

DESIGN EXAMPLES

Example 1 – Aggregate Base Design

Location: Metro, Ramsey County

Design parameters: The predominant soil type is Clay Loam, ESALs = 4,179,000. The minimum depth required is 30 inches (ESALs greater than 1,000,000) unless chart gives greater thickness.

Grading: A 12 inch compaction subcut will be constructed.

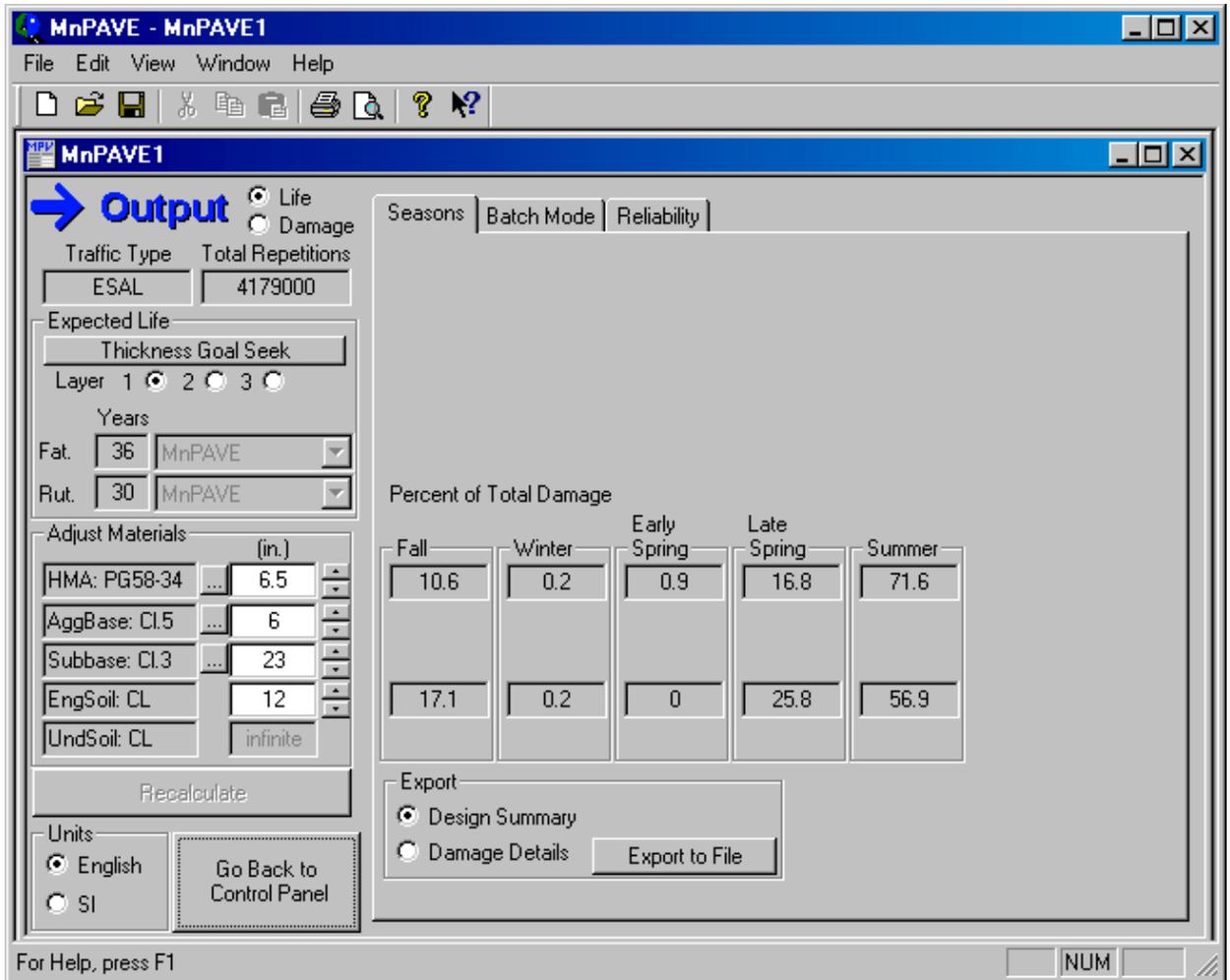
R-value Design

The design chart gives a GE requirement of 36.8 inches and the following minimum thickness: 6.5 inches HMA, 6.0 inches Class 6 base, 6 inches Class 4, and 16.5 inches Class 3. The total thickness of these is over 30 inches so go with this.

MnPAVE Design

1. Fill in the project information under Project Information window (see attached design summary report).
2. Open Climate window, click on Ramsey county.
3. Open Structure window; Input the above pavement structure obtained from the R-value design into MnPAVE (substitute Class 3 for Class 4). In this case, since the R-value of subgrade soils is unknown, Basic level is used for the design. Select Clay Loam for Engineered Soil and Undisturbed Soil. Engineered Soil is used to model the compacted subcut soil.
4. Input design ESALs of 4,179,000 in Traffic window.
5. The output is shown below:

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MnPAVE gives a fatigue design life of 36 years and rutting life of 30 years. Since the pavement design life is 20 years, this design is conservative.

- Now, use the “Thickness Goal Seek” function and select the “Layer 1” option to obtain HMA layer thickness such that one of the design lives reaches 20 years. In this case, the Bearing Capacity check is exceeded as shown below. MnPAVE will automatically dimension the HMA layer such that the stress levels are satisfied.

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Allowable Stress Results

Material: AggBase: Cl.5
 Location: Middle of layer

Adjust Layer 1 Thickness to Meet Requirements

c psi (Results based on Class 5 laboratory tests)

ϕ °

	Current Thickness	Required Thickness
Layer 1 Thickness (in.)	5.2	5.6
σ_1 psi	20.03	18.22
σ_3 psi	0	0
σ_1 critical psi	18.48	18.48

Always show this window
 Show if material fails

7. Select the “Adjust Layer 1 Thickness” button to automatically change the HMA thickness. The resulting output is obtained.

MnPAVE - MnPAVE 1

File Edit View Window Help

MnPAVE 1

Output Life Damage

Traffic Type: ESAL Total Repetitions: 4179000

Expected Life: Thickness Goal Seek

Layer 1 2 3

Years: Fat. 24 MnPAVE Rut. 24 MnPAVE

Adjust Materials (in.)

HMA: PG58-34	5.6
AggBase: Cl.5	6
Subbase: Cl.3	23
EngSoil: CL	12
UndSoil: CL	infinite

Recalculate

Units: English SI

Seasons | Batch Mode | Reliability

Percent of Total Damage

Season	Fall	Winter	Early Spring	Late Spring	Summer
Life	11	0.2	1.1	17.5	70.3
Damage	18	0.2	0	27	54.7

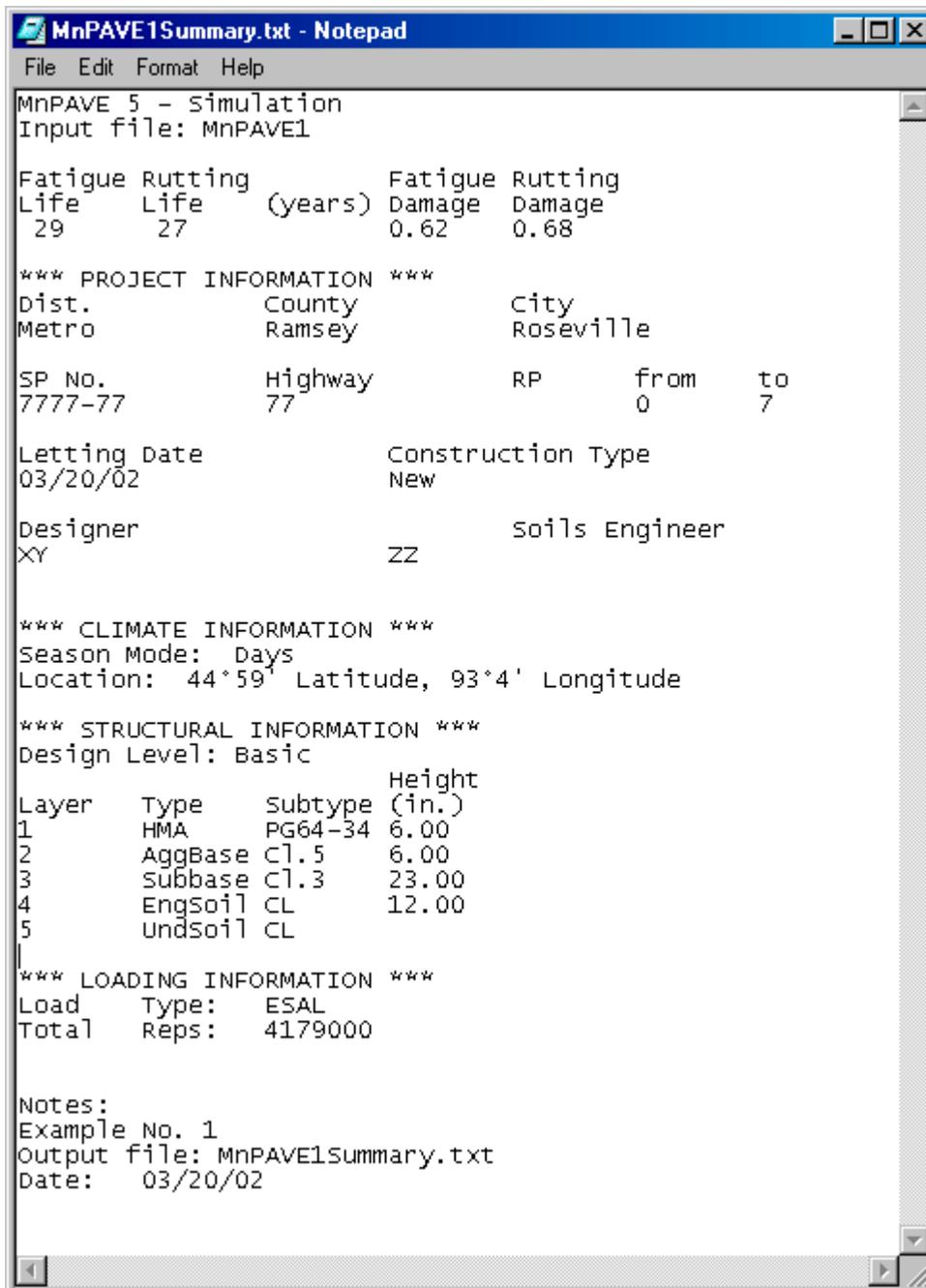
Export: Design Summary Damage Details

For Help, press F1 NUM

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At this point the designer may round the HMA thickness up to 6.0 inches which results in a design that still appears to be conservative. These results were obtained with the default base failure load criteria. The designer should evaluate the validity of these loads for the particular job they are designing for.

- MnPAVE is also capable of exporting results of varying detail. Below is an example of the Design Summary output. This is obtained by selecting "Design Summary" in the "Export" window and clicking the "Export to File" button.



```
MnPAVE 5 - Simulation
Input file: MnPAVE1

Fatigue Rutting      Fatigue Rutting
Life   Life   (years)  Damage  Damage
 29    27                0.62    0.68

*** PROJECT INFORMATION ***
Dist.      County      City
Metro      Ramsey      Roseville

SP No.      Highway      RP      from      to
7777-77      77                0        7

Letting Date      Construction Type
03/20/02          New

Designer      Soils Engineer
XY            ZZ

*** CLIMATE INFORMATION ***
Season Mode: Days
Location: 44°59' Latitude, 93°4' Longitude

*** STRUCTURAL INFORMATION ***
Design Level: Basic

Layer  Type      Subtype  Height
1      HMA       PG64-34  6.00
2      AggBase  C1.5    6.00
3      Subbase  C1.3    23.00
4      Engsoil  CL      12.00
5      Undsoil  CL

*** LOADING INFORMATION ***
Load   Type:  ESAL
Total  Reprs: 4179000

Notes:
Example No. 1
Output file: MnPAVE1Summary.txt
Date: 03/20/02
```

DESIGN EXAMPLES

Example 2 –Full Depth / Deep Strength Design

Location: District 8, Redwood County

Design parameters: The predominant soil type encountered is Clay Loam. The design R-value is 12, ESALs = 4,179,000. Total depth required is 30 inches (ESALs greater than 1,000,000) unless chart gives greater thickness.

Grading: A 12 inch compaction subcut will be constructed.

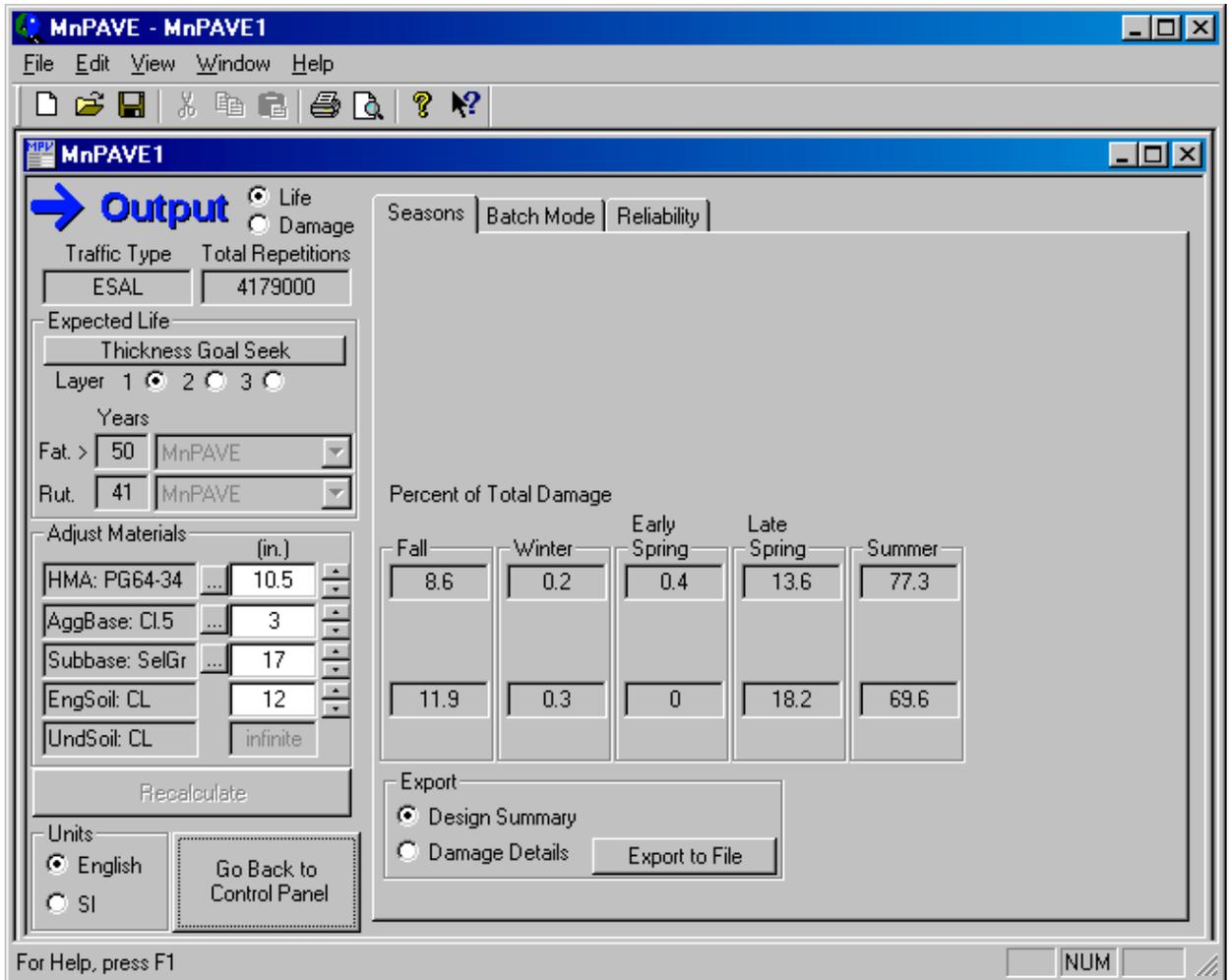
Full Depth Design

The initial thickness is determined from the full-depth design chart (12.2 inches HMA). Determine the “Z” depth ($30 - 3 - 12 = 15$ inches select granular). Determine GE of this ($15 \times 0.5 = 7.5$ inches). Next, adjust the R-value (using R-value chart this is found to be 29). Determine the new full-depth thickness with this adjusted R-value (10.6 inches, use 10.5). The new “Z” depth is $30 - 3 - 10.5 = 16.5$ inches select granular. The final design is: 10.5 inches HMA, 3 inches Class 5, and 17 inches select granular.

MnPAVE Design

1. Fill project information under Project Information window.
2. Open the Climate window, click on Redwood County in District 8.
3. Open Structure window; Input the above pavement structure obtained from the R-value design into MnPAVE. Since the design R-value of the engineered soil is known, the Intermediate level can be used for design. Input R=12 for Engineered Soil under Intermediate window.
4. Input design ESALs of 4,179,000 under the Traffic window.
5. The output is shown below:

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As can be seen the deep strength thickness results in an extremely conservative design compared to the aggregate base thickness shown in the previous example.

6. Now select "Thickness Goal Seek" for the HMA layer to obtain:

DESIGN EXAMPLES

The screenshot shows the MnPAVE software interface. The main window is titled "MnPAVE1" and contains several sections:

- Output Section:**
 - Traffic Type: ESAL
 - Total Repetitions: 4179000
 - Expected Life: Thickness Goal Seek
 - Layer: 1 (selected), 2, 3
 - Years: Fat. 44, MnPAVE; Rut. 20, MnPAVE
 - Adjust Materials (in.):

HMA: PG64-34	7.4
AggBase: CL5	3
Subbase: SelGr	17
EngSoil: CL	12
UndSoil: CL	infinite
 - Units: English (selected), SI
 - Buttons: Recalculate, Go Back to Control Panel
- Percent of Total Damage Table:**

	Fall	Winter	Early Spring	Late Spring	Summer
	10.1	0.2	0.7	15.8	73.3
	14.1	0.3	0	21.4	64.2
- Export Section:**
 - Design Summary (selected)
 - Damage Details
 - Export to File

At the bottom of the window, it says "For Help, press F1" and "NUM".

This results in a total structural thickness that is less than the minimum required 30 inches so if this were an actual design you would need to add several inches of Select Granular.

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Example 3 – Mn/DOT project (Aggregate Base Design)

Location: District 6, Fillmore County

Soil Type(s): Silt loam.

Available test data: A total of 10 samples were tested for R-value. The mean value was 13 with a standard deviation of 3.

Given information: Design ESALs = 1,905,000. Construct top 2 feet of grading subgrade with Select Granular.

R-Value Design

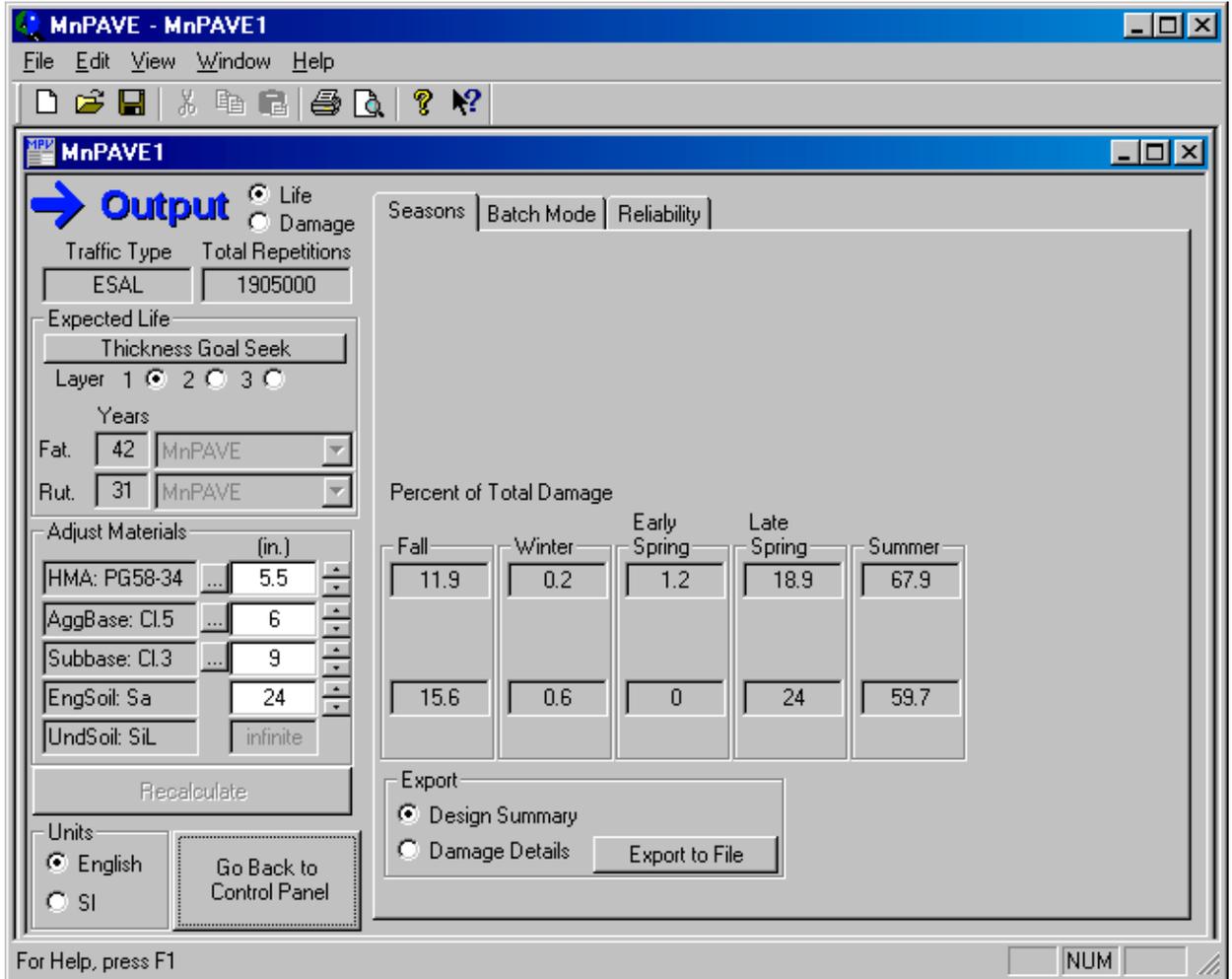
The design chart gives the following minimum thicknesses: 5.4 inches HMA, 6.0 inches Class 6, 6.0 inches Class 4, and 19.1 inches Class 3. Convert part of the Class 3 to Select Granular which leaves approximately 3 inches of Class 3. The final design is: 5.5 inches HMA, 6.0 inches Class 6, 6.0 inches Class 4, 3.0 inches Class 3, and 24 inches Select Granular.

MnPAVE Design

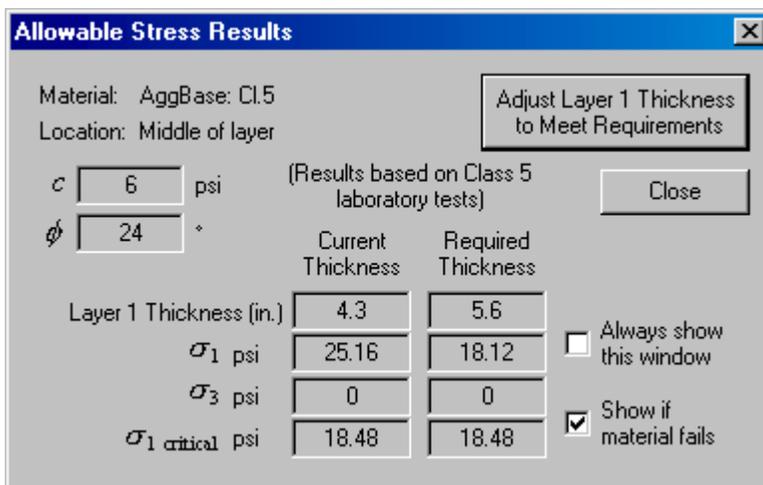
1. Since R-value is known, the designer can use Intermediate level. Input R-value=10 in the Intermediate window. Combine 6.0 inches Class 4 and 3 inches Class 3 to 9 inches Class 3 and use Sand as Engineered Soil to model Select Granular.
2. In the Traffic window, input design ESALs of 1,905,000.

DESIGN EXAMPLES

3. The output is shown below:



4. Since the design is conservative try using “Thickness Goal Seek” to refine the design. This results in the following warning for base bearing capacity:



DESIGN EXAMPLES

If the HMA layer is adjusted to meet the requirements we obtain the following result:

The screenshot shows the MnPAVE software interface. The main window is titled "MnPAVE - MnPAVE1". The interface includes a menu bar (File, Edit, View, Window, Help) and a toolbar. The main area is divided into several sections:

- Output:** A blue arrow icon and the word "Output".
- Life/Damage:** Radio buttons for "Life" (selected) and "Damage".
- Traffic Type:** A dropdown menu showing "ESAL".
- Total Repetitions:** A text box containing "1905000".
- Expected Life:** A text box containing "Thickness Goal Seek".
- Layer:** Radio buttons for "Layer 1", "2", and "3", with "1" selected.
- Years:** Text boxes for "Fat." (44) and "Rut." (31), each with a dropdown menu set to "MnPAVE".
- Adjust Materials:** A table of material layers with their thicknesses in inches (in.):

Material	Thickness (in.)
HMA: PG58-34	5.6
AggBase: Cl.5	6
Subbase: Cl.3	9
EngSoil: Sa	24
UndSoil: SiL	infinite
- Recalculate:** A button.
- Units:** Radio buttons for "English" (selected) and "SI".
- Go Back to Control Panel:** A button.
- Percent of Total Damage:** A table showing damage percentages for different seasons:

Season	Fall	Winter	Early Spring	Late Spring	Summer
Top Row	11.7	0.2	1.1	18.7	68.3
Bottom Row	15.4	0.6	0	23.7	60.2
- Export:** Radio buttons for "Design Summary" (selected) and "Damage Details", with an "Export to File" button.

At the bottom of the window, there is a status bar with the text "For Help, press F1" and a "NUM" indicator.

5. Now try rounding the HMA thickness up or down to 6 or 5.5 inches. As it turns out, a thickness of 5.5 inches, even though it is less than the recommended 5.9 inches, still satisfies the base bearing capacity requirements. This example demonstrates the multiple levels of failure criterion of the procedure. In this case, the bearing capacity of the aggregate base controls the design.

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The screenshot shows the MnPAVE software interface with the following components:

- Menu Bar:** File, Edit, View, Window, Help
- Toolbar:** Standard file operation icons (New, Open, Save, Cut, Copy, Paste, Print, Find, Help, Undo, Redo).
- Output Panel (Left):**
 - Output:** Life (selected), Damage
 - Traffic Type:** ESAL
 - Total Repetitions:** 1905000
 - Expected Life:** Thickness Goal Seek
 - Layer:** 1 (selected), 2, 3
 - Years:** Fat: 42, MnPAVE; Rut: 31, MnPAVE
 - Adjust Materials (in.):**
 - HMA: PG58-34: 5.5
 - AggBase: Cl.5: 6
 - Subbase: Cl.3: 9
 - EngSoil: Sa: 24
 - UndSoil: SiL: infinite
 - Recalculate** button
 - Units:** English (selected), SI
 - Go Back to Control Panel** button
- Seasons Panel (Top):** Seasons | Batch Mode | Reliability
- Percent of Total Damage Table:**

	Fall	Winter	Early Spring	Late Spring	Summer
	11.9	0.2	1.2	18.9	67.9
	15.6	0.6	0	24	59.7
- Export Panel (Bottom):**
 - Design Summary (selected)
 - Damage Details
 - Export to File** button
- Status Bar:** For Help, press F1; NUM

DESIGN EXAMPLES

Example 4 – Soil Factor Design

Location: Metro County

Soil Type: Clay loam, A-6

Available test data: Samples indicate this project has a Soil Factor of 100.

Given Information: Design HCAADT = 450 and measured ESALs = 629,000, Urban section – construct top 2 feet of grading subgrade with Select Granular.

Analysis: The design soil factor is 100.

Soil Factor Design

The design chart gives the following minimum thicknesses: 3.5 inches HMA, 6.0 inches of Class 6, 15.0 inches of Class 4 subbase.

MnPAVE Design

1. Since the R-value of subgrade soil is unknown, use Basic level for the design. Input the above pavement structure into MnPAVE and use Sand to model Select Granular. Substitute Class 4 by Class 3.
2. In the Traffic window, input the design ESALs of 629,000, estimated annual growth rate of 3% and the expected heaviest axle weight. In this case, the heaviest single tire axle weight is 12,000 lbs and the heaviest dual tire axle weight is 20,000 lbs.
3. MnPAVE gives the following warning and shows that the required minimum HMA thickness is 4 inches. The designer may use the required thickness suggested by MnPAVE by click on “Adjust Layer 1 Thickness to Meet Requirements.” However, if the designer does not want to use the required thickness, the designer can ignore this warning by click on “Close.” In this case, the minimum 4 inches of HMA thickness suggested by MnPAVE is used and the design is shown below.

DESIGN EXAMPLES

Allowable Stress Results

Material: AggBase: Cl.6
 Location: Middle of layer

Adjust Layer 1 Thickness to Meet Requirements

c 6 psi (Results based on Class 5 laboratory tests) Close

ϕ 24 °

	Current Thickness	Required Thickness
Layer 1 Thickness (in.)	3.5	4
σ_1 psi	21.28	18.46
σ_3 psi	0	0
σ_1 critical psi	18.48	18.48

Always show this window
 Show if material fails

MnPAVE - MnPAVE1

File Edit View Window Help

MnPAVE1

Output Life Damage

Traffic Type: ESAL Total Repetitions: 629000

Expected Life: Thickness Goal Seek

Layer 1 2 3

Years: Fat. 34 MnPAVE Rut. > 50 MnPAVE

Adjust Materials (in.):

HMA: PG58-34	4
AggBase: Cl.6	6
Subbase: Cl.3	15
EngSoil: Sa	24
UndSoil: CL	infinite

Recalculate

Units: English SI Go Back to Control Panel

Seasons | Batch Mode | Reliability

Percent of Total Damage

	Fall	Winter	Early Spring	Late Spring	Summer
Life	13.2	0.1	2.3	21	63.3
Damage	18.6	0.5	0	27.9	53

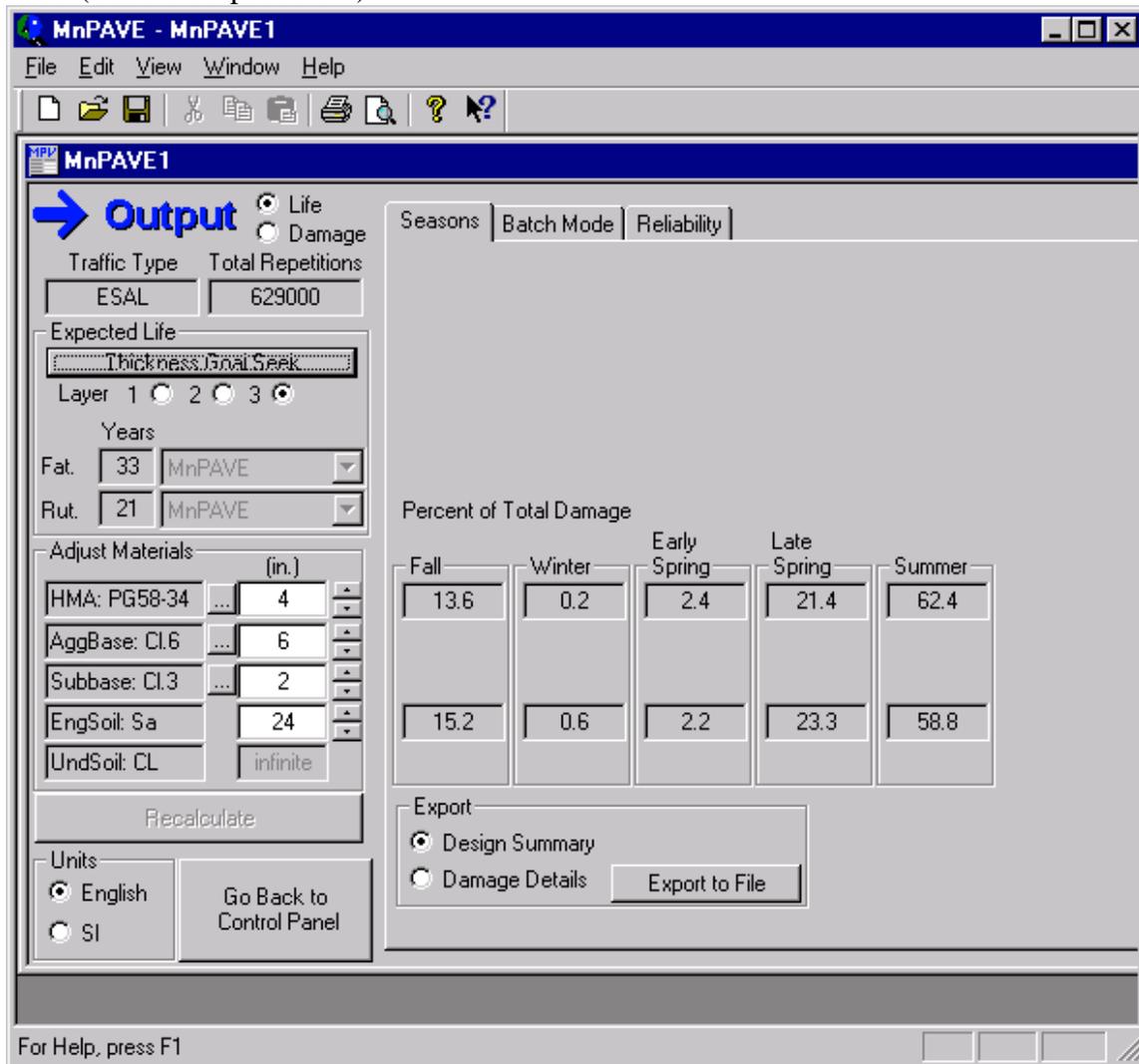
Export: Design Summary Damage Details Export to File

For Help, press F1

DESIGN EXAMPLES

MnPAVE shows that the design rutting life is greater than 50 years. So, this design is conservative. The designer can try to adjust Class 3 thickness so that the rutting life is close to 20 years.

4. Now, use “Thickness Goal Seek” function and select “Layer 3” to obtain the thickness of Class 3 layer. In this case, the rutting life has reached 20 years when Class 3 layer thickness is 2 inches (See the output below).



5. Check the required minimum pavement structural thickness of 30 inches (if it is required)

$$4+6+2+24 = 38 \text{ inches} > 30 \text{ inches. OK.}$$

6. Considering construction feasibility, the designer may convert 2 inches of Class 3 to 2 inches of Class 6, which results in a conservative design. See the design summary below for the final design. Attach the design summary to your design recommendation.

DESIGN EXAMPLES

```
Summary(SFexample4).txt - Notepad
File Edit Search Help
MnPAVE 5 - Simulation
Input file: MnPAVE1

Fatigue Rutting      Fatigue Rutting
Life   Life   (years) Damage  Damage
 36    21                0.46   0.91

*** PROJECT INFORMATION ***
Dist.      County      City
Metro      Ramsey

SP No.     Highway     RP      from   to
xxxxx     xxx                xxxx   xxx

Letting Date      Construction Type
03/18/02          xxxx

Designer          Soils Engineer
xxxxx             xxxxxx

*** CLIMATE INFORMATION ***
Season Mode: Days
Location: 45°0' Latitude, 93°6' Longitude

*** STRUCTURAL INFORMATION ***
Design Level: Basic

Layer  Type      Subtype (in.)  Height
 1     HMA      PG58-34      4.00
 2     AggBase  C1.6         8.00
 3     EngSoil  Sa          24.00
 4     UndSoil  CL

*** LOADING INFORMATION ***
Load   Type:   ESAL
Total  Reprs: 629000

Notes:
County Road Design
Output file: Summary(SFexample4).txt
Date: 03/20/02
```

DESIGN EXAMPLES

Example 5 – Soil Factor Design

Location: Metro County

Soil Type: Clay loam, A-6

Available test data: Samples indicate this project has a Soil Factor of 100.

Given Information: Design HCAADT = 450 and measured ESALs = 629,000, A 2.5 feet compaction subcut will be constructed.

Analysis: The design soil factor is 100.

Soil Factor Design

The design chart gives the following minimum thicknesses: 3.5 inches HMA, 6.0 inches of Class 6, 15.0 inches of Class 4 subbase.

MnPAVE Design

1. Since the R-value of subgrade soil is unknown, use Basic level for the design. Input the above pavement structure into MnPAVE. Substitute Class 4 by Class 3.
2. In the Traffic window, input the design ESALs of 629,000, estimated annual growth rate of 3% and the expected heaviest axle weight. In this case, the heaviest single tire axle weight is 12,000 lbs and the heaviest dual tire axle weight is 20,000 lbs.
3. MnPAVE gives the following warning and shows that the required minimum HMA thickness is 4 inches. The designer may use the required thickness suggested by MnPAVE by clicking on “Adjust Layer 1 Thickness to Meet Requirements.” However, if the designer does not want to use the required thickness, the designer can ignore this warning by click on “Close.” In this case, the minimum 4 inches of HMA thickness suggested by MnPAVE is used and the design is shown below.

DESIGN EXAMPLES

Allowable Stress Results [X]

Material: AggBase: Cl.6
 Location: Middle of layer

Adjust Layer 1 Thickness to Meet Requirements

c psi (Results based on Class 5 laboratory tests)

ϕ °

	Current Thickness	Required Thickness
Layer 1 Thickness (in.)	3.5	4
σ_1 psi	21.03	18.19
σ_3 psi	0	0
σ_1 critical psi	18.48	18.48

Always show this window
 Show if material fails

MnPAVE - MnPAVE1 [Min] [Max] [Close]

File Edit View Window Help

File Edit Print Help ?

MnPAVE1

→ **Output** Life Damage

Traffic Type: Total Repetitions:

Expected Life:

Layer: 1 2 3

Years: Fat. MnPAVE Rut. MnPAVE

Adjust Materials (in.):

HMA: PG58-34	<input type="text" value="4"/>
AggBase: Cl.6	<input type="text" value="6"/>
Subbase: Cl.3	<input type="text" value="15"/>
EngSoil: CL	<input type="text" value="30"/>
UndSoil: CL	<input type="text" value="infinite"/>

Units: English SI

Seasons | Batch Mode | Reliability

Percent of Total Damage

	Fall	Winter	Early Spring	Late Spring	Summer
Life	13.6	0.1	2.2	21.5	62.5
Damage	18.6	0.2	0	27.9	53.3

Export: Design Summary Damage Details

For Help, press F1

DESIGN EXAMPLES

MnPAVE shows that the design rutting life is 39 years. So, this design is conservative. The designer can try to adjust Class 3 thickness so that the rutting life is close to 20 years.

4. Now, use “Thickness Goal Seek” function and select “Layer 3” to obtain the thickness of Class 3 layer. In this case, the rutting life has reached 20 years when Class 3 layer thickness is 8 inches (See the output below).

The screenshot shows the MnPAVE software interface with the 'Output' window open. The 'Thickness Goal Seek' function is active, showing an expected life of 20 years and a Class 3 layer thickness of 8 inches. The 'Percent of Total Damage' table shows values for different seasons: Fall (13.9, 16.9), Winter (0.1, 0.2), Early Spring (2.1, 0), Late Spring (22, 25.7), and Summer (61.8, 57.1). The 'Export' section is set to 'Design Summary'.

Percent of Total Damage		Early Spring	Late Spring	Summer
Fall	Winter	2.1	22	61.8
13.9	0.1			
16.9	0.2	0	25.7	57.1

6. See the design summary for the final design. Attach the design summary to your design recommendation.

DESIGN EXAMPLES

```
Summary(SFexample5).txt - Notepad
File Edit Search Help
MnPAVE 5 - Simulation
Input file: MnPAVE1

Fatigue Rutting      Fatigue Rutting
Life   Life   (years) Damage  Damage
  31   20                0.56   0.97

*** PROJECT INFORMATION ***
Dist.      County      City
Metro      Ramsey

SP No.      Highway      RP      from      to
xxxxx      xxx                xxxx     xxx

Letting Date      Construction Type
03/18/02                xxxx

Designer      Soils Engineer
xxxxx                xxxxxx

*** CLIMATE INFORMATION ***
Season Mode: Days
Location: 45°0' Latitude, 93°6' Longitude

*** STRUCTURAL INFORMATION ***
Design Level: Basic

Layer  Type      Subtype  Height
1      HMA      PG58-34  4.00
2      AggBase  C1.6    6.00
3      Subbase  C1.3    8.00
4      EngSoil  CL      30.00
5      UndSoil  CL

*** LOADING INFORMATION ***
Load   Type:  ESAL
Total  Reps:  629000

Notes:
County Road Design
Output file: Summary(SFexample5).txt
Date: 03/20/02
```