

2012

DARWIN-ME Pavement Analysis and Design Manual for NJDOT

Book 3 – Material Inputs



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Darwin ME

Flexible Pavement Design and Flexible Overlay Design

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Darwin ME – Flexible Pavement Design and Flexible Overlay Design And Material Inputs

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[NJDOT Recommended values are displayed in blue]

Flexible Pavement Design

5.5 Pavement Structure Definition and Materials

HMA Material Inputs

HMA Mixtures; Including SMA, Asphalt Treated or Stabilized Base Layers, and Asphalt Permeable Treated Base Mixes

HMA Layer Inputs

5.5.1 Asphalt Concrete (New) Layer

In DARWin-ME, the material types that fall under the following general definitions can be defined as an asphalt layer:

- Hot Mix Asphalt (HMA)
- Dense Graded
- Open Graded Asphalt
- Asphalt Stabilized Base Mixes
- Sand Asphalt Mixtures
- Stone Matrix Asphalt (SMA)
- Cold Mix Asphalt
- Central Plant Processed
- Cold In-Place Recycling

If a small portion of asphalt and/or emulsion is added to granular base materials, and can be produced at a plant or mixed in-place, this material should not be considered as an AC layer. If needed, it should be combined with the crushed stone base materials or considered as an unbound aggregate mixture.

The key materials inputs required for asphalt concrete layers are:

Dynamic modulus of asphalt mixtures, Rheological properties of asphalt binder (e.g. viscosity, penetration, complex modulus and phase angles), Creep compliance and indirect tensile strength, mix related and other properties (e.g. effective binder content, air voids, heat capacity, thermal conductivity). These inputs are required for predicting pavement responses, climatic analysis, asphalt aging as well as pavement performance.



Note

For non-conventional mixtures, such as the Stone Matrix Asphalt or polymer-modified asphalt mixtures, it is recommended that you use laboratory-tested material properties. Levels 2 and 3 options for estimating dynamic modulus, indirect tensile strength and creep compliance properties provide reasonable results only for conventional Hot Mix Asphalt mixtures.

Way to Access this Interface

Open a new pavement project and select Asphalt Concrete in the Layer control.

Property	Value
Asphalt Layer	
Thickness (in.)	<input checked="" type="checkbox"/> 10
Mixture Volumetrics	
Unit weight (pcf)	<input checked="" type="checkbox"/> 150
Effective binder content (%)	<input checked="" type="checkbox"/> 11.6
Air voids (%)	<input checked="" type="checkbox"/> 7
Poisson's ratio	0.35
Is Poisson's ratio calculated?	False
Poisson's ratio	<input checked="" type="checkbox"/> 0.35
Poisson's ratio Parameter A	<input type="checkbox"/>
Poisson's ratio Parameter B	<input type="checkbox"/>
Mechanical Properties	
Dynamic modulus	<input checked="" type="checkbox"/> Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Using G* based model (not nationally calibrated)	False
Reference temperature (deg F)	<input checked="" type="checkbox"/> 70
Asphalt binder	<input checked="" type="checkbox"/> SuperPave:64-22
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/> 361.14
Creep compliance (1/psi)	<input checked="" type="checkbox"/> Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
Thermal contraction	1.301E-05 (calculated)
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./deg F)	<input type="checkbox"/>
Aggregate coefficient of thermal contraction (in./in./deg F)	<input checked="" type="checkbox"/> 5E-06
Voids in Mineral Aggregate (%)	<input checked="" type="checkbox"/> 18.6
Identifiers	
Dynamic modulus	

New Asphalt Concrete Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Asphalt Concrete layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

Asphalt Layer

Thickness (in): This control allows you to define the thickness, in inches, of the selected layer. (minimum 1- maximum 20)

Mix Volumetrics

Unit weight (pcf): This control allows you to define the weight of the selected material in pounds per cubic foot. (minimum 120- maximum 160) [NJDOT Default SMA 120, Dense 150 pcf]

Effective binder content (%): This control allows you to define the effective binder content of the asphalt concrete mixture. (minimum 5, maximum 15) [NJDOT]

Air Voids (%): This control allows you to define the percent volume of air voids in the as-constructed asphalt concrete pavement layer. (minimum 2, maximum 10), [NJDOT Default 7%]

Poisson's ratio: This control allows you to define the Poisson's ratio of the material in two ways: a constant value (Level 3) or calculate as a function of dynamic modulus (Level 2). (minimum 0.1, maximum 0.4), [NJDOT 0.35 dense, 0.40 for open graded] [Let Darwin ME calculate Poisson's Ratio]

Clicking the plus sign (+) to the left of this control presents the following options:

Is Poisson's ratio calculated?: Select True to calculate Poisson's ratio as a function of dynamic modulus. Select False to use a constant value.

Poisson's ratio: This control allows you to define a constant value of Poisson's ratio .This control is disabled when you select True.

Poisson's ratio Parameter A: This control allows you to define the parameter A of the Poisson's ratio model. You can override the default value of -1.63 to enter mixture-specific values. This control is disabled when you select False.

Poisson's ratio Parameter B: This control allows you to define the parameter B of the Poisson's ratio model. You can override the default value of 3.84E-06 to enter mixture-specific values. This control is disabled when you select False.



Note

Parameters A and B are the empirical coefficients of the predictive model that defines Poisson's ratio as a function of dynamic modulus, as described in the AASHTO Manual of Practice.

Mechanical Properties

Dynamic modulus input level: This control allows you to define the level of inputs for dynamic modulus of asphalt concrete material. Select one of the following options from the dropdown menu:

1: Selecting 1 gives you the option to input the laboratory tested dynamic modulus properties of the asphalt concrete mixture and laboratory tested asphalt binder properties directly. These are described in the AASHTO Manual of Practice as Level 1 inputs.

2: Selecting 2 gives you the option to derive dynamic modulus properties from laboratory tested asphalt binder properties and the aggregate gradation of the asphalt concrete mixture. These are described in the AASHTO Manual of Practice as Level 2 inputs.

3: Selecting 3 gives you the option to derive dynamic modulus properties from typical rheological properties of the asphalt binder grade you select and the aggregate gradation of the asphalt concrete mixture. These are described in the AASHTO Manual of Practice as Level 3 inputs.



Input screens for dynamic modulus and AC binder properties change with the input level selected. For example, the input screen for dynamic modulus properties at level 1 is different from those at levels 2 and 3, while for asphalt binder properties, the input screens at levels 1 and 2 are different from that of Level 3.

Dynamic Modulus

Input the properties necessary to calculate asphalt dynamic modulus. Level 1 requires laboratory measured dynamic modulus at loading frequencies and temperatures. Levels 2 and 3 require aggregate gradation of a given mixture.

Dynamic modulus input level 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No. 4 sieve	60
No. 200 sieve	6

Dynamic modulus input level 2

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No. 4 sieve	60
No. 200 sieve	6

Dynamic modulus input level 1

Select temperature levels 5 Select frequency levels 4

	Frequency (Hz) ---->			
Temperature (d...	0.1	1	10	25
14	0	0	0	0
40	0	0	0	0
70	0	0	0	0
100	0	0	0	0
130	0	0	0	0

[NJDOT Default 5 Temperature levels and 4 Frequency levels]

[NJDOT Default Excel Table for each NMAS, and binder type]

Dynamic Modulus Input Level 1

This control allows you to define the Level 1 dynamic modulus values of the asphalt concrete mixture

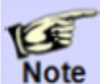
Temperature (deg F)	0.1	1	10	25
14	1631421	2104504	2562055	2733230
40	951191	1372772	1838475	2027229
70	232453	418655	696508	833168
100	57248	114584	221025	282416
130	18716	37111	74790	98548

* Dynamic modulus input values are in psi.

Level 1 Dynamic Modulus of Asphalt Concrete Mixture

Select temperature level: This control allows you to define the number of test temperatures at which the dynamic modulus values is provided for a given mixture.

Select frequency level: This control allows you to define the number of test frequencies at which the dynamic modulus values is provided for a given mixture.



Note

DARWin-ME allows a minimum of 3 and a maximum of 8 temperature levels. It also allows a minimum of 3 and a maximum of 6 frequency levels. Inputs at 5 temperature and 4 frequency levels are recommended.

Temperature (deg F): This control allows you to define the temperature at which the dynamic modulus values were measured for a given mixture. You should enter at least one input value less than 30°F, another in the range of 40 to 100°F, and the third input value higher than 125°F.

Frequency (Hz): This control defines the test frequency at which the dynamic modulus values were measured for a given mixture. You should enter at least one input value less than 1 Hz, two in the range of 1-10 Hz and the fourth input value higher than 10 Hz.

You can populate the cells within the dynamic modulus table provided with corresponding dynamic modulus values for the user-defined temperature and frequency levels. DARWin-ME provides default temperatures of 14, 40, 70, 100 and 130°F, and default frequencies of 0.1, 1, 10 and 25 Hz.

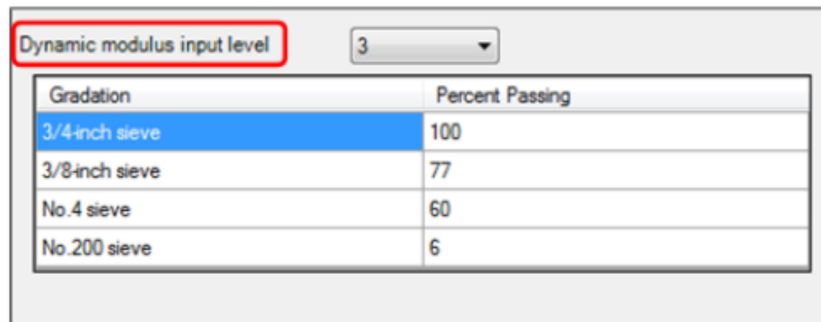
Right-Click Menu Options

Right-click on a cell in the dynamic modulus table to access the following functionality:

- **Copy:** This menu item copies the selected value.
- **Paste:** This menu item pastes the copied value.
- **Import MEPDG Dynamic Modulus (.dwn) Format:** This menu item allows you to import a dynamic modulus file that was created in using MEPDG.

Dynamic Modulus Input Levels 2 and 3

This control allows you to define the aggregate gradation of the asphalt concrete mixture for use in dynamic modulus calculations.



The screenshot shows a software interface for defining aggregate gradation. At the top, there is a label 'Dynamic modulus input level' in a red-bordered box, followed by a dropdown menu currently set to '3'. Below this is a table with two columns: 'Gradation' and 'Percent Passing'. The table contains four rows of data, with the first row highlighted in blue.

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Aggregate Gradation of Asphalt Concrete Mixture

3/4-inch sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the 3/4 inch sieve.

3/8-inch sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the 3/8 inch sieve.

No. 4 sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the #4 sieve.

No. 200 sieve: This control allows you to define the amount of aggregate material (used in the asphalt mixture) that is passing on the #200 inch sieve.

Reference temperature (deg F): This control allows you to define a baseline temperature, in degrees Fahrenheit, for use in deriving the dynamic modulus mastercurve. The suggested value is 70°F. (minimum 60, maximum 80) **[NJDOT Default 70 oF]**

Select HMA Estar (E*) predictive model: This control provides you the option for accounting the effects of loading frequencies when binder G* values are converted to viscosity values.

- True G* model not Nationally calibrated
- False Viscosity based model Nationally calibrated [Witczak predictive model] [NJDOT Default]



Note

The model for determining frequency adjusted viscosity is research grade and not nationally calibrated, while the simple conversion model is nationally calibrated. This option is applicable only for Superpave binders at input levels 1 and 2.

Asphalt Binder

Asphalt Binder: This control allows you to define the inputs of asphalt binder properties of asphalt concrete material. The controls in the dropdown menu vary with the dynamic modulus input level you selected. **Properties** Input the binder grade for level 3 or conventional/Superpave test data for levels 1 and 2. The Superpave test data uses complex shear moduli and phase angles, while the conventional grading test data uses viscosity and penetration values at different temperatures.

<input checked="" type="radio"/> Superpave Performance Grade <input type="radio"/> Penetration/Viscosity Grade			
	Temperature (deg F)	Binder Gstar (Pa)	Phase angle (deg)
*			



Note

Once the dynamic modulus input level is selected, the program automatically defines the same input level for asphalt binder properties. Thus, a Level 1 dynamic modulus input selection will result in a Level 1 input selection for asphalt binder properties. Asphalt binder input level cannot be changed independent of the dynamic modulus input level.

[NJDOT Default Excel Table for binder type]

NuStar PG64-22		
Temperature, F	Angular Frequency = 10 rad/sec	
	G* (Pa)	Delta (degrees)
50	17,600,000	47.3
72	2,506,000	59.9
93	300,700	69.9
115	4,096	80.8
136	581	86.3

SemMaterials PG76-22		
Temperature, F	Angular Frequency = 10 rad/sec	
	G* (Pa)	Delta (degrees)
50	21,070,000	40.0
72	3,570,000	51.2
93	504,600	60.3
115	83,590	63.4
136	18,560	64.0
158	5,504	65.6
180	1,775	69.0

Asphalt Binder Levels 1 and 2

You must first select an appropriate binder grading system and then enter the binder properties.

Superpave Performance Grade

<input checked="" type="radio"/> Superpave Performance Grade <input type="radio"/> Penetration/Viscosity Grade			
	Temperature (deg F)	Binder Gstar (Pa)	Phase angle (deg)
▶	147.2	2802.7	81.34
	158	1295.1	83.05
	168.8	635.9	85.14
*			

Superpave Performance Grade of Asphalt Binder

Temperature (deg F): This control allows you to define the temperature at which the binder dynamic complex modulus, G^* , and phase angle were measured for a given binder.

Binder G^* : This control allows you to define the complex shear modulus of the asphalt binder, measured at the test temperature given in the above control.

Phase angle: This control allows you to define the phase angle measured at the given test temperature.

You should enter at least three values in the above controls, though five is recommended.

Right-Click Menu Options

Right-click on a cell in the table to access the following functionality:

- **Copy:** This menu item copies the selected value.
- **Paste:** This menu item pastes the copied value.
- **Import MEPDG Binder (.bif) Format:** This menu item allows you to import a binder modulus file that was created in using MEPDG.

Penetration/Viscosity Grade

Superpave Performance Grade Penetration/Viscosity Grade

Softening Point (deg F) at 13000 Poise: 129.17

Absolute Viscosity (Poise) at 140 deg F: 5217.4

Kinematic Viscosity (centiStokes) at 275 deg F: 500

Specific Gravity at 77 deg F: 1.022

Penetration

	Temperature (deg F)	Penetration
▶	77	53.76
*		

Brookfield Viscosity

	Temperature	Brookfield Viscosity (centiPoise)
▶	239	1813
	257	927
	275	511

Penetration/Viscosity Grade of Asphalt Binder

Softening point temperature at a viscosity of 13000 Poise: This control allows you to define the softening point temperature of the asphalt binder at a viscosity of 13000 Poise.

Absolute viscosity of the binder at 140 F: This control allows you to define the absolute viscosity of the asphalt binder at a temperature of 140°F.

Kinematic viscosity at 275 F in centistokes: This control allows you to define the kinematic viscosity of the asphalt binder at a temperature of 275 °F.

Specific gravity of asphalt binder at 77 F: This control allows you to define the specific gravity of the asphalt binder at a temperature of 77 °F.

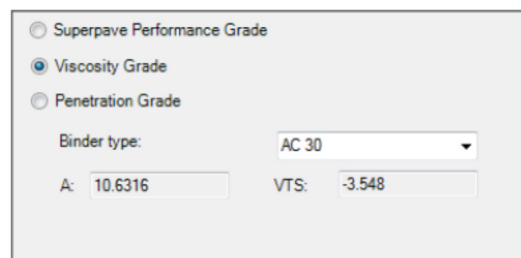
Penetration (both temp and penetration value): This control allows you to define the both the temperature, in degrees Fahrenheit, and the corresponding penetration value of the asphalt binder.

Brookfield viscosity (both temp and viscosity): This control allows you to define both the temperature, in degrees Fahrenheit, and the corresponding viscosity value of the asphalt binder.

You must enter values for the softening point, specific gravity, absolute viscosity, and kinematic viscosity of the asphalt binder as a minimum. In addition, you may choose to provide either binder penetration or Brookfield viscosity properties or both. DARWin-ME allows you to enter penetration or viscosity values for up to six test temperatures.

Asphalt Binder Level 3

The user first selects a binder grading system (radio buttons) and then selects a binder grade from the dropdown menu. (Once a binder grade is selected, the program assumes and displays the typical values of A-VTS parameters for that binder grade).



Level 3 Asphalt Binder

Grade: These controls allow you to define the grade of the binder. Select one of the following options:

Superpave Performance Grade: This control allows you to select an appropriate PG binder from the options provided by the binder type dropdown menu.

Viscosity Grade: This control allows you to select an appropriate viscosity graded binder from the options provided by the binder type dropdown menu.

Penetration Grade: This control allows you to select an appropriate penetration-graded binder from the options provided by the binder type dropdown menu.

A: This control displays the intercept of the ASTM D2493 A-VTS relationship of the binder.

VTS: This control displays the slope of the ASTM D2493 A-VTS relationship of the binder.

Indirect tensile strength at 14 deg F: This control allows you to define the indirect tensile strength of the asphalt concrete mixture at a temperature of 14 °F. You can enter a laboratory measured value (Levels 1 and 2) or **allow the program to calculate a typical value** (Level 3) based on statistical relationships with other AC inputs.

[**NJDOT Default** Let Darwin calculate the values]

Creep Compliance

Creep compliance: This control allows you to define the creep compliance of the asphalt concrete mixture.

Creep compliance level: This control allows you to define the creep compliance level. Select one of the following options:

1: At level 1, laboratory tested creep compliance values at temperatures of -4, 14 and 32 °F are required.

2: At level 2, laboratory tested creep compliance values are required only at 14 °F.

3: At level 3, the program automatically calculates the typical creep compliance values based on statistical relationships with other inputs.

Creep Compliance Input Level 1

Creep compliance level 1			
Loading Time(sec)	Low Temp (-4 deg F)	Mid Temp (14 deg F)	High Temp (32 deg F)
1	3.160338E...	5.072236E...	6.922332E...
2	3.463879E...	5.904065E...	8.805016E...
5	3.910335E...	7.216631E...	1.210158E...
10	4.285911E...	8.400134E...	1.539288E...
20	4.69756E-07	9.777726E...	1.957932E...
50	5.303024E...	1.195147E...	2.690975E...
100	5.812363E...	1.391147E...	3.422847E...

Creep compliance level 2		Creep compliance level 1		
Loading Time(sec)	Mid Temp (14 deg F)	Loading Time(sec)	Low Temp (-4 deg F)	High Temp (32 deg F)
1		1		
2		2		
5		5		
10		10		
20		20		
50		50		
100		100		

Creep Compliance (Level 1)

Loading Time: This column displays the loading time interval.

Low Temp: This column allows you to define the creep compliance of the material at a temperature of -4 °F.

Mid Temp: This column allows you to define the creep compliance of the material at a temperature of 14 °F.

High Temp: This column allows you to define the creep compliance of the material at a temperature of 32 °F.

Creep Compliance Input Level 2

Creep compliance level 2	
Loading Time(sec)	Mid Temp (14 deg F)
1	4.438165E-07
2	5.272275E-07
5	6.6202E-07
10	7.864403E-07
20	9.342441E-07
50	1.173096E-06
100	1.393568E-06

Creep Compliance (Level 2)

DARWin-ME automatically calculates the typical creep compliance values based on statistical relationships with other inputs. No action is necessary.

[NJDOT Default Use Level 3 - Have Darwin ME calculate value]

Right-Click Menu Options

Right-click on a cell in the table to access the following functionality:

- **Copy:** This menu item copies the selected value.
- **Paste:** This menu item pastes the copied value.
- **Import MEPDG Creep Compliance (.thc) Format:** This menu item allows you to import a creep compliance file that was created in using MEPDG software.

Thermal

Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
Thermal contraction	1.3E-05
Is thermal contraction calculated?	False
Mix coefficient of thermal contraction (in./in./deg F)	<input checked="" type="checkbox"/> 1.3E-05
Aggregate coefficient of thermal contraction (in./in./deg F)	<input type="checkbox"/>
Voids in Mineral Aggregate (%)	<input type="checkbox"/>
Identifiers	

Thermal Properties of Asphalt Concrete

Thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the thermal conductivity of the asphalt concrete material. DARWin-ME provides a default value of 0.67. **[NJDOT Default 0.67]**

Heat capacity (BTU/lb-deg F): This control allows you to define the heat capacity of the asphalt concrete material. DARWin-ME provides a default value of 0.23. **[NJDOT Default 0.23]**

Thermal contraction: This control allows you to define the coefficient of thermal contraction of the AC mix in two ways: a direct entry of the coefficient or allow the program to compute as a function of thermal contraction coefficient of the aggregates. Clicking the plus sign (+) to the left of this control presents the following options:

Is thermal contraction calculated?: Select True to calculate the mix contraction coefficient as a function of the aggregate contraction coefficient. Select False to directly enter the mix contraction coefficient.

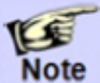
Mix coefficient of thermal contraction: This control allows you to directly enter the coefficient of thermal contraction of the AC mix. DARWin-ME provides a default value of 1.3E-05 in./in./°F.

[NJDOT Default 1.3E-005]

Aggregate coefficient of thermal contraction: This control allows you to directly input the coefficient of thermal contraction of the aggregates. DARWin- ME provides a default value of 5.0 E-06 in./in./°F. **[NJDOT Default 5E-06 °F]**

Poisson's ratio	0.35
Mechanical Properties	
Dynamic modulus	<input checked="" type="checkbox"/> Input level:1
Select HMA Estar predictive model	<input checked="" type="checkbox"/> Use Viscosity based model (nationally calibrated).
Using G* based model (not nationally calibrated)	<input type="checkbox"/> False
Reference temperature (deg F)	<input checked="" type="checkbox"/> 70
Asphalt binder	<input checked="" type="checkbox"/> Level 1 - Conventional:
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/> 365.76
Creep compliance (1/psi)	<input checked="" type="checkbox"/> Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
Thermal contraction	1.3E-05
Is thermal contraction calculated?	<input type="checkbox"/> False
Mix coefficient of thermal contraction (in./in./deg F)	<input checked="" type="checkbox"/> 1.3E-05
Aggregate coefficient of thermal contraction (in./in./deg F)	<input type="checkbox"/>
Voids in Mineral Aggregate (%)	<input type="checkbox"/>
Identifiers	
Indirect tensile strength at 14 deg F (psi)	
Indirect tensile strength at 14 deg F. This value is measured in accordance with AASHTO T322 at input levels 1 and 2. The program calculates internally using correlations at input level 3.	

New Asphalt Concrete Layer Properties



Note

You can retrieve/save asphalt concrete layer data as XML files using Import/Export menu items by right clicking the Flexible layer node under the Projects treeview and Pavement Material Layers folder in the Explorer pane.

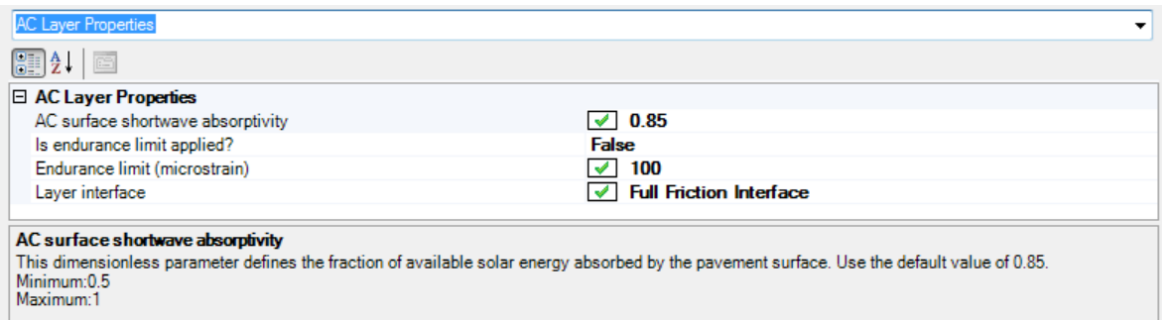
5.6 AC Layer Properties

This screen allows you to define other inputs pertinent to flexible pavement design.

Way to Access this Interface

Open a new/rehabilitation project with asphalt layer and select AC Layer Properties in the Layer control.

AC Layer Properties



Ways to Enter Inputs

There are three methods for entering data:

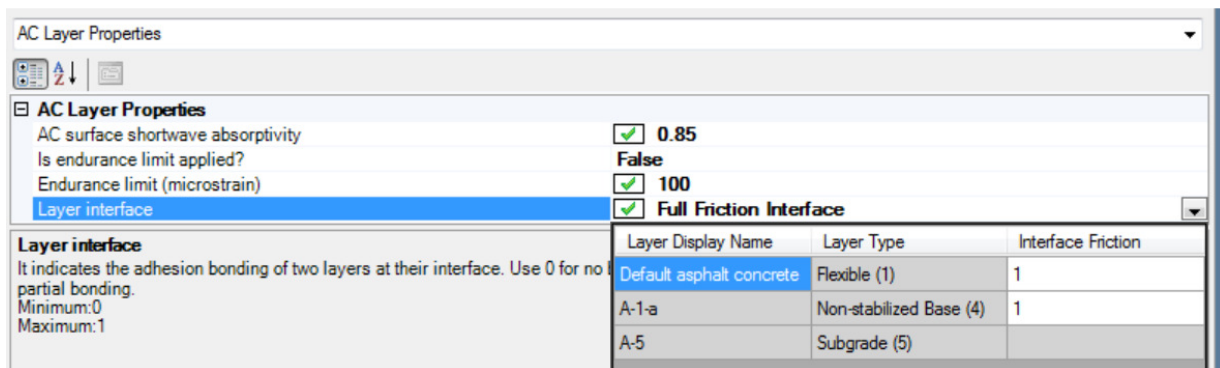
- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface AC Surface Shortwave Absorptivity: This control allows you to define the amount of available solar energy that is absorbed by the flexible pavement surface. DARWin-ME provides a default value of 0.85.

Is endurance limit applied?: This control allows you to determine whether or not you want to consider the endurance limit in the design analysis. Endurance limit is a threshold tensile strain value below which no load-related fatigue damage occurs in the AC layers. Select True to consider the endurance limit in the design analysis or False otherwise.

Endurance limit: This control allows you to define the threshold tensile strain value (endurance limit) in microstrain interface of adjacent layers in the pavement system.

Layer Interface Layer Name: This column shows the display name/identifier you defined for the layer material type.



Layer Type: This column displays the layer material type associated with the layer name.

Interface Friction: This control allows you to define the friction of adjacent layers at their interface. Enter 0 for no friction (full slip condition), 1 for full friction (no slip), or between 0 and 1 for partial friction.

Links to Relevant Section in AASHTO Manual of Practice

Section 11.2 HMA Mixtures; Including SMA, Asphalt Treated or Stabilized Base Layers, and Asphalt Permeable Treated Base Layers

5.5.2 Chemically Stabilized Layer

The required inputs for a chemically stabilized layer can be broadly classified as general, strength, and thermal properties. Note that the strength properties required by DARWin-ME are different for flexible and rigid pavements.

The chemically stabilized materials include lean concrete, cement stabilized, open graded cement stabilized, soil cement, lime-cement-flyash, and lime treated materials.

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.4 Chemically Stabilized Materials; Including Lean Concrete and Cement Treated Base Layer.

Granular Base and Subbase

5.5.3 Non-Stabilized Layer

Non-stabilized materials include AASHTO soil classes A-1 through A-3, as well as those commonly defined in practice as crushed stone, crushed gravel, river gravel, permeable aggregate, and cold recycled asphalt material (includes millings and in-place pulverized material). Inputs required for non-stabilized materials include physical and engineering properties such as dry density, moisture content, hydraulic conductivity, specific gravity, soil-water characteristic curve (SWCC) parameters, classification properties, and the resilient modulus. **Inputs are the same for Base, Subbase, and Subgrade Materials.**

Layer 3 Non-stabilized Base: A-1-a	
Unbound	
Layer thickness (in.)	<input checked="" type="checkbox"/> 10
Poisson's ratio	<input checked="" type="checkbox"/> 0.35
Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/> 0.5
Modulus	
Resilient modulus (psi)	<input checked="" type="checkbox"/> 40000
Sieve	
Gradation & other engineering properties	<input checked="" type="checkbox"/> A-1-a
Identifiers	
Display name/identifier	A-1-a
Description of object	Default material
Approver	
Date approved	1/1/2011
Author	AASHTO
Date created	1/1/2011
County	
State	
District	
Direction of travel	

Way to Access this Interface

Open a new/rehabilitation project with non-stabilized layer and select Non-stabilized Base in the Layer control.

Non-Stabilized Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Non-Stabilized Base:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

General

Layer thickness (in): This control allows you to define the thickness of the selected layer.

Poisson's ratio: This control allows you to define the Poisson's ratio of the unbound material. DARWin-ME provides a default value of 0.35. **[NJDOT Default 0.35]**

Coefficient of lateral earth pressure (k_0): This control allows you to define the pressure that the unbound material exerts in the horizontal plane. DARWin-ME provides a default value of 0.5. **[NJDOT Default 0.5]**

Modulus

Resilient Modulus (psi): This control allows you to define the level of inputs for resilient modulus of the unbound material. This control also allows you to define the resilient modulus or the other material properties that correlate with the resilient modulus. DARWin-ME displays the default value (Level 3) for the selected material class. Click on the Resilient Modulus control to modify the default value and/or input level.

Resilient Modulus (Level 3)

Resilient Modulus (Level 2)

Input Level: This control allows you to define the level of inputs for the non-stabilized material. You can select one of the following options:

2: This option allows you to define the resilient modulus directly or using its correlations with soil index and strength properties. This level of input is considered as Level 2 in the AASHTO Manual of Practice.

3: This option allows you to override the default resilient modulus value (Level 3) of the non-stabilized material. DARWin-ME does not provide Level 1 inputs option for resilient modulus of non-stabilized materials.

To refine the appropriate AASHTO Classification for these materials, we need the gradation curves as well as the Liquid Limit, Plastic Limit, and the Plasticity Index. Use the FWD to Lab conversion to correct the Modulus values.

Analysis Types: These controls allow you to define how DARWin-ME accounts for seasonal variations (freezing, thawing and moisture) in the resilient modulus calculations. Select one of the following options:

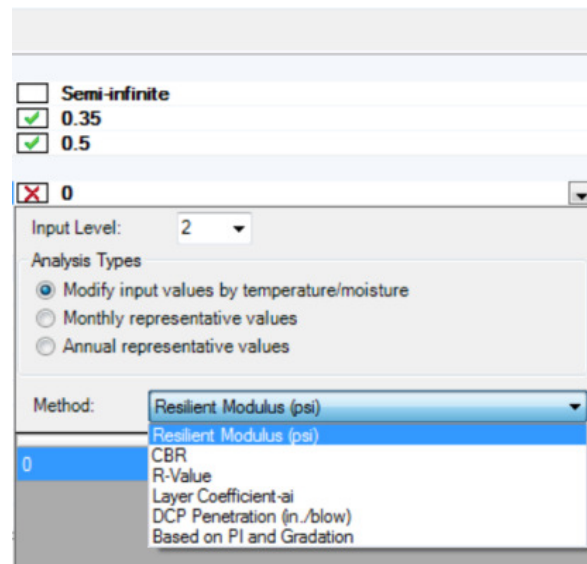
Modify input values by temperature/moisture: This option allows you to define a single resilient modulus value. You can also input a single value of the selected soil index or strength property that is converted by DARWin-ME into a resilient modulus value. DARWin-ME incorporates the effects of seasonal variations on the single resilient modulus value you define.

Monthly representative values: This option allows you to define the resilient modulus throughout the year. You can input a single value of resilient modulus (or the selected soil index or strength property) for each month of a year. By selecting this option, you make DARWin-ME use the inputs you provide directly for seasonal variations without making internal adjustments. This option is available only for Level 2 inputs.

Annual representative values: This option allows you to define a fixed resilient modulus for an entire year. You can input a single value of resilient modulus (or the selected soil index or strength property) that is representative for an entire year. DARWin-ME does not incorporate the effects of seasonal variations on the single resilient modulus value you define.

Method: This control allows you to select how to estimate the resilient modulus using one of the following options:

- Resilient modulus (psi)
- California Bearing Ratio (CBR) (percent)
- R-value
- Layer Coefficient-ai
- Dynamic Cone Penetrometer (DCP) Penetration (in./blow)
- Plasticity Index (PI) and Gradation (i.e., Percent Passing No. 200 sieve)



Values Table: This control allows you to define the values for resilient modulus or the selected soil index and strength property. You are not required to define the values for Plasticity Index(PI) and percent passing No. 200 sieve in the Values Table, as these values will be defined in the Gradation and other engineering properties interface.

The Resilient Modulus levels can be based on FWD and DCP results from Pavement Consultant data collection and analysis.

After the selection is made, the sieve and engineering properties can be refined in the following tables.

[NJDOT Default Use level 3 with values modified for temperature and moisture]

For DGABC use a Resilient Modulus of 40,000 psi

For I-3 Subbase use a Resilient Modulus of 20,000 psi

Sieve

Gradation & other engineering properties

The Sieve dialog box allows you to define the gradation, Atterberg limits, specific gravity, water content, maximum dry density, saturated hydraulic conductivity and the SWCC parameters of non-stabilized materials.

Gradation & other engineering properties

Sieve Size Table: This table allows you to define the percentage of non-stabilized material passing a variety of sieve sizes.

Sieve Size: This column lists the applicable sieve sizes.

Percent Passing: This column allows you to define the percentage of non-stabilized material passing a given sieve size. You are not required to define the percent passing for each sieve size. **However, you are required to enter values for a minimum of 3 sieve sizes including No. 200 sieve.**

Liquid Limit This control allows you to define the liquid limit of the non-stabilized material.

Plasticity Index: This control allows you to define the plasticity index for non-stabilized material.

Is Layer Compacted?: Enable this control to indicate that the layer is compacted. Typically non-stabilized materials used in the base and subbase layers are compacted in place during construction. Disable this control to indicate that the layer is not compacted.

DARWin-ME internally computes the values of the following properties based on the inputs for Gradation, Liquid Limit, Plasticity Index and Is Layer Compacted. The computed values

are based on the defaults initially displayed on the input screen. However, if you choose to modify the default values, you are required to click outside the input screen for the program to update the internally computed values.

Maximum dry unit weight: DARWin-ME internally computes the maximum dry density of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Saturated hydraulic conductivity (ft/hr): DARWin-ME internally computes the saturated hydraulic conductivity of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Specific gravity of solids: DARWin-ME internally computes the specific gravity of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Optimum gravimetric water content (%): DARWin-ME internally computes the moisture content of the non-stabilized material at which maximum dry density is achieved. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

User-defined Soil Water Characteristic Curve (SWCC): DARWin-ME internally computes the coefficients (af, bf, cf, and hr) of the soil water characteristic curve. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Links to Relevant Section in AASHTO Manual of Practice

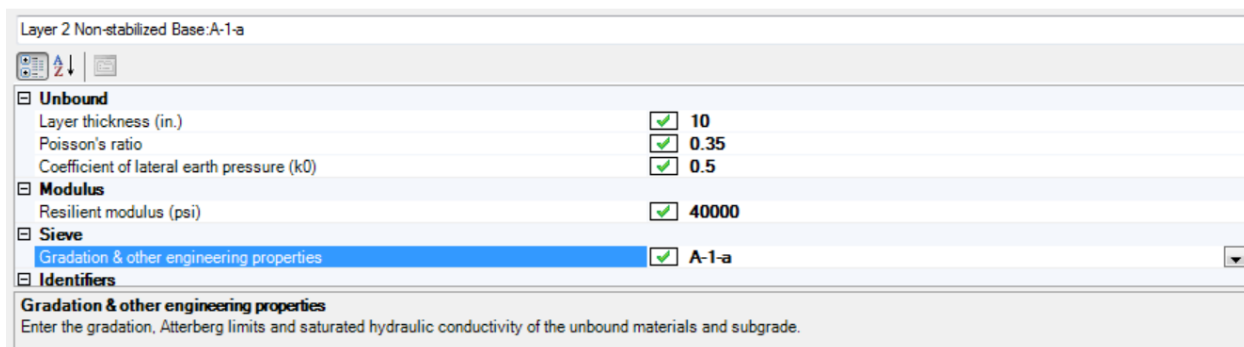
Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

Darwin Recommended Levels 2 and 3 Input Parameters and Values for Unbound Aggregate Base, Subbase, Embankment, and Subgrade Soil Material Properties

Required Input	Recommended Input Level																																																							
Resilient modulus	Use level 3 inputs based on the unbound aggregate base, subbase, embankment, and subgrade soil material AASHTO Soil Classification. AASHTO Soil Class is determined using material gradation, plasticity index, and liquid limit.																																																							
	<table border="1"> <thead> <tr> <th data-bbox="505 449 690 642" rowspan="2">AASHTO Soil Classification</th> <th colspan="3" data-bbox="696 449 1408 512">Recommended Resilient Modulus at Optimum Moisture (AASHTO T 180), psi</th> </tr> <tr> <th data-bbox="696 520 873 642">Base/Subbase for Flexible and Rigid Pavements</th> <th data-bbox="880 520 1143 642">Embankment & Subgrade for Flexible Pavements</th> <th data-bbox="1149 520 1408 642">Embankment & Subgrade for Rigid Pavements</th> </tr> </thead> <tbody> <tr> <td data-bbox="505 651 690 680">A-1-a</td> <td data-bbox="696 651 873 680">40,000</td> <td data-bbox="880 651 1143 680">29,500</td> <td data-bbox="1149 651 1408 680">18,000</td> </tr> <tr> <td data-bbox="505 688 690 718">A-1-b</td> <td data-bbox="696 688 873 718">38,000</td> <td data-bbox="880 688 1143 718">26,500</td> <td data-bbox="1149 688 1408 718">18,000</td> </tr> <tr> <td data-bbox="505 726 690 756">A-2-4</td> <td data-bbox="696 726 873 756">32,000</td> <td data-bbox="880 726 1143 756">24,500</td> <td data-bbox="1149 726 1408 756">16,500</td> </tr> <tr> <td data-bbox="505 764 690 793">A-2-5</td> <td data-bbox="696 764 873 793">28,000</td> <td data-bbox="880 764 1143 793">21,500</td> <td data-bbox="1149 764 1408 793">16,000</td> </tr> <tr> <td data-bbox="505 802 690 831">A-2-6</td> <td data-bbox="696 802 873 831">26,000</td> <td data-bbox="880 802 1143 831">21,000</td> <td data-bbox="1149 802 1408 831">16,000</td> </tr> <tr> <td data-bbox="505 840 690 869">A-2-7</td> <td data-bbox="696 840 873 869">24,000</td> <td data-bbox="880 840 1143 869">20,500</td> <td data-bbox="1149 840 1408 869">16,000</td> </tr> <tr> <td data-bbox="505 877 690 907">A-3</td> <td data-bbox="696 877 873 907">29,000</td> <td data-bbox="880 877 1143 907">16,500</td> <td data-bbox="1149 877 1408 907">16,000</td> </tr> <tr> <td data-bbox="505 915 690 945">A-4</td> <td data-bbox="696 915 873 945">24,000</td> <td data-bbox="880 915 1143 945">16,500</td> <td data-bbox="1149 915 1408 945">15,000</td> </tr> <tr> <td data-bbox="505 953 690 982">A-5</td> <td data-bbox="696 953 873 982">20,000</td> <td data-bbox="880 953 1143 982">15,500</td> <td data-bbox="1149 953 1408 982">8,000</td> </tr> <tr> <td data-bbox="505 991 690 1020">A-6</td> <td data-bbox="696 991 873 1020">17,000</td> <td data-bbox="880 991 1143 1020">14,500</td> <td data-bbox="1149 991 1408 1020">14,000</td> </tr> <tr> <td data-bbox="505 1029 690 1058">A-7-5</td> <td data-bbox="696 1029 873 1058">12,000</td> <td data-bbox="880 1029 1143 1058">13,000</td> <td data-bbox="1149 1029 1408 1058">10,000</td> </tr> <tr> <td data-bbox="505 1066 690 1096">A-7-6</td> <td data-bbox="696 1066 873 1096">8,000</td> <td data-bbox="880 1066 1143 1096">11,500</td> <td data-bbox="1149 1066 1408 1096">13,000</td> </tr> </tbody> </table>	AASHTO Soil Classification	Recommended Resilient Modulus at Optimum Moisture (AASHTO T 180), psi			Base/Subbase for Flexible and Rigid Pavements	Embankment & Subgrade for Flexible Pavements	Embankment & Subgrade for Rigid Pavements	A-1-a	40,000	29,500	18,000	A-1-b	38,000	26,500	18,000	A-2-4	32,000	24,500	16,500	A-2-5	28,000	21,500	16,000	A-2-6	26,000	21,000	16,000	A-2-7	24,000	20,500	16,000	A-3	29,000	16,500	16,000	A-4	24,000	16,500	15,000	A-5	20,000	15,500	8,000	A-6	17,000	14,500	14,000	A-7-5	12,000	13,000	10,000	A-7-6	8,000	11,500	13,000
	AASHTO Soil Classification		Recommended Resilient Modulus at Optimum Moisture (AASHTO T 180), psi																																																					
		Base/Subbase for Flexible and Rigid Pavements	Embankment & Subgrade for Flexible Pavements	Embankment & Subgrade for Rigid Pavements																																																				
	A-1-a	40,000	29,500	18,000																																																				
	A-1-b	38,000	26,500	18,000																																																				
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	A-3	29,000	16,500	16,000																																																				
	A-4	24,000	16,500	15,000																																																				
	A-5	20,000	15,500	8,000																																																				
A-6	17,000	14,500	14,000																																																					
A-7-5	12,000	13,000	10,000																																																					
A-7-6	8,000	11,500	13,000																																																					
Maximum dry density	Estimate using the following inputs: gradation, plasticity index, and liquid limit.																																																							
Optimum moisture content	Estimate using the following inputs: gradation, plasticity index, and liquid limit.																																																							
Specific gravity	Estimate using the following inputs: gradation, plasticity index, and liquid limit.																																																							
Saturated hydraulic conductivity	Select based on the following inputs: gradation, plasticity index, and liquid limit.																																																							
Soil water characteristic curve parameters	Select based on aggregate/subgrade material class.																																																							

Resilient Modulus Test Results – DGABC and NJDOT I-3

Base Course [NJDOT Default DGABC Select A-1-a]



Layer 2 Non-stabilized Base: A-1-a

Unbound

Layer thickness (in.) 10

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 40000

Sieve

Gradation & other engineering properties A-1-a

Identifiers

Gradation & other engineering properties
Enter the gradation, Atterberg limits and saturated hydraulic conductivity of the unbound materials and subgrade.

Resilient Modulus testing was conducted in accordance to AASHTO TP46 on DGABC samples compacted to their respective maximum dry density and optimum moisture content. Table 19 shows the material dependent regression coefficients determined from the resilient modulus testing, as well as the calculated resilient modulus values for the given pavement section.

Table 19 – Resilient Modulus (MR) Test Results for DGABC Samples

Region of NJ	Soil Gradation Type	Regression Coefficients			Resilient Modulus
		k ₁	k ₂	k ₃	M _R (psi)
DGABC North Region	Natural Gradation	1009.8	0.714	-0.049	23,059
	High End	844.1	0.934	-0.159	21,001
	Middle Range	992.4	0.594	-0.0285	21,176
	Low End	987.3	0.498	-0.0547	19,506
DGABC Central Region	Natural Gradation	1023.3	0.4775	-0.0458	20,042
	High End	840.1	0.928	-0.1444	20,982
	Middle Range	950.2	0.526	-0.0271	19,405
	Low End	952.8	0.46	-0.0544	18,364

The range in resilient modulus values clearly shows the dependency of aggregate gradation on the resilient modulus value, although no true trend in test results exists. However, the one trend that is obvious is that the low end of the gradation range resulted in the lowest resilient modulus value. This is most likely due to the excessive fines in the sample. The resilient modulus results for the gradation ranges (high, middle, and low) are relatively close, while a 3,000 psi resilient modulus difference exists between the North and Central Region's natural gradation. The North Region's resilient modulus for the natural gradation was most likely greater due to the coarser nature of the aggregate gradation.

[NJDOT Default use the liquid limit of 6 and 0 Plasticity Index, and indicate that the layer is compacted.] Darwin ME internally computes the maximum dry unit weight, saturated hydraulic conductivity, specific gravity of solids, optimum gravimetric water content and the Soil Water Characteristic Curve.

These values can be changed by clicking the check-box and inserting new values.

Subbase Course [NJDOT Default I-3 Select A-2-4]

Resilient modulus tests were also conducted for the NJDOT I-3 aggregates with the material dependent regression coefficients and the calculated resilient modulus shown in Table 20.

Resilient modulus tests were also conducted for the NJDOT I-3 aggregates with the material dependent regression coefficients and the calculated resilient modulus shown in Table 20.

Table 20 – Resilient Modulus (MR) Test Results for NJDOT I-3 Samples

Region of NJ	Soil Gradation Type	Regression Coefficients			Resilient Modulus
		k ₁	k ₂	k ₃	M _R (psi)
NJDOT I-3 North Region	Natural Gradation	909.0	0.714	-0.049	17,746
	High End	---	---	---	N.A.
	Middle Range	892.4	0.594	-0.0285	16,656
	Low End	887.3	0.498	-0.0547	15,806
NJDOT I-3 Central Region	Natural Gradation	799.4	0.7585	-0.09	15,736
	High End	---	---	---	N.A.
	Middle Range	810.2	0.642	-0.0271	15,433
	Low End	852.8	0.46	-0.0544	14,953
NJDOT I-3 South Region	Natural Gradation	867.2	0.626	-0.0883	16,159
	High End	---	---	---	N.A.
	Middle Range	850.2	0.526	-0.0245	15,440
	Low End	792.1	0.402	-0.0792	13,473

The typical trend found with the remaining gradations was that as the gradation became finer, the resilient modulus value decreased. The resilient modulus values of the middle and natural gradations from the Central and South region were very similar, as would be expected since the gradations of the material were also very similar. The resilient modulus values from the North region were shown to be 2,000 to 3,000 psi greater for the same gradations. This is most likely due to both a coarser gradation and higher compacted density.

Sieve Size	Percent Passing	Liquid Limit	Plasticity Index
0.001mm		14	0
0.002mm			
0.020mm			
#200	4	<input type="checkbox"/> Is layer compacted?	<input type="checkbox"/> Maximum dry unit weight (pcf) 126.8
#100		<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr) 7.161e-02	<input type="checkbox"/> Specific gravity of solids 2.7
#80		<input type="checkbox"/> Optimum gravimetric water content (%) 6.7	<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)
#60		af 2.42744158765371	bf 2.91736107670681
#50	12	cf 0.856276539397693	hr 100
#40			
#30			
#20			
#16			
#10			
#8			
#4	52		
3/8in.			
1/2in.			
3/4in.	98		
1in.	100		
1 1/2in.			
2in.			
2 1/2in.			
3in.			
3 1/2in.			

Resilient Modulus Results – RCA and RCA Blends

Recycled Concrete Aggregate (RCA) was blended with DGABC at percentages of 25, 50, and 75% by total weight. Each blend was compacted to its respective maximum dry density and optimum moisture content. Table 17 compares the resilient modulus results for the RCA blended samples. Since there does not exist simply “one” resilient modulus value for a soil (due to the material property’s stress dependency), the material must be evaluated under some type of pavement stress scenario to actually determine a resilient modulus value.

Table 17 – Resilient Modulus (MR) Test Results for RCA Blended Samples

Region of NJ	Soil Gradation Type	Regression Coefficients			Resilient Modulus
		k ₁	k ₂	k ₃	M _R (psi)
RCA Blend	100% RCA	1735.4	0.5362	0.1387	38,975
	75% RCA, 25% DGA	1532.6	0.5431	0.1096	34,044
	50% RCA, 50% DGA	1350.8	0.5996	0.1618	32,018
	25% RCA, 75% DGA	1278.3	0.3863	-0.2482	21,170
	0% RCA (100% DGA)	1023.3	0.4775	-0.0458	20,042

The table clearly shows that as the percent of RCA increases, the resilient modulus also increases. The DGABC source used for all of the recycled blended samples was from the central region source.

Resilient Modulus Results – RAP and RAP Blends

Recycled Asphalt Pavement (RAP) was blended with DGABC at percentages of 25, 50, and 75% by total weight. Each blend was compacted to its respective maximum dry density and optimum moisture content. Table 18 compares the resilient modulus results for the RAP blended samples using the same methodology as the RCA blended samples.

As with the RCA blended samples, there is a trend of increasing resilient modulus with the increase of percent RAP blended. The 100% RAP sample achieved the largest resilient modulus value for all of the RAP blended samples.

(100% RAC)

Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	2
#100	
#80	
#60	
#50	10
#40	
#30	
#20	
#16	
#10	
#8	
#4	30
3/8-in.	
1/2-in.	
3/4-in.	70
1-in.	83
1 1/2-in.	100
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Liquid Limit	6
Plasticity Index	0
<input checked="" type="checkbox"/> Is layer compacted?	
<input type="checkbox"/> Maximum dry unit weight (pcf)	0.0
<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	1.078e+00
<input type="checkbox"/> Specific gravity of solids	2.7
<input type="checkbox"/> Optimum gravimetric water content (%)	6.6
<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
af	2.97533064283967
bf	2.924783692219
cf	0.87468028002965
hr	100

[NJDOT Default input the gradations as shown above, use the liquid limit of 6 and 0 Plasticity Index, and indicate that the layer is compacted.]

Darwin ME internally computes the maximum dry unit weight, saturated hydraulic conductivity, specific gravity of solids, optimum gravimetric water content and the Soil Water Characteristic Curve.

These values can be changed by clicking the check-box and inserting new values.

Table 18 – Resilient Modulus (MR) Test Results for RAP Blended Samples

Region of NJ	Soil Gradation Type	Regression Coefficients			Resilient Modulus
		k ₁	k ₂	k ₃	M _R (psi)
RAP Blend	100% RAP	1775.6	0.4598	0.1784	38,738
	75% RAP, 25% DGA	1441.9	0.4931	0.0677	30,311
	50% RAP, 50% DGA	1599.2	0.5144	-0.0082	32,739
	25% RAP, 75% DGA	1582.7	0.3822	-0.1175	28,027
	0% RAP (100% DGA)	1023.3	0.4775	-0.0458	20,042

It should again be stated that the resilient modulus values shown in the tables for comparison are simply the resilient modulus for the pavement section and loading scenario described. There could actually be a multitude of resilient modulus values for a single aggregate sample due to the multitude of potential stress conditions.

Subbase Course [NJDOT Default I-3 Select A-2-4]

Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	4
#100	
#80	
#60	
#50	12
#40	
#30	
#20	
#16	
#10	
#8	
#4	52
3/8-in.	
1/2-in.	
3/4-in.	98
1-in.	100
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Liquid Limit	<input type="text" value="14"/>
Plasticity Index	<input type="text" value="0"/>
<input type="checkbox"/> Is layer compacted?	
<input type="checkbox"/> Maximum dry unit weight (pcf)	<input type="text" value="126.8"/>
<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	<input type="text" value="7.161e-02"/>
<input type="checkbox"/> Specific gravity of solids	<input type="text" value="2.7"/>
<input type="checkbox"/> Optimum gravimetric water content (%)	<input type="text" value="6.7"/>
<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	

af	2.42744158765371
bf	2.91736107670681
cf	0.856276539397693
hr	100

[NJDOT Default input the gradations as shown above, use the liquid limit of 14 and 0 Plasticity Index, and indicate that the layer is compacted.]

Darwin ME internally computes the maximum dry unit weight, saturated hydraulic conductivity, specific gravity of solids, optimum gravimetric water content and the Soil Water Characteristic Curve.

These values can be changed by clicking the check-box and inserting new values.

Subgrade and Bedrock:

5.5.4 Subgrade

Subgrade materials include soil classes A-1 through A-7-6 defined in accordance with the AASHTO soil classification system. Inputs required for subgrade materials are same as those of non-stabilized materials, and include physical and engineering properties such as dry density, moisture content, hydraulic conductivity, specific gravity, soil-water characteristic curve (SWCC) parameters, classification properties, and the resilient modulus.

Material Layer Selection

Insert layer below: Layer 2 Non-stabilized Base : A-1-a

Layer type: Subgrade (5)

Select material type

Select from default list
 Import from database

- A-1-a.xml
- A-1-b.xml
- A-2-4.xml
- A-2-5.xml
- A-2-6.xml
- A-2-7.xml
- A-3.xml
- A-4.xml
- A-5.xml
- A-6.xml
- A-7-5.xml
- A-7-6.xml

Layer 4 Subgrade:A-1-a

Unbound
 Layer thickness (in.) 10
 Poisson's ratio 0.35
 Coefficient of lateral earth pressure (k0) 0.5

Modulus
 Resilient modulus (psi)

Sieve
 Gradation & other engineering properties A-1-a

Resilient modulus (psi)
Enter the resilient modulus of the unbound materials and subgrade.

Input Level:	3	2
Analysis Types	<input checked="" type="radio"/> Modify input values by temperature/moisture <input type="radio"/> Monthly representative values <input type="radio"/> Annual representative values	<input checked="" type="radio"/> Modify input values by temperature/moisture <input type="radio"/> Monthly representative values <input type="radio"/> Annual representative values
Method:	Resilient modulus (psi)	Resilient Modulus (psi) Resilient Modulus (psi) CBR R-Value Layer Coefficient-ai DCP Penetration (in./blow) Based on PI and Gradation
	18000	0

[NJDOT Default - Subgrade identification is based on the AAHSTO Soil Classification from the Rutgers Soil Engineering Survey map polygon information.

[NJDOT Default - Level 3 The Resilient Modulus and Sieve Gradations and Engineering Property input tables are the same as those for Non-stabilized Base and Subbase Materials explained in the section above.]

[NJDOT Default - Level 2 The Resilient Modulus levels can be based on FWD and DCP results from Pavement Consultant data collection and analysis or the following table based on the AASHTO Soil Classification.]

Way to Access this Interface

Open a new/rehabilitation project with a subgrade level and select Subgrade in the Layer control.

Subgrade Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Subgrade layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

General

Layer 3 Subgrade:A-7-5	
<input type="checkbox"/> Unbound	
Layer thickness (in.)	<input type="checkbox"/> Semi-infinite
Poisson's ratio	<input checked="" type="checkbox"/> 0.35
Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/> 0.5
<input type="checkbox"/> Modulus	
Resilient modulus (psi)	<input checked="" type="checkbox"/> 7723
<input type="checkbox"/> Sieve	
Gradation & other engineering properties	<input checked="" type="checkbox"/> A-7-5
<input type="checkbox"/> Identifiers	
Display name/identifier	A-7-5
Description of object	Default material
Approver	
Date approved	1/1/2011
Author	AASHTO
Date created	1/1/2011
County	
State	
District	
Direction of travel	

Resilient modulus (psi)
Enter the resilient modulus of the unbound materials and subgrade.

Semi-infinite
 0.35
 0.5
 7723

Input Level: 3
 Analysis Types
 Modify input values by temperature/moisture
 Monthly representative values
 Annual representative values
 Method: Resilient modulus (psi)

7723	

Resilient Modulus (Level 3)

Semi-infinite
 0.35
 0.5
 7723

Input Level: 2
 Analysis Types
 Modify input values by temperature/moisture
 Monthly representative values
 Annual representative values
 Method: Resilient Modulus (psi)

Month	
January	0
February	0
March	0
April	0
May	0
June	0

Resilient Modulus (Level 2)

Layer 3 Subgrade: A-7-5

- Unbound**
 - Layer thickness (in.) Semi-infinite
 - Poisson's ratio 0.35
 - Coefficient of lateral earth pressure (k0) 0.5
- Modulus**
 - Resilient modulus (psi) 7723
- Sieve**
 - Gradation & other engineering properties A-7-5
- Identifiers**
 - Display name/identifier: A-7-5
 - Description of object: Default material
 - Approver:
 - Date approved: 1/1/2011
 - Author: AASHTO
 - Date created: 1/1/2011
 - County:
 - State:
 - District:
 - Direction of travel:

Modify gradation, Liquid Limit and Plastic Index

Gradation & other engineering properties
 Enter the gradation, Atterberg limits and saturated hydraulic conductivity of the unbound materials and subgrade.

Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	70.5
#100	
#80	77.7
#60	
#50	
#40	83.3
#30	
#20	
#16	
#10	90.8
#8	
#4	94
3/8-in.	95.7
1/2-in.	96.3
3/4-in.	97.3
1-in.	97.9
1 1/2-in.	98.4
2-in.	98.8
2 1/2-in.	
3-in.	
3 1/2-in.	99.3

Liquid Limit	57
Plasticity Index	24
<input type="checkbox"/> Is layer compacted?	
<input type="checkbox"/> Maximum dry unit weight (pcf)	102.0
<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	4.281e-06
<input type="checkbox"/> Specific gravity of solids	2.7
<input type="checkbox"/> Optimum gravimetric water content (%)	20.0
<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	

af	125.311677789437
bf	0.577229560549397
cf	0.105241885310042
hr	500

Layer 2 Subgrade A-1-a

<input type="checkbox"/> Unbound	
Layer thickness (in.)	<input type="checkbox"/> Semi-infinite
Poisson's ratio	<input checked="" type="checkbox"/> 0.35
Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/> 0.5
<input type="checkbox"/> Modulus	
Resilient modulus (psi)	<input checked="" type="checkbox"/> 18000
<input type="checkbox"/> Sieve	
Gradation & other engineering properties	<input checked="" type="checkbox"/> A-1-a
<input type="checkbox"/> Identifiers	
Display name/identifier	A-1-a
Description of object	Default Material
Approver	

Layer thickness (in): This control allows you to define the thickness of the selected layer if this layer is not the last layer. The program automatically defines the thickness of as semi-infinite if this layer is the last layer.

Poisson's ratio: This control allows you to define the Poisson's ratio of the subgrade material. DARWin-ME provides a default value of 0.35.

Coefficient of lateral earth pressure (k₀): This control allows you to define the pressure that soil exerts in the horizontal plane. DARWin-ME provides a default value of 0.5.

Modulus

Resilient Modulus (psi): This control allows you to define the level of inputs for resilient modulus of the subgrade material. This control also allows you to define the resilient modulus or the other material properties that correlate with the resilient modulus. DARWin-ME displays the **default value (Level 3)** for the selected material class. Click on the Resilient Modulus control to modify the default value and/or input level.

Resilient Modulus (Level 3) and Resilient Modulus (Level 2)

Input Level: This control allows you to define the level of inputs for the subgrade material. Select one of the following options:

2: This option allows you to define the resilient modulus directly or using its correlations with soil index and strength properties. This level of input is considered as Level 2 in the AASHTO Manual of Practice.

3: This option allows you to override the default resilient modulus value (Level 3) of the subgrade material.

DARWin-ME does not provide Level 1 input option for resilient modulus of subgrade materials.

Analysis Types: These controls allow you to define how DARWin-ME accounts for seasonal variations (freezing, thawing and moisture) in the resilient modulus calculations. Select one of the following options:

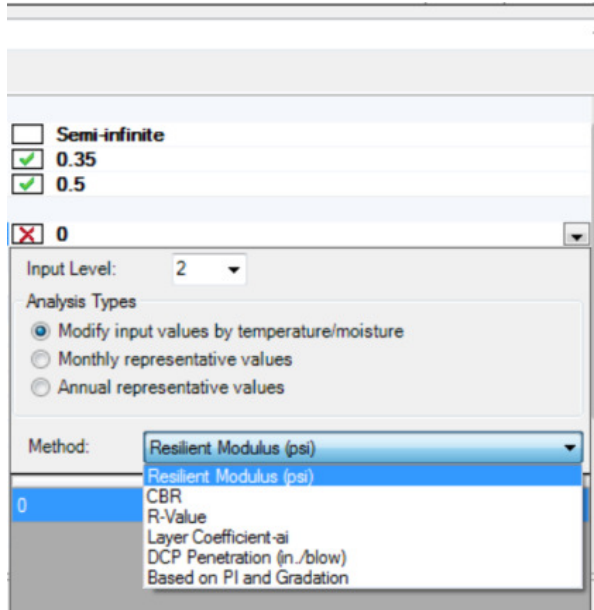
Modify input values by temperature/moisture: This option allows you to define a resilient modulus value. You can also input a single value of the selected soil index or strength property that is converted by DARWin-ME into a resilient modulus value. DARWin-ME incorporates the effects of seasonal variations on the single resilient modulus value you define.

Monthly representative values: This option allows you to define the resilient modulus throughout the year. You can input a single value of resilient modulus (or the selected soil index or strength property) for each month of a year. By selecting this option, you make DARWin-ME use the inputs you provide directly for seasonal variations without making internal adjustments. This option is available only for Level 2 inputs.

Annual representative values: This option allows you to define a fixed resilient modulus for an entire year input a single value of resilient modulus (or the selected soil index or strength property) that is representative for an entire year. DARWin-ME does not incorporate the effects of seasonal variations on the single resilient modulus value you define.

Method: This control allows you to select how to estimate the resilient modulus using one of the following options:

- Resilient modulus (psi)
- California Bearing Ratio (CBR) (percent)
- R-value
- Layer Coefficient-ai
- Dynamic Cone Penetrometer (DCP) Penetration (in./blow)
- Plasticity Index (PI) and Gradation (i.e., Percent Passing No. 200 sieve)



You are not required to define the values for Plasticity Index (PI) and percent passing No. 200 sieve in the Values Table, as these values will be defined in the Gradation and other engineering properties interface.

Values Table: This control allows you to define values for resilient modulus or the selected soil index and strength property.

Sieve

Gradation & other engineering properties

The Sieve dialog box allows you to define the gradation, Atterberg limits, and saturated hydraulic conductivity, specific gravity, water content, maximum dry density, and the SWCC parameters of subgrade materials.

Gradation & other engineering properties

Sieve Size Table: This table allows you to define the percentage of subgrade material passing a variety of sieve sizes.

Sieve Size: This column lists the applicable sieve sizes.

Percent Passing: This column allows you to define the percentage of subgrade material passing a given sieve size. You are not required to define the percent passing for each sieve size. However, you are required to enter values for a minimum of 3 sieve sizes including No.200 sieve.

Liquid Limit This control allows you to define the liquid limit of the subgrade soil.

Plasticity Index: This control allows you to define the plasticity index for the subgrade soil.

Is Layer Compacted?: Enable this control indicate that the layer is compacted. Typically the top twelve inches of the subgrade materials are compacted in place during construction. Disable this control to indicate that the layer is not compacted. DARWin-ME internally computes the values of the following properties based on the inputs for Gradation, Liquid Limit, Plasticity Index and Is Layer Compacted. The computed values are based on the defaults initially displayed on the input screen. However, if you choose to modify the default values, you are required to click outside the input screen for the program to update the internally computed values.

Maximum dry unit weight: DARWin-ME internally computes the maximum dry density of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Saturated hydraulic conductivity (ft/hr): DARWin-ME internally computes the saturated hydraulic conductivity of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Specific gravity of solids: DARWin-ME internally computes the specific gravity of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Optimum gravimetric water content (%): DARWin-ME internally computes the moisture content of the subgrade material at which maximum dry density is achieved. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

User-defined Soil Water Characteristic Curve (SWCC): DARWin-ME internally computes the coefficients (af, bf, cf, and hr) of the soil water characteristic curve. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

NJ Resilient Modulus Values

Material Classification	M _r Range	Typical M _r
A-1-a	38,500 – 42,000	40,000
A-1-b	35,500 – 40,000	38,000
A-2-4	28,000 – 37,500	32,000
A-2-5	24,000 – 33,000	28,000
A-2-6	21,500 – 31,000	26,000
A-2-7	21,500 – 28,000	24,000
A-3	24,500 – 35,500	29,000
A-4	21,500 – 29,000	24,000
A-5	17,000 – 25,500	20,000
A-6	13,500 – 24,000	17,000
A-7-5	8,000 – 17,500	12,000
A-7-6	5,000 – 13,500	8,000

A-1-a

The screenshot displays a software interface for defining material properties. On the left, a sieve analysis table shows the following data:

Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8in.	57.2
1/2in.	63.1
3/4in.	72.7
1in.	78.8
1 1/2in.	85.8
2in.	91.6
2 1/2in.	
3in.	
3 1/2in.	97.6

Below the sieve table, various material properties are listed with input fields:

- Liquid Limit: 6
- Plasticity Index: 1
- Is layer compacted?:
- Maximum dry unit weight (pcf): 127.2
- Saturated hydraulic conductivity (ft/hr): 5.054e-02
- Specific gravity of solids: 2.7
- Optimum gravimetric water content (%): 7.4
- User-defined Soil Water Characteristic Curve (SWCC):
- af: 7.25549682996034
- bf: 1.33282181654764
- cf: 0.824220751940721
- fr: 117.4

On the right, the 'Layer 2 Subgrade A-1-a' property panel is shown with the following settings:

- Unbound**
 - Layer thickness (in.): Semi-infinite
 - Poisson's ratio: 0.35
 - Coefficient of lateral earth pressure (k0): 0.5
- Modulus**
 - Resilient modulus (psi): 18000
- Sieve**
 - Gradation & other engineering properties: A-1-a
- Identifiers**
 - Display name/identifier: A-1-a
 - Description of object: Default Material
 - Approver:

A-1-b

Sieve Size	Percent Passing	Liquid Limit	Plasticity Index
0.001mm		11	1
0.002mm			
0.020mm			
#200	13.4		
#100			
#80	20.8		
#60			
#50			
#40	37.6		
#30			
#20			
#16			
#10	64		
#8			
#4	74.2		
3/8in.	82.3		
1/2in.	85.8		
3/4in.	90.8		
1in.	93.6		
1 1/2in.	96.7		
2in.	98.4		
2 1/2in.			
3in.			
3 1/2in.	99.4		

<input type="checkbox"/> Is layer compacted?	
<input type="checkbox"/> Maximum dry unit weight (pcf)	123.7
<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	2.303e-03
<input type="checkbox"/> Specific gravity of solids	2.7
<input type="checkbox"/> Optimum gravimetric water content (%)	9.1
<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
af	5.82058634036792
bf	0.462071382788545
cf	3.84968153303053
hr	126.8

Layer 2 Subgrade A-1-b	
Unbound	
Layer thickness (in.)	<input type="checkbox"/> Semi-infinite
Poisson's ratio	<input checked="" type="checkbox"/> 0.35
Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/> 0.5
Modulus	
Resilient modulus (psi)	<input checked="" type="checkbox"/> 18000
Sieve	
Gradation & other engineering properties	<input checked="" type="checkbox"/> A-1-b
Identifiers	
Display name/identifier	A-1-b
Description of object	Default material
Approver	

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

18000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

A-2-4

Sieve Size	Percent Passing	Liquid Limit	Plasticity Index
0.001mm		14	2
0.002mm			
0.020mm			
#200	22.4		
#100			
#80	42.3		
#60			
#50			
#40	67.2		
#30			
#20			
#16			
#10	82.5		
#8			
#4	87.2		
3/8 in.	91.6		
1/2 in.	93.5		
3/4 in.	95.9		
1 in.	97.2		
1 1/2 in.	98.5		
2 in.	99		
2 1/2 in.			
3 in.			
3 1/2 in.	99.6		

uf	9.50432143437867
bf	0.643864572475503
cf	3.06363831490942
hr	189.6

Layer 2 Subgrade: A-2-4

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 16500

Sieve

Gradation & other engineering properties A-2-4

Identifiers

Display name/identifier A-2-4

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

16500

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

A-2-5

Sieve Size	Percent Passing	Liquid Limit	Plasticity Index
0.001mm		50	6
0.002mm			
0.02mm		<input type="checkbox"/> Is layer compacted?	
#200	30	<input type="checkbox"/> Maximum dry unit weight (pcf)	121.9
#100		<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	4.64e-07
#80	46	<input type="checkbox"/> Specific gravity of solids	2.7
#60		<input type="checkbox"/> Optimum gravimetric water content (%)	10.1
#50		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	61		
#30			
#20		sf	48.1615150932576
#16		bf	1.09055279901014
#10	75	cf	0.886866888015418
#8		hr	460
#4	81		
3/8 in.	88		
1/2 in.	90		
3/4 in.	94		
1 in.	98		
1 1/2 in.	100		
2 in.	100		
2 1/2 in.			
3 in.			
3 1/2 in.	100		

Layer 2 Subgrade: A-2-5

2 | 4

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 16000

Sieve

Gradation & other engineering properties A-2-5

Identifiers

Display name/identifier A-2-5

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

16000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

A-2-6

Sieve Size	Percent Passing	Liquid Limit	32
0.001mm		Plasticity Index	15
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	121.9
#200	24.8	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	7.651e-06
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	32.4	<input type="checkbox"/> Optimum gravimetric water content (%)	10.0
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#50			
#40	43.5		
#30			
#20		uf	75.5741166481399
#16		bf	0.935138961105029
#10	59.4	cf	0.431523921851399
#8		hr	500
#4	67.2		
3/8in.	78.8		
1/2in.	83.3		
3/4in.	90.4		
1in.	94.5		
1 1/2in.	97.7		
2in.	99.4		
2 1/2in.			
3in.			
3 1/2in.	99.9		

Layer 2 Subgrade: A-2-6

- Unbound
 - Layer thickness (in.) Semi-infinite
 - Poisson's ratio 0.35
 - Coefficient of lateral earth pressure (k0) 0.5
- Modulus
 - Resilient modulus (psi) 16000
- Sieve
 - Gradation & other engineering properties A-2-6
- Identifiers
 - Display name/identifier A-2-6
 - Description of object Default material
 - Approver

Input Level: 3

Analysis Types

- Modify input values by temperature/moisture
- Monthly representative values
- Annual representative values

Method: Resilient modulus (psi)

16000

Input Level: 2

Analysis Types

- Modify input values by temperature/moisture
- Monthly representative values
- Annual representative values

Method: Resilient Modulus (psi)

- Resilient Modulus (psi)
- CBR
- R-Value
- Layer Coefficient-ai
- DCP Penetration (in./blow)
- Based on PI and Gradation

0

A-2-7

Sieve Size	Percent Passing	Liquid Limit	50
0.001mm		Plasticity Index	29
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	120.8
#200	27.4	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	6.832e-06
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	32	<input type="checkbox"/> Optimum gravimetric water content (%)	10.6
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	37.1		
#30			
#20		af	100.49407536548
#16		bf	0.734339283354505
#10	47.6	cf	0.268047171197676
#8		hr	500
#4	55.4		
3/8in.	72.4		
1/2in.	78.1		
3/4in.	85.3		
1in.	89.1		
1 1/2in.	94.6		
2in.	97		
2 1/2in.			
3in.			
3 1/2in.	100		

Layer 2 Subgrade A-2-7

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 16000

Sieve

Gradation & other engineering properties A-2-7

Identifiers

Display name/identifier A-2-7

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

16000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

- Resilient Modulus (psi)
- CBR
- R-Value
- Layer Coefficient-ai
- DCP Penetration (in./blow)
- Based on PI and Gradation

Sieve Size	Percent Passing	Liquid Limit	11
0.001mm		Plasticity Index	0
0.002mm		<input checked="" type="checkbox"/> Is layer compacted?	
0.020mm		<input checked="" type="checkbox"/> Maximum dry unit weight (pcf)	120.0
#200	5.2	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	3.777e-03
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	33	<input type="checkbox"/> Optimum gravimetric water content (%)	7.3
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	76.8		
#30			
#20		af	4.75716877858502
#16		bf	2.88144434468927
#10	93.4	cf	0.869373588738964
#8		hr	100
#4	95.3		
3/8in.	96.6		
1/2in.	97.1		
3/4in.	98		
1in.	98.6		
1 1/2in.	99.2		
2in.	99.7		
2 1/2in.			
3in.			
3 1/2in.	99.9		

Layer 2 Subgrade: A-3

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 16000

Sieve

Gradation & other engineering properties A-3

Identifiers

Display name/identifier A-3

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

16000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

Sieve Size	Percent Passing	Liquid Limit	
0.001mm		Liquid Limit	21
0.002mm		Plasticity Index	5
0.020mm		<input type="checkbox"/> Is layer compacted?	
#200	60.6	<input type="checkbox"/> Maximum dry unit weight (pcf)	118.4
#100		<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	8.325e-06
#80	73.9	<input type="checkbox"/> Specific gravity of solids	2.7
#60		<input type="checkbox"/> Optimum gravimetric water content (%)	11.8
#40	82.7	<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#30			
#20		af	68.8376536119812
#16		bf	0.998285126875545
#10	89.9	cf	0.475715611755117
#8		hr	500
#4	93		
3/8 in.	95.6		
1/2 in.	96.7		
3/4 in.	98		
1 in.	98.7		
1 1/2 in.	99.4		
2 in.	99.6		
2 1/2 in.			
3 in.			
3 1/2 in.	99.8		

Layer 2 Subgrade A-4

- Unbound
 - Layer thickness (in.) Semi-infinite
 - Poisson's ratio 0.35
 - Coefficient of lateral earth pressure (k0) 0.5
- Modulus
 - Resilient modulus (psi) 15000
- Sieve
 - Gradation & other engineering properties A-4
- Identifiers
 - Display name/identifier **A-4**
 - Description of object **Default material**
 - Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

15000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

- Resilient Modulus (psi)
- CBR
- R-Value
- Layer Coefficient-ai
- DCP Penetration (in./blow)
- Based on PI and Gradation

0

Sieve Size	Percent Passing	Liquid Limit	45
0.001mm		Plasticity Index	5
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	119.2
#200	54.3	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	9.256e-07
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	66.2	<input type="checkbox"/> Optimum gravimetric water content (%)	11.4
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	74.3		
#30			
#20		uf	65.233333789426
#16		bf	1.03380442279376
#10	82.6	cf	0.499360213240677
#8		hr	500
#4	86.9		
3/8in.	90.2		
1/2in.	91.9		
3/4in.	94.1		
1in.	95.9		
1 1/2in.	97.5		
2in.	98.5		
2 1/2in.			
3in.			
3 1/2in.	99.5		

Layer 2 Subgrade: A-5

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 8000

Sieve

Gradation & other engineering properties A-5

Identifiers

Display name/identifier A-5

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

8000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

A-6

Sieve Size	Percent Passing	Liquid Limit	33
0.001mm		Plasticity Index	16
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	107.9
#200	63.2	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	1.95e-05
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	73.5	<input type="checkbox"/> Optimum gravimetric water content (%)	17.1
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	82.4		
#30			
#20		af	108.409089366177
#16		bf	0.680069775804912
#10	90.2	cf	0.21612410082307
#8		hr	500
#4	93.5		
3/8in.	96.4		
1/2in.	97.4		
3/4in.	98.4		
1in.	99		
1 1/2in.	99.5		
2in.	99.8		
2 1/2in.			
3in.			
3 1/2in.	100		

Layer 2 Subgrade A-6

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 14000

Sieve

Gradation & other engineering properties A-6

Identifiers

Display name/identifier A-6

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

14000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

0

A-7-5

Sieve Size	Percent Passing	Liquid Limit	57
0.001mm		Plasticity Index	24
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	102.0
#200	70.5	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	4.281e-06
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	77.7	<input type="checkbox"/> Optimum gravimetric water content (%)	20.0
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#50			
#40	83.3		
#30			
#20		cf	125.31167789437
#16		bf	0.577229560549397
#10	90.8	cf	0.105241885310042
#8		hr	500
#4	94		
3/8in.	95.7		
1/2in.	96.3		
3/4in.	97.3		
1in.	97.9		
1 1/2in.	98.4		
2in.	98.8		
2 1/2in.			
3in.			
3 1/2in.	99.3		

Layer 2 Subgrade: A-7-5

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 10000

Sieve

Gradation & other engineering properties A-7-5

Identifiers

Display name/identifier A-7-5

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

10000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

Resilient Modulus (psi)

CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation

A-7-6

Sieve Size	Percent Passing	Liquid Limit	51
0.001mm		Plasticity Index	30
0.002mm		<input type="checkbox"/> Is layer compacted?	
0.020mm		<input type="checkbox"/> Maximum dry unit weight (pcf)	97.7
#200	79.1	<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	8.346e-06
#100		<input type="checkbox"/> Specific gravity of solids	2.7
#80	84.9	<input type="checkbox"/> Optimum gravimetric water content (%)	22.2
#60		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#50			
#40	88.8		
#30			
#20		af	136.417910213149
#16		bf	0.518276775737755
#10	93	cf	0.0323841888255715
#8		hr	500
#4	94.9		
3/8 in.	96.9		
1/2 in.	97.5		
3/4 in.	98.3		
1 in.	98.8		
1 1/2 in.	99.3		
2 in.	99.6		
2 1/2 in.			
3 in.			
3 1/2 in.	99.9		

Layer 2 Subgrade A-7-6

Unbound

Layer thickness (in.) Semi-infinite

Poisson's ratio 0.35

Coefficient of lateral earth pressure (k0) 0.5

Modulus

Resilient modulus (psi) 13000

Sieve

Gradation & other engineering properties A-7-6

Identifiers

Display name/identifier A-7-6

Description of object Default material

Approver

Input Level: 3

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient modulus (psi)

13000

Input Level: 2

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: Resilient Modulus (psi)

0

Resilient Modulus (psi)

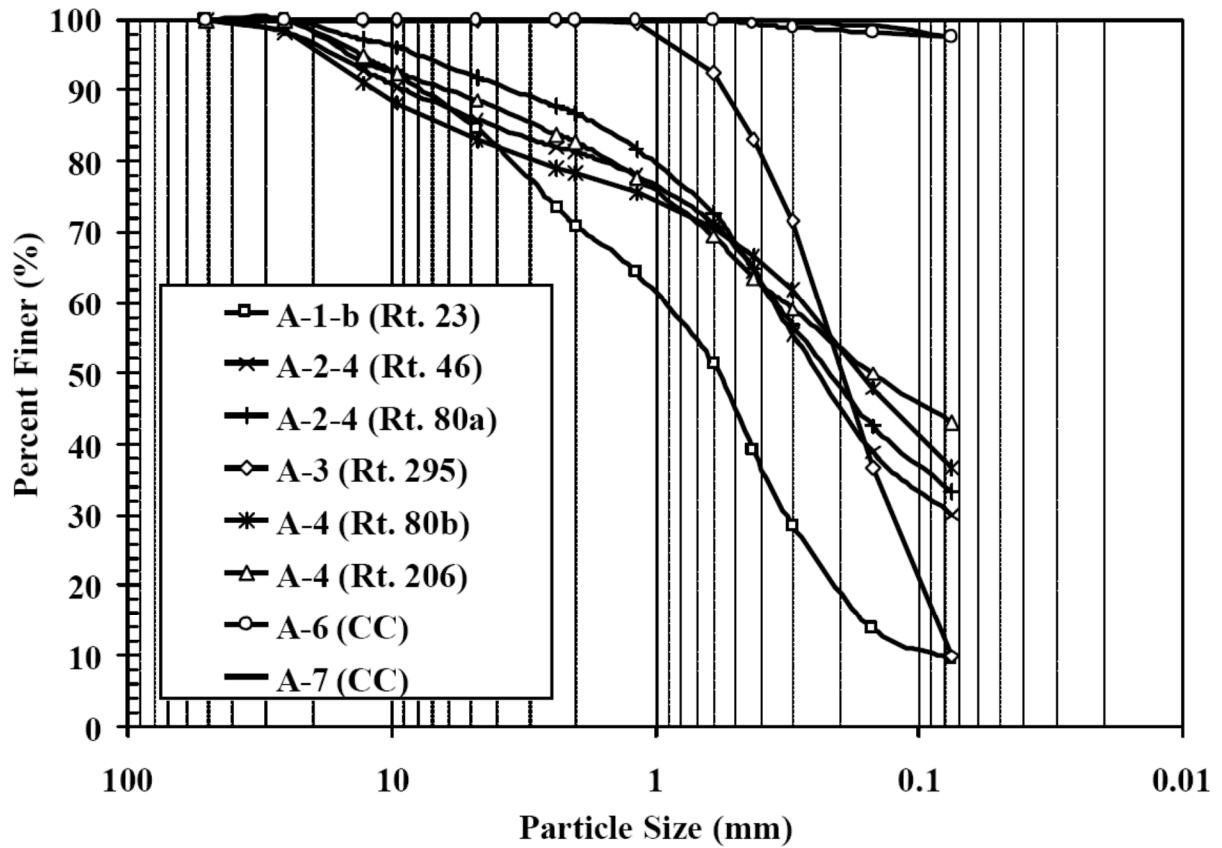
CBR

R-Value

Layer Coefficient-ai

DCP Penetration (in./blow)

Based on PI and Gradation



Gradation Analysis of Soils Tested

NJ Resilient Modulus Values

Material Classification	M_r Range	Typical M_r
A-1-a	38,500 – 42,000	40,000
A-1-b	35,500 – 40,000	38,000
A-2-4	28,000 – 37,500	32,000
A-2-5	24,000 – 33,000	28,000
A-2-6	21,500 – 31,000	26,000
A-2-7	21,500 – 28,000	24,000
A-3	24,500 – 35,500	29,000
A-4	21,500 – 29,000	24,000
A-5	17,000 – 25,500	20,000
A-6	13,500 – 24,000	17,000
A-7-5	8,000 – 17,500	12,000
A-7-6	5,000 – 13,500	8,000

Soil Location	Percent Passing 2.00 mm	Percent Passing 75 µm	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	AASHTO TP 46-92 Classification	AASHTO M 145 Classification
Rt. 23	66.6	7.6	0	N.P.	N.P.	Type 1	A-1-b
Rt. 46	81.5	30.1	15	N.P.	N.P.	Type 2	A-2-4
Rt. 80a	86.8	33.3	0	N.P.	N.P.	Type 2	A-2-4
Rt. 295	99.8	9.9	0	N.P.	N.P.	Type 2	A-3
Rt. 80b	78.4	36.6	20.5	19	1.5	Type 2	A-4
Rt. 206	82.8	43	21	17	4	Type 2	A-4
Cumberland County	100	97.5	39.1	20.2	18.9	Type 2	A-6
Cumberland County	100	97.7	52.5	25.1	27.4	Type 2	A-7

Soil Location	AASHTO Classification	Maximum Dry Density (lb/ft³)	Optimum Moisture Content (%)
Rt. 23	A-1-b	124.2	8.75
Rt. 46	A-2-4	128.5	8.5
Rt. 80a	A-2-4	120.4	9.0
Rt. 295	A-3	115.25	9.0
Rt. 80b	A-4	127.8	8.25
Rt. 206	A-4	128	8.5
Cumberland County	A-6	113.25	14.5
Cumberland County	A-7	104	22.5

Soil Location	AASHTO Classification	Moisture Content Type	Moisture Content (%)	Dry Density (lb/ft ³)	Specific Gravity	Void Ratio	% Saturation (%)
Rt. 23	A-1-b	2% Wet	10.5	121.7	2.69	0.37982	74.4
		OMC	8.5	124.2	2.69	0.35205	64.9
		2% Dry	6.5	122.3	2.69	0.37305	46.9
Rt. 46	A-2-4	2% Wet	10.0	126.1	2.67	0.32178	83.0
		OMC	8.0	128.5	2.67	0.29709	71.9
		2% Dry	6.0	127.2	2.67	0.31035	51.6
Rt. 80a	A-2-4	2% Wet	11.0	119.4	2.6	0.35935	79.6
		OMC	9.0	120.4	2.6	0.34806	67.2
		2% Dry	7.0	127.2	2.6	0.27599	65.9
Rt. 295	A-3	2% Wet	11.0	113.2	2.66	0.46689	62.7
		OMC	9.0	115.2	2.66	0.44142	54.2
		2% Dry	7.0	113.2	2.66	0.46719	39.9
Rt. 80b	A-4	2% Wet	10.2	124.8	2.66	0.33054	82.1
		OMC	8.2	127.8	2.66	0.29931	72.9
		2% Dry	6.2	125.8	2.66	0.31997	51.5
Rt. 206	A-4	2% Wet	11.0	124.6	2.69	0.34771	85.1
		OMC	9.0	127.9	2.69	0.31294	77.4
		2% Dry	7.0	123.6	2.69	0.35861	52.5
Cumberland County	A-6	2% Wet	17.0	112	2.73	0.52162	89.0
		OMC	15.0	113.3	2.73	0.50416	81.2
		2% Dry	13.0	112.4	2.73	0.51621	68.8
Cumberland County	A-7	2% Wet	24.5	101.8	2.71	0.66182	100.3
		OMC	22.5	104.0	2.71	0.62666	97.3
		2% Dry	20.5	102.0	2.71	0.65856	84.4

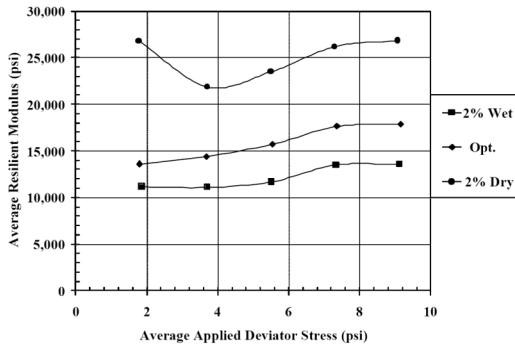


Figure 4.4 Comparison of AASHTO Type 1 (Rt 23) Resilient Modulus Test Results.

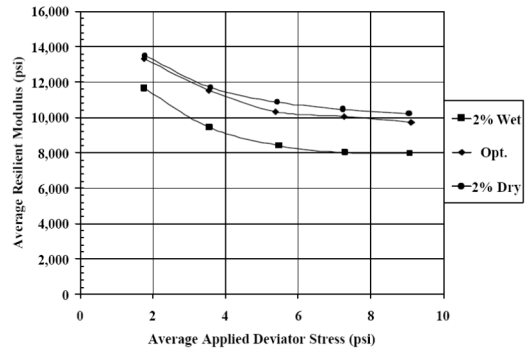


Figure 4.35 Comparison of AASHTO Type 2 (Rt 46) Resilient Modulus Test Results (A-2-4)

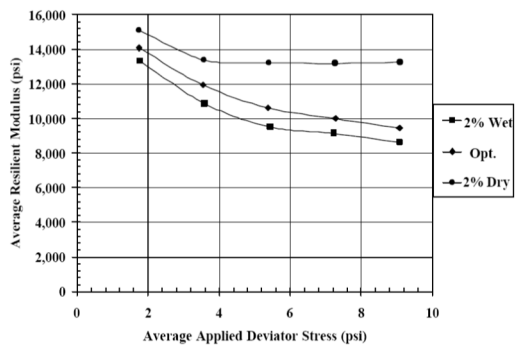


Figure 4.36 Comparison of AASHTO Type 2 (Rt 80a) Resilient Modulus Test Results (A-2-4)

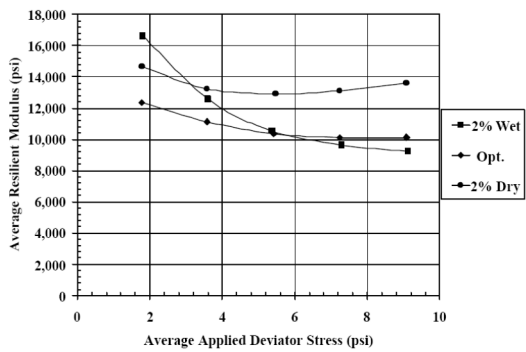


Figure 4.37 Comparison of AASHTO Type 2 (Rt 80b) Resilient Modulus Test Results (A-4)

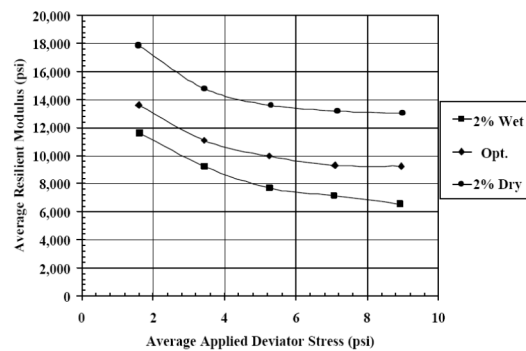


Figure 4.38 Comparison of AASHTO Type 2 (Rt 206) Resilient Modulus Test Results (A-4)

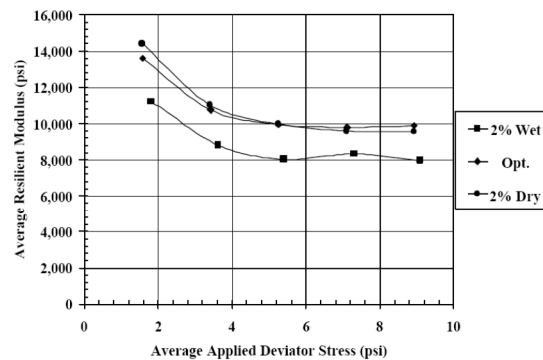


Figure 4.39 Comparison of AASHTO Type 2 (Rt 295) Resilient Modulus Test Results (A-3)

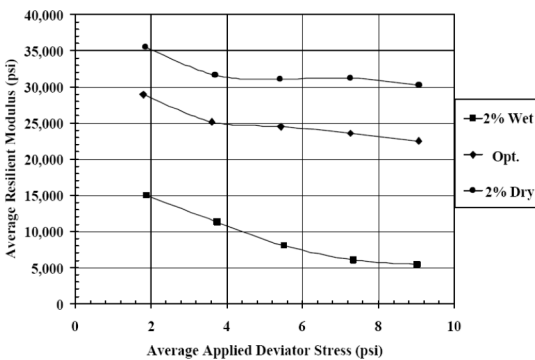


Figure 4.40 Comparison of AASHTO Type 2 (Cumberland County A-6) Resilient Modulus Test Results.

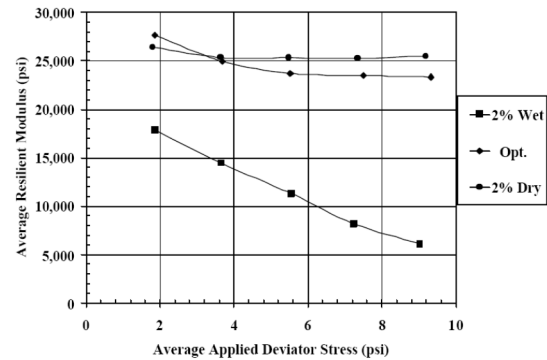
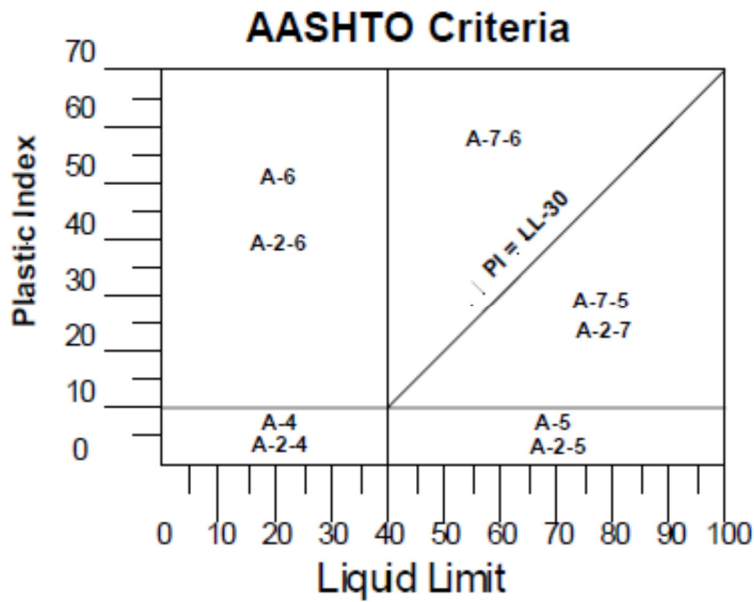


Figure 4.41 Comparison of AASHTO Type 2 (Cumberland County A-7) Resilient Modulus Test Results.

Table 8.1 – Poisson Ratios for Different Materials

Material	Range of Values	Typical Value
Hot Mix Asphalt	0.30 - 0.40	0.35
Portland Cement Concrete	0.15 - 0.20	0.15
Untreated Granular Materials	0.30 - 0.40	0.35
Cement-Treated Granular Materials	0.10 - 0.20	0.15
Cement-Treated Fine-Grained Soils	0.15 - 0.35	0.25
Lime-Stabilized Materials	0.10 - 0.25	0.20
Lime-Fly Ash Mixtures	0.10 - 0.15	0.15
Loose Sand or Silty Sand	0.20 - 0.40	0.30
Dense Sand	0.30 - 0.45	0.35
Fine-Grained Soils	0.30 - 0.50	0.40
Saturated Soft Clays	0.40 - 0.50	0.45



Use level 3 inputs based on the unbound aggregate base, subbase, embankment, and subgrade soil material AASHTO Soil Classification. AASHTO Soil Class is determined using material gradation, plasticity index, and liquid limit.

AASHTO Soil Classification	Recommended Resilient Modulus at Optimum Moisture (AASHTO T 180), psi		
	Base/Subbase for Flexible and Rigid Pavements	Embankment & Subgrade for Flexible Pavements	Embankment & Subgrade for Rigid Pavements
A-1-a	40,000	29,500	18,000
A-1-b	38,000	26,500	18,000
A-2-4	32,000	24,500	16,500
A-2-5	28,000	21,500	16,000
A-2-6	26,000	21,000	16,000
A-2-7	24,000	20,500	16,000
A-3	29,000	16,500	16,000
A-4	24,000	16,500	15,000
A-5	20,000	15,500	8,000
A-6	17,000	14,500	14,000
A-7-5	12,000	13,000	10,000
A-7-6	8,000	11,500	13,000

NOTES:

1. The resilient modulus is converted to a k-value internally within the software for evaluating rigid pavements.
2. The resilient modulus values at the time of construction for the same AASHTO soil classification are different under flexible and rigid pavements because the stress-state under these pavements is different. Soils are stress dependent and the resilient modulus will change with changing stress-state (refer to Table 27). The default values included in the MEPDG software were estimated as the median value from the test sections included in the LTPP database and used engineering judgment. These default values can be used assuming the soils are at the maximum dry density and optimum water content as defined from AASHTO T 180.

Use of the dynamic cone penetrometer (DCP) also provides an estimate of the in-place modulus of the existing soil strata. DCP tests need to be performed in accordance with ASTM D 6951 or an equivalent procedure.

The borings may note the depth and thickness of the different soil layers, depth to a rigid layer or rock strata, the depth to a water table or wet soil layers, and usual conditions that will affect pavement construction and performance. The depth to the water table is an important input.

5.5.5 Bedrock

A bedrock layer, if present under an alignment, could have a significant impact on the pavement's mechanistic responses and therefore need to be fully accounted for in design. This is especially true if backcalculation of layer moduli is adopted in rehabilitation design to characterize pavement materials. While the precise measure of the stiffness is seldom, if ever, warranted, any bedrock layer must be incorporated into the analysis.

Way to Access this Interface

Open a new/rehabilitation project with a bedrock layer and select Bedrock in the Layer control.

Bedrock Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Bedrock layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

Layer thickness (in.): The program automatically defines the thickness of the bedrock layer as semi-infinite.

Poisson's ratio: This control allows you to define the Poisson's ratio of the bedrock material. DARWin-ME provides a default value of 0.15 for solid, massive and continuous bedrock material and 0.30 for highly fractured, weathered bedrock material.

Unit weight (pcf): This control allows you to define the weight per unit volume of the bedrock material. DARWin-ME uses a default value of 140 pcf.

Strength

Elastic/resilient Modulus (psi): This control allows you to define the modulus of the bedrock layer. DARWin-ME provides a default value of 750,000 psi for solid, massive and continuous bedrock material and 500,000 psi for highly fractured, weathered bedrock material.

8. Asphalt Concrete Overlay Design of Existing Flexible Pavement

DARWin-ME can help design an asphalt concrete overlay of an existing flexible pavement. First, you need to decide if any pre-overlay treatment is needed. Pre-overlay treatments may be used to minimize the effect of existing pavement distresses on the future performance of AC overlays. Pre-overlay treatments may include a combination of milling, full or partial depth repairs, or in-place recycling.

Not all types of pre-overlay repairs are considered directly by DARWin-ME. However, the effect of pre-overlay repairs on the general condition of the existing AC layer and pavement is what should be used in the design of AC overlays of existing flexible pavements. In either case, the resulting analysis is an AC overlay of an existing flexible pavement.

Asphalt Concrete Overlay Design of Existing Flexible Pavement Overview

The topics in this section explain the options DARWin-ME offers for creating and evaluating the adequacy of AC Overlay of Existing Flexible Pavement designs:

General Information: This section allows you to select the basic parameters of an AC Overlay of Existing Flexible Pavement design.

Performance Criteria: This section provides a high-level look at the criteria DARWin-ME uses to analyze an AC Overlay of Existing Flexible Pavement design.

Traffic: This section provides details on using DARWin-ME's tables and data to examine the effects of traffic loading on pavement design and lifespan.

Climate: This section provides details on working with data from climate data files and then established weather stations for an area and using that data to analyze the effects of climate variables on pavement response and performance.

Pavement Structure Definition and Materials: This section explains adding additional layers to a roadbed, editing the parameters of those layers, and working with the structure of the roadbed as a whole.

Run Analysis: This section details the various analyses DARWin-ME will run to determine if a pavement design is valid.

Reports: This section details the variety of reports DARWin-ME can create on all facets of a project's design.

Structural Response: DARWin-ME's structural model analyzes pavement structure, accounts for discontinuities in that structure, and analyzes the effects of environment and traffic on that structure.

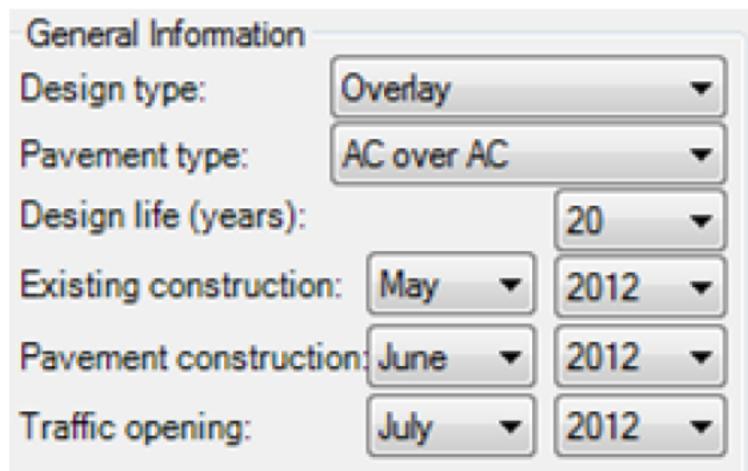
8.1 General Design Inputs

When you open a new project, the first step will be to enter information in the **General Information** area in the top left corner of the **Project Tab**. The inputs in this area will affect the inputs and information in all other parts of the project. Altering them once entered will make changes throughout the project.

The following options allow you to establish the basic parameters of your project.

Way to Access this Interface

Open a new pavement project. The *General Information* area appears at the top-left corner of the Project Tab.



The screenshot shows a 'General Information' panel with the following fields and values:

Field	Value
Design type:	Overlay
Pavement type:	AC over AC
Design life (years):	20
Existing construction:	May 2012
Pavement construction:	June 2012
Traffic opening:	July 2012

General Information

Populating the Inputs for this Interface *Design type:* Select *Overlay*

Pavement type: Select *AC over AC*

In addition to selecting Design and Pavement type, select values for the following basic design parameters:

Design life (years): This control allows you to select from a list the period of time in years from AC overlay placement where the rehabilitated pavement is expected to perform adequately without significant loss of functional and structural integrity. Pavement performance is predicted over the design life beginning from the month the rehabilitated pavement is open to traffic.

Existing construction: This control allows you to select the month and year when the construction of existing flexible pavement was completed.

Pavement construction: This control allows you to select the month and year when the AC overlay is scheduled to be placed.

Traffic opening: This control allows you to select the month and year the rehabilitated pavement is scheduled to be open to traffic. DARWin-ME predicts pavement performance beginning from this month and year.

8.2 Performance Criteria

Performance verification forms the basis of the acceptance or rejection of a trial rehabilitation design evaluated using DARWin-ME. The rehabilitation design procedure is based on pavement performance, and therefore, the critical levels of pavement distresses that can be tolerated by the agency at the selected level of reliability needs to be specified by the user. If the simulation process shows the trial design produces excessive amount of distresses, then the trial design must be modified accordingly to produce a feasible rehabilitation design in the future trials.

The distress types considered in the design of an AC overlay of existing flexible pavement are total rutting (all layers and subgrade), AC rutting, load-related top-down cracking (longitudinal cracking in the wheel path) and bottom-up fatigue cracking (alligator cracking), and thermal cracking (transverse cracking). In addition, pavement smoothness is considered for performance verification and is characterized using the International Roughness Index (IRI).

Performance Criteria	Limit	Reliability	▲
Initial IRI (in./mile)	63		
Terminal IRI (in./mile)	172	90	
AC top-down fatigue cracking (ft/mile)	2000	90	
AC bottom-up fatigue cracking (percent)	25	90	
AC thermal fracture (ft/mile)	250	90	
Chemically stabilized layer - fatigue fracture (percent)	25	90	
Permanent deformation - total pavement (in.)	0.75	90	
Permanent deformation - AC only (in.)	0.25	90	
Reflective cracking (percent)	100	50	▼

Performance Criteria (AC Overlay of Existing Flexible Pavements)

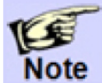
Populating the Inputs in this Interface

This table allows you to define the limits of critical distresses and smoothness that can be tolerated by the agency at the specified reliability levels. This table has three columns:

Performance Criteria: This column provides a list of performance indicators required to ensure that a pavement design will perform satisfactorily over its design life.

Limit: This column allows you to define the threshold values of these performance indicators to evaluate the adequacy of a design.

Reliability: This column allows you to define the probability at which the predicted distresses and smoothness will be less than the limits over the design period.



You can override the program defaults to enter project-specific threshold limits and reliability values representing agency policies. Refer to Chapter 8 of the **AASHTO Manual of Practice** for more guidance on selecting design criteria and reliability level.

Initial IRI (in./mile): The limit control allows you to define the expected smoothness immediately after the AC overlay is placed (expressed in terms of IRI). Initial IRI is a very important input as the time from AC overlay placement to attaining threshold IRI value is very much dependent on the initial IRI obtained at the time of rehabilitation.

Thus, the initial IRI value provided must be what is typically attained in the field. You can override the DARWin-ME default value of 63 in./mi to reflect agency policy and guidelines.

Terminal IRI (in./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for IRI at the end of the rehabilitation design life at a specified reliability level.

AC top-down fatigue cracking (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for surface initiated fatigue cracking at the end of the rehabilitation design life at a specified reliability level.

AC bottom-up fatigue cracking (percent): The limit and reliability controls for this criterion controls allow you to define the not-to-exceed limit for bottom-initiated fatigue cracking at the end of the rehabilitation design life at a specified reliability level.

AC thermal fracture (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for non-load related transverse cracking at the end of the rehabilitation design life at a specified reliability level.

Chemically stabilized layer - fatigue fracture (percent): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for fatigue fracture in the underlying chemically stabilized base layers at the end of the rehabilitation design life at a specified reliability level. This form of distress is only applicable to an AC overlay of existing

flexible pavement with a chemically stabilized layer directly placed under the existing AC layer; therefore no inputs are required if the existing pavement structure is otherwise.

Permanent deformation - total pavement (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for total rutting at the end of the rehabilitation design life at a specified reliability level. Total permanent deformation at the surface is the accumulation of the permanent deformation in all of the asphalt and unbound layers in the pavement system.

Permanent deformation - AC only (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for rutting contributed by the AC layers at the end of the rehabilitation design life at a specified reliability level.

Reflective cracking (percent): The form of distress is only applicable to a flexible pavement with a chemically stabilized layer directly placed under the AC layer. The limit control allows you to define the not-to-exceed limit for reflective cracking at the end of the design life at 50 percent reliability level. In DARWin-ME, reflective cracking is computed as a fraction of the fatigue cracking in the chemically stabilized layer that reflects through the HMA layer to the surface. **The sum of reflective cracking and bottom initiated fatigue cracking is reported as total cracking.**

8.5 Pavement Structure Definition and Materials

8.5.1 Asphalt Concrete (New) Layer

In DARWin-ME, the material types that fall under the following general definitions can be defined as an asphalt layer:

- Hot Mix Asphalt (HMA)
- Dense Graded
- Open Graded Asphalt
- Asphalt Stabilized Base Mixes
- Sand Asphalt Mixtures
- Stone Matrix Asphalt (SMA)
- Cold Mix Asphalt
- Central Plant Processed
- Cold In-Place Recycling

Refer to Section 5.5.1 page 6 for Asphalt Concrete (New) Layer

8.5.2 Asphalt Concrete (Existing) Layer

Way to Access this Interface

Open an AC over AC project and select existing Asphalt Concrete in the Layer control.

<input type="checkbox"/> Asphalt Layer		
Thickness (in.)	<input checked="" type="checkbox"/>	10
<input type="checkbox"/> Mixture Volumetrics		
Unit weight (pcf)	<input checked="" type="checkbox"/>	150
Effective binder content (%)	<input checked="" type="checkbox"/>	11.6
Air voids (%)	<input checked="" type="checkbox"/>	7
<input type="checkbox"/> Poisson's ratio		0.35
<input type="checkbox"/> Mechanical Properties		
Dynamic modulus	<input checked="" type="checkbox"/>	Input level:3
<input type="checkbox"/> Select HMA Estar predictive model		Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	<input checked="" type="checkbox"/>	70
Asphalt binder	<input checked="" type="checkbox"/>	Select Binder
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/>	388.87
Creep compliance (1/psi)	<input checked="" type="checkbox"/>	Input level:3
<input type="checkbox"/> Thermal		
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/>	0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/>	0.23
<input type="checkbox"/> Thermal contraction		1.301E-05 (calculated)
Is thermal contraction calculated?		True
Mix coefficient of thermal contraction (in./in./deg F)	<input type="checkbox"/>	
Aggregate coefficient of thermal contraction (in./in./deg F)	<input checked="" type="checkbox"/>	5E-06
Voids in Mineral Aggregate (%)	<input checked="" type="checkbox"/>	18.6
<input type="checkbox"/> Identifiers		

Existing Asphalt Concrete Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Asphalt Concrete layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

Asphalt Layer

Thickness (in): This control allows you to define the thickness, in inches, of the existing AC layer.

Mix Volumetrics

Unit weight (pcf): This control allows you to define the unit weight of the existing AC layer material in pounds per cubic foot.

Effective binder content (%): This control allows you to define the effective binder content in the existing AC layer material.

Air Voids (%): This control allows you to define the percent air voids of the existing AC layer material.

Poisson's ratio: This control allows you to define the Poisson's ratio of the AC material in two ways: a constant value (Level 3) or calculate as a function of dynamic modulus (Level 2). Clicking the plus sign (+) to the left of this control presents the following options:

Is Poisson's ratio calculated?: Select True to calculate Poisson's ratio as a function of dynamic modulus. Select False to use a constant value.

Poisson's ratio: This control allows you to define a constant value of Poisson's ratio. This control is disabled when you select True.

Poisson's ratio Parameter A: This control allows you to define the parameter A of the Poisson's ratio model. You can override the default value of -1.63 to enter mixture-specific values. This control is disabled when you select False.

Poisson's ratio Parameter B: This control allows you to define the parameter B of the Poisson's ratio model. You can override the default value of 3.84E-06 to enter mixture-specific values. This control is disabled when you select False.



For existing AC layer material, use agency or DARWin-ME defaults. Refer to Section 11.2 of AASHTO Manual of Practice for more information.

Mechanical Properties


Dynamic modulus input level: This control allows you to define the level of inputs to establish an “undamaged” dynamic modulus of the existing AC layer material. Select one of the following options from the drop-down menu:


2: Selecting 2 gives you the option to derive the dynamic modulus of the existing AC layer material from its aggregate gradation and laboratory tested asphalt binder properties. Both aggregate gradation and asphalt binder properties may be obtained from construction records or testing of field samples. Refer to the AASHTO Manual of Practice for more detailed information.

3: Selecting 3 gives you the option to derive the dynamic modulus of the existing AC layer material from its aggregate gradation and asphalt binder grade. DARWin- ME provides a default list of typical asphalt binders. Select a binder grade whose properties are close to the age-hardened asphalt binder of the existing AC layer.



DARWin-ME accounts for the pre-overlay damage of the existing AC layer by first calculating an “undamaged” modulus and then adjusting this modulus for damage using the pre-overlay condition.

 **Note** Pre-overlay condition is defined in three ways: At rehabilitation level 1, backcalculated AC modulus determined using NDT is used as the basis for characterizing condition. At rehabilitation levels 2 and 3, the condition is defined by the extent of alligator cracking at the surface and overall pavement condition rating, respectively.

 **Note** When you select Level 1 for rehabilitation, you must return to the dynamic modulus input screen to enter a backcalculated NDT “damaged” modulus for the existing AC layer material.

Reference temperature (deg F): This control allows you to define a baseline temperature, in °F, for use in deriving the dynamic modulus master curve. The suggested value is 70°F.

Select HMA Estar predictive model: This control provides you the option for accounting the effects of loading frequencies when binder G* values are converted to viscosity values. Select True for frequency-adjusted viscosity estimates or False for simple conversion without frequency adjustments.

Thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the thermal conductivity of the asphalt concrete material. DARWin-ME provides a default value of 0.67.

Heat capacity (BTU/lb-deg F): This control allows you to define the heat capacity of the AC material. DARWin-ME provides a default value of 0.23.

Dynamic Modulus

Dynamic Modulus Input Levels 2 and 3

This control allows you to define the aggregate gradation of the AC mixture for use in dynamic modulus calculations.

Dynamic modulus input level

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Aggregate Gradation of Asphalt Concrete Mixture



DARWin-ME does not require Level 1 dynamic modulus inputs for an existing AC layer material.

3/4-inch sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the 3/4 inch sieve.

3/8-inch sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the 3/8 inch sieve.

No. 4 sieve: This control allows you to define the cumulative amount of aggregate material (used in the asphalt mixture) that is passing on the #4 sieve.

No. 200 sieve: This control allows you to define the amount of aggregate material (used in the asphalt mixture) that is passing on the #200 inch sieve.

Asphalt Binder



Once the dynamic modulus input level is selected, the program automatically defines the same input level for asphalt binder properties.

Asphalt Binder Level 2

You must first select an appropriate binder grading system and then enter the binder properties.

Superpave Performance Grade

<input checked="" type="radio"/> Superpave Performance Grade <input type="radio"/> Penetration/Viscosity Grade			
	Temperature (deg F)	Binder Gstar (Pa)	Phase angle (deg)
▶	147.2	2802.7	81.34
	158	1295.1	83.05
	168.8	635.9	85.14
*			

Superpave Performance Grade of Asphalt Binder

Temperature (deg F): This control allows you to define the temperature at which the binder dynamic complex modulus, G^* , and phase angle were measured for a given binder.

Binder G^* : This control allows you to define the complex shear modulus of the asphalt binder, measured at the test temperature given in the above control.

Phase angle: This control allows you to define the phase angle measured at the given test temperature.

You should enter at least three values in the above controls. Entering five is recommended.

Right-Click Menu Options

Right-click on a cell in the table to access the following functionality:

- **Copy:** This menu item copies the selected value.
- **Paste:** This menu item pastes the copied value.
- **Import MEPDG Binder (.bif) Format:** This menu item allows you to import a binder modulus file that was created in using MEPDG.

Viscosity/Penetration Grade

Superpave Performance Grade
 Penetration/Viscosity Grade

Softening Point (deg F) at 13000 Poise

Absolute Viscosity (Poise) at 140 deg F

Kinematic Viscosity (centiStokes) at 275 deg F

Specific Gravity at 77 deg F

Penetration

	Temperature (deg F)	Penetration
▶	77	53.76
*		

Brookfield Viscosity

	Temperature	Brookfield Viscosity (centiPoise)
▶	239	1813
	257	927
	275	511

Viscosity/Penetration of Asphalt Binder

Softening point temperature at a viscosity of 13000 Poise: This control allows you to define the softening point temperature of the asphalt binder at a viscosity of 13000 Poise.

Absolute viscosity of the binder at 140 F: This control allows you to define the absolute viscosity of the asphalt binder at a temperature of 140 °F.

Kinematic viscosity at 275 F in centistokes: This control allows you to define the kinematic viscosity of the asphalt binder at a temperature of 275 °F.

Specific gravity of asphalt binder at 77 F: This control allows you to define the specific gravity of the asphalt binder at a temperature of 77 °F.

Penetration (both temp and penetration value): This control allows you to define the both the temperature, in °F, and the corresponding penetration value of the asphalt binder.

Brookfield viscosity (both temp and viscosity): This control allows you to define the both the temperature, in °F, and the corresponding viscosity value of the asphalt binder.

You must enter values for the softening point, specific gravity, absolute viscosity, and kinematic viscosity of the asphalt binder as a minimum. In addition, you may choose to provide binder penetration, Brookfield viscosity, or both. DARWin-ME allows you to enter penetration or viscosity values for up to six test temperatures.

Asphalt Binder Level 3

The user first selects a binder grading system (radio buttons) and then selects a binder grade from the drop-down menu. (Once a binder grade is selected, the program assumes and displays the typical values of A-VTS parameters for that binder grade.)

Superpave Performance Grade
 Viscosity Grade
 Penetration Grade

Binder type: AC 30

A: 10.6316 VTS: -3.548

Viscosity Grade of Asphalt Binder

Grade: These controls allow you to define the grade of the binder. Select one of the following options:

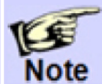
Superpave Performance Grade: This control allows you to select an appropriate PG binder from the options provided by the binder type drop-down menu.

Viscosity Grade: This control allows you to select an appropriate viscosity-graded binder from the options provided by the binder type drop-down menu.

Penetration Grade: This control allows you to select an appropriate penetration graded binder from the options provided by the binder type drop-down menu.

A: This control displays the intercept of the ASTM D2493 A-VTS relationship of the binder.

VTS: This control displays the slope of the ASTM D2493 A-VTS relationship of the binder.



DARWin-ME does not require creep compliance, indirect tensile strength, and mix coefficient of thermal contraction inputs for an existing AC layer material. Although the defaults of these inputs may be displayed, DARWin-ME does not use them in calculations.

Reference temperature (deg F): This control allows you to define a baseline temperature, in degrees Fahrenheit, for use in deriving the dynamic modulus mastercurve. The suggested value is 70°F.

Select HMA Estar predictive model: This control provides you the option for accounting the effects of loading frequencies when binder G^* values are converted to viscosity values. Select True for frequency-adjusted viscosity estimates or False for simple conversion without frequency adjustments.

Thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the thermal conductivity of the asphalt concrete material. DARWin-ME provides a default value of 0.67.

Heat capacity (BTU/lb-deg F): This control allows you to define the heat capacity of the asphalt concrete material. DARWin-ME provides a default value of 0.23.

Links to Relevant Section in AASHTO Manual of Practice

Section 11.2 HMA Mixtures; Including SMA, Asphalt Treated or Stabilized Base Layers, and Asphalt Permeable Treated Base Layers

8.5.3 Chemically Stabilized Layer

The required inputs for a chemically stabilized layer can be broadly classified as general, strength, and thermal properties. Note that the strength properties required by DARWin-ME are different for flexible and rigid pavements.

The chemically stabilized materials include lean concrete, cement stabilized, open graded cement stabilized, soil cement, lime-cement-flyash, and lime treated materials.

Refer to **5.5.2 Chemically Stabilized Layer, page 18**

8.5.4 Sandwiched Granular Layer

Sandwiched granular layers are non-stabilized materials placed between two stabilized pavement layers. The stabilized layers may comprise of any combination of asphalt concrete, asphalt stabilized material, PCC and chemically stabilized material.

The non-stabilized materials include AASHTO soil classes A-1 through A-3, as well as those commonly defined in practice as crushed stone, crushed gravel, river gravel, permeable aggregate, and cold recycled asphalt material (includes millings and in-place pulverized material).

DARWin-ME does not subject sandwiched non-stabilized materials to the effects of freeze, thaw, and moisture that alter strength properties. This is because, placement between two impermeable layers protects such layers from seepage of surface water and rise of groundwater and thus they have relatively constant moisture content throughout the pavement's design life. The constant moisture content implies that the effect of freeze, thaw, etc., on material strength properties is negligible.

Inputs required for sandwiched non-stabilized pavement layers include physical and engineering properties such as unit weight, Poisson's ratio, elastic/resilient modulus, thermal conductivity, and heat capacity.

Way to Access this Interface

Open a project with non-stabilized layer and select Non-stabilized Base in the Layer control.

Section	Property	Status	Value
General	Layer thickness (in.)	<input checked="" type="checkbox"/>	10
	Unit weight (pcf)	<input checked="" type="checkbox"/>	150
	Poisson's ratio	<input checked="" type="checkbox"/>	0.2
Strength	Elastic/resilient modulus (psi)	<input checked="" type="checkbox"/>	50000
Thermal	Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/>	1.25
	Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/>	0.28
Identifiers	Display name/identifier		Sandwich Granular

Sandwiched Granular Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Non-Stabilized Base:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

General

Layer thickness (in): This control allows you to define the thickness of the selected layer.

Unit weight (pcf): This control allows you to define the unit weight of the selected layer.

Poisson's ratio: This control allows you to define the Poisson's ratio of the non-stabilized material. DARWin-ME provides a default value of 0.2.

Strength

Elastic/Resilient Modulus (psi): This control allows you to define elastic/resilient modulus of the sandwiched non-stabilized material. DARWin-ME provides a default value of 50,000 psi.

Thermal

Thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the thermal conductivity of the sandwiched non-stabilized material. DARWin-ME provides a default value of 1.25 Btu/(ft)(hr)(°F).

Heat capacity (BTU/lb-deg F): This control allows you to define the heat capacity of the sandwiched non-stabilized material. DARWin-ME provides a default value of 0.28 Btu/(lb)(°F).

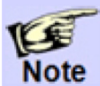
Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

8.5.5 Non-Stabilized Layer

Non-stabilized materials include AASHTO soil classes A-1 through A-3, as well as those commonly defined in practice as crushed stone, crushed gravel, river gravel, permeable aggregate, and cold recycled asphalt material (includes millings and in-place pulverized material).

Inputs required for non-stabilized materials include physical and engineering properties such as dry density, moisture content, hydraulic conductivity, specific gravity, soil-water characteristic curve (SWCC) parameters, classification properties, and the resilient modulus.



Note

If you want to add a non-stabilized layer between two stabilized layers (e.g. AC, PCC, chemically stabilized layer) in your design, select DARWin-ME's [Sandwiched Granular Layer](#) option.

Way to Access this Interface

Open a project with non-stabilized layer and select Non-stabilized Base in the Layer control.

<input type="checkbox"/> Unbound		
Layer thickness (in.)	<input checked="" type="checkbox"/>	10
Poisson's ratio	<input checked="" type="checkbox"/>	0.35
Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/>	0.5
<input type="checkbox"/> Modulus		
Resilient modulus (psi)	<input checked="" type="checkbox"/>	40000
<input type="checkbox"/> Sieve		
Gradation & other engineering properties	<input checked="" type="checkbox"/>	A-1-a
<input type="checkbox"/> Identifiers		
Display name/identifier		A-1-a
Description of object		Default material

Non-Stabilized Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Non-Stabilized Base:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

General

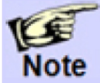
Layer thickness (in): This control allows you to define the thickness of the selected layer.

Poisson's ratio: This control allows you to define the Poisson's ratio of the unbound material. DARWin-ME provides a default value of 0.35.

Coefficient of lateral earth pressure (k0): This control allows you to define the pressure that the unbound material exerts in the horizontal plane. DARWin-ME provides a default value of 0.5.

Modulus

Resilient Modulus (psi): This control allows you to define the level of inputs for resilient modulus of the unbound material. This control also allows you to define the resilient modulus or the other material properties that correlate with the resilient modulus. DARWin-ME displays the default value (Level 3) for the selected material class. Click on the Resilient Modulus control to modify the default value and/or input level.



Note

DARWin-ME requires “a lab tested” resilient modulus value at optimum moisture content for non-stabilized layers and subgrade. For rehabilitation or reconstruction designs, the in-situ resilient modulus may be backcalculated from FWD deflection basin data or estimated from DCP tests. If deflection basin data or DCP tests are used to estimate the “field” modulus, two adjustments need to be made: (1) an adjustment to convert field modulus to laboratory test conditions and (2) an adjustment to convert from field or in-situ moisture content to optimum moisture content. The AASHTO Manual of Practice recommends only the former adjustment and suggests that the user enter an estimate of in-situ moisture content obtained from field testing. Refer to the AASHTO Manual of Practice for more detailed guidance.

Input Level: 3 ▼

Analysis Types

- Modify input values by temperature/moisture
- Monthly representative values
- Annual representative values

Method: Resilient modulus (psi) ▼

40000

Correction factor for NDT modulus

Resilient Modulus (Level 3)

Input Level: 2 ▼

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method: CBR ▼

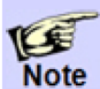
CBR	Resilient Modulus (psi)
30	22529

Resilient Modulus (Level 2)

Input Level: This control allows you to define the level of inputs for the non-stabilized material. You can select one of the following options:

2: This option allows you to define the resilient modulus directly or using its correlations with soil index and strength properties. This level of input is considered as Level 2 in the AASHTO Manual of Practice.

3: This option allows you to override the default resilient modulus value (Level 3) of the non-stabilized material.



Note

DARWin-ME does not provide Level 1 input option for resilient modulus of non-stabilized materials. Use Level 3 to enter backcalculated resilient modulus with an appropriate correction factor for NDT modulus.

Analysis Types: These controls allow you to define how DARWin-ME accounts for seasonal variations (freezing, thawing and moisture) in the resilient modulus calculations. Select one of the following options:

Modify input values by temperature/moisture: This option allows you to define a single resilient modulus value. You can also input a single value of the selected soil index or strength property that is converted by DARWin-ME into a resilient modulus value. DARWin-ME incorporates the effects of seasonal variations on the single resilient modulus value you define.

Monthly representative values: This option allows you to define the resilient modulus throughout the year. You can input a single value of resilient modulus (or the selected soil index or strength property) for each month of a year. By selecting this option, you make DARWin-ME use the inputs you provide directly for seasonal variations without making internal adjustments. This option is available only for Level 2 inputs.

Annual representative values: This option allows you to define a fixed resilient modulus for an entire year. You can input a single value of resilient modulus (or the selected soil index or strength property) that is representative for an entire year. DARWin-ME does not incorporate the effects of seasonal variations on the single resilient modulus value you define.

Method: This control allows you to select how to estimate the resilient modulus using one of the following options:

- Resilient modulus (psi)
- California Bearing Ratio (CBR) (percent)
- R-value
- Layer Coefficient-ai
- Dynamic Cone Penetrometer (DCP) Penetration (in./blow)
- Plasticity Index (PI) and Gradation (i.e., Percent Passing No. 200 sieve)



Note

You are not required to define the values for PI and percent passing No. 200 sieve in the Values Table, as these values will be defined in the Gradation and other engineering properties interface.

Values Table: This control allows you to define the values for resilient modulus or the selected soil index and strength property.

Correction Factor for NDT Modulus: This control allows you to define a correction factor for backcalculated resilient modulus. Click the check box to enable/disable this control. This control is available only for rehabilitation Level 1. Refer to the AASHTO Manual of Practice for more guidance.

Sieve Gradation & other engineering properties

The Sieve dialog box allows you to define the gradation, Atterberg limits, specific gravity, water content, maximum dry density, saturated hydraulic conductivity and the SWCC parameters of non-stabilized materials.

Sieve Size	Percent Passing		
0.001mm		Liquid Limit	6
0.002mm		Plasticity Index	1
0.020mm		<input type="checkbox"/> Is layer compacted?	
#200	8.7	<input type="checkbox"/> Maximum dry unit weight (pcf)	127.2
#100		<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	5.054e-02
#80	12.9	<input type="checkbox"/> Specific gravity of solids	2.7
#60		<input type="checkbox"/> Optimum gravimetric water content (%)	7.4
#50		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)	
#40	20		
#30			
#20			
#16			
#10	33.8		
#8			
#4	44.7		
3/8-in.	57.2		
1/2-in.	63.1		
3/4-in.	72.7		
1-in.	78.8		
1 1/2-in.	85.8		
2-in.	91.6		
2 1/2-in.			
3-in.			
3 1/2-in.	97.6		

af	7.25549682996034
bf	1.33282181654764
cf	0.824220751940721
hr	117.4

Gradation & other engineering properties

Sieve Size Table: This table allows you to define the percentage of non-stabilized material passing a variety of sieve sizes.

Sieve Size: This column lists the applicable sieve sizes.

Percent Passing: This column allows you to define the percentage of non-stabilized material passing a given sieve size. You are not required to define the percent passing for each sieve size. However, you are required to enter values for a minimum of 3 sieve sizes including No. 200 sieve.

Liquid Limit This control allows you to define the liquid limit of the non-stabilized material.

Plasticity Index: This control allows you to define the plasticity index for non-stabilized material.

Is Layer Compacted?: Enable this control to indicate that the layer is compacted. Typically non-stabilized materials used in the base and subbase layers are compacted in place during construction. Disable this control to indicate that the layer is not compacted.



Note

DARWin-ME internally computes the values of the following properties based on the inputs for Gradation, Liquid Limit, Plasticity Index and Is Layer Compacted. The computed values are based on the defaults initially displayed on the input screen. However, if you choose to modify the default values, you are required to click outside the input screen for the program to update the internally computed values.

Maximum dry unit weight: DARWin-ME internally computes the maximum dry density of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Saturated hydraulic conductivity (ft/hr): DARWin-ME internally computes the saturated hydraulic conductivity of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Specific gravity of solids: DARWin-ME internally computes the specific gravity of the non-stabilized material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Optimum gravimetric water content (%): DARWin-ME internally computes the moisture content of the non-stabilized material at which maximum dry density is achieved. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

User-defined Soil Water Characteristic Curve (SWCC): DARWin-ME internally computes the coefficients (af, bf, cf, and hr) of the soil water characteristic curve. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Links to Relevant Section in AASHTO Manual of Practice

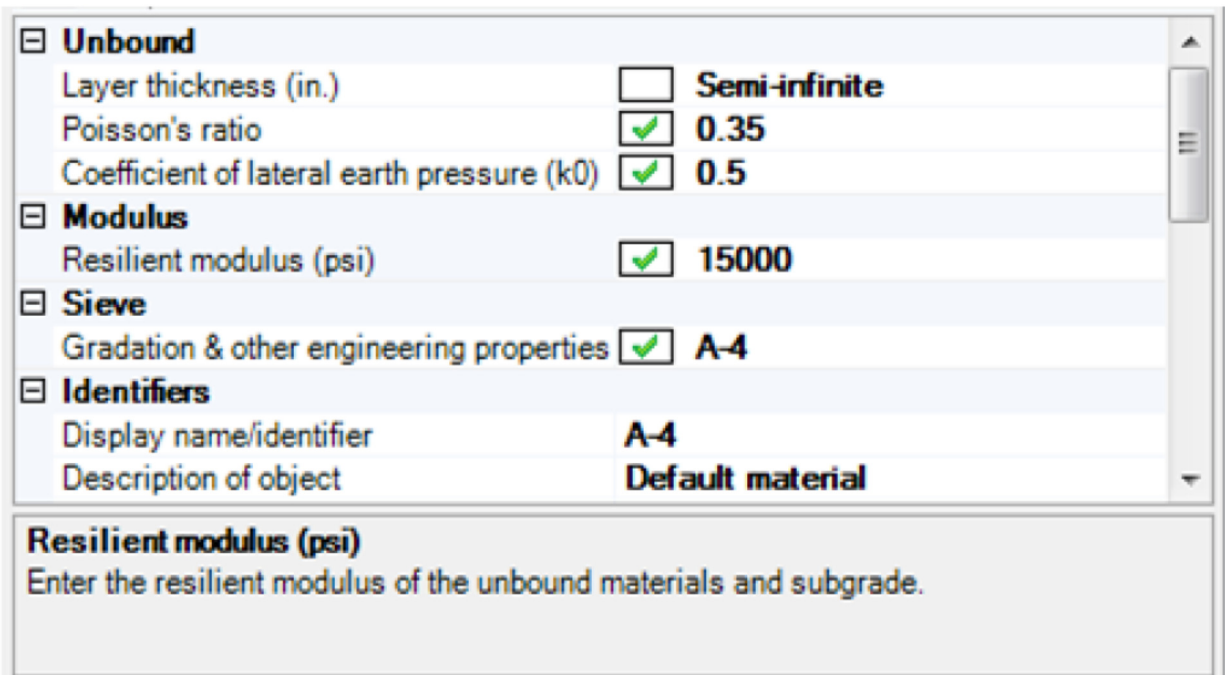
Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

8.5.6 Subgrade

Subgrade materials include soil classes A-1 through A-7-6 defined in accordance with the ASHTO soil classification system. Inputs required for subgrade materials are same as those of non-stabilized materials, and include physical and engineering properties such as dry density, moisture content, hydraulic conductivity, specific gravity, soil-water characteristic curve (SWCC) parameters, classification properties, and the resilient modulus.

Way to Access this Interface

Open a project with a subgrade level and select Subgrade in the Layer control.



<input type="checkbox"/>	Layer thickness (in.)	<input type="checkbox"/>	Semi-infinite
<input checked="" type="checkbox"/>	Poisson's ratio	<input checked="" type="checkbox"/>	0.35
<input checked="" type="checkbox"/>	Coefficient of lateral earth pressure (k0)	<input checked="" type="checkbox"/>	0.5
Modulus			
<input checked="" type="checkbox"/>	Resilient modulus (psi)	<input checked="" type="checkbox"/>	15000
Sieve			
<input checked="" type="checkbox"/>	Gradation & other engineering properties	<input checked="" type="checkbox"/>	A-4
Identifiers			
	Display name/identifier		A-4
	Description of object		Default material

Resilient modulus (psi)
Enter the resilient modulus of the unbound materials and subgrade.

Subgrade Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Subgrade layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

General

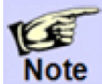
Layer thickness (in): This control allows you to define the thickness of the selected layer if this layer is not the last layer. The program automatically defines the thickness of as semi-infinite if this layer is the last layer.

Poisson's ratio: This control allows you to define the Poisson's ratio of the subgrade material. DARWin-ME provides a default value of 0.35.

Coefficient of lateral earth pressure (k_0): This control allows you to define the pressure that soil exerts in the horizontal plane. DARWin-ME provides a default value of 0.5.

Modulus

Resilient Modulus (psi): This control allows you to define the level of inputs for resilient modulus of the subgrade material. This control also allows you to define the resilient modulus or the other material properties that correlate with the resilient modulus. DARWin-ME displays the default value (Level 3) for the selected material class. Click on the Resilient Modulus control to modify the default value and/or input level.



Note

DARWin-ME requires “a lab tested” resilient modulus value at optimum moisture content for non-stabilized layers and subgrade. For rehabilitation or reconstruction designs, the in-situ resilient modulus may be backcalculated from FWD deflection basin data or estimated from DCP tests. If deflection basin data or DCP tests are used to estimate the “field” modulus, two adjustments need to be made: (1) an adjustment to convert field modulus to laboratory test conditions and (2) an adjustment to convert from field or in-situ moisture content to optimum moisture content. The AASHTO Manual of Practice recommends only the former adjustment and suggests that the user enter an estimate of in-situ moisture content obtained from field testing. Refer to the AASHTO Manual of Practice for more detailed guidance.

Input Level: 3

Analysis Types

- Modify input values by temperature/moisture
- Monthly representative values
- Annual representative values

Method: Resilient modulus (psi)

40000

Correction factor for NDT modulus

Resilient Modulus (Level 3)

Input Level:

Analysis Types

Modify input values by temperature/moisture

Monthly representative values

Annual representative values

Method:

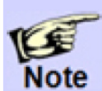
Month	
January	15000
February	14000
March	15000
April	13000
May	13000
June	16000
July	17000

Resilient Modulus (Level 2)

Input Level: This control allows you to define the level of inputs for the subgrade material. Select one of the following options:

2: This option allows you to define the resilient modulus directly or using its correlations with soil index and strength properties. This level of input is considered as Level 2 in the AASHTO Manual of Practice.

3: This option allows you to override the default resilient modulus value (Level 3) of the subgrade material.



Note

DARWin-ME does not provide Level 1 input option for resilient modulus of subgrade materials. Use Level 3 to enter backcalculated resilient modulus with an appropriate correction factor for NDT modulus.

Analysis Types: These controls allow you to define how DARWin-ME accounts for seasonal variations (freezing, thawing and moisture) in the resilient modulus calculations. Select one of the following options:

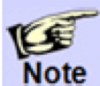
Modify input values by temperature/moisture: This option allows you to define a resilient modulus value. You can also input a single value of the selected soil index or strength property that is converted by DARWin-ME into a resilient modulus value. DARWin-ME incorporates the effects of seasonal variations on the single resilient modulus value you define.

Monthly representative values: This option allows you to define the resilient modulus throughout the year. You can input a single value of resilient modulus (or the selected soil index or strength property) for each month of a year. By selecting this option, you make DARWin-ME use the inputs you provide directly for seasonal variations without making internal adjustments. This option is available only for Level 2 inputs.

Annual representative values: This option allows you to define a fixed resilient modulus for an entire year. You can input a single value of resilient modulus (or the selected soil index or strength property) that is representative for an entire year. DARWin-ME does not incorporate the effects of seasonal variations on the single resilient modulus value you define.

Method: This control allows you to select how to estimate the resilient modulus using one of the following options:

- Resilient modulus (psi)
- California Bearing Ratio (CBR) (percent)
- R-value
- Layer Coefficient-ai
- Dynamic Cone Penetrometer (DCP) Penetration (in./blow)
- Plasticity Index (PI) and Gradation (i.e., Percent Passing No. 200 sieve)



Note

You are not required to define the values for PI and percent passing No. 200 sieve in the Values Table, as these values will be defined in the Gradation and other engineering properties interface.

Values Table: This control allows you to define values for resilient modulus or the selected soil index and strength property.

Correction Factor for NDT Modulus: This control allows you to define a correction factor for backcalculated resilient modulus. Click the check box to enable/disable this control. This control is available only for rehabilitation Level 1. Refer to the AASHTO Manual of Practice for more guidance.

Sieve Gradation & other engineering properties

The Sieve dialog box allows you to define the gradation, Atterberg limits, and saturated hydraulic conductivity, specific gravity, water content, maximum dry density, and the SWCC parameters of subgrade materials.

Sieve Size	Percent Passing										
0.001mm		Liquid Limit	21								
0.002mm		Plasticity Index	5								
0.020mm		<input type="checkbox"/> Is layer compacted?									
#200	60.6	<input type="checkbox"/> Maximum dry unit weight (pcf)	118.4								
#100		<input type="checkbox"/> Saturated hydraulic conductivity (ft/hr)	8.325e-06								
#80	73.9	<input type="checkbox"/> Specific gravity of solids	2.7								
#60		<input type="checkbox"/> Optimum gravimetric water content (%)	11.8								
#50		<input type="checkbox"/> User-defined Soil Water Characteristic Curve (SWCC)									
#40	82.7	<table border="1"> <tbody> <tr> <td>af</td> <td>68.8376536119812</td> </tr> <tr> <td>bf</td> <td>0.998285126875545</td> </tr> <tr> <td>cf</td> <td>0.475715611755117</td> </tr> <tr> <td>hr</td> <td>500</td> </tr> </tbody> </table>		af	68.8376536119812	bf	0.998285126875545	cf	0.475715611755117	hr	500
af	68.8376536119812										
bf	0.998285126875545										
cf	0.475715611755117										
hr	500										
#30											
#20											
#16											
#10	89.9										
#8											
#4	93										
3/8-in.	95.6										
1/2-in.	96.7										
3/4-in.	98										
1-in.	98.7										
1 1/2-in.	99.4										
2-in.	99.6										
2 1/2-in.											
3-in.											
3 1/2-in.	99.8										

Gradation & other engineering properties

Sieve Size Table: This table allows you to define the percentage of subgrade material passing a variety of sieve sizes.

Sieve Size: This column lists the applicable sieve sizes.

Percent Passing: This column allows you to define the percentage of subgrade material passing a given sieve size. You are not required to define the percent passing for each sieve size. However, you are required to enter values for a minimum of 3 sieve sizes including No.200 sieve.

Liquid Limit This control allows you to define the liquid limit of the subgrade soil.

Plasticity Index: This control allows you to define the plasticity index for the subgrade soil.

Is Layer Compacted?: Enable this control indicate that the layer is compacted. Typically the top twelve inches of the subgrade materials are compacted in place during construction. Disable this control to indicate that the layer is not compacted.

Maximum dry unit weight: DARWin-ME internally computes the maximum dry density of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Saturated hydraulic conductivity (ft/hr): DARWin-ME internally computes the saturated hydraulic conductivity of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Specific gravity of solids: DARWin-ME internally computes the specific gravity of the subgrade material. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Optimum gravimetric water content (%): DARWin-ME internally computes the moisture content of the subgrade material at which maximum dry density is achieved. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

User-defined Soil Water Characteristic Curve (SWCC): DARWin-ME internally computes the coefficients (af, bf, cf, and hr) of the soil water characteristic curve. This control allows you to override the internally computed value by enabling the check box. Click the check box to enable/disable this control.

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

8.5.7 Bedrock

A bedrock layer, if present under an alignment, could have a significant impact on the pavement's mechanistic responses and therefore need to be fully accounted for in design. This is especially true if backcalculation of layer moduli is adopted in rehabilitation design to characterize pavement materials. While the precise measure of the stiffness is seldom, if ever, warranted, any bedrock layer must be incorporated into the analysis.

Way to Access this Interface

Open a new pavement project with a bedrock layer and select Bedrock in the Layer control.

<input type="checkbox"/>	Bedrock	
	Layer thickness(in.)	<input type="checkbox"/> Semi-infinite
	Unit weight (pcf)	<input checked="" type="checkbox"/> 140
	Poisson's ratio	<input checked="" type="checkbox"/> 0.15
<input type="checkbox"/>	Strength	
	Elastic/resilient modulus (psi)	<input checked="" type="checkbox"/> 500000
<input type="checkbox"/>	Identifiers	
	Display name/identifier	Highly fractured and weathered
	Description of object	Default material

Elastic/resilient modulus (psi)
Elastic modulus of the bedrock layer.
Minimum:100000
Maximum:2000000

Bedrock Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the Bedrock layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

Bedrock

Layer thickness (in.): The program automatically defines the thickness of the bedrock layer as semi-infinite.

Poisson's ratio: This control allows you to define the Poisson's ratio of the bedrock material. DARWin-ME provides a default value of 0.15 for solid, massive and continuous bedrock material and 0.30 for highly fractured, weathered bedrock material.

Unit weight (pcf): This control allows you to define the weight per unit volume of the bedrock material. DARWin-ME uses a default value of 140 pcf.

Strength

Elastic/resilient Modulus (psi): This control allows you to define the modulus of the bedrock layer. DARWin-ME provides a default value of 750,000 psi for solid, massive and continuous bedrock material and 500,000 psi for highly fractured, weathered bedrock material.

8.6 AC Layer Properties

This screen allows you to define other inputs pertinent to flexible pavement design.

Way to Access this Interface

Open a project with asphalt layer and select AC Layer Properties in the Layer control.

<input checked="" type="checkbox"/> AC Layer Properties	
AC surface shortwave absorptivity	<input checked="" type="checkbox"/> 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	<input checked="" type="checkbox"/> 100
Layer interface	<input checked="" type="checkbox"/> Full Friction Interface
<input checked="" type="checkbox"/> Rehabilitation	
Condition of existing flexible pavement	<input checked="" type="checkbox"/> Rehabilitation Level: 1

AC Layer Properties

Ways to Enter Inputs

There are three methods for entering data:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

AC Surface Shortwave Absorptivity: This control allows you to define the amount of available solar energy that is absorbed by the flexible pavement surface. DARWin-ME provides a default value of 0.85.

Is endurance limit applied?: This control allows you to determine whether or not you want to consider the endurance limit in the design analysis. Endurance limit is a threshold tensile strain value below which no load-related fatigue damage occurs in the AC layers. Select True to consider the endurance limit in the design analysis or False otherwise.

Endurance limit: This control allows you to define the threshold tensile strain value (endurance limit) in microstrain.

Layer Interface: This control opens a table that allows you to define the friction at the interface of adjacent layers in the pavement system.

Layer Display Name	Layer Type	Interface Friction
AC Overlay	Flexible (1)	1
Existing AC	Flexible (1)	1
A-1-a	Non-stabilized Base (4)	1
A-1-a	Subgrade (5)	

Layer Name: This column shows the display name/ identifier you defined for the layer material type.

Layer Type: This column displays the layer material type associated with the layer name.

Interface Friction: This control allows you to define the friction of adjacent layers at their interface. Enter 0 for no friction (full slip condition), 1 for full friction (no slip), or between 0 and 1 for partial friction.

AC Rehabilitation

AC Layer Properties	
AC surface shortwave absorptivity	<input checked="" type="checkbox"/> 0.85
Is endurance limit applied?	False
Endurance limit (microstrain)	<input checked="" type="checkbox"/> 100
Layer interface	<input checked="" type="checkbox"/> Full Friction Interface
Rehabilitation	
Condition of existing flexible pavement	<input checked="" type="checkbox"/> Rehabilitation Level: 1

AC Rehabilitation

Characterization of existing AC layer is a critical factor in the design of AC overlays of the existing flexible pavement. DARWin-ME requires a combination of inputs to determine the damage in the existing AC layer at the time of overlay. DARWin-ME assumes the pre-overlay damage as the starting point to predict future performance of the existing AC layer

over its design life with necessary adjustments for pre-overlay repairs. Detailed guidance on characterizing the existing pavement condition is provided in the AASHTO Manual of Practice. DARWin-ME uses a three-level input hierarchical system for characterizing the existing AC layer and underlying layers.

Rehabilitation input level: This control allows you to select the rehabilitation input level (1, 2, or 3). The input screen changes depending on the level selected.

Rehabilitation input level	1 ▼	
Milled thickness (in.)	0	
Fatigue cracking (%)		
Layer Name	Layer Type	Rut Depth (in)
AC Overlay	Flexible (1)	
Existing AC	Flexible (1)	0
A-2-6	Non-stabilized B...	0
A-2-4	Subgrade (5)	0

AC Rehabilitation (Levels 1 & 2)

- Rehabilitation Level 1 generally uses data from NDT for estimating layer modulus and detailed condition survey data for characterizing damage in the existing pavement.
- Rehabilitation Level 2 combines the use of correlations between modulus and easily measured material characteristics with detailed condition survey data.
- Rehabilitation Level 3 uses typical published or recommended values for modulus and information from general pavement ratings for estimating damage.

Rehabilitation Level 1

Rehabilitation input level	1
Milled thickness (in.)	0
Fatigue cracking (%)	

Layer Name	Layer Type	Rut Depth (in)
AC Overlay	Flexible (1)	
Existing AC	Flexible (1)	0
A-2-6	Non-stabilized B...	0
A-2-4	Subgrade (5)	0

AC Rehabilitation (Level 1)

Milled thickness (in.): This control allows you to enter the thickness of the existing AC layer that was milled during pre-overlay repairs. A value of 0 implies no milling.

Layer Name: This column displays the layers in your project.

Layer Type: This column displays the layer type associated with the layer name.

Rut depth (in.): This control allows you to enter the rut depth for the individual layers of the existing pavement, including the subgrade.



Note

DARWin-ME uses backcalculated NDT moduli to characterize the condition of the existing pavement layers at the time of overlay. When you select Level 1 for rehabilitation, you must return to the material properties input screens of all existing layers to enter NDT-related inputs. For example, you must return to the dynamic modulus input screen to enter a backcalculated NDT “damaged” modulus for the existing AC layer material.

Rehabilitation Level 2

Rehabilitation input level	2
Milled thickness (in.)	0
Fatigue cracking (%)	

Layer Name	Layer Type	Rut Depth (in)
AC Overlay	Flexible (1)	
Existing AC	Flexible (1)	0
A-2-6	Non-stabilized B...	0
A-2-4	Subgrade (5)	0

AC Rehabilitation (Level 2)

Milled thickness (in.): This control allows you to enter the thickness of the existing AC layer that was milled during pre-overlay repairs. A value of 0 implies no milling.

Fatigue Cracking (%): This control allows you to enter a percentage for the alligator cracking on the existing pavement surface before the placement of overlay. This control is activated only if rehabilitation input Level 2 is selected.

Layer Name: This column displays the layers in your project.

Layer Type: This column displays the layer type associated with the layer name.

Rut depth (in.): This control allows you to enter the rut depth for the individual layers of the existing pavement including the subgrade.

Rehabilitation Level 3

Rehabilitation input level	3
Milled thickness (in.)	0
Fatigue cracking (%)	
Pavement rating	Fair (3)
Total rut depth (in.)	0

AC Rehabilitation (Level 3)

Milled thickness (in.): This control allows you to enter a value for a flexible layer's milled thickness.

Pavement rating: If rehabilitation input Level 3 is selected, this control allows you to select a pavement condition rating from a drop-down list containing five options: Excellent, Good, Fair, Poor, and Very Poor.

Total rut depth (in.): If Level 3 is selected, this control allows you to enter a total rut depth for the pavement.

8.7 Backcalculation

The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The moduli typically are obtained using nondestructive deflection basin tests and standard backcalculation procedures. The backcalculated moduli closely match the actual in situ moduli of the existing pavement layers and subgrade. The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The most widely used deflection testing device is the falling weight deflectometer (FWD). Backcalculated layer moduli obtained from FWD testing need to be adjusted to laboratory conditions for use in DARWin-ME. The adjustment to laboratory conditions is discussed in the AASHTO Manual of Practice.

The Backcalculation option in DARWin-ME can be used to:

- Enter or import backcalculated moduli for multiple stations along the project.
- Create multiple files for the same project representing each station along the project by replacing baseline design and material inputs with station-specific layer moduli and related inputs (thickness, unit weight, and Poisson's ratio) of all existing pavement layers.



DARWin-ME does not perform backcalculation. It only allows you use backcalculation results in overlay designs. You are required to perform backcalculation of deflection basin data outside of DARWin-ME.

To use backcalculation results in DARWin-ME, you must first create a baseline project. The pavement structure and layer material types of the baseline project must match with that of the pavement model used in the backcalculation process. For example, if the pavement model used in the backcalculation is a four-layer AC pavement with a chemically stabilized base layer placed on a non-stabilized layer and subgrade, the existing pavement structure you define in the baseline project must be the same four-layer AC pavement structure. **Note that the new overlay layers defined in the baseline project is not considered as part of the existing pavement structure.**



It is advisable to populate all inputs correctly and complete your baseline project in DARWin-ME before you use the backcalculation option. Once you utilize the backcalculation option, DARWin-ME creates multiple files for each station along the project, and any errors contained in the baseline project will be passed on to these multiple files.

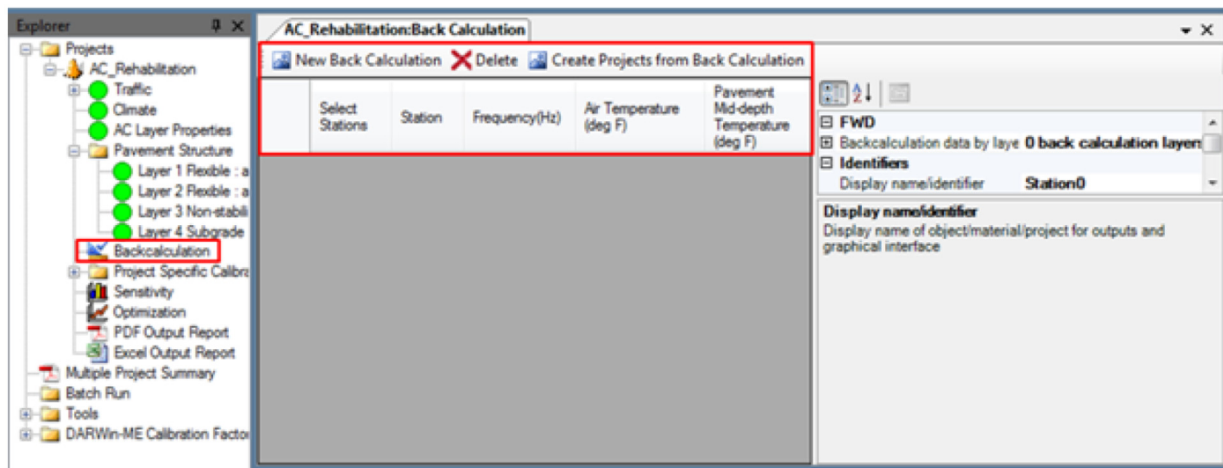
Way to Access this Interface

Click the Backcalculation node in the Explorer pane.

Ways to Enter Inputs

There are three methods for entering backcalculation data:

- Manual entry
- Import from file
- Import from database



Backcalculation

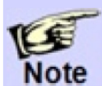
Populating the Inputs in this Interface

Manual Entry

New Backcalculation: This control allows you to enter data manually by creating a new row in the Station Information table. Each row represents an individual station along the project. Click this control to create a new station each time.

Delete: This control allows you to delete a station in the Station Information table. If you select a station for deletion and activate this control, the system will delete the selected station. If no station is selected, the system will delete the station at the end of the current table. It is possible to delete all stations in the table, one at a time.

Create Projects from Backcalculation: When all information has been supplied, this control allows you to create multiple files for the same project, one for each station, by replacing baseline design and material inputs with station specific backcalculation inputs.



Note

You can import station and backcalculation data in XML format using the Import functionality of DARWin-ME. Separate XML files should be imported for each station.

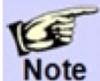
Station Information Table

The controls in the Station Information table vary with the surface layer type (AC or PCC) of the existing pavement.

Select Station: This control allows you to select the designated station.

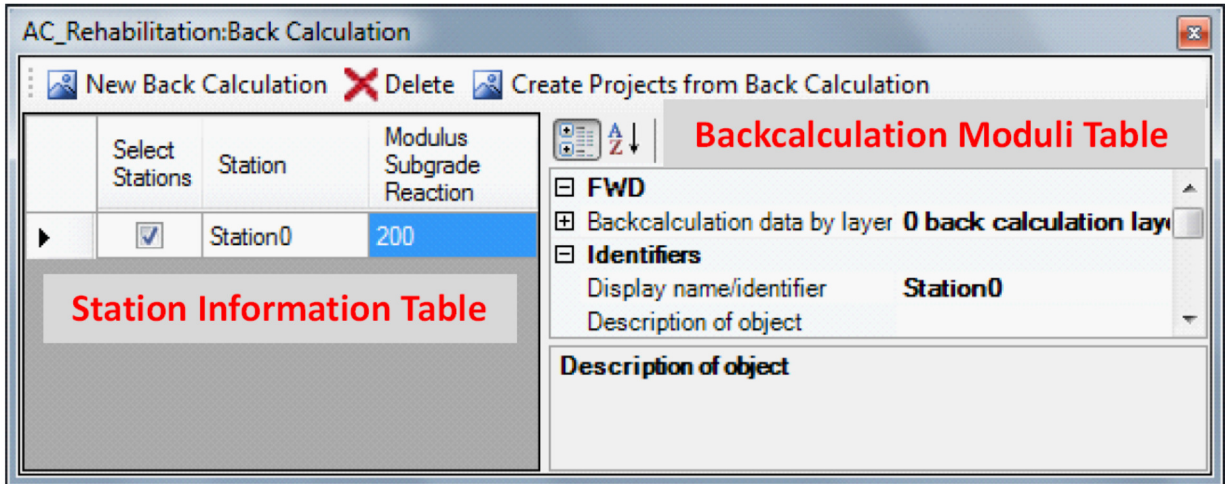
Station: This control allows you to customize the station name by overwriting DARWin-ME's default station designation.

Modulus Subgrade Reaction: This control is displayed only when the existing pavement surface layer type is PCC. It allows you to enter the dynamic modulus of subgrade reaction (k-value) of the existing pavement. Highlight the current value and click inside this field to override the sample value of "200" provided by DARWin-ME.



Note

Under the Foundation Support property grid, set "Is modulus of subgrade reaction measured?" to "True" to allow DARWin-ME to use the k-value you define here. Enter the month of deflection testing to override the default month of September, as needed.



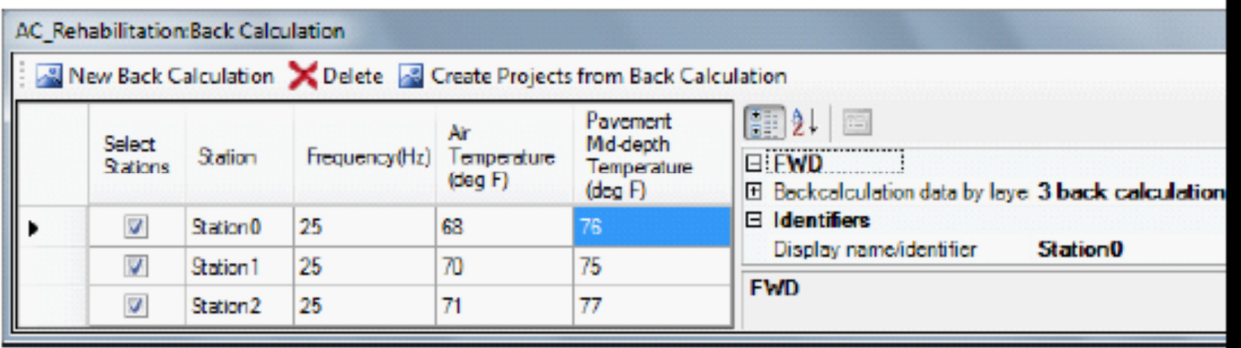
Station Information Table for an Existing Pavement with PCC Surface

The following controls are displayed only when the existing pavement surface layer type is AC:

Frequency: This control allows you enter the test frequency in Hertz used in FWD deflection testing. Highlight the current value and click inside this field to override the sample value of “10” provided by DARWin-ME.

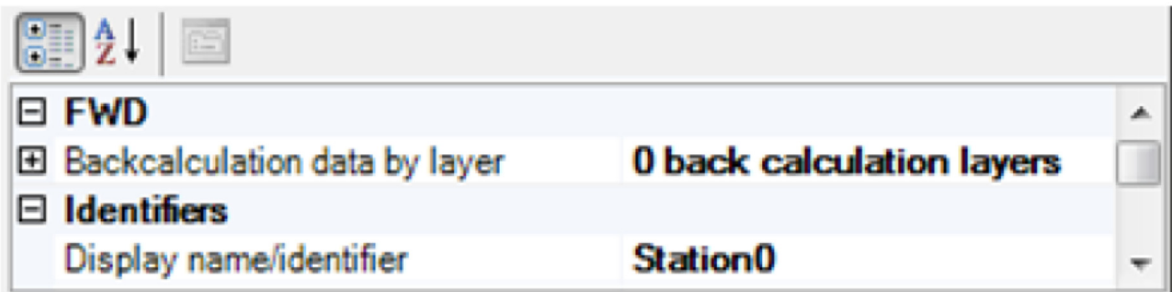
Air Temperature (deg F): This control allows you enter the air temperature in °F at the time deflection testing was conducted. Highlight the current value and click inside this field to override the sample value provided by DARWin-ME.

Pavement Mid-depth Temperature (deg F): This control allows you enter the pavement mid-depth temperature in °F at the time deflection testing was conducted. Highlight the current value and click inside this field to override the sample value provided by DARWin-ME.



Station Information Table for an Existing Pavement with AC Surface

Backcalculated Moduli Table



Accessing Backcalculation Moduli Table

After entering descriptive inputs for a station in the Station Information table, you must enter the backcalculation data for each existing pavement layer of the selected station. Click on the *Back Calculation data* by layer control and open the drop-down menu. You will see the following table:

	NDT Modulus (psi)	Unit Weight (pcf)	Poisson's Ratio	Thickness (in.)
*				

Backcalculation Moduli Table (before entering data)

Use the top row for entering inputs for the surface layer of the existing pavement. For the underlying layers, use multiple rows in order as needed. The number of rows in this table must match with the number of existing pavement layers defined in the baseline project file. If there is a mismatch, you are not defining the existing pavement structure and material inputs in your design accurately.

NDT Modulus: This control allows you to enter the backcalculated modulus in psi for the current layer of the existing pavement.

Unit Weight: Enter the unit weight of the current layer in pcf.

Poisson's Ratio: Enter the Poisson's ratio of the current layer.

Thickness (in.): Enter the thickness of the current layer in inches. Use 0 for the semi-infinite layer.

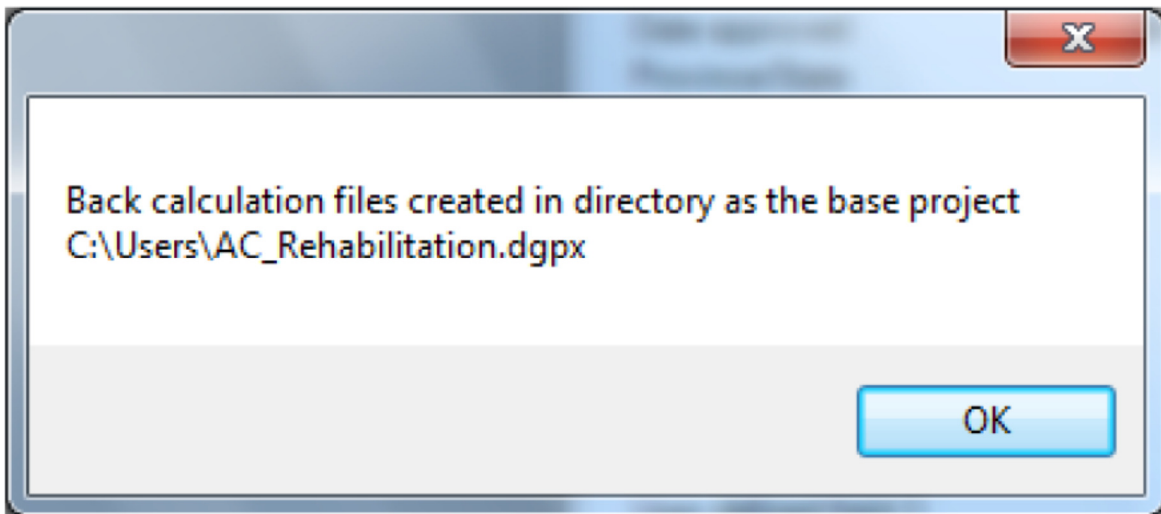
Note: DARWin-ME will overwrite the inputs you defined in the baseline project file with these inputs when multiple project files are created for each station.

	NDT Modulus (psi)	Unit Weight (pcf)	Poisson's Ratio	Thickness (in.)
▶	809000	150	0.35	4.75
	42000	125	0.35	6.25
	10500	100	0.35	0

Backcalculation Moduli Table (after entering data)

Create Projects from Backcalculation

After entering all station description and backcalculation data, click Create projects from Backcalculation to create multiple files each representing a station you defined in the Station Information table. DARWin-ME then displays a message:



The created files will have new file names with the station name appended to the baseline project file name (e.g., Filename_Station0, Filename_Station1).

9 Asphalt Concrete Overlay Design of Existing JPCP

An Asphalt Concrete Overlay of an existing JPCP is a rehabilitation option considered in DARWin-ME.

For the design of AC overlays of existing JPCP using DARWin-ME, you need to first decide on what, if any pre-overlay treatment is needed. Pre-overlay treatments may be used for minimizing the effect of existing JPCP distresses on the future performance of AC overlays. Pre-overlay treatments may include do nothing, full-depth repairs, load transfer restoration, slab replacement, and shoulder replacement.

Not all types of pre-overlay repairs are considered directly by DARWin-ME. However, the effect of pre-overlay repairs on the general condition of the existing PCC layer and JPCP is what should be used in the design of AC overlays of existing JPCP. In either case, the resulting analysis is an AC overlay of an existing JPCP.

AC Overlay Design of Existing JPCP Overview

Design Inputs: The topics in this section explain the options DARWin-ME offers for creating and testing AC Overlay Design of Existing JPCP designs:

General Information: This section allows you to select the basic parameters of an AC Overlay Design of Existing JPCP design.

Performance Criteria: This section provides a high-level look at the criteria DARWin-ME uses to analyze an AC Overlay Design of Existing JPCP design.

Traffic: This section provides details on using DARWin-ME's tables and data to examine the effects of traffic loading on pavement design and lifespan.

Climate: This section provides details on working with data from climate data files and then established weather stations for an area and using that data to analyze the effects of climate variables on pavement response and performance.

Pavement Structure Definition and Materials: This section explains adding additional layers to a pavement, editing the parameters of those layers, and working with the structure of the pavement as a whole.

Run Analysis: This section details the various analyses DARWin-ME will run to determine if a pavement design is valid.

Reports: This section details the variety of reports DARWin-ME can create on all facets of a project's design.

Structural Response: DARWin-ME's structural model analyzes pavement structure, accounts for discontinuities in that structure, and analyzes the effects of environment and traffic on that structure.

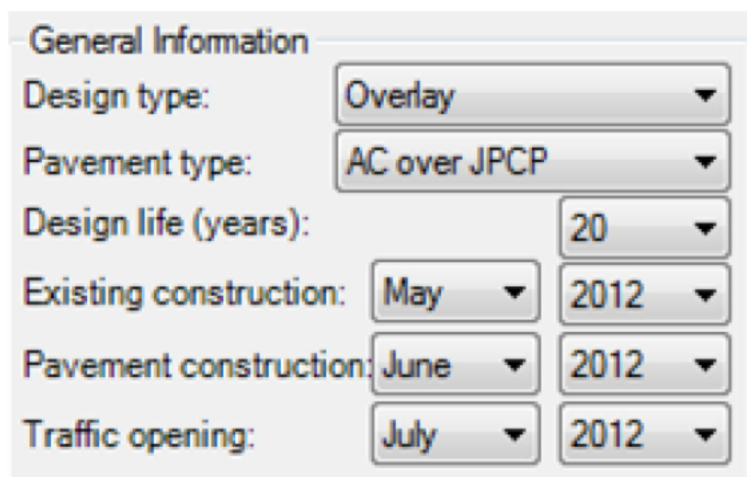
9.1 General Design Inputs

An Asphalt Concrete overlay on an existing JPCP design is a rehabilitation project, using Hot Mix Asphalt (HMA) to remedy the structural or functional deficiencies of an existing JPCP pavement.

The following options allow you to establish the basic parameters of your project.

Way to Access this Interface

Open a new pavement project. The *General Information* area appears at the top-left corner of the [Project Tab](#).



The screenshot shows a 'General Information' form with the following fields and values:

Field	Value
Design type:	Overlay
Pavement type:	AC over JPCP
Design life (years):	20
Existing construction:	May 2012
Pavement construction:	June 2012
Traffic opening:	July 2012

General Information

Design type: Select *Overlay*

Pavement type: Select *AC over JPCP*

In addition to selecting Design and Pavement type, select values for the following basic design parameters:

Design life (years): This control allows you to select from a list the period of time in years from AC overlay placement where the rehabilitated pavement is expected to perform adequately without significant loss of functional and structural integrity. Pavement performance is predicted over the design life beginning from the month the rehabilitated pavement is open to traffic.

Existing construction: This control allows you to select the month and year when the construction of existing JPCP was completed.

Pavement construction: This control allows you to select the month and year when the AC overlay is scheduled to be placed.

Traffic opening: This control allows you to select the month and year the rehabilitated pavement is scheduled to be open to traffic. DARWin-ME predicts pavement performance beginning from this month and year.

9.2 Performance Criteria

Performance verification forms the basis of the acceptance or rejection of a trial rehabilitation design evaluated using DARWin-ME. The rehabilitation design procedure is based on pavement performance, and therefore, the critical levels of pavement distresses that can be tolerated by the agency at the selected level of reliability needs to be specified by the user. If the simulation process shows the trial design produces excessive amount of distresses, then the trial design must be modified accordingly to produce a feasible rehabilitation design in the future trials.

The distress types considered in the design of an AC overlay of existing JPCP are total rutting (all layers and subgrade), AC rutting, load-related top-down cracking (longitudinal cracking in the wheel path) and bottom-up fatigue cracking (alligator cracking), and thermal cracking (transverse cracking). Pavement smoothness is considered for performance verification and is characterized using the International Roughness Index (IRI). In addition, the transverse cracking of the existing JPCP and reflective cracking are also considered.

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal fracture (ft/mile)	250	90
Chemically stabilized layer - fatigue fracture (percent)	25	90
Permanent deformation - total pavement (in.)	0.75	90
Permanent deformation - AC only (in.)	0.25	90
Reflective cracking (percent)	100	50
JPCP transverse cracking (percent slabs)	15	90

Performance Criteria (AC Overlay of Existing JPCP)

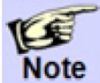
Populating the Inputs in this Interface

This table allows you to define the limits of critical distresses and smoothness that can be tolerated by the agency at the specified reliability levels. This table has three columns:

Performance Criteria: This column provides a list of performance indicators required to ensure that a pavement design will perform satisfactorily over its design life.

Limit: This column allows you to define the threshold values of these performance indicators to evaluate the adequacy of a design.

Reliability: This column allows you to define the probability at which the predicted distresses and smoothness will be less than the limits over the design period.



You can override the program defaults to enter project-specific threshold limits and reliability values representing agency policies. Refer to Chapter 8 of the AASHTO Manual of Practice for more guidance on selecting design criteria and reliability level.

Initial IRI (in./mile): The limit control allows you to define the expected smoothness immediately after the AC overlay is placed (expressed in terms of IRI). Initial IRI is a very important input as the time from AC overlay placement to attaining threshold IRI value is very much dependent on the initial IRI obtained at the time of rehabilitation. Thus, the initial IRI value provided must be what is typically attained in the field. You can override the DARWin-ME default value of 63 in./mi to reflect agency policy and guidelines.

Terminal IRI (in./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for IRI at the end of the rehabilitation design life at a specified reliability level.

AC top-down fatigue cracking (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for surface initiated fatigue cracking at the end of the rehabilitation design life at a specified reliability level.

AC bottom-up fatigue cracking (percent): The limit and reliability controls for this criterion controls allow you to define the not-to-exceed limit for bottom-initiated fatigue cracking at the end of the rehabilitation design life at a specified reliability level.

AC thermal fracture (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for non-load related transverse cracking at the end of the rehabilitation design life at a specified reliability level.

Permanent deformation - total pavement (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for total rutting at the end of the rehabilitation design life at a specified reliability level. Total permanent deformation at the surface is the accumulation of the permanent deformation in all of the asphalt and unbound layers in the pavement system.

Permanent deformation - AC only (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for rutting contributed by the AC layers at the end of the rehabilitation design life at a specified reliability level.

Reflective cracking (percent): The form of distress is only applicable to a flexible pavement with a chemically stabilized layer directly placed under the AC layer. The limit control allows you to define the not-to-exceed limit for reflective cracking at the end of the design life at 50 percent reliability level. In DARWin-ME, reflective cracking is computed as a fraction of the fatigue cracking in the chemically stabilized layer that reflects through the HMA layer to the surface. The sum of reflective cracking and bottom initiated fatigue cracking is reported as total cracking.

Transverse cracking (percent of all slabs): The limit and reliability controls allow you to define the threshold value for transverse cracking of the existing JPCP at a user or agency specified reliability level. DARWin-ME predicts the combined percentage of PCC slabs with bottom-up and top-down transverse cracks that occurs mostly in the middle third of the slab. It is reported as percent slabs cracked.

9.5 Pavement Structure Definition and Materials

9.5.1 Asphalt Concrete (New) Layer

Refer to section 8.5.1 Asphalt Concrete (New) Layer

9.5.2 PCC (Existing Intact JPCP) Layer

Way to Access this Interface

Open an overlay/restoration project with a PCC layer and select existing PCC in the Layer control.

PCC		
Thickness (in.)	<input checked="" type="checkbox"/>	10
Unit weight (pcf)	<input checked="" type="checkbox"/>	150
Poisson's ratio	<input checked="" type="checkbox"/>	0.2
Thermal		
PCC coefficient of thermal expansion (in./in./deg F x 10-6)	<input checked="" type="checkbox"/>	5.5
PCC thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/>	1.25
PCC heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/>	0.28
Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd ³)	<input checked="" type="checkbox"/>	600
Water to cement ratio	<input checked="" type="checkbox"/>	0.42
Aggregate type		Dolomite (2)
PCC set temperature (deg F)	<input type="checkbox"/>	Calculated
Calculated internally?		True
User-specified PCC set temperature	<input type="checkbox"/>	
Ultimate shrinkage (microstrain)	<input type="checkbox"/>	632.3 (calculated)
Calculated internally?		True
User-specified PCC ultimate shrinkage	<input type="checkbox"/>	
Reversible shrinkage (%)	<input checked="" type="checkbox"/>	50
Time to develop 50% of ultimate shrinkage (days)	<input checked="" type="checkbox"/>	35
Curing method		Curing Compound
Strength		
PCC strength and modulus	<input checked="" type="checkbox"/>	Level:3 Rupture(690) Modulus(4200000)
Identifiers		
Display name/identifier		Default

Portland Cement Concrete Properties

Ways to Enter Inputs

There are three methods for entering data for the PCC layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

PCC

Thickness (in.): This control allows you to define the thickness of the PCC layer used in the trial design. Note that this input has a significant impact on DARWin-ME prediction of future JPCP performance.

Unit weight (pcf): This control allows you to define the weight per unit volume of the PCC mix design. Typical values ranges from 140 to 160 pcf.

Poisson's ratio: This control allows you to define the PCC's Poisson's ratio (defined as the ratio of PCC lateral and longitudinal strain under applied loading). Poisson's ratio is an important input required for structural analysis. Values between 0.15 and 0.18 are typical PCC used in JPCP construction.

Thermal

PCC coefficient of thermal expansion (in/in/deg F x 10-6): This control allows you to define the expansion or contraction a material undergoes with change in temperature. PCC coefficient of thermal expansion (CTE) is defined as the increase in length per unit length of PCC (typically 1-in) for a unit increase in temperature (typically 1 °F). PCC CTE has a significant impact on critical curling stresses developed in the JPCP PCC slab and thus the development of transverse cracks. PCC CTE can be considered to be a very critical input that influences the development of transverse cracking.

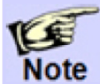
PCC thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the ability of the PCC material to uniformly conduct heat through its thickness when subjected to a temperature differential at the top surface and bottom of the PCC layer. DARWin-ME provides a typical value of 1.25 BTU/hr-ft-°F.

PCC heat capacity (BTU/lb-deg F): This control allows you to define the amount of heat required to raise a unit mass of PCC material (typically 1 lb) by a unit temperature (typically 1 °F). DARWin-ME provides a typical value of 0.28 BTU/hr-ftdeg F.

NOTE: The CTE should be adjusted as follows to reflect the CTE values used to calibrate the current models .

$$\text{CTE}_{\text{input}} = \text{CTE}_{\text{pcc}} - \text{CTE}_{\text{calib}} + 9.61 \times 10^{-6} \text{ in/in/ } ^\circ\text{F}$$

$$\text{CTE}_{\text{input}} = \text{CTE adjusted to reflect CTE values used in calibration, in/in/ } ^\circ\text{F}$$



$$\text{CTE}_{\text{pcc}} = \text{CTE of concrete specimen according to AASHTO T 336 or TP 60, in/in/ } ^\circ\text{F}$$

$$\text{CTE}_{\text{calib}} = \text{CTE of 304 stainless steel calibration or verification specimen used to determine } \text{CTE}_{\text{pcc}}, \text{ in/in/ } ^\circ\text{F}$$

CTE values contained in the LTPP Standard Data Release 24.0 dated January 2010 or later have been updated with this correction. These CTE values should be increased by 0.83×10^{-6} in/in/ °F if they are used as a level 3 input. CTE values prior to LTPP SDR 24.0 do not need to be adjusted.

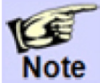
Mix

Cement type: This control allows you to select the type of cement used in the PCC mix. DARWin-ME allows you to select one of the following Portland cement types:

Type I: Type I cements are described as general purpose cements suitable for most pavement construction situations where special properties such as high early strength, high durability, etc., are not required.

Type II: Type II cements contain no more than 8% tricalcium aluminate (C3A) and are suitable for situations where moderate sulfate resistance is required.

Type III: Type III cements have constituents very similar to Type I cements. However, the constituents are ground to produce a finer mix that produces higher levels of early strengths. Thus, Type II cements are generally used in JPCP construction where early strength is required.



For PCC mixes with non-conventional cement types, select the cement type provided by DARWin-ME which is closest in characteristics.

Cementitious material content (lb/yd³): This control allows you to define the total weight of cementitious material (Portland cement, pozzolans, lime, fly-ash, etc.) per unit volume of PCC as per the PCC mix design. The cementitious material along with water content is used to calculate PCC ultimate shrinkage, a critical parameter in structural analysis.

Water to cement ratio: This control allows you to define the ratio of the weight of water to the weight of all cementitious materials used in the PCC mix design. This input is used to calculate the water content of the PCC mix and is used along with cementitious material content to calculate PCC ultimate shrinkage, a critical parameter in structural analysis.

Aggregate type: This control allows you to select the coarse aggregate rock type in the PCC mix. If the coarse aggregate rock type is not uniform, the predominant rock type must be selected. Coarse aggregate is typically described as the material the material retained on the No. 4 sieve. Coarse aggregate rock type is used to calculate PCC ultimate shrinkage. DARWin-ME allows you select one of the following coarse aggregate rock types:

Quartzite: This option allows you to select quartzite as the predominant coarse aggregate rock type in the PCC mix. Quartzite is a metamorphic rock which is extremely resistant to weathering and erosion.

Limestone: This option allows you to select limestone as the predominant coarse aggregate rock type in the PCC mix. Limestone is a sedimentary rock composed largely calcium carbonate and provides a solid base for highway pavements.

Dolomite: This option allows you to select dolomite as the predominant coarse aggregate rock type in the PCC mix. Dolomite is a sedimentary carbonate rock composed mainly of calcium magnesium carbonate. Dolomite like limestone provides a solid base for highway pavements.

Granite: This option allows you to select granite as the predominant coarse aggregate rock type in the PCC mix. Granite is an intrusive, felsic, igneous rock and is extremely resistant to weathering and erosion.

Rhyolite: This option allows you to select rhyolite as the predominant coarse aggregate rock type in the PCC mix. Rhyolite is an igneous, volcanic (extrusive) rock and is extremely resistant to weathering and erosion.

Basalt: This option allows you to select basalt as the predominant coarse aggregate rock type in the PCC mix. Basalt is an extrusive igneous rock and is extremely resistant to weathering and erosion.

Syenite: This option allows you to select syenite as the predominant coarse aggregate rock type in the PCC mix. Syenite is a coarse-grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts. Syenite is extremely resistant to weathering and erosion.

Gabbro: This option allows you to select gabbro as the predominant coarse aggregate rock type in the PCC mix. Gabbro is an intrusive mafic igneous rock, rich in iron and magnesium, poor in silica (quartz) and chemically equivalent to basalt. Gabbro is extremely resistant to weathering and erosion.

Chert: This option allows you to select chert as the predominant coarse aggregate rock type in the PCC mix. Chert is a sedimentary rock widely used in highway pavement construction. It is moderately resistant to weathering and erosion.

PCC set temperature (deg F): This control allows you to define the PCC temperature when the freshly placed PCC slab becomes solid. PCC set temperature can be user entered or estimated by DARWin-ME using (1) average of hourly ambient temperatures for month of construction and (2) cementitious material content. The default for this control is to let DARWin-ME calculate the PCC set temperature. You can, however, override the DARWin-ME default and enter your own PCC set temperature.

Calculated internally? This control allows you to decide whether DARWin-ME should calculate PCC set temperature or not by selecting one of the following options:

True: Selecting this option allows DARWin-ME to calculate the PCC set temperature.

False: This option allows you to input directly PCC set temperature.

User-specified PCC set temperature: This control allows you define the PCC set temperature in degrees Fahrenheit (minimum 70, maximum 212).

Ultimate shrinkage (microstrain): This control allows you to define the ultimate (long-term) shrinkage strain that PCC will develop under laboratory controlled conditions of temperature and humidity (e.g., 40% relative humidity). The default for this control is to let DARWin-ME calculate PCC ultimate shrinkage internally. You can, however, override the DARWin-ME default and enter your own PCC ultimate shrinkage.

Calculated internally? This control allows you to decide whether DARWin-ME should calculate PCC ultimate shrinkage or not by selecting one of the following options:

True: Selecting this option allows DARWin-ME to calculate the PCC ultimate shrinkage.

False: This option allows you to input directly PCC ultimate shrinkage.

User-specified PCC ultimate shrinkage: This control allows you define the PCC ultimate shrinkage in microstrain (minimum 300, maximum 1000).

Reversible Shrinkage (%): Change in PCC humidity/moisture affects the volume of PCC with moisture causes PCC expansion while drying causes PCC shrinkage. Note that this is very different from the drying shrinkage in PCC due to moisture loss during PCC hardening that result in irreversible shrinkage. This control allows you to define the percent of PCC ultimate shrinkage that can be recovered due to changes in PCC humidity/moisture (minimum 0, maximum 100).

Time to develop 50% of ultimate shrinkage (days): This control allows you to define the time required in days to develop 50% of PCC ultimate shrinkage (minimum 30, maximum 50).

Curing method: This control allows you to select curing method applied after PCC placement. DARWin-ME allows you to select one of the following options:

Wet Curing: These are curing methods that prevent PCC surface moisture loss by supplying additional water to the PCC surface. The most common practice is to place wet burlap or other natural or synthetic-fiber blankets at the PCC surface to prevent rapid evaporation of moisture. Selecting this option implies the use of the above listed methods or similar techniques for PCC curing.

Curing Compound: These are curing methods that prevent moisture loss at the PCC surface by placing a liquid membrane-forming chemical compound (typically resins, waxes or synthetic rubbers dissolved in a solvent) that forms a near impermeable membrane over the PCC once the solvent evaporates. Selecting this option implies the use of the above listed methods or similar techniques for PCC curing.

Strength

DARWin-ME requires both PCC modulus of rupture and elastic modulus.

PCC strength input level: This control allows you to select modulus of rupture and elastic modulus input level. DARWin-ME allows for the following options:

Level 1: This option allows you to directly input the elastic modulus and modulus of rupture of existing PCC layer.

Level 2: This option allows you to directly input the compressive strength of existing PCC layer.

Level 3: This option allows you to directly input any of the following combination of inputs:

- 28-day PCC modulus of rupture only.
- 28-day PCC compressive strength only.
- 28-day PCC modulus of rupture and 28-day PCC elastic modulus.
- 28-day PCC compressive strength and 28-day PCC elastic modulus.

Level 1 Modulus of Rupture/Elastic Modulus Table: This table allows you to define modulus of rupture and elastic modulus of the existing PCC layer:

PCC strength input level 1

Time	Modulus of rupture (psi)	Elastic modulus (psi)
0 years	690	4200000

User-defined adjustment factor: 0.8

Level 1 Inputs for PCC Strength (Intact JPCP)

Time: This column lists the age of the existing PCC layer at which the AC overlay is placed. The age is computed internally by DARWin-ME using the existing construction date and pavement (rehabilitation) construction date.

Modulus of Rupture (psi): This column allows you to define the modulus of rupture of the existing PCC layer.

Elastic Modulus (psi): This column allows you to define the elastic modulus of the existing PCC layer. The backcalculated “dynamic” elastic modulus values must be adjusted to “static” values. Refer to the AASHTO Manual of Practice for guidance.

User-defined Modulus Adjustment Factor: This control allows you enter an adjustment factor to convert backcalculated dynamic modulus to static modulus.

Level 2 Compressive Strength Table: This table allows you to define the compressive strength of the existing PCC layer:

PCC strength input level 2

Time	Compressive strength (psi)
0 years	5275

Level 2 Inputs for PCC Strength

Time: This column lists the age of the existing PCC layer at which the AC overlay is placed. The age is computed internally by DARWin-ME using the existing construction date and pavement (rehabilitation) construction date.

Compressive strength (psi): This column allows you to define the compressive strength of the existing PCC layer.

Level 3 Modulus of Rupture, Compressive Strength, and Elastic Modulus

Table: This control allows you to define your preferred combination of PCC strength and elastic modulus inputs at Level 3. DARWin-ME allows for the following combination of inputs by checking the appropriate radio button and check box:

PCC strength input level	<input type="text" value="3"/>
<input checked="" type="radio"/> 28-Day PCC modulus of rupture (psi)	<input type="text" value="620"/>
<input type="radio"/> 28-Day PCC compressive strength (psi)	<input type="text"/>
<input checked="" type="checkbox"/> 28-Day PCC elastic modulus (psi)	<input type="text" value="3956571"/>

Level 3 Inputs for PCC Strength

- 28-day PCC modulus of rupture only.
- 28-day PCC compressive strength only.
- 28-day PCC modulus of rupture and 28-day PCC elastic modulus.
- 28-day PCC compressive strength and 28-day PCC elastic modulus.

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.3 PCC Mixtures, Lean Concrete, and Cement-Treated Base Layers

9.5.3 Asphalt Concrete (Base) Layer

Way to Access this Interface

Open a new pavement project and select Asphalt Concrete in the Layer control.

<input type="checkbox"/> Asphalt Layer	
Thickness (in.)	<input checked="" type="checkbox"/> 10
<input type="checkbox"/> Mixture Volumetrics	
Unit weight (pcf)	<input checked="" type="checkbox"/> 150
Effective binder content (%)	<input checked="" type="checkbox"/> 11.6
Air voids (%)	<input checked="" type="checkbox"/> 7
<input type="checkbox"/> Poisson's ratio	0.35
<input type="checkbox"/> Mechanical Properties	
Dynamic modulus	<input checked="" type="checkbox"/> Input level:3
<input type="checkbox"/> Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	<input checked="" type="checkbox"/> 70
Asphalt binder	<input checked="" type="checkbox"/> Select Binder
Indirect tensile strength at 14 deg F (psi)	<input checked="" type="checkbox"/> 388.87
Creep compliance (1/psi)	<input checked="" type="checkbox"/> Input level:3
<input type="checkbox"/> Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 0.67
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.23
<input type="checkbox"/> Thermal contraction	1.301E-05 (calculated)
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./deg F)	<input type="checkbox"/>
Aggregate coefficient of thermal contraction (in./in./deg F)	<input checked="" type="checkbox"/> 5E-06
Voids in Mineral Aggregate (%)	<input checked="" type="checkbox"/> 18.6
<input type="checkbox"/> Identifiers	
Display name/identifier	New Asphalt Concrete Layer

Asphalt Concrete Base Layer Properties

Refer to Section 5.5.1 **Asphalt Concrete Layer**

Links to Relevant Section in AASHTO Manual of Practice

Section 11.2 HMA Mixtures; Including SMA, Asphalt Treated or Stabilized Base Layers, and Asphalt Permeable Treated Base Layers

9.5.4 Chemically Stabilized Layer

The required inputs for a chemically stabilized layer can be broadly classified as general, strength, and thermal properties. Note that the strength properties required by DARWin-ME are different for flexible and rigid pavements.

Refer to Section 5.5.2 **Chemically Stabilized Layer**

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.4 Chemically Stabilized Materials; Including Lean Concrete and Cement Treated Base Layer.

9.5.5 Non-Stabilized Layer

Non-stabilized materials include AASHTO soil classes A-1 through A-3, as well as those commonly defined in practice as crushed stone, crushed gravel, river gravel, permeable aggregate, and cold recycled asphalt material (includes millings and in-place pulverized material).

Refer to Section 5.5.3 **Non-Stabilized Layer**

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

9.5.6 Subgrade

Subgrade materials include soil classes A-1 through A-7-6 defined in accordance with the AASHTO soil classification system. Inputs required for subgrade materials are same as include physical and engineering properties such as conductivity, specific gravity, soil-water characteristic classification properties, and the resilient modulus.

Refer to Section 5.5.4 Subgrade **Layer**

9.5.7 Bedrock

A bedrock layer, if present under an alignment, could have a significant impact on the pavement's mechanistic responses and therefore need to be fully accounted for in design. This is especially true if backcalculation of layer moduli is adopted in rehabilitation design to characterize pavement materials. While the precise measure of the stiffness is seldom, if ever, warranted, any bedrock layer must be incorporated into the analysis.

Refer to Section 5.5.5 **Bedrock Layer**

9.6 AC Layer Properties

This screen allows you to define other inputs pertinent to flexible pavement design.

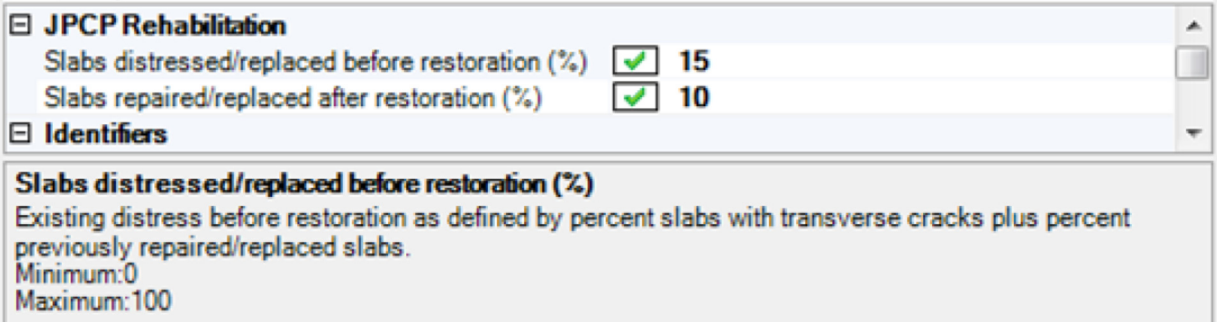
Refer to Section 8.6 AC Layer Properties

9.7 JPCP Rehabilitation

This screen allows you to provide the required DARWin-ME inputs indicative of the existing level of distresses in a restoration or rehabilitation design. The inputs enable DARWin-ME to estimate damage based on the condition of the existing pavement. The extent of repairs undertaken at the time of rehabilitation is used to adjust future performance predictions as needed.

Way to Access this Interface

Open a rehabilitation project with a JPCP layer and select JPCP Rehabilitation in the Layer control.



The screenshot shows a software interface for JPCP Rehabilitation. It features a tree view on the left with 'JPCP Rehabilitation' and 'Identifiers' expanded. The main area contains two input fields, each with a green checkmark icon and a numeric value. Below these is a detailed description of the first input field, including its minimum and maximum values.

Input Field	Value
Slabs distressed/replaced before restoration (%)	15
Slabs repaired/replaced after restoration (%)	10

Slabs distressed/replaced before restoration (%)
Existing distress before restoration as defined by percent slabs with transverse cracks plus percent previously repaired/replaced slabs.
Minimum:0
Maximum:100

JPCP Rehabilitation

Ways to Enter Inputs

There are three methods for entering data for the PCC layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

JPCP Rehabilitation

Slabs distressed/replaced before restoration (%): This control allows you to define the percentage of cracking in slabs before the restoration or rehabilitation. This is essentially the total percentage cracking in the slabs and includes all cracks that were previously.

Slabs repaired/replaced after restoration (%): This option allows you to define the percentage of slabs that were repaired during the restoration or rehabilitation process. The difference between the slabs distressed and slabs replaced is the percentage of slabs that are still cracked after restoration.

9.8 JPCP Design Properties

JPCP design features and construction practices influence long-term performance. The common design features that are considered by DARWin-ME include widened PCC slabs, joint spacing, shoulder type (tied vs. untied PCC or asphalt concrete), presence and size of dowel bars used for transverse joint load transfer, dowel bar spacing, base type and erodibility, (chemically stabilized, asphalt stabilized, and non-stabilized aggregate).

Construction practices include PCC curing method (curing compound vs. wet curing), permanent curl/warp effective temperature difference in the PCC, PCC/base layer friction loss age, initial smoothness, and so on. Some of these design features and construction practices have been described in previous sections.

Way to Access this Interface

Open a project with JPCP layer and select JPCP Design Property in the Layer control.

<input type="checkbox"/> JPCP Design	
PCC surface shortwave absorptivity	<input checked="" type="checkbox"/> 0.85
<input type="checkbox"/> PCC joint spacing (ft)	15
Sealant type	Preformed
<input type="checkbox"/> Doweled joints	Spacing(12). Diameter(1.25)
Is joint doweled ?	True
Dowel diameter (in.)	<input checked="" type="checkbox"/> 1.25
Dowel spacing (in.)	<input checked="" type="checkbox"/> 12
<input type="checkbox"/> Widened slab	Widened(14)
Is slab widened ?	True
Slab width (ft)	<input checked="" type="checkbox"/> 14
<input type="checkbox"/> Tied shoulders	Tied with long term load transfer efficiency of 40
Tied shoulders	True
Load transfer efficiency (%)	<input checked="" type="checkbox"/> 40
Erodibility index	Very erodible (5)
<input type="checkbox"/> PCC-base contact friction	Full friction with friction loss at (240) months
PCC-Base full friction contact	True
Months until friction loss	<input checked="" type="checkbox"/> 240
Permanent curl/warp effective temperature difference (deg F)	<input checked="" type="checkbox"/> -10
<input type="checkbox"/> Identifiers	
Display name/identifier	Default

JPCP Design Properties

Ways to Enter Inputs

There are three methods for entering data for the Stabilized (Flexible) layer:

- Manual entry
- Import from file
- Import from database

Populating the Inputs in this Interface

JPCP Design

PCC surface shortwave absorptivity: This control allows you to define the fraction of solar energy (sunshine) at the PCC surface that is absorbed by the PCC. DARWin- ME presents a default value of 0.85. You can override this default.

PCC joint spacing (ft): This control allows you to define whether transverse joints of the trial design are uniformly or randomly spaced.

Is joint spacing random? This control allows you to define whether transverse joints are uniformly spaced or randomly spaced. DARWin-ME allows for the following options:

True: Selecting this option implies transverse joint are randomly spaced.

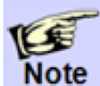
- **Spacing of joint 1:** This option allows you to define the length of the first PCC slab.
- **Spacing of joint 2:** This option allows you to define the length of the second PCC slab.
- **Spacing of joint 3:** This option allows you to define the length of the third PCC slab.
- **Spacing of joint 4:** This option allows you to define the length of the fourth PCC slab.

False: Selecting this option implies transverse joint are uniformly spaced.

Joint spacing: This option allows you to define average length of all the PCC slabs.

Sealant type: This control allows you to select the sealant type applied at the transverse joints. DARWin-ME allows you to choose from the following sealant types:

prefomed, liquid, and silicone.



Sealant type is an input to the JPCP transverse joint spalling model. Spalling is a key input for JPCP smoothness prediction.

Doweled joints: This control allows you to define transverse joint load transfer mechanism.

Is joint doweled?: This control allows you to select whether transverse joint load transfer mechanism is through the dowel bars:

True: Selecting this option implies transverse joint load transfer mechanism is through dowel bars.

False: Selecting this option implies transverse joint load transfer mechanism is through aggregate interlock only.

Dowel diameter (in.): This option allows you to define the diameter of the dowel bars used for load transfer across the transverse joint. A value of zero implies there are no dowel bars and load transfer is primarily through aggregate interlock.

Dowel spacing (in.): This option allows you to define the center-to-center distance between adjacent dowel bars if used for load transfer across transverse joints.

Widened slab: This control displays if the PCC slabs are widened. Note that the typical JPCP PCC slab width is 12-ft.

Is slab widened? This control allows you to select whether or not the JPCP PCC slab width is widened. DARWin-ME allows you to select one of the following options:

True: Selecting this option implies that the PCC slabs are widened (slab width is greater than 12-ft, typically 13- or 14-ft)

False: Selecting this option implies that the PCC slabs are not widened (slab width is 12-ft)

Slab width (ft.): This option allows you to define the slab width. Note slab width is defined only when widened PCC slab option is applied. Otherwise, DARWin-ME assumes a standard 12-ft slab width.

Tied shoulders: This control displays if tied PCC shoulders are used.

Tied shoulders: This control allows you to select whether or not to use tied PCC shoulders. DARWin-ME allows you to select one of the following options:

True: Selecting this option implies the use of tied PCC shoulders.

False: Selecting this option implies the use of other shoulder types such as PCC (without tie bars), asphalt concrete, or gravel shoulders.

Load transfer efficiency (%): This option allows you to define the long-term or terminal deflection LTE at the lane (PCC outer lane slab) to PCC shoulder longitudinal joint. DARWin-ME provides a default value of 40 percent. Typical long-term LTE are 50 to 70 percent for monolithically constructed tied PCC shoulder and 30 to 50 percent for separately constructed tied PCC shoulder.

Erodibility index: This control allows you to select the resistance of the base course to erosion, using an index on a scale of 1 to 5. Material erosion resistance is determined both by its strength and durability. DARWin-ME allows you to select one of the following options:

Extremely erosion resistant: Select an erodibility index of 1 for extremely erosion resistant base materials such as asphalt concrete and lean concrete materials.

Very erosion resistant: Select an erodibility index of 2 for very erosion resistant base materials such as asphalt treated and cement treated materials.

Erosion resistant: Select an erodibility index of 3 for erosion resistant base materials.

Fairly erodible: Select an erodibility index of 4 for fairly erodible base materials such as weakly stabilized aggregate materials and subgrade soils.

Very erodible: Select an erodibility index of 5 for very erodible base materials such as unstabilized subgrade soils.

PCC-base contact friction: The interface between the underlying base and PCC slab is modeled with or without full friction for JPCP design. DARWin-ME allows you to (1) determine whether or not the PCC slab/base interface has full friction at construction and (2) how long full friction will be available at the interface if present after construction. This control displays options available for modeling PCC slab/base interface condition.

PCC-Base full-friction contact: This option allows you to select whether or not there is full friction at the PCC slab/base interface after construction. DARWin-ME allows you to select one of the following options:

True: Selecting this option implies there is full friction at the PCC slab/base interface after friction.

False: selecting this option implies there is relatively little to no friction at the PCC slab/base interface after friction.

Months until friction loss: This option allows you to define the number of months after which full friction at the PCC slab/base interface is lost. The AASHTO Manual of Practice presents recommendations according to base material type. DARWin-ME allows for a range of 0 to 1200 months.

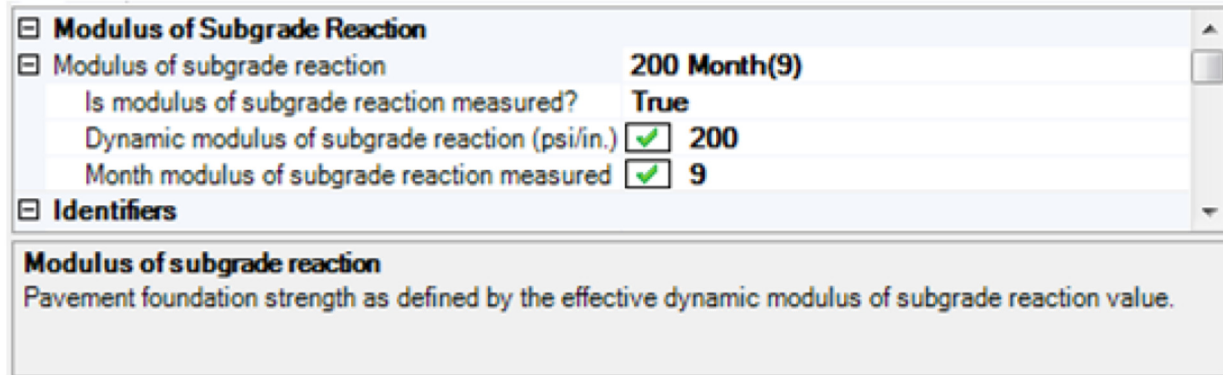
Permanent curl/warp effective temperature difference (deg F): This input describes the combined effect of (1) PCC built-in temperature gradient at time of set, (2) effective gradient of moisture warping in the PCC (dry on top and wet on bottom), (3) long term creep of the PCC slab, and (4) settlement of the PCC into the base. It is defined in terms of equivalent temperature difference. DARWin-ME presents the default value of -10 °F which was established as optimum to minimize error between measured and predicted cracking and measured and predicted faulting during the national calibration.

9.9 Foundation Support

Modulus of subgrade reaction, or k-value, is a soil support parameter. The static k-value is determined from the plate load test and is a measure of the pressure applied on the soil for a unit deformation monitored using a standard size plate. Dynamic k-value is determined through deflection testing and backcalculation. DARWin-ME requires dynamic k-value.

Way to Access this Interface

Open a rehabilitation project with a foundation layer and select Foundation Support in the Layer control.



Modulus of Subgrade Reaction	
Modulus of subgrade reaction	200 Month(9)
Is modulus of subgrade reaction measured?	True
Dynamic modulus of subgrade reaction (psi/in.)	<input checked="" type="checkbox"/> 200
Month modulus of subgrade reaction measured	<input checked="" type="checkbox"/> 9
Identifiers	

Modulus of subgrade reaction
Pavement foundation strength as defined by the effective dynamic modulus of subgrade reaction value.

Foundation Support

Ways to Enter Inputs

There are three methods for entering data for the sandwiched granular layer:

- Manual entry
- Import from file
- Import from database

Modulus of Subgrade Reaction

Modulus of subgrade reaction: This control displays whether the modulus of subgrade reaction is calculated internally by DARWin-ME or user-defined.

Is modulus of subgrade reaction measure?: Select True to define the modulus of subgrade reaction (k-value) and the month of the year it was measured. Select False to allow DARWin-ME to compute this value.

Dynamic modulus of subgrade reaction (psi/in.): This control allows you to define the dynamic k-value.

Month modulus of subgrade reaction measured: This control allows you to define the month of the year when the dynamic k-value was measured.

9.10 Backcalculation

The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The moduli typically are obtained using nondestructive deflection basin tests and standard backcalculation procedures. The backcalculated moduli closely match the actual in situ moduli of the existing pavement layers and subgrade. The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The moduli typically are obtained using nondestructive deflection basin tests and standard backcalculation procedures. The backcalculated moduli closely match the actual in situ moduli of the existing pavement layers and subgrade.

The most widely used deflection testing device is the falling weight deflectometer (FWD). Backcalculated layer moduli obtained from FWD testing need to be adjusted to laboratory conditions for use in DARWin-ME. The adjustment to laboratory conditions is discussed in the AASHTO Manual of Practice.

Refer to Section 8.7 **Backcalculation**

11 Asphalt Concrete Overlay Design of Fractured JPCP

An Asphalt Concrete Overlay of fractured JPCP is a rehabilitation option considered in DARWin-ME. For this AC overlay design type, the pre-overlay activity is fracturing existing PCC slabs. The objective of fracturing existing PCC slabs prior to AC overlay placement is to eliminate reflection of distresses such as cracking in the existing PCC into the AC overlay. This is done by fracturing the PCC slab in place into small fragments, while retaining good interlock between the fractured particles. In effect the integrity of the existing PCC slab is destroyed and replaced with a strong high-quality interlocked non-stabilized material.

DARWin-ME considers the effect of pre-overlay fracturing of the existing PCC slab through the selection of appropriate fractured PCC properties. DARWin-ME can be used to design and evaluate AC Overlays of Fractured JPCP.

AC Overlay Design of Fractured JPCP Overview

Design Inputs: The topics in this section explain the options DARWin-ME offers for creating and testing AC Overlay Design of Fractured JPCP designs:

General Information: This section allows you to select the basic parameters of an AC Overlay Design of Fractured JPCP design.

Performance Criteria: This section provides a high-level look at the criteria DARWin-ME uses to analyze an AC Overlay Design of Fractured JPCP design.

Traffic: This section provides details on using DARWin-ME's tables and data to examine the effects of traffic loading on pavement design and lifespan.

Climate: This section provides details on working with data from climate data files and then established weather stations for an area and using that data to analyze the effects of climate variables on pavement response and performance.

Pavement Structure Definition and Materials: This section explains adding additional layers to a pavement, editing the parameters of those layers, and working with the structure of the pavement as a whole.

Run Analysis: This section details the various analyses DARWin-ME will run to determine if a pavement design is valid.

Reports: This section details the variety of reports DARWin-ME can create on all facets of a project's design.

Structural Response: DARWin-ME's structural model analyzes pavement structure, accounts for discontinuities in that structure, and analyzes the effects of environment and traffic on that structure.

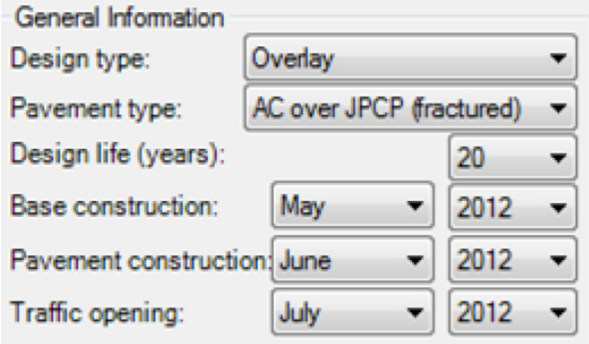
11.1 General Design Inputs

An AC Overlay of Fractured JPCP pavement is a fractured JPCP pavement rehabilitated with a new AC surface.

The following options allow you to establish the basic parameters of your project.

Way to Access this Interface

1. Open a new pavement project. The *General Information* area appears at the top-left corner of the [Project Tab](#).



The screenshot shows a 'General Information' panel with the following fields and values:

Field	Value
Design type:	Overlay
Pavement type:	AC over JPCP (fractured)
Design life (years):	20
Base construction:	May 2012
Pavement construction:	June 2012
Traffic opening:	July 2012

General Information

Design type: Select *Overlay*

Pavement type: Select *AC over JPCP (fractured)*

In addition to selecting Design and Pavement type, select values for the following basic design parameters:

Design life (years): This control allows you to select from a list the period of time in years from completion of construction where the pavement is expected to perform adequately without significant loss of functional and structural integrity. Pavement performance is predicted over the design life beginning from the month the pavement is open to traffic.

Base Construction: This control allows you to select the month and year when the existing JPCP was fractured.

Pavement construction: This control allows you to select the month and year when the AC overlay is scheduled to be placed.

Traffic opening: This control allows you to select the month and year the pavement is scheduled to be open to traffic. DARWin-ME predicts pavement performance beginning from this month and year.

11.2 Performance Criteria

Performance verification forms the basis of the acceptance or rejection of a trial design evaluated using DARWin-ME. The design procedure is based on pavement performance, and therefore, the critical levels of pavement distresses that can be tolerated by the agency at the selected level of reliability needs to be specified by the user. If the simulation process shows the trial design produces excessive amount of distresses, then the trial design must be modified accordingly to produce a feasible design in the future trials.

The distress types considered in the design of an AC overlay of fractured pavement are total rutting (all layers and subgrade), AC rutting, load-related top-down cracking (longitudinal cracking in the wheel path) and bottom-up fatigue cracking (alligator cracking), and thermal cracking (transverse cracking). In addition, pavement smoothness is considered for performance verification and is characterized using the International Roughness Index (IRI).

Performance Criteria (AC Overlay of Fractured JPCP)

Populating the Inputs in this Interface

Performance Criteria	Limit	Reliability
Initial IRI (n./mile)	63	
Terminal IRI (n./mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal fracture (ft/mile)	250	90
Chemically stabilized layer - fatigue fracture (percent)	25	90
Permanent deformation - total pavement (in.)	0.75	90
Permanent deformation - AC only (in.)	0.25	90

Performance Criteria (AC Overlay of Fractured JPCP)

Populating the Inputs in this Interface

This table allows you to define the limits of critical distresses and smoothness that can be tolerated by the agency at the specified reliability levels. This table has three columns:

Performance Criteria: This column provides a list of performance indicators required to ensure that a pavement design will perform satisfactorily over its design life.

Limit: This column allows you to define the threshold values of these performance indicators to evaluate the adequacy of a design.

Reliability: This column allows you to define the probability at which the predicted distresses and smoothness will be less than the limits over the design period.



You can override the program defaults to enter project-specific threshold limits and reliability values representing agency policies. Refer to Chapter 8 of the AASHTO Manual of Practice for more guidance on selecting design criteria and reliability level.

Initial IRI (in./mile): The limit control allows you to define the expected smoothness immediately after new pavement construction (expressed in terms of IRI). Initial IRI is a very important input as the time from initial construction to attaining threshold IRI value is very much dependent on the initial IRI obtained at the time of construction. Thus, the initial IRI value provided must be what is typically attained in the field. You can override the DARWin-ME default value of 63 in./mi to reflect agency policy and guidelines.

Terminal IRI (in./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for IRI at the end of the design life at a specified reliability level.

AC top-down fatigue cracking (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for surface initiated fatigue cracking at the end of the design life at a specified reliability level.

AC bottom-up fatigue cracking (percent): The limit and reliability controls for this criterion controls allow you to define the not-to-exceed limit for bottom-initiated fatigue cracking at the end of the design life at a specified reliability level.

AC thermal fracture (ft./mile): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for non-load related transverse cracking at the end of the design life at a specified reliability level.

Permanent deformation - total pavement (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for total rutting at the end of the design life at a specified reliability level. Total permanent deformation at the surface is the accumulation of the permanent deformation in all of the asphalt and unbound layers in the pavement system.

Permanent deformation - AC only (in.): The limit and reliability controls for this criterion allow you to define the not-to-exceed limit for rutting contributed by the AC layers at the end of the design life at a specified reliability level.

11.5 Pavement Structure Definition and Materials

11.5.1 Asphalt Concrete (New) Layer

Refer to section 8.5.1 Asphalt Concrete (New) Layer

11.5.2 Fractured PCC Layer

DARWin-ME considers three methods of fracturing existing pavement PCC as defined below:

- Rubblization: Applicable to all PCC slabs. Used for fracturing existing PCC slabs into pieces less than 12 inches reducing the existing PCC slab to a high-strength nonstabilized material. Rubblization is commonly applied to PCC layers with extensive deterioration (severe mid-slab cracks, faulting, spalling at cracks and joints, Dcracking, etc.).
- Crack and Seat: Applicable to PCC slabs. Used for fracturing the PCC slabs into pieces typically one to three feet in size.
- Break and Seat: Applicable to jointed reinforced concrete pavement (JRCP) slabs. Used for rupturing the reinforcing steel in JRCP across each crack and breaking its bond with the PCC.

Way to Access this Interface

Open a project with AC over fractured PCC and select fractured PCC in the Layer control.

Layer 1 Stabilized Base : Fractured JPCP	
General	
Layer thickness (in.)	<input checked="" type="checkbox"/> 10
Unit weight (pcf)	<input checked="" type="checkbox"/> 150
Poisson's ratio	<input checked="" type="checkbox"/> 0.2
Strength	
Elastic/resilient modulus (psi)	<input checked="" type="checkbox"/> 2000000
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	<input checked="" type="checkbox"/> 1.25
Heat capacity (BTU/lb-deg F)	<input checked="" type="checkbox"/> 0.28
Identifiers	
Display name/identifier	Fractured JPCP

Elastic/resilient modulus (psi)
The elastic modulus of the chemically stabilized layer.
Minimum:50000
Maximum:5000000

Fractured PCC Layer Properties

Ways to Enter Inputs

There are three methods for entering data for the fractured PCC layer:

- Manual entry
- Import from file
- Import from database

Populating the Input in this Interface

General

Layer thickness (in.): This control allows you to define the thickness of the fractured PCC layer.

Unit weight (pcf): This control allows you to define the weight per unit volume of the fractured PCC material. DARWin-ME provides a default value of 150 pcf.

Poisson's ratio: This control allows you to define the Poisson's ratio of the fractured PCC material. DARWin-ME provides a default value of 0.2.

Strength

Elastic/resilient modulus (psi): This control allows you to define the required elastic/resilient modulus value of fractured PCC materials. One method commonly used to estimate the elastic modulus of the fractured PCC pavement is to perform FWD deflection tests and backcalculate fractured PCC layer modulus from the deflection basins measured. This is mostly done on several similar projects to estimate typical values. Typical moduli values range from 150,000 to 1,000,000 psi for crack/seal and break/seal and 50,000 to 150,000 psi for rubblized PCC.

Thermal

Thermal conductivity (BTU/hr-ft-deg F): This control allows you to define the thermal conductivity of the fractured PCC material. DARWin-ME provides a default value of 1.25 Btu/(ft)(hr)(°F).

Heat capacity (BTU/lb-deg F): This control allows you to define the heat capacity of the fractured PCC material. DARWin-ME provides a default value of 0.28 Btu/(lb)(°F).

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.3 PCC Mixtures, Lean Concrete, and Cement Treated Base Layers

11.5.3 Chemically Stabilized Layer

The required inputs for a chemically stabilized layer can be broadly classified as general, strength, and thermal properties. Note that the strength properties required by DARWin-ME are different for flexible and rigid pavements.

The chemically stabilized materials include lean concrete, cement stabilized, open graded cement stabilized, soil cement, lime-cement-flyash, and lime treated materials.

Refer to Section 5.5.2 **Chemically Stabilized Layer**

11.5.4 Non-Stabilized Layer

Non-stabilized materials include AASHTO soil classes A-1 through A-3, as well as those commonly defined in practice as crushed stone, crushed gravel, river gravel, permeable aggregate, and cold recycled asphalt material (includes millings and in-place pulverized material).

Inputs required for non-stabilized materials include physical and engineering properties such

Refer to Section 5.5.3 **Non-Stabilized Layer**

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

11.5.5 Subgrade

Subgrade materials include soil classes A-1 through A-7-6 defined in accordance with the AASHTO soil classification system.

Inputs required for subgrade materials are same as those of non-stabilized materials, and include physical and engineering properties such as dry density, moisture content, hydraulic conductivity, specific gravity, soil-water characteristic curve (SWCC) parameters, classification properties, and the resilient modulus.

Refer to Section 5.5.3 Subgrade

Links to Relevant Section in AASHTO Manual of Practice

Refer to Section 11.5 Unbound Aggregate Base Materials and Engineered Embankments.

11.5.6 Bedrock

A bedrock layer, if present under an alignment, could have a significant impact on the pavement's mechanistic responses and therefore need to be fully accounted for in design. This is especially true if backcalculation of layer moduli is adopted in rehabilitation design to

characterize pavement materials. While the precise measure of the stiffness is seldom, if ever, warranted, any bedrock layer must be incorporated into the analysis.

Refer to Section 5.5.5 **Bedrock**

11.6 AC Layer Properties

This screen allows you to define other inputs pertinent to flexible pavement design.

Refer to Section 8.5.1 and 8.5.2 AC Layer (New) and AC Layer (Existing)

11.7 Backcalculation

The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The moduli typically are obtained using nondestructive deflection basin tests and standard backcalculation procedures. The backcalculated moduli closely match the actual in situ moduli of the existing pavement layers and subgrade. The Backcalculation option allows you to use backcalculated layer moduli of existing pavement layers and subgrade in overlay designs. The moduli typically are obtained using nondestructive deflection basin tests and standard backcalculation procedures. The backcalculated moduli closely match the actual in situ moduli of the existing pavement layers and subgrade.

Refer to Section 8.7 Backcalculation

5.7 Thickness Optimization

After establishing a trial design, DARWin-ME allows you to optimize the thickness of any layer above the foundation (semi-infinite thickness). **You can only optimize a single layer at a time in 0.5 inch increments.**

Optimization is the selection of the lowest thickness within a given range of maximum and minimum thicknesses you define. DARWin-ME first selects the minimum thickness value and determines if the minimum thickness satisfies the performance criteria. If the run is successful, the process stops there. Otherwise, the program selects the maximum thickness value for its next run. If both minimum and maximum thicknesses are unsuccessful, the process stops. If the maximum thickness value is successful, the program selects the mid-point thickness value between the maximum and minimum thickness for its third run. Irrespective of the outcome, the program chooses the mid-point between the thickness of the last successful run and the last unsuccessful run for all further runs.

Way to Access this Interface

In the Explorer tab, expand Project tree and double-click on the Optimization node.

Populating the Inputs in this Interface

The Design Layers table displays the pavement layers (above the foundation layer) of your trial design. This table has five controls (columns):

Use: This control allows you to select a pavement layer of your choice for which the layer thickness will be optimized. You can select only one layer at a time.

Layer: This control displays the layer type as defined in your trial design.

Default Thickness: This control displays the thickness of the given layer you defined in the materials property page.

Minimum Thickness: This control allows you to define the minimum thickness for which the given layer will be optimized.

Maximum Thickness: This control allows you to define the maximum thickness for which the given layer will be optimized.

Click on the Optimize Thickness button found at the bottom of the screen to run the optimization process. In real-time, DARWin-ME displays the history of the optimization process by showing thickness and outcomes of all previous runs. In addition, the program also displays the thickness and status of the current run. At the top left of the screen, the Last Optimized Thickness control updates the results of the optimization process in real time. A green fill displayed in the control box indicates the thickness of the last successful run, while a red fill indicates the last unsuccessful run i.e. none of the previous runs were successful.

1. Select a layer in the list. Check its check box.
2. Enter values for Minimum Thickness and Maximum Thickness.
3. Click on the Optimize button.
4. The application will perform all calculations. When it has found the lowest allowable thickness, it will display in the Last Optimized Thickness field at the top-left of the tab.

Optimization Rules Table

Use: This control, when activated, includes the current row of rule information as part of the optimization parameters.

Property: This control allows you to select a property of the design to modify in order to customize the optimization process.

Rules: This control allows you to enter valid text rules (one per line) to apply to the design property identified in the Property field of this table.

Criteria: This control allows you to enter valid text that establishes the limits (such as upper and lower) of the modification entered into the Rules field.

5.8 Sensitivity Analysis

The Sensitivity Analysis allows you to define minimums and maximum levels for selected parameters to test the design limits in Sensitivity tab.

Way to Access this Interface

Click the Sensitivity node in the Explorer tree.

Populating the Inputs in this Interface *Run Factorial:* Enable this control to calculate all permutations of the selected number of increments of each defined property range. Disable this control to prevent DARWin-ME from calculating all permutations of the selected number of increments of each defined property range.

Create Sensitivity: This button creates a sensitivity project based on the parameters that you defined in the Sensitivity Table.

Run Sensitivity: This button calculates the sensitivity project.

View Summary: This button generates a summary report of Pass/Fail results based on the parameters that you defined in the Sensitivity Table.

Sensitivity Table: This table allows you to define the parameters of a sensitivity project.

Use: Enable this control to include the associated layer property in the sensitivity analysis. Disable this control to prevent DARWin-ME from including the associated layer property in the sensitivity analysis.

Property: This column displays the names of properties associated with a particular layer.

Layer: This column displays the names of the layers in the project.

Default: This column displays the default values of associated properties for particular layers.

Minimum: This column allows you to define the lower bound of the range for the property of a particular layer that you want to evaluate.

Maximum: This column allows you to define the upper bound of the range for the property of a particular layer that you want to evaluate.

of Increments: This column allows you to define how often DARWin-ME will calculate sensitivity between the minimum and maximum range.

Entering Inputs

To run a sensitivity analysis:

1. Enable the Use control associated with a design property in a layer that you want to evaluate.
2. Define Minimum, Maximum, and # of Increments values for the design property.
3. Click Create Sensitivity and wait until the action is complete.
4. Click Run Sensitivity and wait until the action is complete.
5. Click View Summary to open the report.

5.9 Run Analysis

To perform an analysis on a single project:

After you defined the project parameters, click . DARWin-ME will perform the analysis and generate reports.

To perform a Batch Run:

1. Right click and select the "Load Projects" control on the Batch Run node on the [Explorer Pane](#).
2. Browse to the folder(s) containing the projects to be run in the batch mode.
3. Select the "Run Batch Projects" control to enable DARWin-ME to run multiple projects in batch. Alternately, the user can also click on the icon on the DARWin-ME Menu run projects in batch.

4. After the analysis is complete, right click and select the "View Batch Report" control on the Batch Run node on the [Explorer Pane](#) to generate a summary of the batch project run results. The user can also double click the individual project nodes

14 Interpretation and Analysis of the Trial Design

The Darwin-ME software predicts the performance of the trial design in terms of key distress types and smoothness at a specified reliability (refer to Section 5). The designer initially decides on a “trial design” for consideration, as discussed in Sections 12 and 13. This trial design may be obtained from the current AASHTO Design Guide, the result of another design program, a design catalog, or a design created solely by the design engineer.

The Darwin-ME software analyzes that trial design over the selected design period. The program outputs the following information: inputs, reliability of design, materials and other properties, and predicted performance. Each of these outputs needs to be examined by the designer to achieve a satisfactory design as described in this section. An unacceptable design is revised and re-run to establish its performance until all criteria are met. This “trial and error” process allows the pavement designer to “build the pavement in his/her computer,” prior to building it in the field to ensure that the performance expectations will be met as economically as possible. The purpose of this section is to provide some guidance on what design features could be revised for the trial design to be accepted.

14.1 Summary of Inputs for the Trial Design

A unique feature of the Darwin-ME software is that nearly all of the actual program inputs are included in this section of the outputs. Details of the climatic data and the axle load distributions are not included here. The designer needs to review all of these inputs to ensure that no mistake has been made in entering the data. Given the large number of inputs, this check is essential.

14.2 Reliability of Trial Design

Another important output is an assessment of the design reliability, which may be seen under the Reliability Summary tab. The Distress Target and its corresponding Reliability Target are the first right-hand columns listed, followed by the Distress Predicted and the Reliability Predicted. If the Reliability Predicted is greater than the Reliability Target then the pavement passes. If the reverse is true, then the pavement fails. If any key distress fails, the designer needs to alter the trial design to correct the problem. Examples are shown below for a flexible and rigid pavement (Tables 44 and 45, respectively).

- For the flexible pavement example (Table 44), the asphalt concrete (AC) surface down cracking met the reliability criterion ($99.92 > 90\%$), but terminal IRI did not ($52.51 < 90\%$). This trial design is not acceptable at the 90% reliability level and needs to be revised.
- For the JPCP example (Table 45), the mean joint faulting met the reliability criterion ($98.09 > 95\%$), but terminal IRI did not ($93.98 < 95\%$). This trial design is not acceptable at the 90% reliability level and needs to be revised.

Table 44. Reliability Summary for Flexible Pavement Trial Design Example

Project:	US 305				
Reliability Summary					
Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable?
Terminal IRI (in./mi.)	172	90	169.3	52.51	Fail
AC Surface Down Cracking (Long. Cracking; ft./mi.)	2000	90	5	99.92	Pass
AC Bottom Up Cracking (Alligator Cracking; %)	25	90	0.1	99.999	Pass
AC Thermal Fracture (Transverse Cracking; ft./mi.)	1000	90	1	94.16	Pass
Chemically Stabilized Layer (Fatigue Fracture)	25	90	NA	NA	NA
Permanent Deformation (AC Only; in.)	0.25	90	0.58	1.66	Fail
Permanent Deformation (Total Pavement; in.)	0.75	90	0.71	59.13	Fail

14.3 Supplemental Information (Layer Modulus, Truck Applications, and Other Factors)

Another unique feature of the Darwin-ME software is that the materials properties and other factors are output on a month-by-month basis over the design period. The designer needs to examine the output materials properties and other factors to assess their reasonableness. For flexible pavements, the output provides the HMA dynamic modulus (EHMA) and the resilient modulus (Mr) for unbound layers for each month over the design period. Moisture content and frost condition greatly affects the unbound materials Mr.

The Darwin-ME provides a graphical output of selected modulus values for the HMA layers. The dynamic modulus for the first quintile of temperatures (the lower temperatures) for each sublayer is plotted over the design life of the pavement. All HMA dynamic modulus values for each temperature quintile and sublayer are included in a tabular format. In addition, the resilient modulus for the unbound layers and foundation are also included in that tabular format for each month over the design life of the pavement.

The designer should examine the monthly output materials properties, number of trucks (Class 4 and higher), and other factors to assess their reasonableness. These are all output at the end of the month.

Flexible pavements key outputs that need to be observed and evaluated include the following.

- HMA Dynamic Modulus (EHMA) of each layer. The software divides each HMA input layer into sublayers and each need to be examined for reasonableness. Materials properties as well as temperature and load speed typically have significant effects on EHMA.
- Unbound material resilient modulus (Mr) for unbound layers for each month over the design period can be examined. The software divides each unbound material input layer (such as a

granular base course) into sublayers and each need to be examined for reasonableness. Moisture content and frost condition greatly affects the unbound materials Mr.

○ The number of cumulative Heavy Trucks (Class 4 and above) are output shown for the design traffic lane. The total cumulative Heavy Trucks may be examined at the last month of the analysis period. This parameter is a good general indicator of how heavy the truck traffic (volume) is for the design (e.g., 1 million trucks, 20 million trucks, or 100 million trucks is the terminology recommended for design purposes). Note that these may be converted into flexible pavement 18-kip ESALs by multiplying them by an average truck factor, or the actual number of ESALs may be determined by examining an intermediate file by this name that has this information.

14.4 Predicted Performance Values

The software outputs month-by-month the key distress types and smoothness over the entire design period. The designer needs to carefully examine them to see if they appear reasonable and also meet the specified performance criteria.

Flexible pavements.

○ Longitudinal fatigue cracking: top down fatigue cracking in the wheel paths. A critical value is reached when longitudinal cracking accelerates and begins to require significant repairs and lane closures.

○ Alligator fatigue cracking: traditional bottom up fatigue cracking in the wheel paths. A critical value is reached when alligator cracking accelerates and begins to require significant repairs and lane closures.

○ Transverse cracking: caused by low temperatures that result in fracture across the traffic lanes. A critical value is reached when transverse cracking results in significant roughness.

○ Rutting or permanent deformation: HMA rutting is only in the asphalt bound layers and total rutting combines all of the pavement layers and the subgrade. A critical value is reached when rutting becomes sufficient enough to cause safety concerns.

○ IRI: this index represents the profile of the pavement in the wheel paths. A critical value is reached as judged by highway users as unacceptable ride quality. IRI is a function of longitudinal cracking, transverse cracking, alligator cracking, and total rutting along with climate and subgrade factors.

○ Reflection cracking: reflection cracking occurs only when an HMA overlay is placed over an existing flexible pavement that has alligator fatigue cracking in the wheel paths, or over a jointed rigid pavement where transverse joints and cracks exist and occur. A critical value is reached when reflection alligator cracking results in significant maintenance requirements or when reflection transverse cracking results in significant maintenance requirements or roughness.

14.5 Judging the Acceptability of the Trial Design

While layer thickness is important, many other design factors also affect distress and IRI or smoothness. The designer needs to examine the performance prediction and determine which design feature to modify to improve performance (e.g., layer thickness, materials properties, layering combinations, geometric features, and other inputs). This subsection provides guidance on revising the trial design when the performance criteria have not been met.

The guidance given is distress- specific. The designer needs to be aware, however, that changing a design feature to reduce one distress might result in an increase in another distress. As an example, for excessive transverse cracking of an HMA pavement where the level 3 inputs were used, the user may consider using softer asphalt to reduce transverse cracking, but that will likely increase the predicted rutting. Another option is to use laboratory tests to measure the level 1 inputs, which could reduce or even increase the distress further.

More importantly, some of the input parameters are interrelated; changing one parameter might result in a change to another one. For example, decreasing asphalt content to make the HMA mixture more resistant to rutting will likely increase the in-place air voids resulting in more fatigue cracking. The designer needs to use caution in making changes to individual layer properties. It should be noted that some of these modifications are construction dependent and will be difficult to justify prior to building the pavement or placing the HMA overlay.

Flexible Pavements and HMA Overlays

Distress & IRI	Design Feature Revisions to Minimize or Eliminate Distress
Alligator Cracking (Bottom Initiated)	<ul style="list-style-type: none"> • Increase thickness of HMA layers. • For thicker HMA layers (> 5-inches) increase dynamic modulus. • For thinner HMA layers (<3-inches) reduce dynamic modulus. • Revise mixture design of HMA base layer (increase percent crushed aggregate, use manufactured fines, increase asphalt content, use a harder asphalt but ensure that the same percent compaction level is achieved along the roadway, use a polymer modified asphalt, etc.) • Increase density, reduce air void of HMA base layer. • Increase resilient modulus of aggregate base (increase density, reduce plasticity, reduce amount of fines, etc.)
Thermal Transverse Cracking	<ul style="list-style-type: none"> • Increase the thickness of the HMA layers • Use softer asphalt in the surface layer • Reduce the creep compliance of the HMA surface mixture • Increase the indirect tensile strength of the HMA surface mixture • Increase the asphalt content of the surface mixture
Rutting in HMA	<ul style="list-style-type: none"> • Increase the dynamic modulus of the HMA layers • Use a polymer modified asphalt in the layers near the surface. • Increase the amount of crushed aggregate • Increase the amount of manufactured fines in the HMA mixtures • Reduce the asphalt content in the HMA layers
Rutting in Unbound Layers and Subgrade	<ul style="list-style-type: none"> • Increase the resilient modulus of the aggregate base; increase the density of the aggregate base • Stabilize the upper foundation layer for weak, frost susceptible, or swelling soils; use thicker granular layers. • Place a layer of select embankment material with adequate compaction • Increase the HMA thickness
IRI HMA	<ul style="list-style-type: none"> • Require more stringent smoothness criteria and greater incentives (building the pavement smoother at the beginning). • Improve the foundation; use thicker layers of non-frost susceptible materials • Stabilize any expansive soils • Place subsurface drainage system to remove ground water.
Longitudinal Fatigue Cracking (Surface Initiated)	<p>NOTE: Refer to Section 3; it is recommended that the surface initiated crack prediction equation not be used as a design criterion until the critical pavement response parameter and prediction methodology has been verified.</p> <p>The cumulative damage and longitudinal cracking transfer function (equations 5 and 8) should be used with caution in making design decisions regarding the adequacy of a trial design, in terms of longitudinal cracking (top-down cracking).</p> <ul style="list-style-type: none"> • Reduce the dynamic modulus of the HMA surface course. • Increase HMA thickness. • Use softer asphalt in the surface layer. • Use a polymer modified asphalt in the surface layer; the MEPDG does not adequately address the benefit of PMA mixtures.
Reflection Cracking	<p>NOTE: It is recommended that the amount of reflection cracks not be used as a design criterion until the prediction equation has been calibrated.</p> <ul style="list-style-type: none"> • Increase HMA overlay thickness. • Increase the modulus of the HMA overlay.