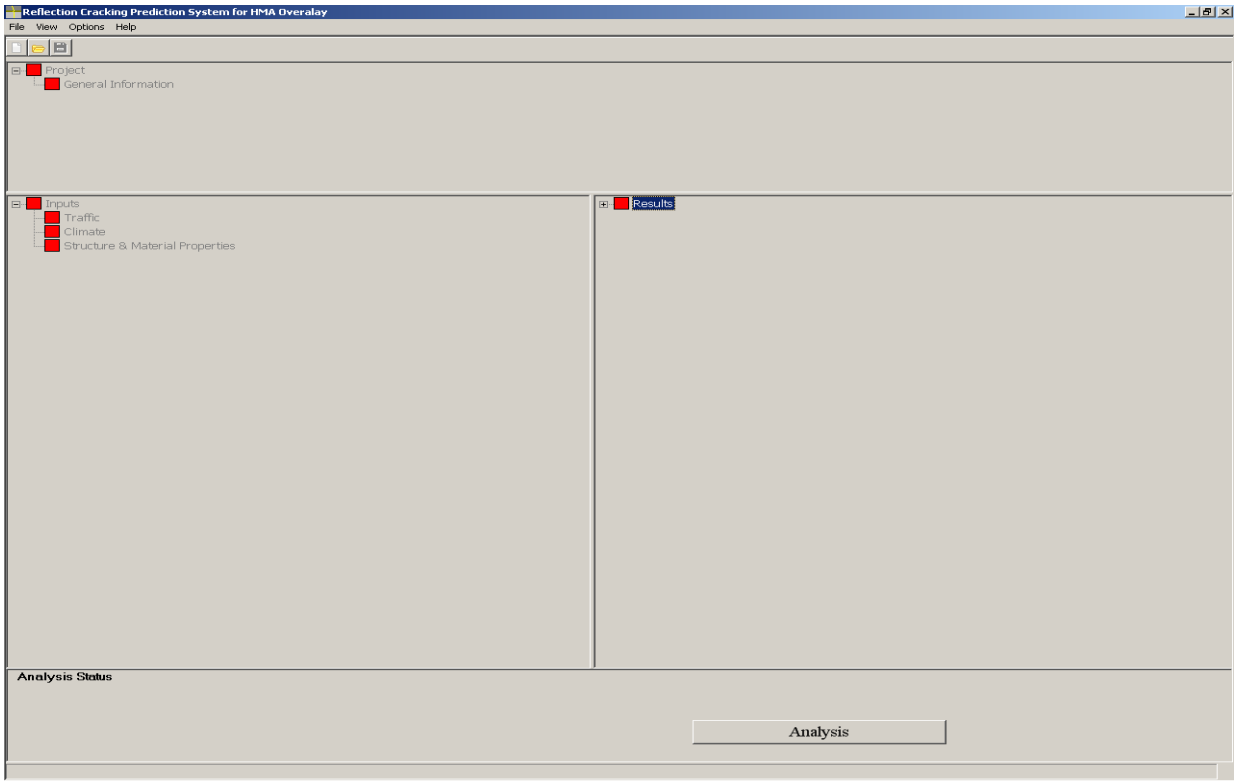
APPENDIX O

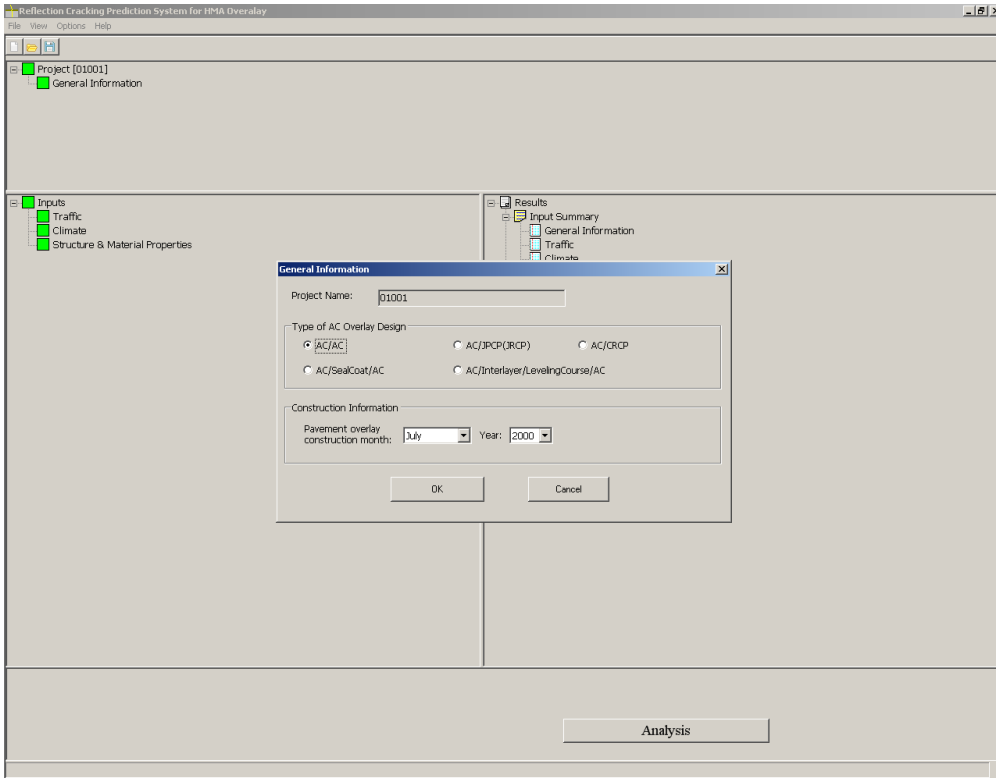
USER'S GUIDE TO THE REFLECTION CRACKING MODEL

LIST OF FIGURES

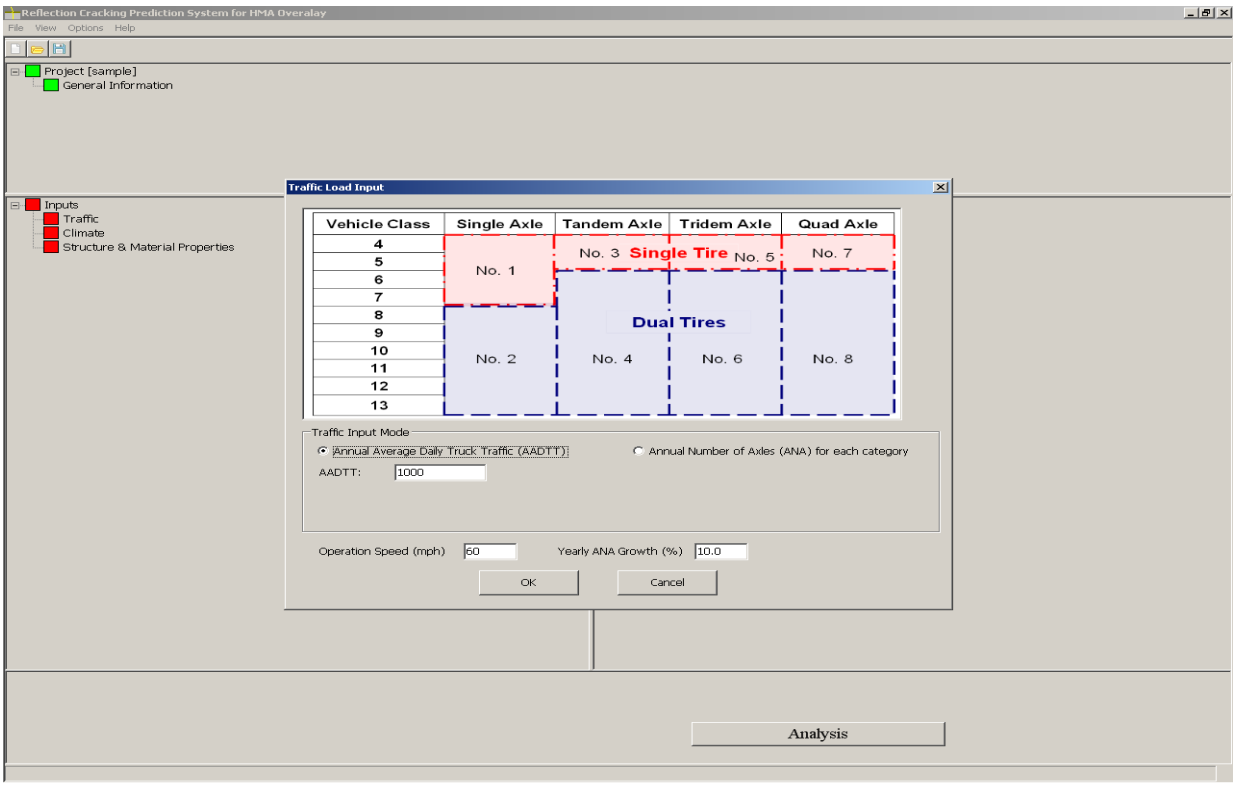
The **Reflection Cracking Prediction System for HMA Overlays** Program includes three main parts which are **General Information** input, **Pavement Related** input, and **Output**. Pavement related input includes **Traffic**, **Climate**, and **Structure & Material Properties**.

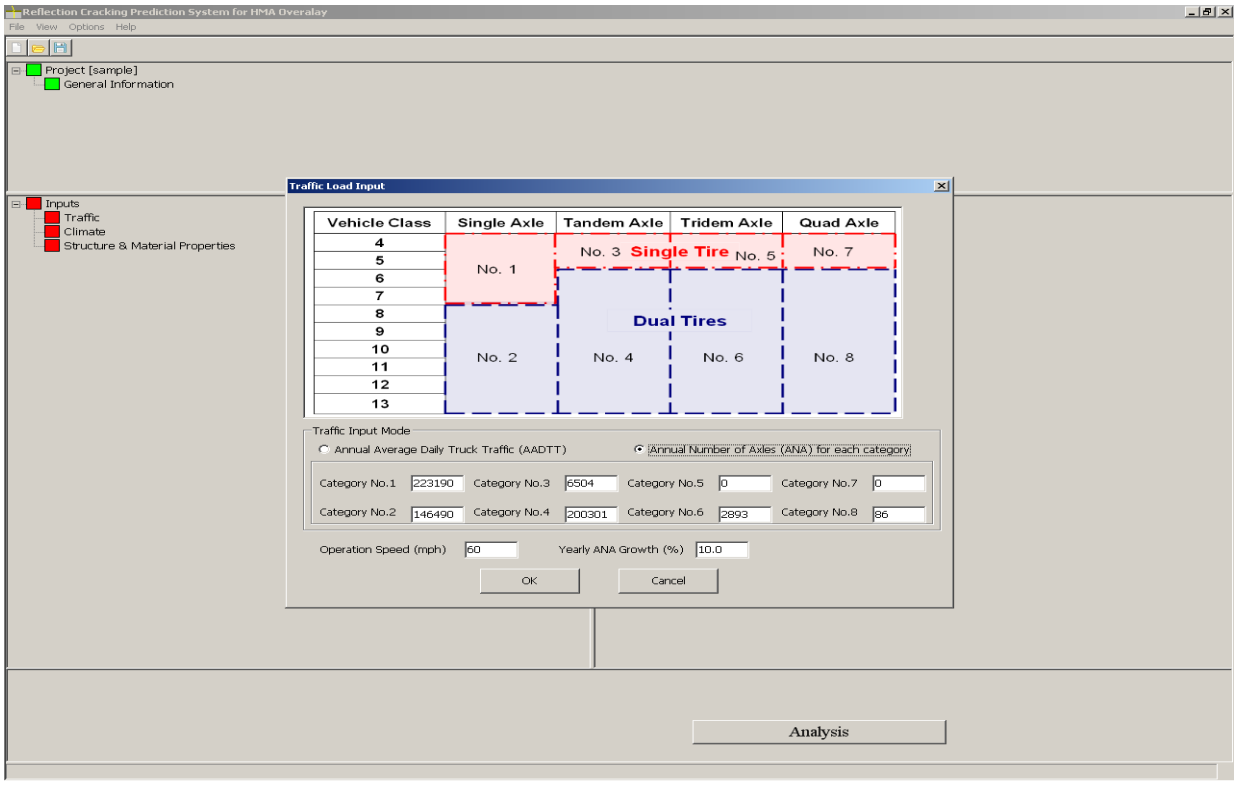


The **General Information** allows the selection of five types of overlay in this program. **Design Life** is the maximum number of days to analyze and predict the appearance the extent and severity of reflection cracking. **Construction Information** gives the date when construction is completed and the overlay is placed in service.

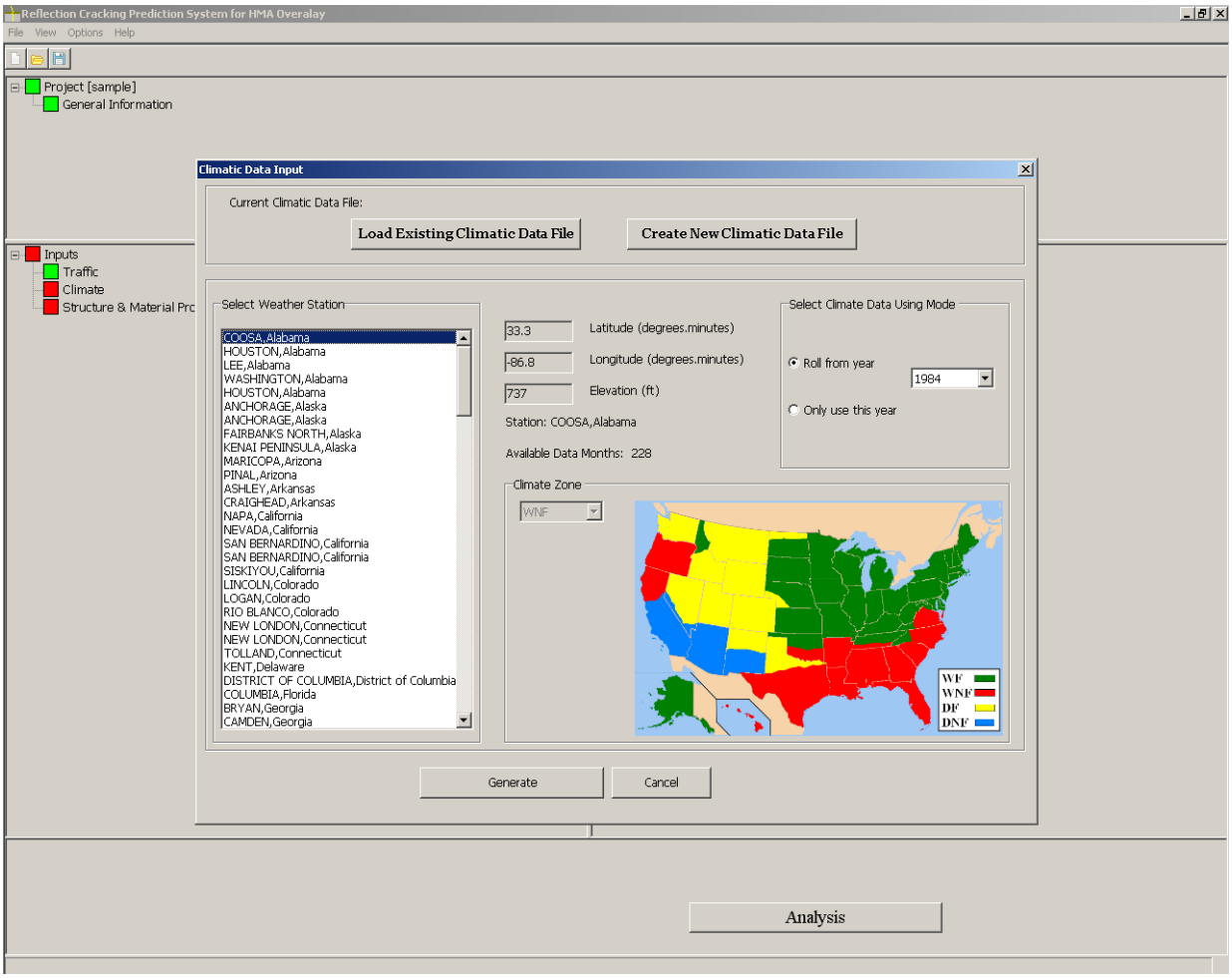


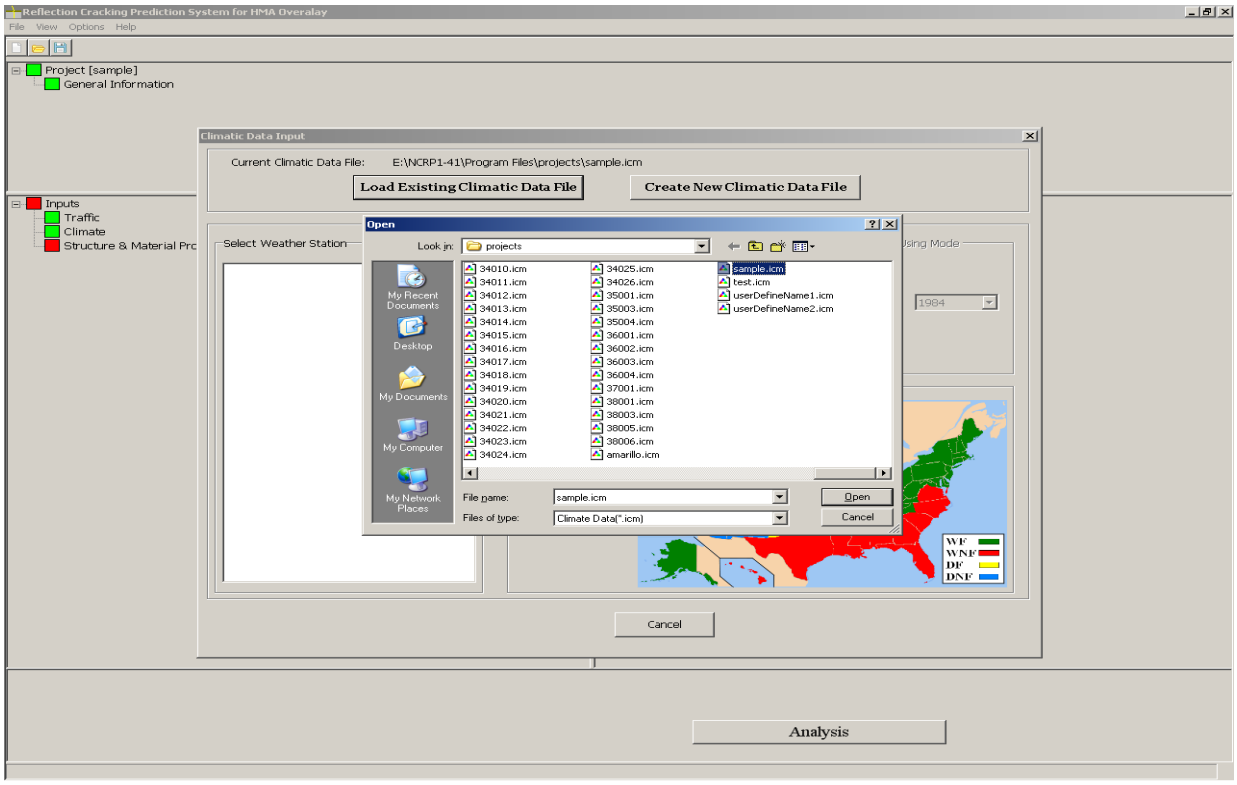
Annual Average Daily Truck Traffic (AADTT) and **Annual Number of Axles (ANA) for each category** are the user input options in the **Traffic Load Input**. **Operational Speed** is the design speed limit in miles per hour.



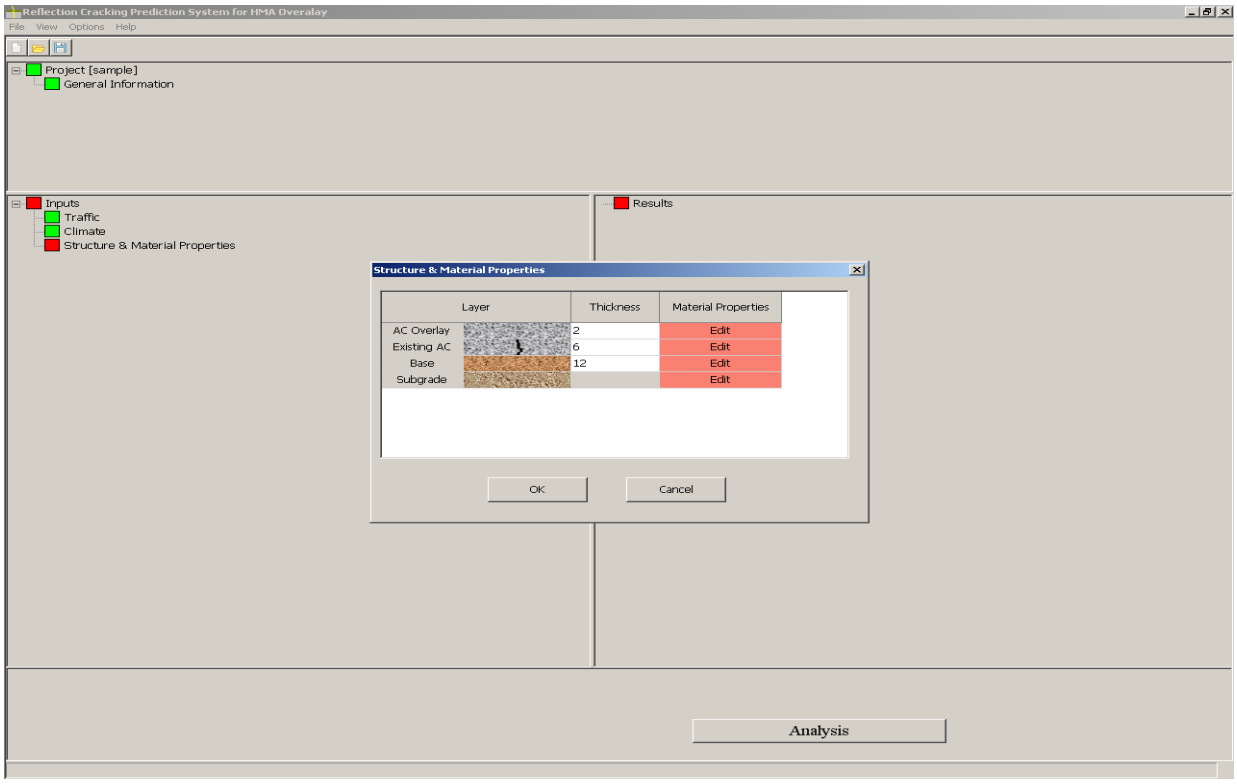

Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [sample]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
Traffic Load Input
Vehicle Class
Single Axle
Tandem Axle
Tridem Axle
Quad Axle
4
5
6
7
8
9
10
11
12
13
No. 1
No. 3
Single Tire
No. 5
No. 7
Dual Tires
No. 2
No. 4
No. 6
No. 8
Traffic Input Mode
Annual Average Daily Truck Traffic (AADTT)
Annual Number of Axles (ANA) for each category
Category No.1 223190
Category No.3 6504
Category No.5 0
Category No.7 0
Category No.2 146490
Category No.4 200301
Category No.6 2893
Category No.8 86
Operation Speed (mph) 60
Yearly ANA Growth (%) 10.0
OK
Cancel
Analysis

Climate data includes air temperature, wind speed, solar radiation, albedo, emissivity, and absorption data. The User can choose any of the 150 weather stations in this program, or can use the EICM model from the MEPDG to generate the *.icm climate data, and load the generated *.icm data into this program. In order to choose the weather station from the database within this program, the user should select the Climate Data Using Model. The climate data from this database can provide the information from 1984 to 2002. Therefore, the user can choose to repeat any specified year in their reflection cracking prediction, or the user can choose the year to start a sequence of years of the climate data.

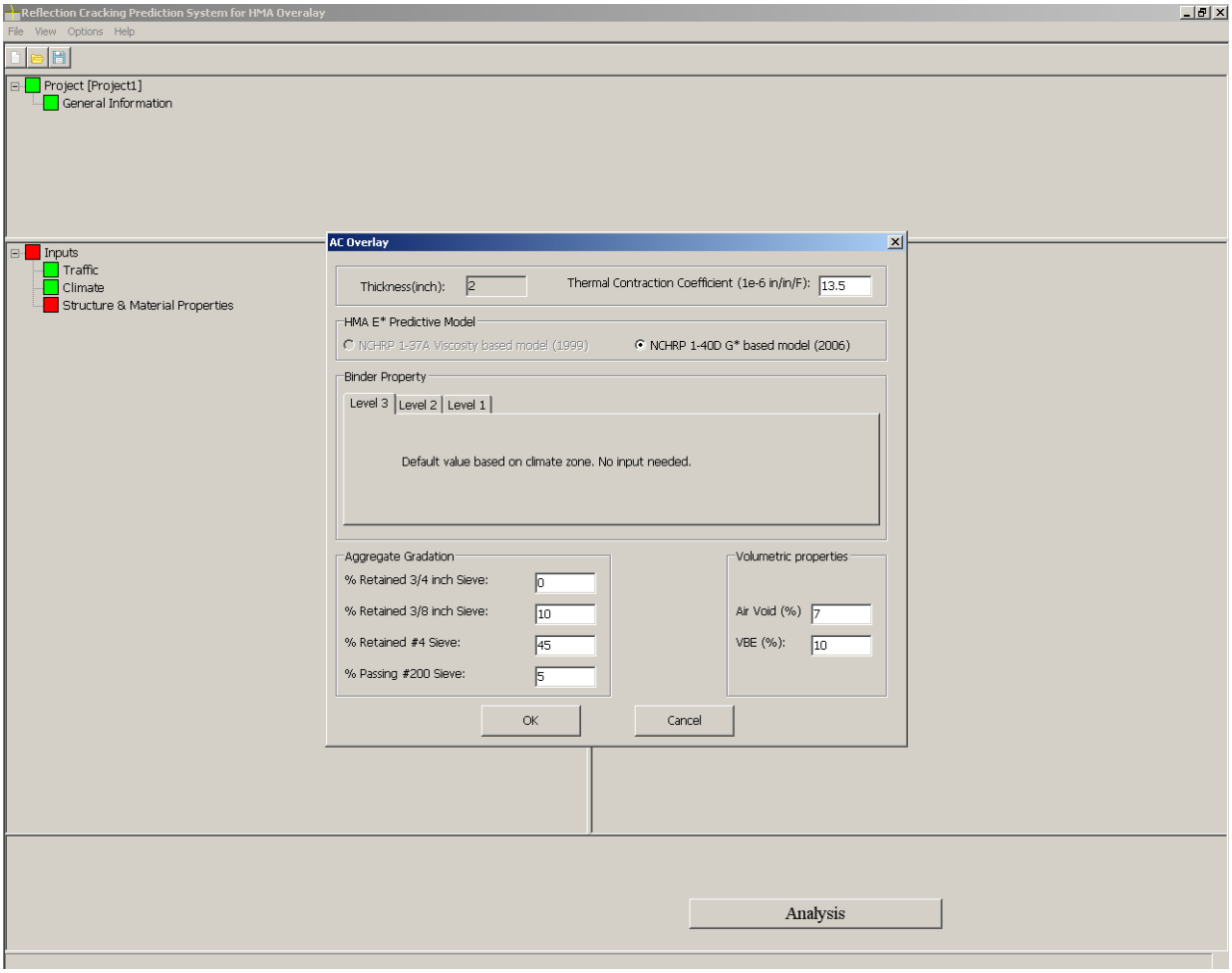


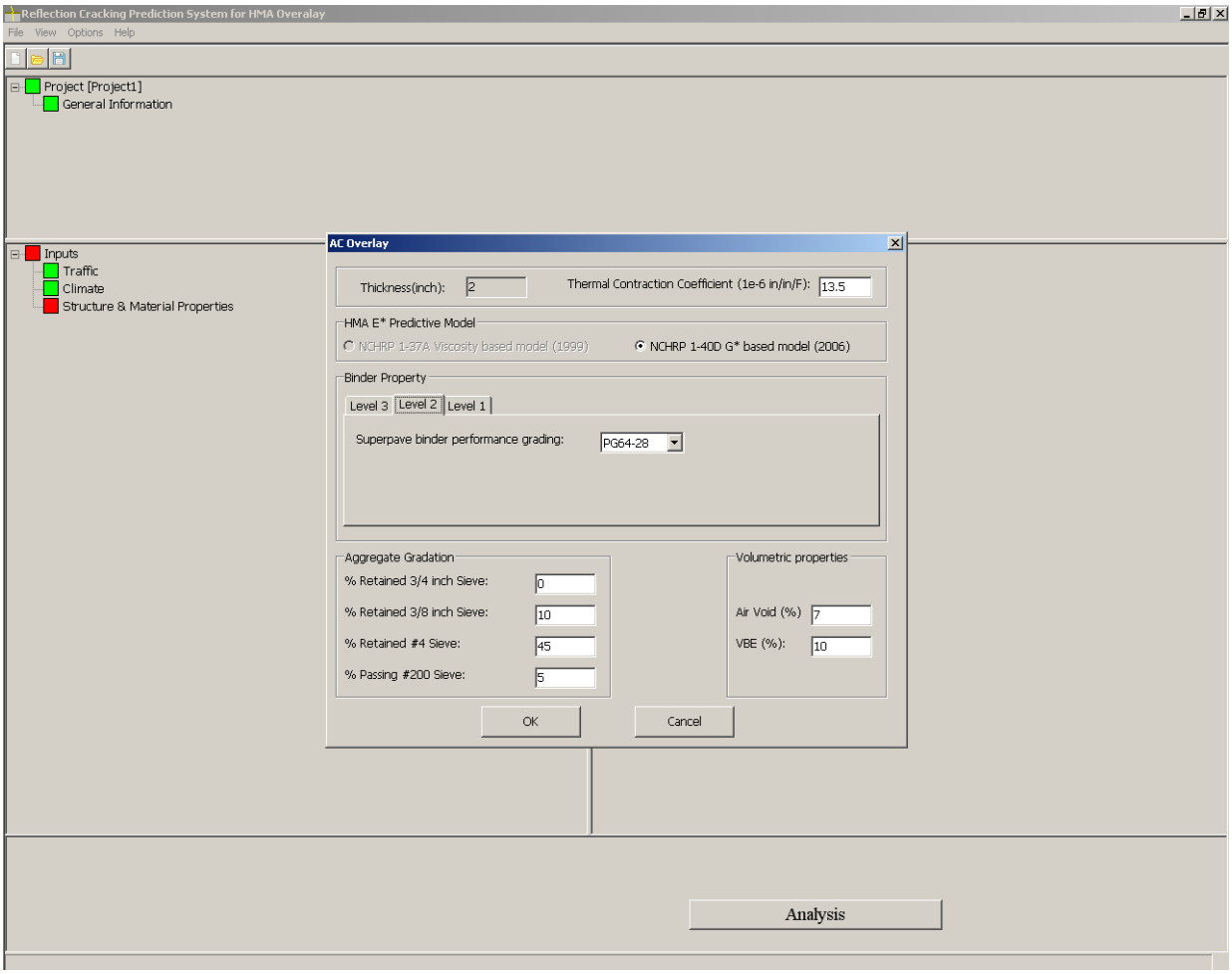

Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [sample]
General Information
Inputs
Traffic
Climate
Structure & Material Pro
Climatic Data Input
Current Climatic Data File: E:\NCRP1-41\Program Files\projects\sample.icm
Load Existing Climatic Data File
Create New Climatic Data File
Select Weather Station
Using Mode
1984
Open
Look in: projects
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
34010.icm
34011.icm
34012.icm
34013.icm
34014.icm
34015.icm
34016.icm
34017.icm
34018.icm
34019.icm
34020.icm
34021.icm
34022.icm
34023.icm
34024.icm
34025.icm
34026.icm
35001.icm
35003.icm
35004.icm
36001.icm
36002.icm
36003.icm
36004.icm
37001.icm
38001.icm
38003.icm
38005.icm
38006.icm
amarillo.icm
sample.icm
test.icm
userDefineName1.icm
userDefineName2.icm
File name: sample.icm
Files of type: Climate Data(*.icm)
Open
Cancel
WF
WNF
DF
DNF
Cancel
Analysis

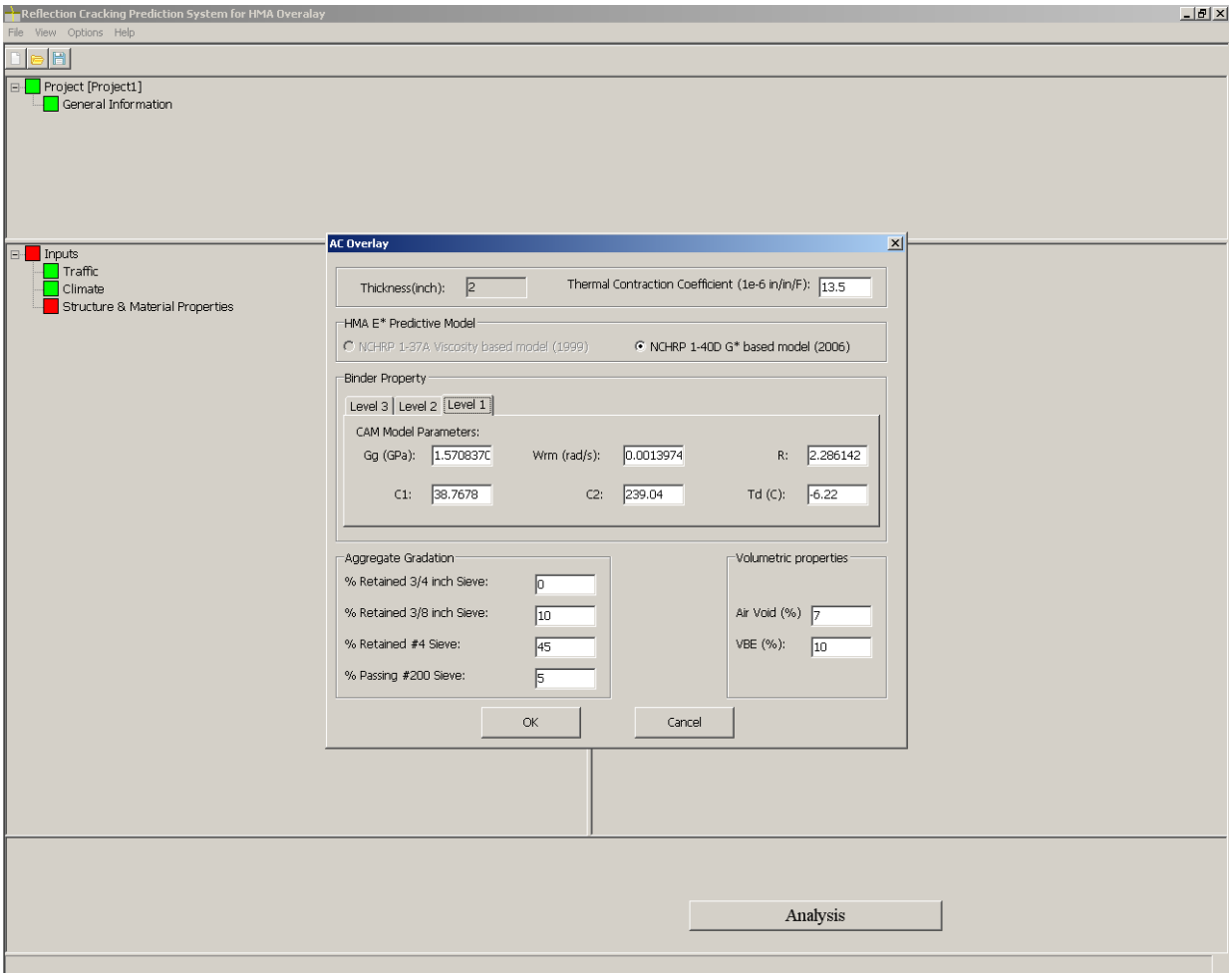
Structure & Material Properties information includes the pavement layer thickness, mixture and binder data. When the input data is completed, the color of the **Edit** button turns from red to green.



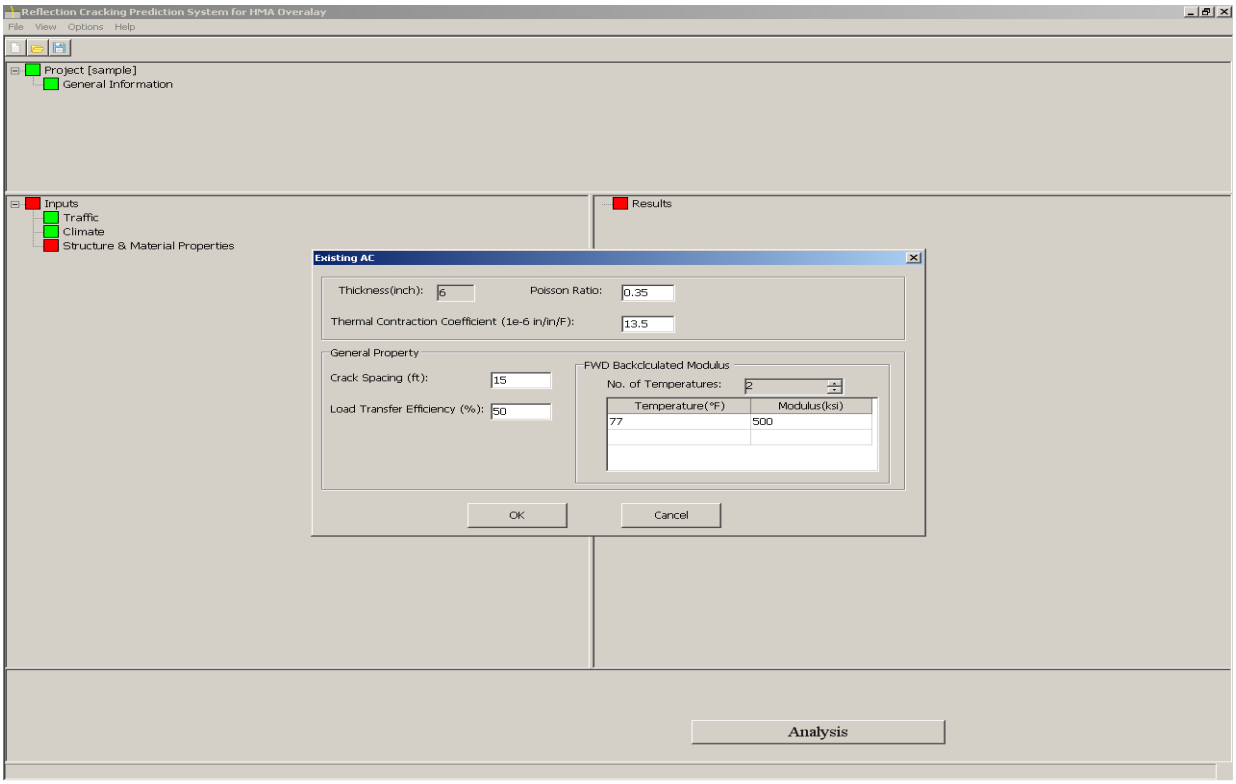
In the AC overlay. **Aggregate Gradation** and **Volumetric Properties** are required. For the input of the **Binder Property**, three levels are considered in this program. Level one requires the user to provide all six of the binder the parameters. Level two parameters are specified by giving the Superpave binder performance grade. The climatic zone input in the previous climatic input provides the remainder of the binder information from historical data on binders used in that region. With Level three input, all of the parameters are determined from our database of the mean binder data used in the previously specified climate zone.



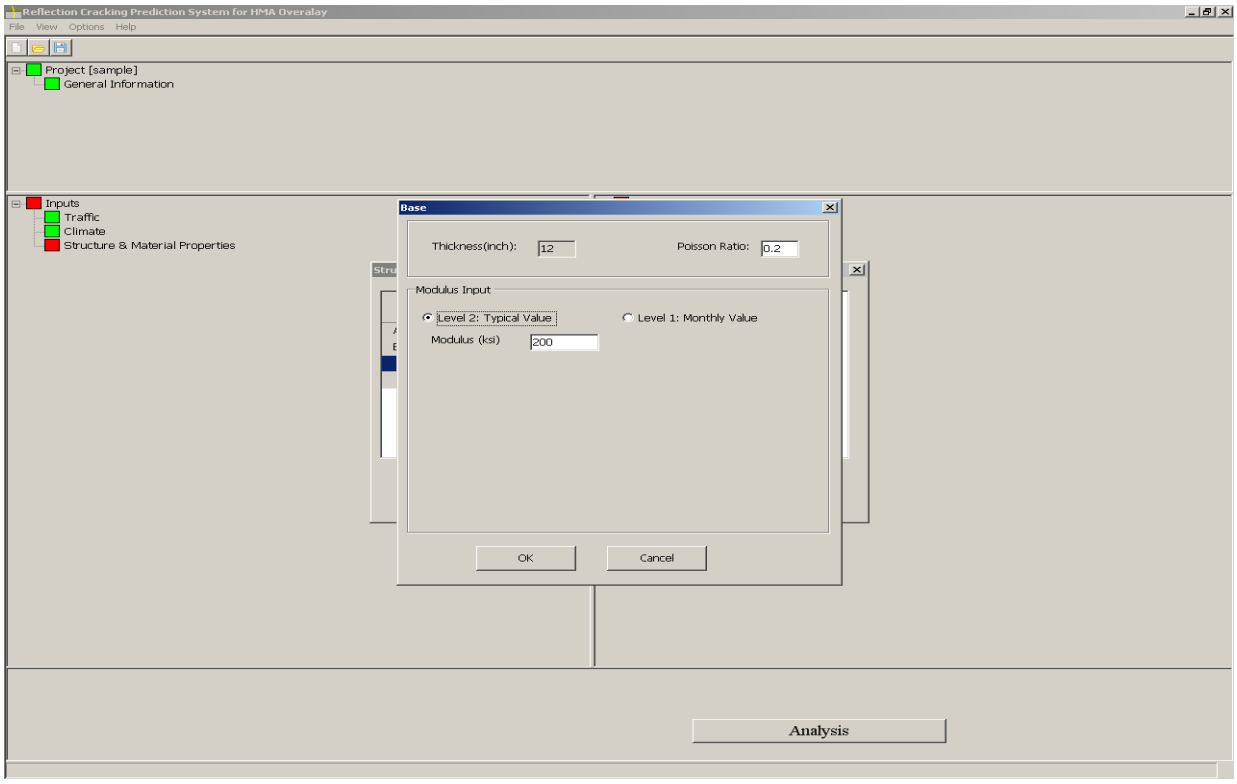

Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [Project1]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
AC Overlay
Thickness(inch): 2
Thermal Contraction Coefficient (1e-6 in/in/F): 13.5
HMA E* Predictive Model
NCHRP 1-37A Viscosity based model (1999)
NCHRP 1-40D G* based model (2006)
Binder Property
Level 3
Level 2
Level 1
Superpave binder performance grading:
PG64-28
Aggregate Gradation
% Retained 3/4 inch Sieve: 0
% Retained 3/8 inch Sieve: 10
% Retained #4 Sieve: 45
% Passing #200 Sieve: 5
Volumetric properties
Air Void (%) 7
VBE (%): 10
OK
Cancel
Analysis

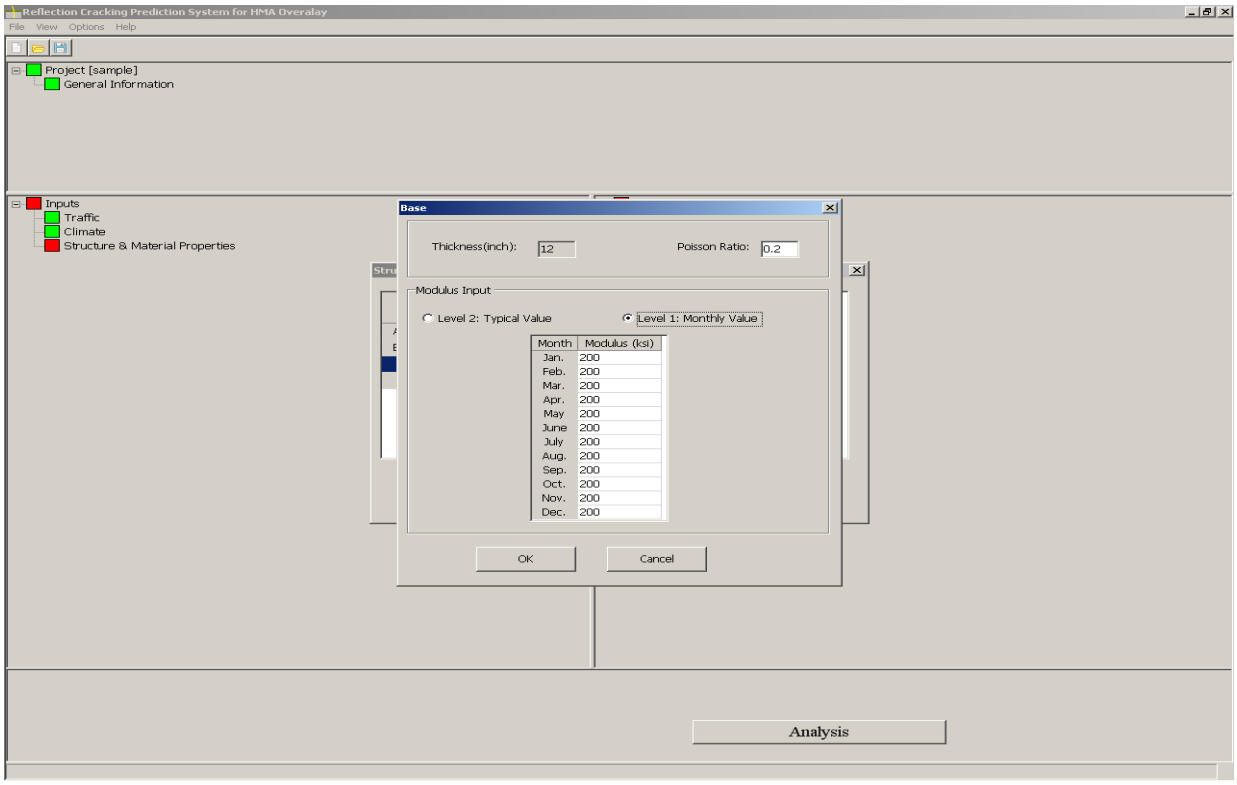

Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [Project1]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
AC Overlay
Thickness(inch): 2
Thermal Contraction Coefficient (1e-6 in/in/F): 13.5
HMA E* Predictive Model
NCHRP 1-37A Viscosity based model (1999)
NCHRP 1-40D G* based model (2006)
Binder Property
Level 3 Level 2 Level 1
CAM Model Parameters:
Gg (GPa): 1.5708370
Wrm (rad/s): 0.0013974
R: 2.286142
C1: 38.7678
C2: 239.04
Td (C): -6.22
Aggregate Gradation
% Retained 3/4 inch Sieve: 0
% Retained 3/8 inch Sieve: 10
% Retained #4 Sieve: 45
% Passing #200 Sieve: 5
Volumetric properties
Air Void (%) 7
VBE (%): 10
OK
Cancel
Analysis

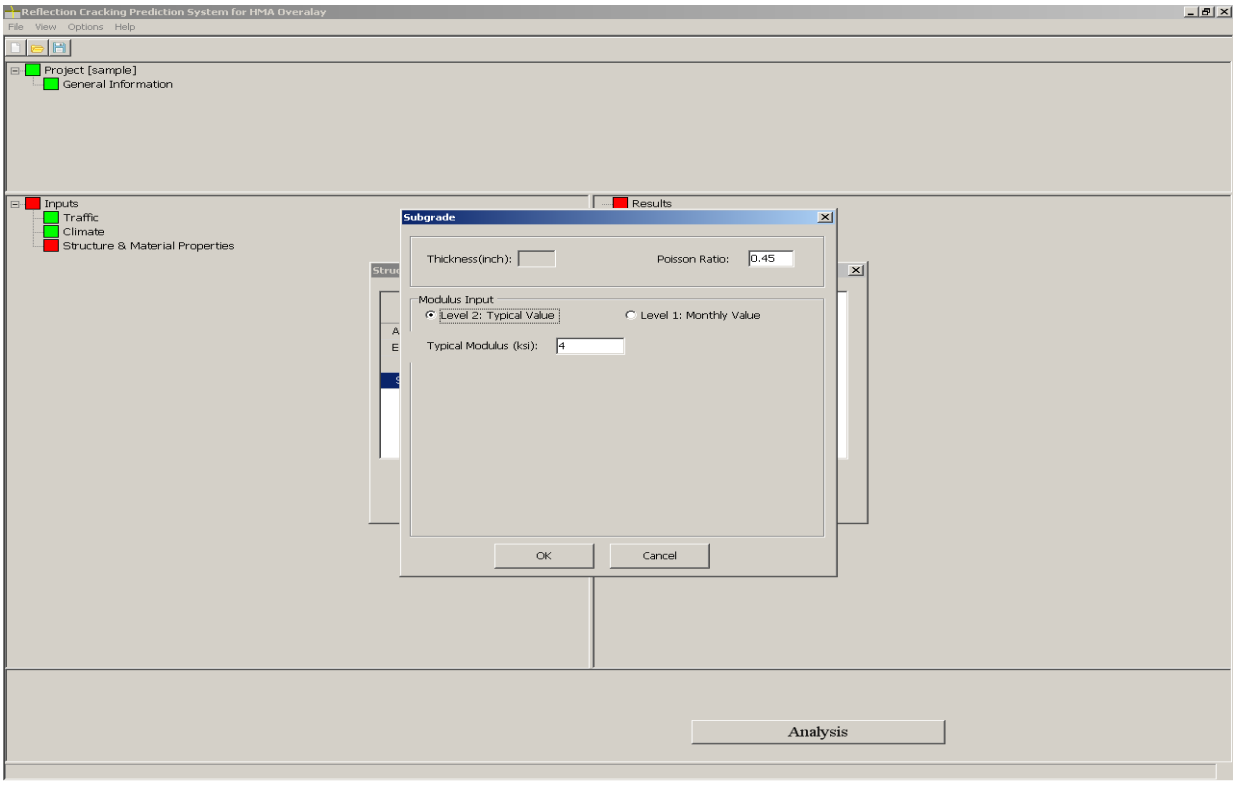
In the input for the **Existing AC** layer, the Level one input of the backcalculated FWD modulus can be at more than one temperature. Levels two and three input can be a measured or an assumed modulus value.

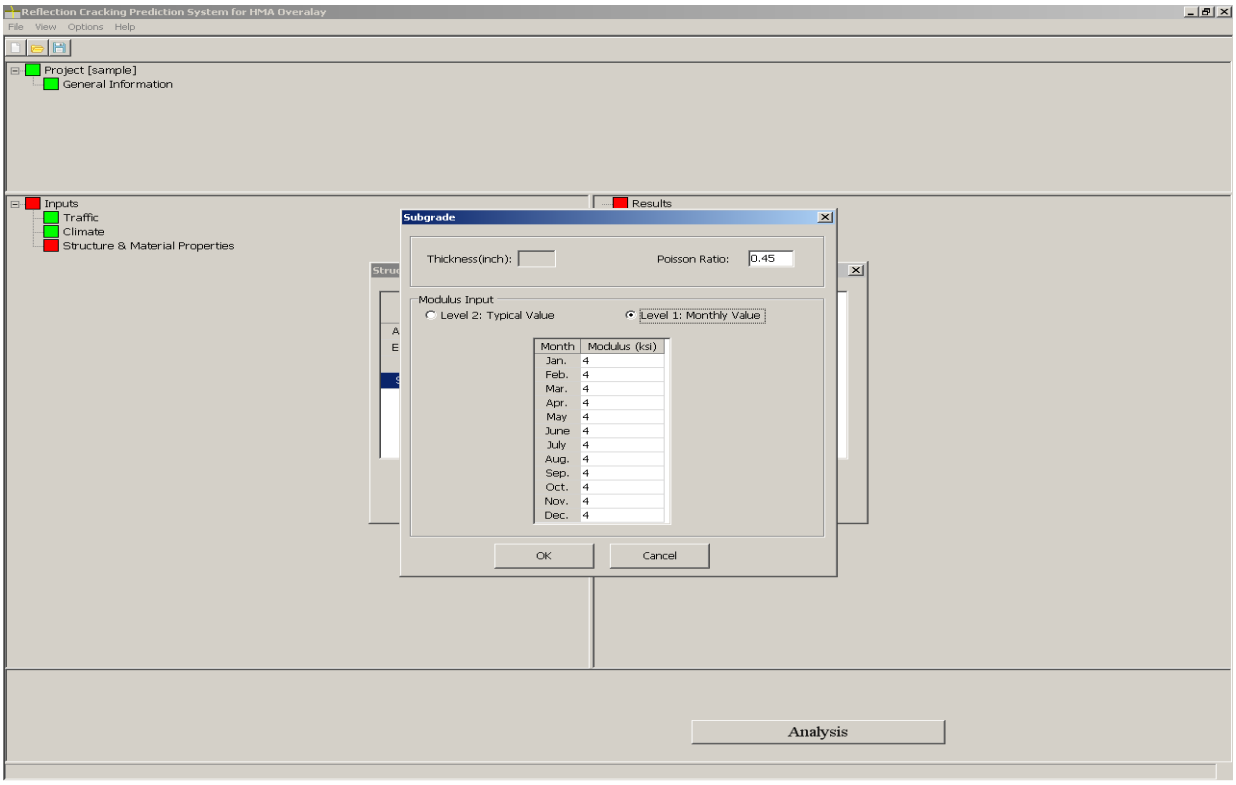


Inputs for **Base** and **Subgrade** layers require moduli and Poisson Ratios. Since the modulus varies with the temperature, Level one input requires **Monthly Values** of the layer moduli. Level two and three input requires only a mean annual **Typical Value** of the layer modulus.

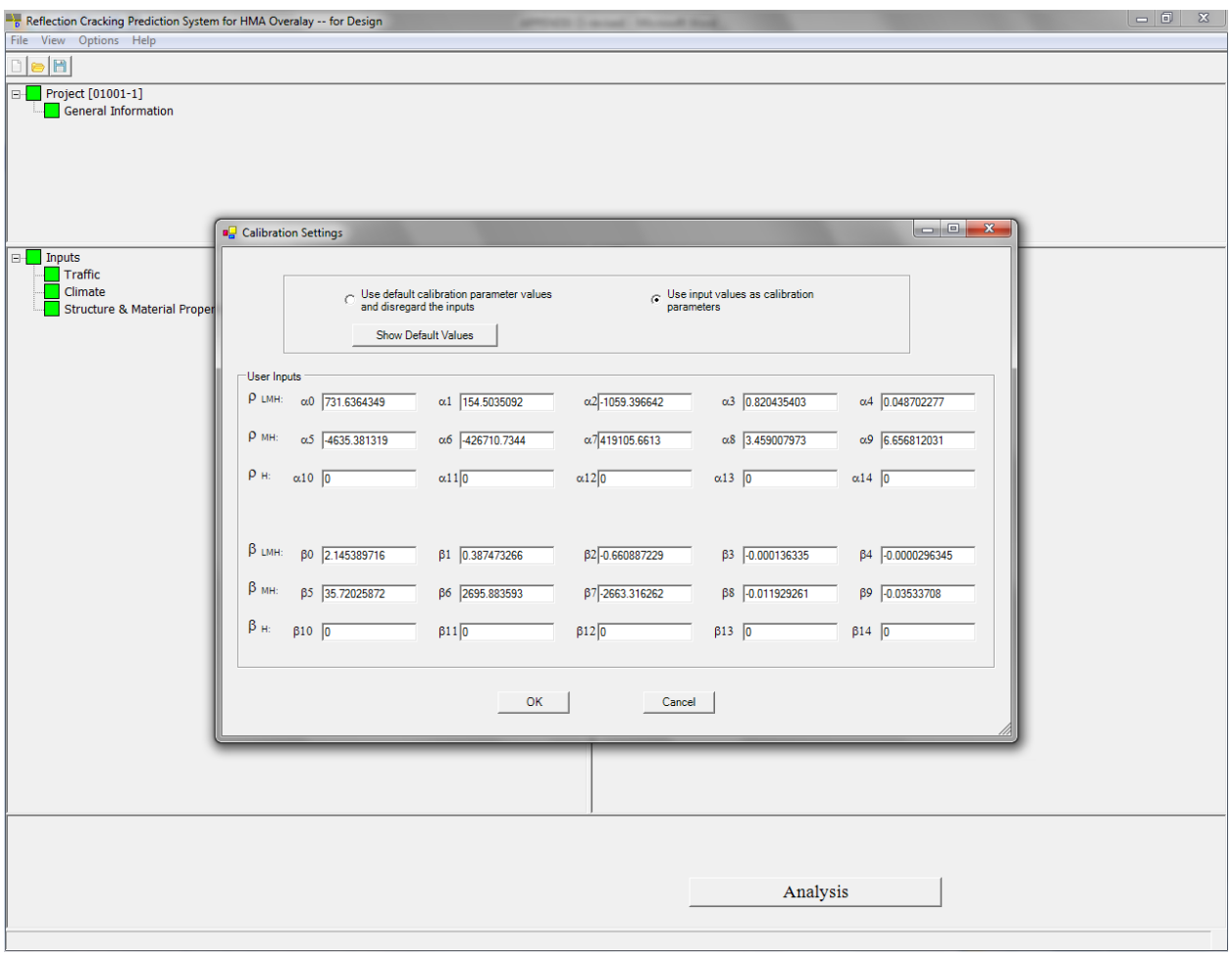



Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [sample]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
Base
Thickness(inch): 12
Poisson Ratio: 0.2
Modulus Input
Level 2: Typical Value
Level 1: Monthly Value
Month Modulus (ksi)
Jan. 200
Feb. 200
Mar. 200
Apr. 200
May 200
June 200
July 200
Aug. 200
Sep. 200
Oct. 200
Nov. 200
Dec. 200
OK
Cancel
Analysis

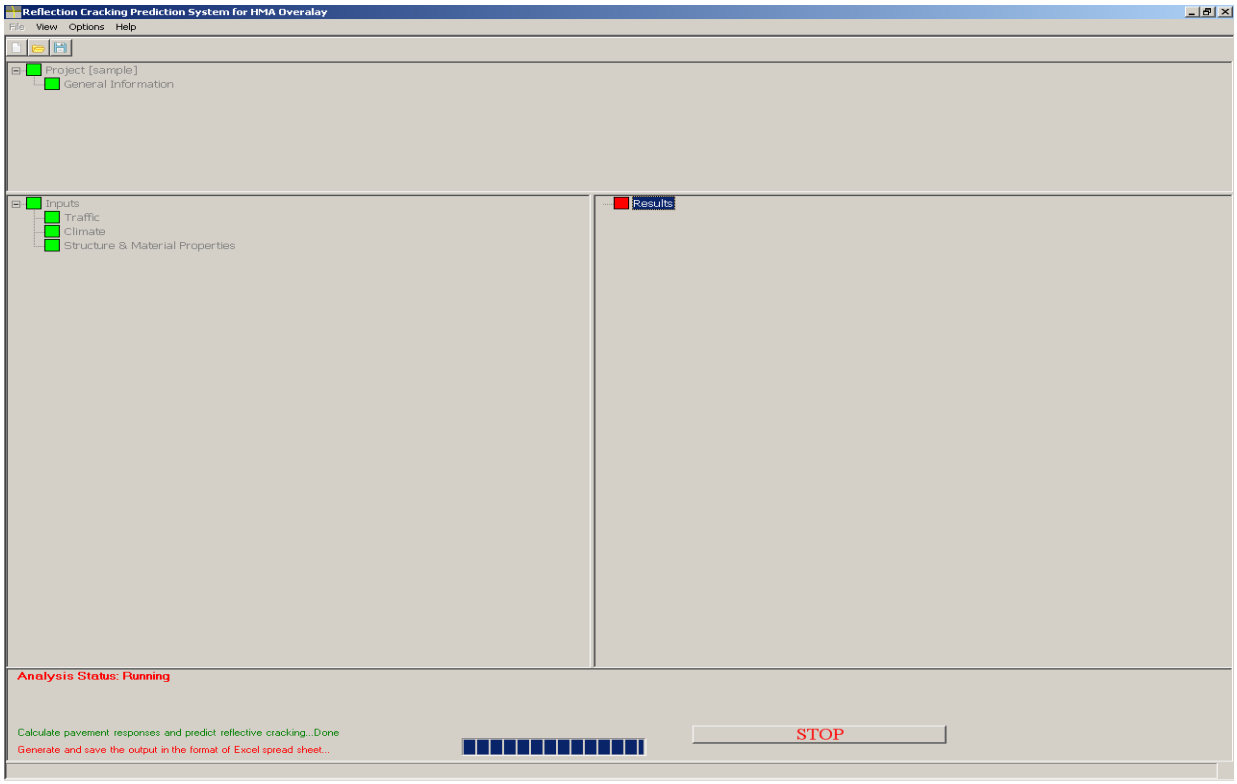

Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [sample]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
Results
Subgrade
Thickness(inch):
Poisson Ratio:
0.45
Modulus Input
Level 2: Typical Value
Level 1: Monthly Value
Typical Modulus (ksi):
4
OK
Cancel
Analysis


Reflection Cracking Prediction System for HMA Overalay
File View Options Help
Project [sample]
General Information
Inputs
Traffic
Climate
Structure & Material Properties
Results
Subgrade
Thickness(inch):
Poisson Ratio: 0.45
Modulus Input
Level 2: Typical Value
Level 1: Monthly Value
Month Modulus (ksi)
Jan. 4
Feb. 4
Mar. 4
Apr. 4
May 4
June 4
July 4
Aug. 4
Sep. 4
Oct. 4
Nov. 4
Dec. 4
OK
Cancel
Analysis

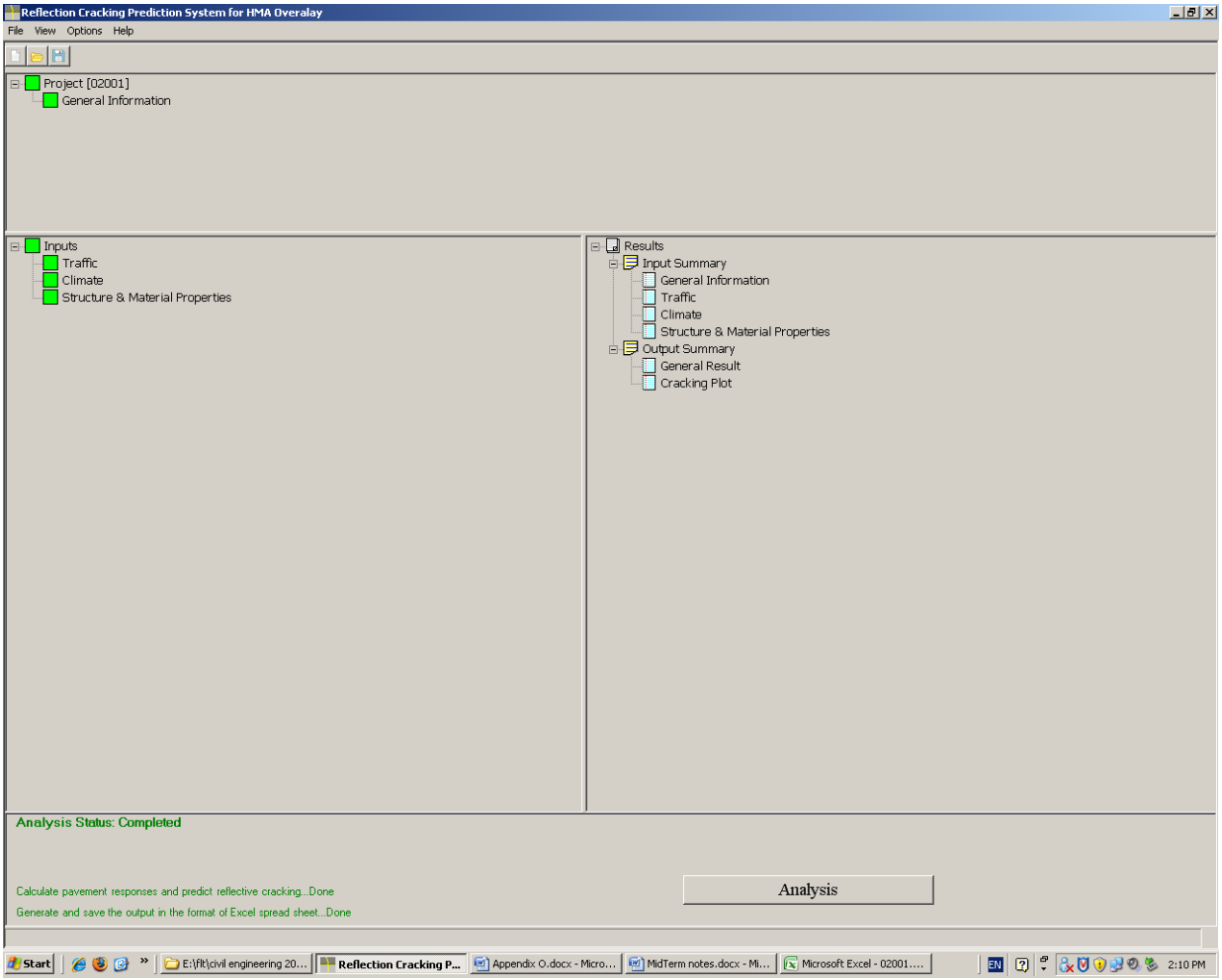
The next step is to provide the calibration parameter set. To complete this step, the user can go to **Options** and click **Calibration Settings**. This program provides two options to the user which are default calibration parameters and the user's own calibration parameters. If the user selects the default parameter, the program will employ a set of calibration parameters that depends on the climatic zone and pavement structure that the user provides in **General Information** and **Climate Input**. The user can also click **Show Default Values** to see these values. If the user selects to input their own calibration parameters, the user needs to input all of the 15 α parameters and 15 β parameters. However, in the case that the user does not have calibration data for one or more severity levels, they will need to input **zero** in each blank box of that severity level for both ρ and β. Click **OK** to finish the calibration setting.



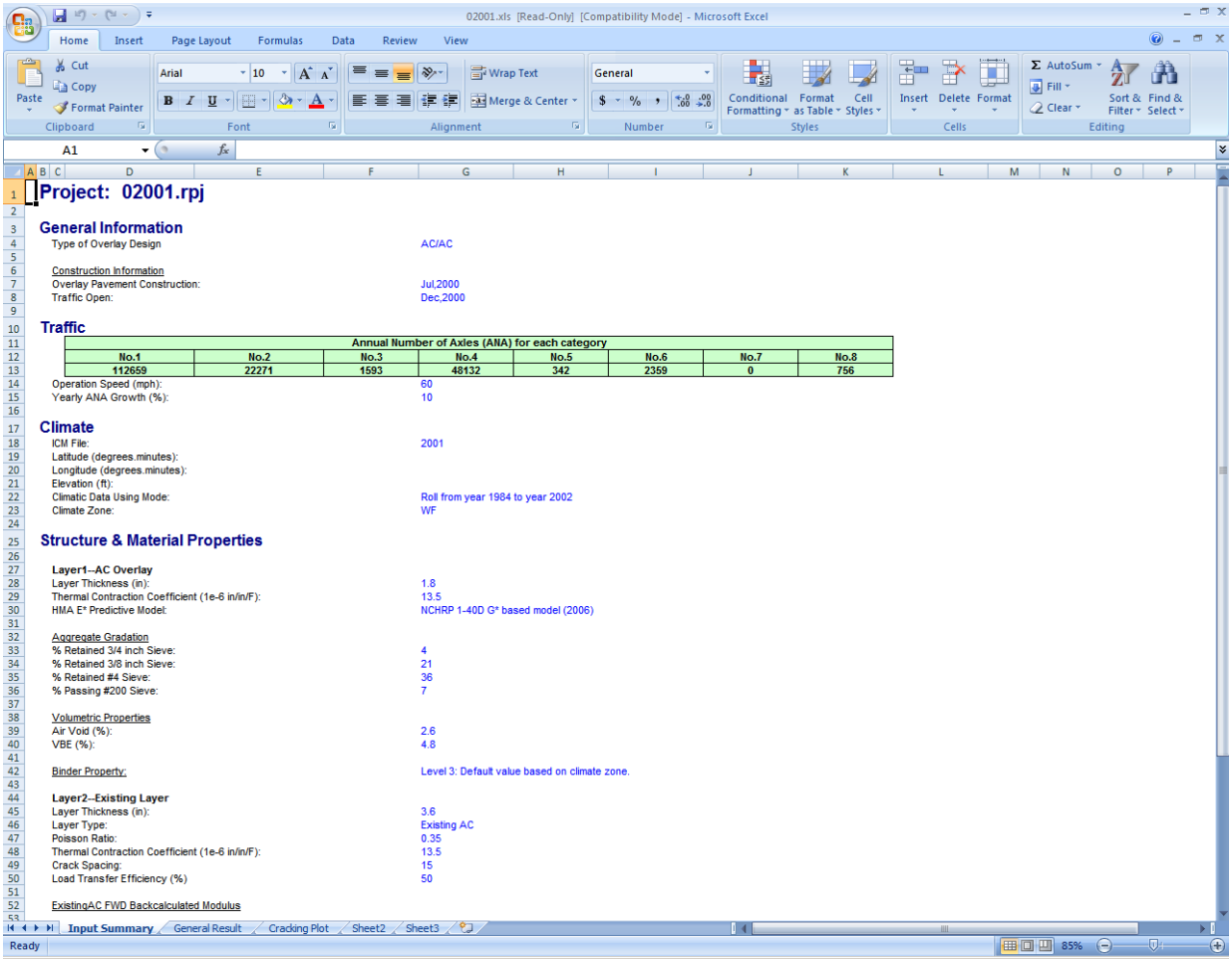
If all of the required input information is completed, the color of the button of each part should turn from a red color to a green color. Then click the **Analysis** button and this program will start to analyze the reflection cracking.



When **Analysis Status** shows **Completed**, the output results are ready to be viewed on the right side.



The results are shown in Excel files. The **Input Summary** Table shows the summary information of this pavement. The **General Result** summarizes the information of reflection cracks due to thermal, shearing, and bending. It also shows the summary of the three severity levels (LMH, MH, and H severity). The Cracking Plot shows the severity curves as a percentage of the total crack length in the original pavement surface versus the number of days.



Project: 02001.rpj

General Information

Type of Overlay Design	AC/AC
Construction Information	
Overlay Pavement Construction:	Jul,2000
Traffic Open:	Dec,2000

Traffic

Annual Number of Axles (ANA) for each category							
No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
112659	22271	1593	48132	342	2359	0	756

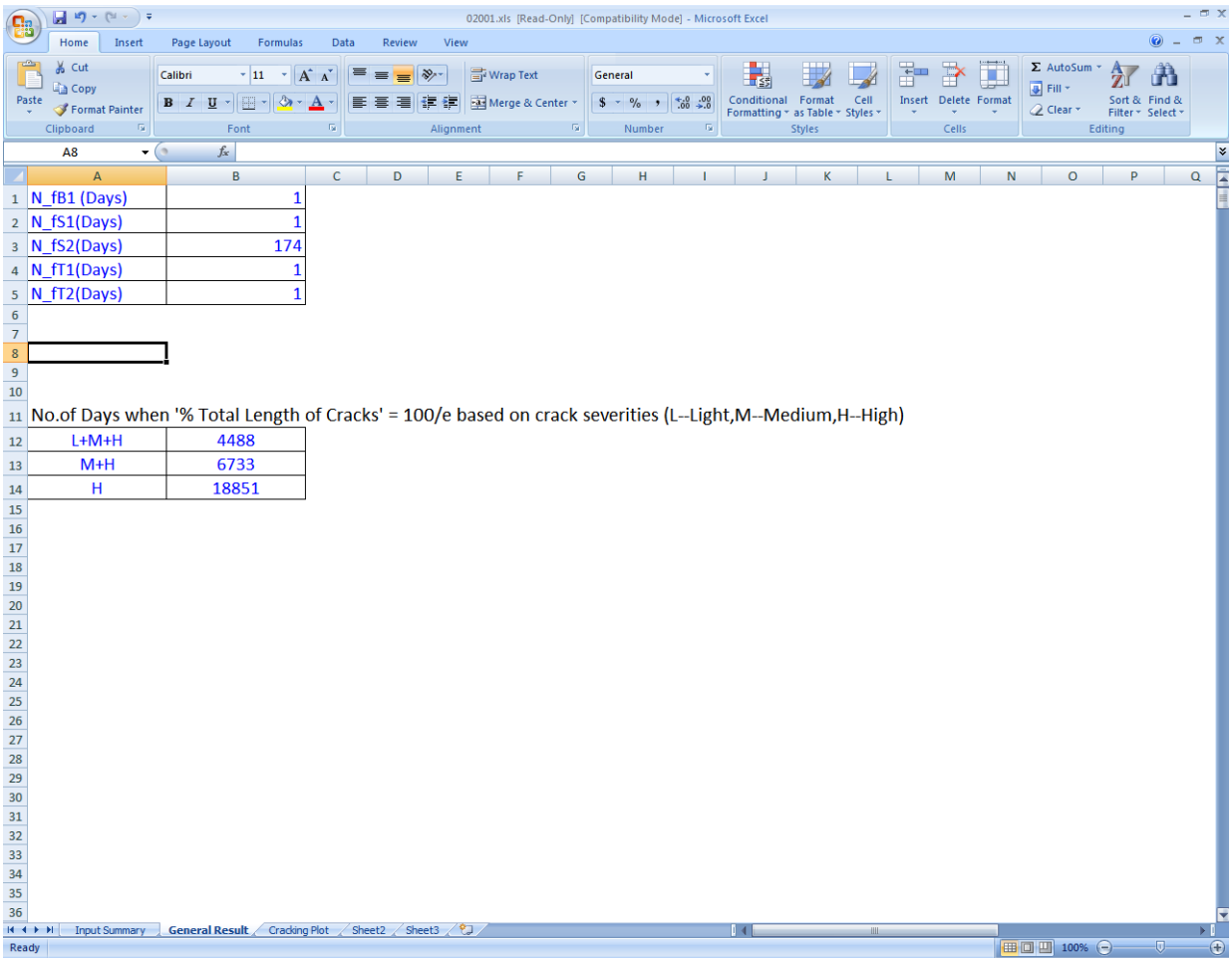
Operation Speed (mph):	60
Yearly ANA Growth (%):	10

Climate

ICM File:	2001
Latitude (degrees.minutes):	
Longitude (degrees.minutes):	
Elevation (ft):	
Climatic Data Using Mode:	Roll from year 1984 to year 2002
Climate Zone:	WF

Structure & Material Properties

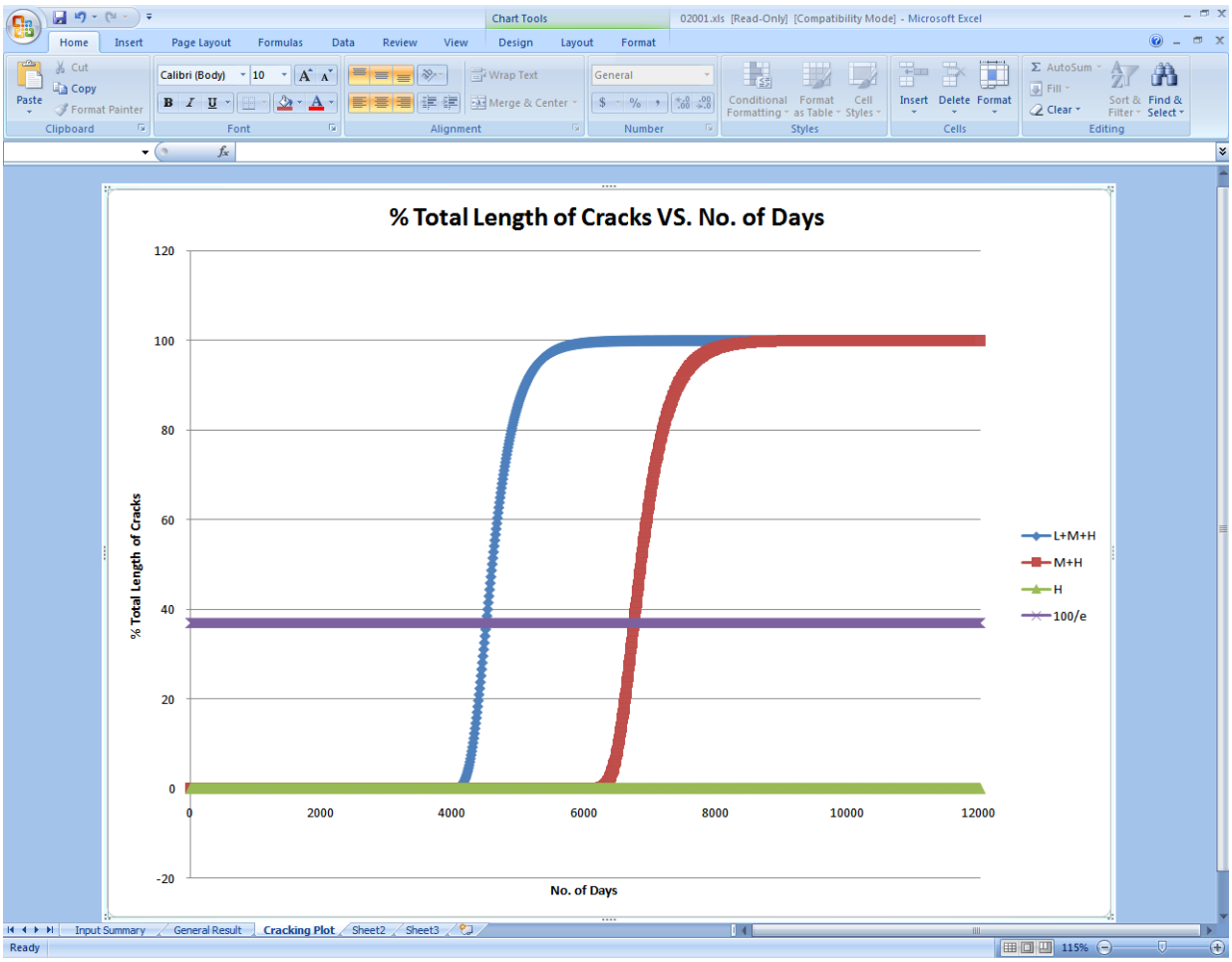
Layer1--AC Overlay	
Layer Thickness (in):	1.8
Thermal Contraction Coefficient (1e-6 in/in/F):	13.5
HMA E* Predictive Model:	NCHRP 1-40D G* based model (2006)
Aggregate Gradation	
% Retained 3/4 inch Sieve:	4
% Retained 3/8 inch Sieve:	21
% Retained #4 Sieve:	36
% Passing #200 Sieve:	7
Volumetric Properties	
Air Void (%):	2.6
VBE (%):	4.8
Binder Property:	Level 3: Default value based on climate zone.
Layer2--Existing Layer	
Layer Thickness (in):	3.6
Layer Type:	Existing AC
Poisson Ratio:	0.35
Thermal Contraction Coefficient (1e-6 in/in/F):	13.5
Crack Spacing:	15
Load Transfer Efficiency (%)	50
ExistingAC FWD Backcalculated Modulus	



N_fB1 (Days)	1
N_fS1(Days)	1
N_fS2(Days)	174
N_fT1(Days)	1
N_fT2(Days)	1

No.of Days when '% Total Length of Cracks' = 100/e based on crack severities (L--Light,M--Medium,H--High)

L+M+H	4488
M+H	6733
H	18851


% Total Length of Cracks VS. No. of Days
% Total Length of Cracks
No. of Days
120
100
80
60
40
20
0
-20
0
2000
4000
6000
8000
10000
12000
L+M+H
M+H
H
100/e
Input Summary
General Result
Cracking Plot
Sheet2
Sheet3
Ready

Figures O-1 to O-11 illustrate some results of using the reflection cracking prediction program to predict the crack extent and severity. Each of the figures is the prediction by one of the eleven sets of model calibration coefficients that were developed in this project. In some cases such as in Figure O-1, the high severity distress required over 100 days to reach 36.8% of the total length of cracks in the original pavement surface. It is the predicted development of transverse reflection cracking in an overlay over a cracked asphalt surface layer in a Wet-Freeze Climate Zone. Figures O-2 and O-3 illustrate the more common graphs of the development of the different levels of severity of reflection cracking. Figure O-2 is for an overlay over a jointed reinforced concrete pavement in a Wet-Freeze Climate Zone. Figure O-3 is for an overlay over an open-graded friction course which was used as a strain absorbing membrane interlayer (SAMI) over a cracked asphalt surface layer in a Wet-Freeze Climate Zone.

Another special case is when the high severity curve remains at zero percent of the total length of cracks in the original pavement surface. This is because there were no high severity data to use for calibration. This was the case for all of the overlaid pavements shown in Figures O-4, O-5, and O-6. Figure O-4 is for an overlay over a continuously reinforced concrete pavement in a Wet-Freeze Climate Zone. Figure O-5 is for an overlay over a geosynthetic reinforced interlayer over a jointed concrete pavement in a Wet-No Freeze Climate Zone. Figure O-6 is for an overlay over a geosynthetic reinforced interlayer over a cracked asphalt surface layer in a Dry-Freeze Climate Zone.

Figure O-7 is for an overlay over a cracked asphalt surface layer in a Wet-No Freeze Climate Zone. Figure O-8 is for an overlay over an open graded friction course which was used as a strain-absorbing membrane interlayer (SAMI) over a cracked asphalt surface layer in a Wet-No Freeze Climate Zone. Figure O-9 is for an overlay over a cracked asphalt surface layer in a Dry-Freeze Climate Zone. Figure O-10 is for an overlay over a cracked asphalt surface layer in a Dry-No Freeze Climate Zone. Finally, Figure O-11 is for an overlay with a geosynthetic reinforcing interlayer over a jointed concrete pavement in a Wet-Freeze Climatic Zone.

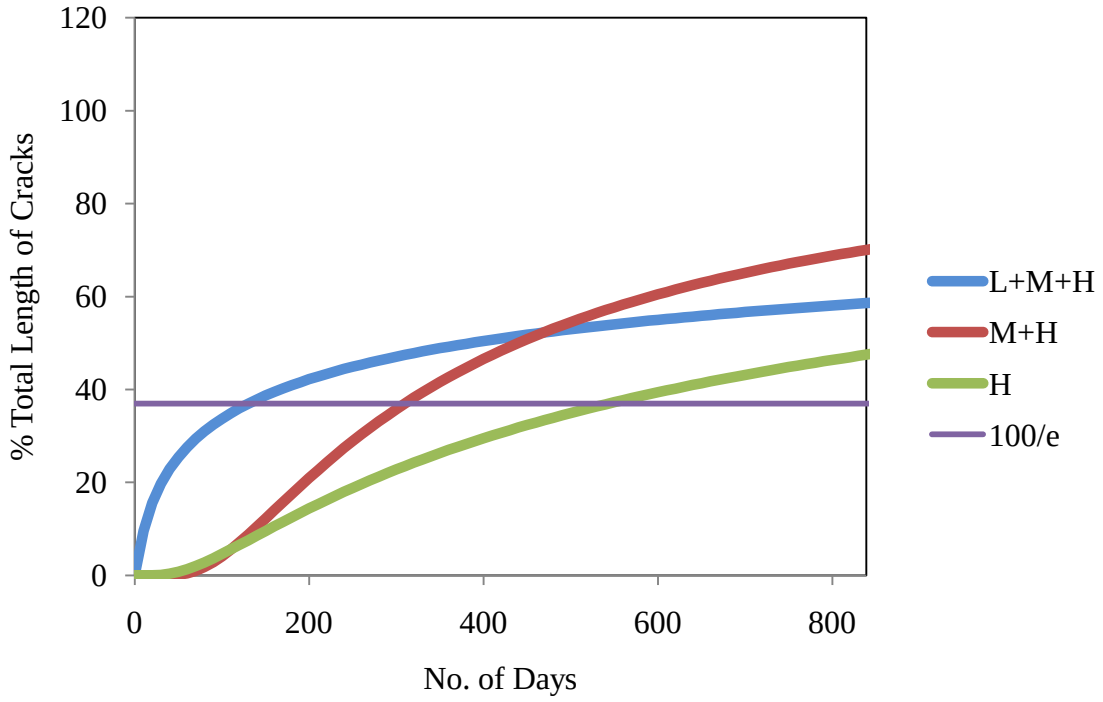


Figure O-1. AC over AC pavement at Lincoln, Maine (WF).

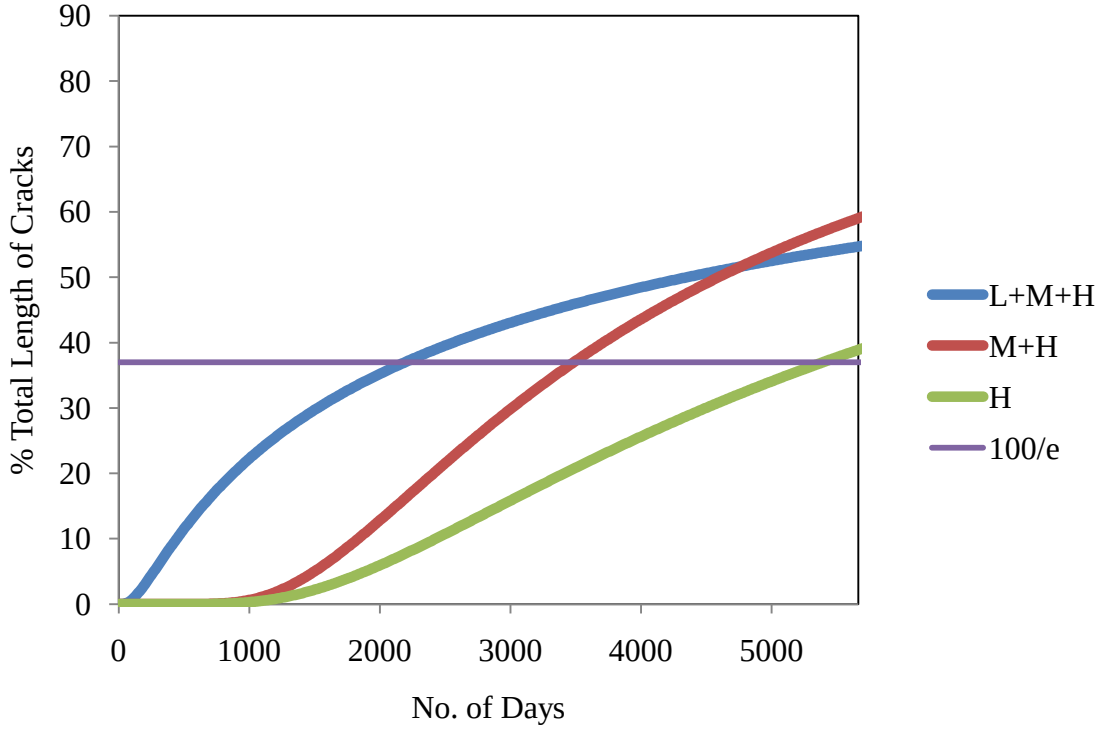


Figure O-2. AC over JRC pavement at Beaver, Pennsylvania (WF).

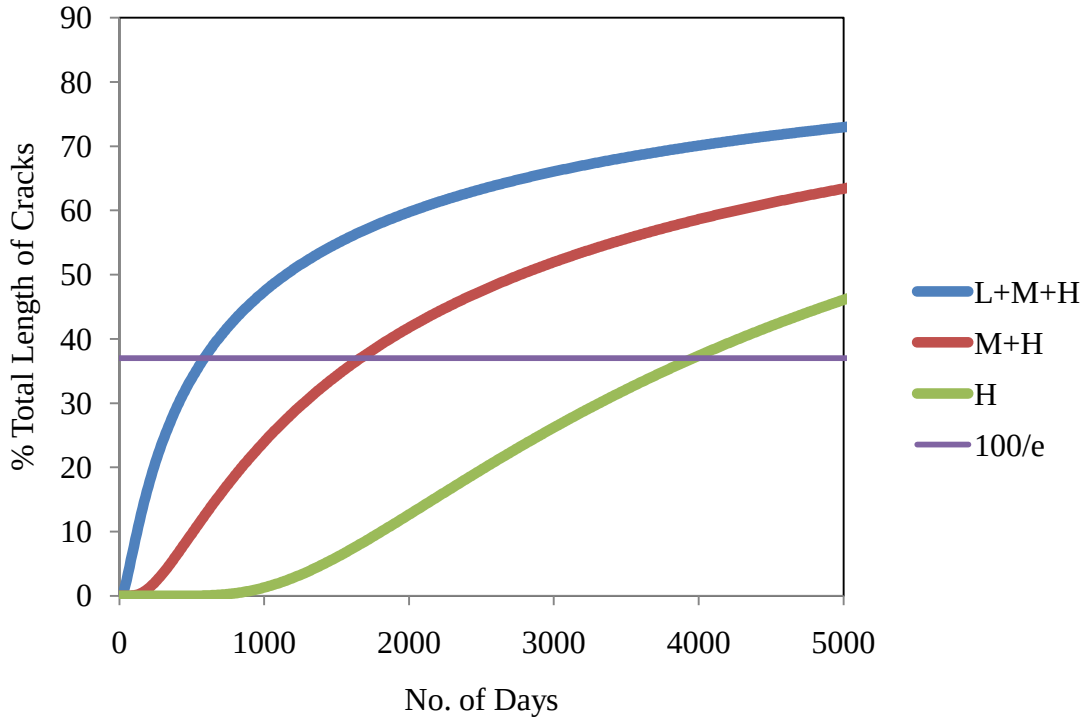


Figure O-3. AC over FC over AC pavement at Frederick, Maryland (WF).

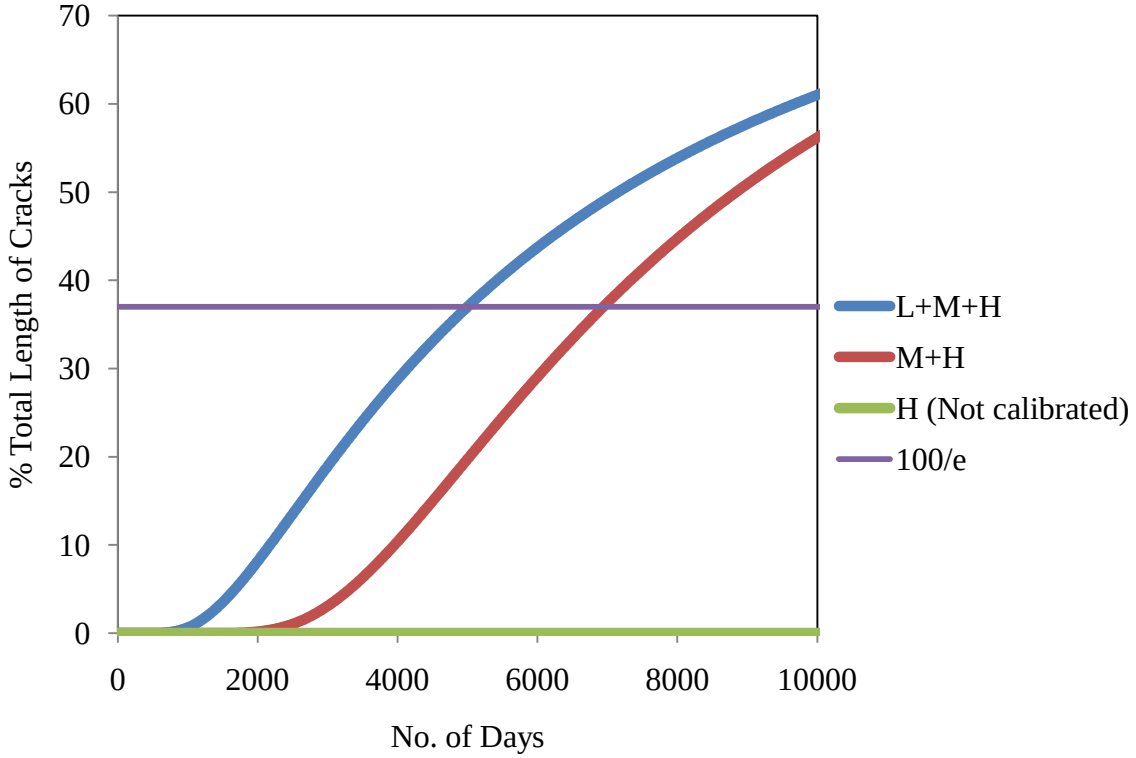


Figure O-4. AC over CRC pavement at Minnesota, Washington (WF).

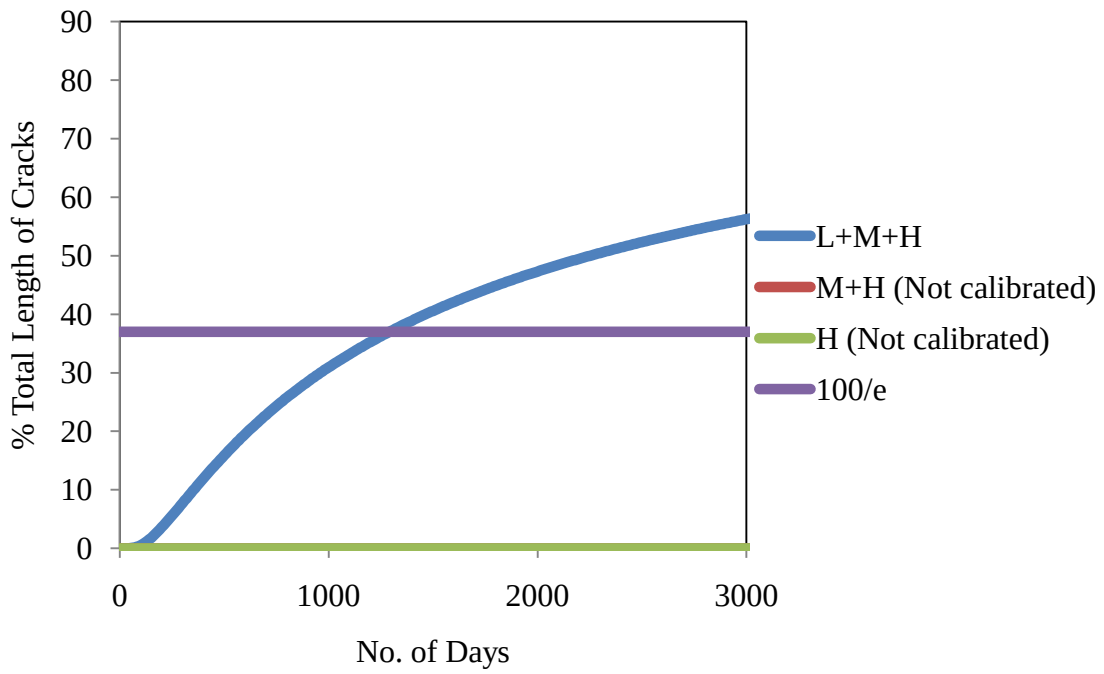


Figure O-5. AC over PetroGrid over PCC pavement at Waco, Texas (WNF).

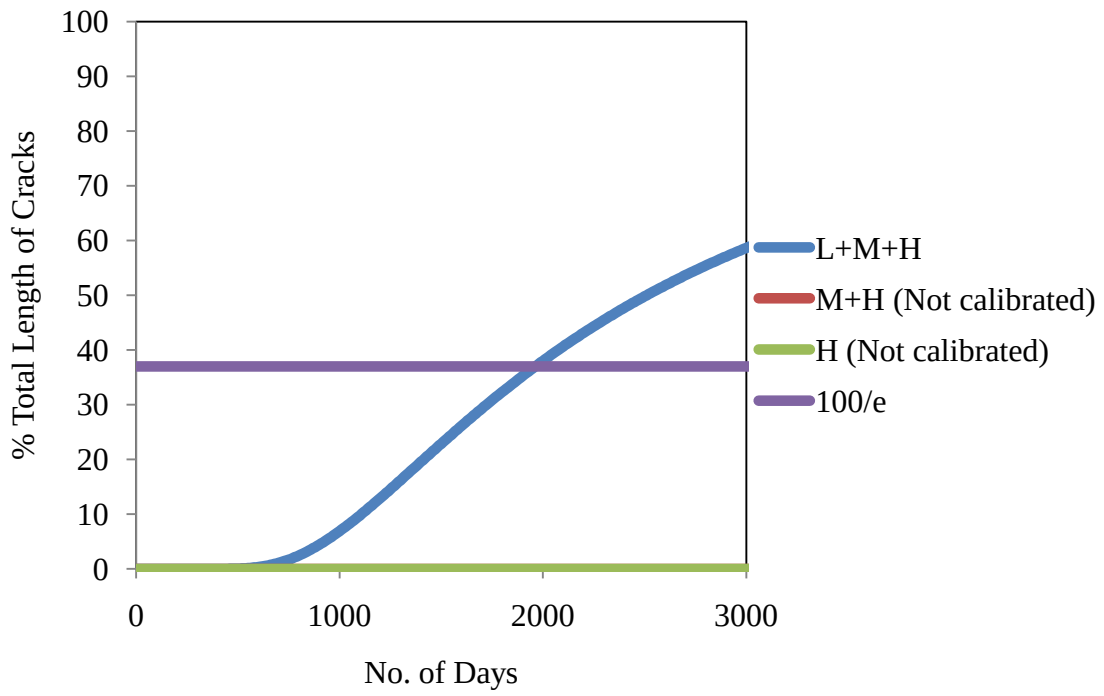


*Figure O-6. AC over PetroGrid over AC pavement at Amarillo, Texas (DF***).**

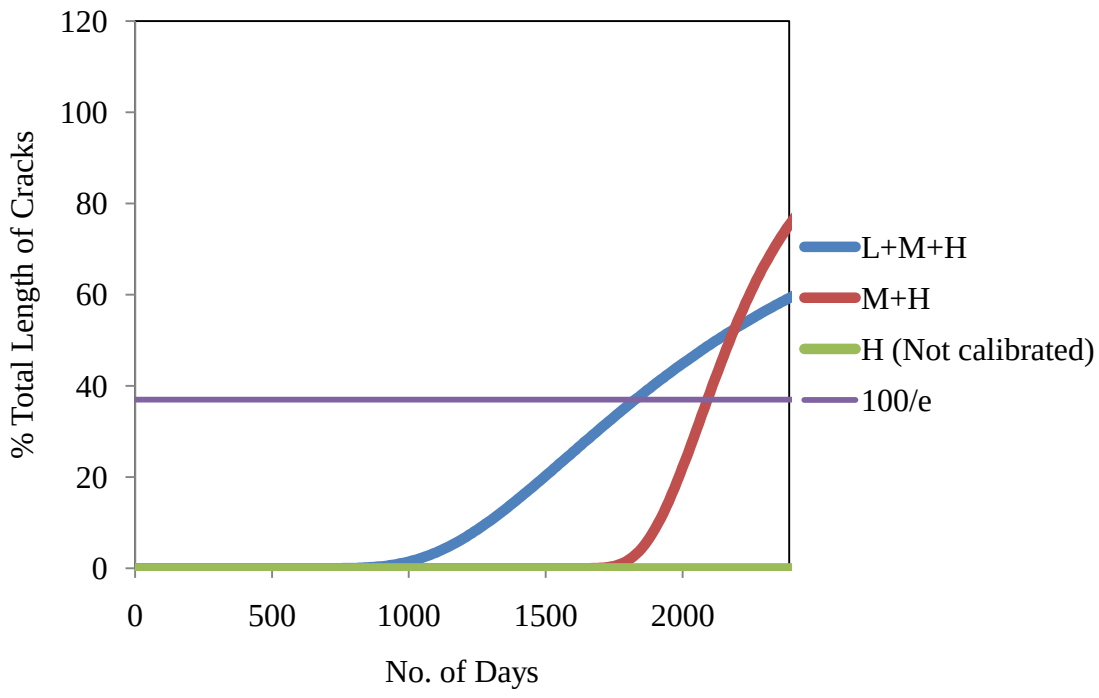


Figure O-7. AC over AC pavement at Pittsylvania, Virginia (WNF).

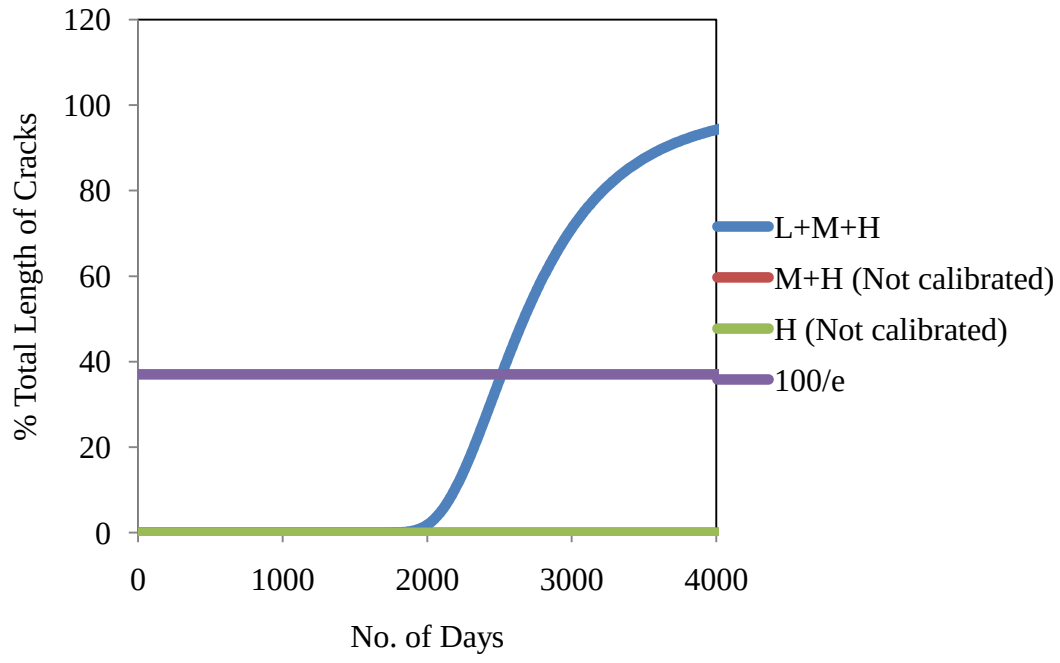


Figure O-8. AC over FC over AC pavement at Yazoo, Mississippi (WNF).

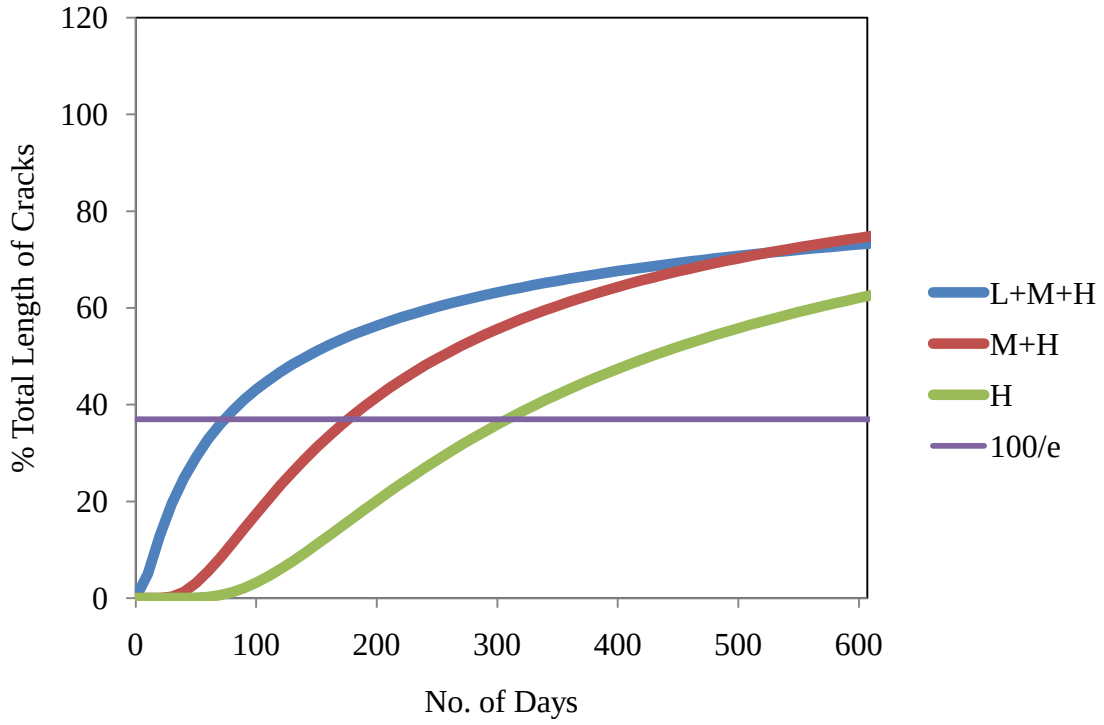


Figure O-9. AC over AC pavement at Deaf Smith County, Texas (DF).

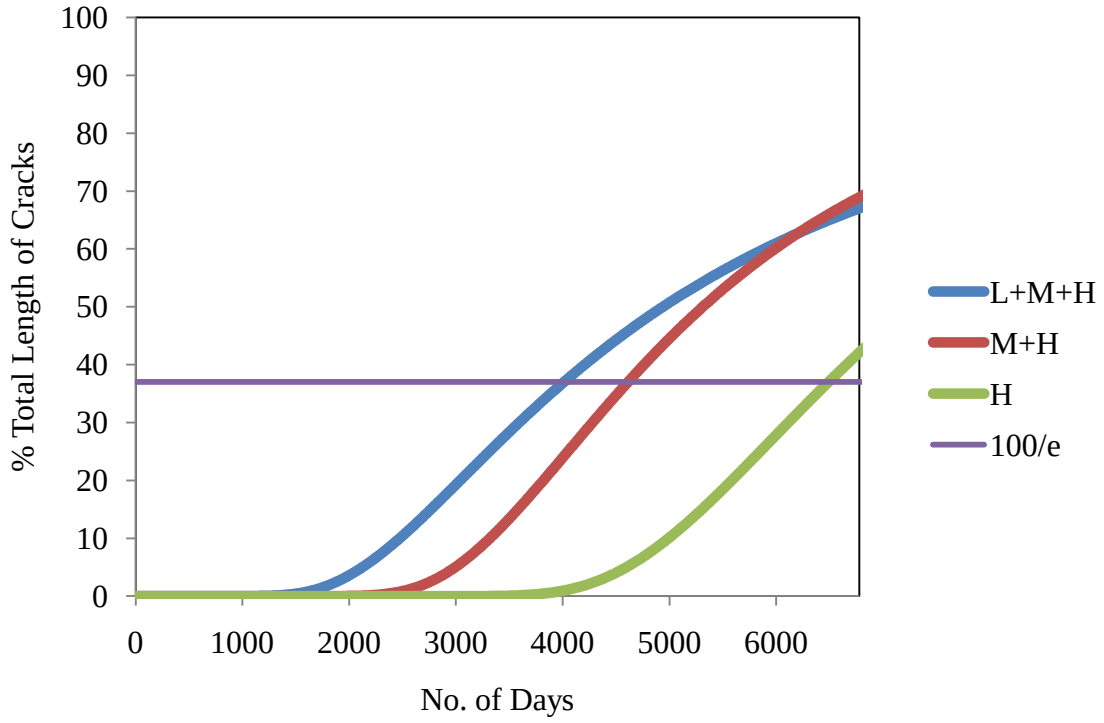


Figure O-10. AC over AC pavement in Pinal, Arizona (DNF).

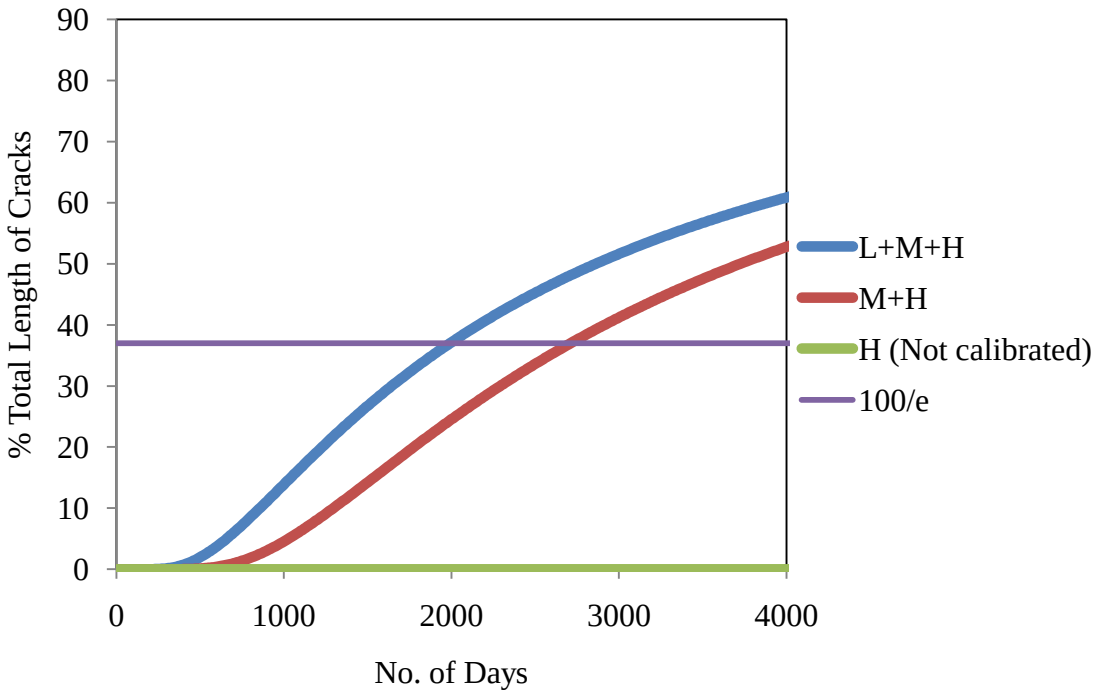


Figure O-11. AC over Petrotac Std. 1 over PC pavement at New York, New York (WF).