PEDRO v1.10

User Guide

March 2019

Contents

Introduction

PEDRO, **PE**rmanent **D**eformation of asphalt concrete layer for **Ro**ads, is a viscoelastic uni-layer model that can be used to predict rutting components (post-compaction and shear rutting) in bituminous pavement layers that are subjected to traffic loading (Safwat F. Said, Hassan Hakim, Erik Oscarsson & Mattias Hjort (2011): Prediction of flow rutting in asphalt concrete layers, International Journal of Pavement Engineering, 12:6, 519-532 **To link to this article:** http://dx.doi.org/10.1080/10298436.2011.559549).

Vehicle characteristics, such as axle load configuration, speed, tyre-pavement interaction, and influence of lateral position, are taken into consideration to estimate rut development as a function of pavement age.

The PEDRO model utilises the viscosity of bituminous materials, hourly measured traffic and climate data, and the geometry of the pavement structure.

Installation

Suitable for Windows operating systems.

Not suitable for Mac applications.

A beta web version is also available at http://www.pedro.vti.se

General

Model Description

The model consists of:

- Two drop down menus
  - File
  - Help
- Five input tabs
  - General
  - Material
  - Traffic
  - Climate
  - Results
- Two command functions:
  - Run
  - Cancel

Drop Down Menus

The “File” drop down menu allows the user to either open saved input data, save input data, save results, or exit the program.

The “Help” drop down menu provides the user with a short description of the model. A help function will be available in a later version of the model.

Input Tabs

To perform a prediction analysis, data is required in the “General”, “Material”, “Traffic”, and “Climate” input tabs. Each tab is divided into sub categories:

Command Functions

The command functions can be used to either start or cancel the analysis process.

The “Run” command can either be used to carry out the initial prediction analysis or to update results after parameter changes in an input tab.

Drop Down Menus

File

It should be noted that an analysis ("Run" command function) must be performed before input data or results can be saved. Alternatively, an existing data file can be opened and saved.

To save the input data:

- Click on the "File" drop-down menu and choose "Save Input Data As"
- Choose a directory and folder where the input data file is to be saved
- Enter a file name for the input data and click on the "Save" function command
- Choose an appropriate programme to open the file

To open previously saved input data:

- Click on the "File" drop-down menu and choose "Open Data"
- Choose the directory and folder where the input data file has been saved
- Click on the input data file name
- Click on the "Open" function command

To save the results:

- Click on the "File" drop-down menu and choose "Save results as"
- Choose a directory and folder where the results file is to be saved
- Enter a file name for the results and click on the "Save" function command
- Choose an appropriate programme to open the file

Help

The "Help" drop down menu provides the user with a short description of the model. A help function will be available in a later version of the model.

Input Tabs

General Input Tab

This tab requires data input in two sub-categories:

- Layers
- Options

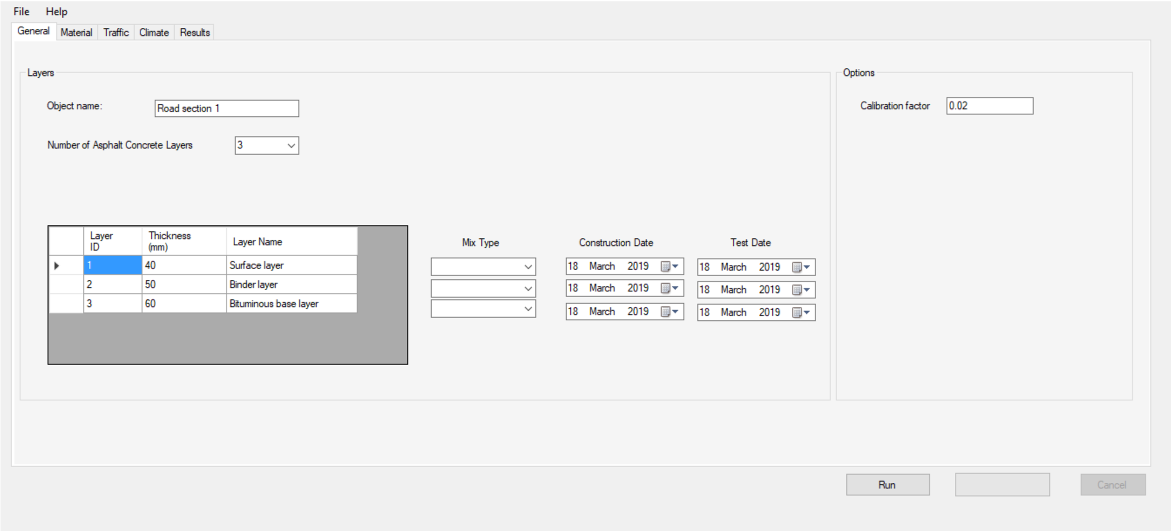


Figure 1. General input tab.

Layers Sub-Category

- Enter an object name
- Select the number of bituminous construction layers (not unbound layers) from the drop-down menu (up to 5 layers)
- Edit layer name (default names are 1,2,3,4, and 5)
- Enter a thickness (mm) for each layer - mandatory
- Enter a mix type or choose a mix type from the drop-down menu (11 options)
- Select the construction date from the drop-down calendar - mandatory for the estimation of ageing impact
- Select the test date from the drop-down calendar - mandatory for the estimation of ageing impact

Note - If different construction and test dates are entered for each layer, the surfacing layers dates will take precedence. This is justified and can be explained through further analysis of the output data.

Options Sub-Category

- Enter calibration factor

Note – The default calibration factor is an approximate single value. The final calibration algorithm has not yet been established.

Material Input Tab

This tab requires data input in two sub-categories:

- Viscosity
- Poisson's Ratio

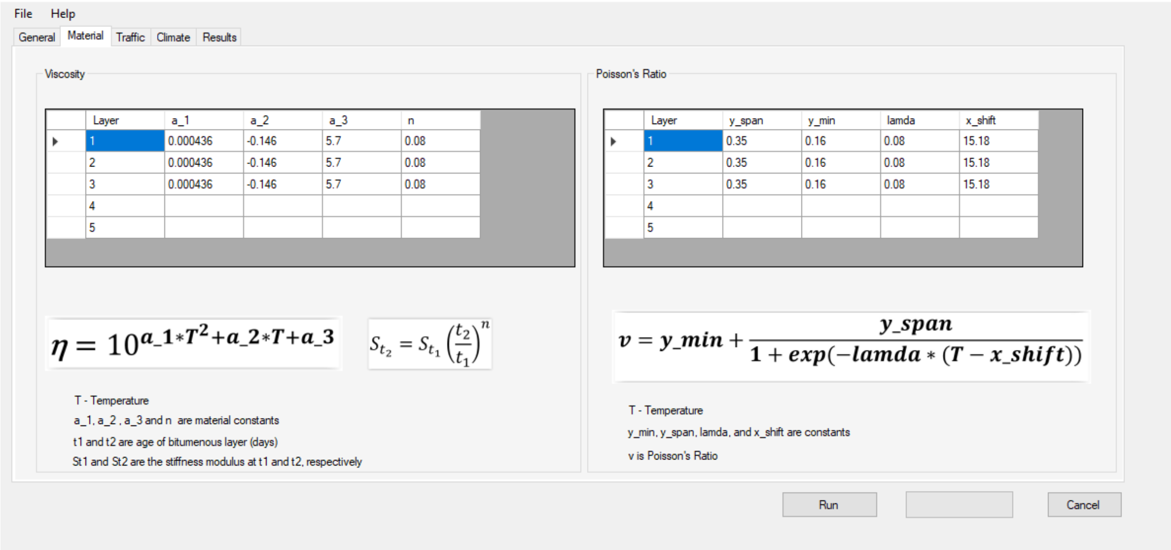


Figure 2. Material input tab.

Viscosity Sub-Category

Viscosity is a fundamental characteristic of a bitumen as it determines how the material will behave at a given temperature and over a temperature range.

A detailed description of the viscosity of bituminous mix can be found in the article Rheological characterisation of asphalt concrete using a shear box (Safwat el al, 2013). In the article, an exponential curve fitting was used, however, in the current version of the PEDRO program, a 2nd degree polynomial is used to fit the log of viscosity (MPas) to the temperature.

$$\eta = 10^{a\_1*T^2+a\_2*T+a\_3}$$

- Edit layer name (default names are 1,2,3,4, and 5)
- For each layer, entering a value for material constants a_1, a_2, a_3, and n is mandatory.

  Note - Variables a1, a2 and a3 are determined from shear testing. The variable "n" is an ageing factor and has a pre-determined default value of 0.08 for conventional mixes (Said 2005). If n=0.0 no ageing impact will be considered. If the ageing impact is to be considered, n-values should be determined for each layer.

Poisson's Ratio Sub-Category

- Edit layer name (default names are 1,2,3,4, and 5)
- For each layer, enter a value for the constants of a sigmoidal function; y_span, y_min, lamda, and x_shift

Traffic

Depending on the choice of Traffic Data, this tab requires data input in three or four sub-categories:

- Traffic Data
- Vehicle Configuration
- Axle Configuration
- Daily Traffic Distribution

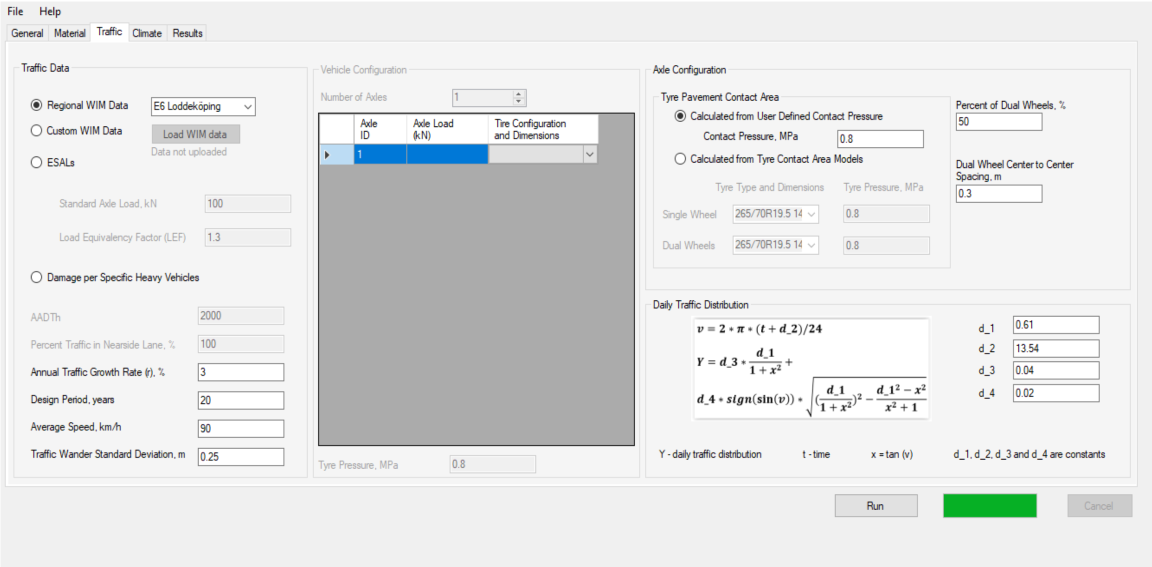


Figure 3. Traffic input tab

Traffic Data

Traffic data is used to calculate the commercial vehicle loading over the design period.

- Choose between four options:
  - Regional WIM Data (12 default Swedish stations via drop-down menu)
  - Custom WIM Data (refer to data example in Appendix 1)
  - ESALs (Equivalent Standard Axle Loads)
  - Damage per Specific Heavy Vehicles; Default 1.3 according to the Swedish specifications

- If Regional WIM Data is selected:
  - Select a relevant WIM station from the drop-down menu.
  - Enter a value for the “Annual Traffic Growth Rate”
  - Enter a value for the “Design Period”
  - Enter a value for the “Average Speed”
  - Enter a value for the “Traffic Wander Standard Deviation” (Recommended 0.29 for motorway)

- If ESALs is selected:
  - Enter a value for the “Standard Axle Load”
  - Enter a value for the “Load Equivalent Factor”
  - Enter a value for the “AADTh” (Average Annual Daily Traffic – heavy)
  - Enter a value for the “Percent Traffic in Nearside Lane”
  - Enter a value for the “Annual Traffic Growth Rate”

- Enter a value for the “Design Period”
- Enter a value for the “Average Speed”
- Enter a value for the “Traffic Wander Standard Deviation”

- If Damage per Specific Heavy Vehicles is selected:
  - Enter a value for the “Number of Heavy Vehicles per Day
  - Enter a value for the “Annual Traffic Growth Rate”
  - Enter a value for the “Design Period”
  - Enter a value for the “Average Speed”
  - Enter a value for the “Traffic Wander Standard Deviation”

Vehicle Configuration

This sub-category becomes active if “Damage per Specific Heavy Vehicles” is selected for the type of traffic data.

- Enter a value for the “Number of Axles”
- Enter an “Axle Load in kN” value for each Axle ID
- Select a “Tyre Configuration and Dimension” value for each Axle ID
- Enter a value for the “Tyre Pressure” (Note: next version will include entering tyre pressure per each tyre)

Axle Configuration

This sub-category becomes fully active if “Regional WIM Data”, “Custom WIM Data”, or “ESALs” is selected for the type of traffic data.

- If “Calculated from User Defined Contact Pressure” is selected:
  - Enter a value for the “Contact Pressure”
- If “Calculated from Tyre Contact Area Models” is selected:
  - Select the appropriate tyre dimensions from the drop down menus
  - Enter a value for the “Tyre Pressure”
- Enter a value for the “Percent of Dual Wheels”
- Enter a value for the “Dual Wheel Centre to Centre Spacing”

If “Damage per Specific Heavy Vehicles” is selected, only the “Dual Wheel Centre to Centre Spacing” field becomes active.

- Enter a value for the “Dual Wheel Centre to Centre Spacing”

Daily Traffic Distribution

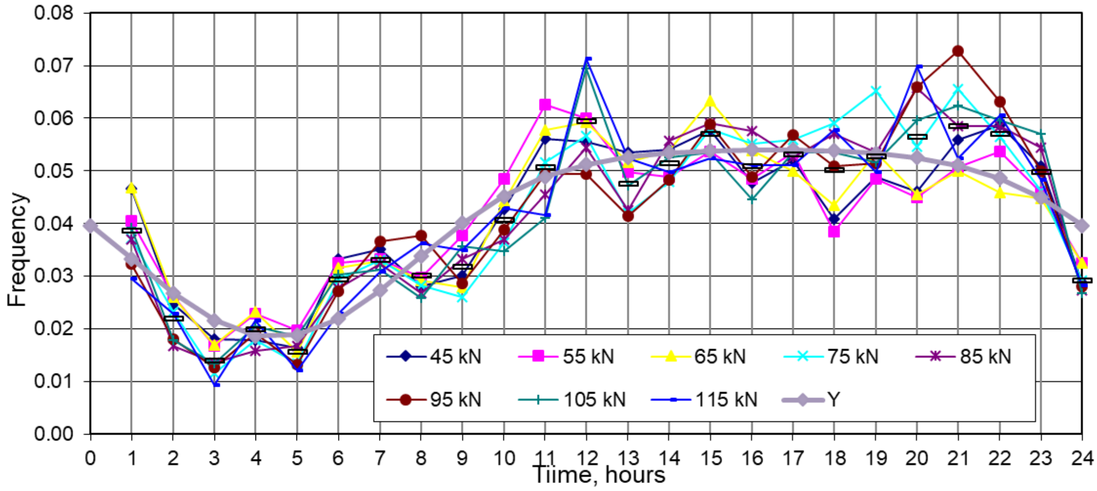
Hourly distribution of heavy vehicles axle load spectra fitted to a compound mathematical function.

$$\emptyset = \frac{2\pi * (t + \beta_3)}{24}$$

$$\mathbf{Y} = \beta_0 + \beta_1 * \left[\frac{\beta_2}{1 + (\tan\emptyset)^2} + sign\,(\sin\emptyset) * \sqrt{\left(\frac{\beta_2}{1 + (\tan\emptyset)^2}\right)^2 - \frac{{\beta_2}^2 - (\tan\emptyset)^2}{(\tan\emptyset)^2 + 1}} \right.$$

T = time of day, hour

$\beta_0, \beta_1, \beta_2$ & β_3 curve fitting constants in the mathematical function (determined ex. By Excel Solver)



- Enter a value for constants d_1, d_2, d_3, and d_4 ($\beta_0, \beta_1, \beta_2$ & β_3)

Climate

This tab requires data input in two sub-categories:

- Climate
- Weather Stations

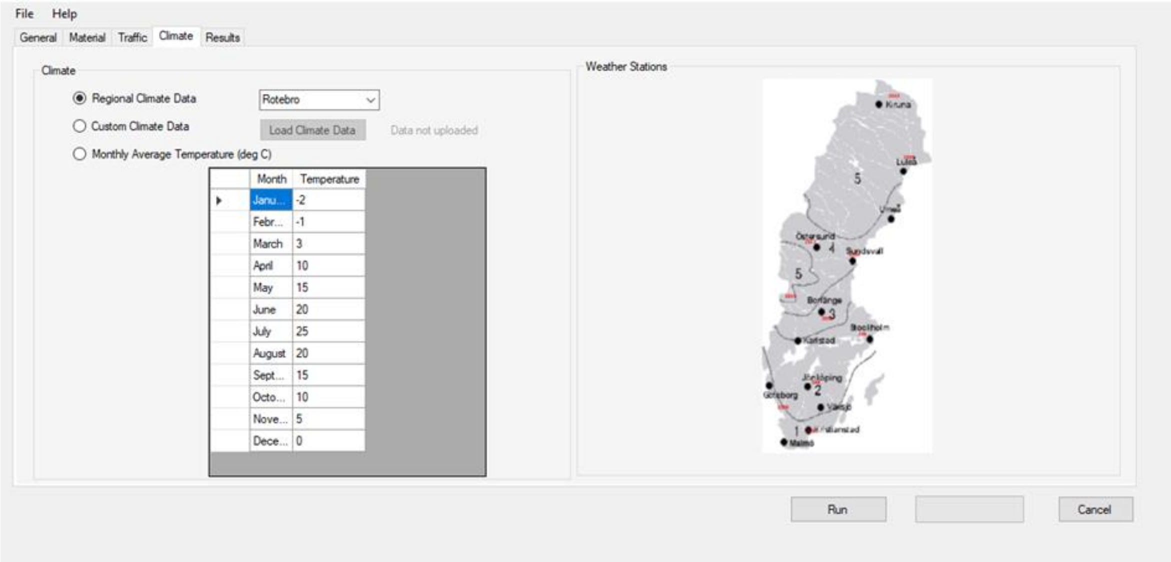


Figure 4. Climate input tab

Climate

- Choose between three options:
  - Regional Climate Data
  - Custom Climate Data
  - Monthly Average Temperature
- If Regional Climate Data is selected:
  - Use the drop-down menu to select a Swedish region (13 regional options)
- If Custom Climate Data is selected:
  - Click on the Load Climate Data command function
  - Select and open custom file (refer to data example in Appendix 2)
- If Monthly Average Temperature is selected:
  - Enter temperature values for each month

Weather Stations

The Swedish Transport Administration has many weather stations strategically placed on the national road network. Based on data from these stations, weather information can be distributed to road users. The stations also provide hourly air and pavement surface temperature data. This is used to estimate pavement temperature at various depths.

Results

To view the results:

- After inputting all relevant data, click on the "Run" command function
- The calculation process can be stopped at any time:
    - Click on the "Cancel" command function
    - Click on "yes" command function to confirm
- Yearly numerical results of maximum depression and a profile view will be shown after the status bar has turned green (figure 5)
- By clicking on the "Profile" command function, the view can be switched to "Rut growth" (Figure 6)
- By clicking on the "Rut growth" command function, the view can be switched back to "Profile" (Figure 5)

  Note - Screen view may be incorrect if construction and test dates are different for different pavement layers. This is justified and can be explained through further analysis of the output data.

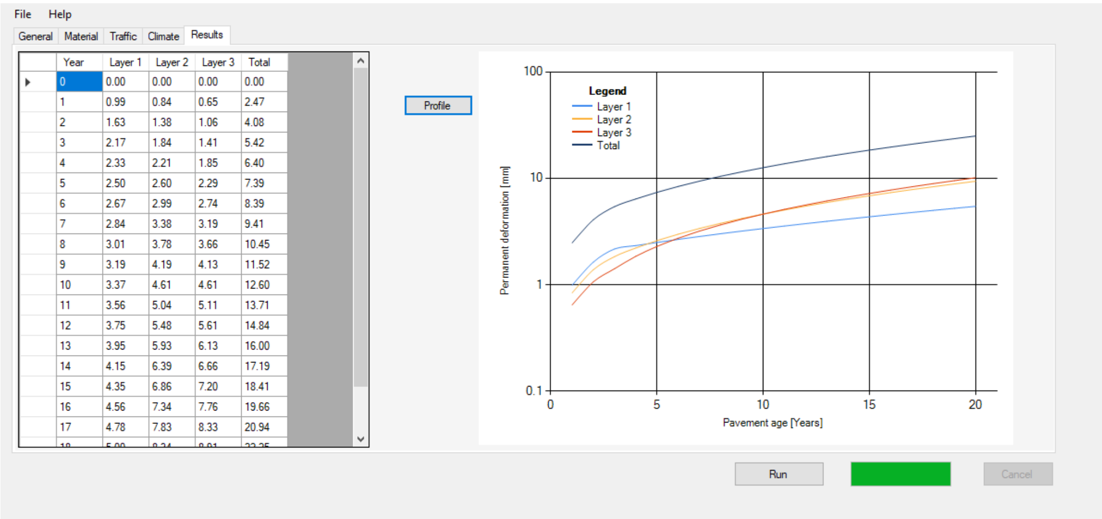


Figure 5. Results showing profile view

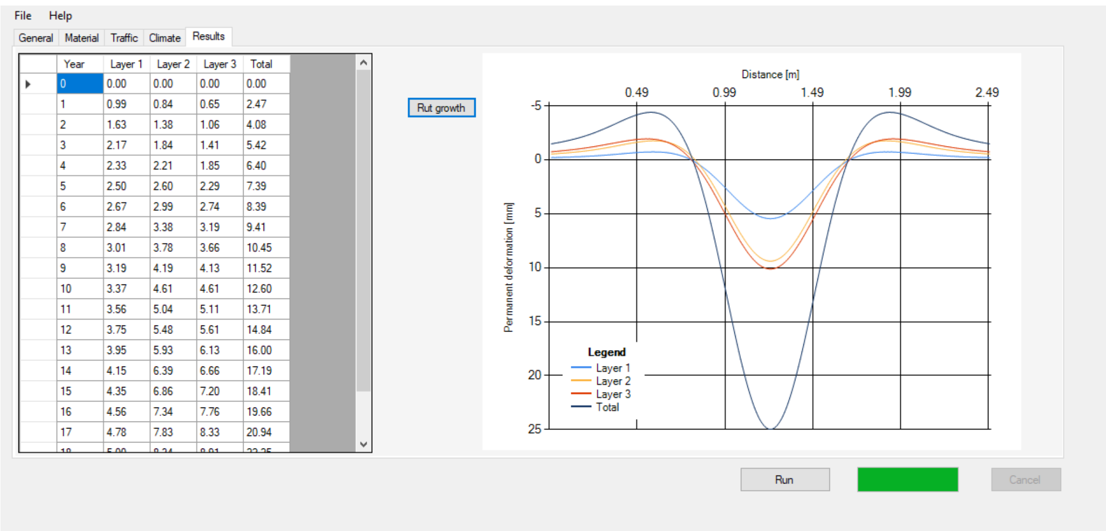


Figure 6: Results showing rut growth view

To save the results:

- Click on the “File” drop-down menu and choose “Save results as”
- Choose a directory and folder where the results are to be saved
- Enter a file name for the results and click on the “Save” function command
- Choose an appropriate programme to open the file

Appendix 1

Custom WIM Data

User defined axle load spectra data can be created using a text file consists of two rows.

The first row is a list of axle loads in KkN. A minimum of one axle load must be provided in the text file.

The second row represents the average number of axles per day for each axle listed in the first row.

The number of elements in the two rows must be equal.

A typical example of a user defined axle load spectra is given below in Figure 7.

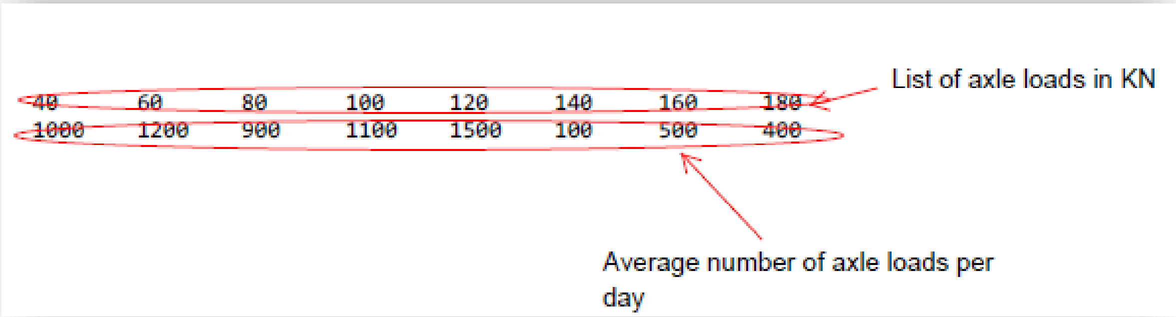


Figure 7. Example of a user defined axle load spectra

Appendix 2

Custom Climate Data

User defined pavement layer average temperature data can be created from a text file that consists of twelve columns (each column represents a month of the year).

The number of rows required depends on number of pavement layers. Each layer requires twenty-four rows (each row represents an hour of the day).

Data for at least one layer must be provided (twelve months by twenty-four hours).

A typical example of user defined pavement layer temperature data, for two asphalt concrete pavement layers, is given below in Table 1.

Table 1. Example of user defined pavement layer temperature data

0.58	0.76	4.97	8.93	16.22	19.88	22.35	20.88	15.68	10.38	5.91	3.14
0.52	0.64	4.63	8.35	15.46	19.09	21.56	20.14	15.2	10.31	5.84	3.11
0.48	0.56	4.27	7.82	14.83	18.38	20.87	19.48	14.84	10.09	5.73	3.04
0.46	0.47	4.07	7.36	14.24	17.77	20.28	18.96	14.52	9.94	5.55	3.02
0.4	0.38	3.89	7	13.75	17.29	19.77	18.62	14.18	9.77	5.63	2.97
0.36	0.26	3.71	6.7	13.23	16.94	19.31	18.29	13.94	9.65	5.56	2.98
0.31	0.18	3.53	6.44	12.95	16.74	19.01	17.89	13.69	9.55	5.41	2.99
0.33	0.12	3.45	6.33	13.05	17.12	19.21	17.83	13.49	9.44	5.44	3.01
0.37	0.11	3.67	6.74	14	18.21	20.09	18.49	13.53	9.41	5.46	3.02
0.43	0.29	4.51	8.03	15.77	19.92	21.67	19.94	14.3	9.75	5.64	3.04
0.6	0.96	6.01	9.93	18.04	22.15	23.71	22.06	15.9	10.36	6.07	3.17
1	1.84	7.79	12.24	20.51	24.4	26.02	24.34	18.07	11.4	6.71	3.5
1.5	2.72	9.52	14.55	23.11	26.58	28.55	26.68	20.2	12.52	7.28	3.87
1.94	3.45	10.81	16.5	25.44	28.64	30.6	28.84	21.89	13.58	7.72	4.25
2.15	3.96	11.8	17.63	26.83	30.15	32.06	30.24	22.99	14.36	7.96	4.4
2.11	4.19	12.25	18.49	27.77	31.02	33.09	31	23.67	14.68	7.93	4.29
1.82	3.85	12.09	18.83	27.91	31.22	33.45	31.21	23.76	14.42	7.45	4.02
1.5	3.16	11.09	18.37	27.37	30.63	33.02	30.75	22.85	13.76	6.98	3.76
1.28	2.44	9.64	17.16	26.16	29.66	31.99	29.64	21.64	12.95	6.64	3.63
1.11	1.92	8.2	15.5	24.58	28.06	30.54	28.09	20.13	12.16	6.36	3.52
0.94	1.6	7.19	13.69	22.59	26.3	28.74	26.3	18.56	11.51	6.21	3.43
0.8	1.35	6.45	12.01	20.4	24.46	26.74	24.39	17.53	11.11	6.07	3.37
0.7	1.16	5.92	10.76	18.6	22.55	24.88	22.79	16.58	10.78	5.96	3.27
0.62	0.98	5.5	9.77	17.4	21	23.45	21.69	16.04	10.55	5.88	3.18
0.82	1	5.51	9.8	17.36	21.09	23.51	21.95	16.5	10.8	6.15	3.3
0.77	0.88	5.17	9.21	16.55	20.27	22.67	21.19	16.01	10.73	6.1	3.26
0.72	0.79	4.8	8.64	15.88	19.53	21.93	20.52	15.65	10.49	5.98	3.19
0.69	0.71	4.56	8.15	15.25	18.88	21.32	19.94	15.29	10.36	5.81	3.18
0.63	0.62	4.37	7.77	14.73	18.34	20.78	19.56	14.92	10.18	5.88	3.12
0.58	0.52	4.18	7.44	14.19	17.94	20.28	19.22	14.65	10.05	5.81	3.13
0.54	0.43	3.96	7.15	13.83	17.61	19.9	18.79	14.39	9.94	5.65	3.13
0.53	0.36	3.88	6.97	13.68	17.66	19.82	18.6	14.16	9.81	5.67	3.13
0.55	0.33	3.92	7.11	14.14	18.25	20.26	18.89	14.11	9.74	5.66	3.14
0.58	0.39	4.37	7.87	15.28	19.37	21.24	19.73	14.48	9.99	5.78	3.15
0.69	0.82	5.4	9.14	16.94	21	22.71	21.21	15.5	10.34	6.06	3.21
0.94	1.41	6.75	10.91	18.89	22.8	24.47	22.98	17.09	11.05	6.53	3.43
1.31	2.09	8.22	12.81	21.02	24.59	26.51	24.87	18.86	11.91	6.97	3.71
1.7	2.73	9.42	14.57	23.12	26.43	28.4	26.77	20.41	12.83	7.35	4.03
1.95	3.25	10.42	15.81	24.65	27.94	29.87	28.23	21.51	13.58	7.65	4.22
2.01	3.6	11.06	16.76	25.71	29.02	31.01	29.18	22.28	14.04	7.79	4.22
1.87	3.53	11.25	17.41	26.26	29.58	31.68	29.7	22.71	14.05	7.53	4.07
1.64	3.14	10.76	17.39	26.21	29.45	31.73	29.7	22.31	13.7	7.18	3.88
1.46	2.62	9.79	16.73	25.53	28.98	31.23	29.13	21.58	13.16	6.86	3.75
1.3	2.17	8.66	15.6	24.49	27.95	30.31	28.09	20.54	12.55	6.59	3.66
1.16	1.86	7.76	14.24	23.05	26.65	29.04	26.8	19.26	11.95	6.44	3.57
1.03	1.62	7.03	12.86	21.31	25.23	27.51	25.29	18.34	11.55	6.3	3.52
0.93	1.42	6.49	11.66	19.74	23.66	25.95	23.85	17.41	11.22	6.2	3.42
0.85	1.25	6.06	10.68	18.57	22.24	24.61	22.78	16.85	10.98	6.11	3.34

References

Said, S.F., H. Hakim, E. Oscarsson & M. Hjort (2011): Prediction of flow rutting in asphalt concrete layers, International Journal of Pavement Engineering, 12:6, 519-532 **To link to this article:** http://dx.doi.org/10.1080/10298436.2011.559549

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