User Manual
Software for Analysis of the Effect of Implements of Husbandry on Rigid Pavements

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

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INTRODUCTION

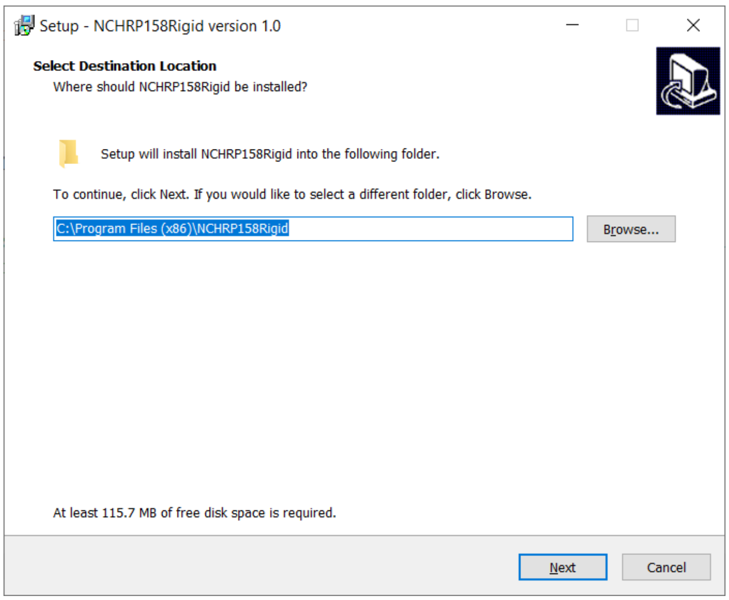
The rigid pavement analysis tool accompanying the NCHRP 1-58 report computes both fatigue damage caused to a rigid pavement by user-specified Implements of Husbandry (IoH) loads and by a reference commercial truck and compares them. This user manual provides instructions for installing the tool and running an analysis on it.

SETUP INSTRUCTIONS

Prerequisites: The tool is designed to only 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

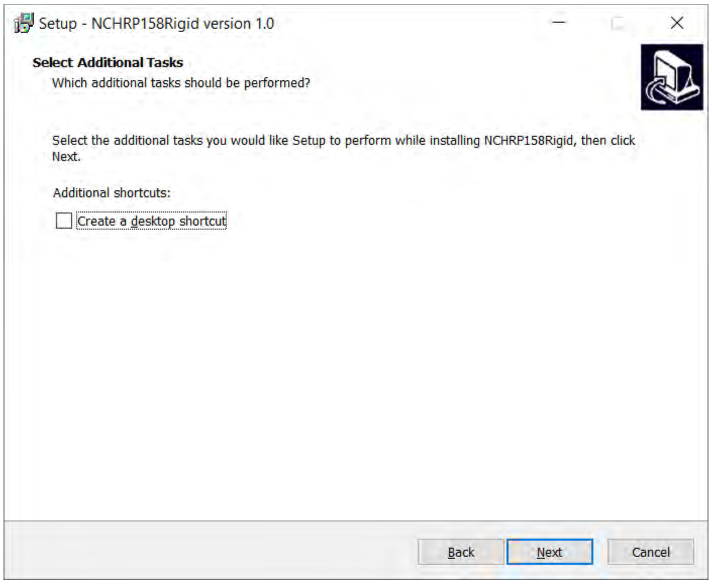
Note: You must be logged in as an administrator to be able to install the program!

From Windows explorer, double click on the **setupNCHRP0158Rigid.exe** file to bring up the following screen:

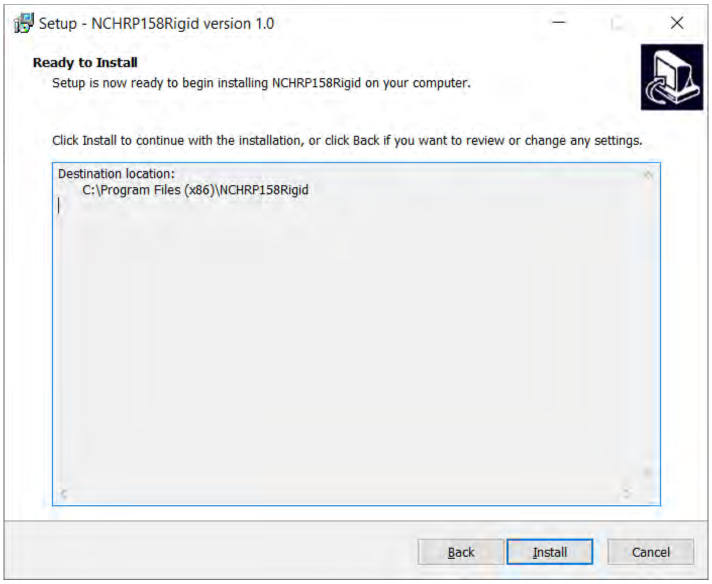


The installer will ask for a directory to install the program into. This can be the default directory provided (C:\Program Files (x86)\CRP\NCHRP0158Rigid\), or the user may click on Browse and specify a different directory. Click Next.

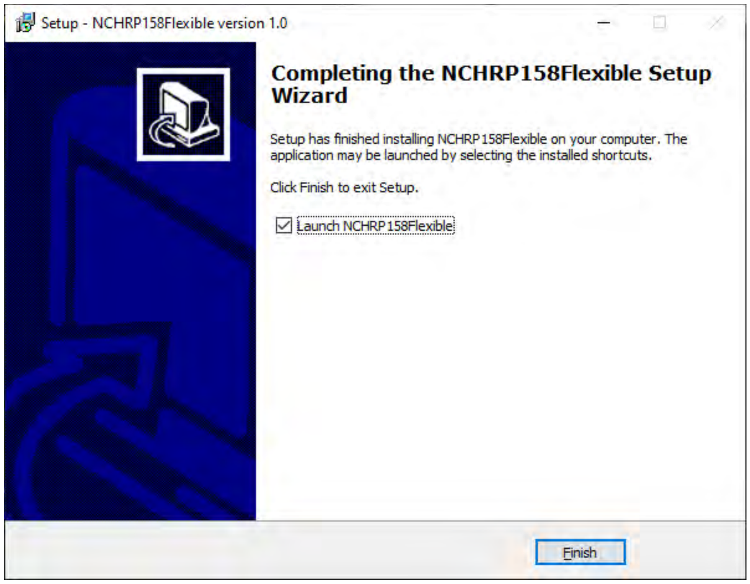
If the "Create a desktop shortcut" check box is checked, the installation process will create a desktop shortcut for the program. Check the box if you want a desktop shortcut and click Next.



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



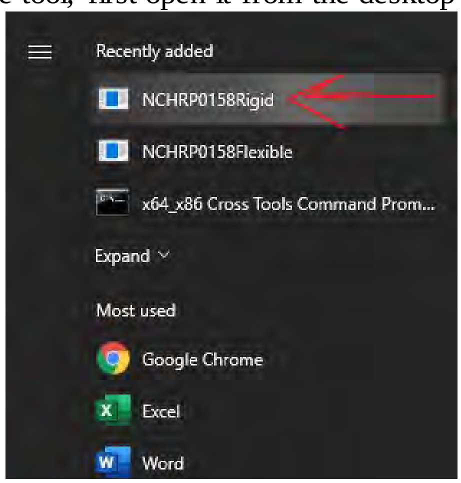
Once installed, the following window will appear.



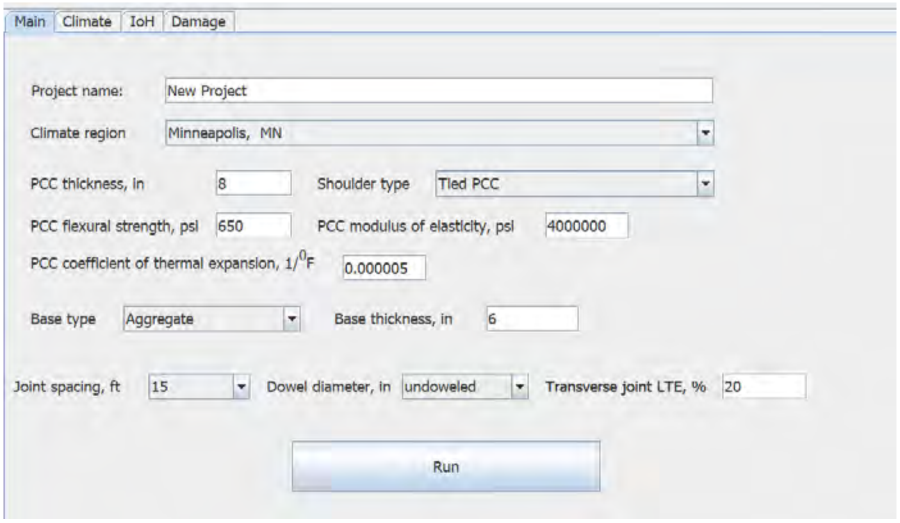
Check the box to open the program immediately and click Finish. The installation is now complete.

NEW ANALYSIS

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



The following screen will appear:



The analysis involves four tabs:

1. Main tab: This is where project details and properties of the pavement layers can be specified.
2. Climate tab: This is where the monthly base moduli and the coefficients of subgrade reaction can be specified.
3. IoH tab: This is where the configuration and load of the IoH can be specified, in addition to specifying a reference truck for comparison.
4. Damage tab: This tab shows the fatigue damage analysis results.

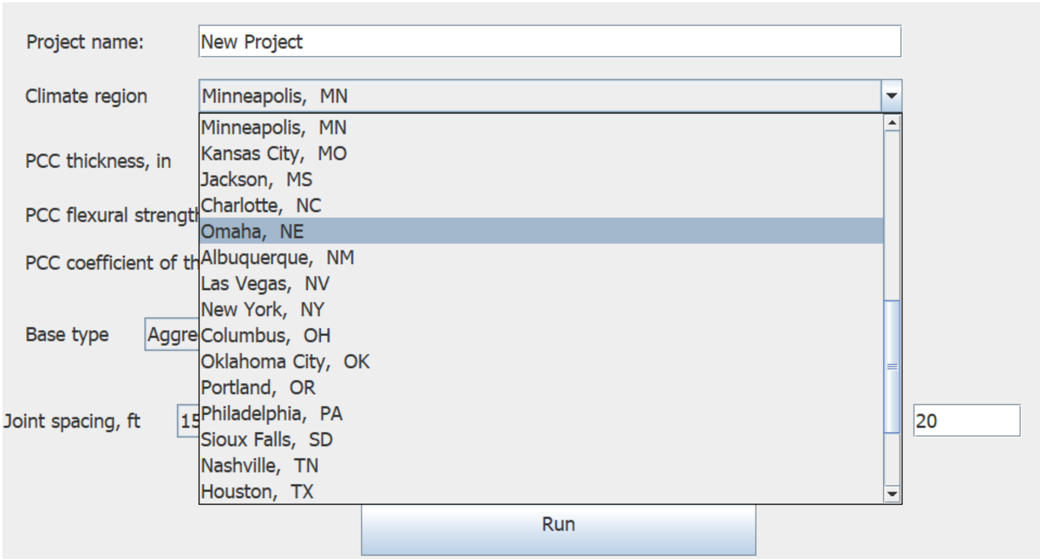
To perform the analysis, sequentially fill in the inputs in the Main, Climate, and IoH tabs, hit Run in the Main tab, and then go to the Damage tab. Each tab is discussed in a greater detail below.

ENTERING PROJECT INPUTS

Main Tab

The analysis begins with the Main tab. In this tab, the user should select the weather station nearest to the project location from the 40 options shown below and input the following data:

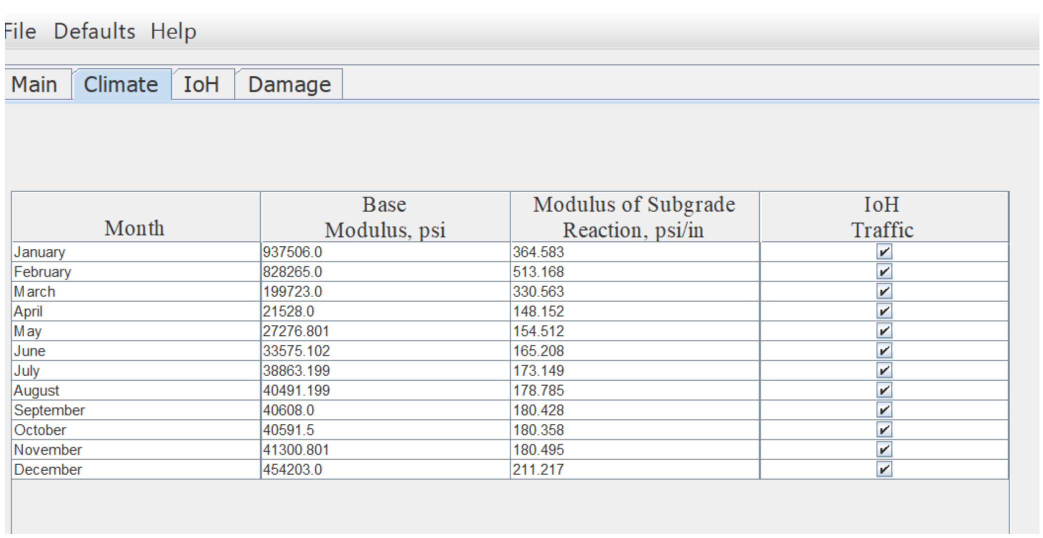
- Project name (optional)
- PCC layer thickness
- Shoulder type (tied PCC or non-tied PCC/asphalt/unpaved)
- PCC flexural strength, modulus of elasticity, and the coefficient of subgrade reaction
- Base thickness
- Base properties: type (aggregate or cement-treated) and thickness
- Joint spacing (15 or 20 ft)
- Dowel diameter
- Transverse joint load transfer efficiency (LTE)



This data may be available for the individual pavement sections being analyzed, or the user may have to guess some values and perform a sensitivity analysis over a reasonable range of values.

Climate Tab

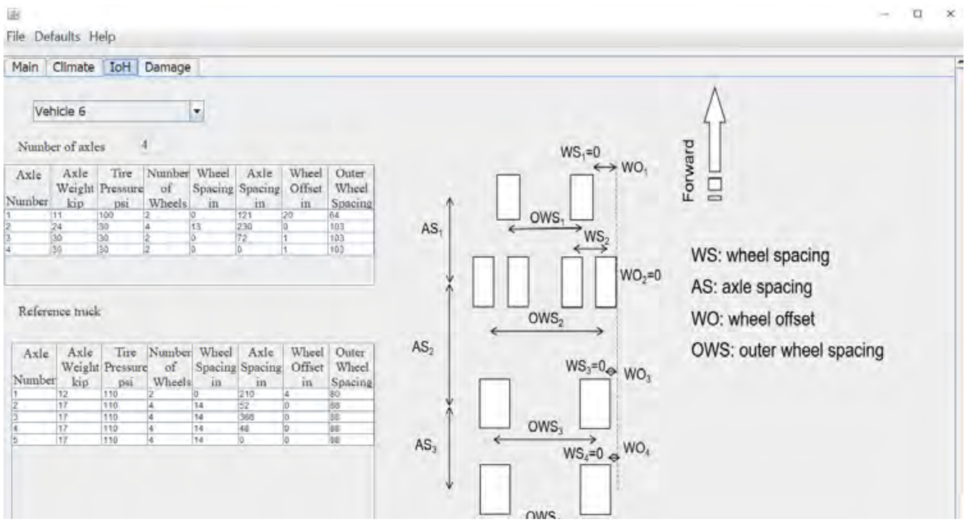
In the Climate tab shown below, the user can review and/or modify base moduli and the moduli of subgrade reaction that will be used for each month in the analysis. In the beginning, default values based on the location will be populated into the table. If the user has project-specific values, they can be modified by double-clicking any cell in the table. The user 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.



Month	Base Modulus, psi	Modulus of Subgrade Reaction, psi/in	IoH Traffic
January	937506.0	364.583	✓
February	828265.0	513.168	✓
March	199723.0	330.563	✓
April	21528.0	148.152	✓
May	27276.801	154.512	✓
June	33575.102	165.208	✓
July	38863.199	173.149	✓
August	40491.199	178.785	✓
September	40608.0	180.428	✓
October	40591.5	180.358	✓
November	41300.801	180.495	✓
December	454203.0	211.217	✓

IoH Tab

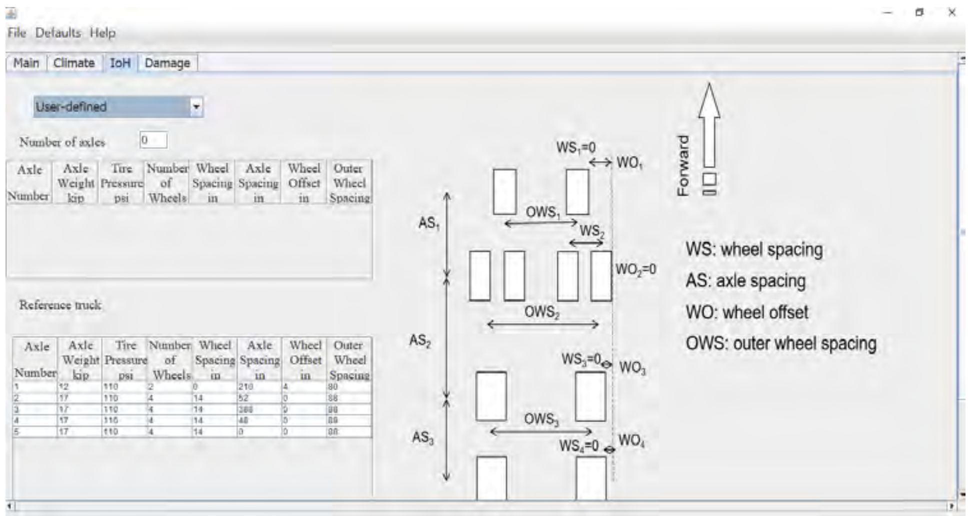
The IoH tab is used to specify the axle configuration of the IoH as well as that of the reference truck. This tab is shown in the image below.



The configuration of each vehicle is specified in terms of the following parameters:

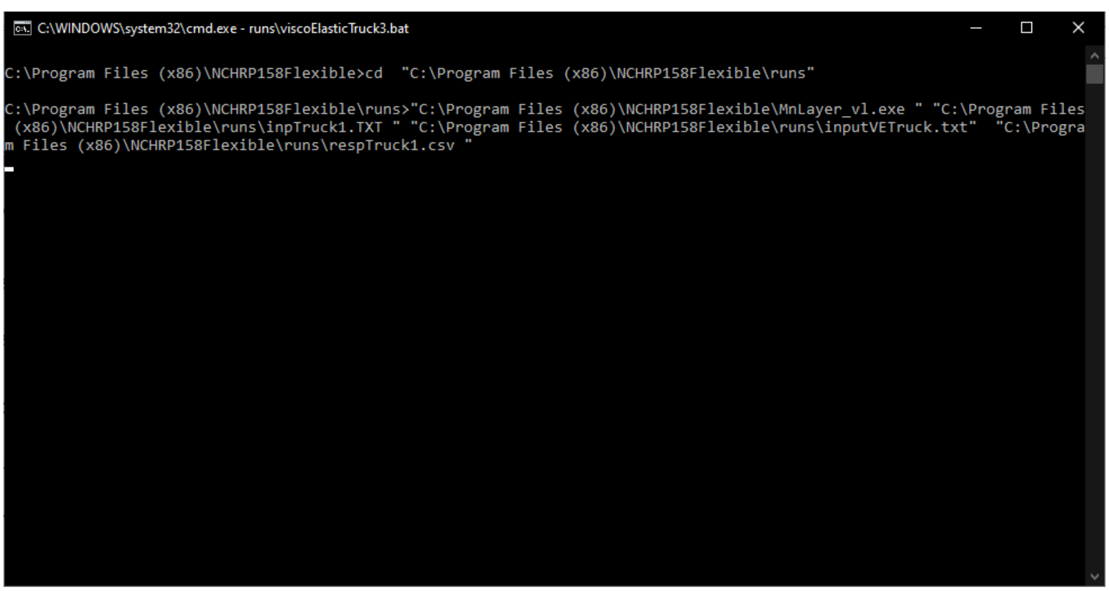
- Number of axles
- Axle weight
- Tire pressure for the wheels in the axle
- Number of wheels in the axle
- Wheel spacing: the distance between the centers of the tire footprints in the right half-axle. Wheel spacing is set to 0 if there is only one wheel in a half-axle, i.e., two wheels in the axle.
- 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, which will populate the configuration. The pre-defined vehicles and their configuration are listed in Appendix E of the report. Alternatively, a User-Defined option is available, which allows the user to define a custom IoH configuration. The user should specify the number of axles and fill out the table, as shown below. These fields can only be changed if the User-Defined option is selected.



PERFORMING ANALYSIS

Upon specifying the model inputs as required above, the user should return to the Main tab and click Run. A command shell similar to that shown below will appear; please don't close it but wait for the analysis to complete. An "Analysis has been completed" message will be displayed in the Main tab when done. Then move to the Damage tab to view the results.



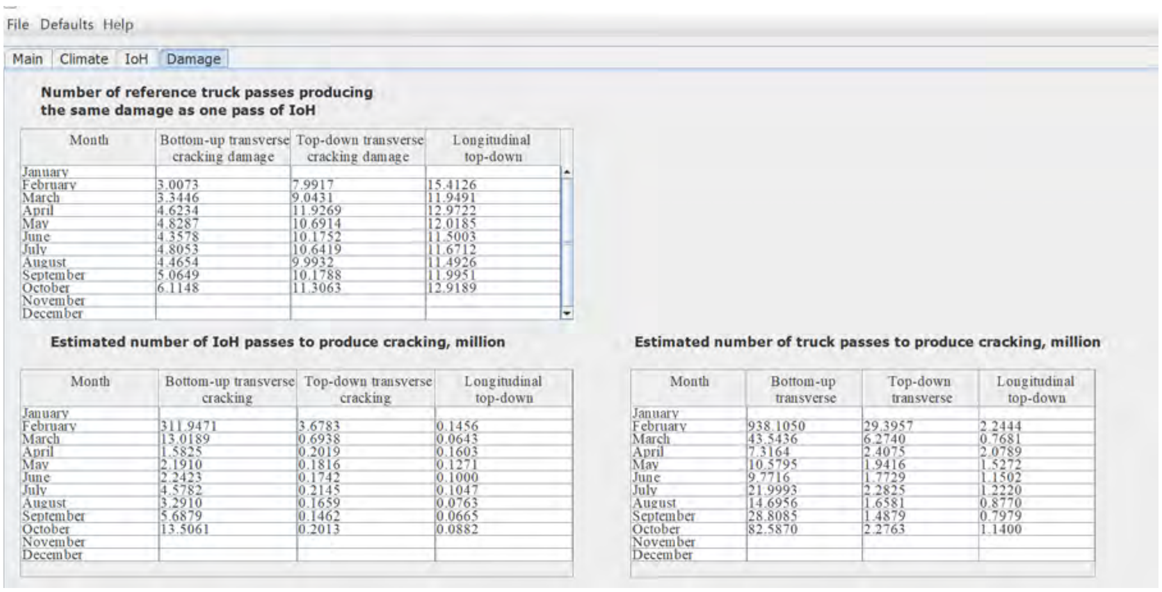
Damage Tab

After the analysis has been completed, the Damage tab shows the computed fatigue damage for each month analyzed. An example is shown below. Fatigue damage leading to transverse cracking can be of two types: top-down and bottom-up, and both are evaluated by the tool. Furthermore, longitudinal damage corresponding to longitudinal top-down cracking is also possible, and this is also evaluated. Rather than directly report damage, which is usually not very intuitive, three different measures are reported.

The upper table, as shown in the figure below, shows the number of passes of the reference truck required to produce the same level of each type of damage as one pass of the IoH. The two lower tables report the number of vehicle passes required to produce a minimal fatigue damage of 0.1. The lower-right table reports the computed number for passes of the reference truck passes, while the lower-left report that for the IoH.

The results in both tables are shown for the months for which the analysis was specified in the Climate tab.

Note: Under certain conditions, the damage caused by the reference truck or IoH may be negligible (for example, if the base happens to be excessively stiff). In this case, the number of passes may be misleadingly high. Therefore, the program shows NA (not applicable) in the corresponding results if the number of reference truck or IoH passes exceeds 10 billion. The results should simply be read as "no significant damage".



File Defaults Help

Main | Climate | IoH | Damage

Number of reference truck passes producing the same damage as one pass of IoH

Month	Bottom-up transverse cracking damage	Top-down transverse cracking damage	Longitudinal top-down
January			
February	3.0073	7.9917	15.4126
March	3.3446	9.0431	11.9491
April	4.6234	11.9269	12.9722
May	4.8287	10.6914	12.0185
June	4.3578	10.1752	11.5003
July	4.8053	10.6419	11.6712
August	4.4654	9.9932	11.4926
September	5.0649	10.1788	11.9951
October	6.1148	11.3063	12.9189
November			
December			

Estimated number of IoH passes to produce cracking, million

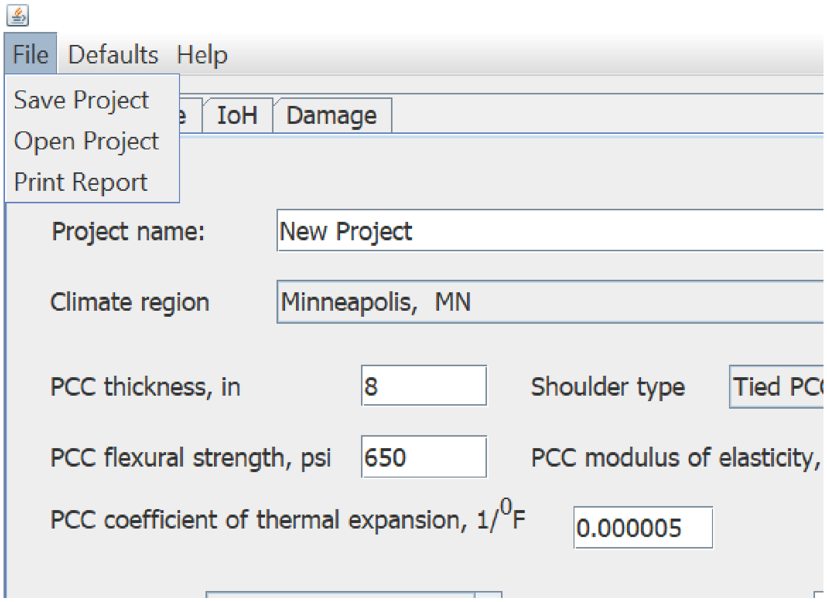
Month	Bottom-up transverse cracking	Top-down transverse cracking	Longitudinal top-down
January			
February	311.9471	3.6783	0.1456
March	13.0189	0.6938	0.0643
April	1.5825	0.2019	0.1603
May	2.1910	0.1816	0.1271
June	2.2423	0.1742	0.1000
July	4.5782	0.2145	0.1047
August	3.2910	0.1659	0.0763
September	5.6879	0.1462	0.0665
October	13.5061	0.2013	0.0882
November			
December			

Estimated number of truck passes to produce cracking, million

Month	Bottom-up transverse	Top-down transverse	Longitudinal top-down
January			
February	938.1050	29.3957	2.2444
March	43.5436	6.2740	0.7681
April	7.3164	2.4075	2.0789
May	10.5795	1.9416	1.5272
June	9.7716	1.7729	1.1502
July	21.9993	2.2825	1.2220
August	14.6956	1.6581	0.8770
September	28.8085	1.4879	0.7979
October	82.5870	2.2763	1.1400
November			
December			

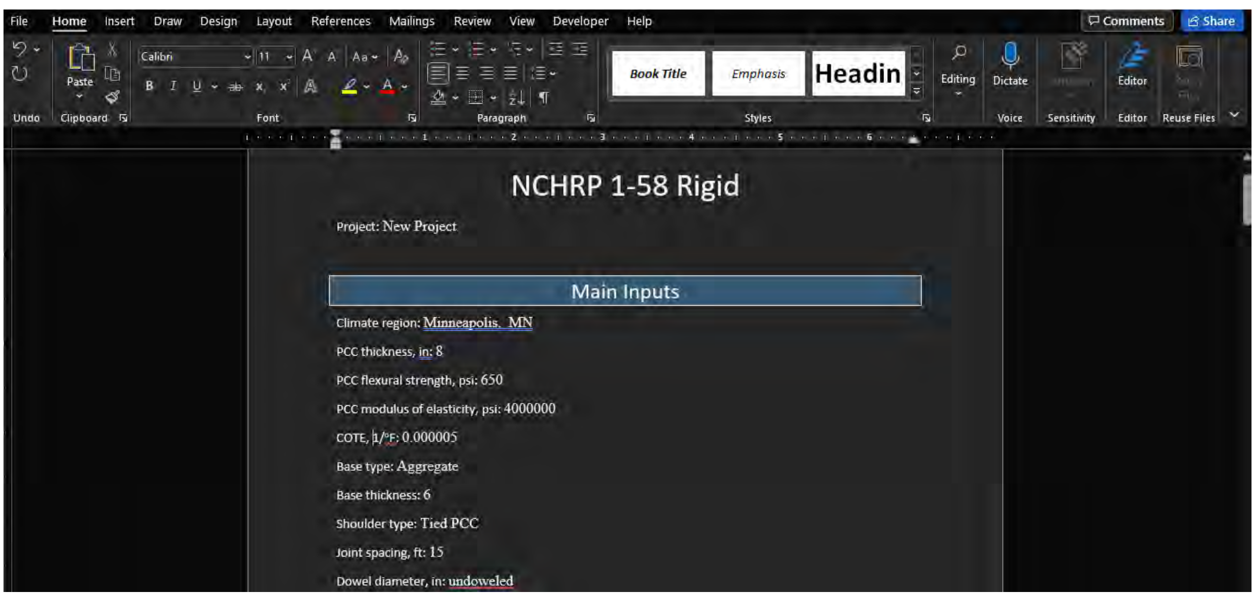
SAVING AND OPENING A PROJECT

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 will be particularly useful, for example, when agencies have a preferred set of inputs in the Climate tab that may be re-used in future analyses. In that case, the user can simply open an existing project, save it with a new name, and change only those inputs that need to be changed.



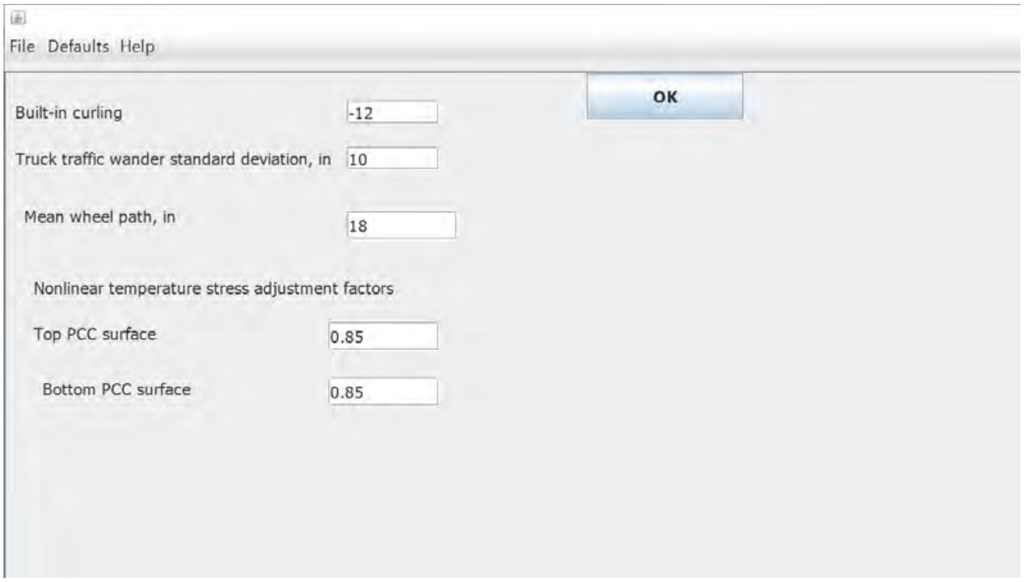
PRINTING A REPORT

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.



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

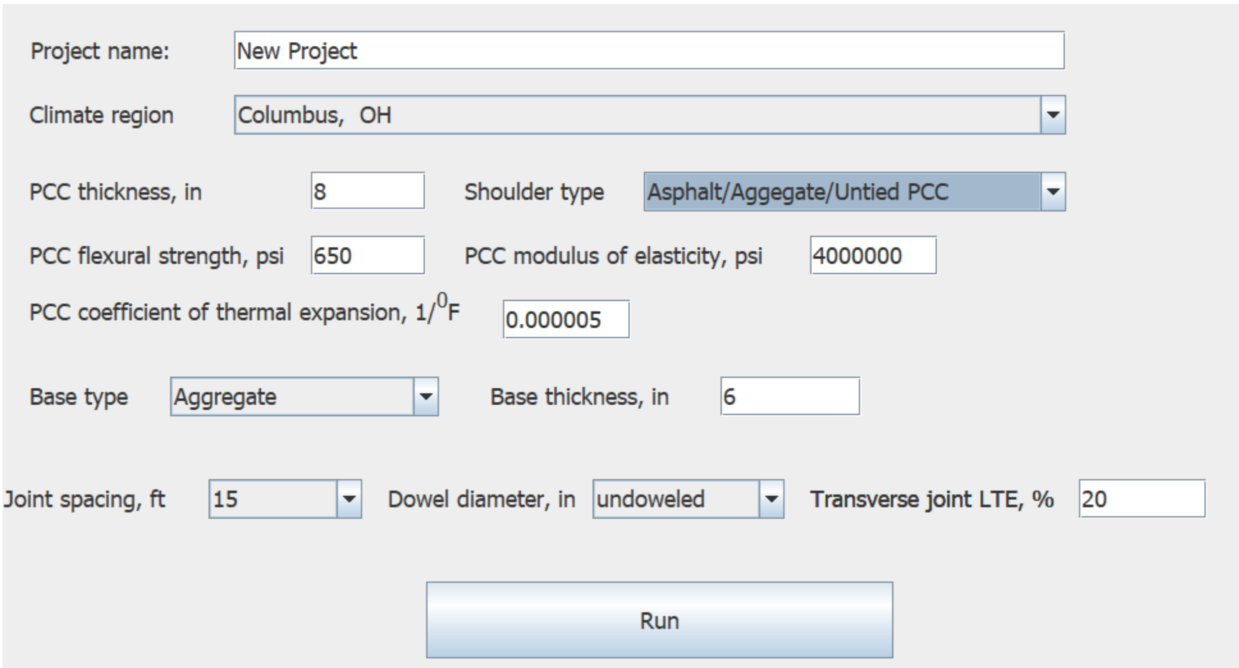
EXAMPLE ANALYSIS

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

- Location: Columbus, OH
- Pavement structure
  - 8 in. thick PCC layer, aggregate shoulder, 15 ft joint spacing
  - The PCC flexural strength, modulus of elasticity, and coefficient of thermal expansion are assumed to be 650 psi, 4,000,000 psi, and 5.0×10^{-6} 1/°F, respectively.
  - Undoweled transverse joint with a low deflection load transfer efficiency equal to 20%
  - 6 in. aggregate base
  - Subgrade
- IoH vehicle: a John Deere 8230 tractor with a 6,000-gallon tank. 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.

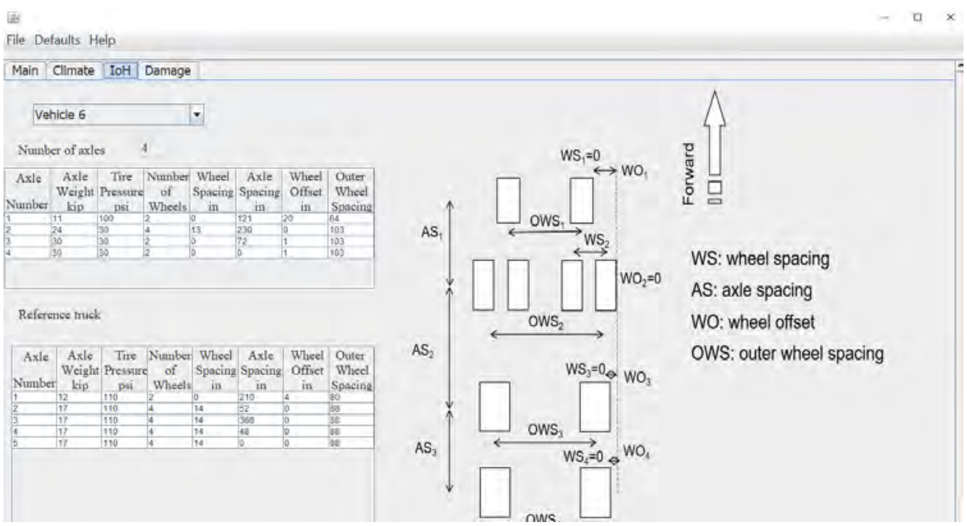


Step 2. Move to the Climate tab to specify seasonal variations for unbound layers stiffness and analysis months. In this case, the problem statement does not provide the monthly base moduli and moduli of subgrade reaction and therefore, the default values were accepted. If these values are available, they can be updated directly in the table.

All boxes, except for April, September, and October, are left unchecked since the damage for only those months needs to be analyzed.

Month	Base Modulus, psi	Modulus of Subgrade Reaction, psi/in	IoH Traffic
January	145630.0	185.642	☐
February	169127.0	178.354	☐
March	23126.1	163.609	☐
April	26268.6	167.287	☑
May	32223.801	172.783	☐
June	37216.801	177.465	☐
July	39361.5	179.535	☐
August	39518.0	179.907	☐
September	39534.801	179.802	☑
October	39552.801	179.708	☑
November	39141.398	179.491	☐
December	46612.102	180.184	☐

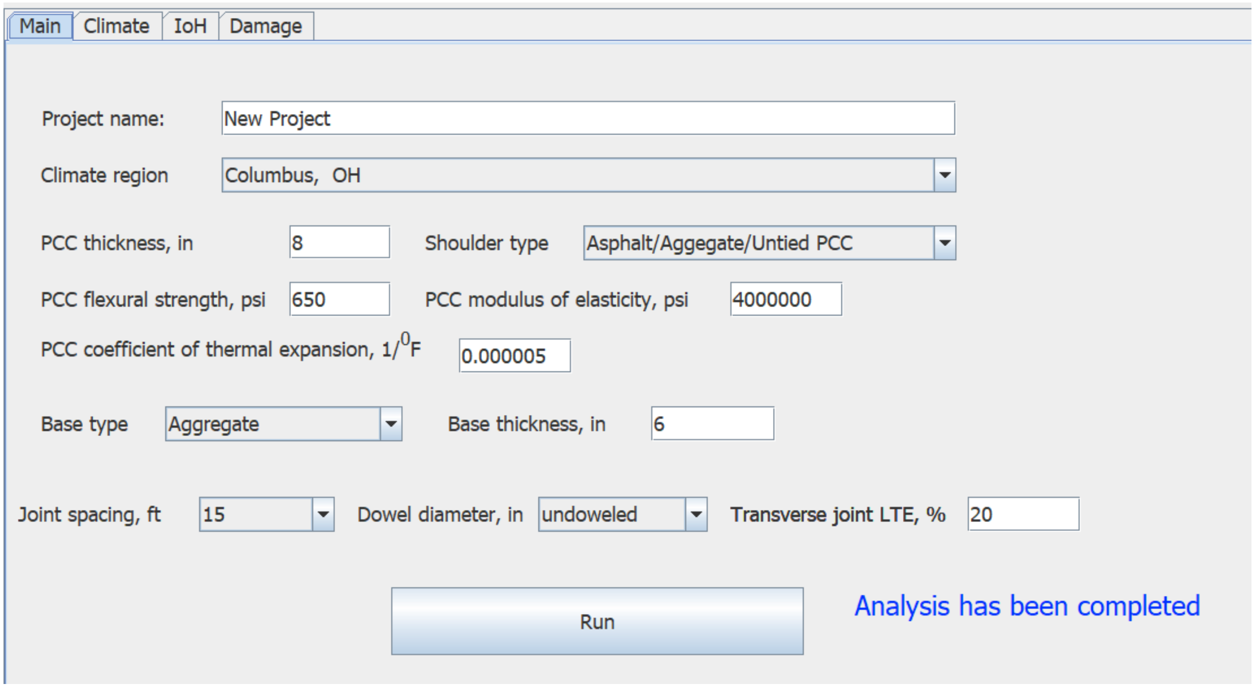
Step 3. Go to the IoH tab to provide the characteristics of the IoH that needs to be analyzed. In this case, Vehicle 6 (see Appendix E) corresponded to the IoH in the problem statement, so this IoH was selected from the list and no changes to the configuration were made. If none of the vehicles in Appendix E correspond to what the user needs to analyze, select User-Defined from the list and enter the configuration of the desired IoH vehicle.



By default, the reference truck is an 80 kips semi-truck shown under the ‘Reference truck’ heading in the IoH tab, as shown in the figure above. The user may change its characteristics if desired.

Step 4. Execute the analysis by returning to the Main tab and hitting Run as shown below. This will launch a Windows command shell – please do not close this but wait for the analysis to finish. The screen will return to the tool and the Main tab will indicate a message next to the Run button when the analysis is completed.

The button should become inactive, and a command shell will appear; several of these shells will open and close as the analysis is performed. An "Analysis has been completed" message will be displayed in the Main tab when done.



Step 5. Once the analysis is completed, the results can be seen by moving to the Damage tab. The following screen should appear:

Main | Climate | IoH | Damage

Number of reference truck passes producing the same damage as one pass of IoH

Month	Bottom-up transverse cracking damage	Top-down transverse cracking damage	Longitudinal top-down
January			
February			
March			
April	4.6123	7.7372	10.7158
May			
June			
July			
August			
September	5.5234	7.1399	10.8279
October	5.9704	7.6446	11.4857
November			
December			

Estimated number of IoH passes to produce cracking, million

Month	Bottom-up transverse cracking	Top-down transverse cracking	Longitudinal top-down cracking
January			
February			
March			
April	0.4613	0.0608	0.0493
May			
June			
July			
August			
September	1.4708	0.0479	0.0357
October	2.3682	0.0549	0.0402
November			
December			

Estimated number of truck passes to produce cracking, million

Month	Bottom-up transverse	Top-down transverse	Longitudinal top-down
January			
February			
March			
April	2.1276	0.4701	0.5280
May			
June			
July			
August			
September	8.1236	0.3421	0.3863
October	14.1391	0.4194	0.4622
November			
December			

The results are presented in three different ways: on the top, the number of reference truck passes causing the same level of damage as one pass of the IoH for each month analyzed is presented. This is a measure of the relative amount of damage caused by the IoH as compared to the reference truck. It can be seen that in April one pass of the IoH produces the same bottom-up transverse damage, top-down transverse damage, and top-down longitudinal damage as 4.6234, 11.9269, and 12.9722 passes of the reference truck, respectively.

The two lower tables present the number of vehicle passes (in millions) needed to produce an appreciable amount of cracking (defined as a fatigue damage of 0.1). The table on the lower left shows this data for the IoH vehicle, and the lower right for the reference truck. It can be seen that it would take 0.46 million IoH passes to produce bottom-up transverse cracking in April while the right table shows that it would take 2.13 million passes of the reference vehicle to produce the same amount of bottom-up transverse cracking in April. This shows the significantly higher damage due to the IoH.

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.