CHAPTER 1
INTRODUCTION

1.1 Introduction

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

This manual presents the following information to assist CDOT pavement design engineers to perform pavement designs using the *AASHTO Interim MEPDG Manual of Practice* and the M-E Design software.

- An overview of the AASHTO Pavement M-E Design procedure
- An overview of the M-E Design software
- Guidelines for obtaining all needed inputs for design/analysis
- Guidance to perform pavement design/analysis using the software
- Examples of pavement design using the Design Guide software

This guidance will assure adequate strength and durability to carry the predicted traffic loads for the design life of each project. Alternative designs (flexible and rigid) should be considered for each project and specific project conditions. The final design should be based on a thorough investigation of projected traffic, specific project conditions, life-cycle economics, and the performance of comparable projects with similar structural sections and conditions.

1.2 Scope and Limitations

1.2.1 Limitations

Design of the pavement structure includes the termination of the thickness of subbases, bases, and surfacing to be placed over subgrade soils. An important aspect of this design is the selection of available materials that are most suited to the intended use. Their grouping in horizontal layers under the pavement, from poorer layers on the bottom to better layers on the top, should be such that the most benefit will be derived from the inherent qualities of each material. In establishing the depth of each layer, the objective is to provide a minimum thickness of overlying material that will reduce the unit stress on the next lower layer and commensurate with the load-carrying capacity of the material within that layer.

The design of the roadbed cross-section is not an exact science. With many variables to be correlated, reducing the problem to exact mathematical terms applied to structures is extremely difficult. Present practice, as discussed herein, stems from mechanistic procedures and empirical

relationships developed from test tracks and other pavement experiments, as well as, the observation of pavements under service throughout the state. Research continues on this subject and current design methods may be subject to frequent modification.

1.2.2 Scope

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

Table 1.1 Recommended Pavement Design Procedures

Pavement Type	Design Methodology	
	CDOT 2017 Pavement M-E Design Manual	CDOT 2014 Pavement Design Manual (18k ESAL Design)
New HMA	✓	
Flexible Overlays of Existing HMA	✓	
Flexible Overlays of Existing Rigid	✓	
New Rigid	✓	
PCC Overlays of Existing Rigid	✓	
Thin and Ultrathin Concrete Overlay		✓
Concrete Pavement Restoration	✓	
Flexible Pavement for Intersections	✓	
Rigid Pavement for Intersections	✓	

1.3 Overview of AASHTO Pavement Mechanistic-Empirical Design Procedure

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

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

- AASHTO, *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*, November 2010, American Association of State Highway and Transportation Officials, Washington, DC, 2010.

- NCHRP, 1-37A Project. *2002 Design Guide: Design of New and Rehabilitated Pavement Structures*, National Cooperative Highway Research Program, National Academy of Sciences, DC, 2004.

The pavement design computations using the M-E Design procedure and software are an iterative process as shown in the flowchart in **Figure 1.1 M-E Design Process**. The software provides:

- A user interface to input design variables
- Computational models for month by month analysis and performance prediction
- Results and outputs from the analysis for decision making
- Outputs in both pdf and Microsoft Excel formats suitable for use in design reports

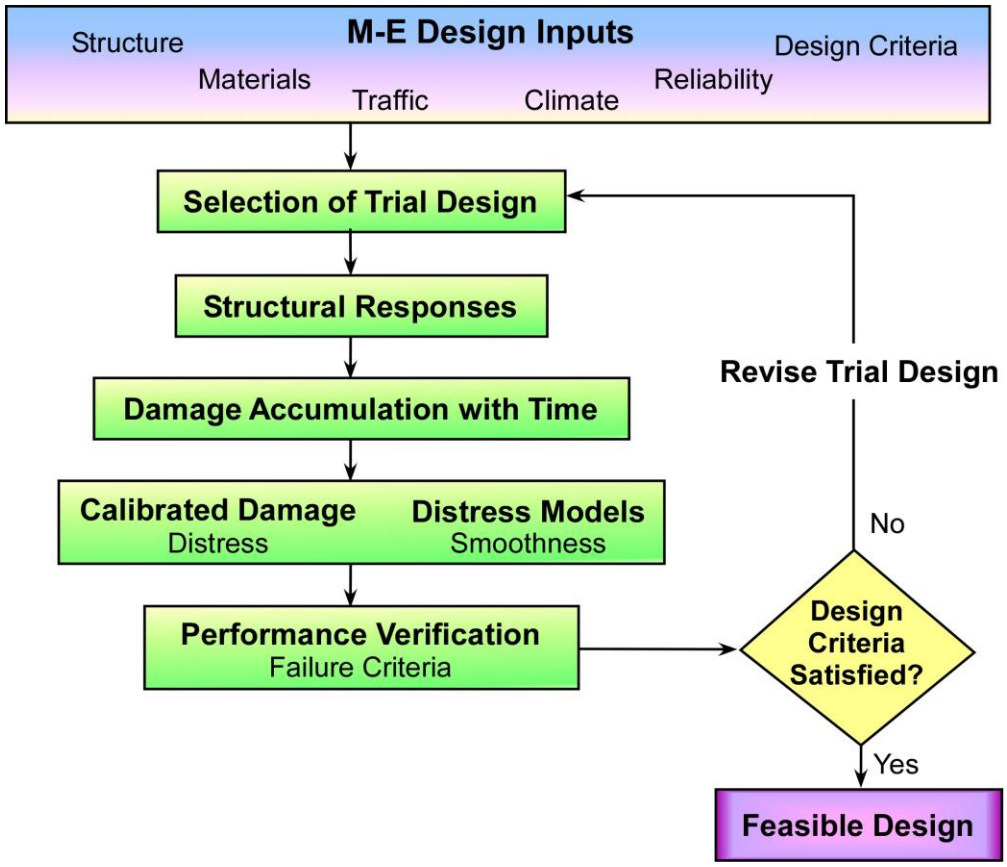

Figure 1.1 M-E Design Process

The design iterative process with the M-E Design procedure involves the following key steps:

1. The designer develops a trial design and obtains all inputs.

2. The software computes the traffic, climate, damage, key distresses (fatigue cracking, rutting, joint faulting, etc.), and International Roughness Index (IRI) over the design life on a month by month basis for concrete and a two week basis for HMA pavement.

3. The predicted performance (distress and IRI) over the design life is compared to the design performance criteria at a desired level of design reliability. Does the design pass or fail to meet the design reliability for each distress and IRI?

4. The design may be modified as needed to meet performance and reliability requirements.

1.4 Overview of AASHTOWare Pavement M-E Design Software

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

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

- From the Windows Start menu, click '*All Programs'* and then select the '*AASHTO DARWin-ME'* folder, refer to **Figure 1.2 Location of M-E Design Software HELP Document**.

- Press the '*F1 key'* after opening the software, see **Figure 1.3 M-E Design Software Default Window** and **Figure 1.4 M-E Design Software HELP Document**.

1.4.1 Installing M-E Design Software

For more information on installing the M-E Design software files, minimum software requirements, and licensing agreements, contact the CDOT IT System Administrator or refer to the M-E Design software HELP document.

1.4.2 Uninstalling M-E Design Software

Never just delete the various files of the M-E design software. Always uninstall the software using the procedure outlined in the M-E Design software HELP document. For more information of

uninstalling the M-E Design software files, contact the CDOT IT System Administrator or refer to the M-E Design software help document.

Note: This process does not remove the :hcd weather station files under the folder. This folder must be manually deleted if desired. If existing old MEPDG weather station files exist, it is recommended to remove all of the files and then download the new weather station files.

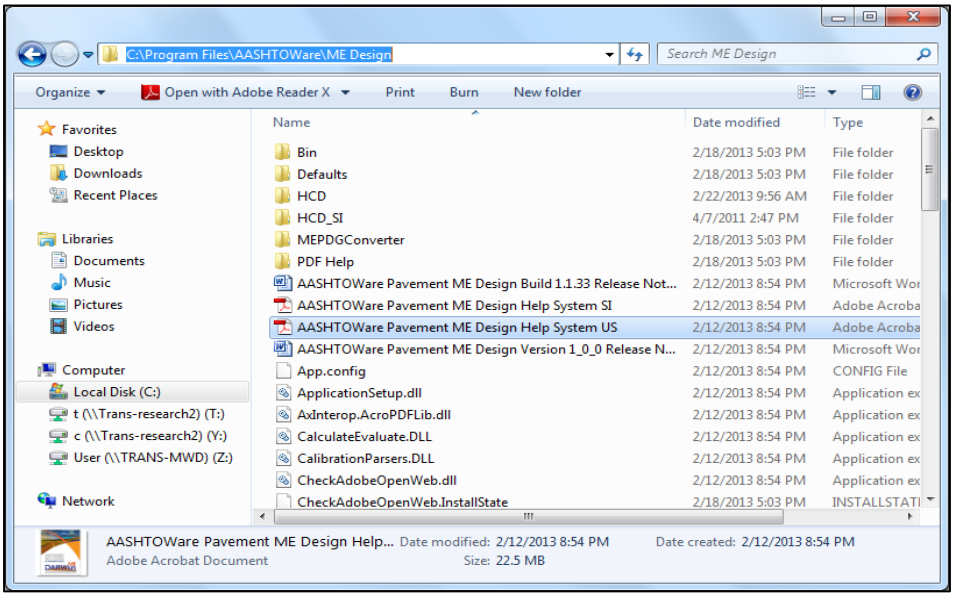

Figure 1.2 Location of M-E Design Software HELP Document

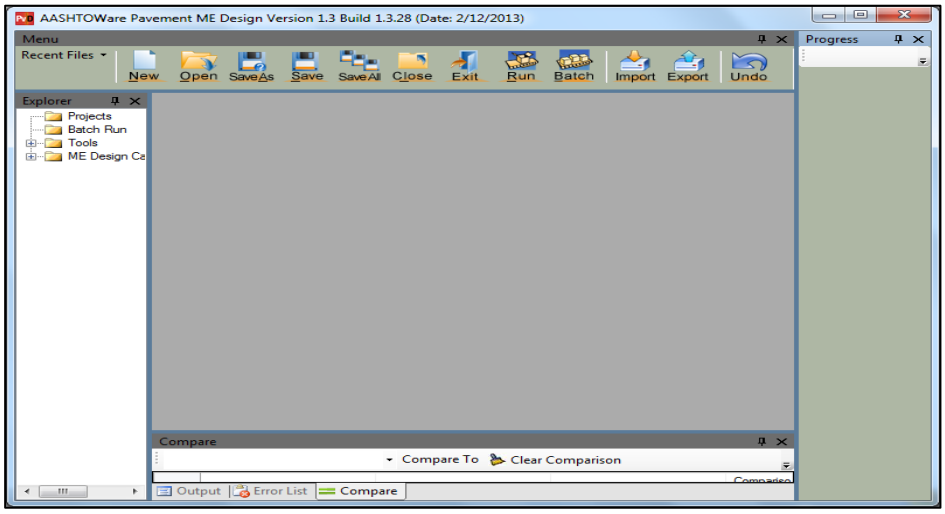

Figure 1.3 M-E Design Software Default Window

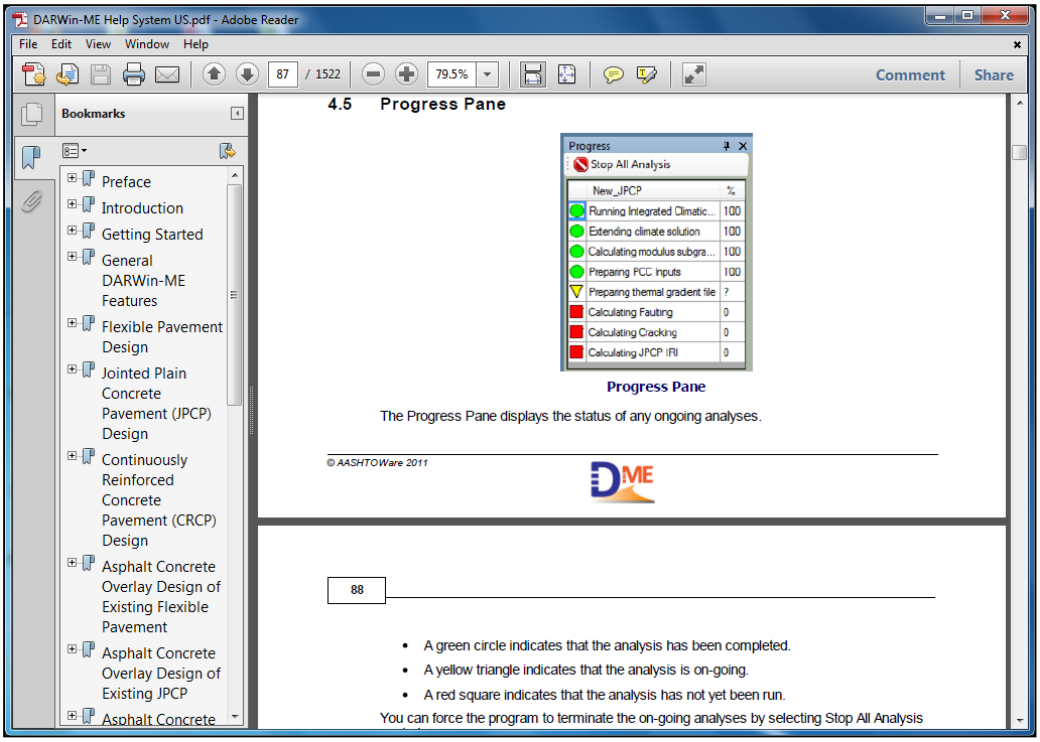

Figure 1.4 M-E Design Software HELP Document

1.4.3 Running M-E Design Software

The M-E Design program will be added to your Windows Start menu during installation and an icon will be added to the PC desktop.

Click the '*Start'* button in the bottom left corner of your screen to find the M-E Design software.

1. Go to the '*Programs'* option to see a list of folders and programs.
2. Select the '*DARWin-ME'* folder and click on the design guide icon.

The program can also be run by double-clicking the '*M-E Design'* icon on the desktop. The software opens with a splash screen shown in **Figure 1.5 M-E Design Software Splash Screen**. A new file must be opened for each new project, much like opening a new file for each document on a word processor or other standard Windows applications. A maximum of ten projects can be opened together by clicking the '*Open Menu'* in M-E Design (see **Figure 1.6 Open M-E Design Projects**). Select '*New'* from the menu on the tool bar to open a new project. A typical layout of the program is shown in **Figure 1.7 M-E Design Software Main Window** and **Figure 1.8 M-E Design Software Project Tab.**

The user first provides the general project information and the inputs for three main categories: traffic, climate, and structure. All inputs for the software program are color coded as shown in **Figure 1.9 M-E Design Software Color-Coded Inputs to Assist User Input**

Accuracy

Input screens that require user entry of data are coded red. Those that have default values but not yet verified and accepted by the user are coded yellow. Default inputs that have been verified and accepted by the user or when the user enters design-specific inputs are coded green. The program will not run until all input screens are either yellow or green.

The user may choose to run the analysis by clicking on the '*Run'* button after all inputs are provided for the trial design. The software will execute the damage analysis and the performance prediction engines for the trial design's input. The user can view input and output summaries created by the program when the execution of the run is complete. The program creates a summary of all inputs and provides an output summary of the distress and performance prediction in both tabular and graphical formats. All charts are plotted in both pdf and Microsoft Excel formats and may be incorporated into electronic documents and reports.

Figure 1.5 M-E Design Software Splash Screen

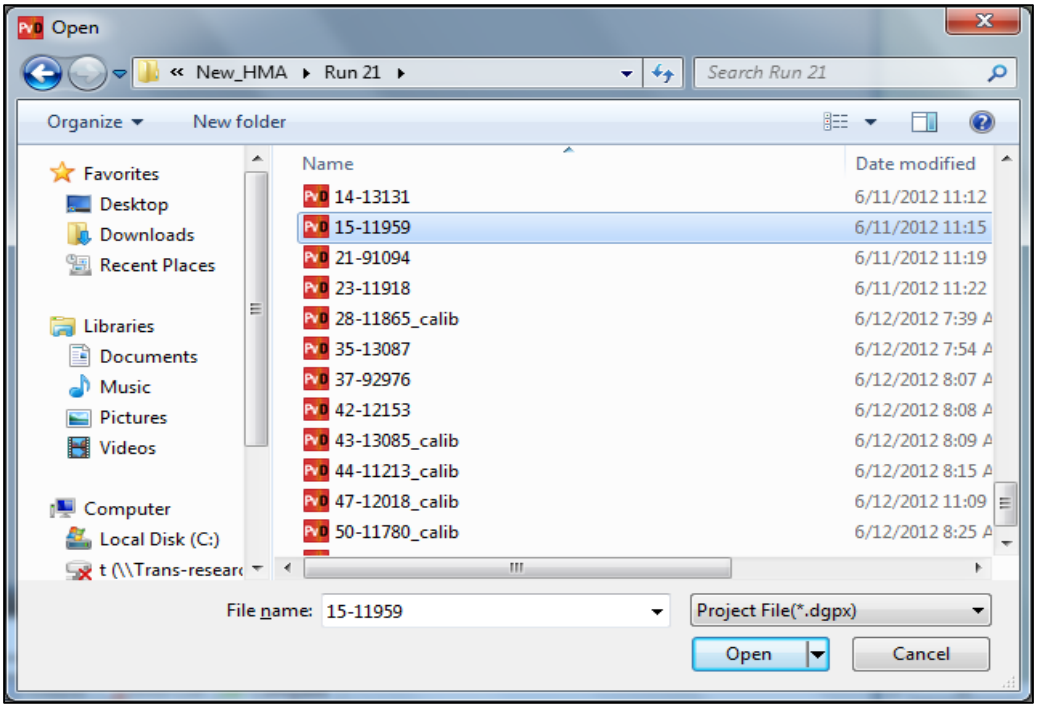

Figure 1.6 Open M-E Design Projects

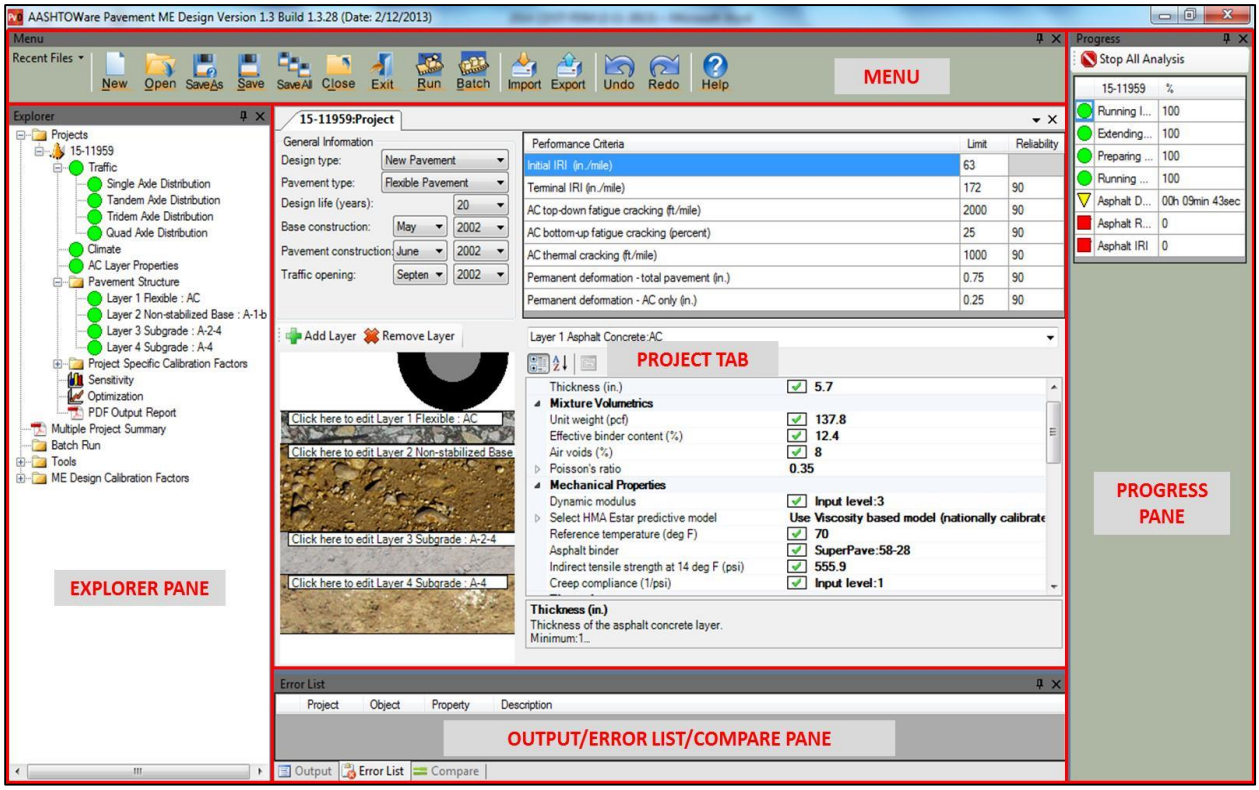

Figure 1.7 M-E Design Software Main Window

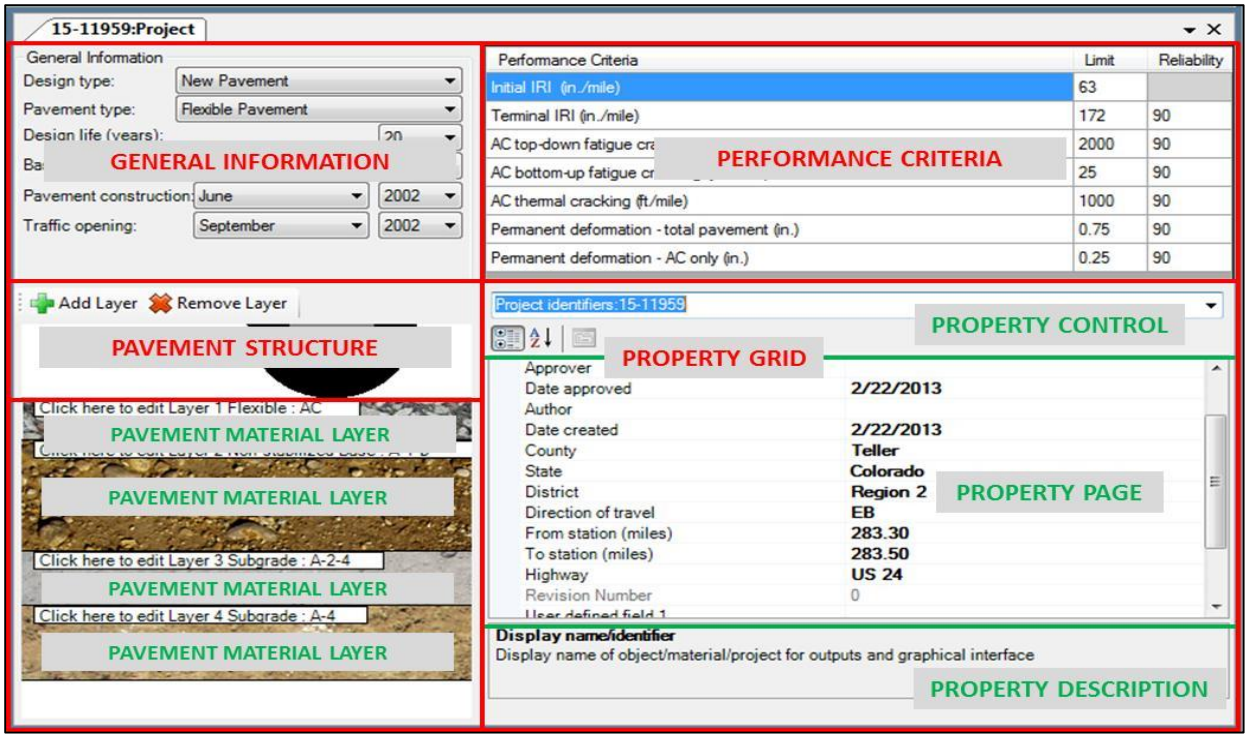

Figure 1.8 M-E Design Software Project Tab

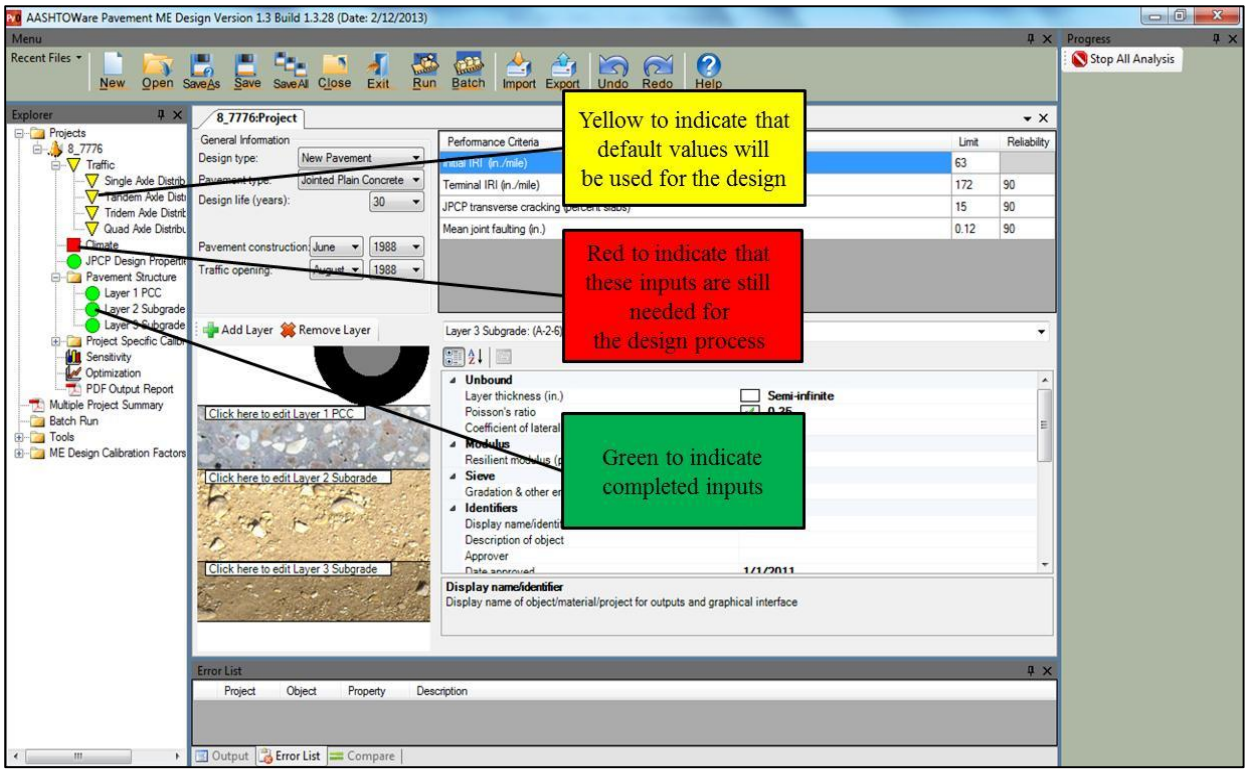

Figure 1.9 M-E Design Software Color-Coded Inputs to Assist User Input Accuracy

1.5 Working with the M-E Design Database

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

Download and Access Instructions

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

Database Installation

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

Installation Requirements

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

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

Once the database is installed, the user can open the M-E Design software and select '*Open M-E Design'* with a data base connection check box (see **Figure 1.10 M-E Design Software Splash Screen Showing Database Login Location.**)

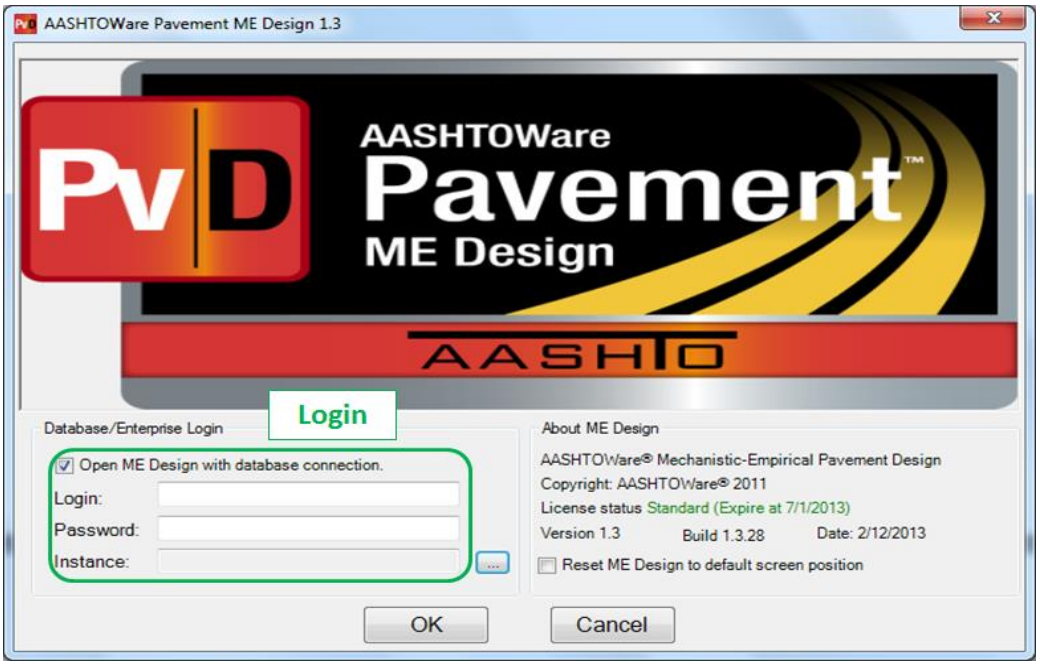

Figure 1.10 M-E Design Software Splash Screen Showing Database Login Location

Enter the Login name and Password supplied by the CDOT IT Department to access the M-E Design database, see **Figure 1.11 M-E Design Software Splash Screen Showing Database Login Information**.

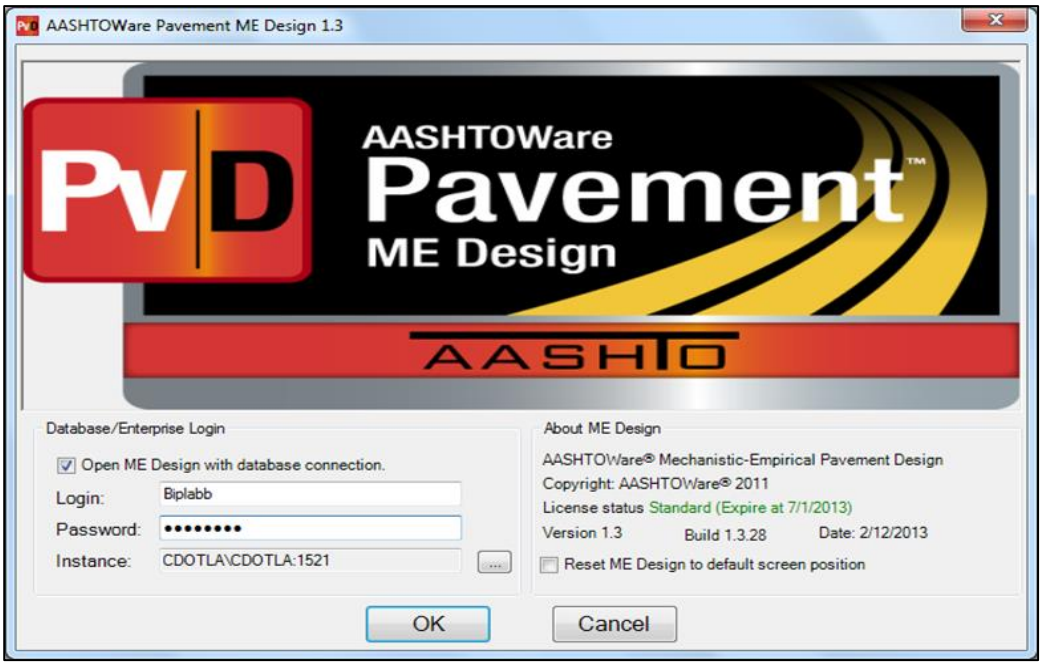

Figure 1.11 M-E Software Splash Screen Showing Database Login Information

1.5.1 Saving to M-E Design Database

This section will discuss how to save M-E Design elements to the database. It will also highlight the differences in how the elements are saved on each screen and supply screenshots for each example. **Note:** In order for the '*Save to Database'* option to be available, the user must connect to a M-E Design database during the login process.

Saving Projects

When a user saves a project, all elements of the project are saved in the database. If any of the project elements have an error, the user will be informed of the error with a message box and asked to correct the error before continuing. There are two ways to save a project to the database:

1. Right click on the project name under the '*Projects'* node and select '*Save to Database'* (see **Figure 1.12 Saving and Entire Project to M-E Design Database (Option 1**)).

2. Click to highlight the project name under the '*Projects'* node and click the '*Insert'* icon on the menu bar across the top of the application (see **Figure 1.13 Saving an Entire Project to the M-E Design (Option 2)**).

If the project contains no errors in the message, '*Project Inserted Successfully'* will pop up (see **Figure 1.14 Window Showing Successful Project Save**). Click '*OK'* to close the message box.

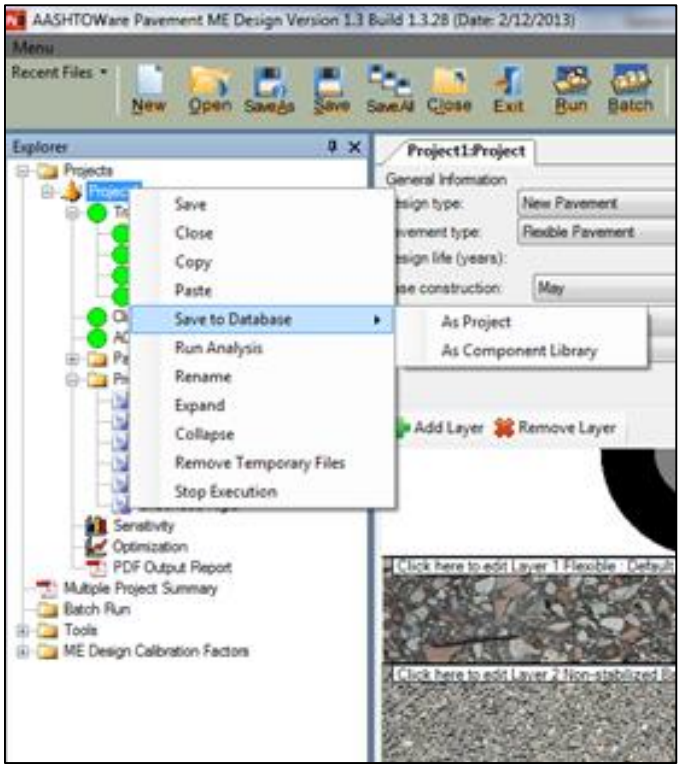

Figure 1.12 Saving an Entire Project to the M-E Design Database (Option 1)

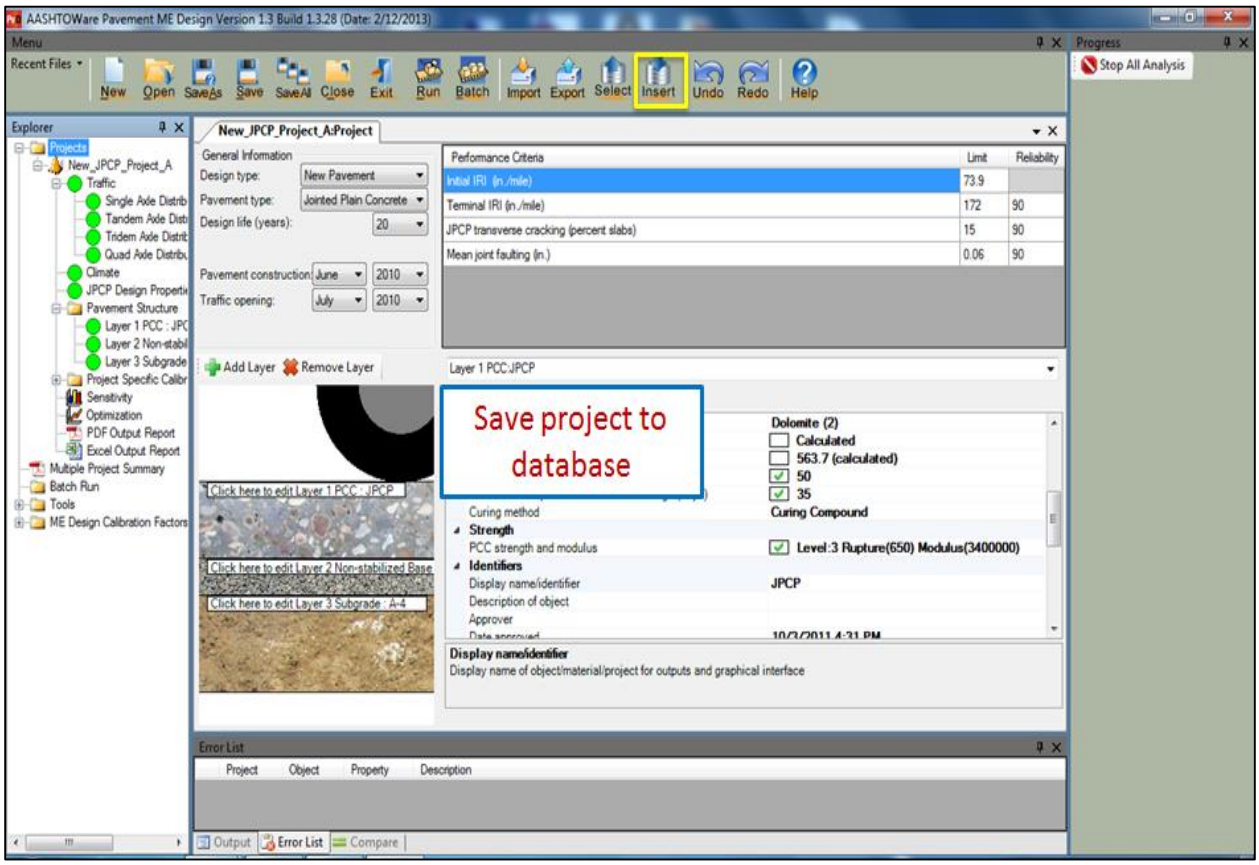

Figure 1.13 Saving an Entire Project to the M-E Design Database (Option 2)

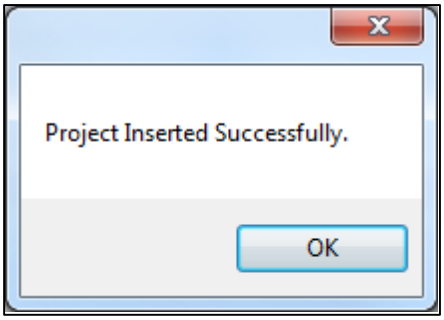

Figure 1.14 Window Showing Successful Project Save

Once a project is saved to the database, the project cannot be saved again under the same name. Only project elements can be "saved over" or updated once they exist in the database. To change the '*Display name/Identifier'* of your project, right click on the project title in the Explorer pane and select '*Rename'* (see **Figure 1.15 Changing the Project Display Name/Identifier**). Chose a new name for your project and then right click on the project in the Explorer and select '*Save to Database'*. The project will now save with a new name.

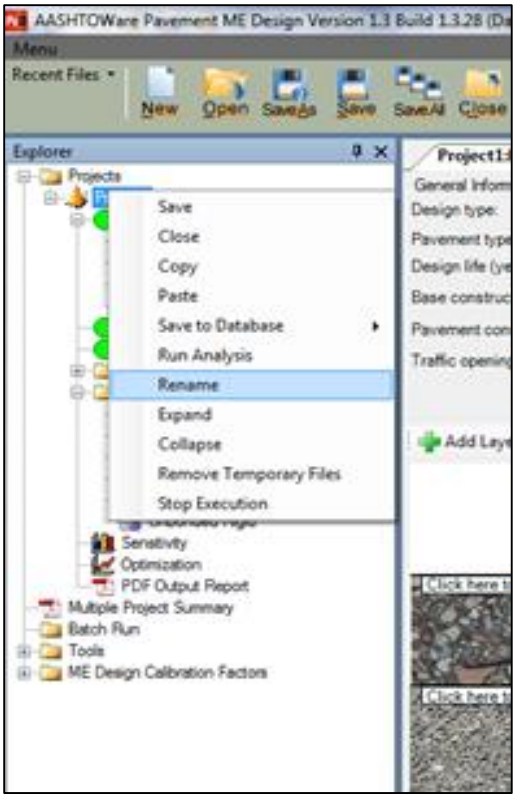

Figure 1.15 Changing the Project Display Name/Identifier

Saving Project Elements

Saving project elements is similar to the steps described in the section titled Saving Projects. Project elements include but are not limited to the following:

- Traffic
  - Single axle distribution
  - Tandem axle distribution
  - Tridem axle distribution
  - Quad axle distribution
- Climate
- Any layers added under "*Pavement Material Layers*" node
- Backcalculation

There is one primary difference between saving an entire project and saving elements within the project. Unlike projects, project elements can be saved over and over again without having to modify any element identifiers. This means if the user wants to save a project element such as '*Traffic*', make changes to it, and save it again, the program will update the project with the new traffic information instead of creating a new one.

All the elements described above have a '*Save to Database'* method associated with them, with a few special cases for traffic and its associated elements. The traffic element provides two unique saving methodologies.

1. Right clicking on the '*Traffic'* node and selecting '*Save to Database'* will save information under the '*Traffic'* node only (see **Figure 1.16 Saving Traffic Data**).

2. The user may also elect to double click on the '*Traffic'* node which will open the traffic interface. The user can then right click on any of the views within the interface including vehicle class distribution and growth, monthly adjustment, or axles per truck; and select '*Save to Database'* to save the applicable traffic element to the database (see **Figure 1.17 Saving Specific Traffic Elements**).

Note: This is the only way to save these particular traffic elements independently as they do not appear in the Explorer tree.

In contrast, saving any one of the axle load elements automatically saves all the others as well. **Figure 1.18 Saving Axle Load Distribution Elements** shows how to save axle load distribution elements in the M-E Design database. If the axle load distribution contains no errors, the message '*Axle Load Inserted Successfully'* will pop up (see **Figure 1.19 Window Showing Successful Axle Load Distribution Save**). Click '*OK*' to close the message box.

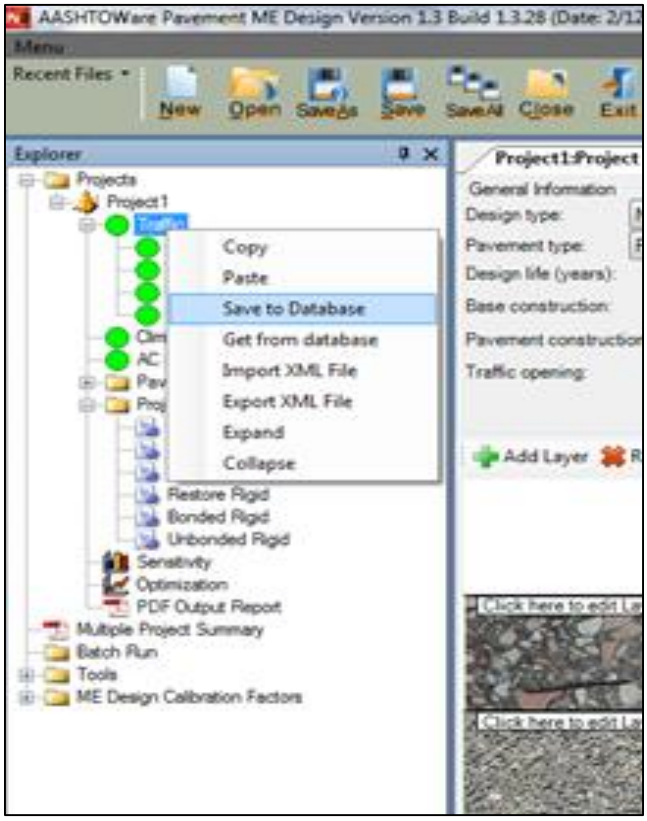

Figure 1.16 Saving Traffic Data

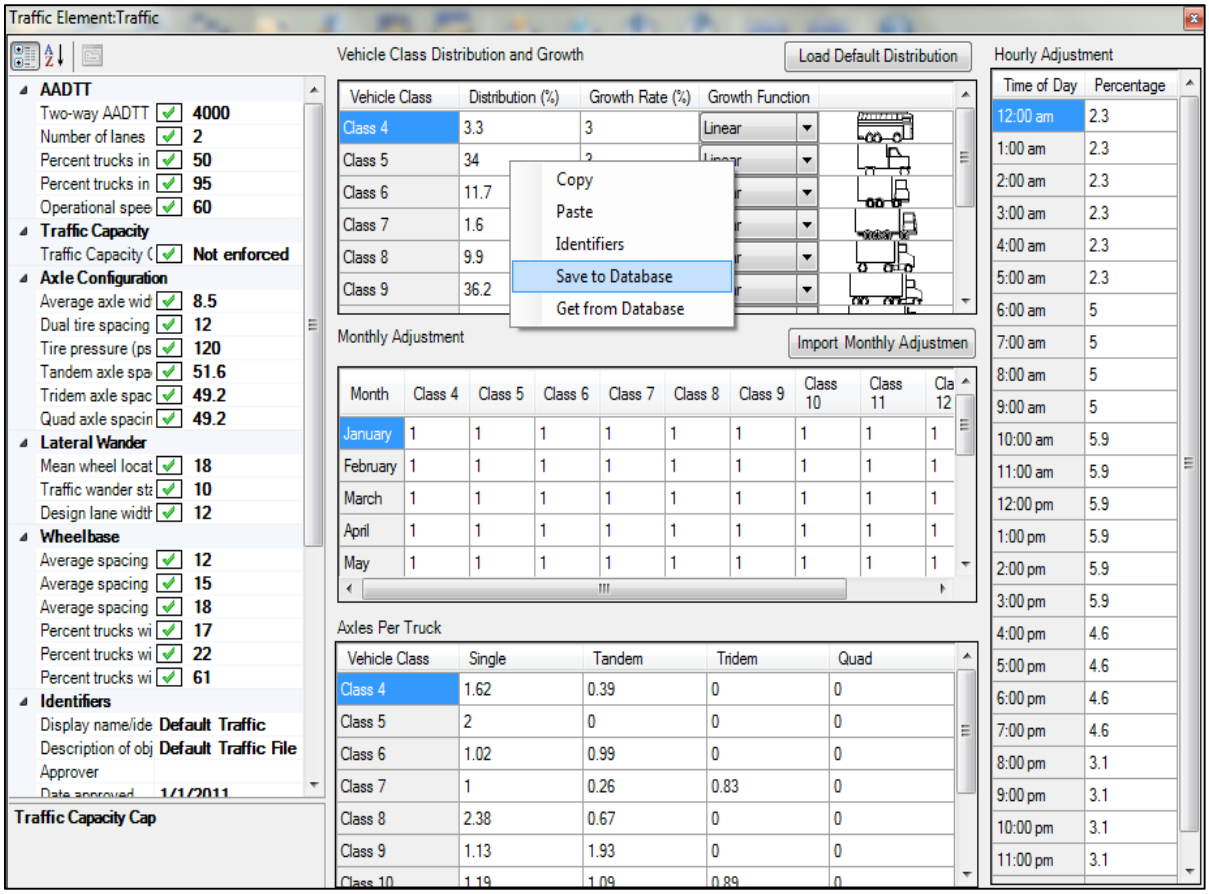

Figure 1.17 Saving Specific Traffic Elements

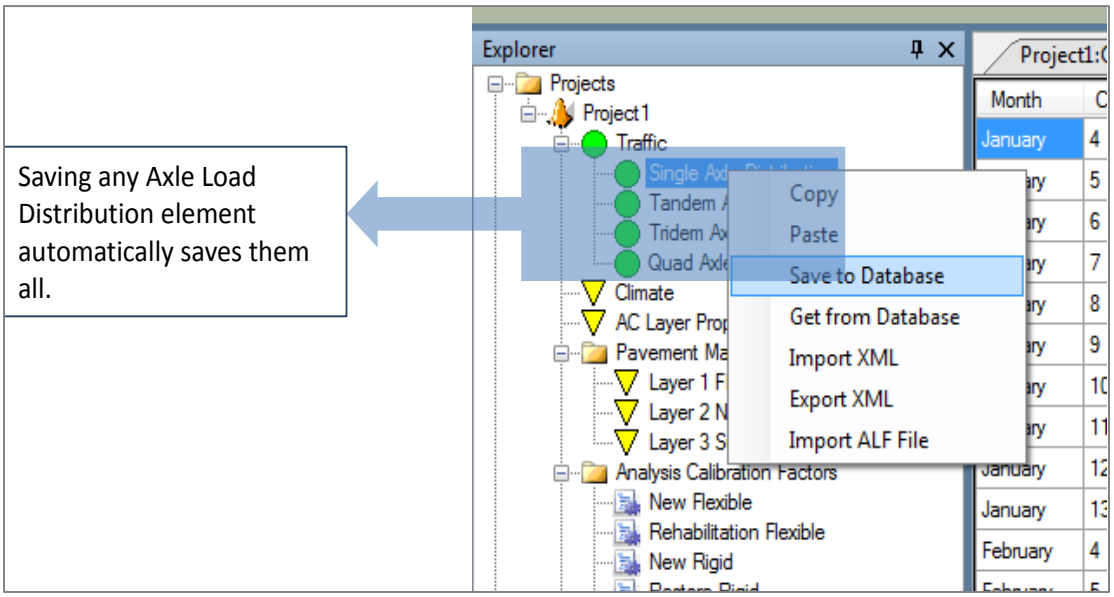

Figure 1.18 Saving Axle Load Distribution Elements

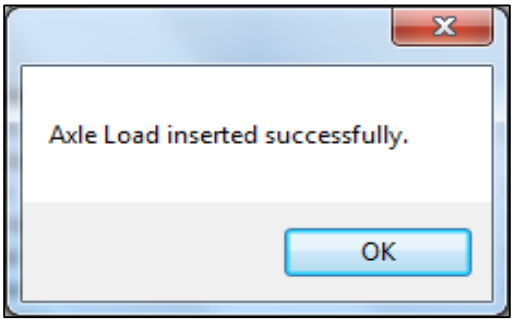

Figure 1.19 Window Showing Successful Axle Load Distribution Save

If the user receives the following error message shown in **Figure 1.20 Error Saving Axle Load Distribution** while saving the project element, then either the user needs to change the existing name of the element/project they are trying to save, or fill in the '*Display Name/Identifier'* field for the element.

This means the user needs to open the axle load distribution interface, right click, and select '*Identifiers'* (see **Figure 1.21 Defining Identifiers for Axle Load Distribution**). The user can fill in the '*Display Name/Identifier'* field shown in **Figure 1.22 Editing Display Name/Identifiers for Axle Load Distribution** and '*Close'* the window. Now the axle load distribution element is saved to the database.

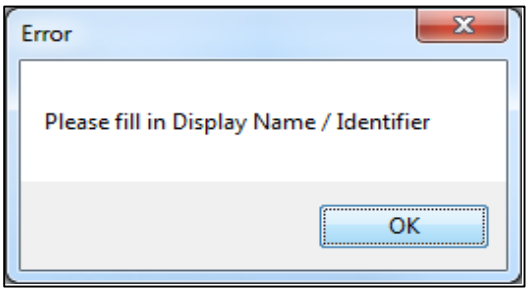

Figure 1.20 Error Saving Axle Load Distribution

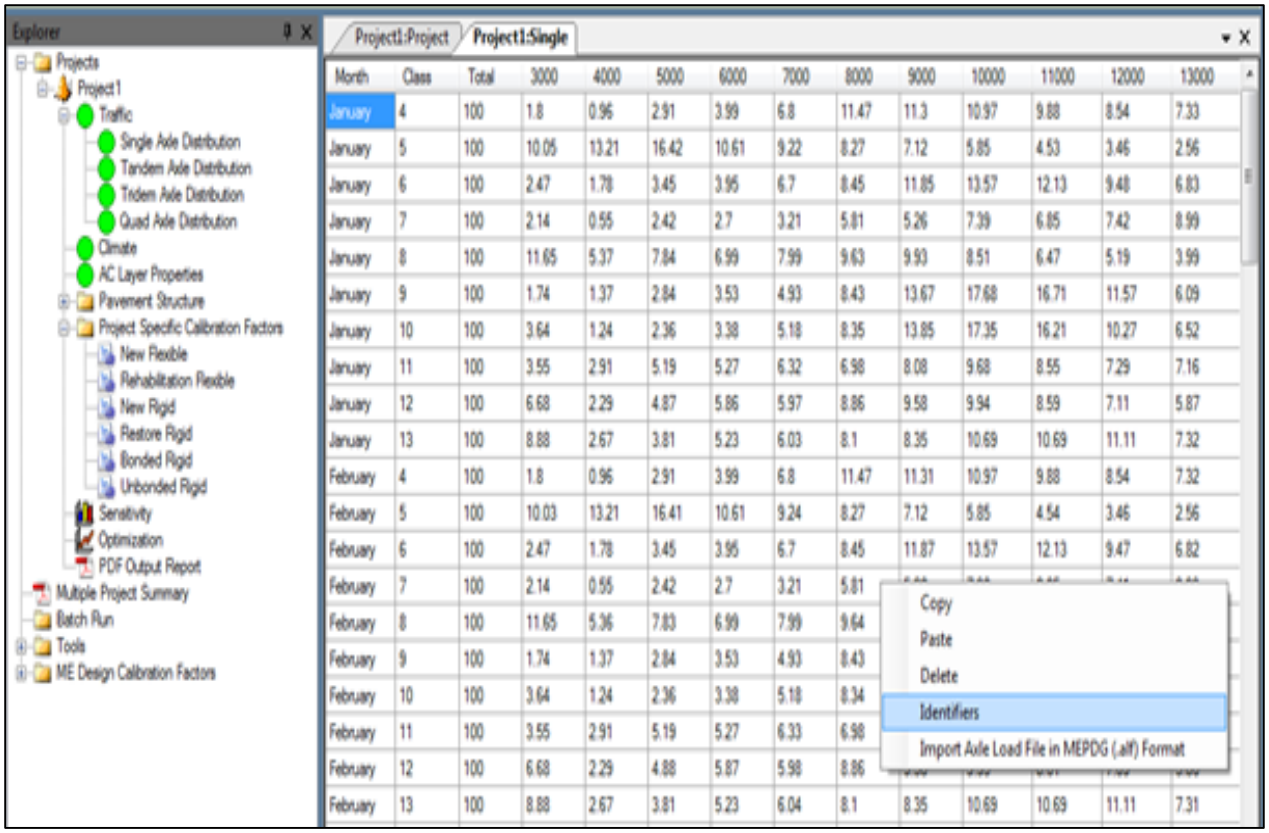

Figure 1.21 Defining Identifiers for Axle Load Distribution

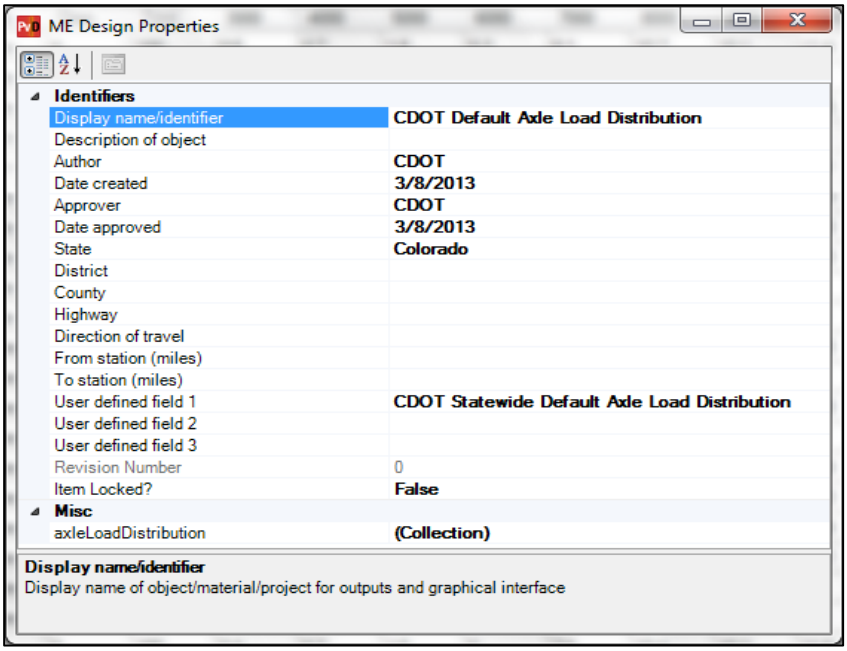

Figure 1.22 Editing Display Name/Identifiers for Axle Load Distribution

1.5.2 Retrieving or Importing from M-E Design Database

The data import process works similar to the save process in which the user should right click on the project or element they wish to import and select '*Get from Database'*. This will load the database information into the appropriate project.

Importing a Project

There are two ways to import an entire project from the database:

1. Right click on the project name under the '*Projects'* node and select '*Get from Database'*.

2. Click to highlight the project name under the '*Projects'* node and click the '*Select'* icon on the menu bar across the top of the application (see **Figure 1.23 Importing an Entire Project from M-E Design Database**).

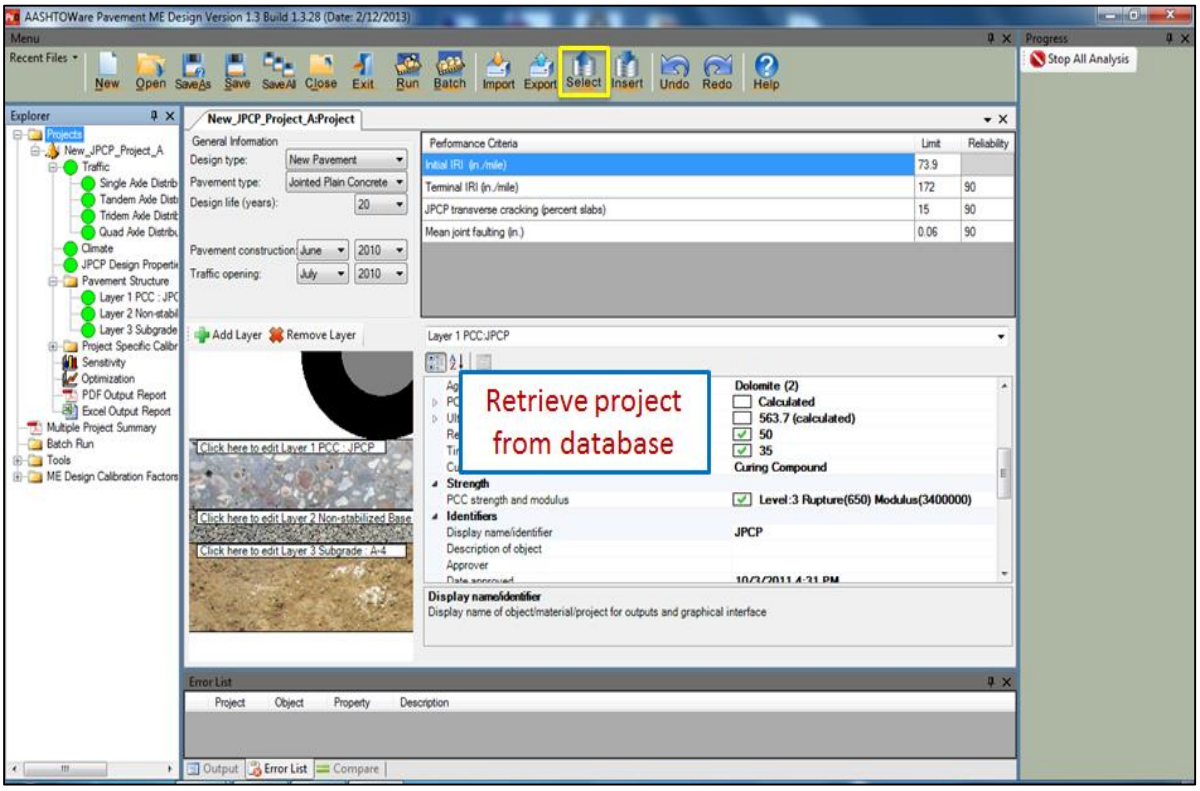

Figure 1.23 Importing an Entire Project from the M-E Design Database

This will open the search tool in M-E Design and will allow users to search for the database objects they wish to pull into the current projects, or they may load an existing project from memory. **Note:** If a user selects an element, but has no active projects in the explorer, a new project will be created. One of the projects from the list can then be selected and loaded into the user interface. Click '*OK'* to import a project or project element from the database. (see **Figure 1.24 Selecting**

a Project to Import from M-E Design Database). Once the statement has been generated, the user clicks on the '*Search'* button and is presented with the following screen.

Importing Elements into a Project

To import project elements, right click on the element you wish to import, and click '*Get from Database'*. This will bring up a window asking the user to select the element they wish to retrieve from the database. For example, to load climate data from the database, the user should right click on '*Climate'* and select '*Get from Database'* (see **Figure 1.25 Getting an Element from the M-E Design Database**). The M-E Design element is then loaded into the current project.

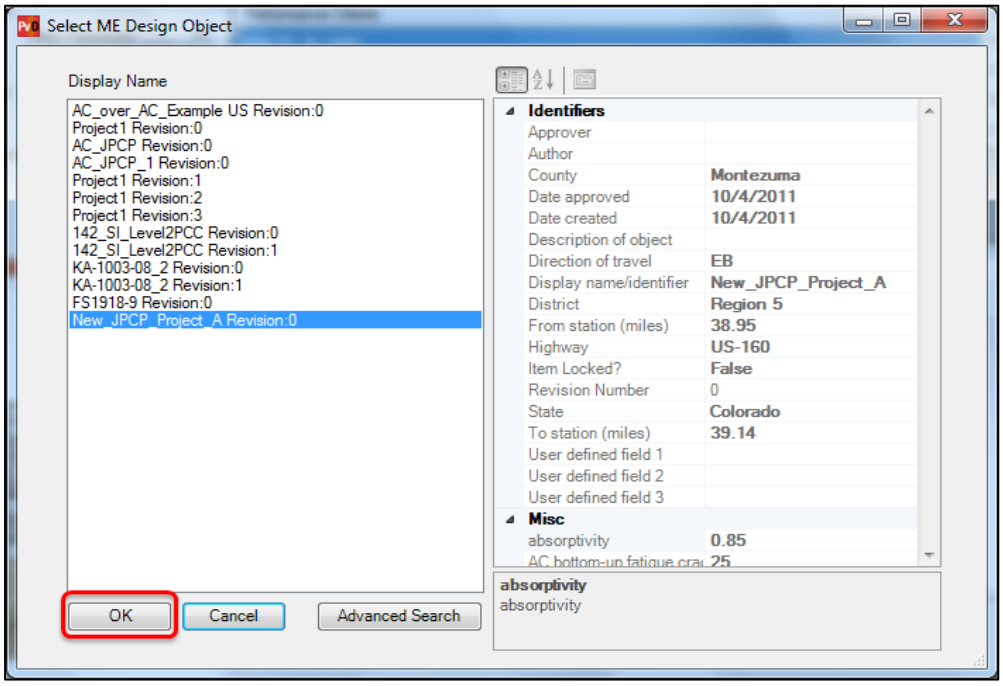

Figure 1.24 Selecting a Project to Import from the M-E Design Database

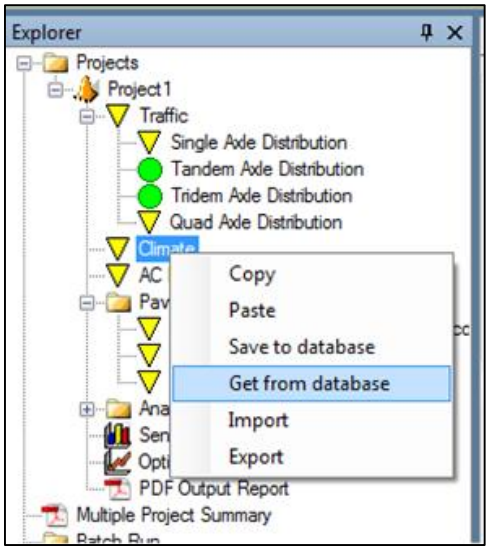

Figure 1.25 Getting an Element from the M-E Design Database

Using Advanced Search Tool

After opening the search tool in M-E Design, click the '*Advanced Search'* option. This will open an advanced search tool which allows a user to form queries to search for the database objects they wish to pull into the current project or to load an existing project from memory. **Note:** If a user selects an element, but has no active projects in the explorer, a new project will be created. Projects and project elements can be queried to find data which matches specific M-E Design criteria. In the example below, the user has selected the project and the variable(s) they wish to use a search. **Figure 1.26 Advanced Search Blank Window in the M-E Design Database** shows the advanced search window.

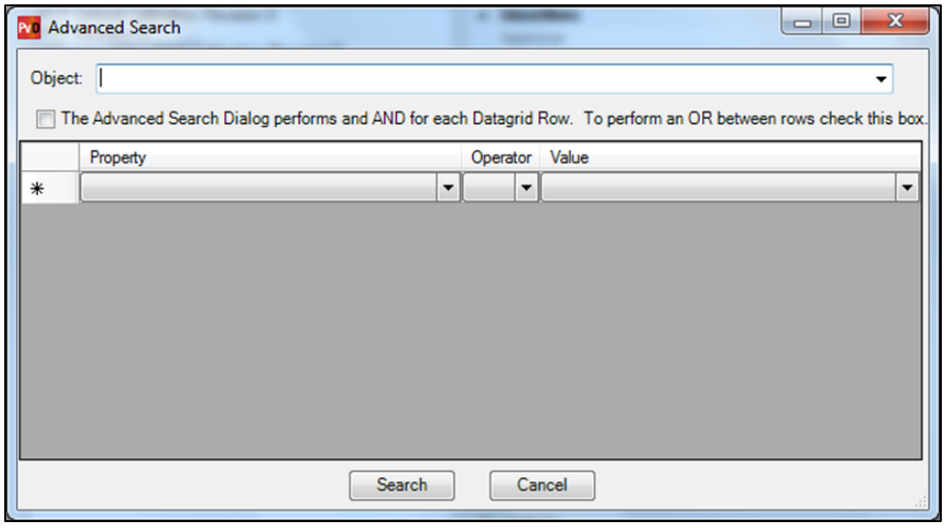

Figure 1.26 Advanced Search Blank Window in the M-E Design Database

First, the user selects the '*Object Type'* (in this case '*Project'*) they wish to filter. Next, they select a property associated with the object type (in this case '*Display Name'*). Finally, the user selects a value to match with the property (in this case '*HMA over HMA'*). The user then selects which type of operator to apply to the statement (in this case'='). Refer to **Figure 1.27 Advanced Search Window with Information**.

Pressing the search button runs the filter and produces a list of projects or project elements for users to select. In this case, the entire statement is generated and shown in **Figure 1.28 Selecting a Project Using Advanced Search Tool**, where '*Display Name = HMA'* place the arrow over HMA, and press '*OK'* to import the project or project element in the M-E Design interface.

A Special Note on Traffic

As previously mentioned, the traffic element works slightly different from the other M-E Design elements. All of the traffic elements for retrieving data from the database mirror the functionality of the save operation (i.e. retrieving a single axle distribution element will import tandem, tridem, and quad axle distribution elements).

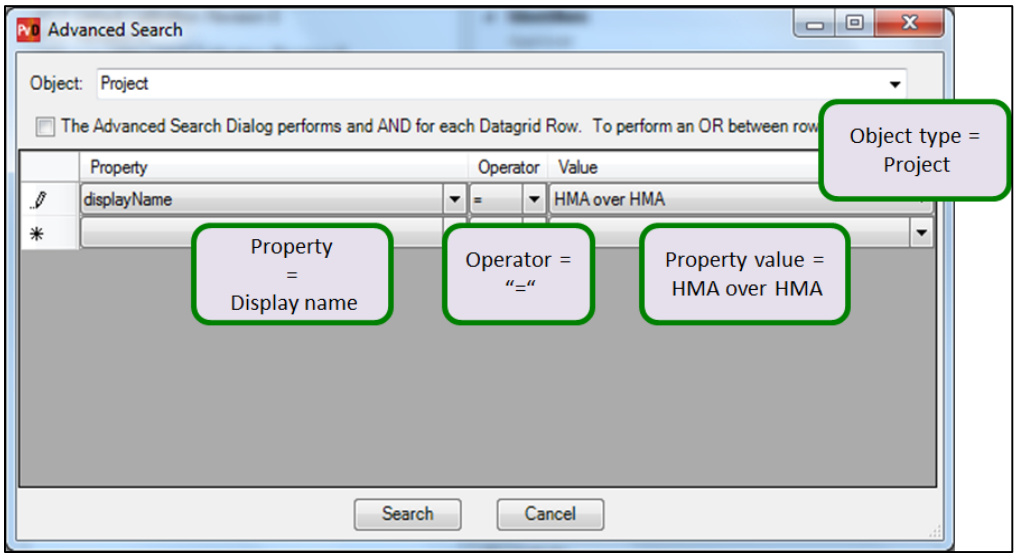

Figure 1.27 Advanced Search Window with Information

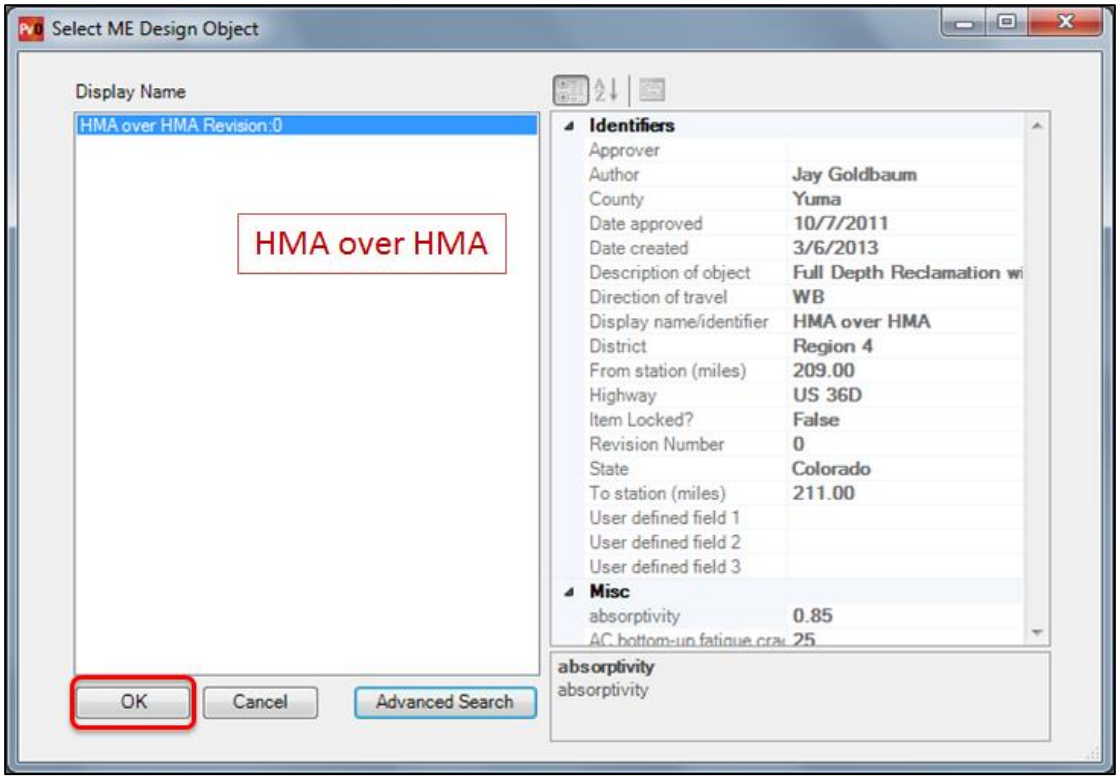

Figure 1.28 Selecting a Project Using Advanced Search Tool

References

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

2. *AASHTO Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*, November 2010, American Association of State Highway and Transportation Officials, Washington, DC, 2010.

3. CDOT Final_Calibration_June_12_2012.