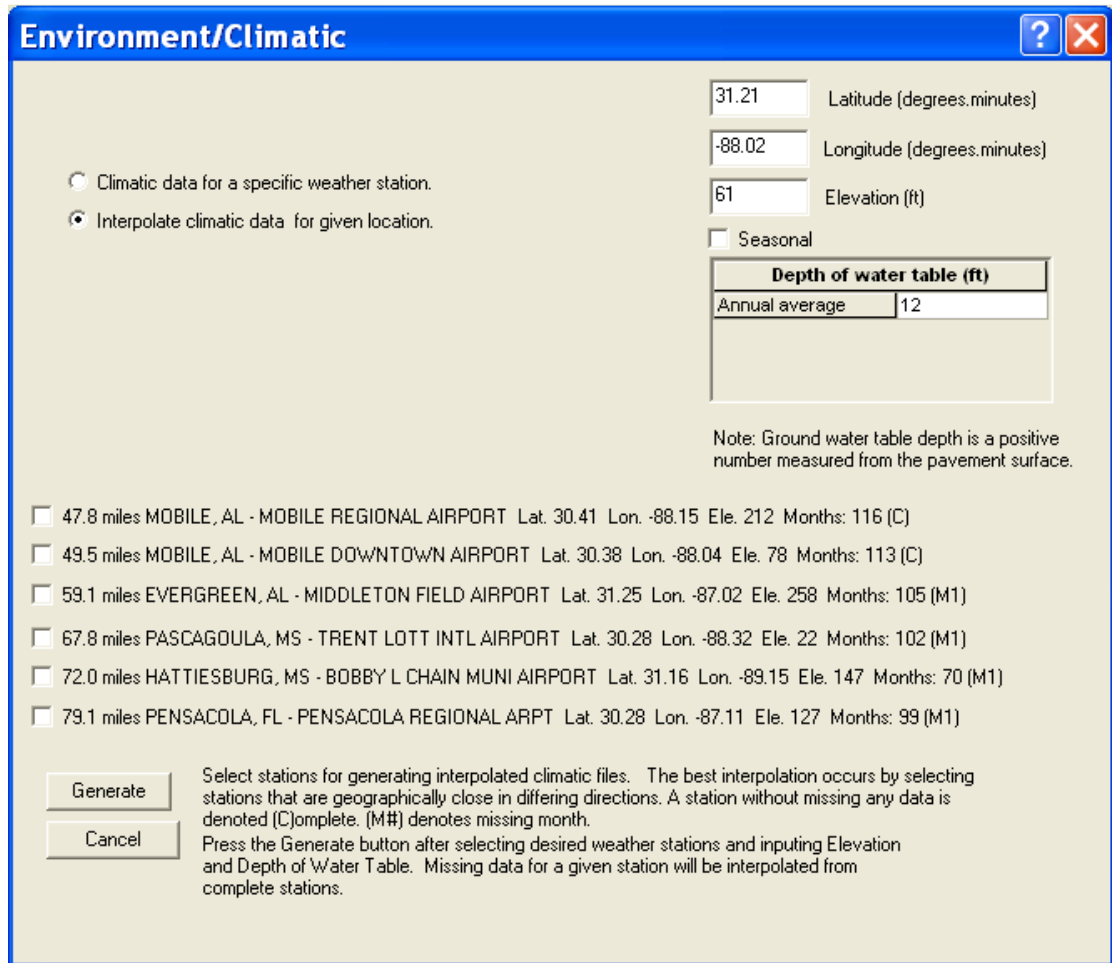


Figure 2.1 Climatic Generating Window in MEPDG

The configuration of weather-related information required for design is the same at all the three hierarchical input levels. Since “icm” files contain all of the information needed to run the EICM numerical engine, design of the database should aim to provide all the data in “icm” file. “icm” files are generated from “hcd” file and “station.dat” file. The file formats used by the EICM numerical engine, including “icm” file, “hcd” file and “station.dat” file, are attached in Appendix A (25).

The MEPDG software identifies 16 weather stations for Arkansas from the NCDC database. It can be seen that the climate stations are not evenly distributed. It is



recommended that 22 more weather stations from six bordering states be also used for Arkansas pavement design. The original data sets are imported and saved to the supporting database tables. The distribution map of all the 38 weather stations (16 in Arkansas plus 22 in the six neighboring states) is presented in Figure 2.2. The detailed locations of the recommended weather stations are in Table 2.1.

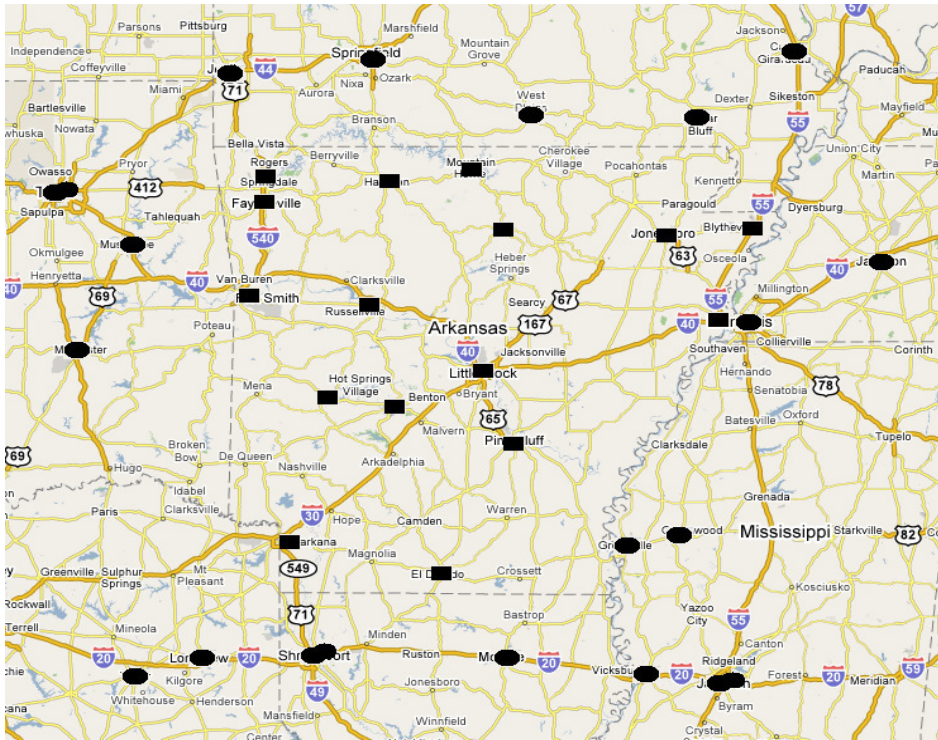


Figure 2.2 Weather Stations Used for Arkansas

Table 2.1 Recommended Weather Stations for Arkansas

ID	Location	Latitude	Longitude	Elevation (ft)
53869	Blytheville, AR	35.56	-89.5	259
93992	EL Dorado, AR	33.13	-92.49	254
93993	Fayetteville, AR	36.01	-94.1	1247
53922	Fayetteville/Springdale, AR	36.17	-94.19	1272
13964	Fort Smith, AR	35.2	-94.22	480
13971	Harrison, AR	36.16	-93.1	1380
03962	Hot Springs, AR	34.29	-93.06	535
03953	Jonesboro, AR	35.5	-90.39	264
13963	Little Rock, AR	34.45	-92.14	292
53919	Monticello, AR	33.38	-91.45	277
53921	Mount IDA, AR	34.33	-93.35	706
53918	Mountain Home, AR	36.22	-92.28	915
93988	Pine Bluff, AR	34.11	-91.56	207
53920	Russellville, AR	35.16	-93.05	382
13977	Texarkana, AR	33.27	-94.01	394
53959	West Memphis, AR	35.08	-90.14	214
13942	MONROE, LA	32.31	-92.02	133
13957	SHREVEPORT, LA	32.27	-93.49	274
53905	SHREVEPORT, LA	32.32	-93.44,	178
03935	CAPE GIRARDEAU, MO	37.14	-89.34	339
13987	JOPLIN, MO	37.09	-94.3	985
03975	POPLAR BLUFF, MO	36.46	-90.19	330
13995	SPRINGFIELD, MO	37.14	,-93.23	1280
53901	WEST PLAINS, MO	36.53	-91.54	1225
13939	GREENVILLE, MS	33.29	,-90.59	150
13978	GREENWOOD, MS	33.3	-90.05	149
03940	JACKSON, MS	32.19	,-90.05	296
13927	JACKSON, MS	32.2	,-90.13,	312
03996	TALLULAH/VICKSBURG, MS	32.21	,-91.02	88
93950	MC ALESTER, OK	34.54	,-95.47	753
93953	MUSKOGEE, OK	35.4	,-95.22	610
13968	TULSA, OK	36.12	,-95.53	742
53908	TULSA, OK	36.02	,-95.59	659
03811	JACKSON, TN	35.35	,-88.55	423
13893	MEMPHIS, TN	35.04	,-89.59	286
03901	LONGVIEW, TX	32.23	,-94.43,	355
13972	TYLER, TX	32.21	,-95.24	531

### 2.2.2 *Groundwater Table Depth*

The groundwater table depth, intended to be either the best estimate of the annual average depth or the seasonal average depth, is another important parameter needed to be input to the MEPDG software. At input Level 1, it could be determined from profile characterization borings prior to design. At input Level 3, an estimate of the annual average value or the seasonal averages can be provided, such as using the data produced by the United States Geological Survey (USGS).

For water table depth data, 34,015 test records at 552 water table depth testing locations from all the 75 counties in Arkansas are collected from the National Water Information System online database (26). If site specific data are not available, data from surrounding sites can be used as level 3 inputs to aid the design procedure.

## 2.3 **Database Tables**

Six database tables are designed for the climate module of the supporting database for MEPDG, as shown in Table 2.2. Following the LTPP schema, a prefix is used throughout “MEPDG” to designate the general topic area for the various data tables. All climate data tables in MEPDG begin with a “Climate” prefix. The “MEPDG\_Climate\_Stations” table contains the general information of all the 38 climate stations, including weather station ID, text description of the site, GPS coordinates, and elevation. The primary keys for this table are the weather station ID, latitude and longitude, through which all the designed tables are related. “MEPDG\_Climate\_Data\_Hourly” table saves the five weather-related parameters

(Hourly air temperature, Hourly precipitation, Hourly wind speed, Hourly percentage sunshine, and Hourly relative humidity) on an hourly basis. These data are imported from the “hcd” files at the specific 38 weather stations from Arkansas and neighboring states. “MEPDG\_Climate\_Seasonal” Table stores the annual water table depth or seasonally water table depth, if available, and monthly average humidity data, from January to December. Each climate station has only one unique record for this table. “MEPDG\_Climate\_Solar\_Radiation\_Daily” table stores the daily solar radiation data, such as sunrise time, sunset time and daily maximum solar radiation. Two tables are designed to store the water table depth data from USGS online database. “MEPDG\_Climate\_GWT\_General” table gives the general descriptive information of the water table depth testing locations, while the “MEPDG\_Climate\_GWT\_Depth” table stores all the testing dates and their corresponding water table depth values.

Table 2.2 Database Tables for Climatic Module

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
General	MEPDG_Climate_Stations	The general information of all the climatic database weather stations, such as the weather station ID, latitude, longitude and elevation.
Climatic Data	MEPDG_Climate_Data_Hourly	The five weather-related parameters (Hourly air temperature, Hourly precipitation, Hourly wind speed, Hourly percentage sunshine, and Hourly relative humidity) on an hourly basis for each weather station.
	MEPDG_Climate_Seasonal	The annual water table depth or seasonally water table depth, if available, and monthly average humidity data, from January to December.
	MEPDG_Climate_Solar_Radiation_Daily	The daily solar data, such as sunrise time, sunset time and daily maximum solar radiation.
	MEPDG_Climate_GWT_General	The general descriptive information of the water table depth testing locations.
Water Table Depth	MEPDG_Climate_GWT_Depth	All the testing dates and their corresponding water table depth values.

## CHAPTER 3 TRAFFIC INPUTS

### 3.1 Traffic Characterization

Traffic is one of the most important inputs in pavement design. Instead of using Equivalent Single Axle Load (ESAL) in the 1993 AASHTO Design Guide to characterize traffic throughout the pavement design life, MEPDG requires the full axle-load spectrum traffic inputs for estimating the magnitude, configuration and frequency of the loads (2). The traffic module of the MEPDG procedure creates the axle load distribution for single, tandem, tridem and quad axles over the design life to accurately determine the axle loads that will be applied on the pavement in each time increment of the damage accumulation process.

As with all other inputs, traffic inputs can be provided in three levels depending upon the extent of traffic information available for the given project and the accuracy therein. Level 1 is considered the most accurate because it requires a very good knowledge of historical axle load spectra, classification, and volume data at or near the project site, which refers to a roadway segment near the design location with no influencing intersecting roadways. Level 2 uses the statewide/regional axle load spectra, instead of the site specific axle load spectra required for Level 1. Level 3 is the least accurate input level in MEPDG. It requires only estimates of average annual daily traffic (AADT) and truck percentage with no site-specific knowledge of traffic characteristics at the design location.

The traffic module in the MEPDG software is shown in Figure 3.1, which allows designers to import all the traffic parameters required. All the importable inputs are saved in 11 files. Studies on these files are summarized in Appendix B.

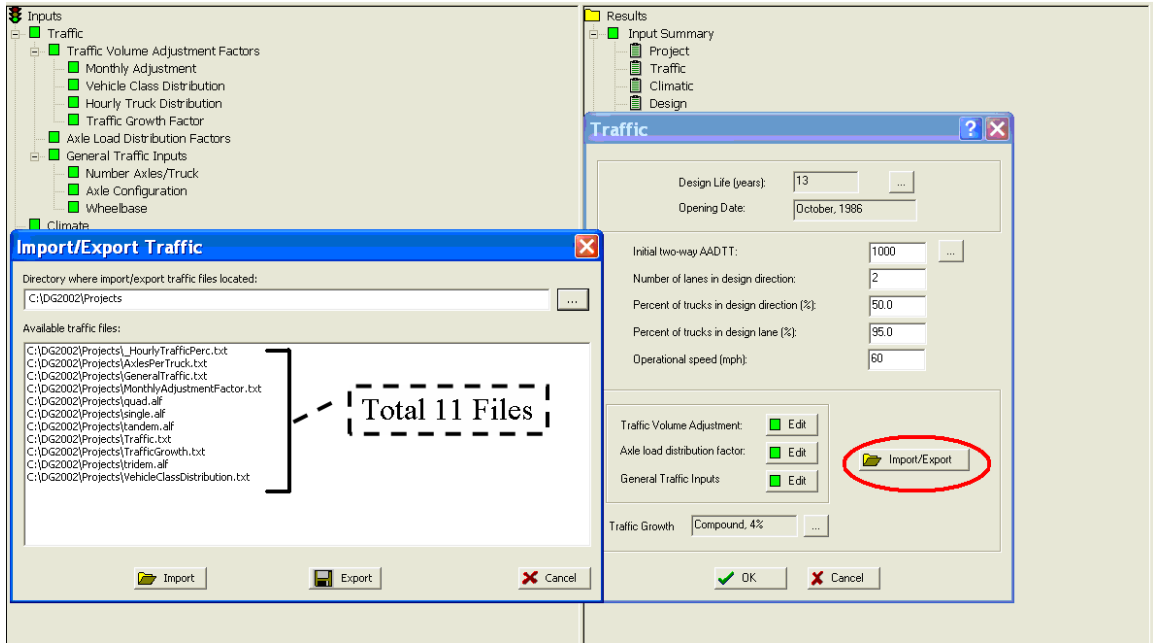


Figure 3.1 Traffic Input in the MEPDG Software

In NCHRP 1-37A report, it was found that the Highway Functional Classifications (HFC) do not properly describe the distribution of trucks traveling on the roadway (2). Therefore, seventeen groupings with similar truck traffic compositions, called Truck Traffic Classifications (TTC), were proposed in MEPDG. In this approach, different types of trucks were grouped into four major categories as follows (2):

- Buses (Vehicle Class 4)
- Single Unit Trucks (Vehicle Classes 5, 6 and 7)
- Tractor-Trailer or Truck-Single Trailer Units (Vehicle Classes 8, 9 and 10)
- Multi-Trailer Trucks (Vehicle Classes 11, 12 and 13)

Initially all normalized truck type distributions were categorized into sites with similar truck percentages only based on truck classes 5, 9 and 13 (2). The criteria used for differentiating among TTCs are shown in Table 3.1. More complete descriptions and definitions for each of the seventeen TTCs are provided in Table 3.2.

Variation of vehicle class distributions for facilities within a functional classification was also reported in TRC 0402 project for AHTD (6). It was found that using the TTC system was more reasonable to classify vehicle class distribution for each station. Therefore it is recommended that vehicle class distributions be grouped based on TTC system in this study.



Table 3.1 Truck Traffic Classification Criteria (2)

TTC	Type	Percent of AADTT			
		VC9	VC5	VC13	VC4
1	truck	>70	<15	<3	-
2	truck	60-70	<25	<3	-
3	truck	60-70	5-30	3-12	-
4	truck	50-60	8-30	0-7.5	-
5	truck	50-60	8-30	>7.5	-
6	truck	40-50	15-40	<6	-
7	truck	40-50	15-35	6-11	-
8	truck	40-50	9-25	>11	-
9	truck	30-40	20-45	<3	-
10	truck	30-40	25-40	3-8	-
11	truck	30-40	20-45	>8	-
12	truck	20-30	25-50	0-8	-
13	truck	20-30	30-40	>8	-
14	truck	<20	40-70	<3	-
15	truck	<20	45-65	3-7	-
16	truck	<20	50-55	>7	-
17	bus	-	-	-	>35

Table 3.2 Truck Traffic Classification Criteria (2)

Buses	Multi-Trailer	Single-Trailer and Single-Unit Trucks	TTC
Low to None (<2%)	Relatively High Amount of Multi-Trailer Trucks (>10%)	Predominantly single-trailer trucks	5
		High percentage of single-trailer trucks, but some single-unit trucks	8
		Mixed truck traffic with a higher percentage of single-trailer trucks	11
		Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	13
		Predominantly single-unit trucks	16
	Moderate Amount of Multi-Trailer Trucks (2-10%)	Predominantly single-trailer trucks	3
		Mixed truck traffic with a higher percentage of single-trailer trucks	7
		Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	10
		Predominantly single-unit trucks	15
	Low to None (<2%)	Low to Moderate (>2%)	Predominantly single-trailer trucks
Predominantly single-trailer trucks, but with a low percentage of single-unit trucks			2
Predominantly single-trailer trucks with a low to moderate amount of single-unit trucks			4
Mixed truck traffic with a higher percentage of single-trailer trucks			6
Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks			9
Mixed truck traffic with a higher percentage of single-unit trucks			12
Predominantly single-unit trucks			14
Bus Route (>25%)	Low to None (<2%)	Mixed truck traffic with about equal single-unit and single-trailer trucks	17

### 3.2 Traffic Inputs

The MEPDG requires four basic categories of traffic inputs for the structural pavement design: the base traffic volume, traffic volume adjustment factors, axle load distribution factors, and other factors (2).

### *3.2.1 The Base Year Traffic Volume*

The traffic generating screen allows the user to enter the basic traffic information necessary to determine the total traffic volume at the time of construction and opening to traffic (Figure 3.1). The base year for the traffic inputs is defined as the first year that the roadway segment under design is opened to traffic. This information consists of:

- Two-way annual average daily truck traffic (AADTT),
- Number of lanes in the design direction,
- Percent trucks in design direction,
- Percent trucks in design lane,
- Vehicle (truck) operational speed.

One important input in this category is the annual average daily truck traffic (AADTT). It is commonly obtained from traffic counts obtained from WIM, AVC, vehicle counts, and traffic forecasting and trip generation models during a given time period.

### *3.2.2 Traffic Volume Adjustment Factors*

The base year AADTT must be adjusted by using traffic volume adjustment factors, including monthly distribution, hourly distribution, class distribution, and traffic growth factors.

Truck traffic Monthly Adjustment Factors (MAF) specify the monthly variation of the annual truck traffic for a given truck class (Figure 3.2). Although the truck traffic

distribution can be varied every year, they are assumed to be constant over the entire design period in MEPDG (2).

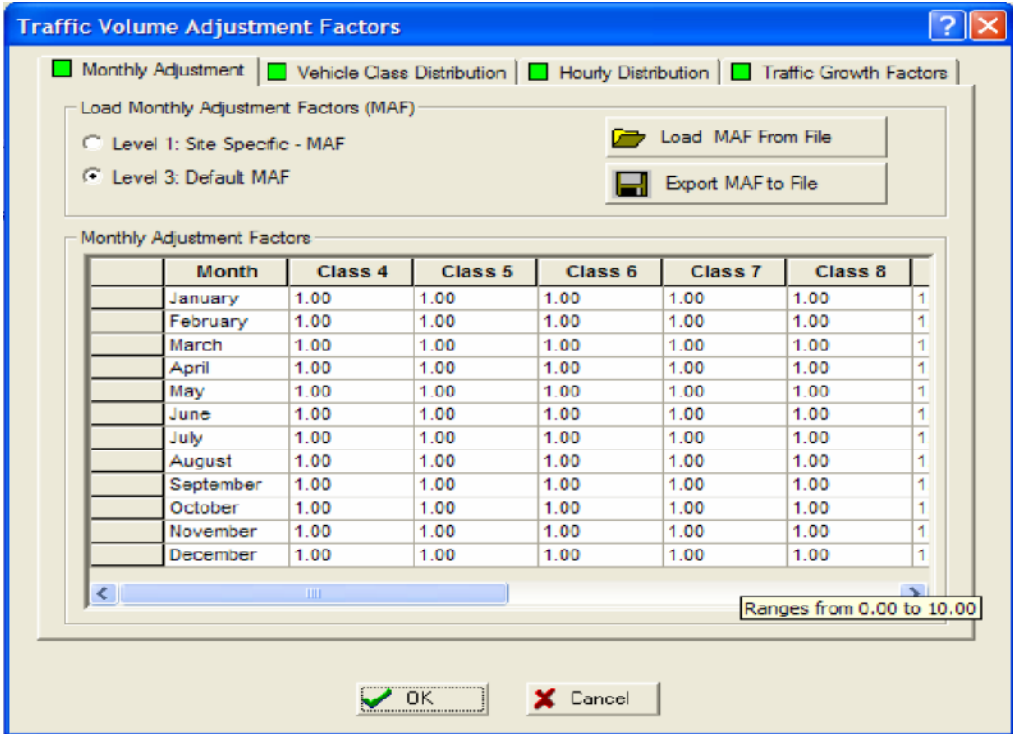

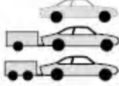

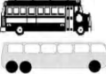



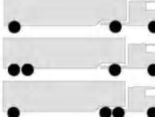
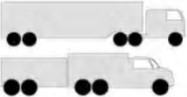


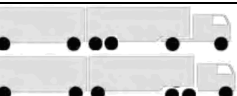
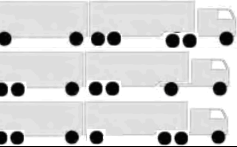


Figure 3.2 Traffic Monthly Adjustment Factors in MEPDG

Traffic information based on classification is of great importance for pavement design and rehabilitation, because the percentage of each truck class in the truck flow varies and the effect of individual trucks on pavement differs. The FHWA classification scheme utilize an algorithm to interpret axle spacing information to categorize vehicles into 13 classes, illustrated in Table 3.3, among which truck classes are from class 4 to class 13. The non-truck classes, from class 1 to class3, are motorcycles, passenger cars, other two-axle, and four-tire single vehicles respectively. Although non-trucks constitute a major part of vehicle volumes, due to their low axle loads compared to

heavy commercial trucks their contributions to the deterioration of the pavement are very limited. On the contrary, the ten classes of trucks are those relevant to pavement design and rehabilitation.

Table 3.3 FHWA Vehicle Classification

Vehicle Class	Description	# of Axles
1		2
2		2 & 3 & 4
3		
4		2 3
5		2
6		3
7		4
8		3 4 4
9		5
10		6 7
11		5
12		6
13		7 or more

Vehicle Class Distribution Factors (CDF) specify the percentage of each truck class (Classes 4 through 13) within the AADTT for the base year. The MEPDG software offers the user a choice of 13 truck classes to define the distribution of truck traffic based on truck classes. Figure 3.3 shows the vehicle class distribution in the MEPDG software.

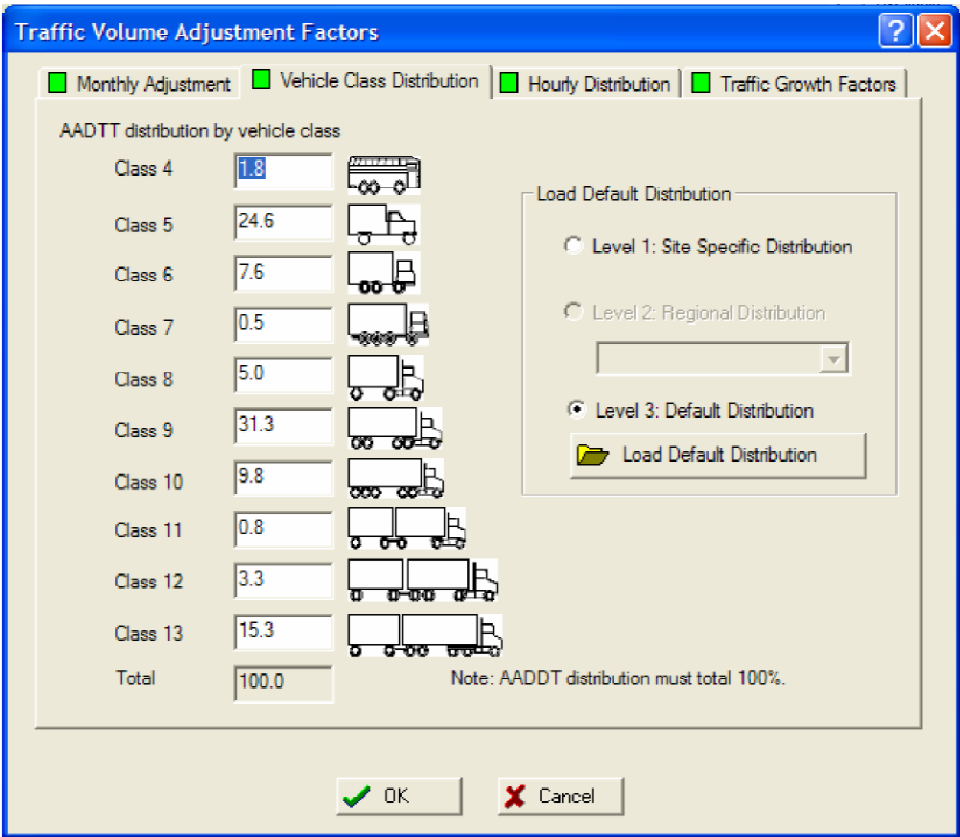


Figure 3.3 Vehicle Class Distribution Factors in MEPDG

Hourly Distribution Factors (HDF) are used to adjust truck volume throughout the day. The software screen is shown in Figure 3.4. Throughout the day, five time

periods are defined: (1) Midnight to 6 a.m.; (2) 6 a.m. to 10 a.m.; (3) 10 a.m. to 4 p.m.; (4) 4 p.m. to 8 p.m., and (5) 8 p.m. to midnight.

Hourly truck traffic distribution by period beginning:	
Midnight	2.3
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5.0
7:00 am	5.0
8:00 am	5.0
9:00 am	5.0
10:00 am	5.9
11:00 am	5.9
Noon	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1
10:00 pm	3.1
11:00 pm	3.1

Note: The hourly distribution must total 100%

Total: 100.0

Figure 3.4 Hourly Distribution Factors in MEPDG

The traffic growth factors are used to calculate class-specific growth. Input data include growth rate and growth functions per class, which is shown in Figure 3.5.

Three different traffic growth functions: no growth, linear growth and compound growth, are allowed in the MEPDG software to compute the growth or decay in truck traffic over time. Further, the user also has the option of selecting a different growth rate and growth function for each truck class by clicking on the radio button for

"vehicle-class specific traffic growth". For each truck class, the drop down menu offers a choice of the three growth functions and the user enters the rate of growth.

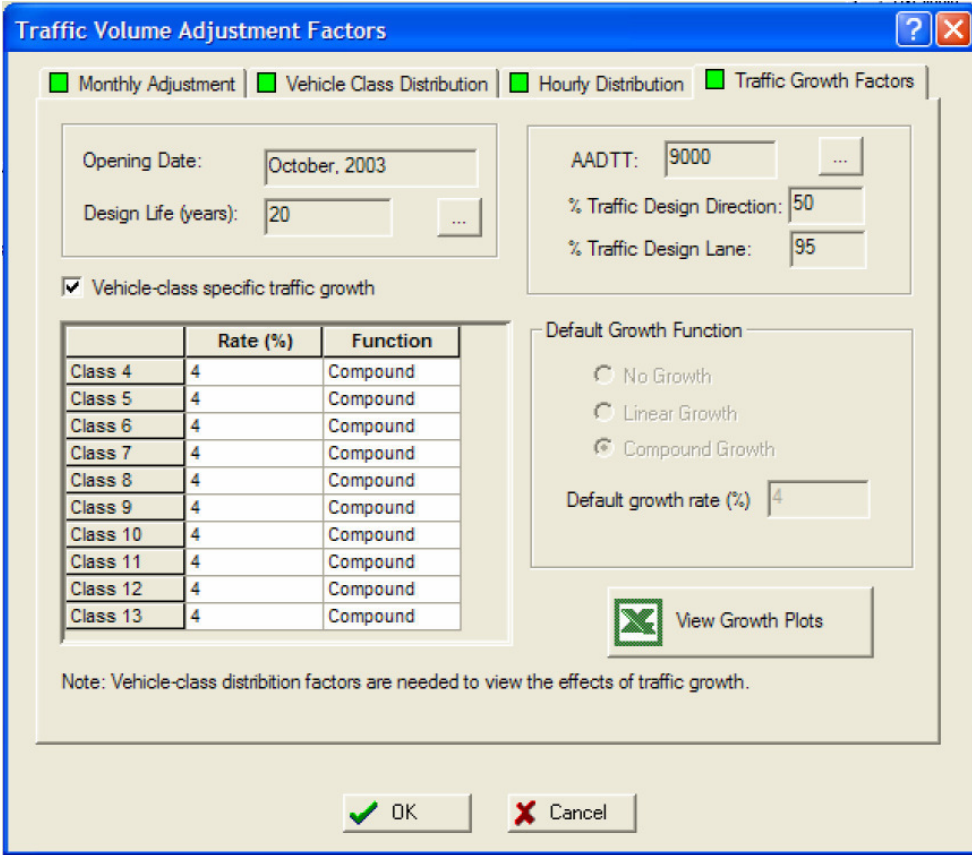


Figure 3.5 Traffic Growth Factors in MEPDG

3.2.3 Axle Load Distribution Factors

The second submenu within the main traffic menu contains the tables for the incorporation of the axle distribution factors. These axle distribution factors represent the axle load spectra for all traffic classes (class 4 to class 13), all axle types (single, tandem, tridem, and quad), and for each month of the year. The axle load distribution



factor is the percentage of axles in each load interval by single, tandem, tridem or quad axle type for a specific truck class (Figure 3.6).

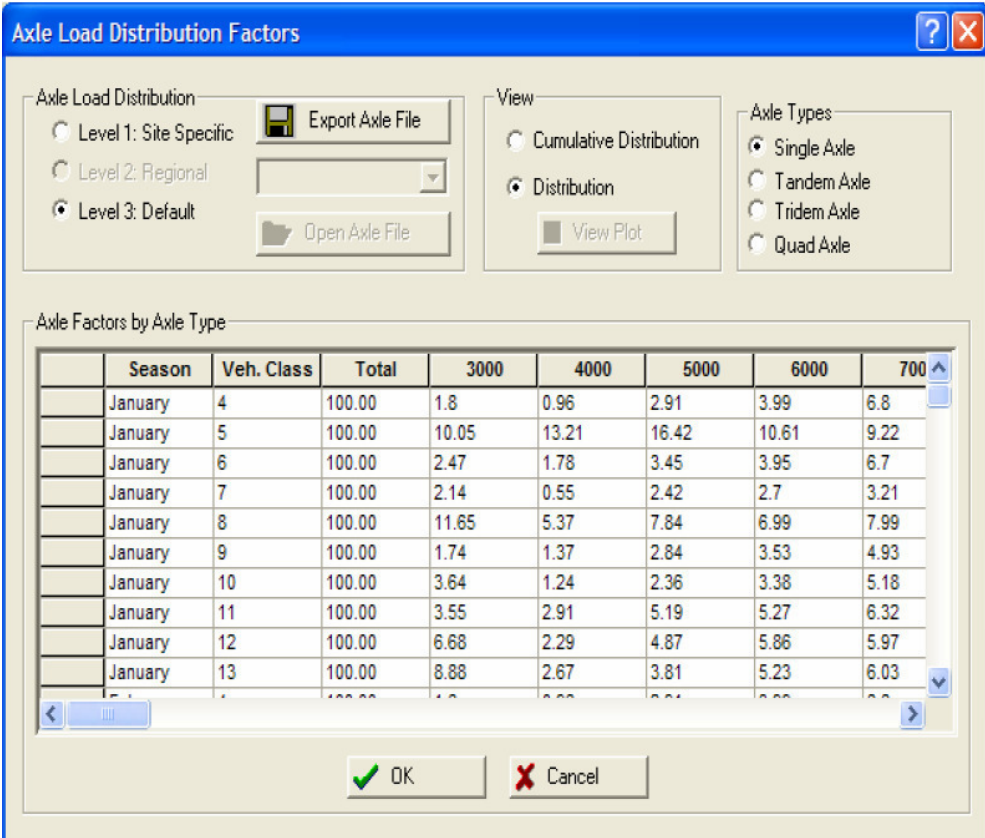


Figure 3.6 Axle Load Distribution Factors in MEPDG

Among the four types of axle groups, a single axle is defined in MEPDG (2) as an axle on a vehicle that is separated from any leading or trailing axle by more than 96 inches, and includes both the single axle with single tires or dual tires. A tandem axle refers to two consecutive axles that are more than 40 inches but not more than 96 inches apart and are articulated from a common suspension system. In the same way, for a

group of three axles, if both of the distances between the consecutive axles are more than 40 inches but not more than 96 inches, it is a tridem.

Axle load distribution for each axle type for each load interval is defined in MEPDG software as: (1) Single axles – 3,000 lb to 40,000 lb at 1,000-lb intervals; (2) Tandem axles – 6,000 lb to 80,000 lb at 2,000-lb intervals; (3) Tridem and quad axles – 12,000 lb to 102,000 lb at 3000-lb intervals.

#### *3.2.4 General Traffic Inputs*

The general traffic information contains three main components (Figure 3.7): (1) expected number of axles per truck, (2) typical axle configuration, and (3) average wheelbase dimensions. Additional input information is required on the average location of the outer wheel from the lane marking, an estimation of the standard deviation of the traffic wander, and the width of the design lane.

Most of the inputs under this category define the axle load configuration and loading details used for calculating pavement responses. The exceptions are “Number of Axles by Axle Type per Truck Class” and “Wheelbase” inputs, which are used in the traffic volume calculations. The default values for the general traffic inputs were determined from the LTPP database. Default values are recommended if more accurate information is not available.

**General Traffic Inputs** [?] [X]

Lateral Traffic Wander

Mean wheel location (inches from the lane marking):

Traffic wander standard deviation (in):

Design lane width (ft): (Note: This is not slab width)

Number Axles/Truck |  Axle Configuration |  Wheelbase

	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

[OK] [Cancel]

Figure 3.7 General Traffic Inputs in MEPDG

### 3.3 Traffic Data Collection

In order to collect the traffic data, a statewide traffic collection plan usually consists of permanent, continuously operating data collection sites and short duration data collection efforts (6 and 27).

#### 3.3.1 Continuous Count Programs

Continuous count programs help establish seasonal, daily and hourly traffic characteristics for a variety of design, operation and management purposes. Three types

of traffic collection devices, automatic traffic recorders (ATR), automatic vehicle classifiers (AVC), and weigh-in-motion (WIM) scales are typically used.

Automatic traffic recorders are used to provide continuous traffic data at selected locations. Automatic traffic recorders are typically road tubes and ATR data are usually hourly traffic volumes by lane. The data are analyzed to provide statistics relative to the traffic volume for design purposes (27): (1) Annual Average Daily Traffic at the site (AADT); (2) Annual Average Weekday Traffic at the site (AAWDT); (3) Seasonal adjustment factors; (4) Day-of-week adjustment factors; (5) Lane/directional distribution factors; (6) Growth factors. The above factors are used to adjust short duration counts to AADT.

Automatic vehicle classifiers are used to detect and classify vehicles based on vehicle characteristics, such as the number and type of axles, vehicle length, or vehicle weight. The most common sensors in use are based on dual-inductance loops or piezoelectric cables. The continuous vehicle classification sites allow the monitoring of changes in truck traffic characteristics by classification over time (27): (1) Annual Average Daily Truck Traffic at the site (AADTT); (2) Seasonal and day-of-week traffic patterns for trucks; (3) Direction, lane and growth factors for trucks.

Weigh-In-Motion (WIM) devices provide the most extensive traffic data, including volume, classification, and axle/weight data. WIM devices measure transient tire forces that are utilized later to determine static axle weights using computer algorithms. Bending plates, hydraulic load cells, piezoceramic cables, piezopolymer cables, and piezoquartz sensors are typical WIM types for continuous counts (6, and 22). Each sensor technology has its own strengths and weaknesses. Performance of any

WIM system is dependent on environment and site conditions. WIM sites cannot be selected in a purely random fashion because a WIM system only works accurately on a flat, smooth, and well condition pavement.

### *3.3.2 Short Duration Count Programs*

Short count programs can provide up-to-date traffic data for a wide geographic coverage of roadways, which is normally used portable sensors or mats placed on top of the roadway surface and revised each year based on the agency design, operation, and maintenance plans. Short duration counts are most commonly collected for periods of 24 or 48 hours, although seven consecutive days are used as many as possible (22). Because the short count data only represent the traffic conditions in a short time period, the data should be adjusted based on the adjustment factors obtained from the continuous count program.

### *3.3.3 Traffic Monitoring Program in Arkansas*

The traffic monitoring program in Arkansas is currently performed and managed by the Technical Services of Arkansas State Highway and Transportation Department (AHTD). The traffic monitoring program in Arkansas is developed based on the guidelines in FHWA's Traffic Monitoring Guide (TMG) published in May 2001 (27), which deals with the collection of three specific types of data: volume, vehicle classification, and truck weights. Currently, the Technical Services performed two traffic count programs: (1) continuous count program, and (2) short-duration count program. For the continuous count program, the Technical Services operates 79 automated traffic data collection sites, as shown in Figure 3.8.

Of the 79 automated sites, 55 data collection sites are based on Weigh-In-Motion (WIM). The WIM stations are used to continuously collect traffic volume, vehicle classification and vehicle weight. All WIM sites in Arkansas use piezoelectric sensors. The WIM sites are calibrated every three years. The calibration is performed following the guidelines in FHWA’s Traffic Monitoring Guide (27). Since WIM data can develop all the traffic input parameters required in MEPDG software, the WIM monitoring data collected are going to be imported to the database for this project.

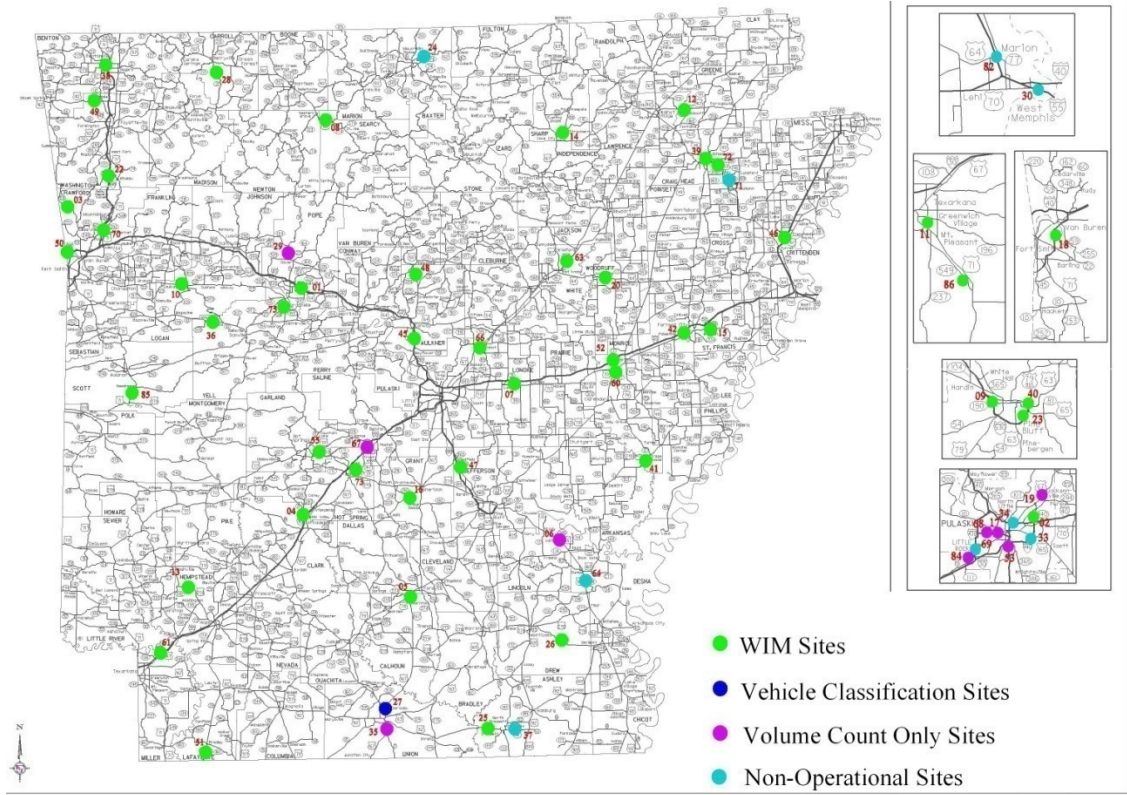


Figure 3.8 Traffic Data Collection in Arkansas (6)

**3.4 Weight-In-Motion (WIM) Traffic Data Quality Check**

Several publications have reported that the traffic data collected from the automated traffic collection sites often have errors, especially the data collected from the WIM sites which use temperature-dependent piezoelectric sensors (6, 22, and 28). Therefore, it is of great importance to conduct quality check on the WIM traffic data.

#### *3.4.1 File Formats*

The WIM traffic monitoring data following FHWA TMG guide are classified into four types (27): station description data, traffic volume data, vehicle classification data, and truck weight data. A Station Description file contains one record for each traffic monitoring station per year. Each type of data is recorded on monthly basis with its own individualized record format. The traffic volume data collected via the FHWA ATR format, which is known as #3 record. The Traffic Volume file contains one record for each day of traffic monitoring. The basis for the vehicle classification data record format is FHWA # 4 Card (also called C-card). This record format supplies one hour of volume information for each of the FHWA 13 category classification by lane for each record in a file. The weight data is recorded in W-Card. The Truck Weight file contains one record for each truck with its axle weights and axle spacings. Specific coding instructions and record layouts are included in Appendix C, which can also be found in Chapter 6 in the 2001 Traffic Monitoring Guide (27).

#### *3.4.2 Vehicle Classification Data*

Firstly, the hourly vehicle classification data should be checked to ensure that only days with exactly twenty-four hours of data were used in deriving the daily traffic counts. The data quality checking methodology proposed in the NCHRP 1-37 A report

(2) is used in this project except for small changes. At start, the program creates a temporary array (Table 3.4), reads the first record of the data file, and enters it into the temporary array with the traffic counts for that record. The program then reads the next record and checks to see if the next record has the same State ID, Traffic Station ID and Date strings as the one stored in the temporary array. If it does, the traffic count for each vehicle class is added to the corresponding value in the array. If it does not, the information in the temporary array is recorded into the master file. Meanwhile, the “tally count” field in the array keeps track of the number of hours of data that is entered into the array. If the count is more or less than 24, the array is discarded. The process continues until every line of data in the file has been processed. Then the program moves to the next data file and this continues until all the data files have been processed. When the program has completed its work, a master data file containing all the daily traffic information will have been created.

Table 3.4 AVC Temporary Array of Hourly Data

	State ID	TRF ID	Year	Month	Day	Direction	Lane	Functional Class	Tally Count	VC1-VC13
# of fields	1	1	1	1	1	1	1	1	1	13

WIM traffic data are collected on monthly basis in Arkansas. However, data other than the specified month and year, data with wrong state code etc. exist in the original data files. It is recommended that the wrong traffic data in the original file be removed and only data with correct time be then processed. In addition, days without a single vehicle counted are also excluded because complete lack of traffic for any days is highly questionable.



After the preliminary check on data completeness, four-step data check procedure, which was used in FHWA 2001 TMG guide, LTPP traffic data collection and TRC 0402 Project (6, 22, and 27), is adopted to evaluate the vehicle classification data. The first step is to compare the manual classification counts and the hourly AVC data. The absolute difference between the manual counts and the hourly AVC data should be less than five percent for each of the primary vehicle categories. The primary vehicle categories are varied based on the roadway functional classification and the design purpose. For MEPDG, the primary vehicle categories that significantly influence traffic loading are vehicle Classes 5, 9, and 13 (2). The second step is to check the number of Class 1 (motorcycles). If a significant number of motorcycles are reported, the equipment may mistakenly record trailers separated from tractors, and the last tandem is recorded as a motorcycle because of its short spacing. The evaluation procedure recommended that the number of Class 1 should be less than five percent unless their presence is noted. The third step is to check the reported number of unclassified vehicles. The number of unclassified vehicles should be less than five percent of the vehicles recorded. If more than five percent of recorded vehicles are unclassified, the equipment may have axle sensing malfunctions that prevent the equipment from measuring all of the appropriate axle pulses. Finally, the current truck percentages by class are compared with the corresponding historical percentages to determine if significant changes in vehicle mix have occurred. One important thing to look for is the unexpected changes of similar vehicle classes, such as vehicle Classes 8 and 9.

For this research project, the manual vehicle classification counts were not available, so the first evaluation step was not performed. For the second and third evaluation steps, the percent of Class 1 (motorcycles) and unclassified vehicles were calculated and evaluated for every station each month. The last step can be performed as follows (2):

(1) Determine the number of trucks by class for each month (January through December) using the available vehicle classification data for each station.

(2) Calculate the normalized class distribution for each month using Equation 3.1.

$$MCDF_j = \frac{AMDTT_{ij}}{\sum_{j=4}^{13} AMDTT_{ij}} \dots\dots\dots(3.1)$$

Where  $MCDF_j$  = Monthly Class Distribution Factor for month i and truck class j;  
 $AMDTT_{ij}$  = Average Monthly Daily Truck Traffic for month i and class j.

(3) Compare the normalized class distribution for each month to determine if unexpected changes in vehicle mix had occurred. Data in the months which had unexpected changes due to the malfunctions of equipment were discarded.

*3.4.3 Vehicle Weight Data*

One of the most important data from a WIM system is vehicle weight data. The weight data must also be checked. The evaluation methods used in LTPP and FHWA TMG guide are adopted to perform the quality control checks for vehicle weight data (22, and 27).

The FHWA and LTPP evaluation procedures recommend two basic steps be taken to evaluate recorded vehicle weight data (6, 22, and 27). All the data check processes are based on vehicle class 9 because vehicle class 9 accounts for the majority of the truck traffic stream. First, the front axle and drive tandem axle weights of Class 9 trucks are checked. Although the front axle is heavier when a truck is loaded, the front axle weight should be between 8,000 and 12,000 lb. The drive tandems of a fully loaded Class 9 truck (generally more than 72,000lb.) should be between 30,000 and 36,000 lb. These limits are based on the extensive analyses of vehicle weight data in the LTPP database (6, 22, and 27).

The next step is to check the gross vehicle weights of Class 9 trucks (6, 22, and 27). This step requires a histogram plot of the gross vehicle weights of Class 9 trucks using a 4,000-lb. increment. The histogram plot should have two peaks for most sites. Based on the LTPP data, for most sites the height of these peaks may be seasonally changed, but the location of the two peaks is fairly constant over time (6, and 27). One represents unloaded Class 9 trucks and should be between 28,000 and 36,000 lb. The second peak represents the most common loaded vehicle condition, whose weigh should be between 72,000 and 80,000 lb. If both peaks shifted in the same direction from their locations based on historical data, the scale is most likely out of calibration. If the loaded peak shifted and the other peak correctly located, the site should be reviewed using additional information, including the types of commodities carried by Class 9 trucks and the load distribution right after the site was last calibrated.

Another statistical parameter should be reviewed is the number of vehicles over the legal weight limit (for the state of Arkansas, the legal weight limit is 80,000 lb.),

especially the number of Class 9 vehicles over 100,000 lb. If the percentage of overweight vehicles is high, the scale calibration should be checked.

In order to carry out the aforesaid evaluation, the computer software to be developed for this project follows these steps (6):

(1) Open a W-Card file;

(2) Find the rows recording the weight data of Class 9 trucks;

(3) Count the number of records for generating the following plots needed for the traffic weight data evaluation:

- For the gross vehicle weights, count the number of trucks that fall in between each 4,000-lb. weight bin;

- For the front axle weights, count the number of front axles that fall in between each 1,000-lb. weight bin;

- For the drive tandem axle weights, count the number of drive tandem axles corresponding to the fully loaded trucks (more than 72,000 lb.) that fall in between each 1,000lb. weight bin;

(4) Generate the histogram plots and follow the data check procedures to evaluate the weight data.

If any data doesn't pass the quality control process, the weight data are regarded as inaccurate and will be marked as bad data in the supporting database.

### **3.5 Traffic Data Processing for MEPDG Inputs**

Only two WIM monitoring files are used to generate the traffic inputs needed by MEPDG software: (1) the vehicle classification record (C-Card), and (2) the vehicle weight record (W-Card). Each vehicle classification file contains one-month record of hourly traffic volume by vehicle class. Each vehicle weight file contains one-month record of passing vehicles with their axle weights and axle spacings.

*3.5.1 Annual Average Daily Traffic (AADT)*

AADT by vehicle category and for total traffic for each station was computed using AASHTO method—a three-step averaging process (27). This method was used instead of the simple average of days approach because it has the advantage of effectively removing most biases that result from missing days of data. This advantage is especially important when missing days are unequally distributed across months or days of the week by weighting each day of the week and each month with the same method regardless of how many days are actually present within that category (27). In the first step of this process, 7 averages corresponding to the 7 days of the week were obtained for each month of the year for each vehicle category and total traffic. These 84 (12 months by 7 days) Monthly Average Days of the Week Traffic (MADWT) volumes are then averaged across all 12 months to yield 7 Annual Average Days of the Week (AADW). The 7 AADW values are averaged to produce AADT. The AASHTO approach for computing AADT can be expressed mathematically as follows (27):

$$AADT_C = \frac{1}{7} \sum_{i=1}^7 \left[ \frac{1}{12} \sum_{j=1}^{12} \left( \frac{1}{n} \sum_{k=1}^n VOL_{ijk} \right) \right] \dots\dots\dots (3.2)$$

Where:

$AADT_c$  = Annual Average Daily Traffic for vehicle category  $c$ ;

$VOL_{ijk}$  = Daily traffic volume for day  $k$ , day-of-week  $i$ , and month  $j$ ;

$i$  = Day of Week (DOW), ranging from 1 to 7 (i.e., Monday through Sunday);

$j$  = Month of the year, ranging from 1 to 12 (i.e., Jan to Dec);

$k$  = Data day used in computation

$n$  = The number of data days from a particular DOW used in computing the average of that DOW in a particular month (maximum of five).

### 3.5.2 Monthly Adjustment Factors

Based on the traffic counts by class obtained from WIM data, the monthly adjustment factors can be calculated. The general procedure can be summarized as follows (2):

(1) For the given traffic data, determine the total number of trucks (in a given class) for each 24-hour period.

(2) Determine the Average Monthly Daily Truck Traffic for each month (AMDTT) in the year.

(3) Sum up the average daily truck traffic for each month for the entire year.

(4) Calculate the monthly adjustment factors by dividing the average daily truck traffic for each month by summing the average daily truck traffic for each month for the entire year and multiplying it by 12 as given below in Equation 3.3 (2, and 27):

$$MAF_1 = 12 \times \frac{AMDTT_1}{\sum_{i=1}^{12} AMDTT_i} \dots\dots\dots (3.3)$$

Where  $MAF_i$  = Monthly Adjustment Factor for month i;  $AMDTT_i$  = Average Monthly Daily Truck Traffic for month i.

*3.5.3 Vehicle Class Distribution Factors*

Normalized vehicle class distribution represents the percentage of each truck class, classes 4 through 13, within the AADTT for the base year. The vehicle class distribution factors can be determined using Equation 3.4. The sum of Class Distribution Factors (CDF) for all classes should equal 100% (2).

$$CDF_j = \frac{AADTT_j}{AADTT} \dots\dots\dots(3.4)$$

Where:  $CDF_j$  = Class Distribution Factor for vehicle class j;  $AADTT_j$  = Annual Average Daily Truck Traffic for class j;  $AADTT$  = Annual Average Daily Truck Traffic for all classes

*3.5.4 Hourly Truck Distribution Factors*

The hourly data are used to determine the percentage of total trucks within each hour as follows:

- (1) Determine the total number of trucks counted within each hour of traffic data in the sample.
- (2) Average the number of trucks for each of the 24 hours of the day in the sample.
- (3) Total the 24 hourly averages from step 3.
- (4) Divide each of the 24 hourly averages from step 2 by the total from step 3 and multiply by 100.

The hourly data can be used to determine Hourly Distribution Factors (HDF) using Equation 3.5 (2). The sum of the percent of daily truck traffic per time increment must add up to 100 percent.

$$HDF_i = \frac{HATT_i}{\sum_{j=1}^{24} HATT_j} \dots\dots\dots(3.5)$$

Where:  $HDF_i$  = Hourly Distribution Factor for ith one-hour time period;  $HATT_i$  = Hourly Average Truck Traffic for ith one-hour time period

3.5.5 *Axle Load Distribution Factors*

Axle load distribution factors can be calculated using WIM data to average the daily number of axles measured within each load interval of an axle type for a truck class divided by the total number of axles for all load intervals. The procedures can be summarized as follows (2):

(1) Assemble WIM data (total the number of axles measured within each axle load range by axle type within each truck class) and calculate the percentage of the total number of axle applications within each load range for each axle type and truck class for each year of data. In other words, normalize the number of axle load applications within each truck class and axle type. The normalized axle load distribution factors must total 100 for each axle type within each truck class.

(2) Calculate the annual mean and variance for each axle load range for each axle type within each truck class. Both the mean and variance are important for determining if there are significant differences between years.



(3) Compare the annual normalized axle load spectra or distributions for the truck class that has the greatest number of truck applications at the site. If the annual normalized values are not significantly different from year to year, all of the years can be combined to result in a site normalized load distribution for each truck class and axle type. If statistical differences (defined based on local experience) are found, the years should be considered separately, and the designer has the following options:

- Decide which axle load distribution should be used as the base year. It is suggested that one axle load distribution for each axle type and truck class be used and that distribution be kept constant throughout the analysis period.
- Decide whether to combine all years, selected years or use only one year of data to determine the base annual axle load distribution for each axle type and truck class.
- Determine how the normalized load distributions change with time and then predict the load distribution values for future years. The load distribution values for future years can then be used to compute an effective load distribution value to design.

#### 3.5.6 *Other Factors*

With the WIM data, some other traffic input parameters can be produced. The developments of these factors are straightforward. These inputs include:

- (1) Percent of truck traffic (class 4 to class 13),
- (2) Percent of trucks in each direction,
- (3) Percent of trucks in design lane,
- (4) Two way annual average daily truck traffic (AADTT),

(5) Traffic growth factors (class 4 to class 13).

### **3.6 Database Tables**

The database tables are designed to meet the requirements for MEPDG software, shown in Table 3.5. The designed tables can be grouped into five categories: tables for general information of WIM stations, tables for vehicle classification data check, tables for weight data check, tables for traffic volume adjustment factors development, and tables for axle load spectra distribution factors development. The tables are self-explanatory through the two columns in Table 3.5: table names and description of table elements.

The structures of the table designs for storing vehicle classification and weight data are different from those in the raw TMG monitoring data files and are customized to meet the requirements in MEPDG. The reason is that the size of the original file is very big and redundant (tens of gigabytes), and therefore pre-processing of the raw data based on MEPDG requirements is necessary to be applied to reduce file size.

Table 3.5 Database Tables for Traffic Module

Data Category	Table Name	Descriptions of Data Elements
General	MEPDG_Traffic_Stations_Yearly	The yearly general descriptive information of the WIM stations.
	MEPDG_Traffic_Stations_TTC	The truck traffic classification (TTC) of the WIM stations.
	MEPDG_Traffic_QC_Vehicle_Class_Available_Month	The month which vehicle classification data are available.
Data Check	MEPDG_Traffic_QC_Vehicle_Class_Result	The quality control result of vehicle classification data.
	MEPDG_Traffic_QC_Weight_Available_Month	The month which weight data are available.
	MEPDG_Traffic_QC_Weight_Average_Front_Axle_Weight	The average front axle weight data for quality control purpose.
	MEPDG_Traffic_QC_Weight_Average_Tandem_Axle_Weight	The average drive tandem axle weight data for quality control purpose.
	MEPDG_Traffic_QC_Weight_Front_Axle_Weight_Monthly	The monthly front axle weight data for quality control purpose.
	MEPDG_Traffic_QC_Weight_Gross_Monthly	The monthly gross weight data for quality control purpose.
	MEPDG_Traffic_QC_Weight_Result	The quality control result of weight data.
	MEPDG_Traffic_Vehicle_Class_Hourly	The original hourly vehicle classification data.
Vehicle Classification Data	MEPDG_Traffic_Vehicle_Class_Average_Monthly	The original monthly vehicle classification data.
	MEPDG_Traffic_Vehicle_Class_Modified_Monthly	The original annual average monthly vehicle classification data. The monthly vehicle classification data which passed the quality control.

Weight Data	MEPDG_Traffic_Weight_Single_Monthly	The original monthly weight data for single axles.
	MEPDG_Traffic_Weight_Average_Single_Monthly	The original annual average monthly weight data for single axles.
	MEPDG_Traffic_Weight_Tandem_Monthly	The original monthly weight data for tandem axles.
	MEPDG_Traffic_Weight_Average_Tandem_Monthly	The original annual average monthly weight data for tandem axles.
	MEPDG_Traffic_Weight_Tridem_Monthly	The original monthly weight data for tridem axles.
	MEPDG_Traffic_Weight_Average_Tridem_Monthly	The original annual average monthly weight data for tridem axles.
	MEPDG_Traffic_Weight_Quad_Monthly	The original monthly weight data for quad axles.
	MEPDG_Traffic_Weight_Average_Quad_Monthly	The original annual average monthly weight data for quad axles.

## CHAPTER 4 MATERIAL INPUTS

### 4.1 Material Characterization

In MEPDG, six major material groups have been developed: asphalt materials, PCC materials, chemically stabilized materials, non-stabilized granular materials, subgrade soils, and bedrock. For each material group, the parameters needed for the design process are classified into three major groups: (1) pavement response model material inputs, (2) material-related pavement distress criteria, and (3) other material properties. Table 4.1 (2) is a tabular summary of the materials inputs arranged by the major material groups.

In the first category are material properties required to predict the states of stress, strain, and displacement within the pavement structure when subjected to an external wheel load. These properties are mandatory inputs for each pavement layer in the system, including elastic modulus ( $E$ ) and Poisson's ratio ( $\mu$ ) of the material. In the second category are all the materials-related inputs that enter the distress or smoothness models directly. Pavement distresses are affected by pavement material properties such as modulus and Poisson's ratio. In addition, parameters such as strength, expansion-contraction characteristics, friction between slab and base, erodibility of underlying layers, layer drainage characteristics, plasticity and gradation, and other material attributes directly influence how a material contributes to a given distress mechanism. These additional materials inputs are specific to the pavement type and distress model

under consideration. Finally, in the third category are materials-related inputs that enter the climatic module to help determine the temperature and moisture profiles through the pavement cross-section. These include engineering index properties (e.g., plasticity index), gradation parameters (porosity, effective grain sizes, etc), and thermal properties (absorptivity, heat capacity, coefficient of thermal expansion, and so on).

Table 4.1 Major Material Inputs by Material Groups

Materials Category	Materials Inputs Required		
	Materials inputs required for critical response computations	Additional materials inputs required for distress/transfer functions	Additional materials inputs required for climatic modeling
Hot-Mix Asphalt Materials (this covers surface, binder, base, and subbase courses)	<ul style="list-style-type: none"> <li>● Time-temperature dependent dynamic modulus (<math>E^*</math>) of HMA mixture.</li> <li>● Poisson's ratio.</li> </ul>	<ul style="list-style-type: none"> <li>● Tensile strength, creep compliance, coefficient of thermal expansion.</li> </ul>	<ul style="list-style-type: none"> <li>● Surface shortwave absorptivity (only required for surface course), thermal conductivity, and heat capacity of HMA.</li> <li>● Asphalt binder viscosity (stiffness) characterization to account for aging.</li> </ul>
PCC Materials (this covers surface layer only)	<ul style="list-style-type: none"> <li>● Static modulus of elasticity (E) adjusted with time.</li> <li>● Poisson's ratio.</li> <li>● Unit weight</li> <li>● Coefficient of thermal expansion.</li> </ul>	<ul style="list-style-type: none"> <li>● Modulus of rupture, split tensile strength, compressive strength, cement type, cement content, water-to-cement (w/c) ratio, ultimate shrinkage, amount of reversible shrinkage.</li> </ul>	<ul style="list-style-type: none"> <li>● Surface shortwave absorptivity, thermal conductivity, and heat capacity of PCC.</li> </ul>
Chemically Stabilized Materials (this covers lean concrete, cement treated, soil cement, lime-cement-flyash, lime flyash, and lime stabilized layers)	<ul style="list-style-type: none"> <li>● Elastic modulus (E) for high quality lean concrete, cement treated material, soil cement, and lime-cement-flyash. Resilient modulus (Mr) for lime stabilized soil.</li> <li>● Poisson's ratio.</li> <li>● Unit weight.</li> </ul>	<ul style="list-style-type: none"> <li>● Minimum resilient modulus (used in flexible design), Modulus of rupture (used in flexible design), base erodibility (for rigid design).</li> </ul>	<ul style="list-style-type: none"> <li>● Thermal conductivity and heat capacity of PCC.</li> </ul>
Unbound Base/ Subbase and Subgrade Materials	<ul style="list-style-type: none"> <li>● Seasonally adjusted resilient modulus (Mr).</li> </ul>	<ul style="list-style-type: none"> <li>● Gradation parameters and base erodibility (for rigid design).</li> </ul>	<ul style="list-style-type: none"> <li>● Plasticity index, gradation parameters, effective grain sizes,</li> </ul>

Materials Category	Materials Inputs Required		
	Materials inputs required for critical response computations	Additional materials inputs required for distress/transfer functions	Additional materials inputs required for climatic modeling
	<ul style="list-style-type: none"> <li>● Poisson's ratio.</li> <li>● Unit weight.</li> <li>● Coefficient of lateral pressure.</li> </ul>		specific gravity, saturated hydraulic conductivity, optimum moisture contents, parameters to define the soil water characteristic curve.
Recycled Concrete Materials—Fractured PCC Slabs	<ul style="list-style-type: none"> <li>● Resilient modulus (Mr).</li> <li>● Poisson's ratio.</li> </ul>	<ul style="list-style-type: none"> <li>● Base erodibility (for rigid design).</li> </ul>	<ul style="list-style-type: none"> <li>● Thermal conductivity and heat capacity.</li> </ul>
Recycled asphalt mix (central plant processed)	Treated same as hot-mix asphalt surface course.		
Cold recycled asphalt pavement (used as aggregate)	Treated same as granular materials with no moisture sensitivity.		
Bedrock	<ul style="list-style-type: none"> <li>● Elastic modulus (E).</li> <li>● Poisson's ratio.</li> <li>● Unit weight.</li> </ul>	None.	None.



## 4.2 Data Sources

### 4.2.1 Default Values in MEPDG

Studies (13 and 29) were performed to assess the relative sensitivity of the models used in the MEPDG Design Guide to inputs relating to PCC materials in the analysis of JPCP pavements, and to inputs relating to Hot-Mix Asphalt (HMA) materials. Based on the studies of sensitivity of various input parameters, the significant levels of inputs can be determined. If certain input does not influence the performance models, the designer can accept the default value provided in MEPDG software with confidence. On the other hand, if an input is "critical" to a successful design, further research will be needed to determine appropriate input value of this parameter. The most "critical" parameters for MEPDG software include dynamic modulus ( $E^*$ ) for Asphalt concrete, Coefficient of Thermal Expansion (CTE) for PCC layers, and resilient modulus ( $M_R$ ) for unbound base, sub-base and subgrade.

### 4.2.2 Dynamic Modulus

The dynamic modulus ( $E^*$ ) of hot-mix asphalt (HMA) is one of the fundamental inputs in MEPDG. To provide the laboratory measured  $E^*$  inputs for AHTD, a comprehensive research effort, project TRC 0304 (7), was completed in Arkansas. The research included a study evaluating different  $E^*$  testing protocols, derived by varying combinations of the number of test replicates and the number of measurement instruments affixed on each test specimen recommended in AASHTO TP 62-03. The total research effort included three replicate specimens from each of four aggregate types (MCA, GMQ, ARK, and JET), three nominal maximum aggregate sizes (12.5, 25,

and 37.5 mm), two PG binder grades(PG 70-22 and PG 76-22), and two air-void levels(design and 7 percent). The  $E^*$  tests were conducted using five test temperatures (-10, 4, 21, 38, and 54<sup>0</sup>C) and six loading frequencies (0.1, 0.5, 1, 5, 10, 25 Hz). The raw mix design data and dynamic modulus test data are from the previous study and stored in “MEPDG\_Material\_AC\_Dyn\_Mod” table in the database under development for AHTD.

#### 4.2.3 *Coefficient of Thermal Expansion*

Studies (5, 8, 13 and 29) have identified the CTE of concrete materials as a very sensitive parameter affecting rigid pavement distress predictions with the MEPDG software. However, many state agencies, including AHTD, currently do not routinely determine the CTE of concrete materials. AHTD has sponsored a research project *PCC Materials Input Values for Mechanistic Empirical Pavement Design Guide*, Project TRC-0708 (8). The CTE measuring equipment is developed in accordance with the AASHTO TP 60. A testing plan including typical aggregates and cement types used for concrete mixture constructed in Arkansas is conducted to develop the typical CTE inputs. The interactive effect of aggregate and cement types on the CTE and pavement performance predictions are under evaluation. In addition, the testing of the PCC strength properties is also included in this project. All the resulting relevant data will be housed in the database upon the completion of TRC-0708.

#### 4.2.4 *Resilient Modulus*

The resilient modulus ( $M_R$ ) parameter is not currently measured by the AHTD, but rather it is typically estimated from R-Value test results. This convention was

accepted primarily to avoid equipment and labor expenses associated with the resilient modulus test. Several previous research projects were conducted in the early 1990s (17 and 18). Two more recent research projects (19 and 20) aim to provide the tools needed to effectively estimate the resilient modulus of subgrade soils throughout Arkansas for MEPDG. Project MBTC 2007 (19) aims to improve the resilient modulus prediction method by developing a material model for subgrade soil based on correlation of soil index properties with the resilient modulus parameter instead of the resilient modulus or R-Value. Twenty soils that contribute a broad aerial coverage (approximately 80%) of the surface soils in the state of Arkansas were selected and tested for simple index and repeated load testing by Qiu, Neo, and Zhao (21). Project MBTC 2032 (20) aims to establish the appropriate testing protocol to determine subgrade resilient modulus using a potential combination of FWD, laboratory testing and seismic methods. The database under development has table spaces to contain relevant data sets based on the previous projects.

#### *4.2.5 LTPP Database*

The Long-Term Pavement Performance (LTPP) program made extensive data collection efforts in both laboratory and field materials testing (30). Therefore, it can be another source to determine the inputs whose values cannot be easily determined in the first stage of the implementation of MEPDG in Arkansas. In the LTPP database, for example, many CTE testing data were found in Specific Pavement Studies (SPS) pavement sections in Arkansas. In addition, large amount of FWD testing data, subgrade and unbound materials resilient modulus, and performance data, are available

in the online LTPP database. The data can be used in the database if proper data check processes are exercised.

### 4.3 Database Tables

Twenty database tables in the materials module of the database are designed to contain material inputs required by the MEPDG software, which can be classified into seven sub-categories: general information, Asphalt Concrete, Portland Cement Concrete (PCC), stabilized base, unbound materials, subgrade and bedrock. The overall structures of the tables are in Table 4.2.

“MEPDG\_Material\_Layer” table contains layer information of a pavement project. This table not only links the master table through the primary key *Project\_ID* and *Section\_ID*, but also acts as a layer reference table for the other material module tables via *Layer\_No* field. All the material tables contain the *Layer\_No* field to refer the layer structure described in the “MEPDG\_Material\_Layer” table. “MEPDG\_Material\_Admix” table contains information on admixture type and amount for PCC layers. “MEPDG\_Material\_Gradation” table contains data on the gradation of combined aggregates for PCC, AC, base, and subgrade. “MEPDG\_Material\_Shoulder” table contains shoulder composition, geometric, and structural properties, including surface material type, width, thickness, base type, and associated details needed for PCC pavement designs.

Seven tables are included in the database for Asphalt Concrete materials. “MEPDG\_Material\_AC\_Binder\_Conventional” table contains the conventional testing

data for asphalt binder, including asphalt grade, original and lab aged asphalt properties obtained from conventional test, such as specific gravity, viscosity, penetration, ductility, and softening point. “MEPDG\_Material\_AC\_Binder\_Brookfield” table contains results from Brookfield (rotational) viscosity testing, whose data can be used as level 1 and level 2 inputs for asphalt binders in MEPDG. “MEPDG\_Material\_AC\_Binder\_DSR” table contains complex modulus and phase angle from Dynamic Shear Rheometer (DSR) tests on asphalt binder at different temperatures. “MEPDG\_Material\_AC\_Mix” table contains mixture data from laboratory mix properties. Data included in this table are maximum specific gravity, bulk specific gravity, effective binder content, air voids, voids in the mineral aggregate, unit weight, poison’s ratio, and general thermal parameters for asphalt mixture.

“MEPDG\_Material\_AC\_Dyna\_Mod” table contains dynamic modulus ( $E^*$ ) testing results of asphalt mixture at different temperatures and rates of loading. Dynamic modulus, as a function of loading frequency and temperature, is the primary mixture-related property of interest for asphalt stabilized layers by the Design Guide software. *Temp\_AC\_Dyna\_Mod* and *Freq\_AC\_Dyna\_Mod* are two important fields to store testing temperatures and loading rates. Dynamic modulus testing data are stored in the *Ave\_AC\_Dyna\_Mod* and *STDEV\_AC\_Dyna\_Mod* fields to represent the average and standard deviation of the testing data. “MEPDG\_Material\_AC\_Creep\_Compliance” table contains data for the creep compliance tests. Creep compliance is stored in the *Creep\_Comp\_\*\_Sec* fields, where \* is the time interval from the initiation of the test in which the creep compliance was calculated. These time intervals are 1, 2, 5, 10, 20, 50, and 100 seconds. “MEPDG\_Materials\_AC\_IDT” table contains testing data for the

indirect tensile strength test. Indirect tensile strengths for three specimens are stored in the *IDT\_Specimen\_\** fields, while the average is stored in the *IDT\_Average* field.

Five tables are designed for PCC materials inputs. “MEPDG\_Material\_PCC\_Joint” table contains information on formed joints in PCC layers, including joint type, joint spacing, load-transfer system, joint sealant, and tie bars. “MEPDG\_Material\_PCC\_Mixture” table contains PCC mix properties, including cement type, air entrainment, slump, and mix proportions. “MEPDG\_Material\_PCC\_Steel” table contains information on steel reinforcement in PCC layers, including reinforcing steel type, diameter, design amount of longitudinal reinforcing, and depth. “MEPDG\_Material\_PCC\_Strength” table contains strength data at different ages for PCC layers, including flexural strength, compressive strength, and elastic modulus. “MEPDG\_Material\_PCC\_Thermal” table contains the thermal properties of PCC layers, such as CTE, thermal conductivity and heat capacity. The coefficient of thermal expansion is stored in the *Coeff\_Thermal\_Expansion* field.

“MEPDG\_Material\_Stabil” table contains data on stabilizing agents used in base and subbase layers, including layer material properties, strength properties, and thermal properties. The strength property inputs for stabilized base required by the MEPDG software are different for flexible and rigid pavements. The rigid pavement analysis requires the elastic or resilient modulus and Poisson's ratio. In addition to these two inputs, the flexible pavement analysis requires the minimum elastic or resilient modulus, and the initial 28-day flexural strength. These inputs are stored in this table.

“MEPDG\_Material\_Subgrade” table contains information on the properties of the subgrade, including plasticity indices, soil classification (AASHTO and Unified

methods), soil strength, laboratory moisture-density relationships, soil suction, expansion index, frost susceptibility, and key gradation properties. “MEPDG\_Material\_Unbound” table contains information on the properties of base layers, including plasticity indices, classification, strength, and laboratory moisture-density relationships. The strength properties of unbound and subgrade required in MEPDG software can be resilient modulus (for level 1 inputs), CBR, R-value, layer coefficient, penetration from DCP (for level 3 inputs). Level 3 strength inputs are stored in “MEPDG\_Material\_Subgrade” table and “MEPDG\_Material\_Unbound” table for subgrade and unbound respectively. The resilient modulus testing data is saved in “MEPDG\_Material\_MR” table, which contains computed values for three load cycles and average values. The three computed values are instantaneous resilient modulus, total resilient modulus, and Poisson’s ratio. The instantaneous resilient modulus is calculated using only the strain recovered during the unloading portion of the cycle, while the total resilient modulus includes the strain recovered during the resting portion of the cycle.

Table 4.2 Database Tables for Material Module

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
General	MEPDG_Material_Layer	Layer information of a pavement project, which links to the master table, materials tables, and performance related tables.
	MEPDG_Material_General_Admix	Admixture amounts and types
	MEPDG_Material_General_Gradation	Gradations of aggregates for all material categories
	MEPDG_Material_General_Shoulder	Shoulder information and associate data needed in PCC design
Asphalt Concrete	MEPDG_Material_AC_Binder_Conventional	(1) Asphalt binder grade; (2) original and lab aged asphalt properties obtained from conventional test, such as softening point, absolute viscosity, Kinematic viscosity, penetration, specific gravity etc.
	MEPDG_Material_AC_Binder_Brookfield	Brookfield (rotational) viscosity of asphalt binder
	MEPDG_Material_AC_Binder_DSR	Binder dynamic complex modulus (G*) and phase angle information from Dynamic Shear Rheometer (DSR) testing
	MEPDG_Material_AC_Mix	(1) Asphalt mixture general properties, such as asphalt content, VMA, air voids, unit weight, poison ratio etc; (2) general thermal parameters for asphalt mixture
	MEPDG_Material_AC_Dyna_Mod	Dynamic modulus of asphalt mixture at different temperatures and rates of loading
	MEPDG_Material_AC_Creep_Compliance	Creep compliance testing at different testing temperature and test duration (1, 2, 5, 10, 20, 50, and 100 seconds)
	MEPDG_Materials_AC_IDT	The tensile strength of the material when subjected to an indirect tensile strength test at a temperature of 14 <sup>0</sup> F
	MEPDG_Material_PCC_Joint	Portland cement concrete layers joint data
	MEPDG_Material_PCC_Mixture	Portland cement concrete layers mixing data
	MEPDG_Material_PCC_Steel	Portland cement concrete layers reinforcing steel data



<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
(PCC)	MEPDG_Material_PCC_Strength	Portland cement concrete layers strength data, including Young's modulus, modulus of rupture, compressive strength and poisson's ratio
	MEPDG_Material_PCC_Thermal	Portland cement concrete layers thermal properties, such as Coefficient of Thermal Expansion (CTE), thermal conductivity and heat capacity parameter
Stabilized Base	MEPDG_Material_Stabil	Stabilizing agent and strength data, including layer material properties, strength properties, and thermal properties
Unbound	MEPDG_Material_Unbound	(1) Strength properties (level 3) of unbound base or subbase material, including CBR, R-value, layer coefficient, DCP value etc; (2) ICM properties of unbound base or subbase material, such as plasticity index, soil classification (AASHTO and Unified), laboratory moisture relationships etc.
Subgrade	MEPDG_Material_Subgrade	(1) Strength properties of subgrade, including CBR, R-value, layer coefficient, DCP value etc; (2) ICM properties of subgrade, such as plasticity index, soil classification (AASHTO and Unified), laboratory moisture relationships etc.
	MEPDG_Material_MR	The resilient modulus testing data (level 1 strength input), which contains basic information on the tested specimen, the resilient modulus, loading conditions, and intermediate calculations for each load sequence.
Bedrock	MEPDG_Material_Bedrock	Bedrock data, such as bedrock type, unit weight, poisson's ratio, resilient modulus of the bedrock

## **CHAPTER 5 CONSTRUCTION, PERFORMANCE, AND MAINTENANCE**

### **DATA**

In addition to setting up required database tables for MEPDG, related data sets, such as construction data, pavement performance data, and maintenance data, are also important for pavement design and management. The database tables are established as follows: 1) the construction information database including as-built sections and results of construction related material tests, 2) the necessary performance measurements as a function of time, 3) the maintenance treatments applied to the constructed pavement sections, which may influence pavement performances.

The main references for this part are based on Long Term Pavement Performance (LTPP) data collection guides (31, 32, 33, and 34) and LTPP Information Management Systems (35).

#### **5.1 Construction Module and Database Tables**

Sound pavement design is important for improving pavement performance, but construction is equally critical for achieving good long-term pavement performance. The construction data collection can be accomplished by core drilling, auguring, test pit opening, sampling, and nuclear density testing along with the subsequent performance of a suite of laboratory material characterization tests on the MEPDG designed pavement sections. These data will be characterized to further enhance the analysis and calibration efforts. In order to facilitate and document the as-constructed pavement

structures, standard laboratory testing protocols and database tables have been developed to record construction and construction related data collected both from the field and from the laboratory.

Forty two tables are designed for construction data and five categories of construction related material testing data (Field sampling, AC, PCC, stabilized base, unbound base & subgrade). The primary keys consist of the PROJECT\_ID, SECTION\_ID, CONSTRUCTION\_NO, LAYER\_NO, SAMPLE\_NO, and TEST\_NO fields, through which database tables in Chapter 2, Chapter 3, Chapter 4, and Chapter 5 are all related. SAMPLE\_NO indicates where the sample was obtained, which can be used as a surrogate for the actual longitudinal and transverse location of the sampling at a test section. TEST\_NO is a subsequence number assigned to the test samples. The tables for construction module and their descriptions are shown in Table 5.1.

#### *5.1.1 As-Constructed Data*

Construction data tables are designed for four categories of pavements in the developed supporting database: AC pavements, PCC pavements, AC overlays, and PCC overlays.

“MEPDG\_Construction\_AC\_Compaction” table contains compaction data for all types of AC layers, including information on the type, weight, and speed of rollers used for compaction and their coverages. “MEPDG\_Construction\_AC\_Const” table contains construction data for AC layers. This table includes plant information, lay-down temperatures and lift thickness, etc.

“MEPDG\_Construction\_PCC\_Aggr” table contains the properties of the aggregate used in PCC layers, including aggregate composition, durability, specific gravity, and gradation. “MEPDG\_Construction\_PCC\_Const” table contains construction data for PCC layers, including information on curing, temperature, and existing surface preparation. “MEPDG\_Construction\_PCC\_Joint” table contains joint data for PCC layers, including information on construction and expansion joints, sealants, and load-transfer devices. “MEPDG\_Construction\_PCC\_Mix” table contains PCC mixture data, including information on mix design, admixtures, slump, air entrainment, and other PCC mix properties. “MEPDG\_Construction\_PCC\_Steel” table contains information on reinforcing steel used in PCC layers, including the type and strength of the reinforcement and some placement information.

“MEPDG\_Construction\_Subgrade\_Prep” table contains subgrade preparation data, including information on compaction, stabilizing agents, and lift thicknesses for fill sections. “MEPDG\_Construction\_Unbound\_Agg” table contains placement information associated with unbound aggregate base layers, including compaction equipment and lift thicknesses.

“MEPDG\_Construction\_AC\_Overlay” table contains placement data for AC overlays, including equipment and plant information, surface preparation, haul times for each AC layer, etc. “MEPDG\_Construction\_PCC\_Overlay” table contains information on placement operations of PCC overlays, including air temperatures, curing, sawing, grouting, and texturing.

### *5.1.2 Field Materials Sampling Data*

The field sampling information from materials sampled in-place in the field is stored in “MEPDG\_Const\_Hole\_Log” table and “MEPDG\_Const\_Sample\_Log” table. “MEPDG\_Const\_Hole\_Log” table contains a record of each coring hole, auguring hole, or testing pit cut in testing pavement sections for the purpose of extracting material samples. This table includes the date the hole was dug, the location of the hole, the dimensions of the hole, etc. “MEPDG\_Const\_Sample\_Log” contains the sampling information, which includes where the sample was taken and a description of the material sampled.

“MEPDG\_Const\_InSitu\_Nuclear\_Gauge” table contains in situ density and moisture content measurements using a nuclear density gauge. Up to six measurements of dry density (ISD\_DRY\_\*), wet density (ISD\_WET\_\*), and moisture content (ISMC\_\*), along with their respective averages (ISD\_DRY\_AVG, ISD\_WET\_AVG, ISMC\_AVG) are stored in this table.

“MEPDG\_Const\_InSitu\_DCP” table contains the results of the measurements from the Dynamic Cone Penetrometer (DCP) test. The measurements are stored for each reading. Each reading consists of the number of blows since the last reading, the penetration since the last reading, the cumulative penetration, and the DCP index.

### *5.1.3 AC Testing Data*

The following AC related tables include the testing results of sampled and extracted binder, aggregate, and cores.

“MEPDG\_Const\_AC\_Core\_General” table contains the results of a visual examination of an AC core. The height of the core is stored in the

CORE\_AVG\_THICKNESS field. “MEPDG\_Const\_AC\_Specific\_Gravity\_Bulk” table contains bulk specific gravity test results from AC cores. Calculated bulk specific gravity is stored in the BSG field. In addition, percent moisture absorption is available from the WATER\_ABS field. “MEPDG\_Const\_AC\_Specific\_Gravity\_Max” table contains theoretical maximum specific gravity test results from AC cores. Calculated maximum specific gravity is stored in the MAX\_SPEC\_GRAVITY field. “MEPDG\_Const\_AC\_Extracted\_Asphalt\_Content” table contains extracted asphalt content test results from AC cores. Calculated asphalt content is stored in the ASPHALT\_CONTENT\_MEAN field. “MEPDG\_Const\_AC\_Volumetric” table contains test results and corresponding computed volumetric properties of laboratory compacted and field cores of asphalt concrete. The volumetric properties include effective binder content, voids in the mineral aggregate (VMA), air voids (AV), voids filled with asphalt (VFA), and specific gravity of the mix components.

“MEPDG\_Const\_Binder\_Penetration” table contains the results of penetration tests conducted on extracted asphalt cements at 25 °C (77 °F) and 68 °C (155 °F). The three data fields are PENETRATION\_77\_F, PENETRATION\_155\_F, and PENETRATION\_INDEX. “MEPDG\_Const\_Binder\_Specific\_Gravity” table contains the results of specific gravity tests on extracted asphalt cement. Calculated specific gravity is stored in the SPECIFIC\_GRAVITY data field. “MEPDG\_Const\_Binder\_Viscosity\_Kinematic\_Absolute” table contains the results of kinematic viscosity testing at 135 °C (275 °F) and absolute viscosity testing at 60 °C (140 °F). The summary data fields are KINEMATIC\_VISC\_275\_F and ABSOLUTE\_VISC\_140\_F. “MEPDG\_Const\_Binder\_DSR” table contains the test

device configuration information, the complex modulus and phase angle data from DSR tests on asphalt cement samples at different temperatures.

“MEPDG\_Const\_ExtractAggregate\_Specific\_Gravity\_Coarse” table contains the bulk specific gravity and percent moisture absorption of extracted coarse aggregate from AC cores. These data are stored in the BSG\_OF\_COARSE\_AGG and ABSORPTION\_OF\_COARSE\_AGG fields.

“MEPDG\_Const\_ExtractAggregate\_Specific\_Gravity\_Fine” table contains the bulk specific gravity and percent moisture absorption of extracted fine aggregate from AC cores. These data are stored in the BSG\_OF\_FINE\_AGG and ABSORPTION\_OF\_FINE\_AGG fields.

“MEPDG\_Const\_ExtractAggregate\_Gradation” table contains the gradation of extracted aggregate from AC cores. Gradation is determined by sieve analysis. The sieve set used consists of 37.5-mm (1½-inch), 25.0-mm (1-inch), 19.0-mm (¾-inch), 12.5-mm (½-inch), 9.5-mm (⅜-inch), 4.75-mm (No. 4), 2.00-mm (No. 10), 425-µm (No. 40), 180 µm (No. 80), and 75µm (No. 200) sieves. The percent passing each sieve is stored in a data field such as ONE\_AND\_HALF\_PASSING for the 37.5-mm (1½-inch) sieve or NO\_80\_PASSING for the 180 µm (No. 80) sieve.

#### *5.1.4 PCC Testing Data*

“MEPDG\_Const\_PCC\_Core\_General” table contains the visual examination notes for PCC cores. This table provides the thickness of the core, which is stored in the CORE\_AVG\_THICKNESS field. “MEPDG\_Const\_PCC\_Density” table contains the density measurements for PCC cores. Bulk specific gravity, apparent specific gravity,

density, and percent voids are stored in the BULK\_SPECIFIC\_GRAVITY\_DRY, APPARENT\_SPECIFIC\_GRAVITY, DENSITY\_OF\_PCC, and PERCENT\_VOIDS\_IN\_PCC fields respectively.

“MEPDG\_Const\_PCC\_Compressive\_Strength” table contains the compressive strength of PCC cores. Compressive strength is stored in the COMP\_STRENGTH field and the observed fracture mechanism is stored in the COMP\_FRAC\_OTHER field. Several other intermediate calculations, such as the length and diameter of the specimen, are also stored. “MEPDG\_Const\_PCC\_Elastic\_Modulus” table contains the elastic modulus of PCC cores. Elastic modulus is stored in the ELASTIC\_MOD field, Poisson’s ratio is stored in the POISSON\_RATIO field, and unit weight is stored in the UNIT\_WT field. “MEPDG\_Const\_PCC\_Rupture” table contains the rupture strength of PCC beams that are poured from materials sampled at the time of construction. The modulus of rupture is stored in the MODULUS\_OF\_RUPTURE field.

“MEPDG\_Const\_PCC\_CTE” table contains the CTE data of PCC cores. The coefficient of thermal expansion is stored in the COEFF\_THERMAL\_EXPANSION field. Because aggregate type significantly influences the CTE value (6), a text description of the character of the aggregate type is included in the AGGR\_TYPE\_PCC field.

#### *5.1.5 Stabilized Base/Subbase Testing Data*

“MEPDG\_Const\_Stablized\_General” table contains various classification results for treated base materials. The overall description of the treated material is stored in the DETAIL\_TREAT\_MATL field. The DETAIL\_TREAT\_TYPE field identifies



the treatment agent. In addition, there are various soil geology-related fields and aggregate-type fields that may or may not be populated based on the nature of the treated material.

“MEPDG\_Const\_Stablized\_Compressive\_Strength” table contains unconfined compressive strength results for treated base materials. Compressive strength is stored in the COMP\_STRENGTH field. Its corresponding fracture mode is stored in the COMP\_STRENGTH\_FRAC field.

#### *5.1.6 Unbound Materials and Subgrade Testing Data*

Some subgrade and unbound layer tests can be conducted according to the same protocols. Therefore the table with a name reflecting both materials are designed to store the corresponding data. For example, testing data of sieve analysis for unbound materials and subgrade are located in MEPDG\_Const\_Unbound/Subgrade\_Sieve\_Analysis.

“MEPDG\_Const\_Unbound/Subgrade\_Sieve\_Analysis” table contains the gradation of unbound granular base, subbase, and subgrade materials. Gradation analysis is conducted by the washed sieve test, with the washed fines included with the percent passing the 75- $\mu$ m (No. 200) sieve. The sieve set specified in the test protocol consists of the 75-mm (3-inch), 50-mm (2-inch), 37.5-mm (1½-inch), 25.0-mm (1-inch), 19.0-mm (¾-inch), 12.5-mm (½-inch), 9.5-mm (⅜-inch), 4.75-mm (No. 4), 2.00-mm (No. 10), 425- $\mu$ m (No. 40), 180- $\mu$ m (No. 80), and 75- $\mu$ m (No. 200) sieves. The name of field is based on the U.S. customary sieve size name. In addition, the total dry weight of the sample before washing is stored in the SAMPLE\_WT field and the moisture content of the sample prior to testing is stored in the MOISTURE\_CONTENT field. “MEPDG\_Const\_Unbound/Subgrade\_Classification” table contains the general

classification of unbound granular base, subbase, and subgrade materials. Information in this table includes maximum particle size (MAX\_PART\_SIZE), soil color (SOIL\_COLOR), fields for the description codes of the type SOIL\_CRITERA, including American Society for Testing and Materials (ASTM) classification (DESC\_CODE\_\*), and AASHTO classification (AASHTO\_SOIL\_CLASS). “MEPDG\_Const\_Unbound/Subgrade\_Atterberg\_Limits” table contains the Atterberg limit test results for unbound granular base, subbase, and subgrade materials. The liquid limit, plastic limit, and plasticity index are stored in the LIQUID\_LIMIT, PLASTIC\_LIMIT, and PLASTICITY\_INDEX fields respectively. “MEPDG\_Const\_Unbound/Subgrade\_Proctor” table contains standard Proctor test results for unbound granular base, subbase, and subgrade materials. Only the optimum dry density and moisture content are stored in the table (in the MAX\_LAB\_DRY\_DENSITY and MAX\_LAB\_MOISTURE fields, respectively). “MEPDG\_Const\_Unbound/Subgrade\_InSitu\_Moisture” table contains the in situ moisture content of unbound base, subbase, and subgrade materials as measured by drying samples in the laboratory. Measured moisture content is stored in the MOIST\_CONTENT field. “MEPDG\_Const\_Unbound/Subgrade\_Specific\_Gravity” table contains the specific gravity of unbound base and subgrade materials. The field SPEC\_GRAVIT contains the specific gravity value for the material sample.

“MEPDG\_Const\_Unbound/Subgrade\_Resilient\_Modulus” table contains the average resilient modulus and some intermediate calculations for the five loading sequences at each stress state. The stress state is indicated by the combination of the CON\_PRESSURE and NOM\_MAX\_AXIAL\_STRESS fields. Average cyclic stress

and resilient strain are stored in the APPLIED\_CYCLIC\_STRESS\_AVG and RES\_STRAIN\_AVG fields respectively, with standard deviations stored in APPLIED\_CYCLIC\_STRESS\_STD and RES\_STRAIN\_STD. The average and standard deviations of the resilient moduli values calculated for that specimen and the stress state are stored in the RES\_MOD\_AVG and RES\_MOD\_STD fields respectively. Several intermediate calculations (including maximum axial stress, contact stress, and average deformations) are also included.

Table 5.1 Database Tables for Construction Module

Data Category	Table Name	Descriptions of Data Elements
Construction	MEPDG_Construction_AC_Compaction	Compaction data for AC layers.
	MEPDG_Construction_AC_Const	Construction data for AC layers.
	MEPDG_Construction_PCC_Aggr	The properties of the aggregate used in PCC layers, including aggregate composition, durability, specific gravity, and gradation.
	MEPDG_Construction_PCC_Const	Construction data for PCC layers, including information on curing, temperature, and existing surface preparation.
	MEPDG_Construction_PCC_Joint	Joint data for PCC layers, including information on construction and expansion joints, sealants, and load-transfer devices.
	MEPDG_Construction_PCC_Mix	PCC mixture data for PCC layers, including information on mix design, admixtures, slump, air entrainment, and other PCC mix properties.
	MEPDG_Construction_PCC_Steel	Information on reinforcing steel used in PCC layers, including the type and strength of the reinforcement and some placement information.
	MEPDG_Construction_Subgrade_Prep	Subgrade preparation data, including information on compaction, stabilizing agents, and lift thicknesses for fill sections.
	MEPDG_Construction_Unbound_Agg	Placement information associated with unbound aggregate base layers, including compaction equipment and lift thicknesses.
	MEPDG_Construction_AC_Overlay	Placement data for the AC overlays, including

Data Category	Table Name	Descriptions of Data Elements	
		equipment and plant information, surface preparation, haul times for each AC layer, etc.	
	MEPDG_Construction_PCC_Overlay	Information on the placement operations of PCC overlays, including air temperatures, curing, sawing, grouting, and texturing.	
Field Materials & Sampling	MEPDG_Const_Hole_Log	Records of coring holes, auguring holes, or testing pit cuts in testing pavement sections.	
	MEPDG_Const_Sample_Log	Sampling information.	
	MEPDG_Const_InSitu_Nuclear_Gauge	In situ density and moisture content measurements using a nuclear density gauge.	
	MEPDG_Const_InSitu_DCP	The results of the measurements from the Dynamic Cone Penetrometer (DCP) test.	
	MEPDG_Const_AC_Core_General	The results of a visual examination of an AC core.	
	MEPDG_Const_AC_Specific_Gravity_Bulk	Bulk specific gravity test results from AC cores.	
	MEPDG_Const_AC_Specific_Gravity_Max	Theoretical maximum specific gravity test results from AC cores.	
	MEPDG_Const_AC_Extracted_Ashphalt_Content	Extracted asphalt content test results from AC cores.	
	AC Construction Related Testing	MEPDG_Const_AC_Volumetric	Test results and corresponding computed volumetric properties of sampled asphalt concrete, including effective binder content, VMA, AV, VFA, and specific gravity.
		MEPDG_Const_Binder_Penetration	The results of penetration tests conducted on extracted asphalt cements at 25 °C (77 °F) and 68 °C (155 °F).
MEPDG_Const_Binder_Specific_Gravity		The results of specific gravity tests on extracted asphalt cement.	
MEPDG_Const_Binder_Viscosity_Kinematic_Absolute		the results of kinematic viscosity testing at 135 °C	

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
		(275 °F) and absolute viscosity testing at 60 °C (140 °F)
	MEPDG_Const_Binder_DSR	The DSR test device configuration, the complex modulus and phase angle at different temperatures.
	MEPDG_Const_ExtractAggregate_Specific_Gravity_Coarse	The bulk specific gravity and percent moisture absorption of extracted coarse aggregate from AC cores
	MEPDG_Const_ExtractAggregate_Specific_Gravity_Fine	The bulk specific gravity and percent moisture absorption of extracted fine aggregate from AC cores
	MEPDG_Const_ExtractAggregate_Gradation	The gradation of extracted aggregate from AC cores
	MEPDG_Const_PCC_Core_General	The visual examination notes for PCC cores
	MEPDG_Const_PCC_Density	The density measurements for PCC cores
	MEPDG_Const_PCC_Compressive_Strength	The compressive strength of PCC cores
	MEPDG_Const_PCC_Elasticity_Modulus	The static modulus of elasticity of PCC cores
	MEPDG_Const_PCC_Rupture	The rupture strength of PCC beams
	MEPDG_Const_PCC_CTE	The CTE data of PCC cores
	MEPDG_Const_Stabilized_General	Classification results for treated base materials.
	MEPDG_Const_Stabilized_Compressive_Strength	Unconfined compressive strength results for treated base materials
	MEPDG_Const_Unbound/Subgrade_Sieve_Analysis	Gradation of unbound granular base, subbase, and subgrade materials
	MEPDG_Const_Unbound/Subgrade_Classification	General classification of unbound granular base, subbase, and subgrade materials.
	MEPDG_Const_Unbound/Subgrade_Atterberg_Limits	Atterberg limit test results for unbound granular base, subbase, and subgrade materials
	MEPDG_Const_Unbound/Subgrade_Proctor	Standard Proctor test results for unbound granular
PCC Construction Related Testing		
Stabilized Construction Related Testing		
Unbound and Subgrade Construction Related Testing		

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
		base, subbase, and subgrade materials
	MEPDG_Const_Unbound/Subgrade_InSitu_Moisture	In situ moisture content of unbound base, subbase, and subgrade materials
	MEPDG_Const_Unbound/Subgrade_Specific_Gravity	Specific gravity of unbound base and subgrade materials
	MEPDG_Const_Unbound/Subgrade_Resilient_Modulus	Testing results of resilient modulus.

## 5.2 Performance Module and Database Tables

Pavement performance in MEPDG includes consideration of functional performance, structural performance, and safety. MEPDG is primarily concerned with functional and structural performance.

The structural performance of a pavement relates to its physical condition, such as fatigue cracking and rutting for flexible pavements, and joint faulting, and slab cracking for rigid jointed pavements, or other conditions that would adversely affect the load-carrying capability of the pavement structure or would require maintenance (2).

The functional performance of a pavement concerns how well the pavement serves highway users. Riding quality is the dominant characteristic of functional performance. In MEPDG, the chosen functional performance indicator is pavement smoothness as indicated by the International Roughness Index (IRI).

Although information pertinent to safety is not required in MEPDG, it is of great importance for pavement operation. The guideline on pavement friction was developed in the *Guide for Pavement Friction* (32). Database tables to store safety data are designed for potential future usage.

Some nondestructive testing (NDT) methods are included in MEPDG for existing pavement evaluation. The NDT techniques include the application of Ground Penetrating Radar (GPR) to determine in-situ layer thickness and material properties, profile testing to determine pavement surface smoothness, friction testing to determine pavement surface-vehicle tire skid resistance, and deflection testing with a Falling Weight Deflectometer (FWD).



The pavement performance data are stored in the MEPDG\_Perf module, including distress, faulting, transverse profile distortion (Rutting), longitudinal profile (IRI), Falling Weight Deflectometer (FWD) deflection, friction, and Ground Penetrating Radar data. There are ten tables for the MEPDG\_Perf module. Their descriptions are shown in Table 5.2.

Data stored in the “MEPDG\_Perf\*\_Distress” tables provide a measure of pavement surface condition, including the amount and severity of cracking, patching and potholes, existence of surface deformation, joint defects, and other types of surface defects. \* can stand for AC, JPCP and CRCP. The tables are designed according to the *Distress Identification Manual for the Long-Term Pavement Performance (33)*. A null should be interpreted that a particular distress was not rated or a measurement was not performed. A zero indicates that the distress was not present. “MEPDG\_Perf\_JPCC\_Faulting” table contains measurements of faulting height on individual joints and cracks. Data on the transverse profile (IRI) and rut-related distresses are stored in “MEPDG\_Perf\_Profile” table and “MEPDG\_Perf\_Rutting” table.

“MEPDG\_Perf\_FWD\_General” table contains the general information of each FWD measurements, including test date, test location, FWD serial number, operator, deflection sensor offsets etc. “MEPDG\_Perf\_FWD\_Testing\_Data” table contains peak deflection and applied load measurements for every drop conducted at each test point on a pavement section. “MEPDG\_Perf\_Friction” table stores the results of friction tests on pavement sections. “MEPDG\_Perf\_GPR” table stores the Ground Penetrating Radar (GPR) data to provide an estimate of pavement layer thickness.

Table 5.2 Database Tables for Performance Module

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
Distress	MEPDG_Perf_AC_Distress	Distress survey of pavements with AC surfaces, including the amount and severity of cracking, patching and potholes, existence of surface deformation, and other types of surface defects.
	MEPDG_Perf_AC_Rutting	Field measured rut depths and elevation difference profile
	MEPDG_Perf_JPCP_Distress	Distress survey of pavements with jointed PCC surfaces, including the amount and severity of cracking, patching, joint defects, and other types of surface defects.
IRI	MEPDG_Perf_JPCP_Faulting	Joint faulting for JPCP pavement surfaces, containing measurements of faulting height on individual joints and cracks.
	MEPDG_Perf_CRCP_Distress	Distress survey of pavements with continuously reinforced PCC surfaces, including the amount and severity of cracking, patching, and other types of surface defects.
FWD Deflection	MEPDG_Perf_Profile	Transverse pavement surface profile and IRI data
	MEPDG_Perf_FWD_General	The general information of each FWD measurements, including test date, test location, FWD serial number, operator, deflection sensor offsets etc.
	MEPDG_Perf_FWD_Testing_Data	Peak deflection and applied load measurements for every drop conducted at each test point on a pavement section
Friction	MEPDG_Perf_Friction	The results of friction tests on pavement sections
GPR	MEPDG_Perf_GPR	The Ground Penetrating Radar (GPR) data to provide an estimate of pavement layer thickness

### **5.3 Maintenance Module and Database Tables**

Maintenance plays an essential role in the life of a pavement. Some maintenance activities may change the deterioration of pavement performance and therefore it may be important for MEPDG pavement performance calibration. Generally, it is assumed that there is no significant pavement structure change from a maintenance event, and therefore no maintenance layer table exists.

During pavement rehabilitation, pavement structures have changed and the required data inputs are similar to those for newly designed pavements. Therefore, rehabilitation data can be saved into the tables designed for newly designed pavements. In this project, no tables are specifically designed to store rehabilitation data.

If rehabilitation does apply to the pavement section, the field of CONSTRUCTION\_NO will be assigned to a subsequent number to reveal the number of rehabilitation treatments. For example, 0 for CONSTRUCTION\_NO indicates newly pavement without any rehabilitation, while 1 means that the pavement was once rehabilitated. The rehabilitation data (including required material inputs, as-construction data, monitoring performance data, etc.) are then saved into the corresponding tables in the database designed for newly designed pavements.

The MEPDG\_MAINT module contains data reported on maintenance treatments. The common applied maintenance activities include seal coats, crack sealing, patching, joint sealing, grinding, milling less than 25.4 millimeters (mm) (1 inch) deep, and grooving. The tables designed for the database under development and their descriptions are shown in Table 5.3.

“MEPDG\_Maint\_PCC\_Crack\_Seal” table contains crack sealing information for PCC pavements, including the type of sealant used, how it was applied, and how much sealing was performed. “MEPDG\_Maint\_PCC\_Full\_Depth” table contains information on full-depth PCC repair, including the reasons for the repair, the size of the replacement slab, the material used for replacement, the interface of the replacement with the existing pavement, and finishing/curing methods. “MEPDG\_Maint\_PCC\_Joint\_Reseal” table contains joint resealing information for PCC pavements, including information on the removal of existing joint sealant, the application and type of the new sealant, and the quantity of sealing performed. “MEPDG\_Maint\_PCC\_Part\_Depth” table contains information on partial-depth patching for PCC pavements, including the reasons for patching, the type of patching performed, the material used for patching and material properties, jointing, and curing methods for PCC patches.

“MEPDG\_Maint\_Asphalt\_Crack\_Seal” table contains crack sealing information for AC pavements, including the type of sealant used, how it was applied, and how much sealing was performed. “MEPDG\_Maint\_Asphalt\_Patch” table contains patching information for AC pavements, including the reasons for patching, the size of patching, and patching techniques. “MEPDG\_Maint\_Asphalt\_Seal” table contains seal-coat application information for AC pavements, including the reasons for sealing, the type and properties of the sealant used, and application information.

“MEPDG\_Maint\_GMG” table contains information on diamond grinding, milling, and grooving of all pavement surface types, including the reasons for treatment and the details of the treatment type and application.

Table 5.3 Database Tables for Maintenance Module

<b>Data Category</b>	<b>Table Name</b>	<b>Descriptions of Data Elements</b>
PCC	MEPDG_Maint_PCC_Crack_Seal	Crack sealing information for PCC pavements.
	MEPDG_Maint_PCC_Full_Depth	Information on full-depth PCC repair.
	MEPDG_Maint_PCC_Joint_Reseal	Joint resealing information for PCC pavements.
	MEPDG_Maint_PCC_Part_Depth	Information on partial-depth patching for PCC pavements.
AC	MEPDG_Maint_Asphalt_Crack_Seal	Crack sealing information for AC pavements.
	MEPDG_Maint_Asphalt_Patch	Patching information for AC pavements.
	MEPDG_Maint_Asphalt_Seal	Seal-coat application information for AC pavements.
Others	MEPDG_Maint_GMG	Information on diamond grinding, milling, and grooving of all pavement surface types.

## CHAPTER 6 DATABASE AND SOFTWARE PREPME APPLICATION

### 6.1 Database Structural Design

Microsoft Access is used to set up the relational supporting database for MEPDG. A relational database model is used with multiple tables with “fields” and “records”. Data is entered in “cells”, the boxes created by the fields and records. Multiple tables are linked by key fields relating their contents to each other. The *primary key field*, which is present in all tables, serves as the main identifier for the data linking all tables.

The developed supporting database is divided into seven modules: General Information Module, Climate Data Module, Traffic Data Module, Material Data Module, Construction Data Module, Performance Data Module, and Maintenance Data Module, each with a distinctive function. The “MEPDG\_General\_Project” is the only table designed in the Genral Information Module to serve as the master control table of the database. . It contains the general project information required in MEPDG software, including not only project location coordinates by route number and milepost, longitude and latitude, direction of travel, road identification number, construction number, but also the pavement functional class, the Truck Traffic Classification which represents the traffic stream information, pavement type, lane width, number of lanes, construction completion and traffic open dates. All the other data module are discussed in Chapter 2 to Chapter 5.

Following the LTPP schema, a prefix “MEPDG” is used for all data table names. The second part of a table name identifies the module to which a particular table belongs. Others define the specific type of data stored in the table. For example, the table named with “MEPDG\_Material\_AC\_Dyna\_Mod” stores the asphalt concrete dynamic modulus testing data in the Material Module for MEPDG usage.

Figure 6.1 illustrates the relational structure of the supporting database. “MEPDG\_Geneal\_Project” table serves as the master table to link all the other tables in the database. Fields with primary keys are shown with a key symbol in Figure 6.1. The “MEPDG\_Material\_Layer” contains layer structure information of a pavement project. This table not only links the master table through the primary key *Project\_ID* and *Section\_ID*, but also acts as a layer reference table to the material module tables and performance module tables via *Lay\_No* field.

The developed software program in this research is called PrepME for the preparation of input data sets for MEPDG.

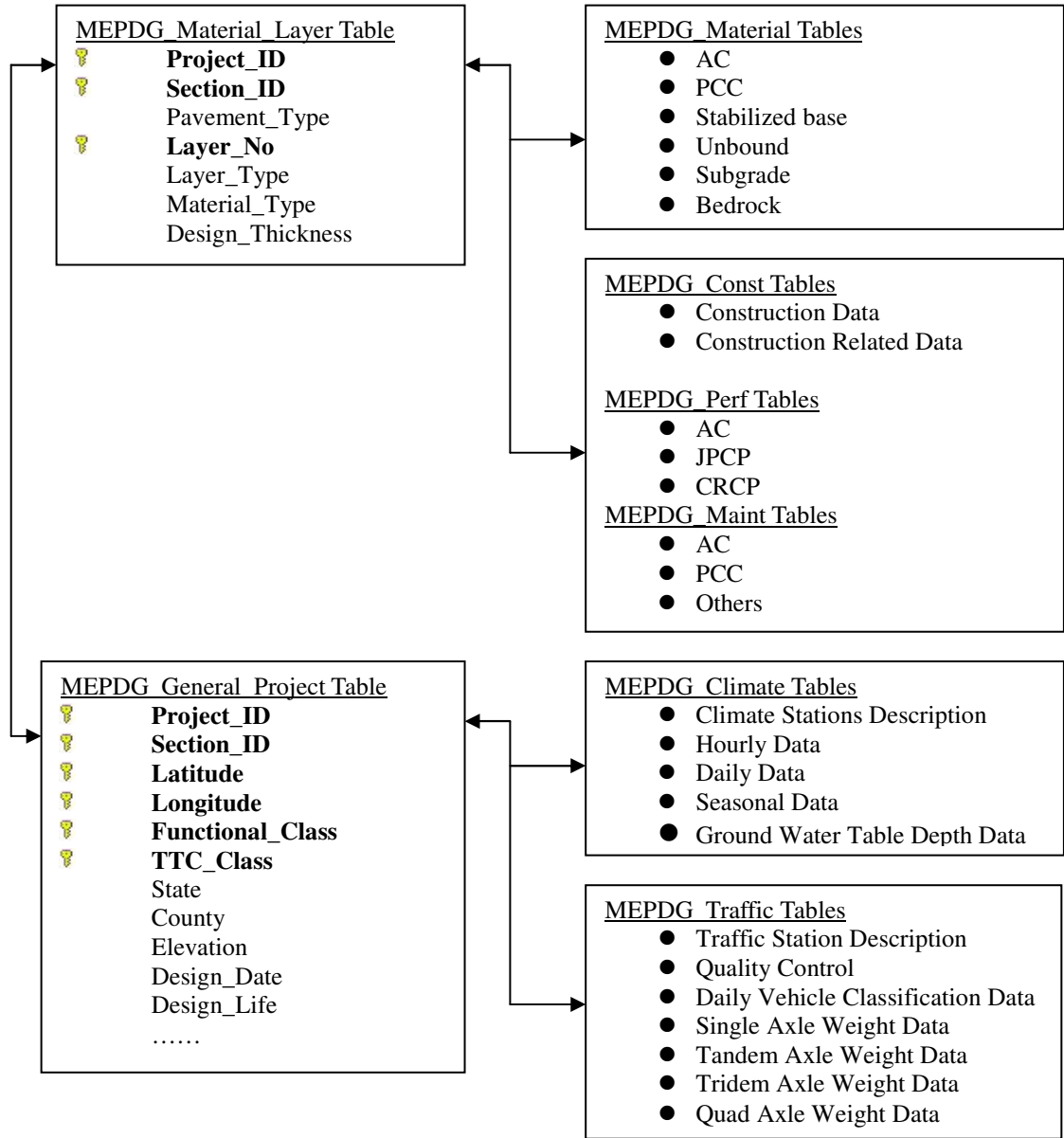


Figure 6.1 Supporting Database Structure



**6.2 Software Capabilities of PrepME**

The opening interface of the developed software, PrepME, is shown in Figure 6.2. Four capabilities are provided in PrepME: “Import Raw Data”, “Traffic Data Check”, “Interpolation of Climate & Traffic Data” and “Retrieve Material Data”.

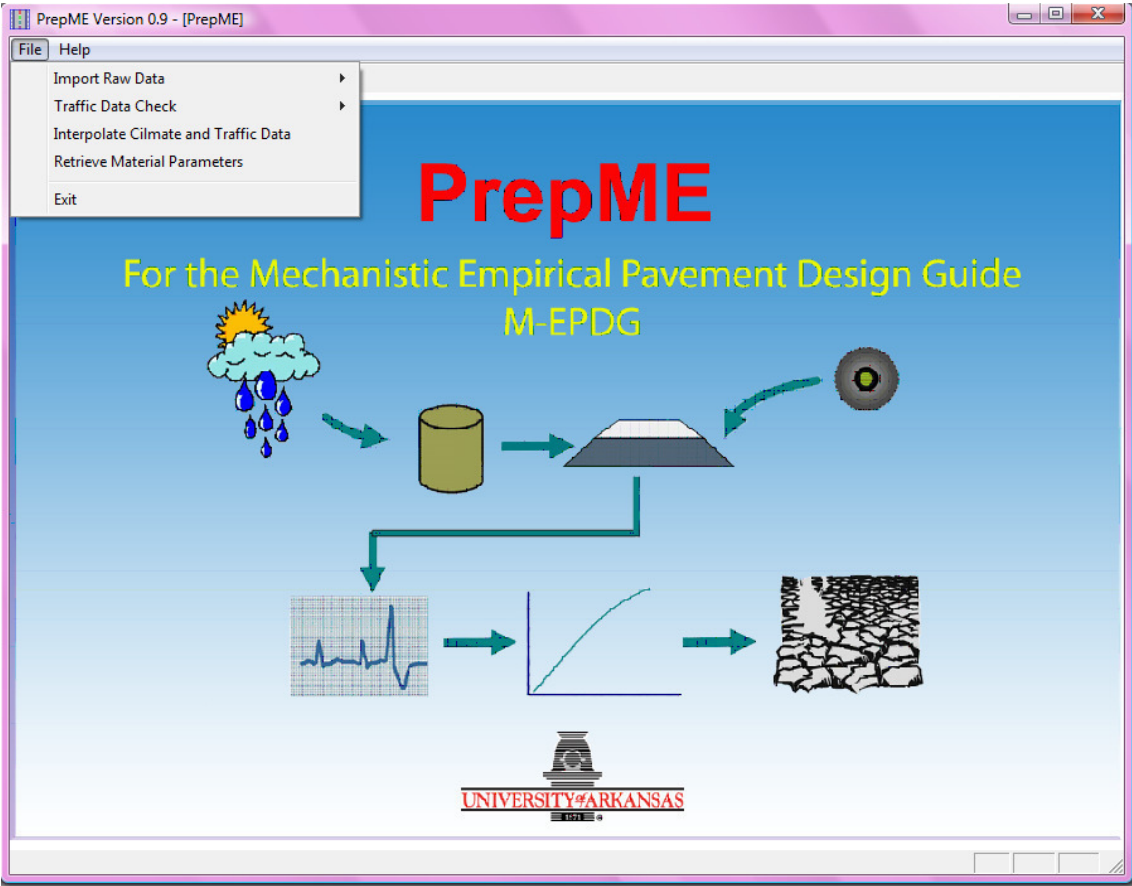


Figure 6.2 Opening Interface of PrepME

*6.2.1 Climate Module*

The PrepME software has the capability to prepare climate data files that can be directly imported to the MEPDG software. If GPS coordinates of a design project are available, the database software can automatically search the closest adjacent weather stations and water table depth testing stations in the vicinity of the project and interpolate the required data among these locations inversely weighted by the distances from the location, and then generate the climate file (“icm” file) for the specific design project. When the data generating process is completed, a geo-referenced map (Figure 6.3) is activated to show the geographical relationships among the project designed, climate stations adopted in the interpolation process, and the surrounding area. This mapping utility is integrated into the database application, and has all major functions of Go-mapping, such as displaying satellite imagery and zooming functionalities.

Although the climate module is an integral part of the MEPDG software, the climate software module in PrepME has several advantages: (1) the PrepME software provides the water table depth data sets and automatically produces the “icm” file with all required climate data. The designer just needs to locate the prepared file and import to the MEPDG software. By contrast, with the MEPDG software, water table depth should be manually input through MEPDG software interface; (2) the geo-referenced map utility in PrepME is an important auxiliary tool in the design process. The flowchart of processing climate data is illustrated in Figure 6.4.

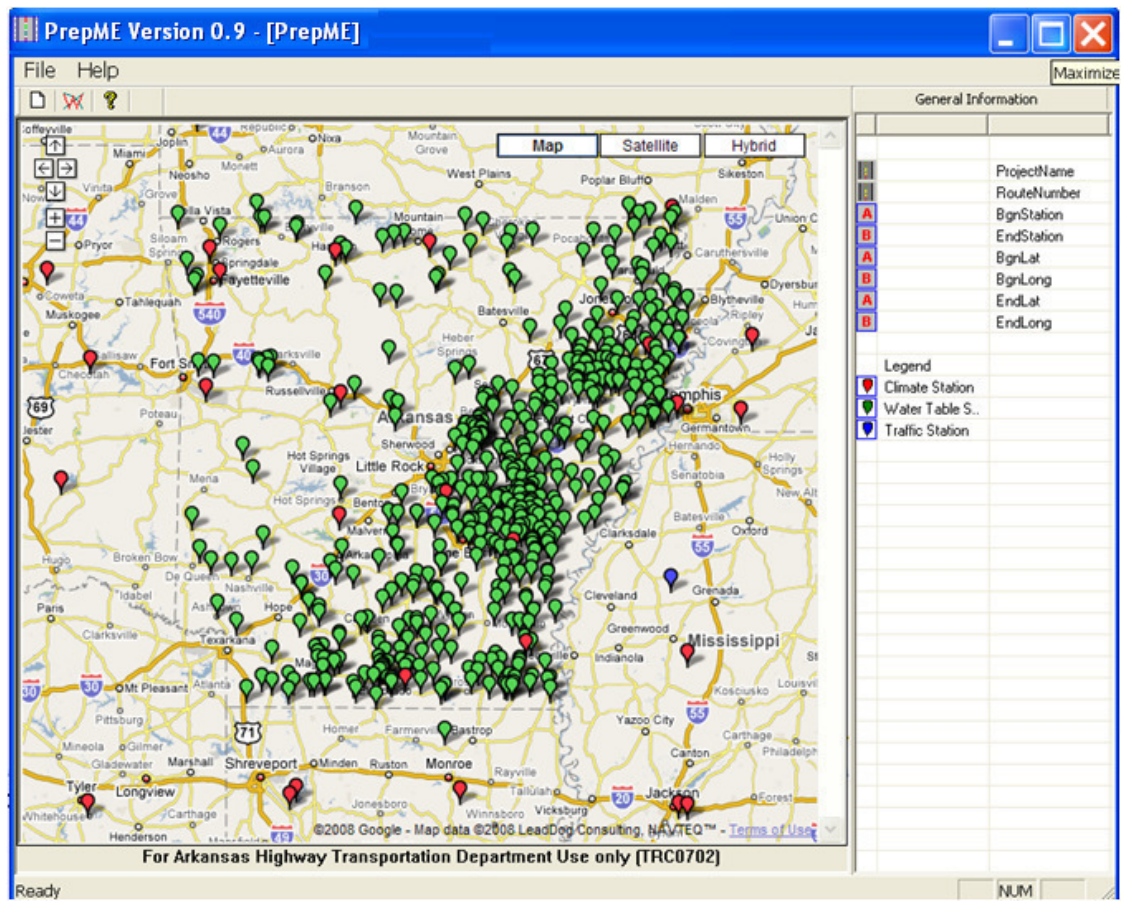


Figure 6.3 Geo-Mapping Utility in PrepME

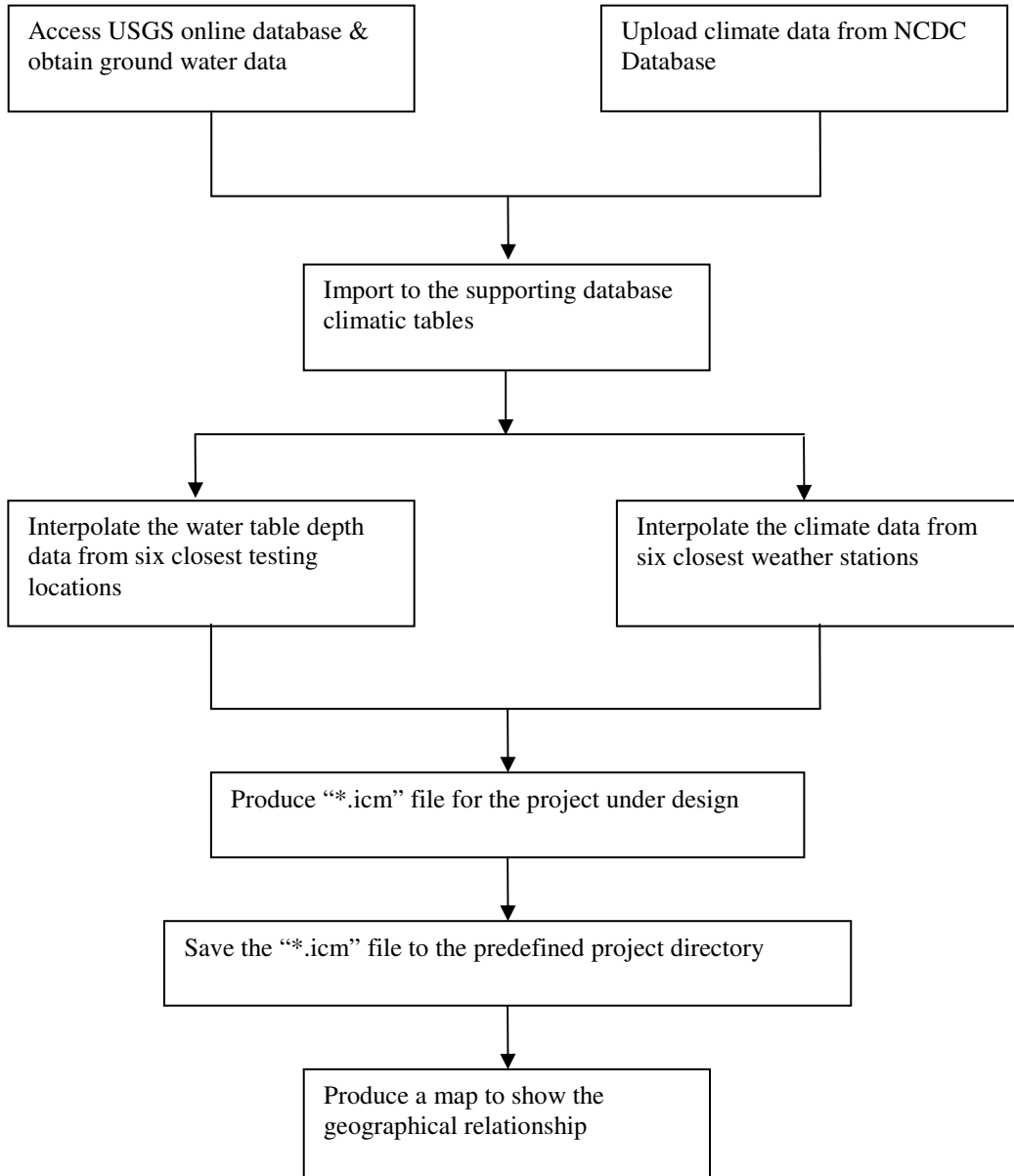


Figure 6.4 Climate Data Process

## 6.2.2 Traffic Module

The traffic module in the PrepME software has two functionalities. First, the software can check the quality of the original vehicle classification data and truck weight data based on the adopted algorithms, and then identify the data which have passed the quality check in the database tables. The snapshot of the “Traffic Data Check” windows for classification data and weight data are shown in Figure 6.5 and Figure 6.6 respectively.

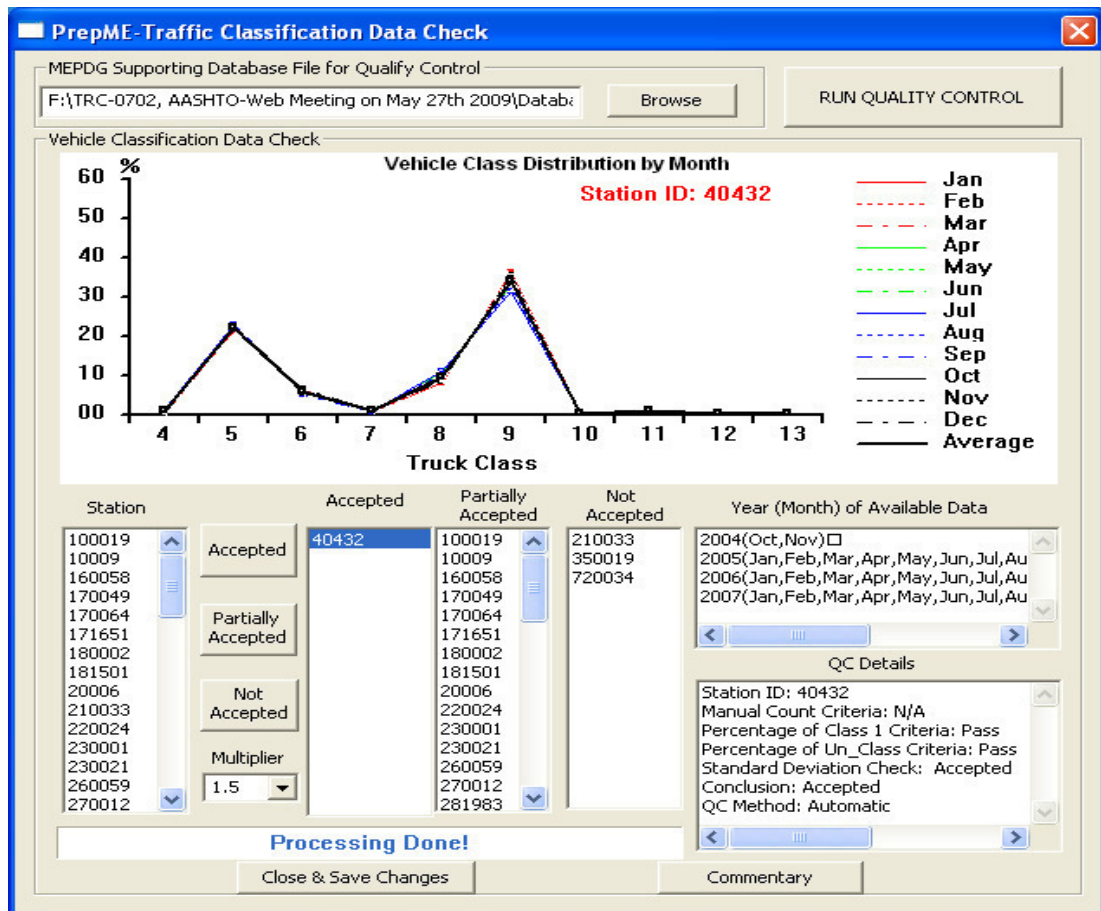


Figure 6.5 Vehicle Classification Data Check in PrepME

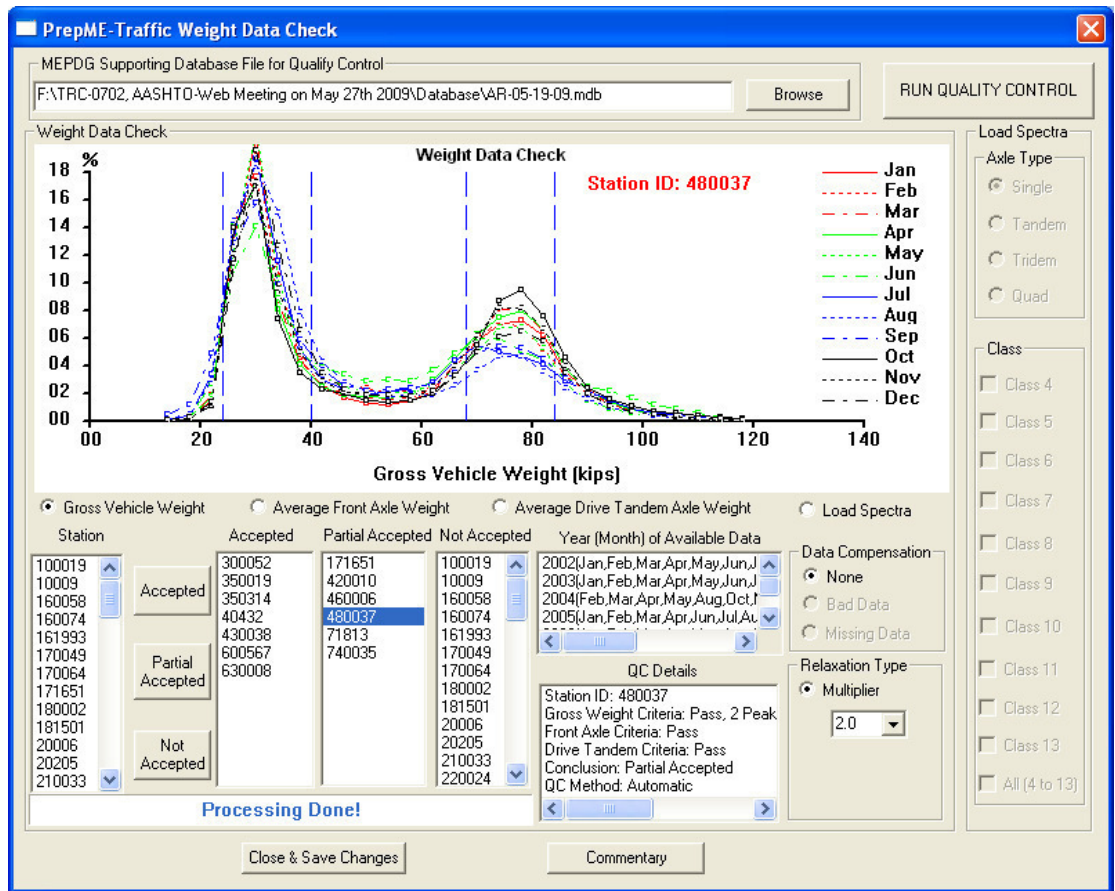


Figure 6.6 Weight Data Check in PrepME

The data check results are divided into three states: “Accepted”, “Partial Accepted”, and “Not Accepted”. In “Accepted” case, all the data sets from a station are accepted. In “Partially Accepted” case, the months that don’t pass the data check are excluded from the data sets and the remaining data can still represent 12 months in a year (i.e., January through December), which is necessary to determine the monthly adjustment factors. In “Not Accepted” case, all the data sets from a station are excluded, either because all the data sets don’t pass the data check, or the remaining data are insufficient to represent 12 months in a year. The data check summary results are shown in the software. Because the data check algorithms are based on statistical analysis and

may have potential errors, histograms of the checked data are illustrated in the middle of the “Traffic Data Check” window so that the data can be visually checked as well. If wrong classification of the data is found, designers can change its state manually and save the changes with the software. In addition, to make these values suitable for Arkansas usage and more flexible to use, the software introduces the concept of “**multipliers**” to relax the data check criteria if necessary. For vehicle classification data check, the multiplier is set as 1.0 when default criterion  $2\sigma$ . If the multiplier is 1.5, it indicates that  $3\sigma$  ( $1.5 \times 2\sigma$ ) is used as the statistical criterion. The multiplier only applies to the criterion in the fourth step for vehicle classification data check process. Designers can choose different multiplier to alter the ranges of the statistical criteria. For weight data check, if the multiplier is set to 1.0, the defined weight ranges are used, such as 2,000 lb for front axle. In this case, the front axle weight should be between 8,000 and 12,000 lb ( $10,000 \pm 2,000$  lb). If the multiplier is set to 1.2, the range will be 2,400 lb ( $2,000 \text{ lb} \times 1.2 = 2,400 \text{ lb}$ ) for front axle. Therefore, the front axle weight should be between 7,600 lb and 12,400 lb ( $10,000 \pm 2,400$  lb) instead. Note that a selected multiplier will be applied to all the data check criteria for traffic weight data check processes.

The second functionality of the traffic module in PrepME is the preparation of the MEPDG software required 11 traffic files (Figure 6.7). These files are generated according to the file formats specified in MEPDG software, so that the designers can directly import these files into the MEPDG software for a specific design. The file format of the MEPDG importable 11 files are attached in APPENDIX B. The interpolation process is based on the truck traffic classification (TTC) system. Note that



there are only 7 TTC classes in Arkansas. They are TTC class 1, 2, 4, 6, 7, 9, and 12. Similar to the climate module, the traffic WIM stations selected for traffic characterization for a particular design project is also displayed on the geo-referenced map. The flowchart of processing traffic data is illustrated in Figure 6.8.

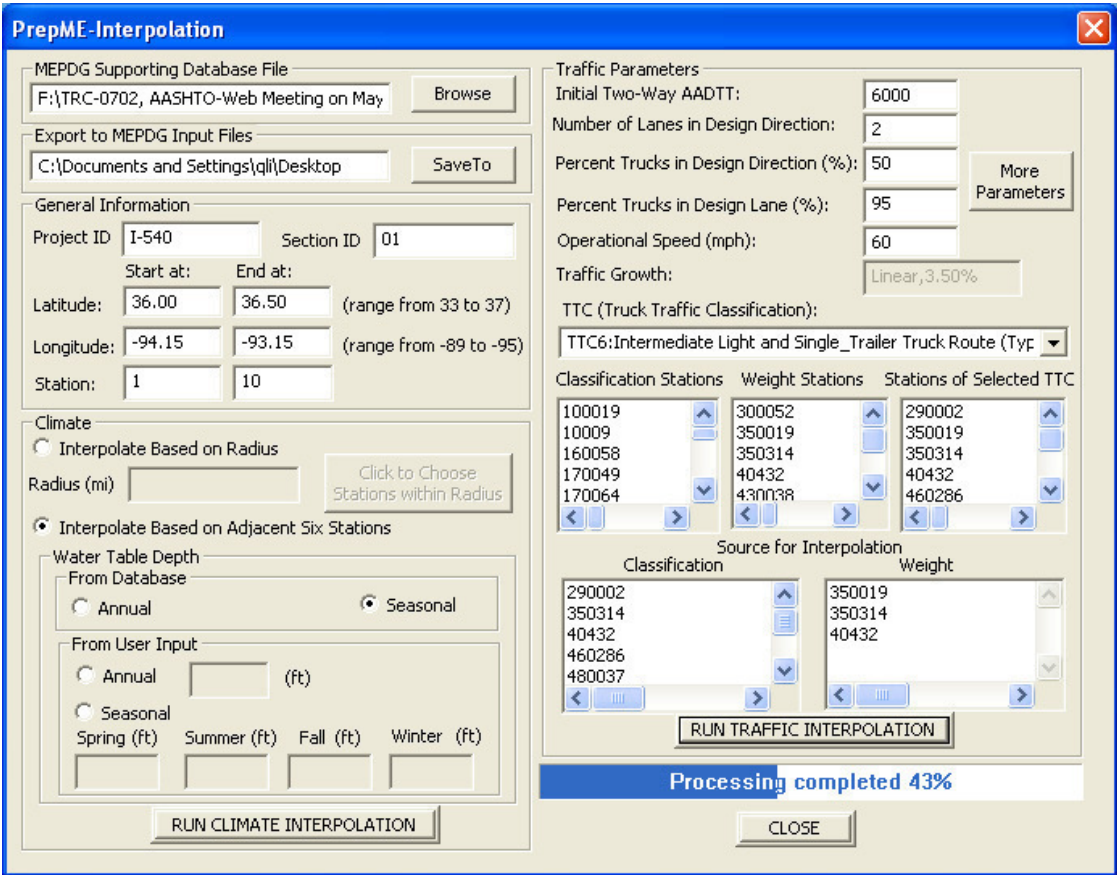


Figure 6.7 Data Files Interpolation in PrepME



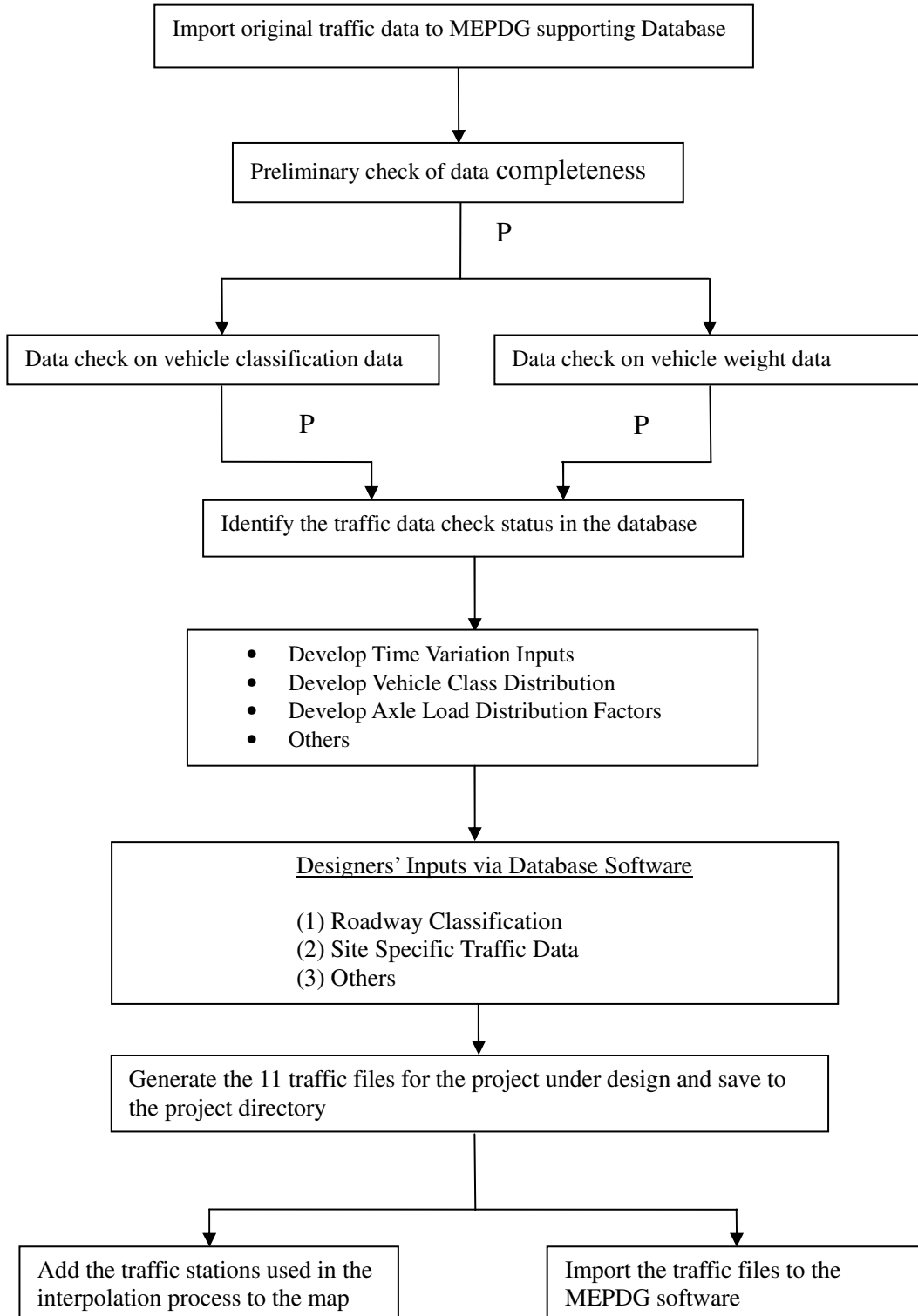


Figure 6.8 Processing Traffic Data

### 6.2.3 Materials Module

The data for three significant influencing material parameters, Dynamic Modulus ( $E^*$ ) Modulus ( $E^*$ ) for flexible pavement, Coefficient of Thermal Expansion (CTE) for PCC pavement, and Resilient Modulus ( $M_R$ ) for unbound materials and sub grade (

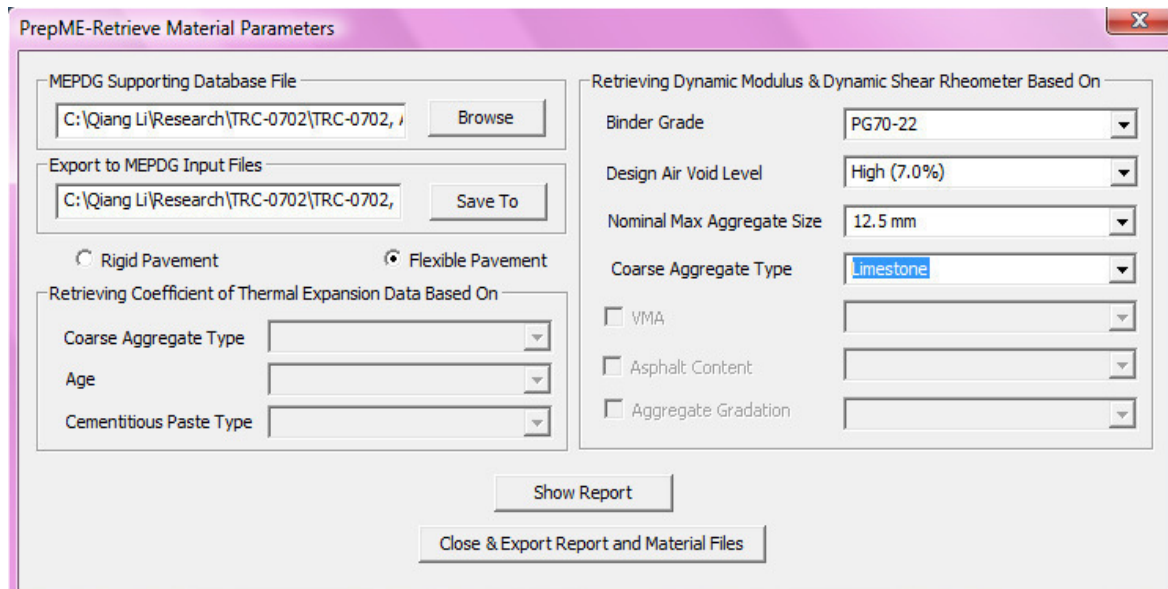


Figure 6.9), can be retrieved from lab data from past experiments stored in the database software PrepME. Based on the retrieved data sets, designers can make proper engineering judgments and make the corresponding level 2 or level 3 input values for a specific design project if site specific testing data are not available.

In pavement engineering practice, the common parameters in mix design which can be controlled by designers are asphalt binder grade and nominal aggregate size. Therefore, binder grade and nominal aggregate size are adopted as the default searching parameters to retrieve dynamic modulus data. Designers can also customize the searching parameters based on the local engineering experiences.

The coarse aggregate type used in a mixture significantly influences the CTE and pavement performance prediction (13, and 29). The type of coarse aggregate is used as the primary searching criteria to obtain similar CTE testing data in the database. Based on the retrieved data plus engineering judgments, an appropriate value can be decided for the design purpose.

For unbound and subgrade materials, the user needs first to identify the material classification, and then enter physical properties of the candidate construction material. The resilient modulus value of the material will be picked as a reference for designers to consider. Currently this functionality is not activated due to the lack of testing data.

The material data retrieving in the PrepME software is illustrated in

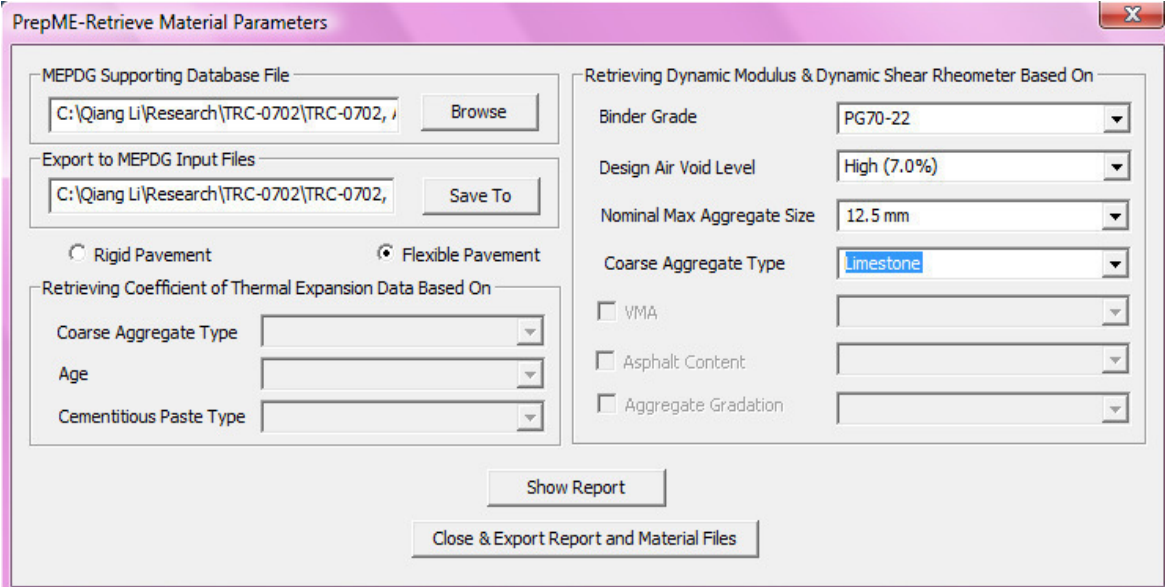


Figure 6.9. When the retrieving parameters are set, the data reports for dynamic modulus and CTE are shown in Figure 6.10 and Figure 6.11 respectively.

Currently the data retrieved from the database can only be manually input on the screens of the MEPDG software. In the future, the database may be linked to the

MEPDG software to facilitate direct delivery of the information when the MEPDG software is ready to accommodate such a link.

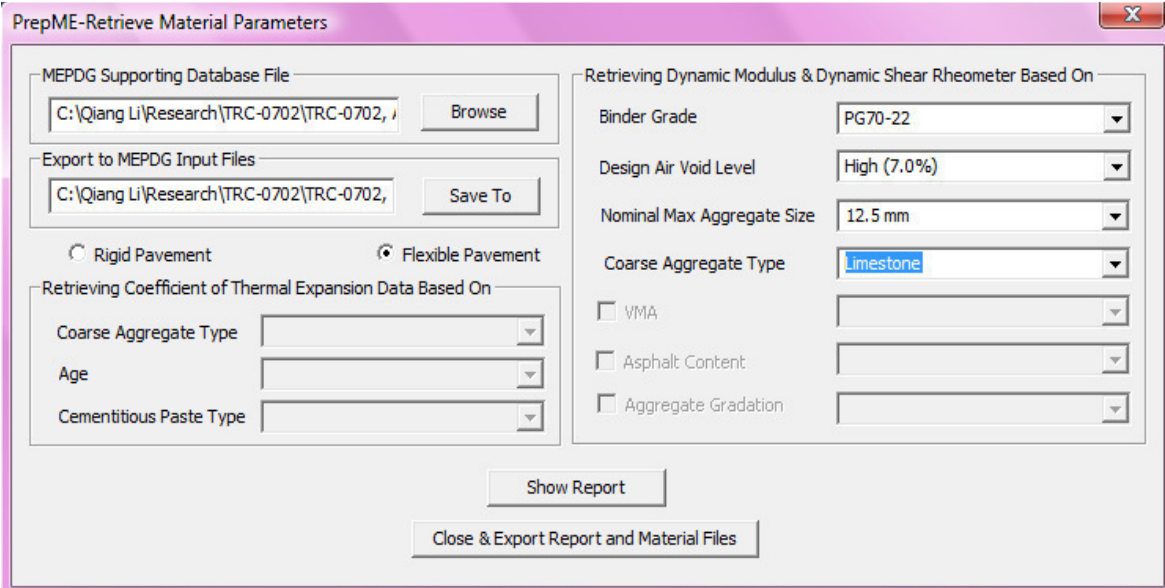


Figure 6.9 Material Data Retrieving Window in PrepME

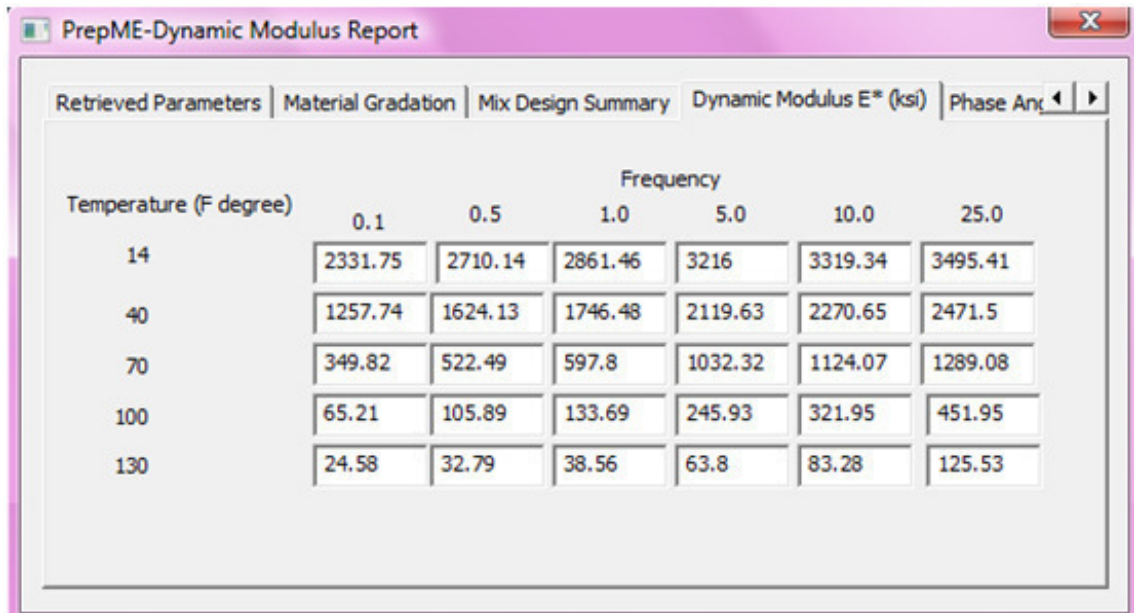


Figure 6.10 Dynamic Modulus Data Report in PrepME

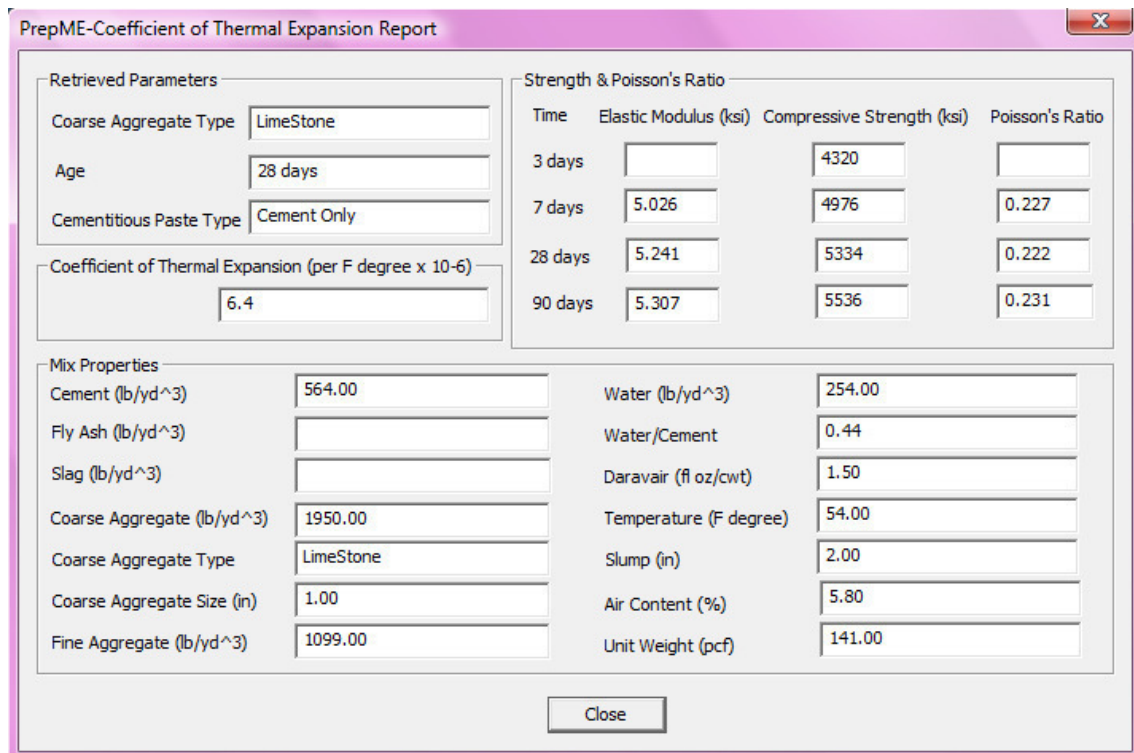


Figure 6.11 CTE Data Report in PrepME

## CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

### 7.1 Conclusions

In this project, the supporting database and software PrepME for MEPDG is designed and developed. The incorporated database feature can be directly used by Arkansas Highway and Transportation Department (AHTD) pavement designers in their efforts to calibrate and implement the MEPDG procedure. In this project, the following tasks are conducted:

- Based on the study of all the necessary inputs and analysis parameters required in MEPDG, a comprehensive centralized supporting database for MEPDG is developed to provide pavement designers a tool to pre-process and store the required data sets. The database tables are designed for seven distinctive data modules, including general information, climate data, traffic data, material data, performance data, construction data, and maintenance data.
- The availability of the required data sets in Arkansas is identified and the data sets are populated into the database. The available data sets include climate data, Weigh-In-Motion (WIM) traffic data, Dynamic Modulus ( $E^*$ ) testing data, and Coefficient of Thermal Expansion (CTE) testing data.
- An external software interface, PrepME, is produced to automatically generate the climate, traffic, and material data files that can be directly imported to the MEPDG software. A geo-referenced map can be activated in

the database software to display the geographical relationships based on the project in design, climate and traffic stations adopted in the design process, and the surrounding area.

- The historic water table depth testing data are obtained from the online USGS database and integrated to the PrepME database software, which can be used as level 3 inputs to aid pavement designs if site specific data are not available.
- The traffic module of the PrepME software interface provides a robust tool to prepare the traffic data inputs based on the tremendous amount of raw WIM data sets. The capabilities developed include: automatically preprocessing and importing raw WIM traffic data, checking the quality of the original traffic data, and generating the traffic inputs in accordance with the file format requirements in the MEPDG software. The concept of “multiplier” is first introduced in the traffic data check procedure to relax the national data check criteria.
- The most significant influencing material parameters, such as Dynamic Modulus ( $E^*$ ) for flexible pavement, Coefficient of Thermal Expansion (CTE) for PCC pavement, and Resilient Modulus ( $M_R$ ) for unbound materials and sub grade, can be retrieved from the past laboratory experiments data in the database. Based on the retrieved data sets, designers can make proper engineering judgments and make a corresponding level 2 or level 3 input values for a specific design project if site specific testing data are not available.

## 7.2 Recommendations

The following tasks are recommended to be conducted in future research:

- It is recommended that the available database sources in AHTD, such as pavement management system, SiteManager<sup>®</sup> construction database, resilient modulus data, be integrated into the centralized database and PrepMe so that it can be further used to calibrate the MEPDG and to support engineering practices of pavement management for the state of Arkansas.
- The development of traffic load spectra inputs for MEPDG is a major concern for most highway agencies. Even though tremendous work has been conducted in the PrepME software, improvements of the traffic module are still needed. These improvements can be (1) to conduct cluster analysis for the traffic inputs required, (2) to develop Truck Loading Groups to reflect basic truck loading patterns in Arkansas.
- More flexible QA/QC process to retrieve usable data sets among the large volume of WIM databases.



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## **APPENDIX A   Formats of the Integrated Climatic Model Files**

The Integrated Climatic Model uses several file formats for modeling pavement temperature and moisture profiles. The format of these files is outlined below.

#### ICM Files (\*.icm)

ICM files are generated by the hourly climatic database and contain all of the information needed to run the Integrated Climatic Model numerical engine.

StartDate(YYYYMMDD) – EndDate(YYYYMMDD): The period for which this file contains data for.

19960701-20011231

Longitude, Latitude, Annual Water Table Depth(-1 if using seasonal), spring water table depth, summer water table, fall water table, winter water table, monthly average humidity (12 total-start January)

-86.23,32.18,227,-

1,10,20,19,10,64.8035,12.8717,44.1237,72.3013,69.6847,65.7183,70.4444,70.5253,75.7314,75.2074,74.7334,74.5993,72.8259,74.0491,75.2558

Month, Day, Year, Sunrise time (decimal-24 hour), sunset, daily solar radiation maximum. Sunrise/Sunset calculated from Lat/Long. Solar radiation data from rad.dat file, correct for Lat/Long.

7 1 1996 4.95899 19.041 3730.48

Hour, temperature, precipitation, wind speed, percent sunshine, hourly ground water depth.

0 72 0 0 100 20

1 71.1 0 0 100 20

2 70 0 3 100 20

3 70 0 0 100 20

4 70 0 3 75 20

5 72 0 0 100 20

6 77 0 6 100 20

7 82 0 6 100 20

8 87.1 0 7 100 20

9 90 0 7 100 20

10 91 0 7 100 20

11 93 0 5 75 20

12 91.9 0 5 25 20

13 93.9 0 6 100 20

14 95 0 5 75 20

15 93 0 5 100 20  
16 91 0 6 100 20  
17 89.1 0 5 100 20  
18 86 0 3 100 20  
19 84 0 4 100 20  
20 81 0 4 100 20  
21 80.1 0 4 100 20  
22 79 0 5 100 20  
23 77 0 3 100 20

#### Hourly Climatic Database Files (\*.hcd)

Hourly climatic database files contain information for a specific weather station. To add a weather station to those that are available within the ME-PDG, create a new \*.hcd file. Assign a number unused in the station.dat file (described below). Add that number to the station.dat file list.

YYYYMMDDHH, Temperature (F), Wind speed (mph), % Sun shine, Precipitation, Relative humidity.

1997060100,57.9,9,0,0.2,97  
1997060101,57.9,9,0,0.35,97  
1997060102,57.9,5,0,0.18,100  
1997060103,59,9,0,0.06,93  
1997060104,59,10,0,0.05,93  
1997060105,59,12,0,0.07,96  
1997060106,59,12,0,0.07,96  
1997060107,60.1,9,0,0.03,96  
1997060108,61,9,0,0.03,97  
1997060109,62.1,9,0,0.06,96  
1997060110,63,5,0,0,97  
1997060111,64,4,0,0.01,96  
1997060112,64.9,3,0,0.04,97  
1997060113,68,0,0,0,90  
1997060114,69.1,0,0,0,87  
1997060115,69.1,0,0,0,84  
1997060116,69.1,0,0,0,84  
1997060117,69.1,0,0,0,78  
1997060118,66.9,0,25,0,87  
1997060119,64.9,4,100,0,97  
1997060120,64,0,100,0,100  
1997060121,62.1,0,50,0,100  
1997060122,60.1,3,0,0,100  
1997060123,62.1,0,0,0,100  
1997060200,62.1,0,0,0,100

### Station File (station.dat)

The station.dat file contains all of the hourly climatic database weather stations. Each weather station included has the following information.

Weather station number, weather station abbreviation, location (city|state), latitude, longitude, elevation, first date in file (YYYYMMDD)

25704,ADK,ADAKIAK,ADAK NAS,51.53,-176.39,17,19960701



**APPENDIX B    Formats of the MEPDG Traffic Import Files**

The MEPDG traffic export/import files, 11 in total, come as follows. They contain all the traffic data sets that are required in the MEPDG analysis.

\_HourlyTrafficPercentage.txt

MonthlyAdjustmentFactor.txt

VehicleClassDistribution.txt

TrafficGrowth.txt

Traffic.txt

GeneralTraffic.txt

AxlesPerTruck.txt

Single.alf

Tandem.alf

Tridem.alf

Quad.alf

Table B.1 Studies on the 11 Importable Traffic Files for MEPDG

Categories	File Name	Data Included	Notes	
Basic Information	Traffic.txt	<ul style="list-style-type: none"> <li>◆Initial two-way AADTT</li> <li>◆Number of lanes in the design direction</li> <li>◆Percent of trucks in the design direction</li> <li>◆Percent of trucks in the design lane</li> <li>◆Operational speed</li> </ul>		
	MonthlyAdjustmentFactor.txt VehicleClassDistribution.txt ( ) _HourlyTrafficPerc.txt TrafficGrowth.txt	<p>Table for Monthly Adjustment Factor</p> <p>Percent trucks in Class</p> <p>Hourly truck traffic distribution in 24 hours</p> <ul style="list-style-type: none"> <li>◆Traffic growth function: 0 or 1</li> <li>◆Input growth : No, Linear or Compound</li> <li>◆Growth Rate – Number (%) growth rate</li> </ul>	10 numbers that sum to 100	
Axle Load Distribution Factors	single.alf	Axle load distribution factors----single load	0 -- Composite vehicle class growth; 1 -- Vehicle-class specific growth;	
	tandem.alf	Axle load distribution factors---- tandem load		
	tridem.alf	Axle load distribution factors---- tridem load		
	quad.alf	Axle load distribution factors---- quad load		
General Traffic Inputs	GeneralTraffic.txt	<ul style="list-style-type: none"> <li>◆Mean Wheel Location</li> <li>◆Traffic Wander</li> <li>◆Design land width</li> <li>◆Average Axle Width(edge to edge) Outside dimensions</li> <li>◆Dual Tire Spacing</li> <li>◆Tire Pressure</li> <li>◆Tandem, tridem, and quad axle spacing</li> <li>◆Short axle spacing</li> <li>◆Percent trucks with short axle spacing</li> <li>◆Medium axle spacing</li> <li>◆Percent of trucks with medium axle spacing</li> <li>◆Long axle spacing</li> <li>◆Percent of trucks with long axle spacing</li> <li>◆Axles per truck at different load categories</li> </ul>	1. These files can be opened with WordPad; 2. The formats of these files are same as those in MEPDG	

**APPENDIX C    Formats of Weigh-In-Motion (WIM) Traffic Data Files**

## Station Description Record

<b>Field</b>	<b>Columns</b>	<b>Width</b>	<b>Description</b>
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-9	6	Station ID
4	10	1	Direction of Travel Code
5	11	1	Lane of Travel
6	12-13	2	Year of Data
7	14-15	2	Functional Classification Code
8	16	1	Number of Lanes in Direction Indicated
9	17	1	Sample Type for Traffic Volume
10	18	1	Number of Lanes Monitored for Traffic Volume
11	19	1	Method of Traffic Volume Counting
12	20	1	Sample Type for Vehicle Classification
13	21	1	Number of Lanes Monitored for Vehicle Class.
14	22	1	Method of Vehicle Classification
15	23	1	Algorithm for Vehicle Classification
16	24-25	2	Classification System for Vehicle Classification
17	26	1	Sample Type for Truck Weight
18	27	1	Number of Lanes Monitored for Truck Weight
19	28	1	Method of Truck Weighing
20	29	1	Calibration of Weighing System
21	30	1	Method of Data Retrieval
22	31	1	Type of Sensor
23	32	1	Second Type of Sensor
24	33	1	Primary Purpose
25	34-45	12	LRS Identification
26	46-51	6	LRS Location Point
27	52-59	8	Latitude
28	60-68	9	Longitude
29	69-72	4	SHRP Site Identification
30	73-78	6	Previous Station ID
31	79-80	2	Year Station Established
32	81-82	2	Year Station Discontinued
33	83-85	3	FIPS County Code
34	86	1	HPMS Sample Type
35	87-98	12	HPMS Sample Identifier
36	99	1	National Highway System
37	100	1	Posted Route Signing
38	101-108	8	Posted Signed Route Number
39	109	1	Concurrent Route Signing
40	110-117	8	Concurrent Signed Route Number
41	118-167	50	Station Location

Hourly Traffic Volume Record (#3 Record)

<b>Field</b>	<b>Columns</b>	<b>Length</b>	<b>Description</b>
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-5	2	Functional Classification
4	6-11	6	Station Identification
5	12	1	Direction of Travel
6	13	1	Lane of Travel
7	14-15	2	Year of Data
8	16-17	2	Month of Data
9	18-19	2	Day of Data
10	20	1	Day of Week
11	21-25	5	Traffic Volume Counted, 00:01 - 01:00
12	26-30	5	Traffic Volume Counted, 01:01 - 02:00
13	31-35	5	Traffic Volume Counted, 02:01 - 03:00
14	36-40	5	Traffic Volume Counted, 03:01 - 04:00
15	41-45	5	Traffic Volume Counted, 04:01 - 05:00
16	46-50	5	Traffic Volume Counted, 05:01 - 06:00
17	51-55	5	Traffic Volume Counted, 06:01 - 07:00
18	56-60	5	Traffic Volume Counted, 07:01 - 08:00
19	61-65	5	Traffic Volume Counted, 08:01 - 09:00
20	66-70	5	Traffic Volume Counted, 09:01 - 10:00
21	71-75	5	Traffic Volume Counted, 10:01 - 11:00
22	76-80	5	Traffic Volume Counted, 11:01 - 12:00
23	81-85	5	Traffic Volume Counted, 12:01 - 13:00
24	86-90	5	Traffic Volume Counted, 13:01 - 14:00
25	91-95	5	Traffic Volume Counted, 14:01 - 15:00
26	96-100	5	Traffic Volume Counted, 15:01 - 16:00
27	101-105	5	Traffic Volume Counted, 16:01 - 17:00
28	106-110	5	Traffic Volume Counted, 17:01 - 18:00
29	111-115	5	Traffic Volume Counted, 18:01 - 19:00
30	116-120	5	Traffic Volume Counted, 19:01 - 20:00
31	121-125	5	Traffic Volume Counted, 20:01 - 21:00
32	126-130	5	Traffic Volume Counted, 21:01 - 22:00
33	131-135	5	Traffic Volume Counted, 22:01 - 23:00
34	136-140	5	Traffic Volume Counted, 23:01 - 24:00
35	141	1	Restrictions

## Vehicle Classification Record

<b>Field</b>	<b>Columns</b>	<b>Length</b>	<b>Description</b>
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-9	6	Station ID
4	10	1	Direction of Travel Code
5	11	1	Lane of Travel
6	12-13	2	Year of Data
7	14-15	2	Month of Data
8	16-17	2	Day of Data
9	18-19	2	Hour of Data
10	20-24	5	Total Volume
11	25-29	5	Class 1 Count
12	30-34	5	Class 2 Count
13	35-39	5	Class 3 Count
14	40-44	5	Class 4 Count
15	45-49	5	Class 5 Count
16	50-54	5	Class 6 Count
17	55-59	5	Class 7 Count
18	60-64	5	Class 8 Count
19	65-69	5	Class 9 Count
20	70-74	5	Class 10 Count
21	75-79	5	Class 11 Count
22	80-84	5	Class 12 Count
23	85-89	5	Class 13 Count
24	90-94	5	Class 14 Count (optional)
25	95-99	5	Class 15 Count (optional)

## Truck Weight Record

Field	Columns	Length	Description
1	1	1	Record Type
2	2-3	2	FIPS State Code
3	4-9	6	Station ID
4	10	1	Direction of Travel Code
5	11	1	Lane of Travel
6	12-13	2	Year of Data
7	14-15	2	Month of Data
8	16-17	2	Day of Data
9	18-19	2	Hour of Data
10	20-21	2	Vehicle Class
11	22-24	3	Open
12	25-28	4	Total Weight of Vehicle
13	29-30	2	Number of Axles
14	31-33	3	A-axle Weight
15	34-36	3	A-B Axle Spacing
16	37-39	3	B-axle Weight
17	40-42	3	B-C Axle Spacing
18	43-45	3	C-axle Weight
19	46-48	3	C-D Axle Spacing
20	49-51	3	D-axle Weight
21	52-54	3	D-E Axle Spacing
22	55-57	3	E-axle Weight
23	58-60	3	E-F Axle Spacing
24	61-63	3	F-axle Weight
25	64-66	3	F-G Axle Spacing
26	67-69	3	G-axle Weight
27	70-72	3	G-H Axle Spacing
28	73-75	3	H-axle Weight
29	76-78	3	H-I Axle Spacing
30	79-81	3	I-axle Weight
31	82-84	3	I-J Axle Spacing
32	85-87	3	J-axle Weight
33	88-90	3	J-K Axle Spacing
34	91-93	3	K-axle Weight
35	94-96	3	K-L Axle Spacing
36	97-99	3	L-axle Weight
37	100-102	3	L-M Axle Spacing
38	103-105	3	M-axle Weight

Note: The number of axles determines the number of axle weight and spacing fields.



## **APPENDIX D User's Guide of PrepME Database Software**

# **User's Guide of PrepME Database Software**

Civil Engineering

University of Arkansas

May 2009

## **I. INTRODUCTION**

This guide includes procedural steps to use the PrepME database software application developed at the University of Arkansas to support the MEPDG effort of the Arkansas State Highway and Transportation Department (AHTD). Technical description of the software application is contained in the Final Report for AHTD TRC-0702 project. The database software application includes the capability of creating and preparing design data sets directly usable in MEPDG software, such as input and output utilities of data sets for designers to locate, select, and use relevant input values for the design process, along with a location reference system for designers to identify design site through visually displayed geo-mapping utility.

## **II. USER'S GUIDE OF PREPME DATABASE SOFTWARE**

### **Step 1. Start PrepME**

The PrepME program is started by double clicking the "PvmtDesigner.exe". In the version 0.9 software, four capabilities are provided: "Import Raw Data", "Traffic Data Check", "Interpolate Climate and Traffic Data", and "Retrieve Material Parameters", which are placed as four submenus under the "File" menu (Figure D.1).

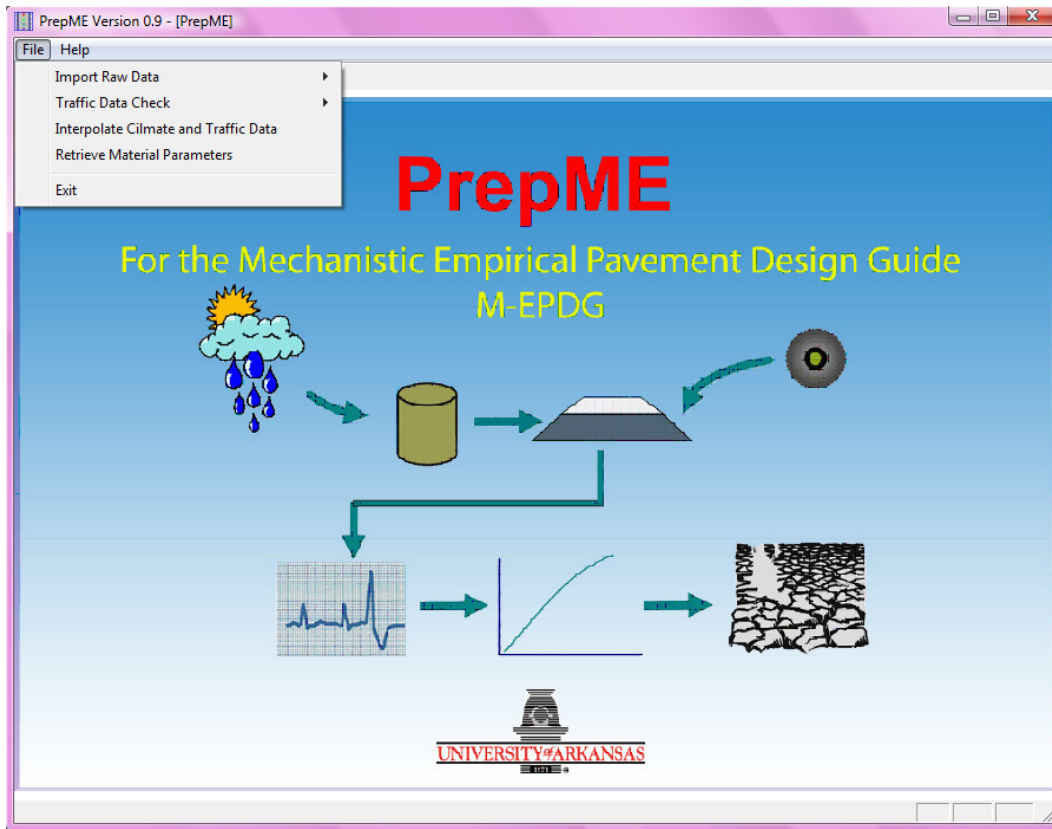


Figure D.1 Opening Interface of PrepME

## Step 2. Import Raw Data

The PrepME software can import raw data through “complete import” mode or “update new data” mode (Figure D.2). The “complete import” mode is mainly used for the first time users to import all the historical available raw climate and traffic data. The “update new data” mode is used to update the database if new monitoring data are available. Please note that using the “complete import” option may take hours to extract information from raw data sets. This option is normally used once at the beginning of setting up the design database for MEPDG work.

In this step, the user needs to select the name of the state from which the import raw data come, to locate the directories of raw climate, traffic and materials raw data, and to assign the name of the database that the raw data will be converted to. The default state is set for Arkansas (Figure D.3). The MEPDG supporting database is generated in this step.

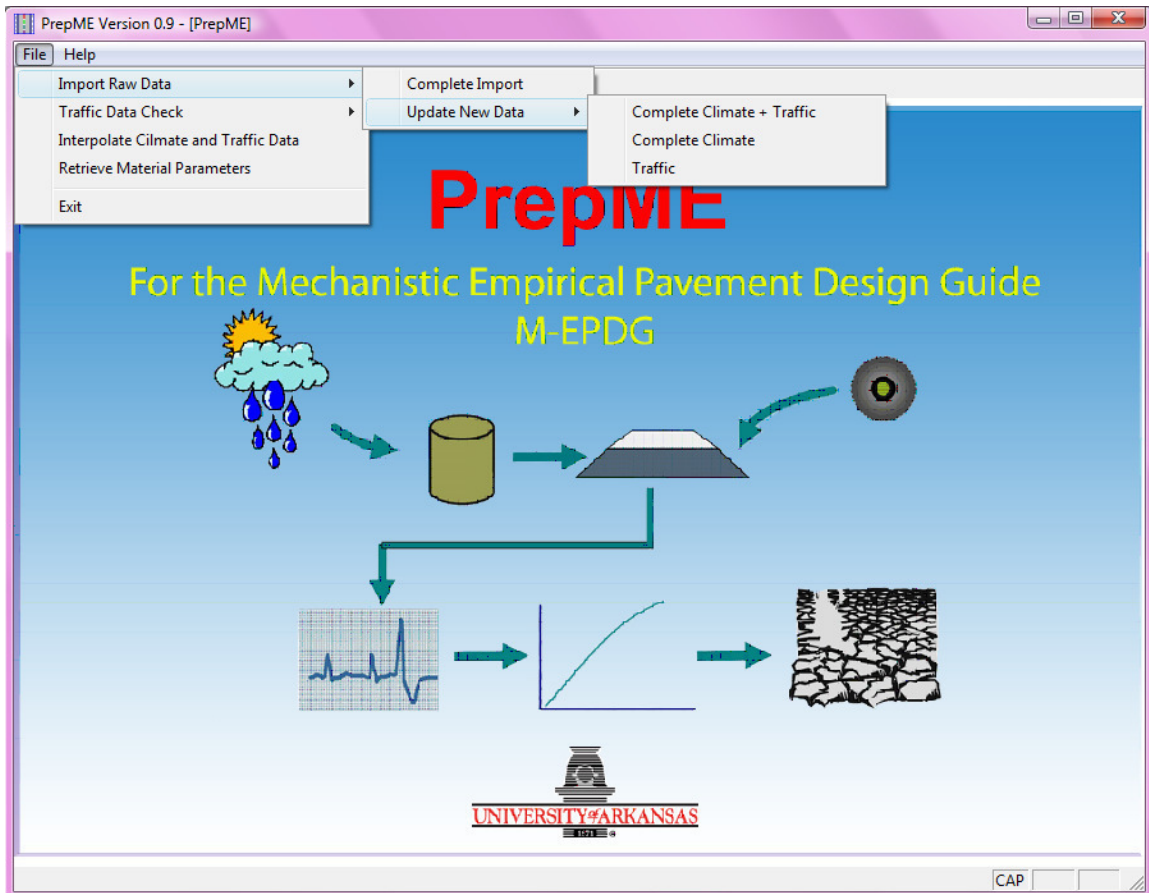


Figure D.2 Data Importing Menu

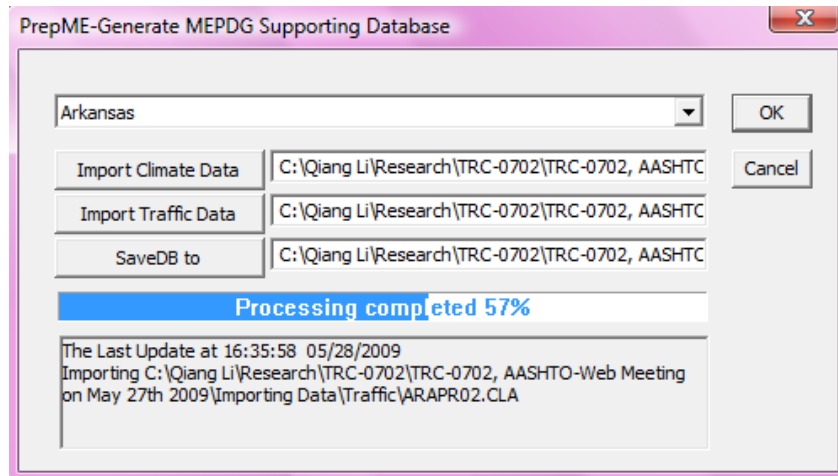


Figure D.3 Data Importing Window

The detailed steps are:

(1) Click “**Import Raw Data**” menu and select “**Complete Import**” as an example (Figure D.3).

(2) In the “**Generate MEPDG Supporting Database**” window, Click “**Import Climate Data**” button to locate the directory where original climate data are. The default directory is the parent directory of where the database software is located.

(3) Click “**Import Traffic Data**” button to locate the directory where original traffic data are. The default directory is the parent directory of where the database software locate.

(4) Click “**Save DB to**” button to choose the directory where the original data sets will be converted to and provide a name for the database.

(5) Click “**OK**” button to start processing, or click “**Cancel**” button to exit out.

If “**OK**” bottom is clicked, the software starts generating the base MEPDG supporting database, which is in Microsoft ACCESS format. The progress bar reports the

data importing rate. The status bar also provides the latest time that the database was updated and the information about which file is being processed (Figure D.3).

When the data importing process is completed, a geo-referenced map based on Google map is activated to show the geographical locations of weather stations, water table depth testing points, traffic stations, and surrounding area (Figure D.4). This mapping utility is integrated into the database application, and has all major functions of Google map, such as displaying satellite imagery, zooming in and zooming out.

The raw climate data consist of three parts: hourly climate data, water table depth, and elevation. For Arkansas, the hourly climate data are originated from the climate files provided on the MEPDG website ([www.trb.org/mepdg/climatic\\_state.htm](http://www.trb.org/mepdg/climatic_state.htm)), including the data for the state of Arkansas and those in six neighboring states (Missouri, Tennessee, Mississippi, Louisiana, Texas, and Oklahoma). The water table depth data are from USGS online database, and the elevation data are obtained using Google Earth. The raw traffic data are originated from the traffic monitoring program managed by the Arkansas Highway and Transportation Department (AHTD), which follows the federal 2001 Traffic Monitoring Guide (TMG).

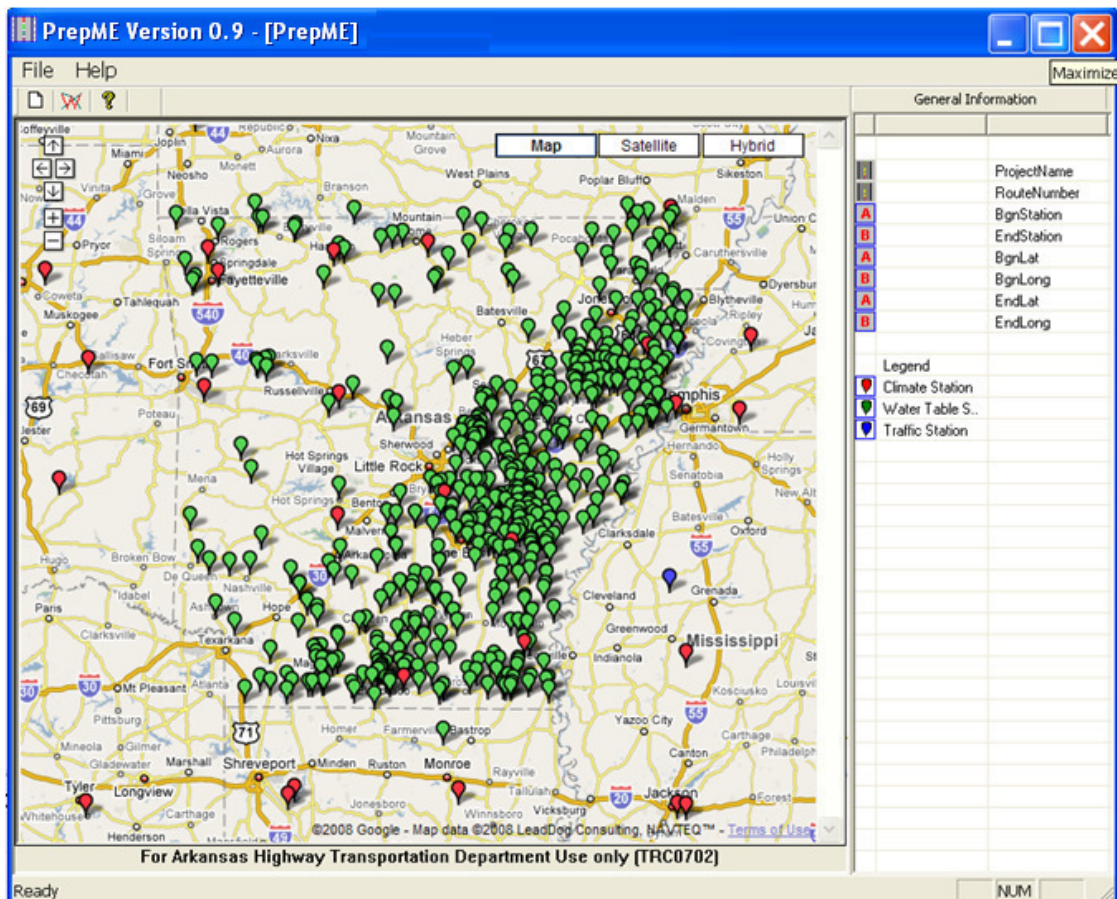


Figure D.4 Google Map Utility

### Step 3. Traffic Data Check

In the “Traffic Data Check” screen, the PrepME software can automatically process the data check of weight data and vehicle classification data (Figure D.5).

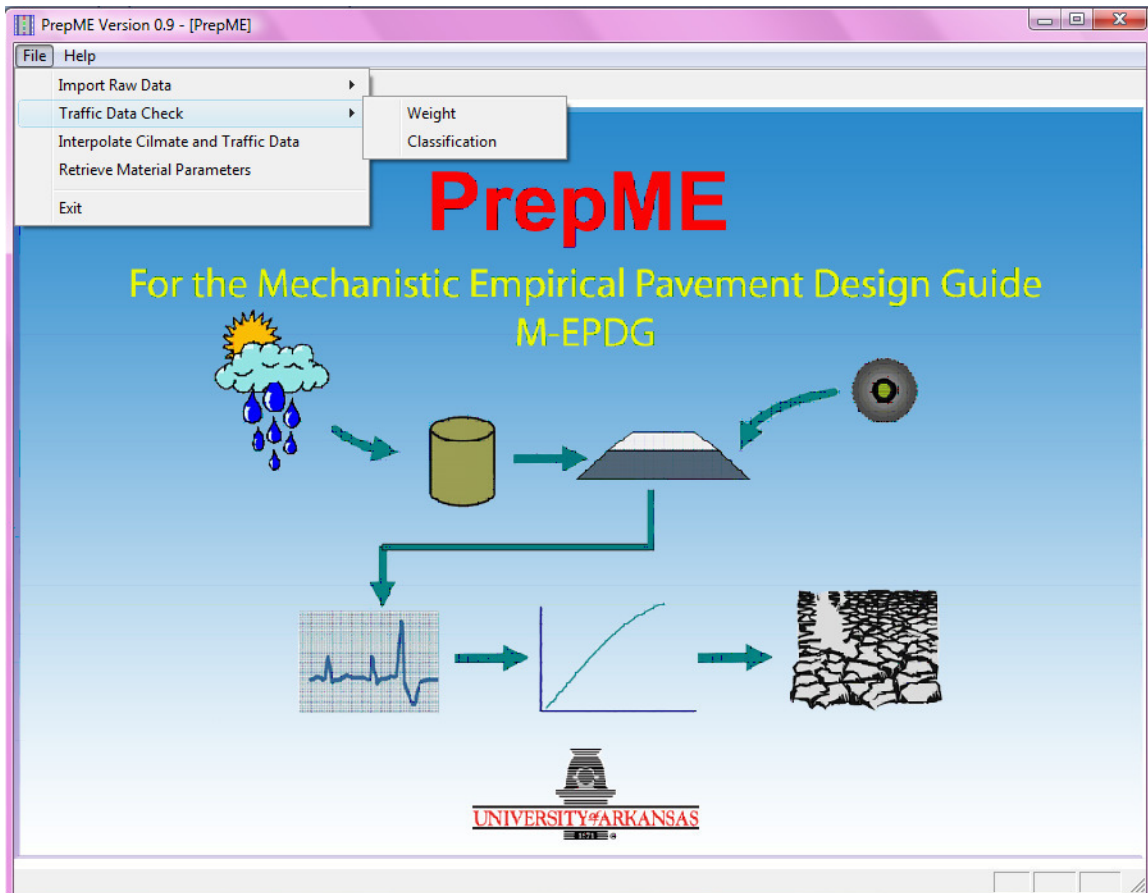


Figure D.5 Traffic Data Check

*Vehicle Classification Data Check*

For vehicle classification data check (Figure D.6), the detailed steps are as follows:

(1) Click **“File”** Menu on the database software main interface, select **“Traffic Data Check”** submenu, and click **“Classification”**.

(2) Locate the folder where the generated database is located through the **“Browse”** button.



In this step, the available vehicle classification stations will be listed on the left side of the window.

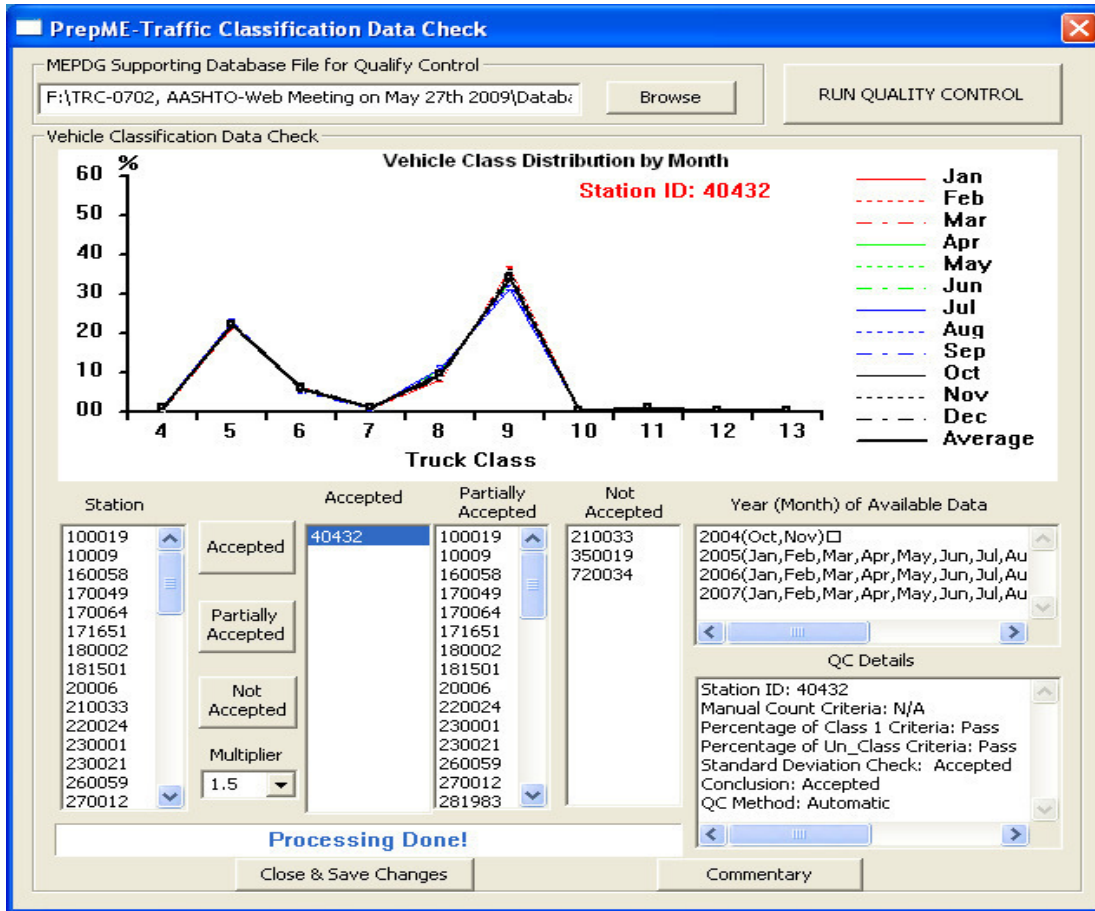


Figure D.6 Vehicle Classification Data Check

(3) Click **“RUN QUALITY CONTROL”** button

The original vehicle classification data will be automatically checked. The data check results for vehicle classification are divided into three states: Accepted, Partial Accepted, and Unaccepted. In “Accepted” case, all classification data from a station are accepted. It indicates that the normalized class distribution curves are consistent and no unexpected change in the vehicle distribution is found in the data. In “Partially Accepted”

case, classification data from a station are partially accepted. Initially, the normalized class distribution curves were not consistent. Further analyses were required to verify and discard the in-consistent data. Finally, the data collected from the station were partially accepted. In “Not Accepted” case, all classification data from a station are excluded. The normalized class distribution curves were not consistent. After verifying and discarding the in-consistent data, the remaining data do not represent 12 months (i.e., January through December), which is necessary to determine the monthly adjustment factors. The station is excluded for further analyses.

In the PrepME software the traffic data check procedure in TMG is adopted: (1) To compare the manual classification counts and the hourly vehicle classification data. The absolute difference should be less than five percent for each of the primary vehicle categories. (2) To check the number of Class 1 (motorcycles). The evaluation procedure recommended that the number of Class 1 should be less than five percent unless their presence is noted. (3) To check the reported number of unclassified vehicles. The number of unclassified vehicles should be less than five percent of the vehicles recorded. (4) To compare the current truck percentages by class with the corresponding historical percentages. No significant changes in the vehicle mix are anticipated. The first step is not processed since no manually data are available. The second and third step can be checked with the imported vehicle classification data. In the fourth step, a statistical approach is proposed. Firstly, the normalized class distribution for each month is calculated. Then the mean value ( $\mu$ ) and the standard deviation ( $\sigma$ ) for each month by vehicle class are obtained to determine if unexpected changes in vehicle mix had occurred. Two standard deviation ( $2\sigma$ ) is used as the default criteria to identify outliers. If

the normalized class distribution for each month falls into the range of  $\mu \pm 2\sigma$ , it is considered that there is no significant changes in the vehicle mix. Otherwise, the data will be discarded as outlier and the statistical calculations are repeated until all the data are qualified.

However, only a small percentage of the traffic data can pass the data check process. To make these values suitable for Arkansas usage, the software introduces the concept of “**multipliers**” to relax the data check criteria if necessary. For vehicle classification data check, the multiplier is set as 1.0 when default criterion  $2\sigma$ . If the multiplier is 1.5, it indicates that  $3\sigma$  ( $1.5 \times 2\sigma$ ) is used as the statistical criterion. Please note that the multiplier only applies to the criterion in the fourth step for vehicle classification data check process. Designers can choose different multiplier to alter the ranges of the statistical criteria.

The year (month) of the available data of a specified traffic station are shown on the right side of the window. Because the data check algorithms are based on statistical analysis and may have potential errors, histograms of the checked data, which has zooming in and zooming out capabilities, are illustrated in the middle of the window. Designers can double check the software classified data state. If wrong classification of the data is found, designers can change its state manually by clicking the corresponding state button when the relevant station is highlighted. However, this process should be done only if user has sufficient confidence or 3<sup>rd</sup> party data support for the status change.

The algorithms used for data check, the definitions of the data check results , and why multipliers are introduced can be found by clicking the “**Commentary**” button on the software window.

(4) Click “**Close and Save Changes**” button.

The vehicle classification data which passed the data check are saved into the database as good data for design purposes.

#### *Truck Weight Data Check*

For weight data check (Figure D.7), the steps are similar except for two differences:

(1) The data check algorithm used in LTPP and TMG for weight is different from that of vehicle classification. There are two basic steps to evaluate recorded vehicle weight data. Firstly, to check the front axle and drive tandem axle weights of Class 9 trucks. The front axle weight should be between 8,000 and 12,000 lb ( $10,000 \pm 2,000$  lb). The drive tandems of a fully loaded Class 9 truck should be between 30,000 and 36,000 lb ( $33,000 \pm 3,000$  lb). Secondly, to check the gross vehicle weights of Class 9 trucks. This step requires a histogram plot of the gross vehicle weights of Class 9 trucks using a 4,000-lb. increment. The histogram plot should have two peaks for most sites. One represents unloaded Class 9 trucks and should be between 28,000 and 36,000 lb ( $32,000 \pm 4,000$  lb). The second peak represents the most common loaded vehicle condition with a weigh between 72,000 and 80,000 lb ( $76,000 \pm 4,000$  lb).

In PrepME, the corresponding histograms for each data check criterion can be checked by clicking the radio buttons among “**Average Front Axle Weight**”, “**Average Drive Tandem Axle Weight**”, or “**Gross Vehicle Weight**” (Figure D.7). In addition, the load spectra of the traffic data are also available when the button “**Load Spectra**” is clicked for each axle type and truck class.

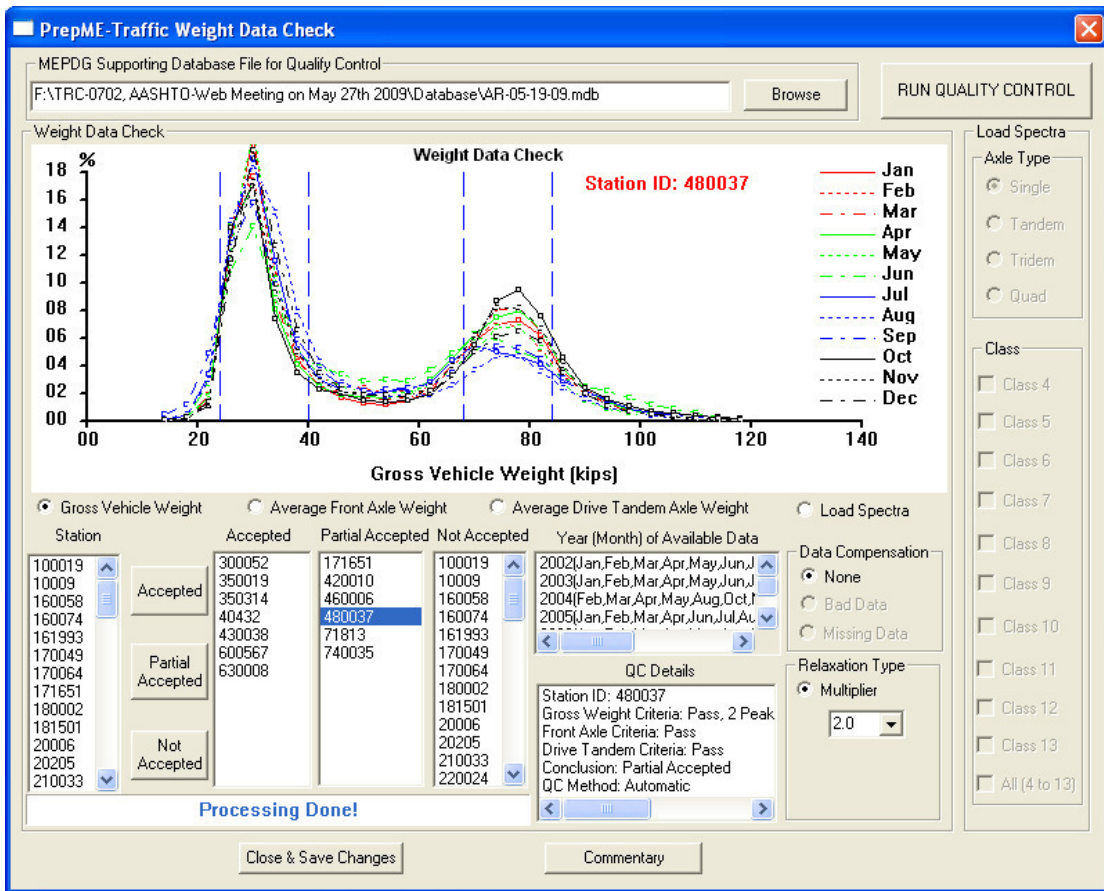


Figure D.7 Weight Data Check

The data check results for traffic weight are divided into two states: “Accepted”, “Partial Accepted”, and “Not Accepted”. In “Accepted” case, all the data sets from a station are accepted. In “Partially Accepted” case, the months that don’t pass the data check are excluded from the data sets and the remaining data can still represent 12 months in a year (i.e., January through December), which is necessary to determine the monthly adjustment factors. In “Not Accepted” case, all the data sets from a station are excluded, either because the remaining data are insufficient to represent 12 months in a year, or all the data sets don’t pass the data check. It indicates that the WIM scale was not properly calibrated and should be recalibrated immediately. The reasons varied from

station to station, including **Fluctuated Data, One Peak Shifted, Two Peaks Shifted,** and **Overweight Trucks.**

– **Fluctuated Data:** if the weight data collected from the station were fluctuated, the WIM scale was classified as failed, and the calibration should be checked immediately.

– **One Peak Shifted:** If a plot shows one peak correctly located but another peak shifted from its expected location, the site should be reviewed for other potential scale problems. Additional information on that site may also need to be obtained to determine whether the scale is operating correctly. In the software, the plot of average front axle weights for different loading situations (unloaded, partially loaded, and fully loaded) is checked. If the plot lies inside the expected range of  $10,000 \pm 2,000$  lb, the data will be accepted.

– **Two Peaks Shifted:** If a plot shows both peaks shifted from their expected location in the same direction, the scale is most likely out of calibration. The participating agency should then recalibrate that scale at that site and collect a new sample of data.

– **Overweight Trucks:** If the percentage of overweight vehicles (particularly vehicles over 100,000 lb.) for vehicle class 9 is high, the scale calibration is questionable. In this software, 5% is adopted as the threshold.

(2) The multipliers are applied differently. The multipliers for weight data check are used to alter the ranges for the criteria. If the multiplier is set to 1.0, LTPP criterion thresholds are used, such as  $10,000 \pm 2,000$  lb for front axle. If the multiplier is set to 1.2, the range will be  $10,000 \pm 2,400$  lb ( $2,000 \times 1.2 = 2,400$  lb) for front axle. Please note that the multiplier will be applied to all the criteria for traffic weight data check process.

#### Step 4. Interpolate Climate and Traffic Data

In this step the climate and traffic files that can be directly used for the MEPDG software are interpolated. The user only needs to specify the fundamental inputs, such as project name, GPS coordinates, and basic traffic parameters (Figure D.8).

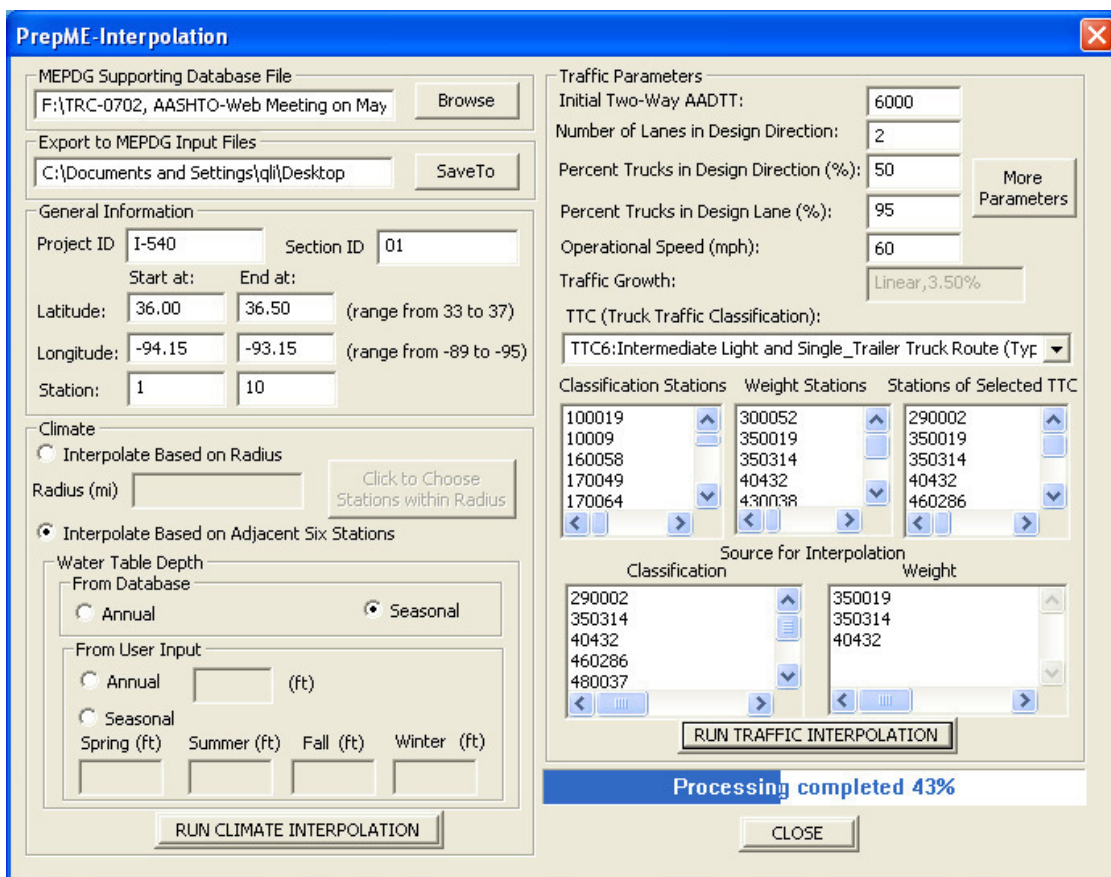


Figure D.8 Data Files Interpolation

The detailed steps are:

- (1) Click “**File**” Menu on the database software opening interface and select “**Interpolate Climate and Traffic Data**” submenu.

(2) Click “**MEPDG Supporting Database Files**” button and locate the generated MEPDG supporting database.

(3) Click “**Export to MEPDG Input Files**” button and choose the folder where to save the MEPDG importable climate and traffic files.

(4) Fill in the **General Information** for a project

The general data for a project include the Project ID, Section ID, starting and ending GPS coordinates and mileposts. The PrepeME software can prepare the data files for climate and traffic that can be directly used by the MEPDG software.

(5) Fill in the data needed for climate interpolation.

The interpolation process can be processed based on either user defined climate influencing radius or adjacent six closest climate stations. The water table depth data can be derived annually or seasonally either from the database generated based on the USGS data or user’s inputs if site specific testing data are available.

(6) Fill in the data needed for traffic interpolation

The data need for traffic interpolation include the Initial two-way AADTT, number of lanes in design direction, operational speed. The interpolation process is based on the truck traffic classification (TTC) system. If the TTC class of the pavement under design is known, the designer can choose the TTC class from the drop down menu, otherwise state wide average value can be used. Please note that there are only 7 TTC classes in Arkansas. They are TTC class 1, 2, 4, 6, 7, 9, and 12.

All the other traffic parameters, most of which have default values, are embedded in the “**More Parameters**” dialog. If designers have detailed site specific data, changes



can be made through this dialog and press OK button. Otherwise, default values will be used.

**PrepME-General Traffic Default Inputs**

**Lateral Traffic Wander**

Mean Wheel Location (inches from lane marking): 18.00

Traffic Wander Standard Deviation (in): 10.00

Design Lane Width (ft): 12.00

**Default Growth Function**

No Growth  Vehicle-Class Specific Traffic Growth

Linear Growth

Compound Growth

Default Growth Rate (%): 3.5

Edit Specific Traffic Growth

**Number Axles/Truck**

	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0.00	0.00
Class 5	2.00	0.00	0.00	0.00
Class 6	1.02	0.99	0.00	0.00
Class 7	1.00	0.26	0.83	0.00
Class 8	2.38	0.67	0.00	0.00
Class 9	1.13	1.93	0.00	0.00
Class 10	1.19	1.09	0.89	0.00
Class 11	4.29	0.26	0.06	0.00
Class 12	3.52	1.14	0.06	0.00
Class 13	2.15	2.13	0.35	0.00

**Axle Configuration**

Average Axle Width (edge to edge) (ft): 8.50

Dual Tire Spacing (in): 12.00

Tire Pressure (psi): 120.00

Tandem Axle Spacing (in): 51.60

Tridem Axle Spacing (in): 49.20

Quad Axle Spacing (in): 49.20

**Wheelbase**

Average Axle Spacing (ft): Short: 12.00 Medium: 15.00 Long: 18.00

Percent of Trucks (%): Short: 33.00 Medium: 33.00 Long: 34.00

OK Cancel

Figure D.9 General Traffic Default Values

(5) Click “**RUN INTERPOLATION**” button for either climate or traffic and the files will be generated and saved in the predefined directory.

The interpolated climate and traffic files can be found in the directory (Figure D.10) and can be directly imported to the MEPDG software for pavement design. The name of the climate file will be the same as the project name. The other 11 files contain all the traffic files needed in the MEPDG software.

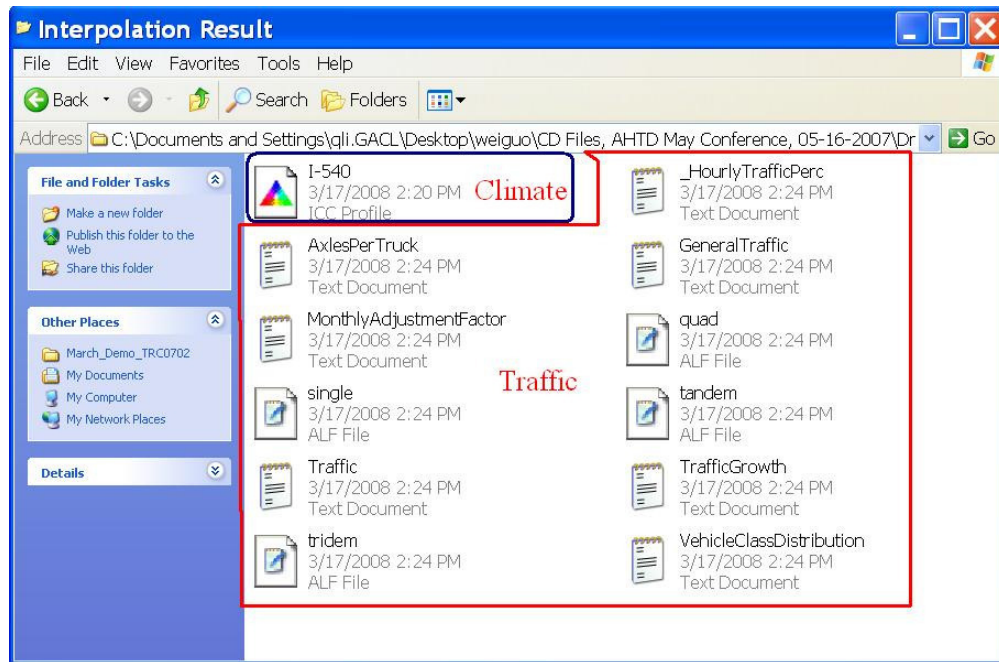


Figure D.10 Interpolated climate and traffic files

## Step 5. Retrieve Material Parameters

In this step, the most significant input parameters, such as Dynamic Modulus for asphalt concrete, Coefficient of Thermal Expansion (CTE) for PCC pavement, and resilient modulus for unbound and subgrade materials, can be retrieved based on the testing results from previous research projects. Currently the retrieving of resilient modulus is not ready yet.

The steps to retrieve the parameters are:

(1) Click “**File**” Menu on the database software opening interface and select “**Retrieve Material Parameters**” submenu.

(2) Click “**MEPDG Supporting Database Files**” button and locate the generated MEPDG supporting database (Figure D.11).

(3) Click “**Export to MEPDG Input Files**” button and choose the folder where to save the retrieved material files.

(4) Set up the retrieving criteria.

For Dynamic modulus, the retrieving parameters are Binder Grade, Design Air Void Level, Nominal Aggregate Size, and Coarse Aggregate Type.

For CTE, the retrieving parameters are Coarse Aggregate Type, Age, and Cementitious Paste Type.

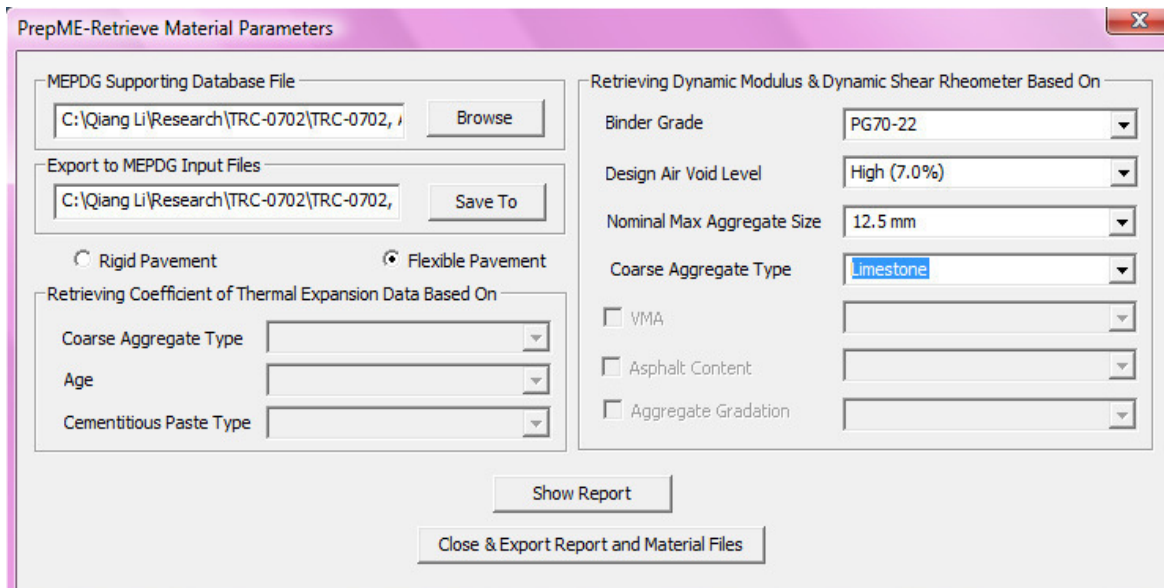


Figure D.11 Retrieve Material Parameters

(5) Click “**Show Report**” button and the software will retrieve the material data summary report.

The designer can check the report and compare the data obtained from the database with the material to be designed, then make proper engineering judgments and provide the input values for a specific design project if site specific testing data are not

available. Figure D.12 is the snapshot of the summary report window for E\*, and Figure D.13 for CTE.

PrepME-Dynamic Modulus Report

Retrieved Parameters | Material Gradation | Mix Design Summary | Dynamic Modulus E\* (ksi) | Phase Ang

Temperature (F degree)	Frequency					
	0.1	0.5	1.0	5.0	10.0	25.0
14	2331.75	2710.14	2861.46	3216	3319.34	3495.41
40	1257.74	1624.13	1746.48	2119.63	2270.65	2471.5
70	349.82	522.49	597.8	1032.32	1124.07	1289.08
100	65.21	105.89	133.69	245.93	321.95	451.95
130	24.58	32.79	38.56	63.8	83.28	125.53

Figure D.12 Dynamic Modulus Report

PrepME-Coefficient of Thermal Expansion Report

Retrieved Parameters

Coarse Aggregate Type:

Age:

Cementitious Paste Type:

Coefficient of Thermal Expansion (per F degree x 10-6):

Strength & Poisson's Ratio

Time	Elastic Modulus (ksi)	Compressive Strength (ksi)	Poisson's Ratio
3 days	<input type="text"/>	4320	<input type="text"/>
7 days	5.026	4976	0.227
28 days	5.241	5334	0.222
90 days	5.307	5536	0.231

Mix Properties

Cement (lb/yd <sup>3</sup> )	<input type="text" value="564.00"/>	Water (lb/yd <sup>3</sup> )	<input type="text" value="254.00"/>
Fly Ash (lb/yd <sup>3</sup> )	<input type="text"/>	Water/Cement	<input type="text" value="0.44"/>
Slag (lb/yd <sup>3</sup> )	<input type="text"/>	Daravair (fl oz/cwt)	<input type="text" value="1.50"/>
Coarse Aggregate (lb/yd <sup>3</sup> )	<input type="text" value="1950.00"/>	Temperature (F degree)	<input type="text" value="54.00"/>
Coarse Aggregate Type	<input type="text" value="LimeStone"/>	Slump (in)	<input type="text" value="2.00"/>
Coarse Aggregate Size (in)	<input type="text" value="1.00"/>	Air Content (%)	<input type="text" value="5.80"/>
Fine Aggregate (lb/yd <sup>3</sup> )	<input type="text" value="1099.00"/>	Unit Weight (pcf)	<input type="text" value="141.00"/>

Figure D.13 Coefficient of Thermal Expansion Report

(6) Click “Close & Export Report and Material Files” button

Because the MEPDG software version 1.0 has the capability to import dynamic modulus and binder DSR data, in this step the software can generate the dynamic modulus and binder DSR files based on the file formats defined in MEPDG software. For CTE data, because the MEPDG software doesn't have the capability of directly importing, the designer needs to manually input the CTE value from the summary report. In addition, the summary reports are also saved for the designer's reference at this step in the specified directory. The generated dynamic modulus and binder DSR files are shown in Figure D.14.

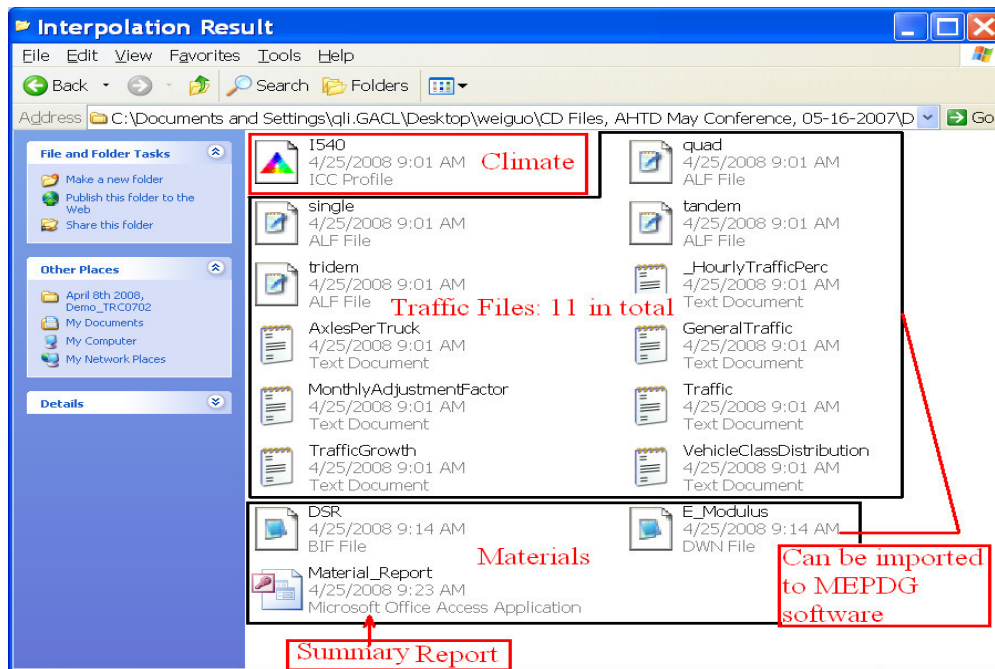


Figure D.14 Interpolated climate, traffic, and material files

### III. IMPORT THE GENERATED DATA FILES INTO MEPDG

The detailed steps on how to import the data files generated by PrepME come as follows:

#### Step 1. Start the MEPDG Software.

#### Step 2. Import Generated Climate File to MEPDG

(1) Double click on “Climate” icon on the MEPDG software interface (Figure D.17).

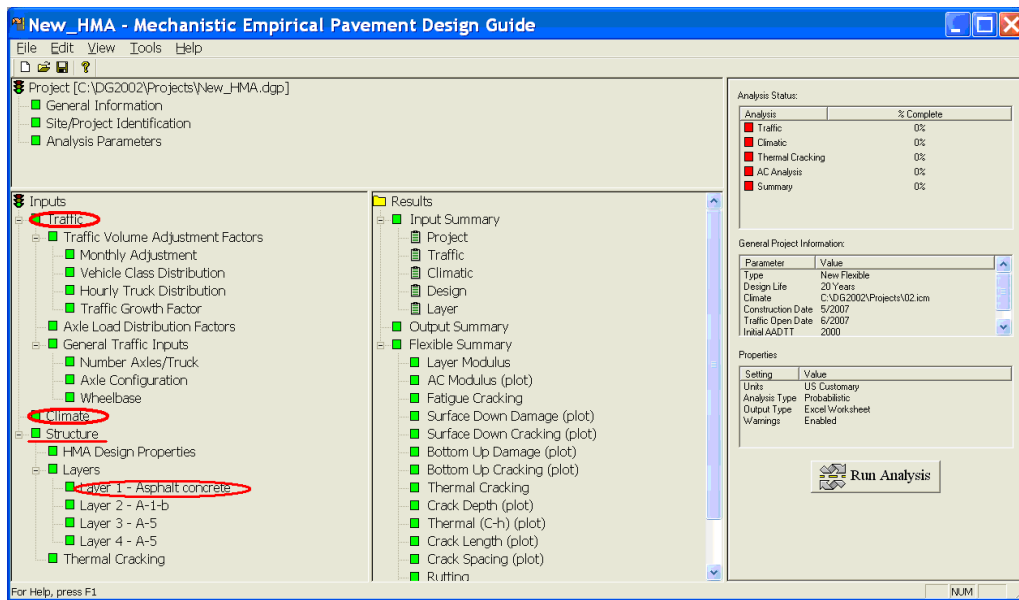


Figure D.15 The Opening interface of MEPDG software

(2) Click “Import” button, locate the generated importable climate file, and click “Accept Station” (Figure D.16).

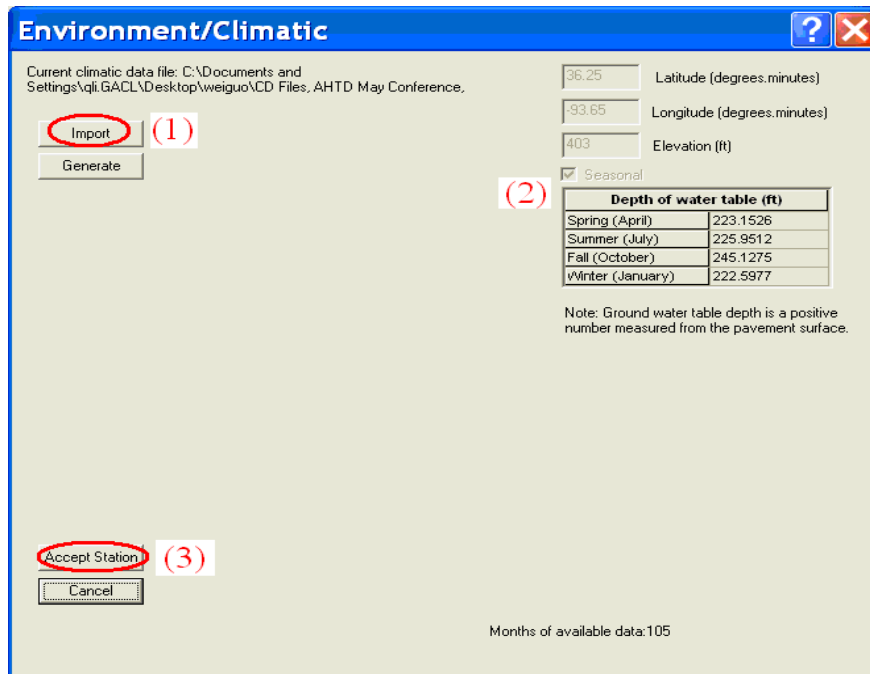


Figure D.16 Climate Import Capabilities in MEPDG Software

### Step 3. Import Generated Traffic Files to MEPDG

(1) Double click on “**Traffic**” icon on the MEPDG software interface (Figure D.15).

(2) First click the “**Import/Export**” button and the Import/Export Traffic window will pop up; then locate the directory of the traffic files that were saved and the list of generated traffic files will show under the “**Available traffic files**” window; and click the “**Import**” bottom and the traffic files are imported to the MEPDG software (Figure D.17).

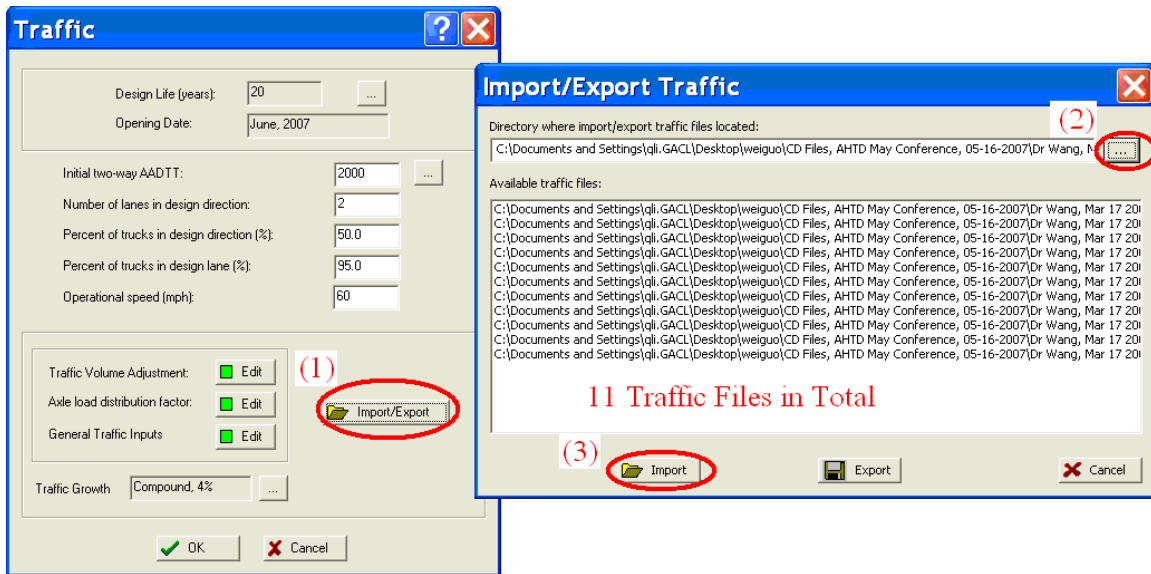


Figure D.17 Traffic Import/Export Capabilities in MEPDG Software

#### Step 4. Import Generated Material Files to MEPDG

(1) Double click on “**Layer 1—Asphalt Concrete**” icon under “**Structure**” Menu on the MEPDG software interface (Figure D.17).

(2) On the “**Asphalt Material Properties**” window, change the design level from the default level 3 to level 1 and choose the “**Asphalt Mix**” tab, then click the “**Import**” button and select the generated dynamic modulus file. After the file is imported, the data will be shown on the screen (Figure D.18)

(3) Similarly, the DSR data can be imported to the MEPDG software by clicking the “**Asphalt Binder**” tab and choose the “**Superpave binder test data**” (Figure D.19).



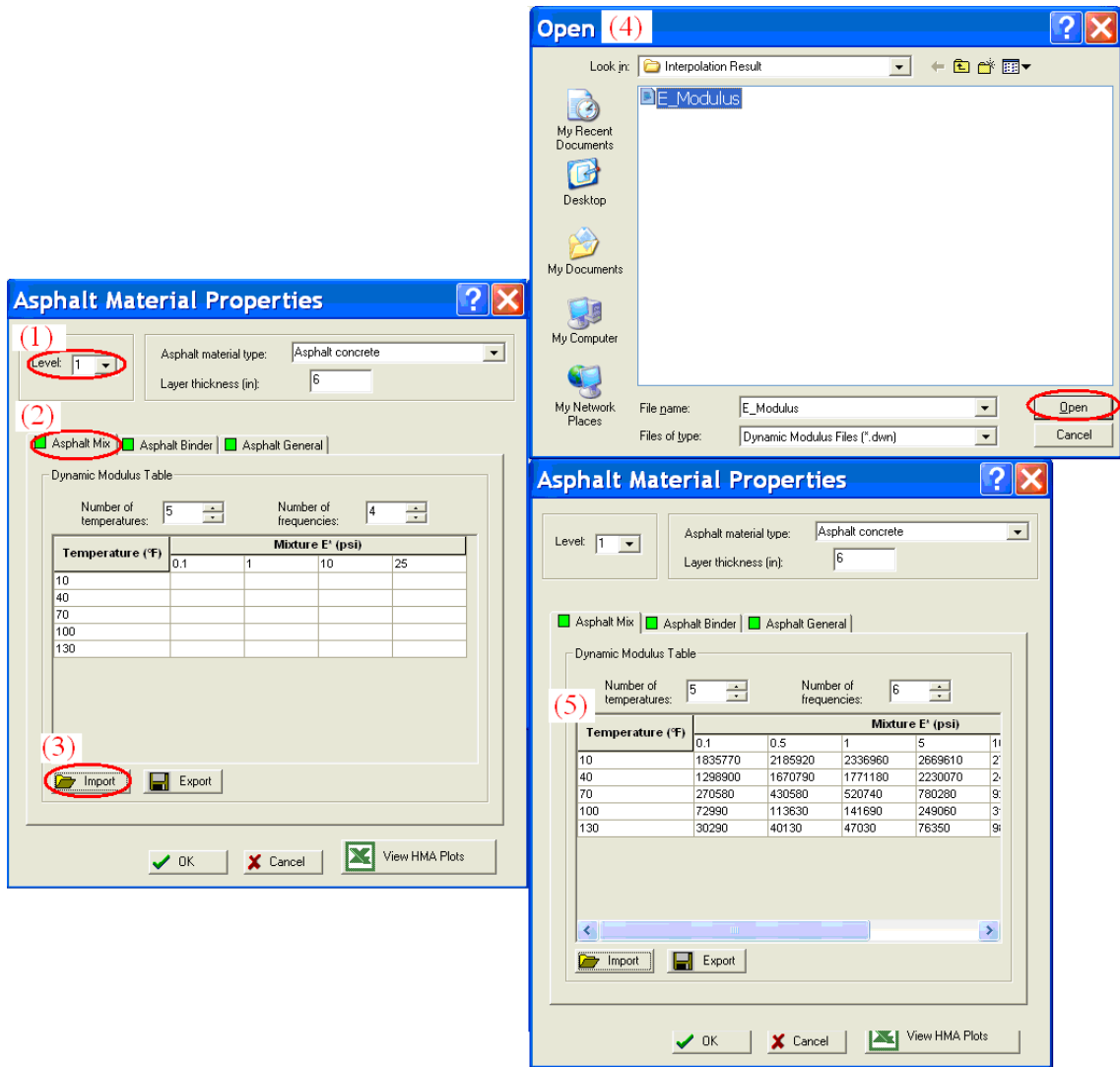


Figure D.18 Import Dynamic Modulus Data to the MEPDG software

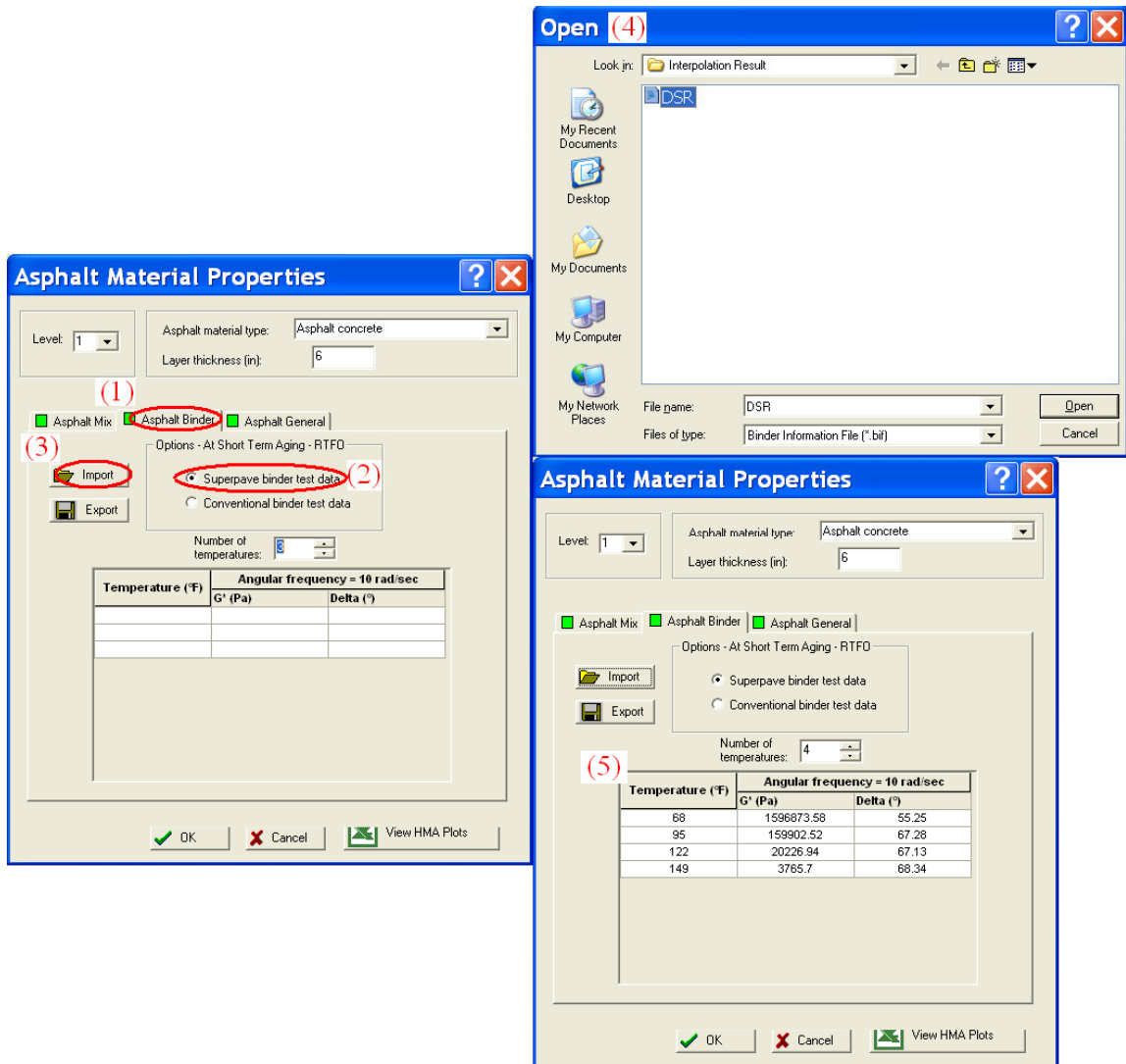


Figure D. 19 Import DSR Data to the MEPDG software