

# **User Manual**

## **Software for Analysis of the Effect of Implements of Husbandry on Flexible Pavements**

NCHRP Project 01-58  
Quantifying the Effects of Implements of Husbandry on  
Pavements

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May 2022

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INTRODUCTION .....	1
SETUP INSTRUCTIONS .....	1
NEW ANALYSIS .....	4
MAIN TAB.....	5
HMA TAB.....	6
CLIMATE TAB.....	7
IOH TAB.....	8
DAMAGE ANALYSIS .....	9
DAMAGE TAB.....	10
TRUCK RESPONSES TAB AND IOH RESPONSE TAB.....	11
SAVING AND OPENING A PROJECT .....	12
OTHER OPTIONS .....	12
EXAMPLE .....	14

## INTRODUCTION

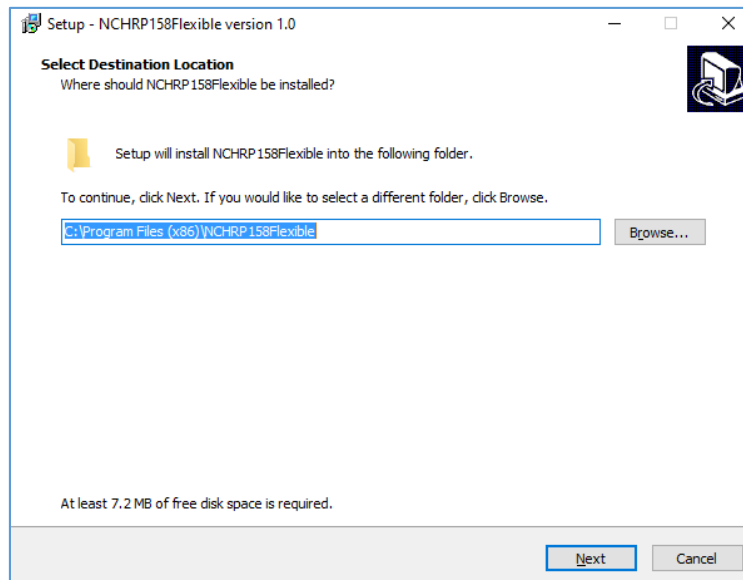
The flexible pavement analysis tool accompanying the NCHRP 1-58 procedure evaluates the viscoelastic response and the pavement damage of a flexible pavement to user-specified Implements of Husbandry (IoH) loads and compares them to that of a reference truck. This user manual provides instructions for installing the program and running an analysis on it.

## SETUP INSTRUCTIONS

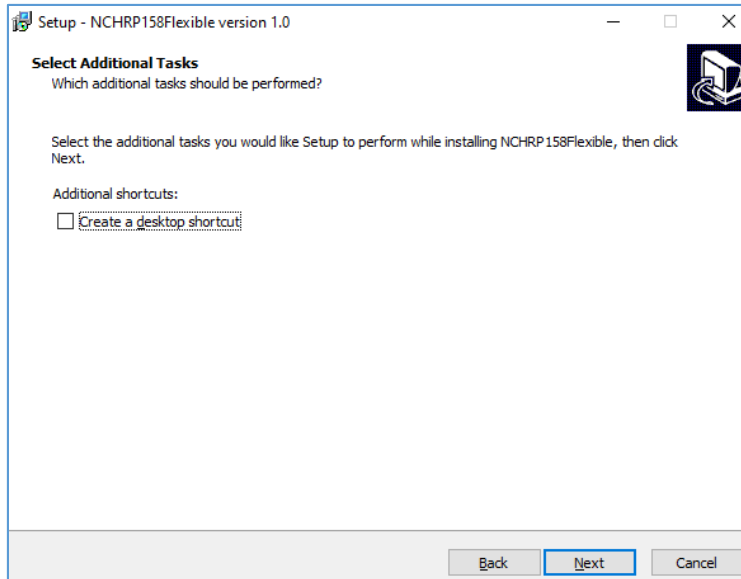
**Prerequisites:** The tool is designed only to work in a Windows environment. Java must also be installed as a pre-requisite; the latest version can be downloaded from this link: [https://www.java.com/download/ie\\_manual.jsp](https://www.java.com/download/ie_manual.jsp)

**Note: You must be logged in as an administrator to be able to install the program!**

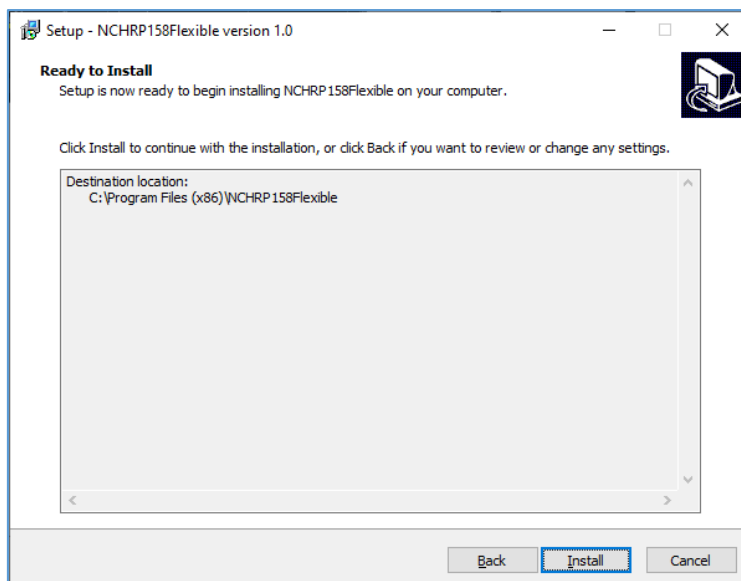
Download **setupNCHRP0158Flex.exe** file. From Windows Explorer, double click the **setupNCHRP0158Flex.exe** file to bring up the following screen:



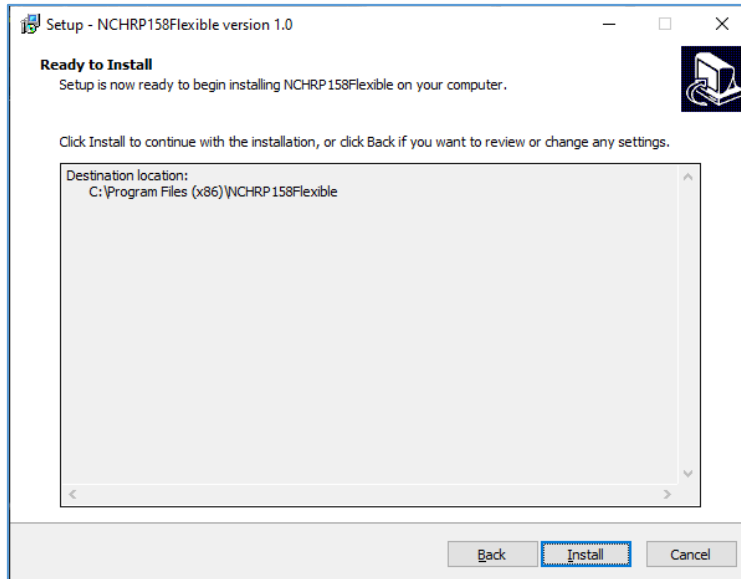
The installer will ask for a directory to install the program into. This can be the default directory provided (C:\Program Files (x86)\CRP\NCHRP0158Flex\), or the user may select Browse and specify a different directory. Click Next.



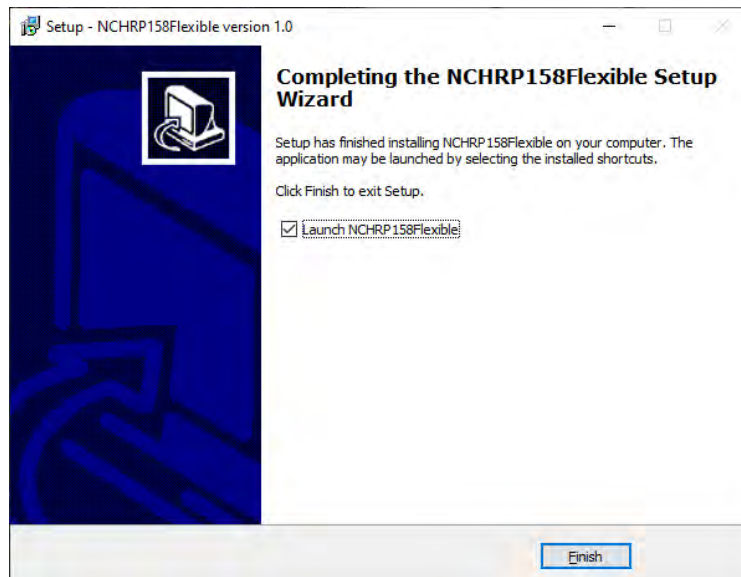
If the “Create a desktop shortcut” check box is checked, the installation process will create a desktop shortcut for the program. Check the box if you want a desktop shortcut and click Next.



Review the installation settings (click Back if necessary to change them) and then click Install.

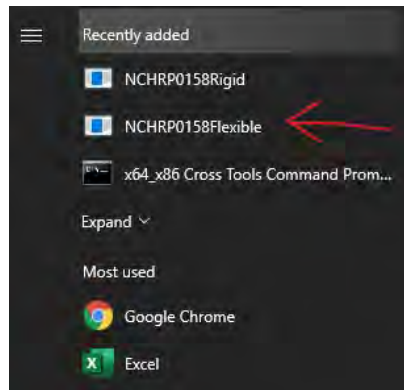


Once installed, the following window will appear. Check the box to open the program immediately and click Finish. The installation is now complete.

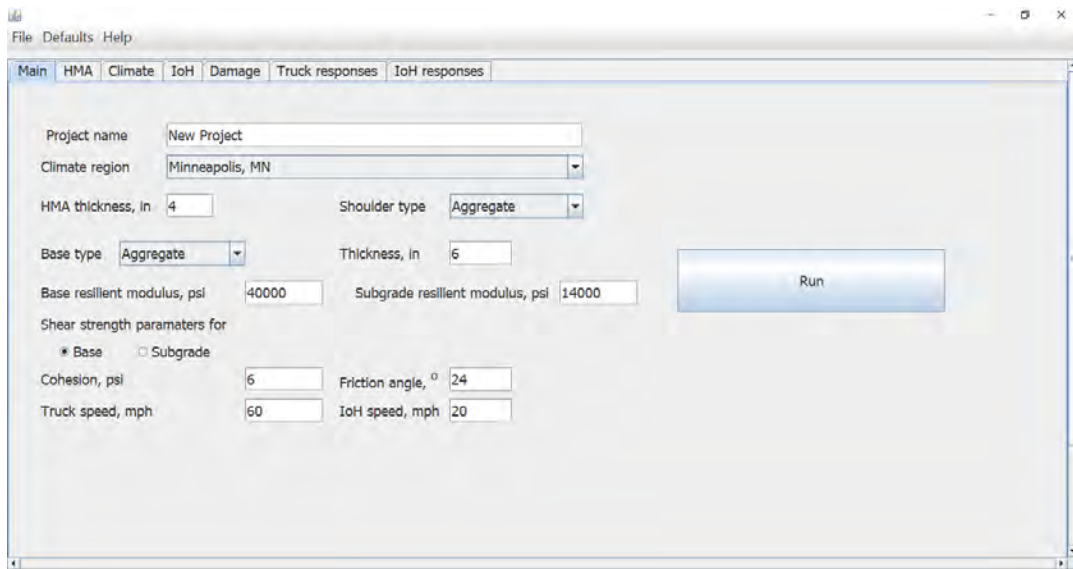


## NEW ANALYSIS

To run a new analysis using this tool, open it from the desktop shortcut or Start menu:



The following screen will appear:



The analysis involves seven tabs:

1. Main tab: This is where project details and properties of the elastic layers (base and subgrade) can be specified.
2. HMA tab: This is where the relaxation function of the HMA can be specified.
3. Climate tab: This is where the representative monthly HMA temperature, base modulus, and subgrade modulus can be specified.
4. IoH tab: This is where the configuration and load of the IoH can be specified, in addition to specifying a reference truck for comparison.
5. Damage tab: This tab shows the relative damage in the HMA, base, and subgrade calculated over each month of the analysis.
6. Truck responses: This tab displays graphs that show the monthly viscoelastic responses of the pavement to the reference truck.

7. IoH responses: This tab displays graphs that show the monthly viscoelastic responses of the pavement to the IoH.

To perform an analysis, sequentially fill in the inputs in tabs 1-4, hit Run in tab 1, and then go to tabs 5-7. Each tab is discussed in greater detail below.

## MAIN TAB

On the Main tab, the user should first select the weather station nearest to the project location from the 40 options available, as shown in the figure below.

The screenshot shows a software interface for the Main tab. It features a form with the following elements:

- Project name:** A text input field containing "New Project".
- Climate region:** A dropdown menu currently open, displaying a list of 40 weather stations including Minneapolis, MN; Kansas City, MO; Jackson, MS; Charlotte, NC; Omaha, NE; Albuquerque, NM; Las Vegas, NV; New York, NY; Newark, OH; Oklahoma City, OK; Portland, OR; Philadelphia, PA; Sioux Falls, SD; Bristol, TN; and Dallas, TX.
- HMA thickness, in:** An empty text input field.
- Base type:** A dropdown menu set to "Aggregate".
- Base resilient modulus:** A text input field containing "100".
- Shear strength parameters:** Radio buttons for "Base" (selected) and "Subgrade".
- Cohesion, psi:** An empty text input field.
- Truck speed, mph:** An empty text input field.
- Run:** A blue rectangular button on the right side of the form.

The user should also input the following data into the Main tab of the interface program:

- Project name (optional)
- HMA layer thickness
- Shoulder type (aggregate or asphalt)
- Base properties: type (aggregate or cement-treated), thickness, and resilient modulus
- Subgrade properties: resilient modulus,
- Shear failure analysis: The user should select whether shear failure is to be evaluated in the base or subgrade, and then provide the cohesion ( $c$ ) and angle of internal friction ( $\phi$ ) for that layer. In case a cement-treated base is used, shear failure is evaluated only in the subgrade.
- Speeds of the IoH and reference truck

It is possible that some of the required inputs may not be available. In that case, the user can accept the default values to proceed with the analysis. However, a sensitivity analysis within a reasonable range of the input parameters is recommended. Many of the inputs may be available from the agency's practice with using Pavement ME or from the MnPAVE manual (<http://www.dot.state.mn.us/app/mnpave/>).

## HMA TAB

On the HMA tab, as shown below, the user should provide the stress relaxation function for the HMA layer by specifying the relaxation times and corresponding relaxation moduli as well as the long-term modulus (glass modulus).

PG 58-28

Long-time modulus, ksi  Number of relaxation times

Relaxation Time, sec	Relaxation Modulus, ksi
2.00E-07	1.20E+03
2.00E-06	2.16E+02
2.00E-05	4.00E+02
2.00E-04	5.47E+02
2.00E-03	5.41E+02
2.00E-02	4.82E+02
2.00E-01	3.74E+02
2.00E+00	1.85E+02
2.00E+01	1.17E+02
2.00E+02	1.04E+01
2.00E+03	2.24E+01

$\log a[T] = a_0 + a_1 T + a_2 T^2$   
 $a_0 =$    
 $a_1 =$    
 $a_2 =$

In many cases, this data will not be available. In that case, the user may select from the default data corresponding to the PG binder grade used by the local agency, as shown in the figure below. A discussion on how this data was obtained is presented in Appendix D. The program allows the user to modify this data and save it as a new material in the database. This can be done by entering a name in the textbox and clicking the Update button, as shown below.

If the agency already has data available for their mixes, the User-Defined option will bring up a blank table to directly enter the data.



User-defined PG 58-28

Long-time modulus, ksi  Number of relaxation times

Relaxation Time, sec	Relaxation Modulus, ksi
2.00E-07	
2.00E-06	
2.00E-05	
2.00E-04	
2.00E-03	
2.00E-02	
2.00E-01	
2.00E+00	
2.00E+01	
2.00E+02	
2.00E+03	

$\log a[T] = a_0 + a_1 T + a_2 T^2$   
 $a_0 =$    
 $a_1 =$    
 $a_2 =$

The tab also displays the time-temperature shift factor  $a(T)$ , which is used later in the analysis (temperature is in °C). The user can simply accept the default values in the program and proceed or enter/modify it manually in case project-specific values are available.

## CLIMATE TAB

The Climate tab is presented below. It shows the monthly HMA temperature (calculated based on location), base modulus, and subgrade modulus that will be used for the viscoelastic analysis. These values can be modified by double-clicking any cell in the grid, or the user can use the default values if project-specific values are not available.

Users can also specify the month(s) for which the analysis should be performed by checking the corresponding box for each month in the last column.

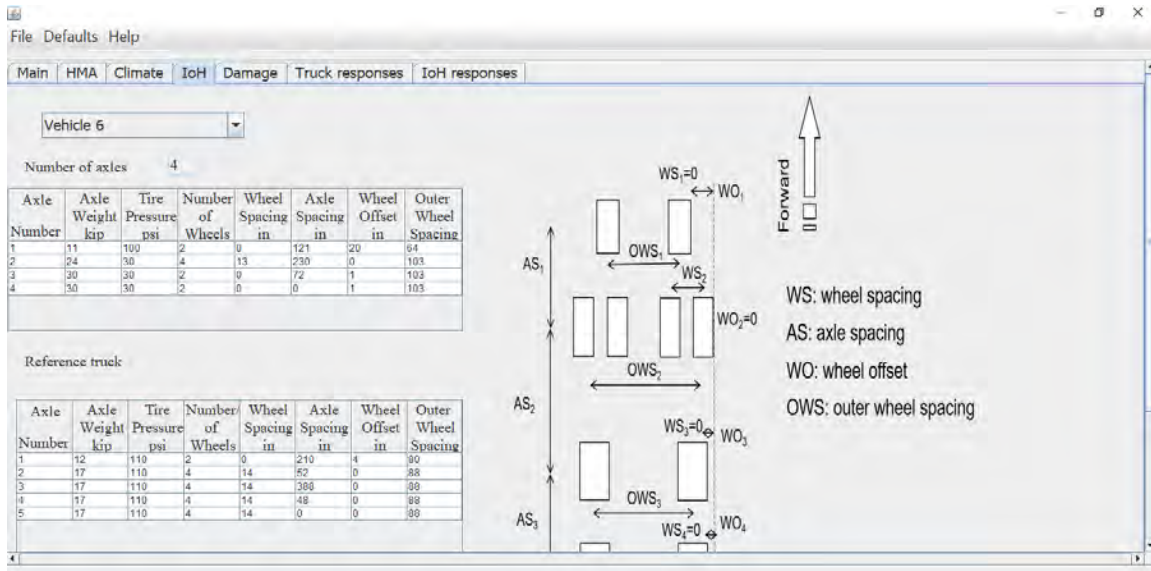
File Defaults Help

Main HMA **Climate** IoH Damage Truck responses IoH responses

Month	HMA Temp	base modulus, ...	Subgrade mod. ...	IoH Traffic
January	23.80	898716.70	371935.28	<input type="checkbox"/>
February	32.64	2062919.11	780223.31	<input type="checkbox"/>
March	45.66	709840.98	231765.17	<input type="checkbox"/>
April	67.15	16084.93	5441.18	<input checked="" type="checkbox"/>
May	84.34	16733.95	5835.63	<input type="checkbox"/>
June	95.07	19512.99	6815.02	<input type="checkbox"/>
July	105.36	21788.73	7620.19	<input type="checkbox"/>
August	101.56	23718.94	8305.16	<input type="checkbox"/>
September	85.26	24333.05	8517.34	<input type="checkbox"/>
October	64.49	24316.05	8510.16	<input checked="" type="checkbox"/>
November	47.01	24365.06	8546.21	<input type="checkbox"/>
December	30.52	53566.04	27739.33	<input type="checkbox"/>

## IoH TAB

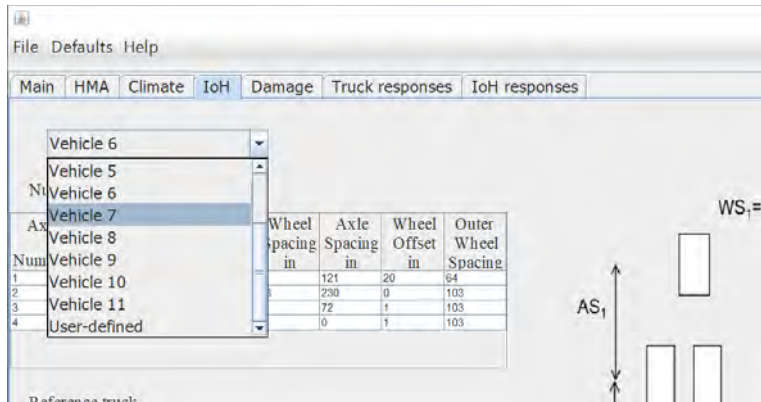
The IoH tab is used to specify the axle configuration of the IoH as well as that of a reference truck. This tab is shown in the image below.



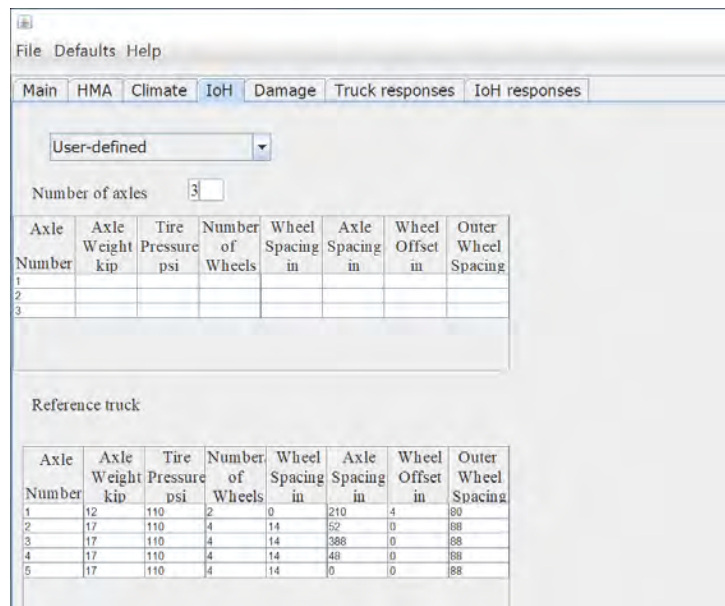
The configuration is specified in terms of the following parameters:

- Number of axles
- Axle weight
- Tire pressure for the wheels in the axle
- Number of wheels in the axle
- Wheel spacing: the distance between the centers of the tire footprints in the right half-axle. Wheel spacing is set to 0 if there is only one wheel in a half-axle, i.e., two wheels in the axle.
- Axle spacing: distance to the next axle. Set to 0 for the last axle.
- Wheels offset: the difference between the right edges of the footprints of the current axle and the reference axle for which the offset is set to 0.
- Outer wheel spacing: the distance between the rightmost and leftmost wheels in the axle.

The user can select any pre-defined IoH vehicle from the drop-down menu (the configurations of these vehicles are defined in Appendix E of the report), which will populate the configuration.

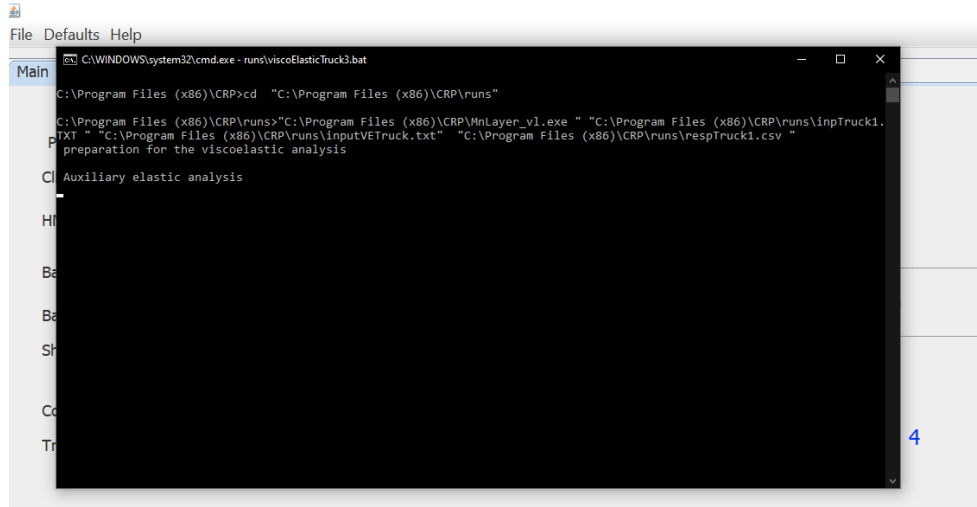


Alternatively, a User-Defined option is available, which allows the user to define a new IoH configuration that may not be available in the list shown in Appendix E and in the program. The user should specify the necessary inputs for the user defined IoH, as shown in the figure below.



## DAMAGE ANALYSIS

Once all the inputs in the Main, HMA, Climate, and IoH tabs are specified, go to the Main tab and click Run. A command line shell similar to that shown below will appear – several of these shells will open and close as the analysis is performed, please don't close anything and wait for the analysis to complete. An "Analysis is Complete" message will be displayed in the Main tab when done.



## DAMAGE TAB

Once the analysis is complete, the results can be checked in the Damage tab, as shown in the figure below. This tab has four tables. The table on the top left summarizes the relative damage from one pass of the IoH as compared to the reference truck. The damage is quantified in terms of fatigue damage in the HMA and subgrade layers, and the relative shear stress ratio (RSSR) of the base or subgrade (whichever is selected in the Main tab). The next three tables show the absolute values of the damage. The table on the top right shows the shear stress ratio (SSR) for the reference truck and IoH corresponding to the base or subgrade, which was selected. The two tables at the bottom show the allowable number of passes of the reference truck and IoH vehicle.

Relative damage from one pass of IoH compared to the reference truck				Shear stress/strength ratio in the base		
Month	HMA Layer	Subgrade	RSSR	Month	Reference Truck	IoH
January				January		
February				February		
March				March		
April	3.978	2.726	1.123	April	0.236	0.265
May				May		
June				June		
July				July		
August				August		
September				September		
October	3.392	2.710	1.069	October	0.290	0.310
November				November		
December				December		

Allowable Number of Reference Truck Passes			Allowable Number of IoH Passes		
Month	HMA Fatigue Damage	Subgrade Damage	Month	HMA Fatigue Damage	Subgrade Damage
January			January		
February			February		
March			March		
April	1,567,996.5	544,493.4	April	394,190.5	199,726.1
May			May		
June			June		
July			July		
August			August		
September			September		
October	2,488,353.4	825,780.6	October	733,527.8	304,670.0
November			November		
December			December		

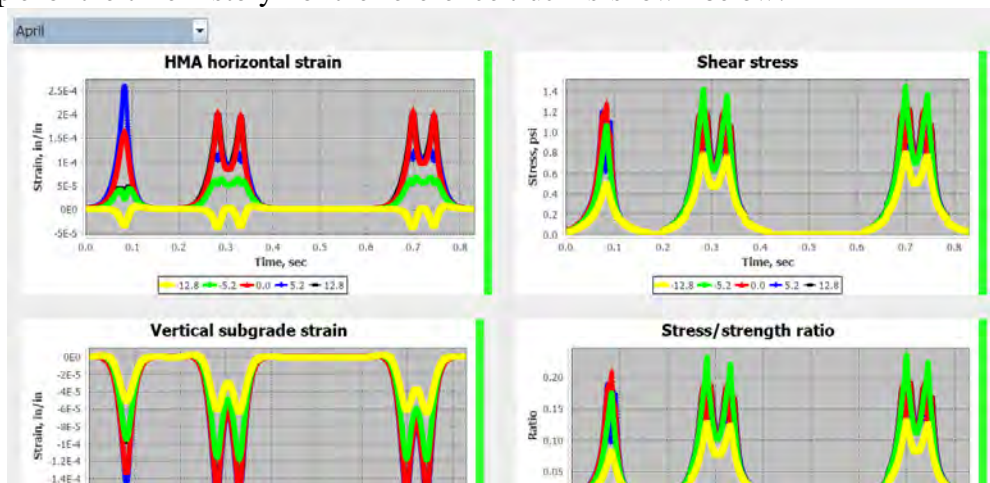
## TRUCK RESPONSES TAB AND IOH RESPONSE TAB

These two tabs provide time histories of the pavement responses for the reference truck and IoH vehicles. The user can review the following calculated time histories of the pavement responses along several offsets for each month the analysis was performed:

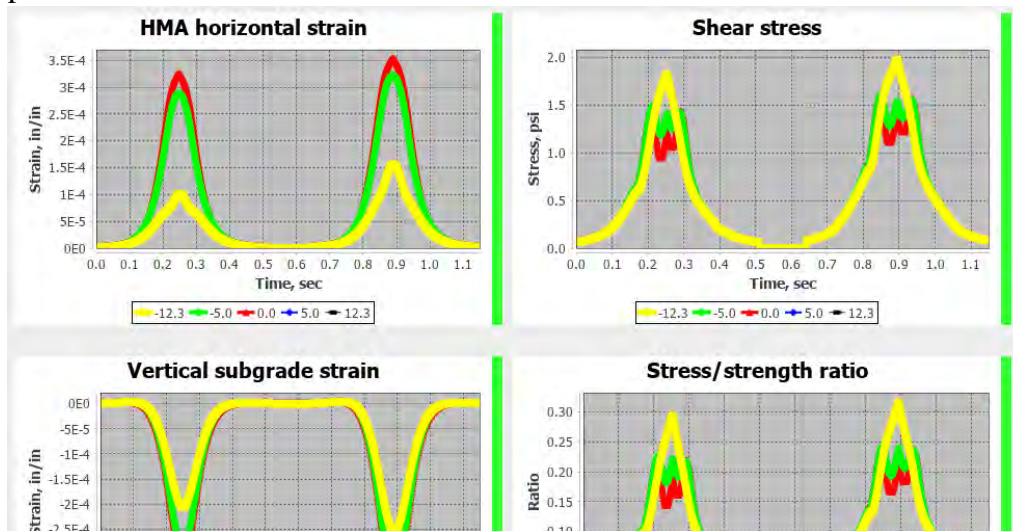
- horizontal strain at the bottom of the HMA layer
- vertical strain at the top of the subgrade
- shear stress at the mid-depth of the aggregate base layer
- shear stress ratio (SSR) at the mid-depth of the base layer

The time histories for the reference truck and IoH can be viewed on the Truck responses and IoH responses tabs, respectively. For both tabs, the user can view the responses for any month analyzed by selecting the corresponding month from the top left dropdown box.

An example of the time history for the reference truck is shown below:



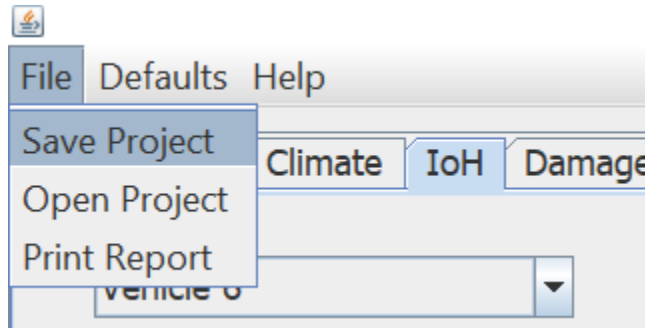
An example for an IoH is shown below:



In both these cases, the response at different offsets from the mean wheel path are shown.

## SAVING AND OPENING A PROJECT

At any time, the user can go to File > Save Project to save the project. Project files have a \*.ptr extension. To open an existing project, go to File > Open Project, navigate to the directory where the project file is saved, and open it. This may be useful, for example, if the agency has certain pre-defined set of inputs to the Climate tab, which can be re-used for future analyses.



## PRINTING A REPORT

Once the analysis is complete, the user can go to File > Print Report to generate a Microsoft Word file that summarizes the results of the analysis. Select a location to save the file. The report is automatically opened for the user. If Windows asks which program to open the file in, select Microsoft Word.



## OTHER OPTIONS

The Defaults > View Defaults option in the toolbar can be used to view default values and options at any time.

number of functions	<input type="text" value="5"/>			<input type="button" value="OK"/>
Evaluation time, s	<input type="text" value="0.3"/>			
Number of points	<input type="text" value="1000"/>	Number of intermediate points	<input type="text" value="5"/>	
Evaluation distance, in.	<input type="text" value="90"/>			
Distance increment, in.	<input type="text" value="2"/>			
Temperature standard deviate	<input type="text" value="1.282"/>			
HMA Damage coefficients	$k_1 =$ <input type="text" value="0.008"/>	$k_2 =$ <input type="text" value="4"/>	$k_3 =$ <input type="text" value="1.3"/>	
Subgrade damage	$k_{\text{subgr},1} =$ <input type="text" value="0.03"/>	$k_{\text{subgr},2} =$ <input type="text" value="2.05"/>		
Mean wheel path, in.	<input type="text" value="18"/>	Traffic wander standard deviation, in.	<input type="text" value="10"/>	

The Help menu allows the user to view the Help file as well as information about the program.

## EXAMPLE ANALYSIS

As an example of a type of analysis that a user may want to run, the following case was analyzed using the tool:

- Location: Des Moines, IA
- Pavement structure
  - 4 in. HMA layer, PG 58-28
  - 6 in. aggregate base with the resilient modulus at the optimum moisture content equal to 40,000 psi;
  - Shear failure to be evaluated in the base with cohesion and friction angle: 4 psi and 24°, respectively.
  - Subgrade with the resilient modulus at the optimum moisture content equal to 14,000 psi;
  - Aggregate shoulder.
- IoH vehicle: a John Deere 8230 tractor with a 6,000-gallon tank traveling at a speed of 20 mph.
- The axle geometry has the following characteristics:
  - Axle 1: axle load: 11 kips; tire pressure 100 psi; number of wheels: 2; outer wheel spacing: 64 in., distance from the next axle: 121 in.
  - Axle 2: axle load: 24 kips; tire pressure: 30 psi; number of wheels: 4; wheel spacing in the dual wheel assembly: 13 in.; outer wheel spacing: 103 in.; distance from the next axle: 230 in.
  - Axle 3: axle load: 30 kips; tire pressure 30 psi; number of wheels: 2; outer wheel spacing: 103 in.; distance from the next axle: 72 in.
  - Axle 4: axle load: 30 kips; tire pressure 30 psi; number of wheels: 2; outer wheel spacing: 103 in.

Determine relative damage in April, September, and October.

**Step 1.** Open the program to start a new analysis. In the Main tab, specify the section location and design features on the Main tab. In this case, all the inputs are provided in the problem statement. If this were not the case, the user can accept the default values to proceed. Additional guidance on these inputs may be available through the agency's local practice with Pavement ME and the MnPAVE user's guide.



Project name

Climate region

HMA thickness, in  Shoulder type

Base type  Thickness, in

Base resilient modulus, psi  Subgrade resilient modulus, psi

Run

Shear strength parameters for

Base  Subgrade

Cohesion, psi  Friction angle, °

Truck speed, mph  IoH speed, mph

**Step 2.** Move to the HMA tab to specify the HMA mix properties. In this case, a PG 58-28 mix is specified in the problem statement but no information about the relaxation spectrum is provided. So, the default values may be used. In case project-specific values are available, the user can update the default values and save them to the database using the Update button or select User-Defined from the list and enter the data into a blank table. This is for both the shift factor coefficients as well as the relaxation modulus spectrum.

Long-time modulus, ksi  Number of relaxation times

Relaxation Time, sec	Relaxation Modulus, ksi
2.00E-07	1.20E+03
2.00E-06	2.16E+02
2.00E-05	4.00E+02
2.00E-04	5.47E+02
2.00E-03	5.41E+02
2.00E-02	4.82E+02
2.00E-01	3.74E+02
2.00E+00	1.85E+02
2.00E+01	1.17E+02
2.00E+02	1.04E+01
2.00E+03	2.24E+01

$\log a[T] = a_0 + a_1 T + a_2 T^2$

$a_0 =$

$a_1 =$

$a_2 =$

**Step 3.** Next, move to the Climate tab. Based on the location, this is pre-populated with local-specific default values for HMA temperature, base modulus, and subgrade modulus. Review these default values and edit them with project-specific ones, if available. Also, check the months for which the analysis is to be performed in the last column. In the problem statement, these are the months of April, September, and October.

The screenshot shows a software window with a menu bar (File, Defaults, Help) and a tabbed interface. The 'Climate' tab is selected. Below the tabs is a table with the following data:

Month	HMA Temp	base modulus, ...	Subgrade mod...	IoH Traffic
January	32.43	82700.15	55060.50	<input type="checkbox"/>
February	42.40	148976.73	127411.45	<input type="checkbox"/>
March	54.51	25324.16	9713.97	<input type="checkbox"/>
April	72.50	17939.09	6139.25	<input checked="" type="checkbox"/>
May	87.60	19888.81	6854.82	<input type="checkbox"/>
June	101.72	22031.65	7640.33	<input type="checkbox"/>
July	110.51	23558.89	8211.59	<input type="checkbox"/>
August	107.73	24321.99	8510.37	<input type="checkbox"/>
September	93.78	24339.05	8518.73	<input checked="" type="checkbox"/>
October	71.99	24313.04	8509.28	<input checked="" type="checkbox"/>
November	52.95	24294.52	8506.83	<input type="checkbox"/>
December	38.89	27510.09	10102.65	<input type="checkbox"/>

**Step 4.** Next, provide IoH Characteristics in the IoH tab. In this case, Vehicle 6 in the list (see Appendix E for the configuration) corresponds to the one specified in the problem statement, so select this one and accept the default configuration. If a different IoH vehicle needs to be analyzed and is not available in the list provided in Appendix E, the user can select the User-Defined option from the list and specify the configuration.

Vehicle 6

Number of axles 4

Axle Number	Axle Weight kip	Tire Pressure psi	Number of Wheels	Wheel Spacing in	Axle Spacing in	Wheel Offset in	Outer Wheel Spacing
1	11	100	2	0	121	20	64
2	24	30	4	13	230	0	103
3	30	30	2	0	72	1	103
4	30	30	2	0	0	1	103

Reference truck

Axle Number	Axle Weight kip	Tire Pressure psi	Number of Wheels	Wheel Spacing in	Axle Spacing in	Wheel Offset in	Outer Wheel Spacing
1	12	110	2	0	210	4	80
2	17	110	4	14	52	0	88
3	17	110	4	14	388	0	88
4	17	110	4	14	48	0	88
5	17	110	4	14	0	0	88

Legend:  
 WO: wheel offset  
 WS: wheel spacing  
 AS: axle spacing

By default, the reference truck is an 80 kips semi-truck. This is shown under the 'Reference truck' heading in the IoH tab, as shown above, and may be modified by the user if so desired.

**Step 5.** Once all the inputs are finalized, the user can execute the analysis by returning to the Main tab and clicking “Run”

The button should become inactive, and a command shell will appear; several of these shells will open and close as the analysis is performed – please do not close any of them and wait for the analysis to complete. An “Analysis has been completed” message will be displayed in the Main tab when done.

Project name: New Project  
 Climate region: Des Moines, IA  
 HMA thickness, in: 4      Shoulder type: Aggregate  
 Base type: Aggregate      Thickness, in: 6  
 Base resilient modulus, psi: 40000      Subgrade resilient modulus, psi: 14000  
 Shear strength parameters for:  
 Base     Subgrade  
 Cohesion, psi: 6      Friction angle, °: 24  
 Truck speed, mph: 60      IoH speed, mph: 20

Run

Analysis has been completed

**Step 6.** When the message indicating that the analysis is completed is displayed, the user can see the results of the analysis.

To see the relative damage caused by the IoH as compared to the reference truck, move to the Damage tab. The following screen should appear:

Relative damage from one pass of IoH compared to the reference truck				Shear stress/strength ratio in the base		
Month	HMA Layer	Subgrade	RSSR	Month	Reference Truck	IoH
January				January		
February				February		
March				March		
April	3.978	2.726	1.123	April	0.236	0.265
May				May		
June				June		
July				July		
August				August		
September				September		
October	3.392	2.710	1.069	October	0.290	0.310
November				November		
December				December		

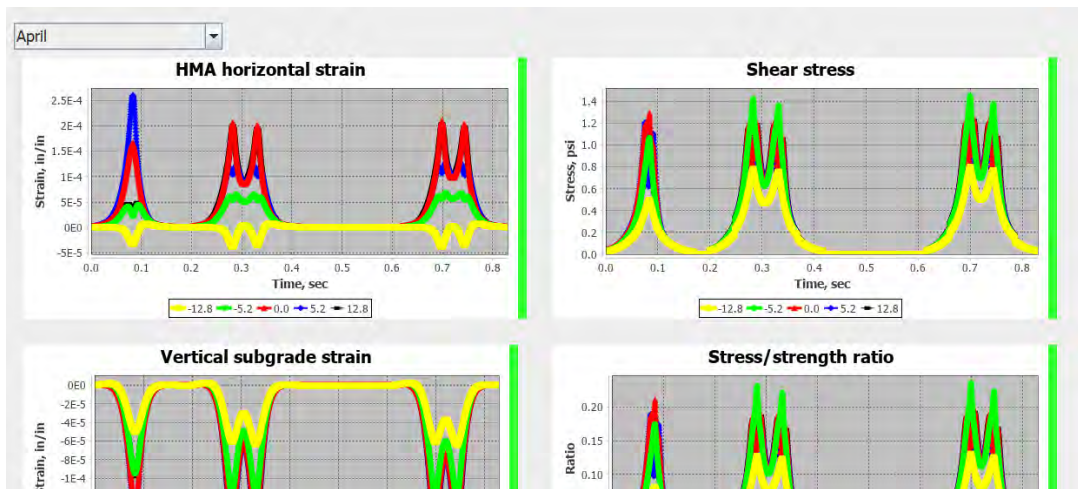
  

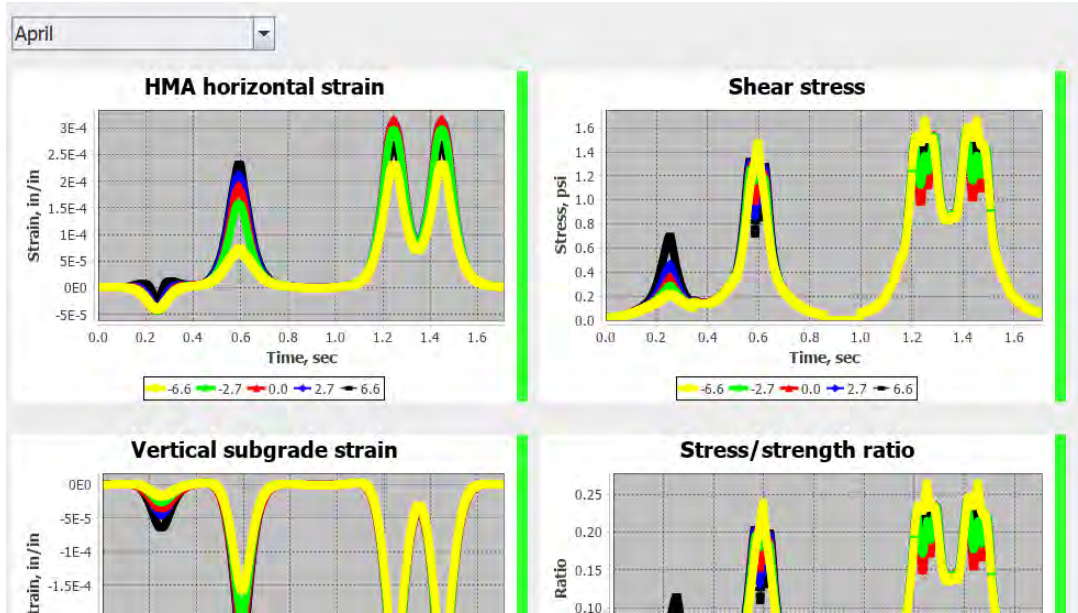
Allowable Number of Reference Truck Passes			Allowable Number of IoH Passes		
Month	HMA Fatigue Damage	Subgrade Damage	Month	HMA Fatigue Damage	Subgrade Damage
January			January		
February			February		
March			March		
April	1,567,996.5	544,493.4	April	394,190.5	199,726.1
May			May		
June			June		
July			July		
August			August		
September			September		
October	2,488,353.4	825,780.6	October	733,527.8	304,670.0
November			November		
December			December		

The top left table shows that in April, one pass of the IoH produces the same HMA damage and the same subgrade damage as 3.978 and 2.726 passes of the reference truck, respectively. Additionally, the SSR of the base layer is 1.123 times greater for the IoH than that of the reference truck. Similar results can be seen for the month of October.

The top right table reports that the Shear Stress Ratio (SSR) for the IoH and reference truck in April as 0.265 and 0.236 respectively, both of which are comfortably below any danger of failure. The bottom left and right tables shows the allowable passes of the reference truck and IoH respectively. In this case, about 1.5 million and 0.5 million passes of the reference truck are required to cause failure in the HMA and subgrade, respectively, in the month of April. The corresponding numbers for the IoH are 0.4 million and 0.2 million, respectively, showing the significantly higher damage caused by the IoH.

If the user wants to see the time history of the pavement responses, this is shown in the Truck responses and IoH responses tabs for the reference truck and IoH vehicle, respectively.





The analysis is now complete. The user can save the project and exit the program. The user can also print a project report, if desired.