Application Manual (Bridge, Civil & Structural)

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Table of Contents

Application Manual (Bridge, Civil & Structural)

Introduction

This manual covers application-specific modelling and results facilities for LUSAS Bridge and LUSAS Civil & Structural software products. Menu entries for these application products are inserted onto the main menu based upon the software key you have installed on your system or, if you are using LUSAS Academic software, by the selection of a software product during the set-up procedure. Occasionally, some facilities for LUSAS Bridge and LUSAS Civil & Structural use only appear on the general menu.

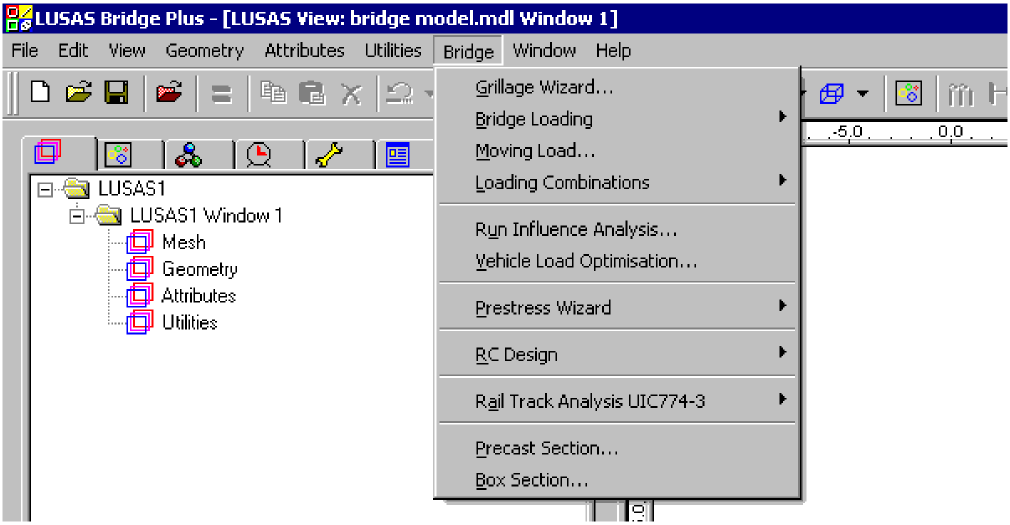
This manual describes the options available for the following menu items:

- **Bridge menu**
- **Civil menu**

More detailed on-line help information on each of the application specific features described can be accessed from the Help button on the relevant dialog.

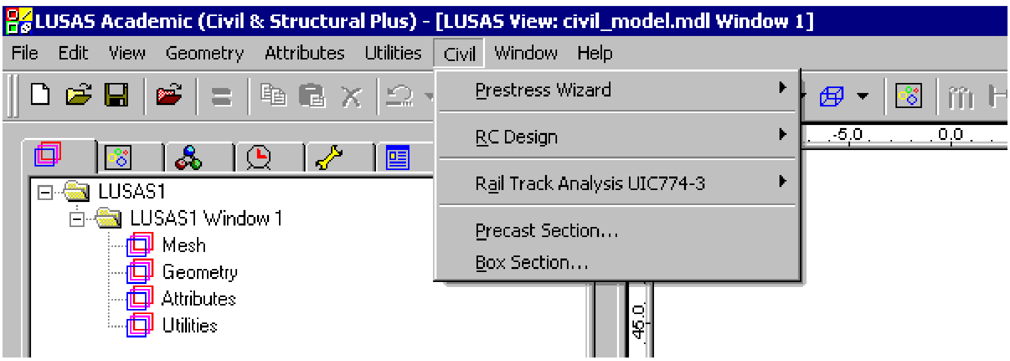
The Bridge Menu

The Bridge menu item will appear between the Utilities and Window menu items as shown:



The Civil Menu

The Civil menu item will appear between the Utilities and Window menu items as shown:



Grillage Wizard

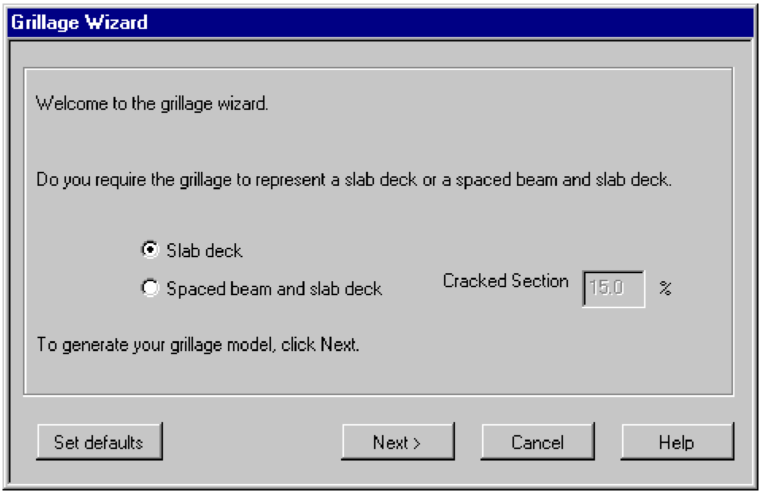
Overview

The grillage wizard comprises a series of dialogs and enables orthogonal, skewed and curved grillages to be generated from user-defined data.

When creating a grillage model some basic guidelines should be considered:-

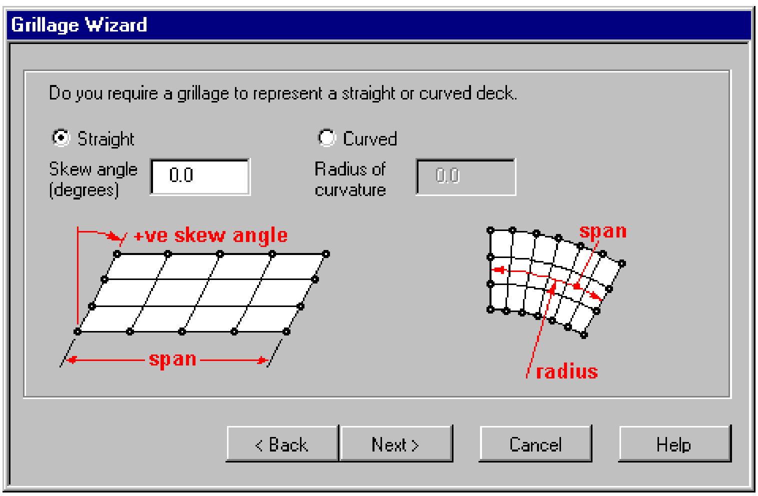
- Grillage wizard models are created with 1 line mesh division for each grillage element. Additional line mesh attributes can be created and assigned to the model should this ever prove to be required.
- Longitudinal grillage members should be placed along lines of design strength. For a slab model this could be where there was a concentration of reinforcement in the slab itself. For a composite bridge this could be at the location of a steel girder / prestress beam.
- The aspect ratio between the length of the transverse and longitudinal members should be set so that a good static distribution of loading is achieved. An aspect ratio of 1 to 1 is normally used but an aspect ratio of up to 1 to 3 is acceptable.
- Whenever possible it is recommended that a grillage model should have supports located at the intersection of longitudinal and traverse members.
- The grillage wizard automatically places rigid supports onto the model at bearing locations. These supports can be overwritten with new attributes of, say, an elastomeric bearing using a spring support. The supports should be chosen to as closely represent the actual structure as possible.
- If the results from a coarse grillage are in doubt for any reason a more refined grillage should be used to check the results.

Grillage Wizard : Step 1 - Grillage Type



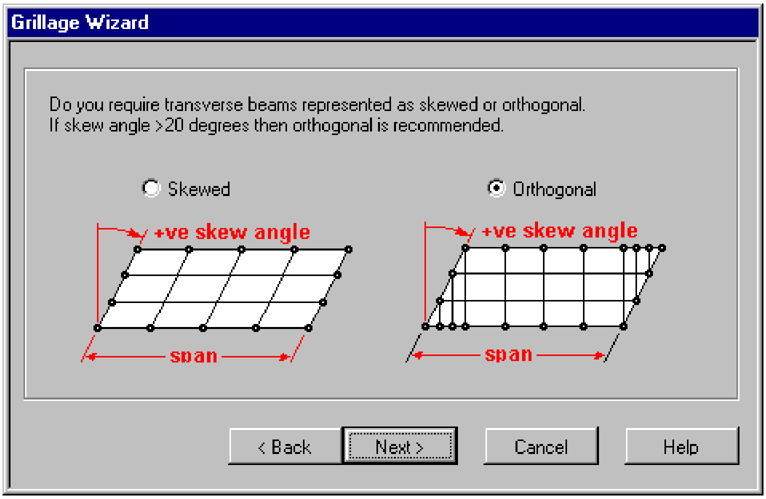
- Select the type of grillage model that you require. Both slab deck and spaced beam with slab deck constructions are supported and cracked section may be included.
- Spaced beam and slab deck models will automatically have elements defined for the allocation of cracked properties. By default 15% of the span (over internal supports) will be assumed to be cracked but this can be modified if required.
- The wizard accounts for multiple spans and applies support conditions. Groups are created to enable geometric and material properties to be easily assigned.

Grillage Wizard : Step 2 - Straight or Curved Deck



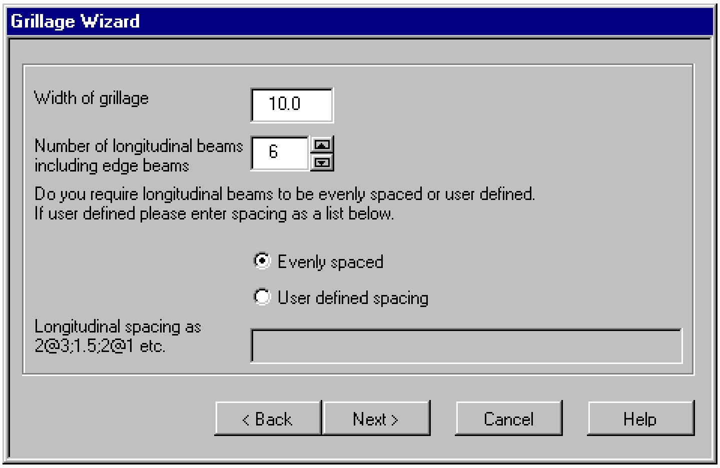
- Select whether a straight grillage or curved grillage is required. For a straight grillage a skew angle can be set. For a curved grillage a radius of curvature needs to be entered.
- For a straight grillage if any angle other than zero is entered, when the **Next** button is selected a dialog allowing a skewed or orthogonal transverse beam arrangement will be shown.

Grillage Wizard : Step 2a - Skewed or Orthogonal Beams



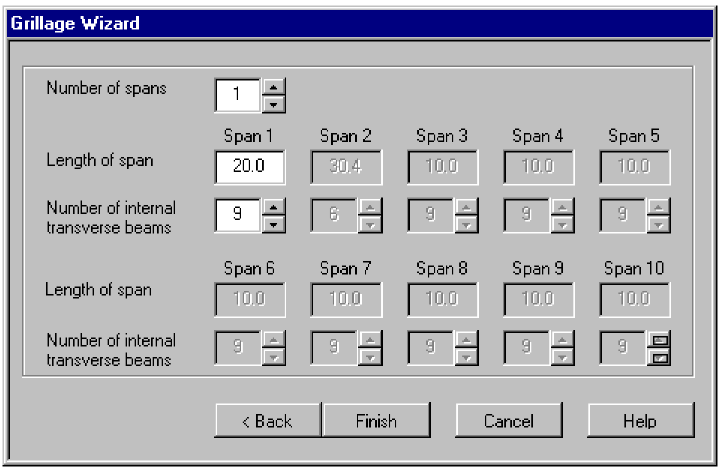
- If an angle has been entered for a straight grillage the geometry can be formed from skewed grillage elements or orthogonal grillage elements.
- If the skew angle is above 20 degrees then an orthogonal arrangement is recommended.

Grillage Wizard : Step 3 - Longitudinal Beam Detail



- The width of the grillage and the number of longitudinal beams can be set on this dialog
- The longitudinal beams can be evenly spaced or a user defined spacing can be set up allowing if services troughs dictate this is necessary.

Grillage Wizard : Step 4 - Span Details



- The number of spans, their lengths and the number of transverse elements can be set on this dialog.
- Clicking the **Finish** button creates the grillage model from the values specified.

Section generators and property calculators

In addition to the range of generally available standard section property calculators and the arbitrary section property calculator the following are available from the Bridge (or Civil) menu:

- **Precast Beam Section Generator**
- **Box Section Property Calculator**

Precast Beam Section Generator

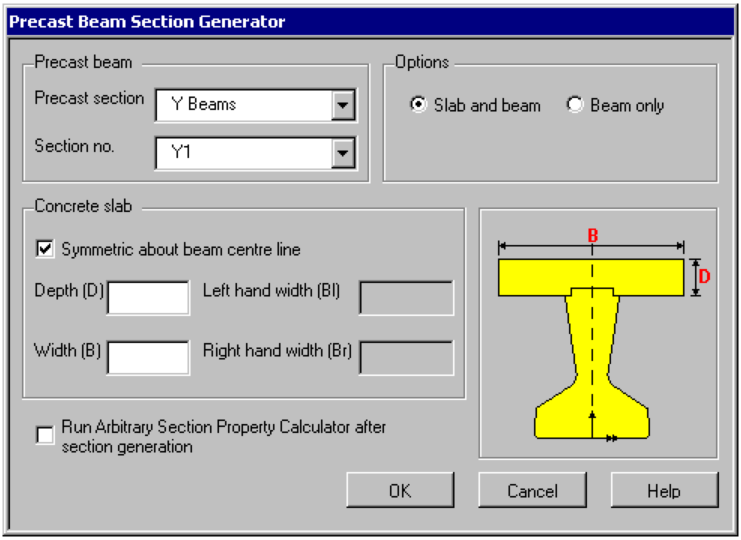
The Precast Beam Section Generator is provided in Bridge and Civil & Structural software products only. It produces 2D cross-sectional models of country-specific precast concrete beams having an optional top slab. These models are typically used to calculate beam section properties for use in grillage and frame models.

The library of sections supplied currently includes:

- **UK beams: Y, YE, TY, TYE, SY, M, UM and U beam types**
- **US beams: AASHTO Types II to VI, Florida Bulb T72 and T78 beams, NU Girders and Texas DoT 'I' Beams, North-East 'T' Bulbs.**
- **Australian and New Zealand beams: Super-T beams T1 to T5 (open and closed)**
- **Canadian 'I' beams**

Use

The Precast Beam Section Generator is accessed from the **Utilities> Section Property Calculator> Precast Section** menu item.



- ❑ **Precast section** allows selection of a range of precast beam types.
- ❑ **Section no** allows selection of a particular beam type.

- ❑ **Slab and beam** allows a contribution from a top slab to be included so that the section properties required for a grillage model can be obtained.
- ❑ **Beam only** ignores any defined slab values and centres the cros section about the origin.

- ❑ **Symmetric about beam centre line** option, if ticked, creates a slab of a width that is centred about the beam centre. If unchecked, left and right hand widths for the slab can be entered.

- ❑ **Run Arbitrary Section Property Calculator** is used to compute the section properties. If Run Arbitrary Section Property Calculator is checked a 2D model of the beam geometry will be created and the **Arbitrary Section Property Calculator** dialog will be displayed to enable section properties to be computed and saved in a section library.

To use the computed section properties in a model the section must be saved to a local or server library. To add a library item to the Attributes treeview select the **Attributes**> **Geometric**> **Section Library** menu item, then select **User Sections,** then select **Local** or **Server** before choosing the section required from the list available. The geometric properties can then be **assigned** to the required Line(s) in the model.

Notes:

- When the chosen section contains a void a surface will be created that represents the void, and this surface will be put in to a group named "Holes". This group will automatically be set as invisible. This is for use in the **Arbitrary Section Property Calculator**.
- Differences in concrete strengths between the beam and the slab are not considered. However, this can be calculated and the relevant width of slab entered if required.
- Span loading information for United Kingdom precast beam sections in the library is shown in the on-line help. Beam spans are based on 45 units HB loading, including 2.4kN/m2 for finishes.

Box Section Property Calculators

The Box Section Property Calculator is provided in Bridge and Civil & Structural software products only. It is accessed from the **Utilities> Section Property Calculator > Box Section...** menu item or from the Bridge menu.

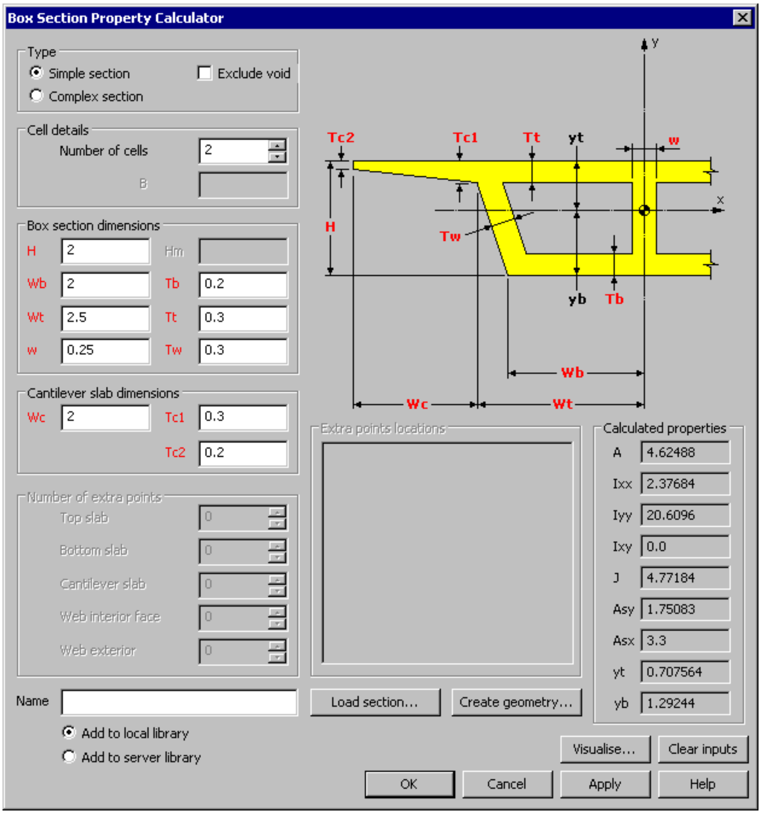
The box section property calculators calculate the section properties from user defined dimensional data. The section shape can be defined either as a **simple box section** or as **complex box section** created from as many points as are required to form a suitable representation of the true cross-sectional shape. A void can be included or excluded from a section. The sections generated are of a type typically used in precast and segmentally constructed bridges.

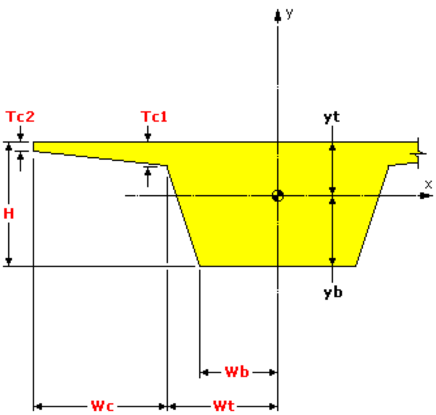
Section properties (area, moments of inertia and torsion constant etc.) of the section are computed automatically once a valid set of dimensions have been defined, using the same units as those specified on the model startup dialog. Extreme fibre positions for use when plotting stresses on beams are also calculated. The resulting section can additionally be:

- Visualised to check for correct values being entered and to see the automatically defined fibre locations
- Converted into model geometry. This would typically be used, for example, if it was required to modify the generated section in some way inside LUSAS Modeller before re-calculating the new section properties of the edited section using the **Arbitrary Section Property Calculator**.
- Added to a local or server library to enable the section properties to be used on the current project or on other projects.

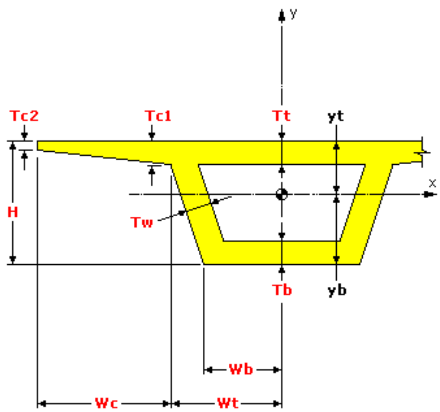
Simple Box Section

The simple box section calculator creates a box section of the style shown from user-defined values. No fillets can be specified internally when a void is present.

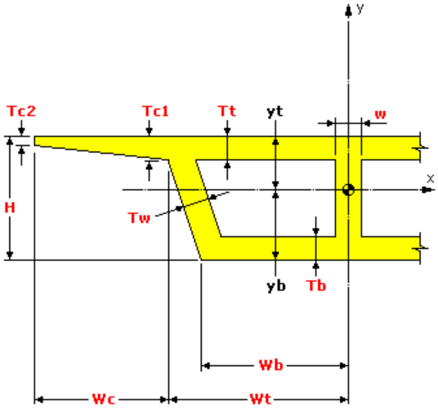




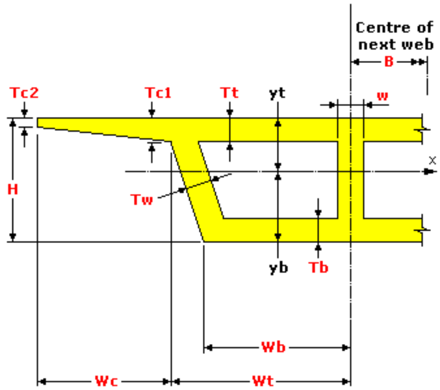
Simple box section without void



One cell simple box section



Two cell simple box section



Multi-cell simple box section

Dimensional data:

- ❑ **Cell details** Specify the number of cells, and the spacing between centre to centre distances of webs
- ❑ **Box section dimensions** These specify the overall height and width of the box, and the thicknesses of top and bottom slabs and side walls.
- ❑ **Cantilever slab dimensions** These specify the width and thickness of the cantilever.

Saving and using the defined section:

- ❑ The **Name** of the section must be entered.
- ❑ **Add to local library** Adds the calculated values to the local library when the Apply or OK button is selected.
- ❑ **Add to server library** Adds the calculated values to the server library when the Apply or OK button is selected.
- ❑ **Existing sections...** Displays a list of previously created and saved cross-sections that can be re-selected to populate the fields of the dialog. The list displayed is for the local or server library that is set.
- ❑ **Create geometry** Creates a 2D LUSAS model from the dimensional data. This would typically be used, for example, if it was required to modify the generated section in some way inside LUSAS Modeller before re-calculating the new section properties of the edited section using the Arbitrary Section Property Calculator. Additional options are available to position or orientate the section geometry that is created in a view window. By default a section created has its centre of gravity set at the view origin, that is 0,0,0.
- ❑ **Visualise...** Shows the cross-section that has been defined by the entered data. It also shows the fibre locations that are automatically created. Note that the axes shown on

the visualisation are view axes. An additional option to add a picture of this visualised section to the Annotation layer is provided. Select Create Annotation to do this.

- **Clear inputs** Clears any entered or populated data.
- Use the **Apply** button to save a section to a library and continue to modify values or define another section using the same dialog. Use the **OK** button to save the defined section and close the dialog.

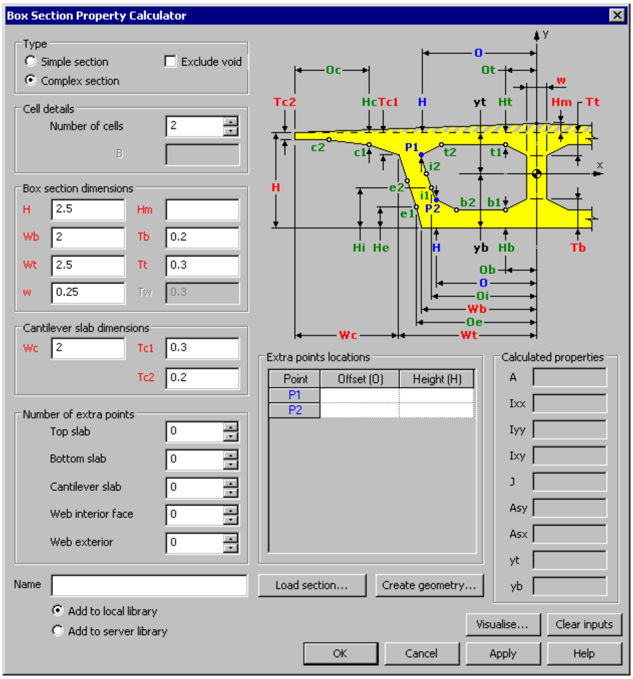
Using a defined box section

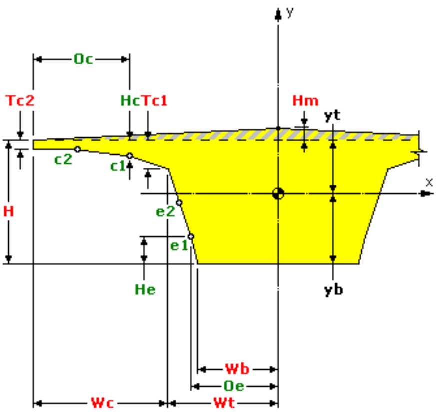
To use the computed section properties in a model the section must have been saved to a local or server library.

To add a library item to the Attributes treeview select the **Attributes> Geometric> Section Library** menu item, then select **User Sections,** then select **Local** or **Server** before choosing the section required from the list available. The geometric properties can then be **assigned** to the required Line(s) in the model. If the section shape is constant over a line feature a direct assignment to a line can be made. If the section shape varies over a line feature a set of pre-defined box sections can be used with the **Multiple Varying Sections** facility to create a multiple varying section line attribute for assignment to a line or lines on a model.

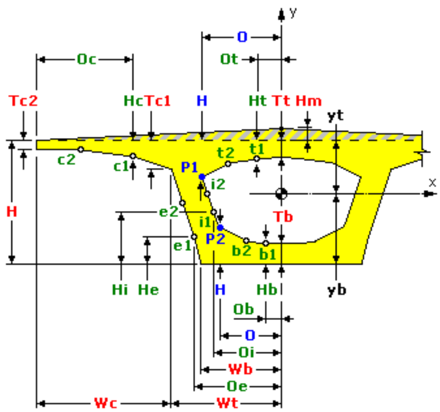
Complex Box Section

The complex box section calculator creates a box section of the style shown from user-defined values and as many additional points as are required to form the cross-sectional shape. A camber in the top slab can be optionally created for one and two celled sections. Fillets can be specified internally when a void is present.

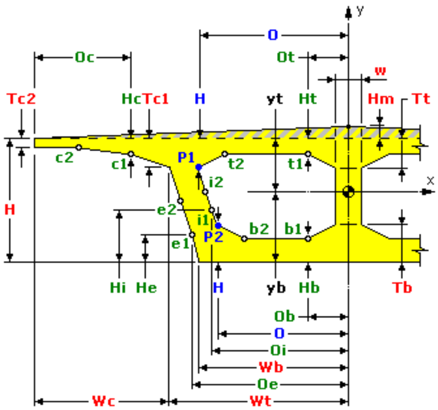




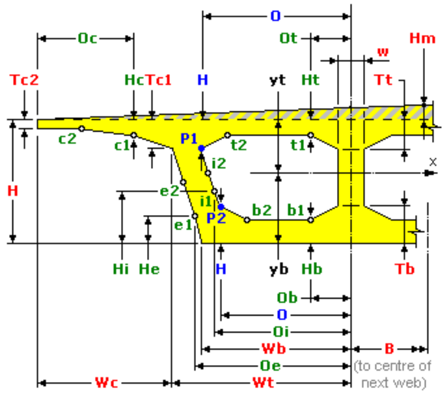
Complex box section without void



One cell complex box section



Two cell complex box section



Multi-cell complex box section

Dimensional data:

- **Cell details** Specify the number of cells, and the spacing between centre to centre distances of webs
- **Box section dimensions** These specify the overall height and width of the box and the thicknesses of the top and bottom slabs.
- **Cantilever slab dimensions** These specify the width and thickness of the cantilever.
- **No of internal points** These allow for any number of additional points to be defined in specified areas of the cross-section in order to accurately represent the true section shape. When extra points are added, additional dimensional data must be entered in the Points panel of the dialog.

Saving and using the defined section:

- The **Name** of the section must be entered.
- **Add to local library** Adds the calculated values to the local library when the Apply or OK button is selected.
- **Add to server library** Adds the calculated values to the server library when the Apply or OK button is selected.
- **Existing sections...** Displays a list of previously created and saved cross-sections that can be re-selected to populate the fields of the dialog. The list displayed is for the local or server library that is set.
- **Create geometry** Creates a 2D LUSAS model from the dimensional data. This would typically be used, for example, if it was required to modify the generated section in some way inside LUSAS Modeller before re-calculating the new section properties of the edited section using the Arbitrary Section Property Calculator. Additional options are available to position or orientate the section geometry that is created in a view

window. By default a section created has its centre of gravity set at the view origin, that is 0,0,0.

- **Visualise...** Shows the cross-section that has been defined by the entered data. It also shows the fibre locations that are automatically created. Note that the axes shown on the visualisation are view axes. An additional option to add a picture of this visualised section to the Annotation layer is provided. Select Create Annotation to do this.
- **Clear inputs** Clears any entered or populated data.
- Use the **Apply** button to save a section to a library and continue to modify values or define another section using the same dialog. Use the **OK** button to save the defined section and close the dialog.

Defining a complex box section

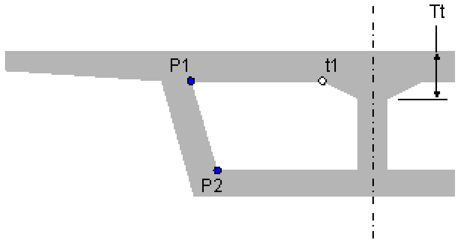
The main box cell, section and cantilever setting out dimensions for a complex box section are shown dimensioned with a height (H), width (W), slab thickness (T) and in the case of three or more celled sections, a breadth, (B). Slab thickness specifies the thickness of the slab at the location shown on the section dialog. Note that on multi-celled box sections, dependent upon the thickness specified, this may represent the distance from the top of the slab to the bottom of an internal fillet (Tt) or the distance from the bottom of the slab to the top of an internal fillet (Tb). In addition to these primary dimensions extra points can be defined to model a particular box section shape. Some extra points are mandatory as in the case of points P1 and P2. Others such as t1, b1, e1, i1, c1 etc. are optional.

Notes on defining a complex box section

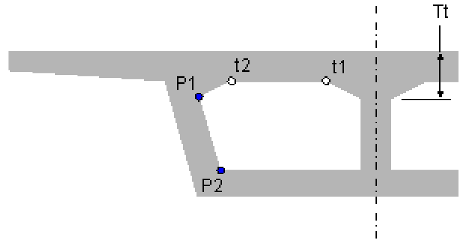
- Points P1 and P2 define the extent of the interior face of the external web. These points must be defined in the Extra Points grid in all cases, even when no fillets are required. Points P1 and P2 will lie at the corners of a void if no fillets are specified.
- Additional points can be defined to either model a particular cantilever shape, a side wall shape or to model simple fillets at top or bottom slab locations. Selecting the location and number of the points required in the No. of extra points cell will add fields to the Extra Points grid to allow offsets (O) and heights (H) for these points to be defined. As an example, to define fillets at the junction of the upper slab and the side and internal walls of a two cell box section, two internal points in the Top slab drop-down list would need to be specified (t1 and t2) in addition to specifying a thickness (Tt) from the top of the slab to the bottom of the fillet. Defining fillets for the lower slab/wall connections would be similar. See the Complex Box Section Examples for details.
- To model a curving external box section profile as many points on the web exterior face and cantilever slab can be defined as necessary to approximate the actual profile.
- A camber in the top slab can be optionally created by entering a value for the height of the midpoint of the slab (Hm).

Complex Box Section Examples

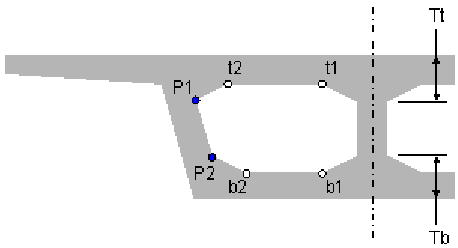
These examples show which extra points must be specified in addition to all other dimensions shown on the dialog in order to obtain the section shape shown. A two-cell box with no camber in the top slab is shown. The definition of extra points for single and multiple box sections is similar.



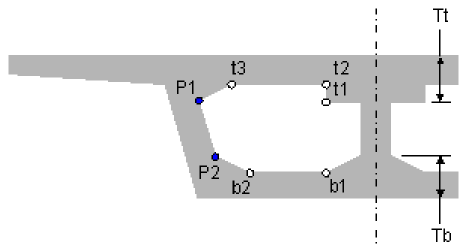
Upper slab fillet to internal wall only



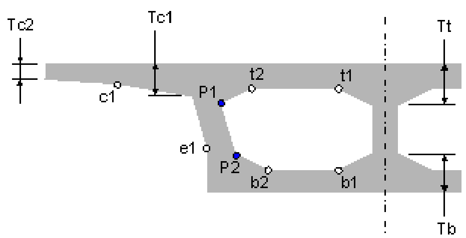
Upper slab fillet to all walls in section



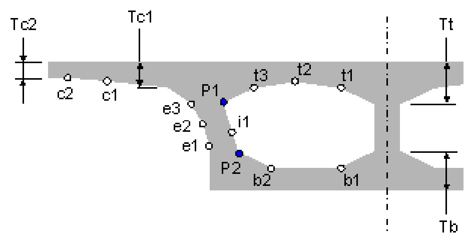
Upper and lower slab fillet to all walls



Custom connection to upper slab



Use of extra points to define outer wall and cantilever soffit



Use of multiple extra points

Complex section extra points explained

Extra points	Description	Mandatory / Optional
P1, P2	Define the extent of the interior face of the outer walls	Mandatory
t1, t2, t3...	Define upper slab fillets.	Optional
b1, b2, b3...	Define lower slab fillets	Optional
e1, e2, e3...	Define the shape of the external face of the outer walls	Optional
i1, i2, i3...	Define the shape of the interior face of the outer walls	Optional
c1, c2, c3...	Define cantilever soffit shape	Optional

Using a defined box section

To use the computed section properties in a model the section must have been saved to a local or server library.

To add a library item to the Attributes treeview select the **Attributes> Geometric> Section Library** menu item, then select **User Sections,** then select **Local** or **Server** before choosing the section required from the list available. The geometric properties can then be **assigned** to the required Line(s) in the model. If the section shape is constant over a line feature a direct assignment to a line can be made. If the section shape varies over a line feature, a set of pre-defined box sections can be used with the **Multiple Varying Sections** facility to create a multiple varying section line attribute for assignment to a line or lines on a model.

Bridge Loading

Overview

Bridge loading types are accessed from the **Bridge > Bridge Loading** menu item.

The following bridge loading types and facilities are available:

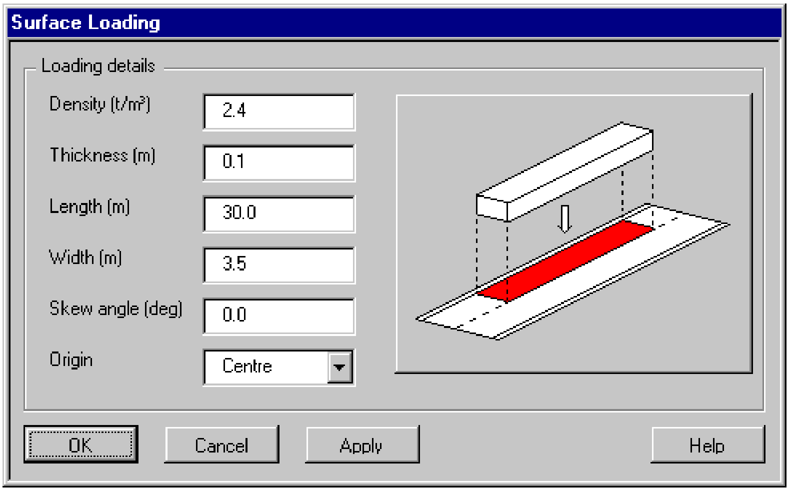
- **Gravity**
- **Surfacing Loading**
- **Static Vehicle Loads**
- **Moving Loads**
- **Vehicle Load Optimisation**

Gravity Loading

By selecting the **Gravity** option a load attribute is added to the Loading Treeview. Gravity loading is defined in accordance with the vertical axis direction that was specified either initially on the New Model dialog or subsequently on the Vertical Axis dialog accessed using the **Utilities> Vertical Axis** menu item.

Surface Loading

Surface loading is computed for each lane from the density and thickness of the surfacing material. The density is defined in t/m^3 and the dimension of the lane and thickness of the surfacing are defined in metres. The surface loading is then computed in the units selected initially on the New Model dialog.



To use this loading type:

- **Density** - specifies the density of the surfacing in t/m^3
- **Thickness** - specifies the thickness of the surfacing
- **Length** - specifies the length of the surfacing
- **Width** - specifies the width of the surfacing
- **Skew** angle - specifies the skew angle
- **Origin** - specifies the orgin of the surfacing load to be used to position the loading on the structure.

Static Vehicle Loads

Vehicle loading types are accessed from the **Bridge > Bridge Loading** menu item.

A number of dialogs are available to simplify the input of bridge loading in accordance with regional codes of practice. These are continually being extended and currently include:

- **Australia**
- **Canada**
- **China**
- **Eurocode Vehicle Loading**
- **Eurocode Train Loading**
- **Finland**
- **India**
- **Israel**
- **Korea**

- **New Zealand**
- **Norway**
- **Poland**
- **South Africa**
- **Sweden**
- **United Kingdom Vehicle Loading**
- **United Kingdom Train Loads**
- **United Kingdom Special Vehicle Loads**
- **United States of America - AASHTO**
- **United States of America - Oregon Vehicle Loading**

All bridge loads are defined as discrete load attributes which are saved in the discrete loads section of the Treeview. These loads are assigned to a point (which need not form part of the model) at the chosen load origin by dragging the load definition from the Treeview onto the graphics display. Discrete loads can be assigned to, and manipulated on a model as a set or load train by creating a compound discrete load.

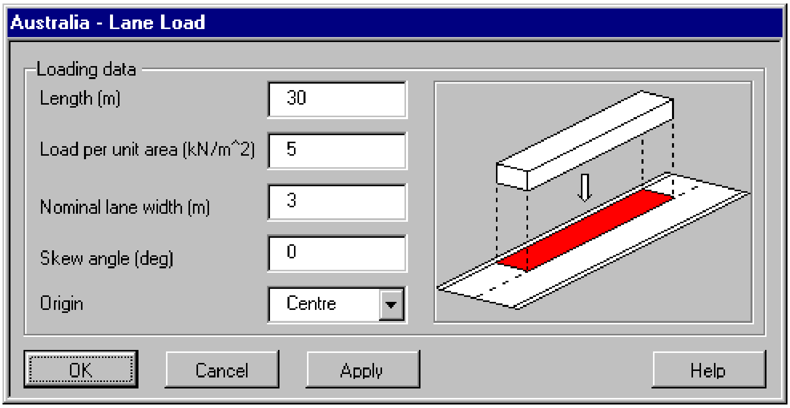
A moving load generator can be used to track the path of a static vehicle load (or a set of vehicle loads) across a structure.

Australia Vehicle Loading

Australian vehicle loads are defined to the AUSTROADS Bridge Design Code HB77.2, AS 5100.2-2004 : Bridge design - Design loads and AS 5100.7-2004 : Bridge design - Rating of existing bridges.

Australia Lane Loads

The lane load generator produces a uniform patch load based on notional lane width, loaded length and intensity. The lane load intensity is set to a default value but this can be modified to any value required.

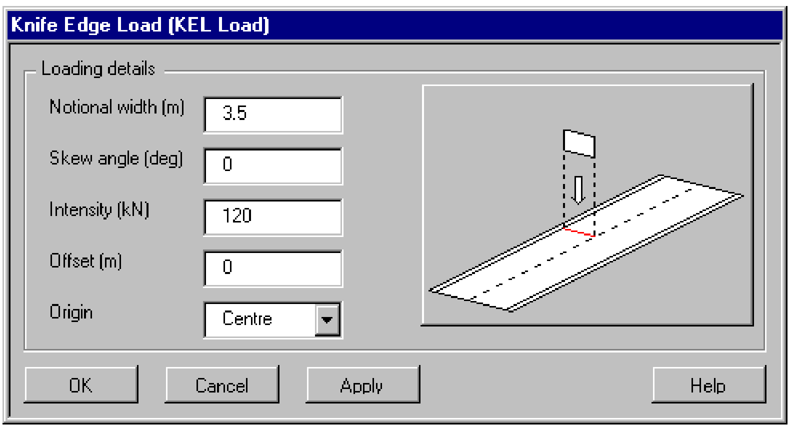


To use this loading type:

- Specify the loaded length.
- Specify the load per unit area.
- Specify the notional lane width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

Australia Knife Edge Loads (KEL) Loads

The KEL load generator produces a knife-edge load based on notional lane width and intensity. The intensity of the knife-edge load is et to a default value but can be modified to any value required.



To use this loading type:

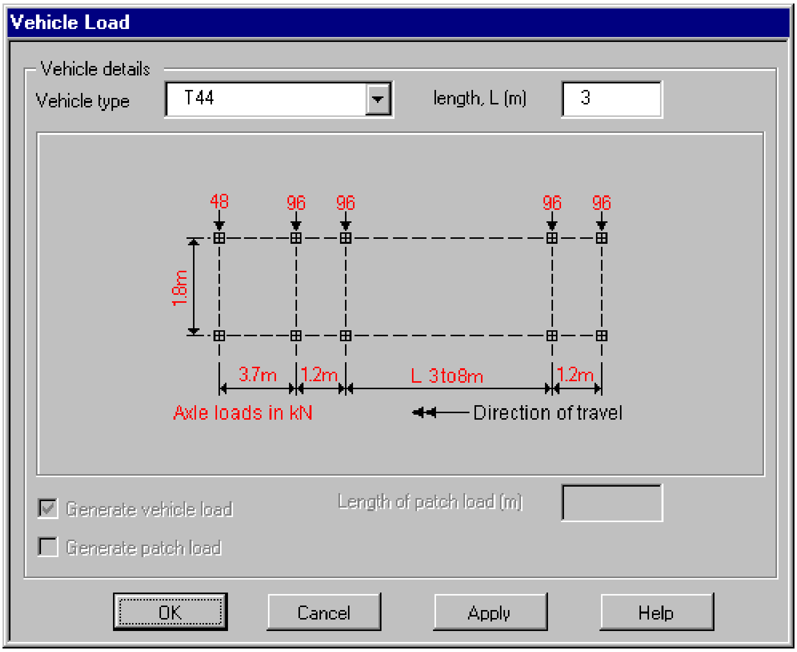
- Specify the notional width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Specify the intensity.
- Specify the offset.
- Choose the origin about which the load is to be generated.

Australia Vehicle Load

For the vehicle loads the following truck types can be created: T44, HLP320, HLP400, W80, A160, M1600 and S1600.

For the truck types T44, HLP320, HLP400, M1600 and S1600 the variable axle spacing, L, can be set to the required value.

For the truck types M1600 and S1600 the vehicle load and the accompanying patch can also be created.

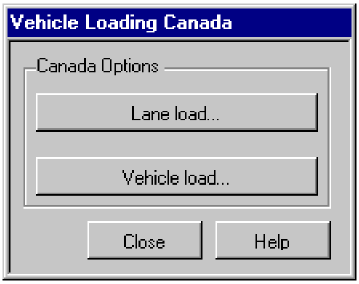


To use this loading type:

- Choose the vehicle type, and if necessary specify a value for the length.

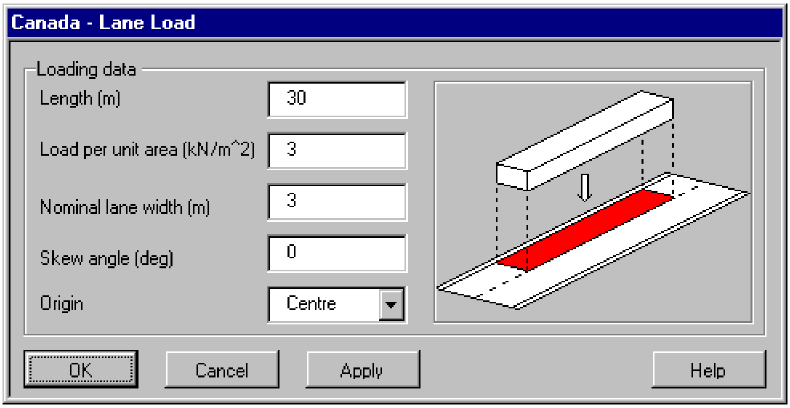
Canada Vehicle Loading

Canadian vehicle loads are defined to the CHBDC.



Canada Lane Loads

The lane load generator produces a uniform patch load based on notional lane width, loaded length and intensity. The lane load intensity is set to a default value but this can be modified to any value required.

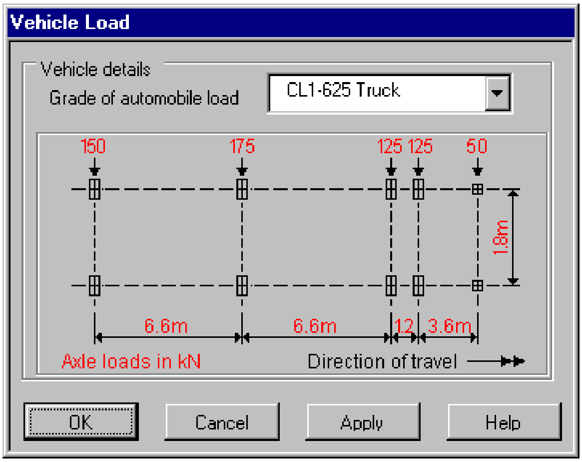


To use this loading type:

- Specify the loaded length.
- Specify the load per unit area.
- Specify the notional lane width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

Canada Vehicle Load

For the vehicle loads the following types can be created: CL1-625, CL2-625, CL3-625, CHBDC Maintenance. The load intensity maybe reduced to 80% for use with lane loading and the Ontario variations are provided.

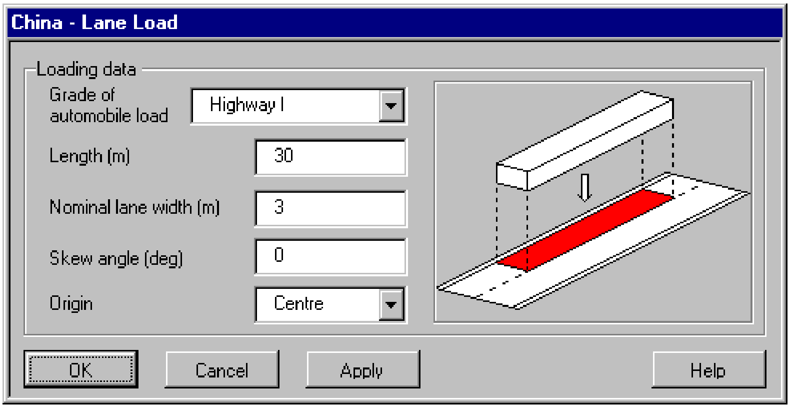


China Vehicle Loading

Chinese vehicle loads are defined to the JTG D60-2004 General Code for Design of Highway Bridges and Culverts.

China Lane Loads

The lane load generator produces a uniform patch load based on notional lane width, loaded length and grade of automobile loading (Highway I, Highway II and Highway II – fourth grade). The intensity of the patch is calculated based on the loaded length entered with shorter loaded lengths having higher intensity.

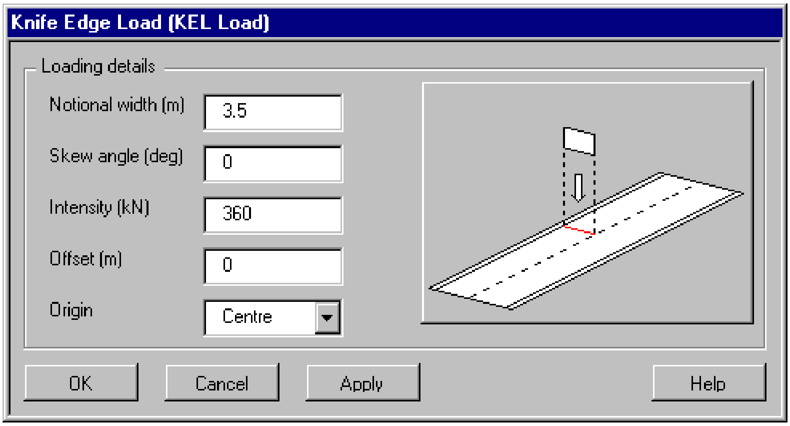


To use this loading type:

- Choose the grade of automobile load.
- Specify the length of loading.
- Specify the nominal lane width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

China Knife Edge Loads (KEL) Loads

The KEL load generator produces a knife-edge load based on notional lane width and intensity. The intensity of the knife-edge load has a default value set but can be modified to any value required.

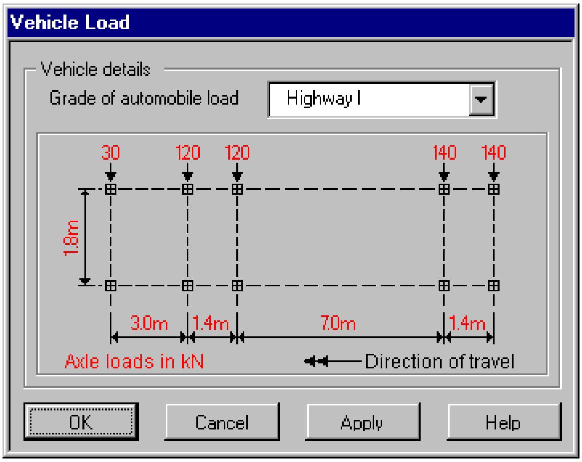


To use this loading type:

- Specify the notional width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Specify the load intensity.
- Specify the offset.
- Choose the origin about which the load is to be generated.

China Vehicle load

The vehicle load generator produces truck loads based on grade of automobile loading (Highway I, Highway II and Highway II – fourth grade).

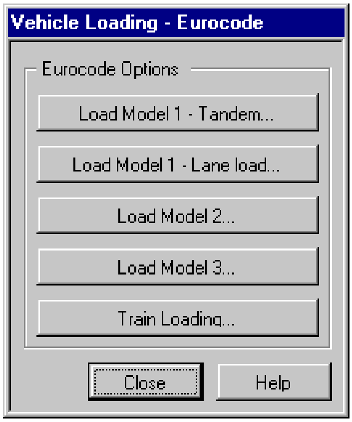


To use this loading type:

- Choose the grade of automobile required.

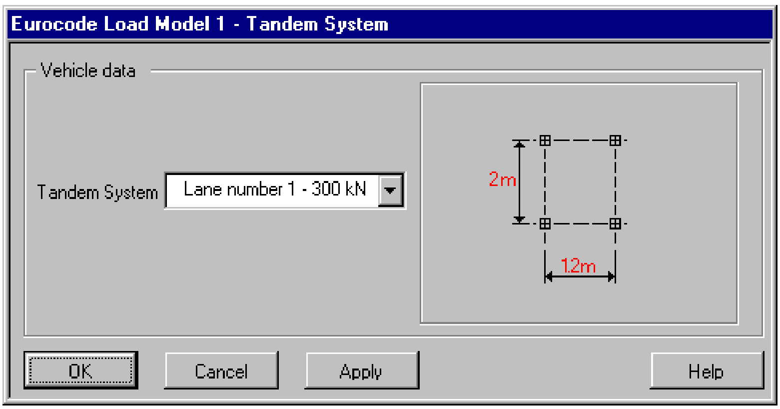
Eurocode Vehicle Loading

Eurocode vehicle loads are defined to Eurocode vehicle loads are defined to Eurocode vehicle loads to EN1991-2:2003 Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges".



Eurocode Load Model 1 - Tandem

The load model 1 - tandem generator produces loads based on required intensity (300kN, 200kN and 100kN).

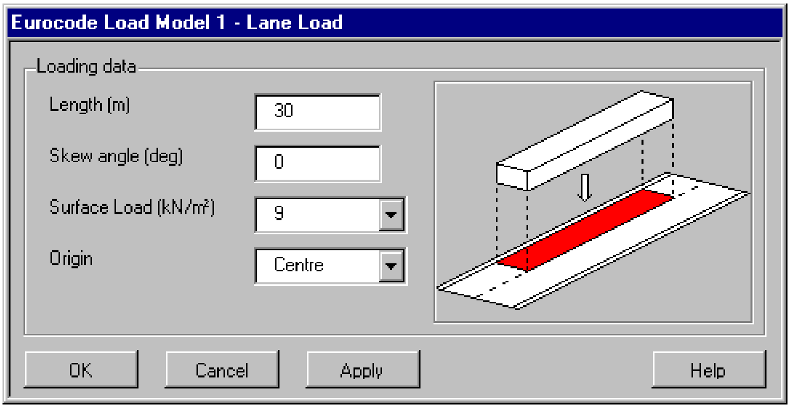


To use this loading type:

- Choose the tandem system from the drop down list.

Eurocode Load Model 1 – Lane load

The load model 1 – lane load generator produces a uniform patch load based on loaded length and required intensity (9kN/m2 and 2.5kN/m2).

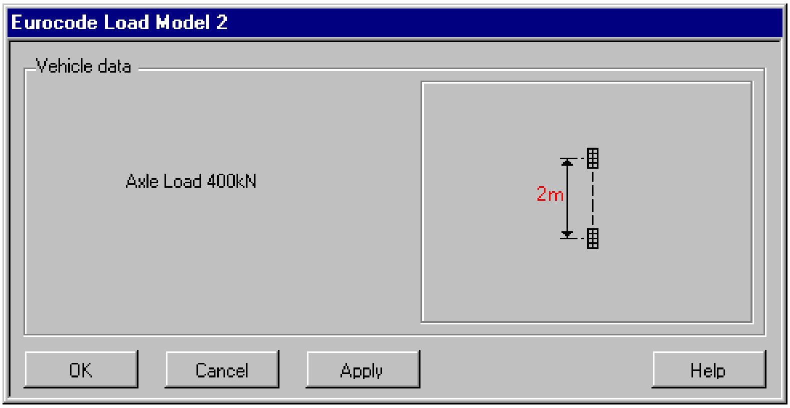


To use this loading type:

- Specify the length of lane load.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the surface load.
- Choose the origin about which the load is to be generated about.

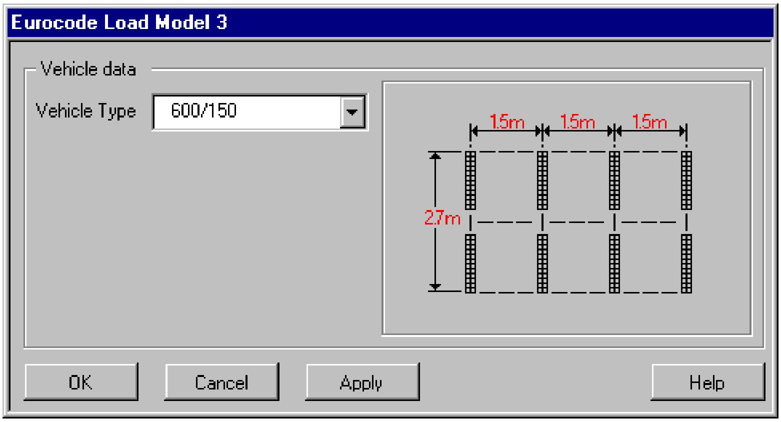
Eurocode Load Model 2

The load model 2 generator produces a single axle load of 400kN.



Eurocode Load Model 3

The load model 3 generator produces the following vehicle loads: 600/150, 900/150, 1200/150, 1200/200, 1500/150, 1200/200, 1800/150, 1800/200, 2400/200, 2400/240, 2400/200/200, 3000/200, 3000/240, 3000/200/200, 3600/200, 3600/240 and 3600/200/200.



To use this loading type:

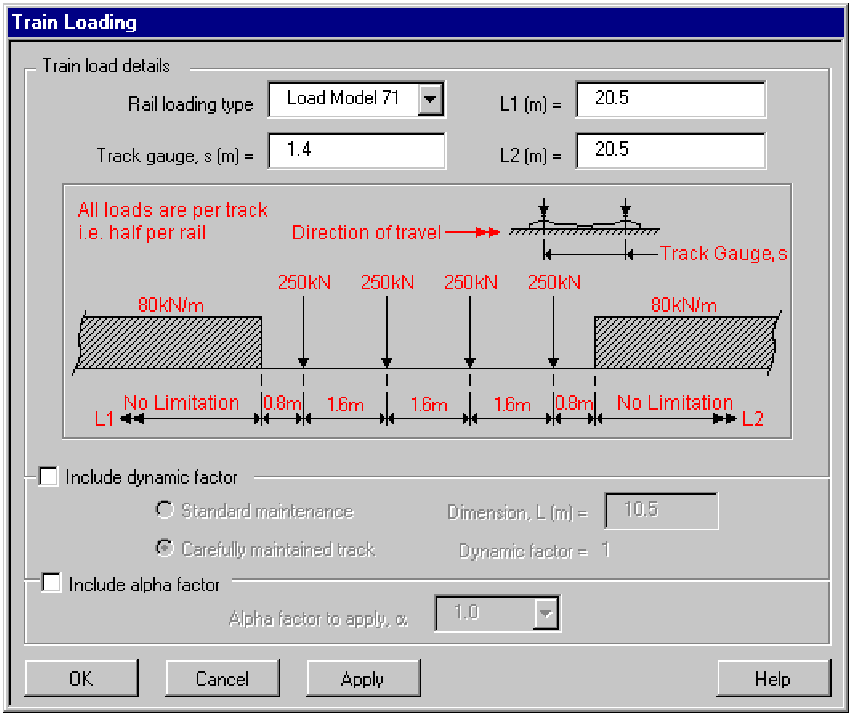
- Choose the special vehicle from the drop down list.

Classes of Special Vehicles

Total weight	Composition	Notation
600 kN	4 axle-lines of 150 kN	600/150
900 kN	6 axle-lines of 150 kN	900/150
1200 kN	8 axle-lines of 150 kN	1200/150
	or 6 axle-lines of 200 kN	1200/200
1500kN	10 axle-lines of 150 kN	1500/150
	or 7 axle-lines of 200 kN + 1 axle line of 100 kN	1500/200
1800 kN	12 axle-lines of 150 kN	1800/150
	or 9 axle-lines of 200 kN	1800/200
2400 kN	12 axle-lines of 200 kN	2400/200
	or 10 axle-lines of 240 kN	2400/240
	or 6 axle-lines of 200 kN (spacing 12m) + 6 axle-lines of 200 kN	2400/200/200
3000 kN	15 axle-lines of 200 kN	3000/200
	or 12 axle-lines of 240 kN + 1 axle-line of 120 kN	3000/240
	or 8 axle-lines of 200 kN (spacing 12 m) + 7 axle-lines of 200 kN	3000/200/200
3600kN	18 axle-lines of 200 kN	3600/200
	or 15 axle-lines of 240 kN	3600/240
	or 9 axle-lines of 200 kN (spacing 12 m) + 9 axle-lines of 200 kN	3600/200/200

Eurocode Train Loading

Eurocode train loading is accessed from the Eurocode Vehicle Loading dialog:



- ❑ **Rail loading type** Standard railway loading consists of Load Model 71 (and Load Model SW/0 for continuous bridges) to represent normal rail traffic on mainline railways and Load Model SW/2 to represent heavy loads.

  - Load Model 71 represents the static effect of vertical loading due to normal rail traffic. It consists of four 250kN concentrated loads preceded, and followed, by a uniformly distributed load of 80kN/m.
  - Load Model SW/0 represents the static effect of vertical loading due to normal rail traffic on continuous beams. It consists of two uniformly distributed loads of 133kN/m, each 15m long and separated by a distance of 5.3m.
  - Load Model SW/2 represents the static effect of vertical loading due to heavy rail traffic. It is similar to SW/0 Loading, however, the uniformly distributed loads are 150kN/m, each 25m long and separated by a distance of 7m.

- ❑ **Track gauge** is to be entered in metres. This has to be 1.4m or greater.
- ❑ **L1 and L2** are to be entered as appropriate for the load model chosen. All dimensions are in metres.

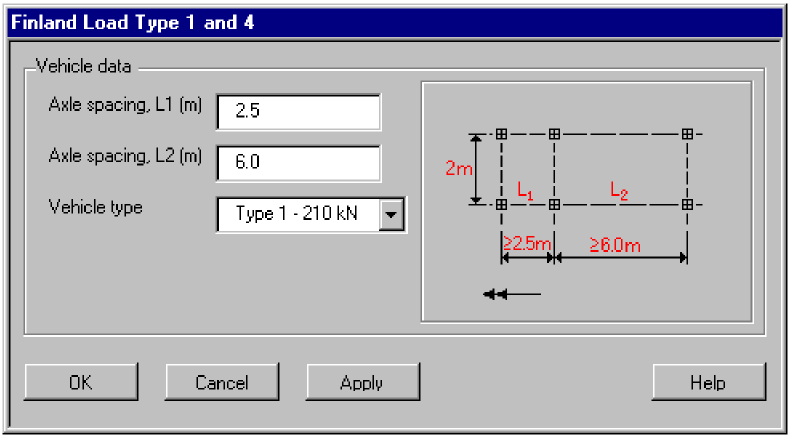
- **Dynamic factor** The inclusion of a dynamic factor should always be carried out with reference to a particular design code. Particular railway loading types can be multiplied by an appropriate dynamic factor to allow for impact, oscillation and other dynamic effects including those caused by track and wheel irregularities. The dynamic factor takes account of the dynamic magnification of stresses and vibration effects in the structure but does not take account of resonance effects. The factor used will vary according to dimension *L* and whether the track receives standard maintenance or is carefully maintained. In deriving the dynamic factor, *L* is taken as the length (in m) of the influence line for deflection of the element under consideration. For non-symmetrical influence lines, *L* is twice the distance between the point at which the greatest ordinate occurs and the nearest end point of the influence line. In the case of floor members 3m should be added to the length of the influence line as an allowance for load distribution through track.
- **Alpha factor** The characteristic values of Load Model 71 and SW/0 Loading shall be multiplied by a factor α, on lines carrying rail traffic which is heavier or lighter than normal rail traffic. When multiplied by the factor the loads are called “classified vertical loads”.

Finland Vehicle Loading

Finland vehicle loads are defined to the Finnish loading design code.

Finland Load Types 1 and 4

The load types 1 and 4 generator produces vehicle loads based on the selection of type 1 or 4. The variable axle spacings can be set to the required distance.

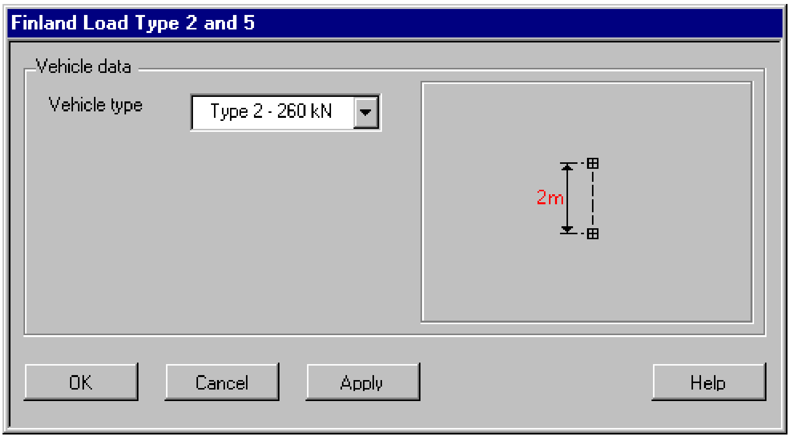


To use this loading type:

- Specify the axle spacings for L1 and L2 that you require for the vehicle. Note that L1 has to be greater than 2.5m and L2 greater than 6m. The vehicle will be generated about the second axle's centre point.
- Choose the vehicle type from the drop down list.

Finland Load Types 2 and 5

The load types 2 and 5 generator produces vehicle loads based on the selection of type 2 or 5.

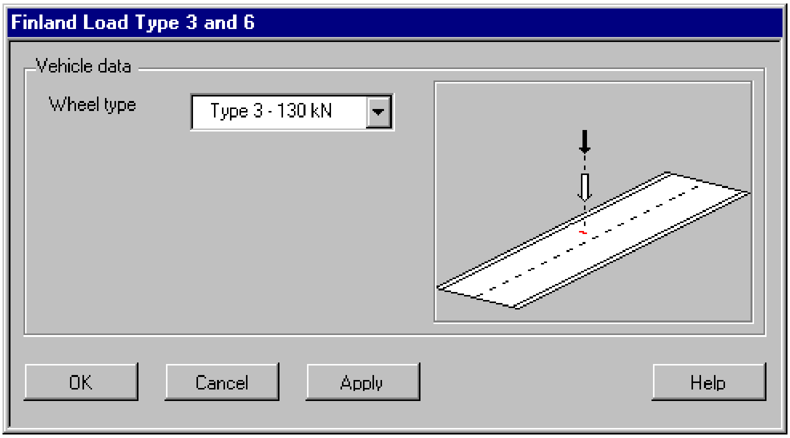


To use this loading type:

- Choose the vehicle type from the drop down list. The vehicle will be generated about the axle's centre point.

Finland Load Types 3 and 6

The load types 3 and 6 generator produces vehicle loads based on the selection of type 3 or 6.

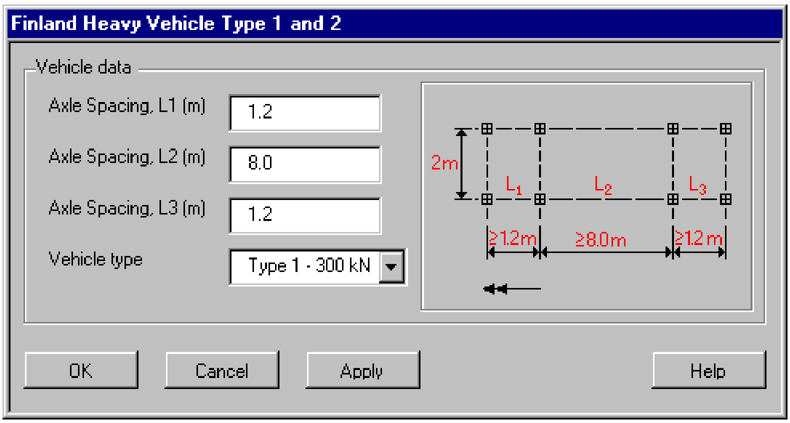


To use this loading type:

- Choose the vehicle type from the drop down list.

Finland Heavy Vehicle Types 1 and 2

The heavy vehicle type 1 and 2 generator produces vehicle loads based on the selection of type 1 or 2. The variable axle spacings can be set to the required distance.



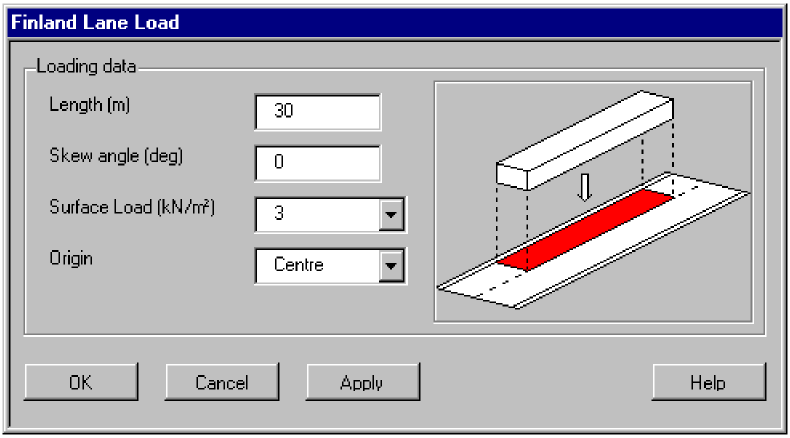
To use this loading type:

- Specify the axle spacings for L1, L2 and L3 that you require for the vehicle. Note that L1 and L3 has to be greater than 1.2m and L3 greater than 8m. The vehicle will be generated about the vehicle's centroid.

- Choose the vehicle type from the drop down list.

Finland Lane Loads

The lane load generator produces a uniform patch load based on loaded length and intensity. The intensity of the lane load has a default value set but can be modified to any value required.

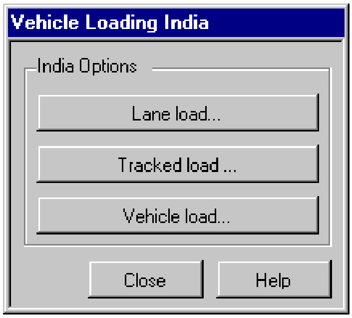


To use this loading type:

- Specify the length of lane load that you require to generate about the centre line of patch.
- Specify the skew angle to applied to the lane loading (clockwise positive).
- Choose the surface load intensity from the drop down list.
- Choose the origin that the load will be generated about.

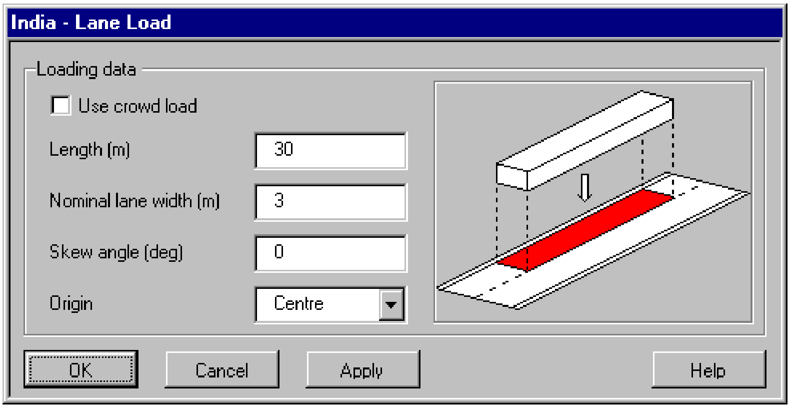
India Vehicle Loading

Indian vehicle loads are defined to IRC:6-2000 Section: II Loads and Stresses.



India Lane Load

The Lane load generator produces a uniform patch load based on loaded length and notional lane width. The option to include crowd load can be added to the loading.

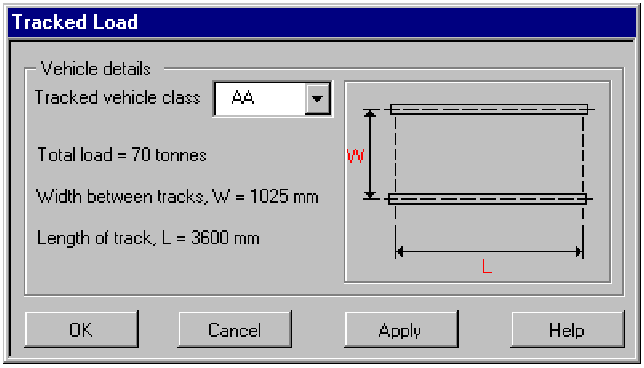


To use this loading type:

- Choose **Use crowd load** if applicable.
- Specify the length of lane load.
- Specify the nominal lane width in metres
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

India Tracked Load

The tracked load generator produces the following tracked vehicle loads: AA, 5R, 9R, 12R, 18R, 24R, 30R, 40R, 50R, 60R and 70R.

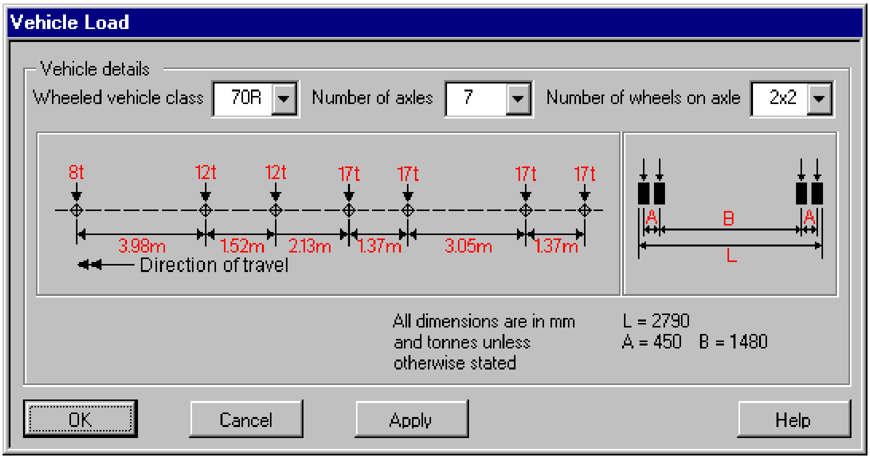


To use this loading type:

- Choose the tracked vehicle class.

India Vehicle Load

The India load generator produces the following vehicle loads: 3, 5R, 9R, 12R, 18R, 24R, 30R, 40R, 50R, 60R, 70R A, B and AA. Each of these vehicles can have many different configurations by setting the number of axles and wheels.



To use this loading type:

- Choose the wheeled vehicle class.
- Choose the number of axles.

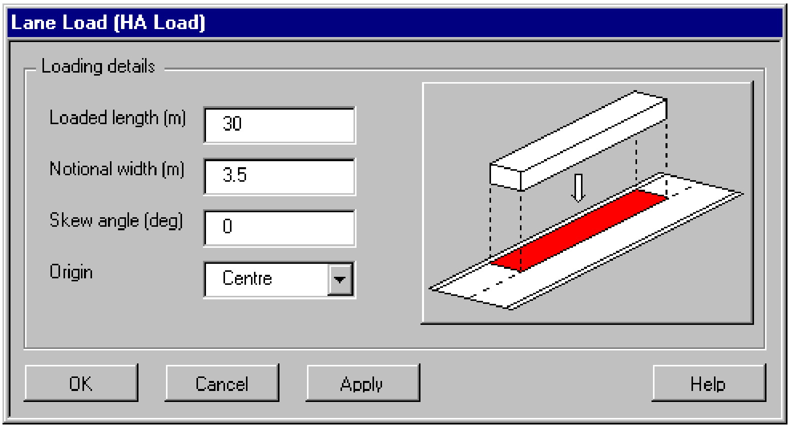
- Choose the number of wheels on the axle.

Israel Vehicle Loading

Israel vehicle loads are defined to the Israeli loading design code.

Israel Lane Load (HA Loads)

The HA load generator produces a uniform patch load based on notional lane width and loaded length. The intensity of the patch is calculated based on the loaded length entered with shorter loaded lengths having higher intensity

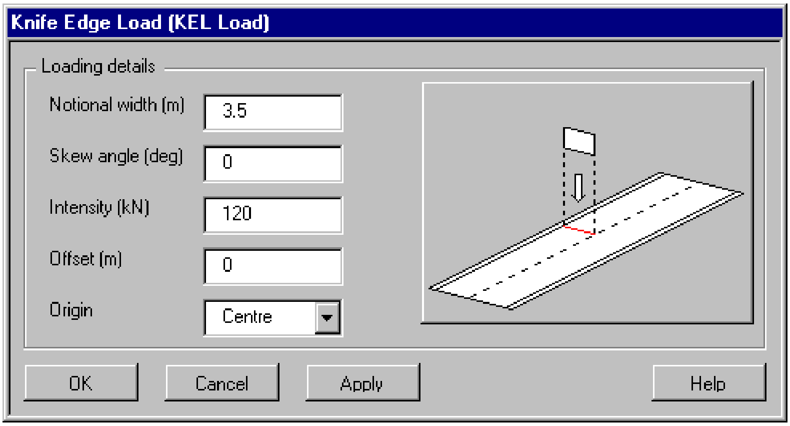


To use this loading type:

- Specify the loaded length.
- Specify the notional width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

Israel Knife Edge Load (KEL Loads)

The KEL load generator produces a knife-edge load based on notional lane width and intensity. The intensity of the knife-edge load has a default value set but this can be modified to any value required.

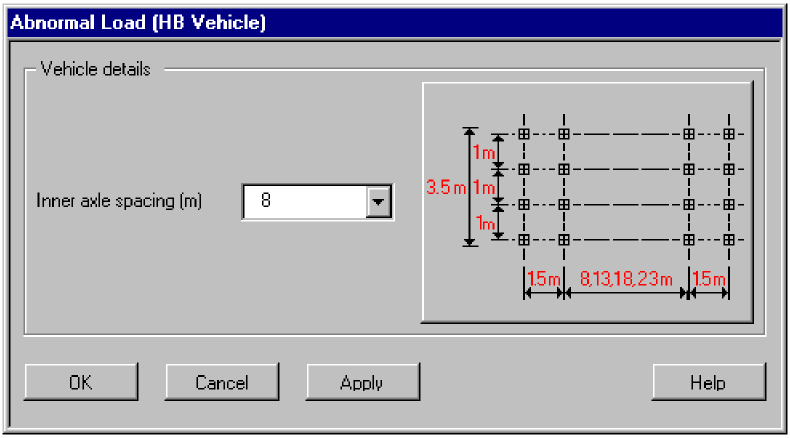


To use this loading type:

- Specify the notional width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Specify the intensity
- Specify the offset.
- Choose the origin about which the load is to be generated.

Israel Abnormal Load Generator (HB Vehicle)

The HB load generator produces a HB vehicle by setting the inner axle spacing (8m, 13m, 18m, & 23m).

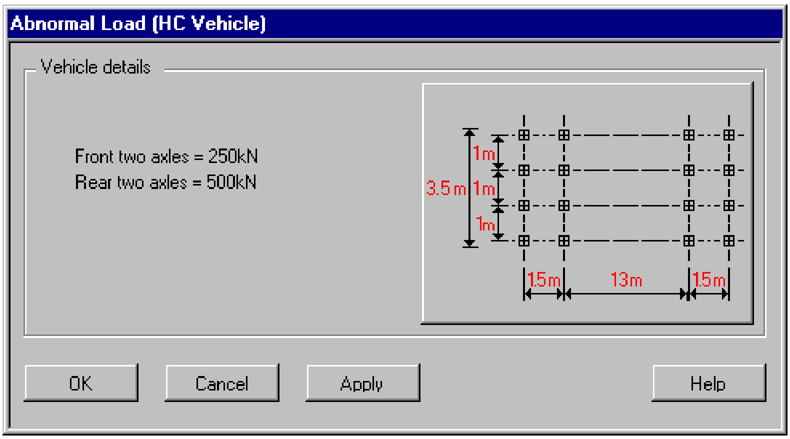


To use this loading type:

- Choose the inner axle spacing.

Israel Abnormal Load Generator (HC Vehicle)

The HC load generator produces a HC vehicle.



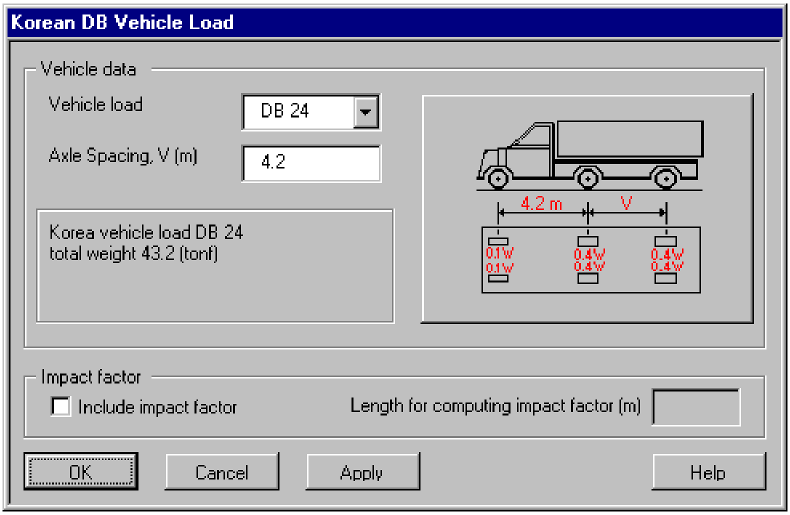
Korea Vehicle Loading

Korean vehicle loads are defined to the Korean loading code.

Korean DB Vehicle Load

The DB vehicle load generator can produce vehicle loads types DB24, DB18 and DB13.5 including the variable axle spacing which can be set between 4.2m and 9m.

For all the loads types the additional impact factor can be added to the loads based on loaded length.



To use this loading type:

- Choose which vehicle you require to generate as a vehicle load.
- Specify the variable axle spacing that you require for the vehicle.

- Choose whether you want to generate a vehicle to represent a forward movement, reverse movement or both directions (Forward is in the negative X direction with the cab at the front).
- If an impact factor is to be considered, select the check box and enter a length for computing the impact factor in the current length units. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. Assuming the model length units to be metres the impact factor is calculated from the equation below.

  I=15/(40+L)

  where L=length for computing the impact factor in metres

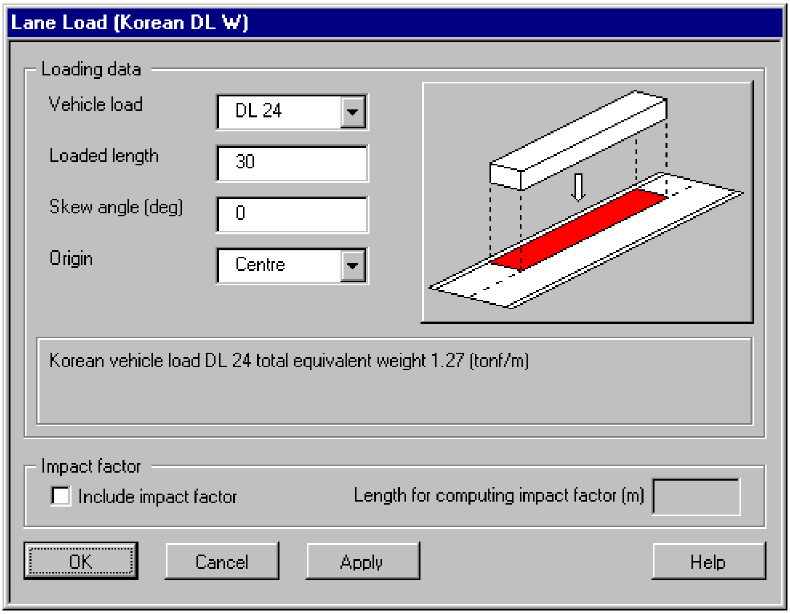
  This equation will automatically be adjusted to take in to account other model units if used. For example if the model length units are feet the impact factor is calculated from the equation below.

  I=(15*3.28)/((40*3.28)+L)

  where L=length for computing the impact factor in feet

Korea Lane Load (DL W)

The lane load generator can produce a uniform patch load based on load types DB24, DB18 and DB13.5 and loaded length. For all the loads types the additional impact factor can be added to the loads based on loaded length.



To use this loading type:

- Choose which vehicle you require to generate as a vehicle load.
- Specify the length of lane load that you require to generate.
- Specify the skew angle to apply to the lane loading. (clockwise positive)
- Choose the origin for which the load is to be generated about.
- If an impact factor is to be considered, select the check box and enter a length for computing the impact factor in the current length units. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. Assuming the model length units to be metres the impact factor is calculated from the equation below.

  I=15/(40+L)

  where L=length for computing the impact factor in metres

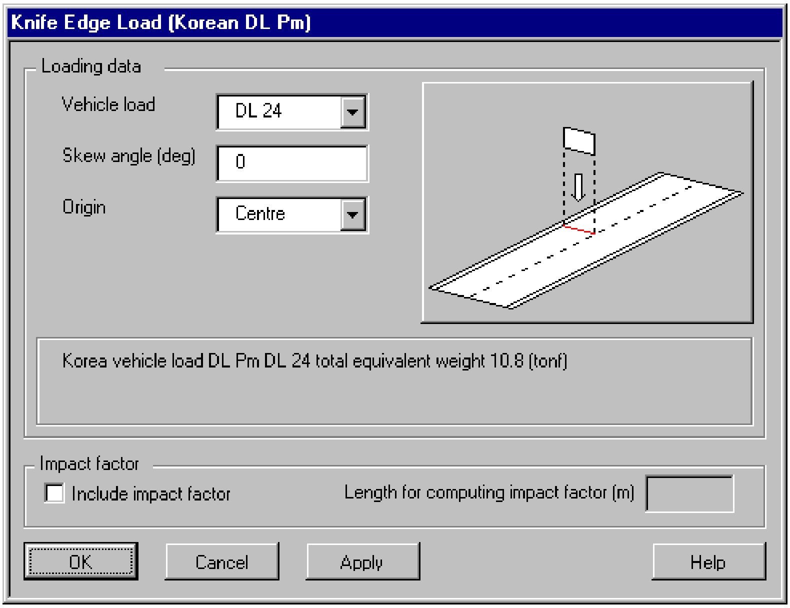
  This equation will automatically be adjusted to take in to account other model units if used. For example if the model length units are feet the impact factor is calculated from the equation below.

  I=(15*3.28)/((40*3.28)+L)

  where L=length for computing the impact factor in feet

Korea Knife Edge Load (DL Pm)

The knife edge load (Korean DL Pm) generator can produce a line load based on the following load types DB24, DB18 and DB13.5. For all the loads types the additional impact factor can be added to the loads based on loaded length.



To use this loading type:

- Choose which vehicle you require to generate as a vehicle load.
- Specify the skew angle to applied to the lane loading (clockwise positive).
- Choose the origin for which the load is to be generated about.
- If an impact factor is to be considered, select the check box and enter a length for computing the impact factor in the current length units. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. Assuming the model length units to be metres the impact factor is calculated from the equation below.

  I=15/(40+L)

  where L=length for computing the impact factor in metres

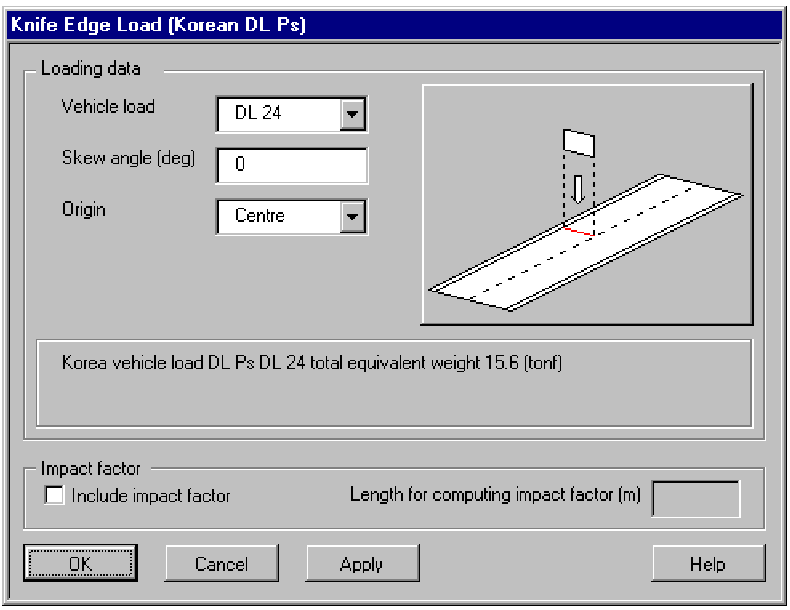
  This equation will automatically be adjusted to take in to account other model units if used. For example if the model length units are feet the impact factor is calculated from the equation below.

  I=(15*3.28)/((40*3.28)+L)

  where L=length for computing the impact factor in feet

Korea Knife Edge Load (DL Ps)

The knife edge load (Korean DL Ps) generator can produce a line load based on the following load types DB24, DB18 and DB13.5. For all the loads types the additional impact factor can be added to the loads based on loaded length.



To use this loading type:

- Choose which vehicle you require to generate as a vehicle load.
- Specify the skew angle to applied to the lane loading (clockwise positive).
- Choose the origin for which the load is to be generated about.
- If an impact factor is to be considered select the check box and enter a length for computing the impact factor in the current length units. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. Assuming the model length units to be metres the impact factor is calculated from the equation below.

$$I=15/(40+L)$$

where L=length for computing the impact factor in metres

This equation will automatically be adjusted to take in to account other model units if used. For example if the model length units are feet the impact factor is calculated from the equation below.

$$I=(15*3.28)/((40*3.28)+L)$$

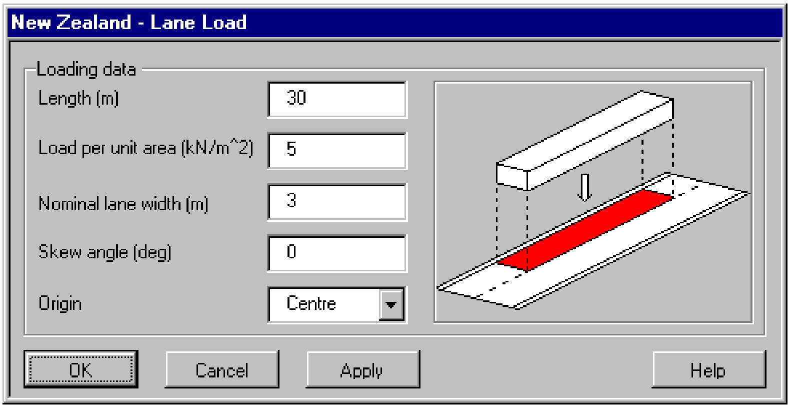
where L=length for computing the impact factor in feet

New Zealand Vehicle Loading

New Zealand vehicle loads are defined to the New Zealand loading code.

New Zealand Lane Loads

The lane load generator produces a uniform patch load based on notional lane width, loaded length and intensity. The intensity of the lane load has a default value set but can be modified to any value required.

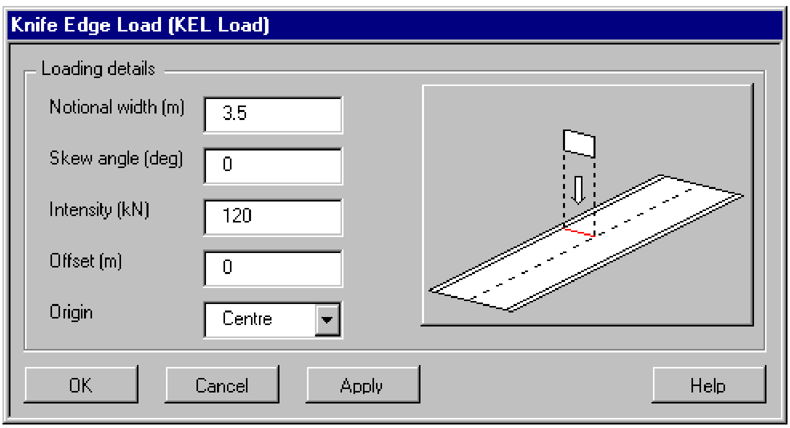


To use this loading type:

- Specify the loaded length.
- Specify the load per unit area.
- Specify the notional lane width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

New Zealand Knife Edge Loads (KEL) Loads

The KEL load generator produces a knife-edge load based on notional lane width and intensity. The intensity of the knife-edge load has a default value set but can be modified to any value required.

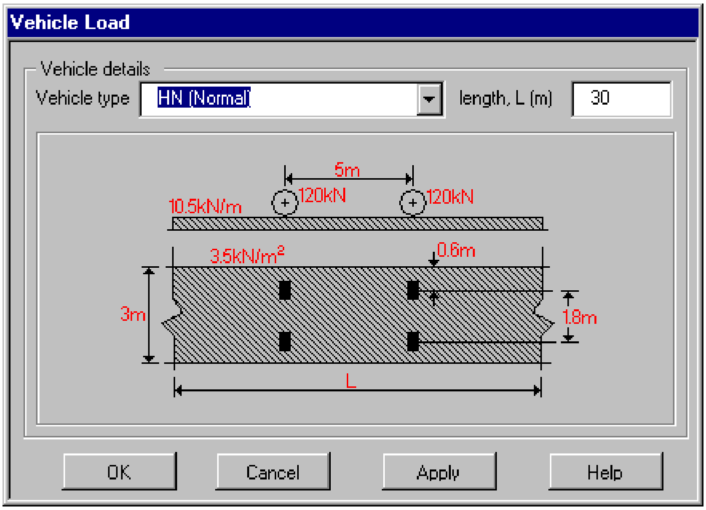


To use this loading type:

- Specify the notional width.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Specify the intensity.
- Specify the offset.
- Choose the origin about which the load is to be generated.

New Zealand Vehicle Load

The following truck types can be created: HN (normal) and HO (overload).

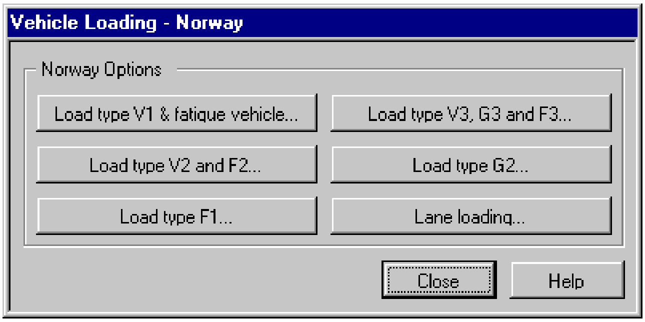


To use this loading type:

- Choose the vehicle type required, and specify the length if applicable.

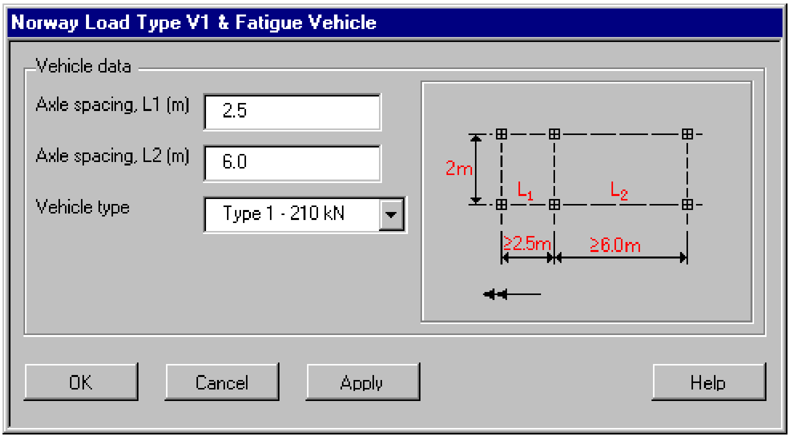
Norway Vehicle Loading

Norway vehicle loads are defined to the Norwegian loading design code.



Norway Load Type V1 & Fatigue Vehicle

The load type V1 & Fatigue Vehicle generator produces vehicle loads based on the selection of type V1 & Fatigue Vehicle. The variable axle spacings can be set to the required distance.

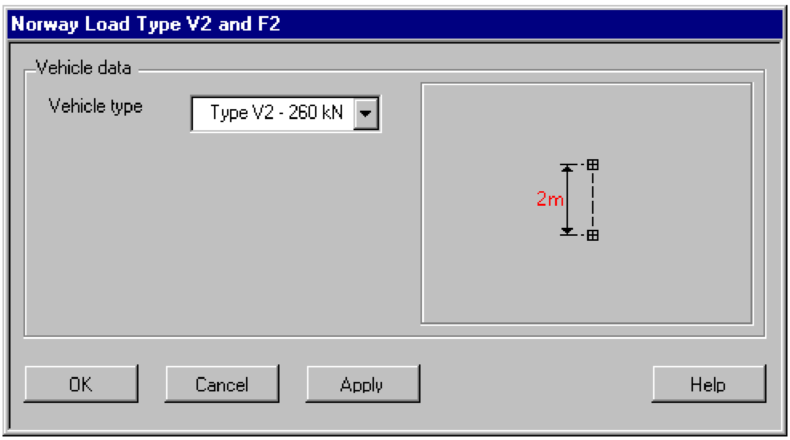


To use this loading type:

- Choose the axle spacings for L1 and L2 that you require for the vehicle. Note that L1 has to be greater than 2.5m and L2 greater than 6m. The vehicle will be generated about the second axle's centre point.
- Choose the vehicle type from the drop down list.

Norway Load Types V2 and F2

The load types V2 and F2 generator produce vehicle loads based on the selection of type V2 or F2.

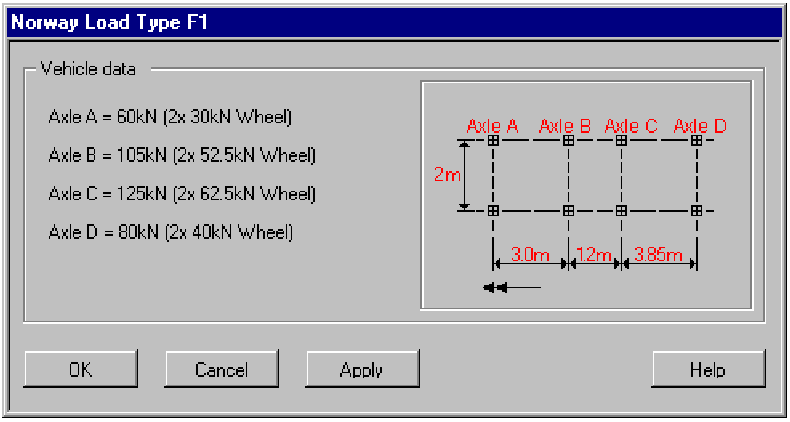


To use this loading type:

- Choose the vehicle type from the drop down list. The vehicle will be generated about the axle's centre point.

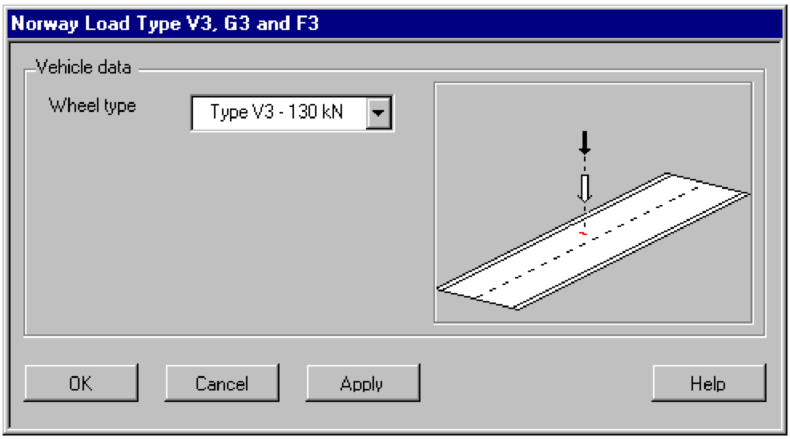
Norway Load Types F1

The load type F1 generator produces a vehicle load based on the selection of type F1.



Norway Load Types V3, G3 and F3

The load types V3, G3 and F3 generator produces vehicle loads based on the selection of type V3, G3 and F3 .

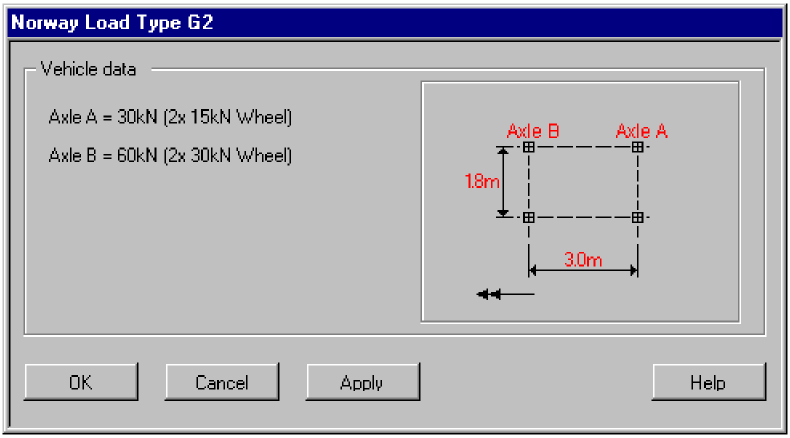


To use this loading type:

- Choose the vehicle type from the drop down list.

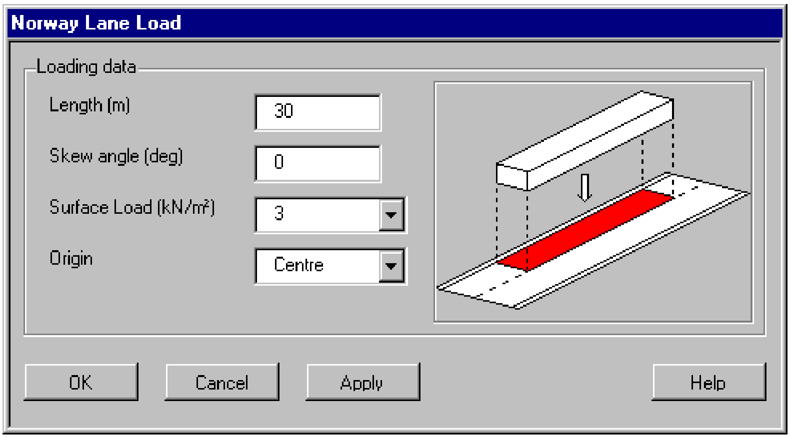
Norway Load Types G2

The load type G2 generator produces a vehicle load based on the selection of type G2.



Norway Lane Load

The lane load generator produces a uniform patch load based on loaded length and intensity. The intensity of the lane load has a default value set but can be modified to any value required.



To use this loading type:

- Specify the length of lane load that you require to generate about the centre line of patch.
- Specify the skew angle to applied to the lane loading (clockwise positive).
- Specify the Surface load intensity from the drop down list.

- Choose the origin that the load will be generated about.

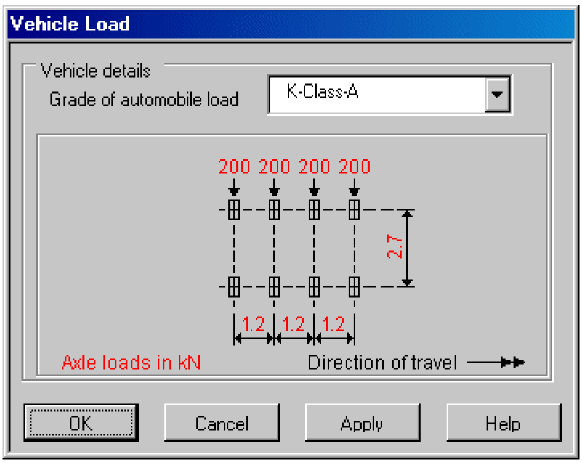
Poland Vehicle Loading

Poland vehicle loads are defined to the Polish loading code.

Poland Vehicle Loads

The Poland vehicle load generator produces the following grades of automobile loads:

- K-Class types A to E
- S-Class 123, 4 and 5



To use this loading type:

- Select a vehicle load type and press the OK or Apply button to add that loading to the Attributes Treeview.

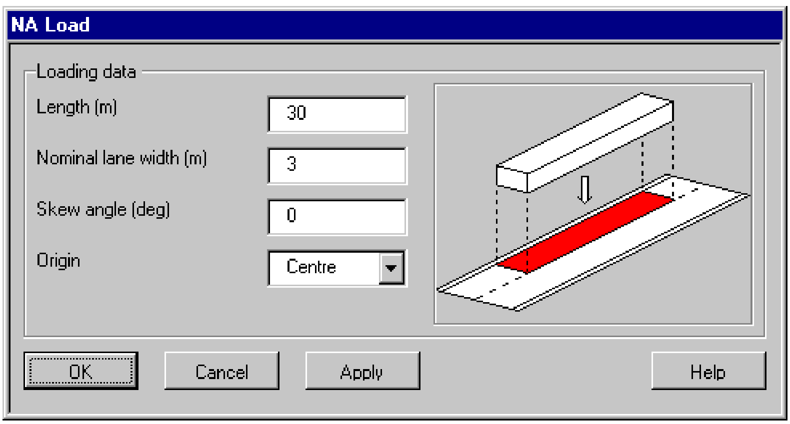
South Africa Loading

South Africa vehicle loads are defined to the TMH7 Code of Practice for the Design of Bridges and Culverts in South Africa 1981 with 1988 revisions.

Vehicle loads can be created for normal vehicle loading (NA), single abnormal vehicle loading (NB) and multi-wheeled trailer combination or multi-wheeled self-propelled vehicle loading (NC) loads with reference to TMH7 parts 1 and 2.

South Africa Lane Loads (NA Load)

For normal vehicle loading the lane load generator produces a uniform patch load based on a nominal lane width and loaded length. A skew angle can be defined and if done, should be defined clockwise positive.The intensity of loading is in accordance with the loading curve for NA loading as defined in the code.



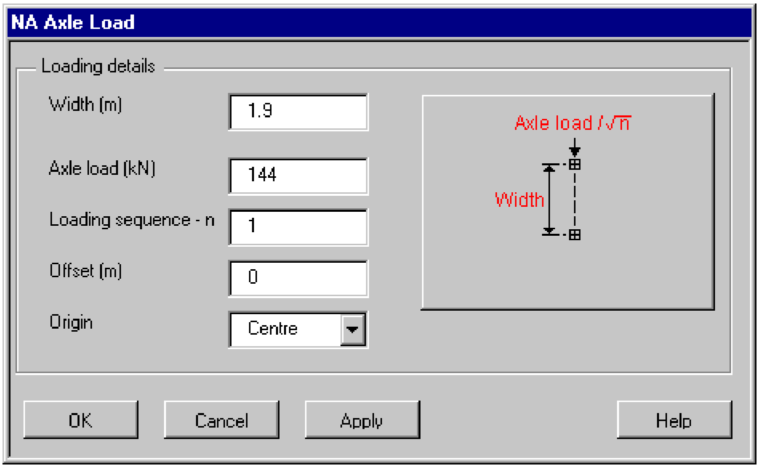
To use this loading type:

- Specify the loaded length.
- Specify the nominal lane width.

- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

South Africa Vehicle Load (NA Axle)

For NA axle loads a nominal axle load at a specified width can be defined. Two point loads are generated of an intensity computed in Kn from the formula (Axle load)/√n kN where n is the loading sequence number. For multiple applications of an axle load across more than one lane the loading sequence identifier should be incremented each time in accordance with the code. Setting an offset will position the loading away from an origin point that itself can be defined in one of three positions.

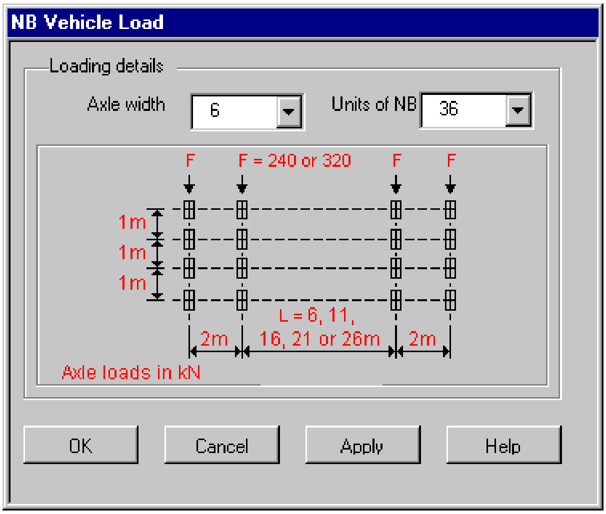


To use this loading type:

- Specify the width between wheels.
- Specify the axle load.
- Increment the loading sequence if loading is to be added to a different lane to any previously defined loading.
- Enter an offset (if any) and choose the origin about which the load is to be generated.

South Africa Vehicle Load (NB load)

NB loading is a notional load representing a single abnormal vehicle. For this loading pre-defined axle spacings and a choice of units of HB are available. The dialog allows selection of axle widths of 6, 11, 16, 21 or 26m and generates 24 or 36 units of NB loading where 1 unit is equal to 2.5kN per wheel.

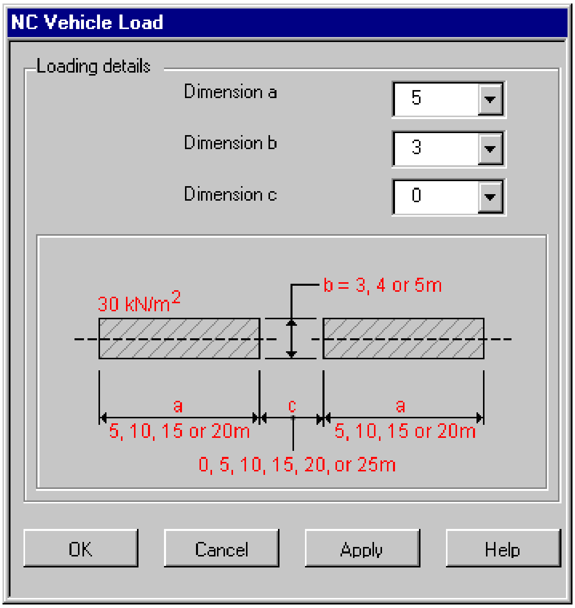


To use this loading type:

- Choose a longitudinal length between internal axles
- Choose the appropriate units of HB

South Africa Vehicle Load (NC load)

NC loading represents a multi-wheeled trailer combination (or self-propelled multi-wheeled vehicles) with controlled hydraulic suspension and steering intended to transport very heavy indivisible payloads. These loads are represented by a grid of point loads with a load intensity of 30kN/m^2. The dimensions a, b and c should be selected between the limits shown to have the most severe effect.



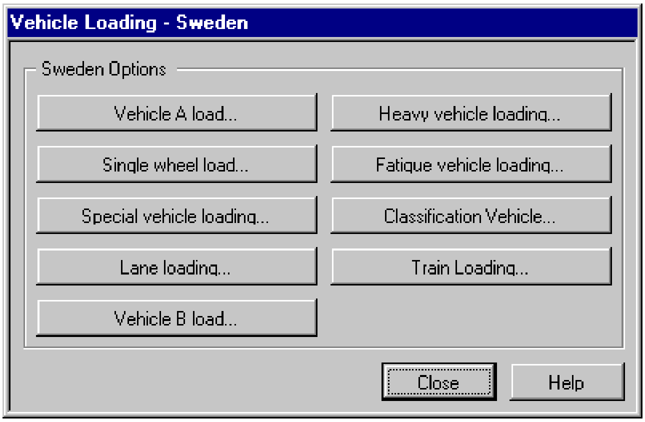
To create this loading type:

- Specify the extent of the loading by defining dimensions a, b and c.

For this loading a number of discrete load attributes will be created that are used to define a compound load. It is the compound load that should be assigned to the model.

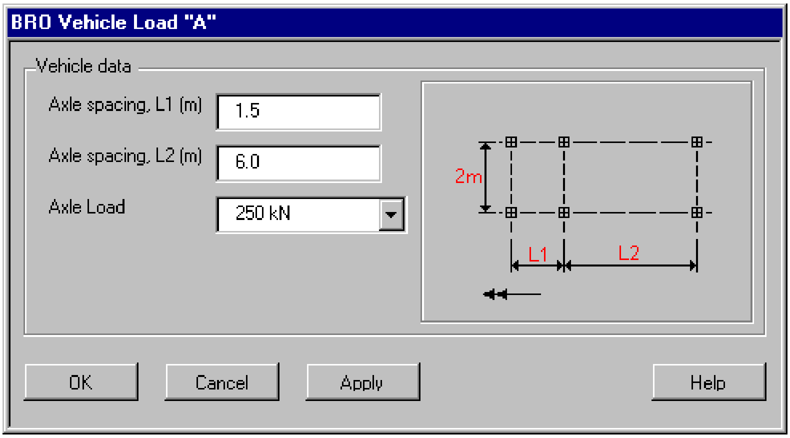
Sweden Vehicle Loading

Swedish vehicle loads are defined to Swedish bridge BRO Classification loads.



Sweden BRO Vehicle Load A

The load type A generator produces a vehicle load based on axle weight (250kN or 170kN). The variable axle spacings can be set to the required distance.

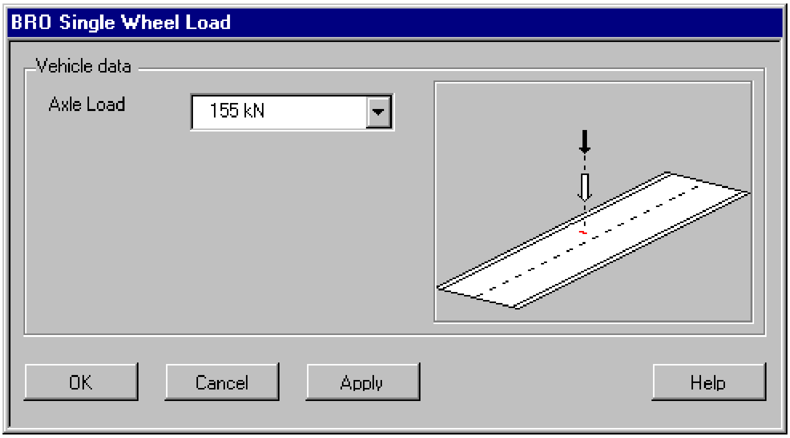


To use this loading type:

- Specify the front axle spacing that you require for the vehicle.
- Specify the back axle spacing that you require for the vehicle.
- Choose which intensity of axle load you wish to generate.

Sweden BRO Single Wheel Load

The load single wheel generator can produce a point load based on the selection of 155kN.

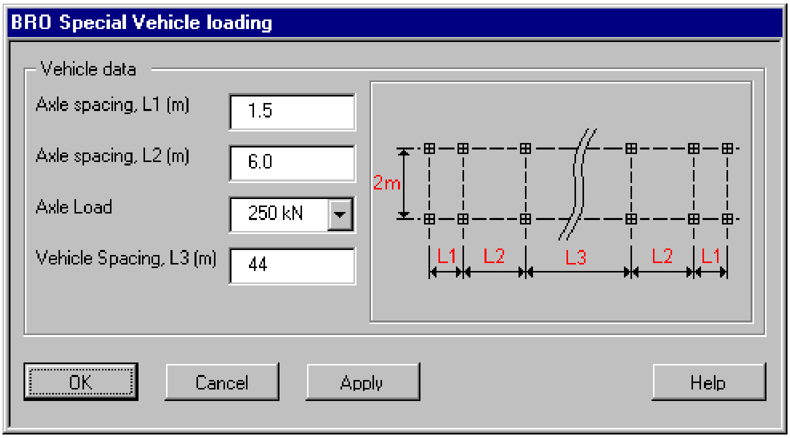


To use this loading type:

- Choose which intensity of axle load you wish to generate.

Sweden BRO Special Vehicle Loading

The special vehicle load generator can produce a vehicle loads based on axle weight (250kN or 170kN). The variable axle spacings can be set to the required distance.

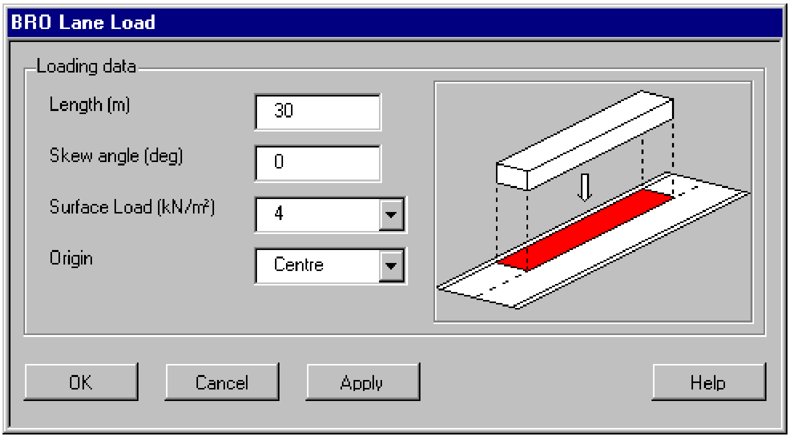


To use this loading type:

- Specify the front axle spacing that you require for the vehicle.
- Specify the back axle spacing that you require for the vehicle.
- Choose which intensity of axle load you wish to generate.
- Specify the distance between the vehicles.

Sweden BRO Lane Load

The lane load generator can produce a uniform patch load based on loaded length and intensity. The intensity of the lane load has a default value set but can be modified to any value required.

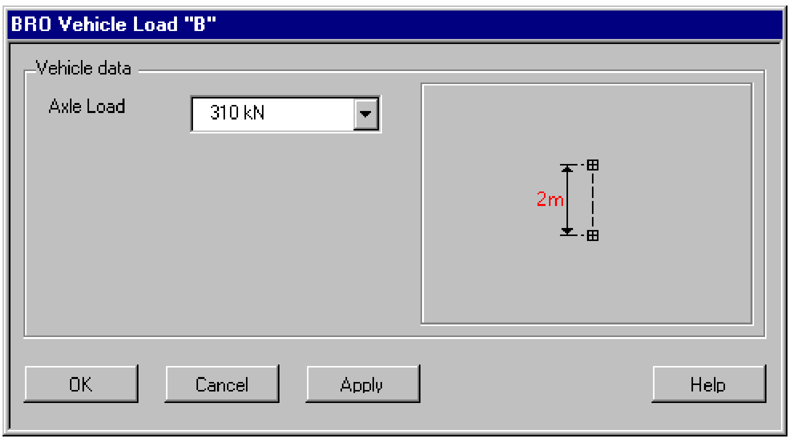


To use this loading type:

- Specify the length of lane load that you require to generate.
- Specify the skew angle to apply to the lane loading. (clockwise positive)
- Choose which intensity of load you wish to generate.
- Choose the origin for the about which the load is to be generated about.

Sweden BRO Vehicle Load B

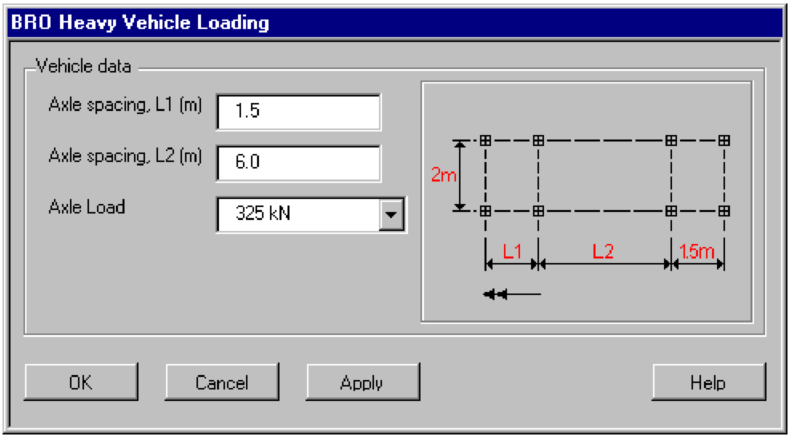
The load type A generator can produce a vehicle loads based on axle weight (310kN or 210kN).



To use this loading type:

- Choose which intensity of load you wish to generate.

Sweden BRO Heavy Vehicle Load

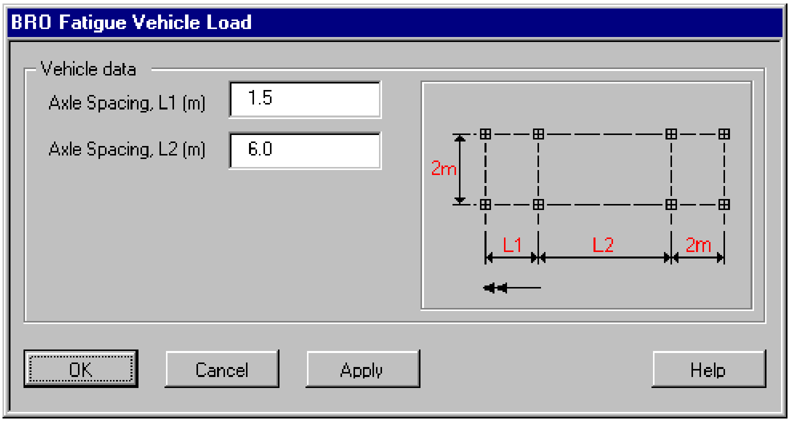


To use this loading type:

- Specify the front axle spacing that you require for the vehicle.
- Specify the back axle spacing that you require for the vehicle.
- Choose which intensity of load you wish to generate.

Sweden BRO Fatigue Vehicle Load

The fatigue load generator can produce a vehicle load based on the selection of fatigue vehicle. The variable axle spacings can be set to the required distance.

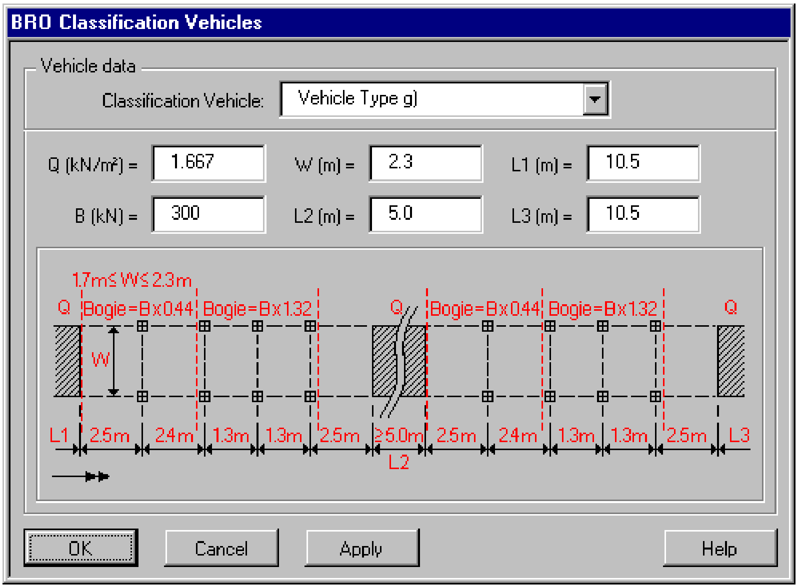


To use this loading type:

- Specify the axle spacing that you require for the vehicle.

Sweden BRO Classification Vehicles

The classification vehicle generator produce the following vehicle loads: Type a, b, c, d, e, f, g, h, i, military vehicle 45 ton and military vehicle 60 ton. Each of these vehicles can have many different configurations by setting the number of axle weights and spacings.



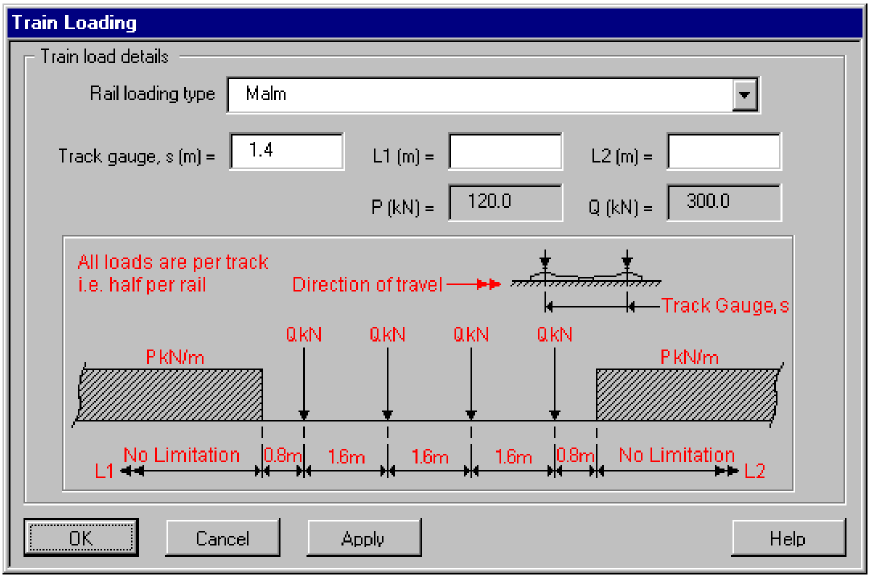
To use this loading type:

- Choose the classification vehicle required from the list and enter the required information.
- Patch load intensity, Q, units of kN/m^2
- Axle Weight, B, units of kN
- Width of vehicle, W, units of m
- Axle spacings; L1, L2 and L3, units of m

Notes

- Classification vehicles g), h), I), Military Vehicle 45 ton and Military Vehicle 60 ton will consist of several discrete load parts that must be used in combination to define the entire vehicle.

Sweden BRO Train Loading



To use this loading type:

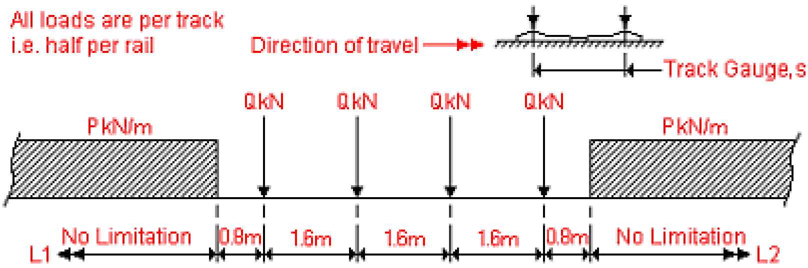
- Select the standard rail loading type from the drop down list.
- Enter the track gauge in metres. This has to be 1.4m or greater.
- Enter the dimension data required as appropriate for the chosen load to be generated. All dimensions are in metres and kN.

Notes

- The trainload will be generated about the loaded area's centre point.
- Load Model HSLM (High Speed Load Model) is only used in dynamic analysis and comprises of two separate Universal Trains with variable coach lengths, HSLM-A and HSLM-B.
- Limits of validity of Load Model HSLM are given in EN 1991-2 Annex E.
- Load Model HSLM is generally used to represent the loading from passenger trains at speed exceeding 200 km/h (dynamic analysis).
- The load HSLM-B should only be applied to simply supported plate bridges and simply supported beam bridges, or similar, with span lengths below 7m.
- Continuous bridges are not applicable for HSLM B.
- The definition of L is the span length.

- All other dynamic analyses on railway bridges should use the load HSLM-A.

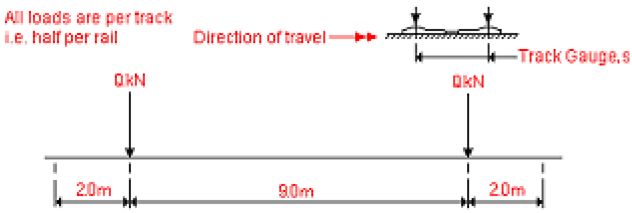
Rail Loading Type Malm, Malm 2000 and BV 2000



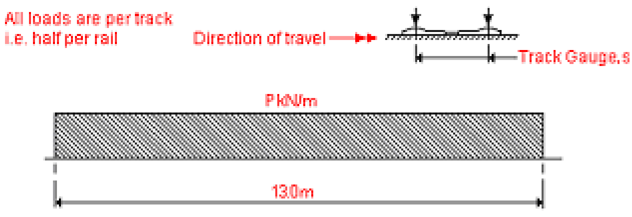
Malm, Malm 2000 and BV 2000

Train Load	P (kN)	Q (kN/m)
Malm	300	110
Malm 2000	350	120
BV 2000	330	120

Rail Loading Type RV-25 / RV-30



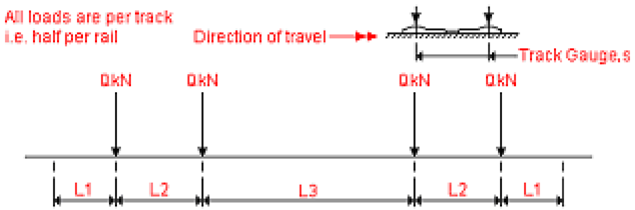
RV-25 / RV-30 Point load arrangement



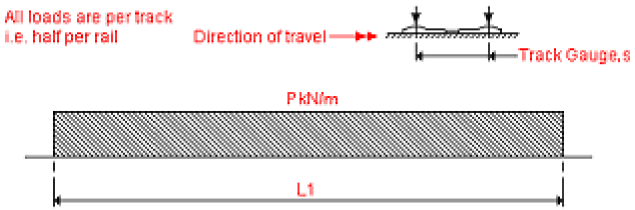
RV-25 / RV-30 UDL arrangement

Train Load		Load
RV25	Point, Q (kN)	250
	UDL, P (kN/m)	39
RV-30	Point, Q (kN)	300
	UDL,P (kN/m)	46

Rail Loading Type A to BV-4



Train loads A to BV-4 Point load arrangement

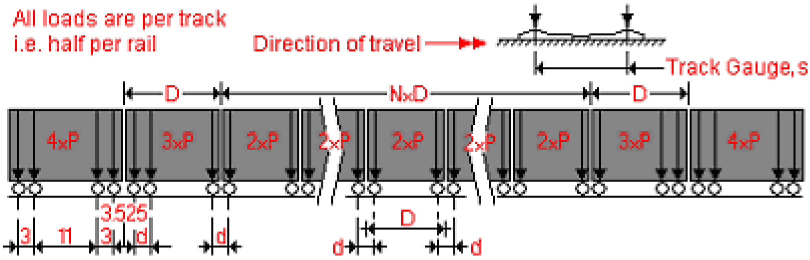


Train loads A to BV-4 arrangement UDL

Train Load		Load	L1 (m)	L2 (m)	L3 (m)
A	Point, Q (kN)	160	1.50	1.80	5.20
	UDL, P (kN/m)	50	12.80		
B1	Point, Q (kN)	180	1.50	1.80	7.80
	UDL, P (kN/m)	50	14.40		

B2	Point, Q (kN)	180	1.50	1.80	4.65
	UDL, P (kN/m)	64	11.25		
C2	Point, Q (kN)	200	1.50	1.80	5.90
	UDL, P (kN/m)	64	12.50		
C3	Point, Q (kN)	200	1.50	1.80	4.50
	UDL, P (kN/m)	72	11.10		
C4	Point, Q (kN)	200	1.50	1.80	3.40
	UDL, P (kN/m)	80	10.0		
D2	Point, Q (kN)	225	1.50	1.80	7.45
	UDL, P (kN/m)	64	14.05		
D3	Point, Q (kN)	225	1.50	1.80	5.90
	UDL, P (kN/m)	72	12.50		
D4	Point, Q (kN)	225	1.50	1.80	4.65
	UDL, P (kN/m)	80	11.25		
BV-2	Point, Q (kN)	250	1.50	1.80	7.30
	UDL, P (kN/m)	72	13.90		
BV-3	Point, Q (kN)	250	1.50	1.80	5.90
	UDL, P (kN/m)	80	12.50		
BV-4	Point, Q (kN)	300	1.50	1.80	5.40
	UDL, P (kN/m)	100	12.0		

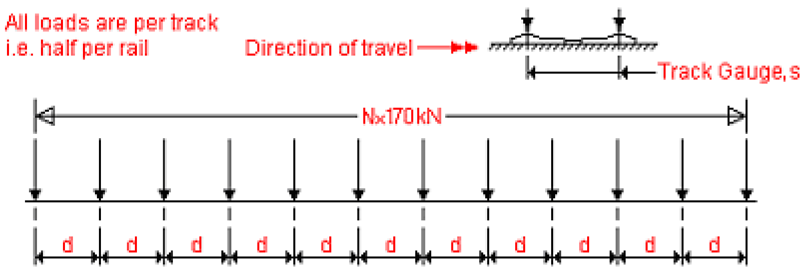
Rail Loading Type HSLM-A (A1 to A10)



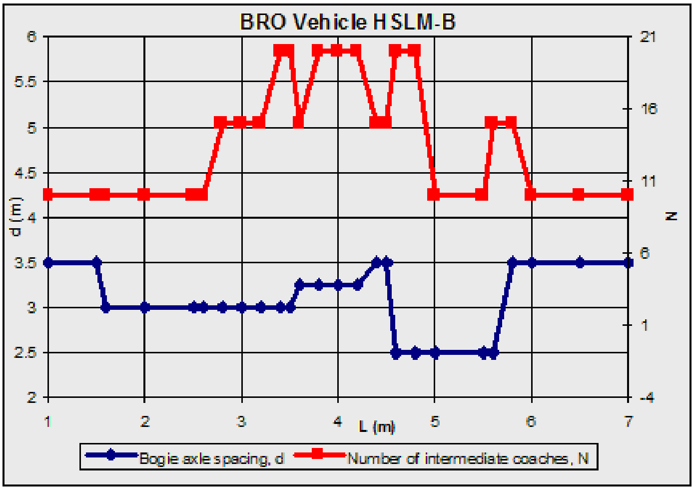
Train loads HSLM-A (A1 to A10)

Universal Train	Number of intermediate coaches (N)	Coach length D (m)	Bogie axle spacing d (m)	Point force P (kN)
A1	18	18	2.0	170
A2	17	19	3.5	200
A3	16	20	2.0	18
A4	15	21	3.0	190
A5	14	22	2.0	170
A6	13	23	2.0	180
A7	13	24	2.0	190
A8	12	25	2.5	190
A9	11	26	2.0	210
A10	11	27	2.0	210

Rail Loading Type HSLM-B

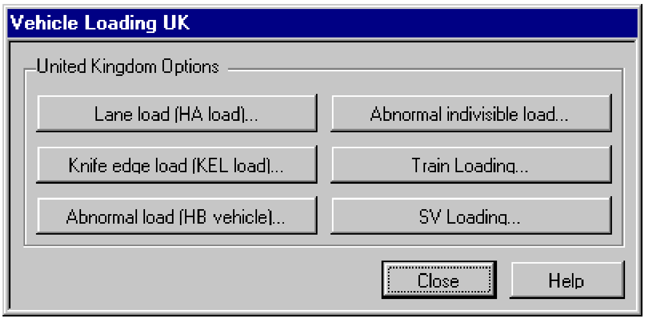


Train load HSLM-B



United Kingdom Vehicle Loading

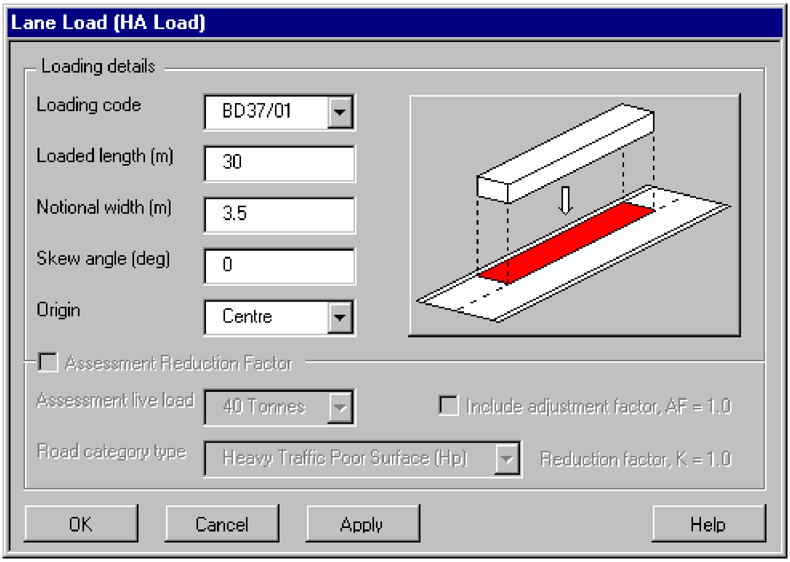
The United Kingdom vehicle loads are defined to the UK bridge codes BS5400, BD37/88 and BD37/01, BD21/97, BD21/01.



United Kingdom HA Loads

The HA load generator produces a uniform patch load based on notional lane width and loaded length. The intensity of the patch is calculated based on the loaded length entered with shorter loaded lengths having higher intensity. The exact intensity will depend on the code being used.

For the assessment codes BD21/97and BD21/01 an additional reduction factor can be included. This is based on the assessment live load being used and the road category type.



To use this loading type:

- Choose the loading code to be used
- Specify the loaded length..
- Specify the notional width of lane load..
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin about which the load is to be generated.

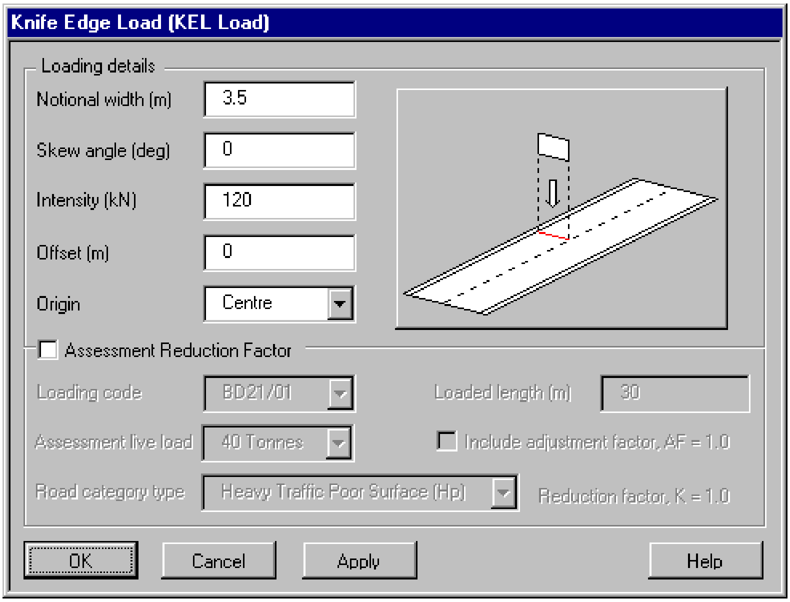
Notes

- If an assessment code (BD21/97 or BD21/01) has been selected from the design code list the option to apply an assessment reduction factor will be given. Switching this option off will generate a nominal unfactored assessment load.
    - Select the assessment live load vehicle type from the list
    - Select the road category type from the list
    - Choose whether to include the adjustment factor, AF, in the calculation.
- The calculate reduction factor will be displayed. Clicking the Apply button to generate the loading will also apply the calculated factor. For assessment loading the loaded length must be between 2m and 50m. For loaded lengths outside of this range the user should seek advice from the appropriate design code.

United Kingdom KEL Loads

The KEL load generator produces a knife-edge load based on notional lane width and intensity. The intensity of the knife-edge load has a default value set but can be modified to any value required.

For the assessment codes BD21/97and BD21/01 an additional reduction factor can be included. This is based on the assessment live load being used and the road category type.



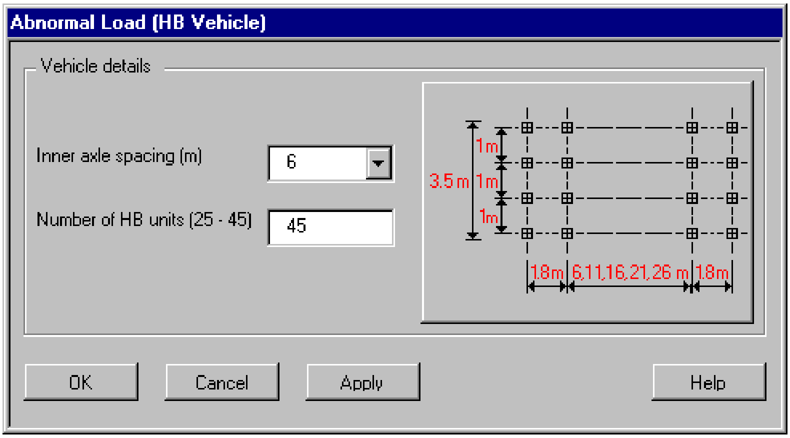
To use this loading type:

- Specify the width of lane load.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Specify the intensity of load.
- Specify the offset for the load.
- Choose the origin for the about which the load is to be generated.
- The option to apply an assessment reduction factor is given. Switching this option off will generate a nominal unfactored assessment load.
- Select the assessment live load vehicle type from the list
- Select the road category type from the list
- Specify the length of carriageway to allow the assessment reduction factor to be calculated.

- Choose whether to include the adjustment factor, AF, in the calculation.
- The calculate reduction factor will be displayed. Clicking the Apply button to generate the loading will also apply the calculated factor.

United Kingdom Abnormal Load Generator (HB Vehicle)

The HB load generator produces a HB vehicle by setting the inner axle spacing (6m, 11m, 16m, 21m, & 26m) and the number of HB units required (25-45).

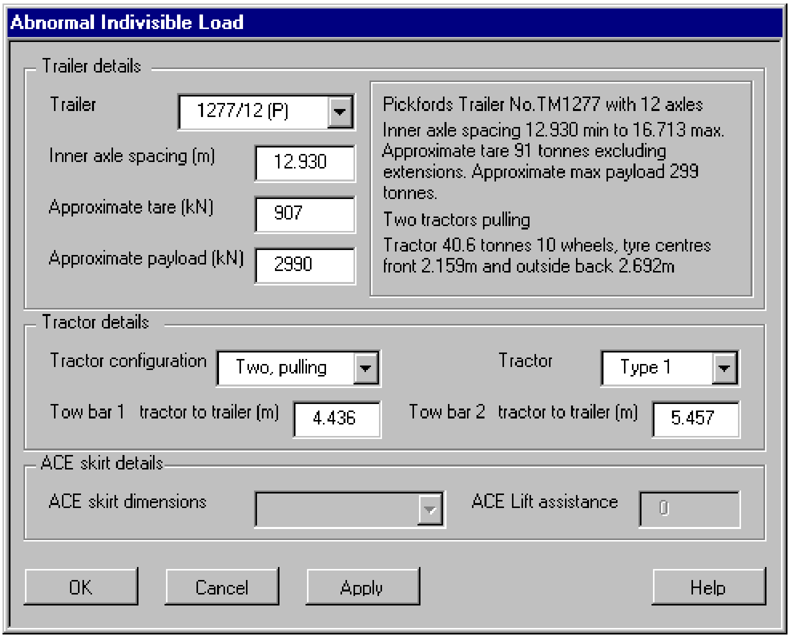


To use this loading type:

- Choose the inner axle spacing.
- Specify the number of HB units to be considered for the vehicle.

United Kingdom Abnormal Indivisible Loads

The abnormal indivisible load generator produces loads that represent heavy haulage vehicles. Many different configurations of trailer and tractor units can be created with user-defined loading intensities.

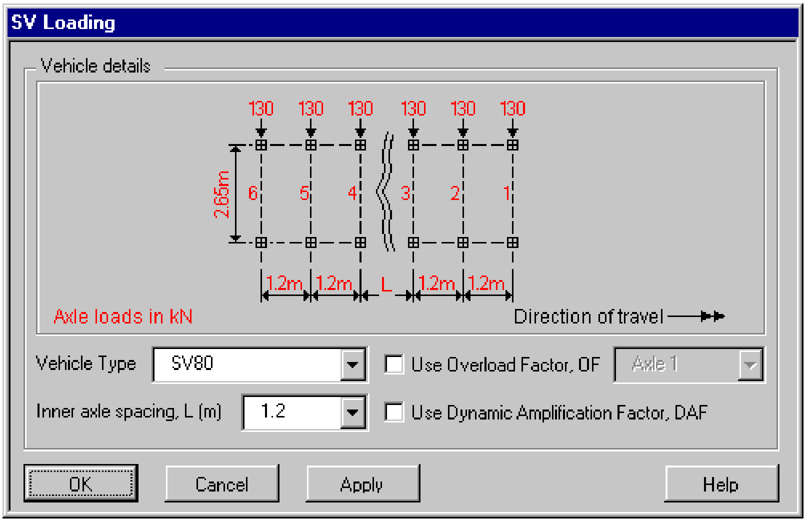


To use this loading type:

- Choose which trailer you require to generate as a vehicle load. A description is provided in the right hand panel.
- Specify the inner axle spacing for the trailer.
- Specify the approximate tare of the trailer.
- Specify the approximate payload of the trailer.
- Choose the tractor arrangement that is required for the vehicle.
- Choose the trailer type (a description is given in the panel above)
- Choose distance of tow to tractor (one or two)
- If a trailer with ACE has been chosen set up the details of the air skirt.

United Kingdom Special Vehicle Loads

The special vehicle dialog allows the creation of SV loading as defined in BD 86/04 “The Assessment of Highway Bridge and Structures for the Effects of Special Types General Order (STGO) and Special Order (SO) Vehicles”.



- ❑ **Vehicle Type** SV loading is defined in accordance to BD86/04 "The Assessment of Highway Bridge and Structures for the Effects of Special Types General Order (STGO) and Special Order (SO) Vehicles". Five load models can be generated that simulate the vertical effects of different types of STGO vehicles with basic axle weights not exceeding 16.5 tonnes and military tank transporter vehicles with basic axle weights of up to 25 tonnes.

  - The SV80 vehicle is intended to model the effects of STGO Category 2 vehicles with a maximum gross vehicle weight of 80 tonnes and a maximum basic axle load of 12.5 tonnes.
  - The SV100 vehicle is intended to model the effects of STGO Category 3 vehicles with a maximum gross vehicle weight of 100 tonnes and a maximum basic axle load of 16.5 tonnes.
  - The SV150 vehicle is intended to model the effects of STGO Category 3 vehicles with a maximum gross vehicle weight of 150 tonnes and a maximum basic axle load of 16.5 tonnes.
  - The SV-Train is intended to model the effects of a single locomotive pulling a Category 3 trailer.
  - The SV-TT is intended to model the effects of a military tank transporter vehicles with a maximum basic axle load of 25 tonnes.

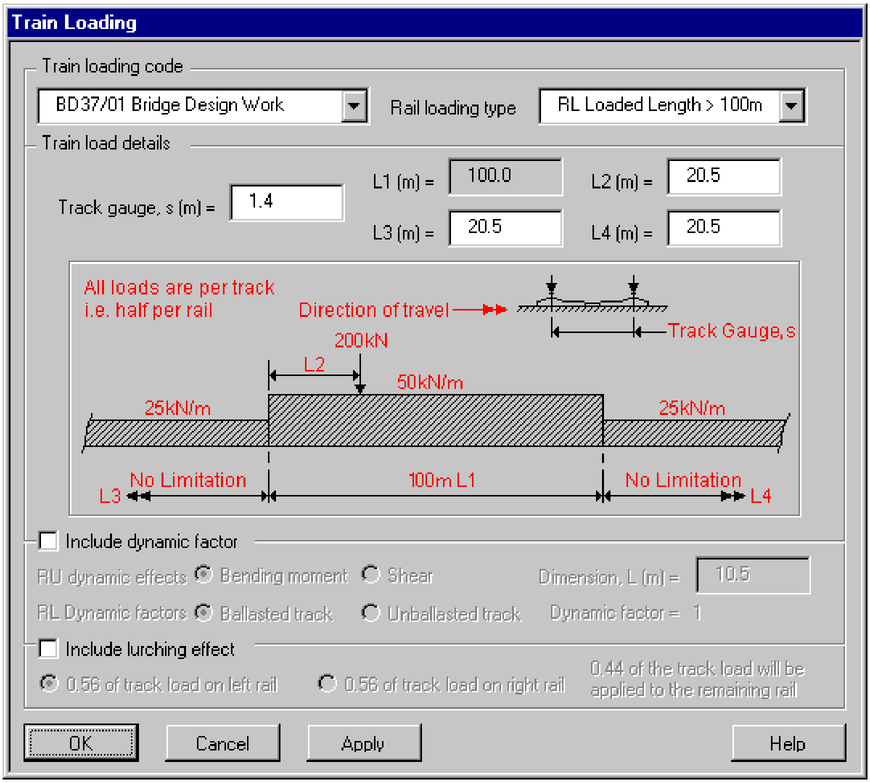
- ❑ Choose the **Overload Factor**, OF, to model SV vehicles in excess of the gross weight and axle weights notified by the hauliers to highway authorities. The Overload Factor shall be taken as 1.2 for the worst critical axle, chosen from the drop-down list, and 1.1 for all other axles.

- The **Dynamic Amplification Factor**, DAF, will factor each axle using the following equation:

  DAF = [1.7 X (basic axle load / 10) ^ -0.15]

United Kingdom Train Loading

The train load generator can produce loading types RU, SW/0, SW/2, RL, RA1, RT, Class 67 and Class 91.



- **Train loading code** Defines the design code to be used
- **Rail loading type** Standard railway loading consists at two types, RU and RL. RU loading allows for all combinations of vehicles currently running or projected to run on railways in the Continent of Europe, including the United Kingdom, and is to be adopted for the design of bridges carrying main line railways of 1.4m gauge and above.

  - RL loading is a reduced loading for use only on passenger rapid transit railway systems on lines where main line locomotives and rolling stock do not operate. The derivation of standard railway loadings is given in appendix D of BD37.

- Nominal type RU loading consists of four 250kN concentrated loads preceded, and followed, by a uniformly distributed load of 80kN/m.
- Nominal type SW/0 loading consists of a two uniformly distributed loads of 133kN/m, each 15m long and separated by a distance of 5.3m.
- Nominal type RL loading consists of a single 200kN concentrated load coupled with a uniformly distributed load of 50kN/m for loaded lengths up to 100m. For loaded lengths in excess of l00m the distributed nominal load shall be 50kN/m for the first l00m and shall be reduced to 25kN/m for lengths in excess of l00m. Alternatively, two concentrated nominal loads, one of 300kN and the other of 150kN, spaced at 2.4m intervals along the track, shall be used on deck elements where this gives a more severe condition. These two concentrated loads shall be deemed to include dynamic effects.
- The standard railway loadings RU and RL as specified in BD37 clause 8.2.1 and 8.2.2 (except the 300kN and 150kN concentrated alternative RL loading) are equivalent static loadings and shall be multiplied by appropriate dynamic factors to allow for impact, oscillation and other dynamic effects including those caused by track and wheel irregularities.

❑ **Include dynamic factor** In deriving the dynamic factor, *L* is taken as the length (in m) of the influence line for deflection of the element under consideration. For unsymmetrical influence lines, *L* is twice the distance between the point at which the greatest ordinate occurs and the nearest end point of the influence line. In the case of floor members. 3m should be added to the length of the influence line as an allowance for load distribution through track. The dynamic factors given below should be adopted, provided that maintenance of track and rolling stock is kept to a reasonable standard.

Dimension L	Bending Moment	Shear
up to 3.6m	2.0	1.67
from 3.6m to 67	$0.73 + 2.16/(L^{0.5} - 0.2)$	$0.82 + 1.44/(L^{0.5} - 0.2)$
over 67	1.0	1.0

The dynamic factor for RL loading. when evaluating moments and shears, shall be taken as 1.20, except for unballasted tracks where, for rail bearers and single-track cross girders, the dynamic factor shall be increased to 1.40. The dynamic factor applied to temporary works may be reduced to unity when rail traffic speeds are limited to not more than 25 km/h.

❑ **Include lurching effect** Lurching results from the temporary transfer of part of the live loading from one rail to another, the total track load remaining unaltered. The dynamic factor applied to RU loading will take into account the effects of lurching, and the load to be considered acting on each rail shall be half the track load.

Notes.

- The dynamic factor applied to RL loading will not adequately take account of all lurching effects. To allow for this, 0.56 of the track load shall be considered acting on one rail concurrently with 0.44 of the track load on the other rail. This distribution of load need only be taken into account on one track where members support two tracks. Lurching may be ignored in the case of elements that support load from more than two tracks.
- Train loads will be generated about the centre point.

United States of America Vehicle Loading

USA vehicle loads can be defined for:

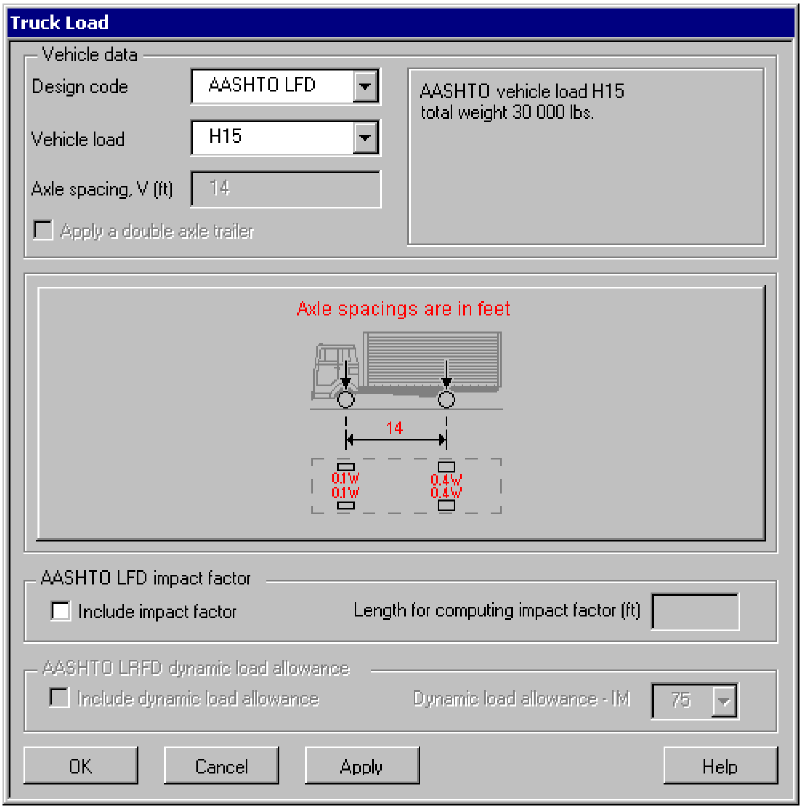
- ❑ **Truck loads** AASHTO LFD and LFRD loading and other state dependent design loading such as Oregon LRFR.
- ❑ **Tandem loads**
- ❑ **Uniform loads**
- ❑ **Concentrated Pm loads**
- ❑ **Concentntarted Ps loads**
- ❑ **Train loading**

United States of America Truck Loading

The truck load generator produces vehicle loads based on the AASHTO LFD and AASHTO LRFD codes and other state dependent codes such as Oregon LRFR for example.

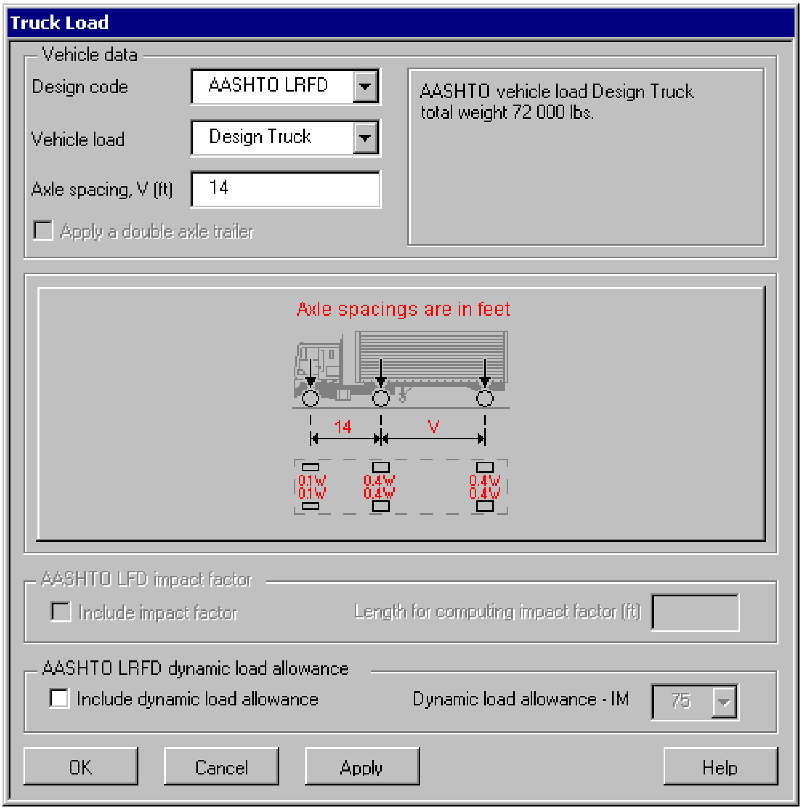
AASHTO LFD Truck Loading

For the AASHTO LFD code the following truck types can be created: H15, H20, HS15, HS20 and HS25. For the HS15, HS20 and HS25 the variable axle spacing can be set between 14ft and 30 ft. For all the trucks the additional impact factor can be added to the loads based on loaded length.



AASHTO LFD Truck Loading

For the AASHTO LRFD code the design truck that forms part of the HL-93 loading can be created. For the design truck the additional dynamic load allowance can be added to the loads based on the impact factor (IM).



To use either loading type:

- Choose the design code that the truck load is to be calculated from.
- Choose the vehicle type required to be generated. Note that if axle spacing is required this has to be between 14 and 30 feet for the **AASHTO LFD** vehicles and 14 and 32 feet for the **AASHTO LRFD** design truck. The vehicle will be generated about its centroid.

  For **AASHTO LFD**'s **H20** and **HS20** the option to have a double axle trailer is possible. This is applicable for timber or orthotropic steel decks (excluding transverse beams). For these vehicles either one 32 000 lbs or two 16 000 lbs four feet apart axles can be used. The vehicle giving the most adverse effect should be used for design.

  For **AASHTO LFD**, if an impact factor is to be considered, select the check box and enter a length for computing the **impact factor**. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. The impact factor is calculated from the equation below.

  $$I = 50 / (L + 125)$$

where L = length for computing the impact factor in feet

For **AASHTO LRFD** what was known as impact in the Standard Specification is called **dynamic load allowance** (IM) in the LRFD Specification and is expressed as a percentage. The base dynamic load allowance factors are present in LRFD Table 3.6.2.1-1. Designers should note that the base values are reduced for buried components and for wood structures.

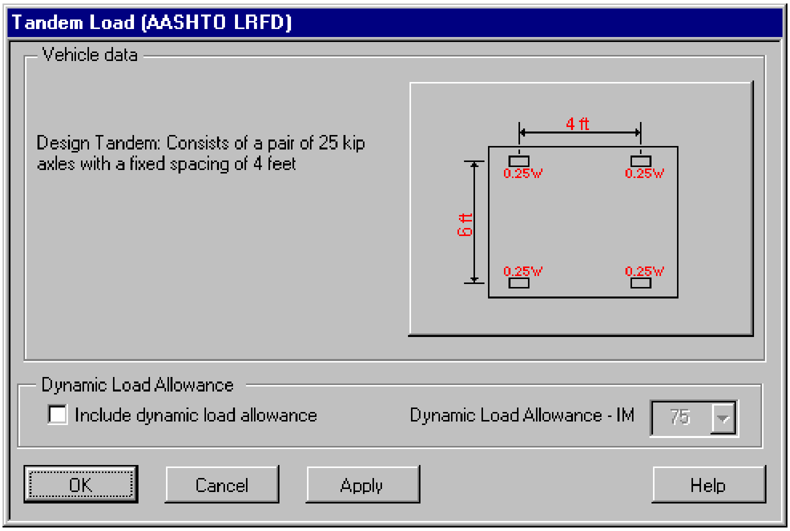
Oregon LRFR Truck Loading

See **Oregon Department of Transportation Truck Loading**

United States of America Tandem Load (AASHTO LRFD)

The tandem load generator produces load groups based on the AASHTO LRFD code.

For the AASHTO LRFD code the tandem load that forms part of the HL-93 loading can be created. For the tandem load the additional dynamic load allowance can be added to the loads based on the impact factor (IM).



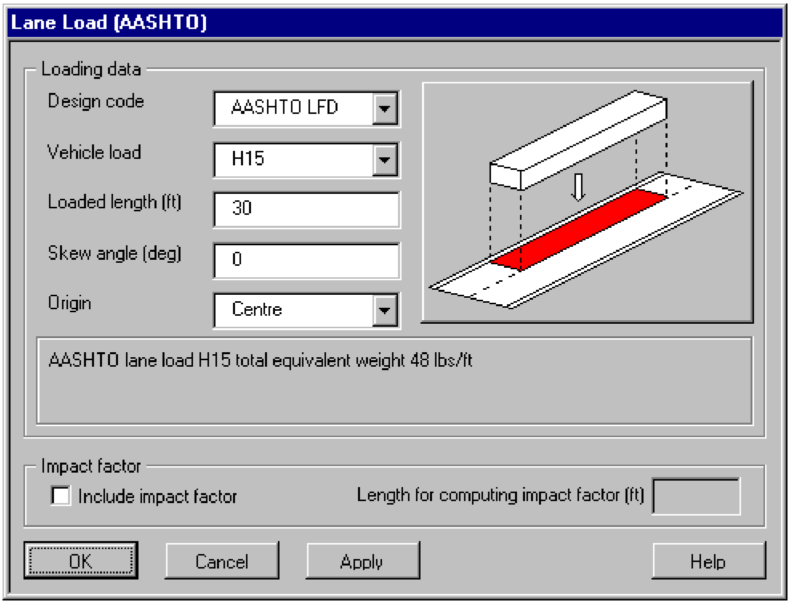
For AASHTO LRFD what was known as impact in the Standard Specification is called dynamic load allowance (IM) in the LRFD Specification and is expressed as a percentage. The base dynamic load allowance factors are present in LRFD Table 3.6.2.1-1. Designers should note that the base values are reduced for buried components and for wood structures.

United States of America Lane Load (AASHTO)

The lane load generator produces a uniform patch load based on the AASHTO LFD and AASHTO LRFD codes.

For the AASHTO LFD code the following load types can be created: H15, H20, HS15, HS20 and HS25. For all the load types the additional impact factor can be added to the loads based on loaded length.

For the AASHTO LRFD code the design lane load that forms part of the HL-93 loading can be created. For the design lane load the additional dynamic load allowance can be added to the loads based on the impact factor (IM).



To use this loading type:

- Choose the design code that the lane load is to be calculated from.
- Choose the patch type from the drop down list to specify the load intensity.
- Specify the length of lane load that you require to generate about the centre line of patch.
- Specify the skew angle to apply to the lane loading (clockwise positive).
- Choose the origin that the load will be generated about.

For AASHTO LFD, if an impact factor is to be considered, select the check box and enter a length for computing the impact factor. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. The impact factor is calculated from the equation below.

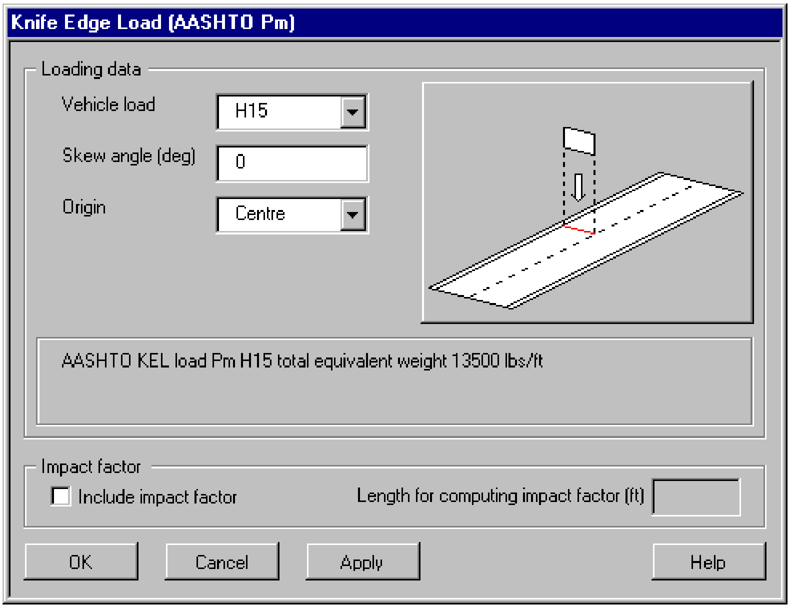
$$I = 50 / (L + 125)$$

where L=length for computing the impact factor in feet

United States of America AASHTO Knife Edge Load (Moment, Pm)

The knife edge load (moment, Pm) generator produces a line load based on the AASHTO LFD code.

For the AASHTO LFD code the following load types can be created: H15, H20, HS15, HS20 and HS25. For all the load types the additional impact factor can be added to the loads based on loaded length.



To use this loading type:

- Choose the vehicle load type from the drop down list.
- Specify the skew angle to apply to the KEL loading (clockwise positive).
- Choose the origin for which the load is to be generated about.
- If an impact factor is to be considered, select the check box and enter a length for computing the impact factor. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. The impact factor is calculated from the equation below.

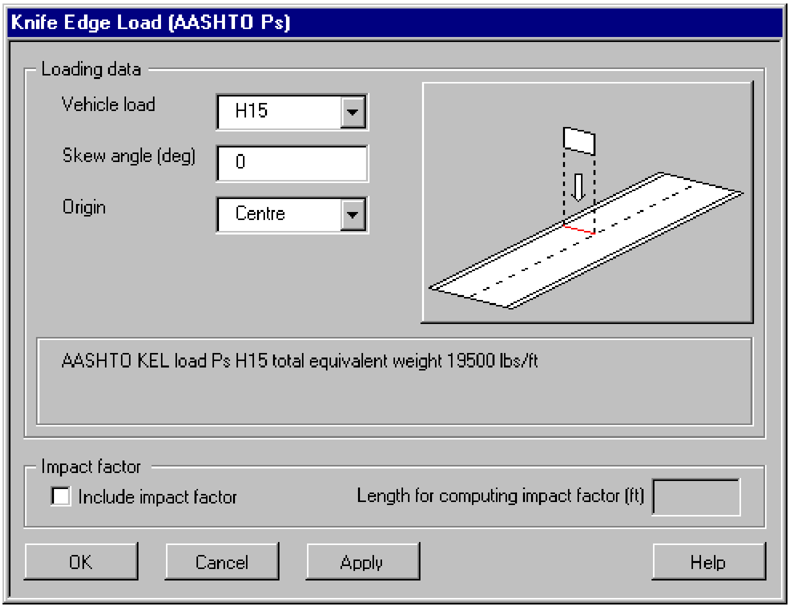
$$I = 50 / (L + 125)$$

where L=length for computing the impact factor in feet

United States of America AASHTO Knife Edge Load (Moment, Ps)

The knife edge load (moment, Ps) generator produces a line load based on the AASHTO LFD code.

For the AASHTO LFD code the following load types can be created: H15, H20, HS15, HS20 and HS25. For all the loads types the additional impact factor can be added to the loads based on loaded length.



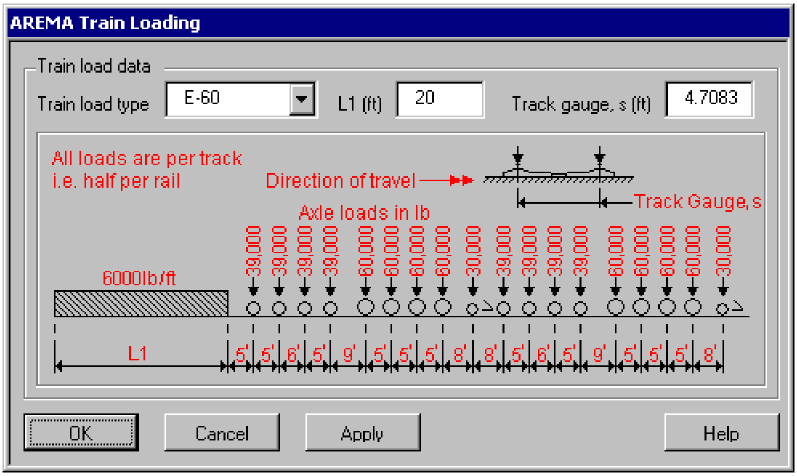
To use this loading type:

- Choose the vehicle load type from the drop down list.
- Specify the skew angle to apply to the KEL loading (clockwise positive).
- Choose the origin for which the load is to be generated about.
- If an impact factor is to be considered, select the check box and enter a length for computing the impact factor. The impact allowance is a maximum of 30 % making the impact factor a maximum of 1.3. The impact factor is calculated from the equation below.

$$I = 50 / (L + 125)$$

where L=length for computing the impact factor in feet

United States of America Train Loading – AREMA



To create this loading type:

- Select the standard rail loading type from the drop down list.
- Enter the dimensions L1 as appropriate for the load model chosen.
- Enter the track gauge.

For this loading a number of discrete load attributes will be created that are used to define a compound load. It is the compound load that should be assigned to the model.

Oregon Department of Transportation Truck Loading

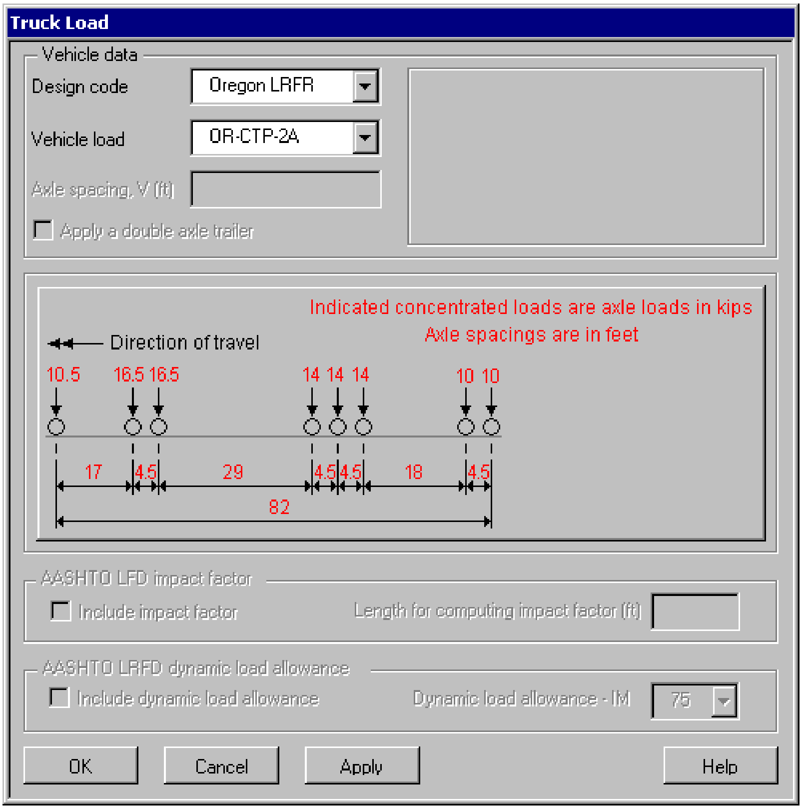
Oregon vehicle loadings are accessed from the Bridge > Bridge Loading > United States of America > Truck Load... menu item. Oregon vehicle loadings are defined to Oregon Department of Transportation specification (ODOT LRFR Manual, 2008). They include the following types:

- **ODOT Continuous Trip Permit (CTP) Trucks**
- **ODOT Legal Trucks (LEG)**
- **ODOT Permit Load (PERMIT) Trucks**
- **ODOT Single Trip Permit (STP) Trucks**
- **Specialized Hauling Vehicles (Denoted as SU Trucks)**

For all vehicle types all axle loadings and axle spacings are set. No user input is required. Only the first dialog of each specific truck type will be shown here.

Continuous Trip Permit (CTP) Trucks

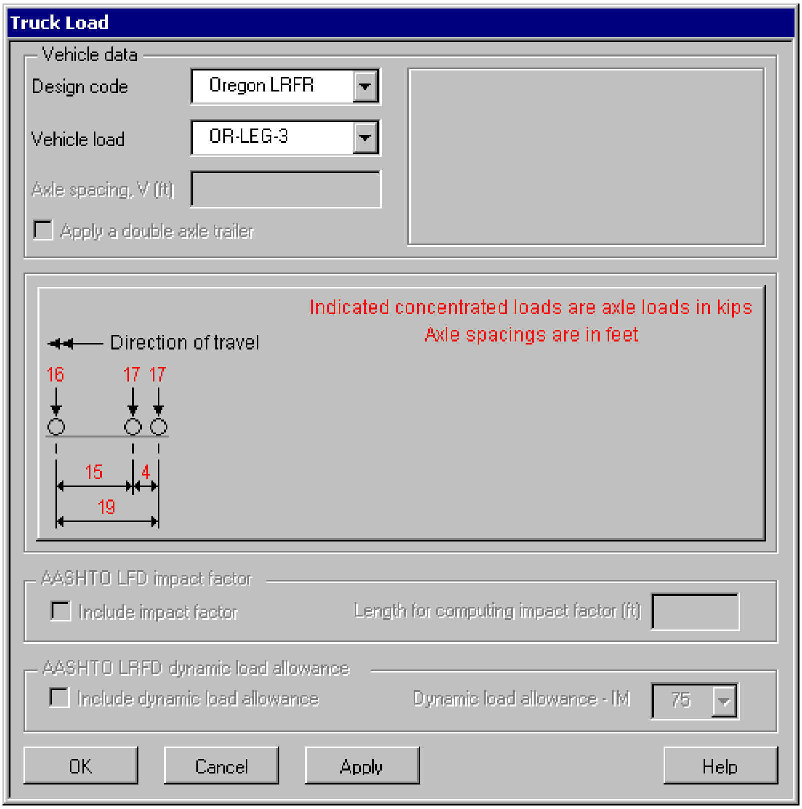
The designations for ODOT permit vehicles contain indicators of the type Continuous Trip Permit (CTP) or Single Trip Permit (STP), and the number of the MTCD weight table it represents. For example, “Type CTP-2A” indicates a Continuous Trip Permit vehicle that conforms to Weight Table 2.



The following Continuous Trip Permit (CTP) Trucks are provided:

- **OR-CTP-2A**
- **OR-CTP-2B**
- **OR-CTP-3**

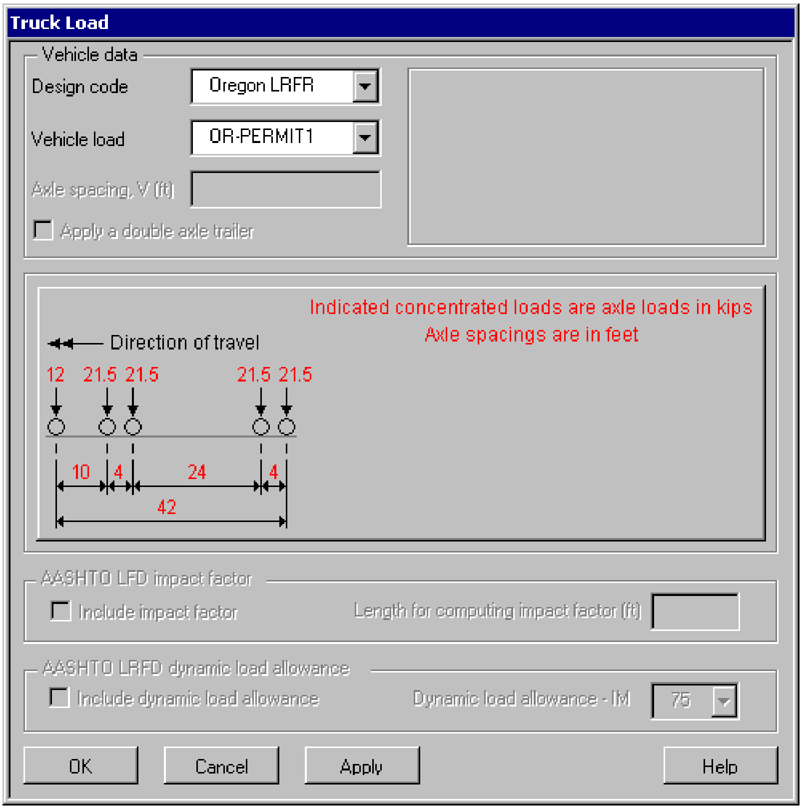
ODOT Legal Trucks (LEG)



The following Legal Trucks (LEG) are provided:

- **OR-LEG-3**
- **OR-LEG-3-3**
- **OR-LEG-3-3 TRAIN**
- **OER-LEG-3S2**

ODOT Permit Load (PERMIT) Trucks

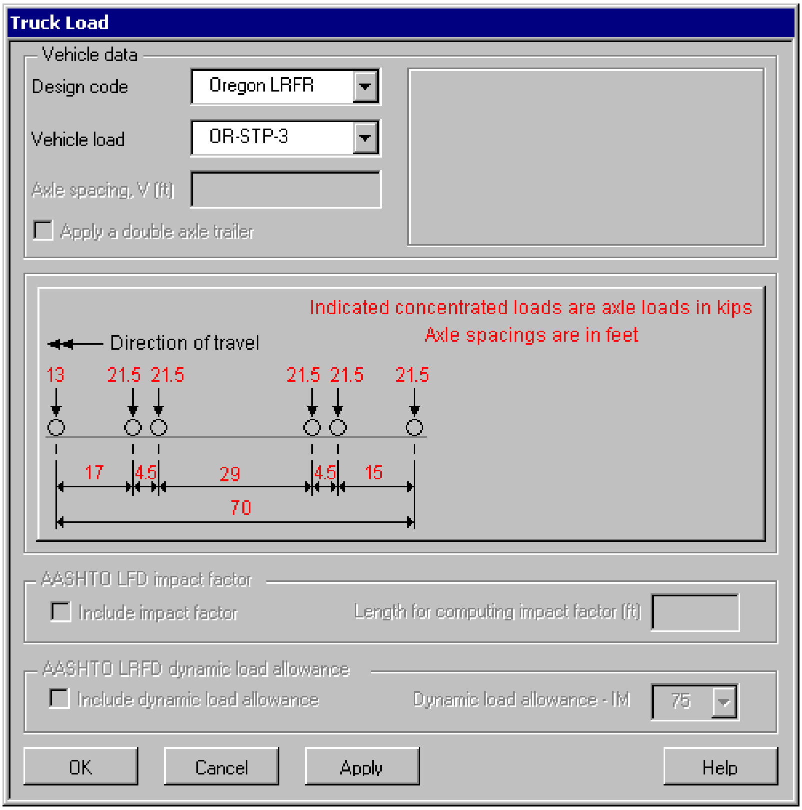


The following Permit (PERMIT) Trucks are provided:

- **OR-PERMIT1**
- **OR-PERMIT2**
- **OR-PERMIT3**
- **OR-PERMIT4**
- **OR-PERMIT5**
- **OR-PERMIT6**
- **OR-PERMIT7**

ODOT Single Trip Permit (STP) Trucks

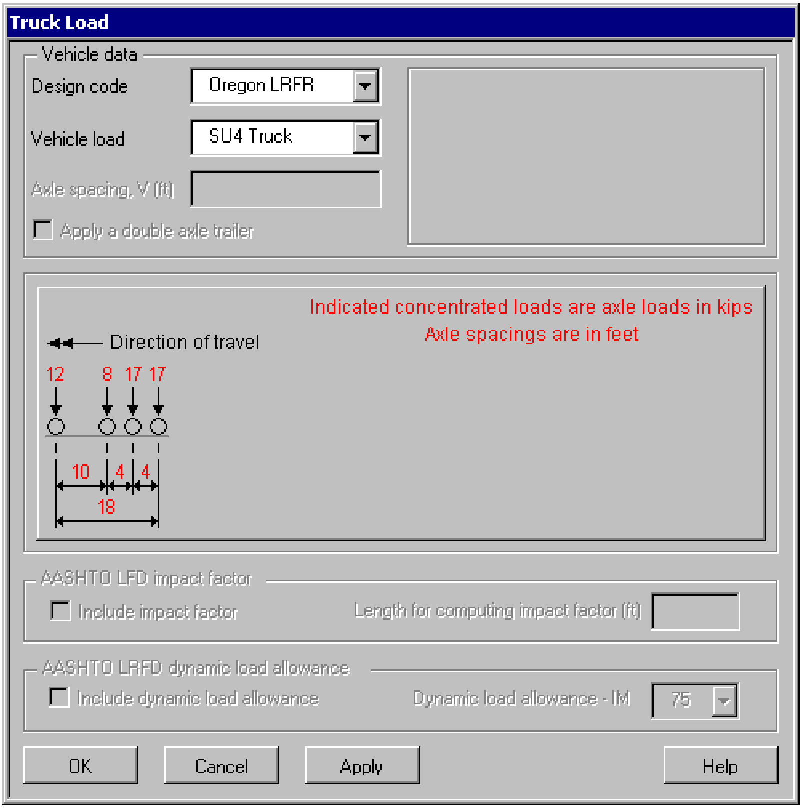
The designations for ODOT Permit Vehicles contain indicators of the type of Continuous Trip Permit (CTP) or Single Trip Permit (STP) and the number MTCD Weight Table it represents. For example, “Type STP-4A” indicates this is a Single Trip Permit vehicle that conforms to Weight Table 4.



The following Single Trip Permit (STP) Trucks are provided:

- **OR-STP-3**
- **OR-STP-4A**
- **OR-STP-4B**
- **OR-STP-4C**
- **OR-STP-4D**
- **OR-STP-4E**
- **OR-STP-5BW**

Specialized Hauling Vehicles (denoted as SU Trucks)



The following Specialized Hauling Vehicles (denoted as SU Trucks) are provided:

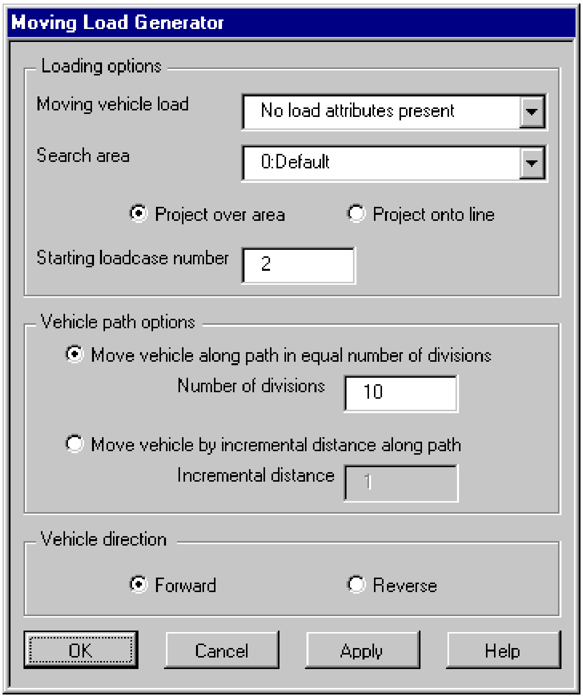
- **OR-SU4 Truck**
- **OR-SU5 Truck**
- **OR-SU6 Truck**
- **OR-SU7 Truck**

Moving Load Generator

Overview

The moving load generator is accessed from the **Bridge > Moving Load...** menu item. It is used to track the path of a vehicle (or a set of vehicles) across a structure by automatically setting up a number of static loadcases at prescribed locations along a selected line. These loadcases produced can then be enveloped to provide the maximum effect of the vehicle passing over the structure.

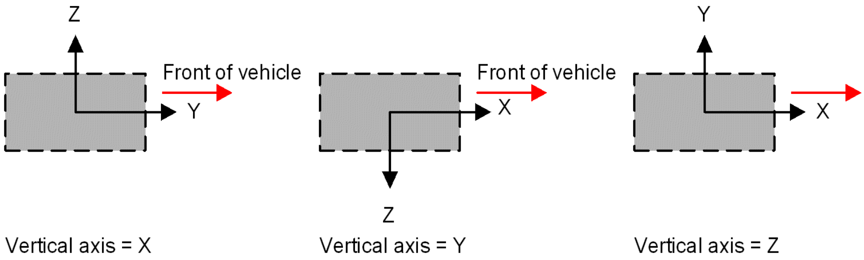
Prior to using the moving load generator a slab or grillage model that will allow the application of discrete loads must have been created. Ensure that the discrete load group representing the vehicle to be moved across the structure has been defined in the Treeview and that a line representing the vehicle path across the structure has been defined and selected. The line representing the vehicle path should <u>not</u> be one of the lines forming the model. If a combined line is selected then the generator will use the points joining the lines within the combined line as the locations for the application of the vehicle loads. For straight lines or arcs the generator will split the selected line representing the vehicle path into a number of segments and create a loadcase for the vehicle in each load position. Only the first line within the selection will be processed.



- ❑ **Moving vehicle load** Select the pre-defined vehicle load to be moved along the line
- ❑ **Search area** can used to restrict the area of application of point and patch loads to pre-defined part of the model. Generally, for grillage models, a search area is not required.
- ❑ **Project over area** needs to selected if the vehicle load is to be applied to a grillage or slab model (3D)
- ❑ **Project onto line** needs to be selected if the load is to be applied to a line beam model (2D)
- ❑ **Starting loadcase number** can be set to whatever loadcase number is required but by default will be set to be the next free loadcase number.
- ❑ **Vehicle path options** define whether the vehicle is to be moved across the structure by a equal number of divisions or by an incremental distance of the line representing the vehicle path.
- ❑ **Vehicle direction** allows for forward (defined by the geometric line direction) and reverse passing of the loading.

Load direction

When moving a discrete load where the load direction and the projection vector do not match care should be taken in the direction of the discrete load to ensure that the loading applies in the correct direction along the path. For all vehicles defined using the Bridge > Bridge Loading menu item the front of the vehicle and local axes are defined as follows:

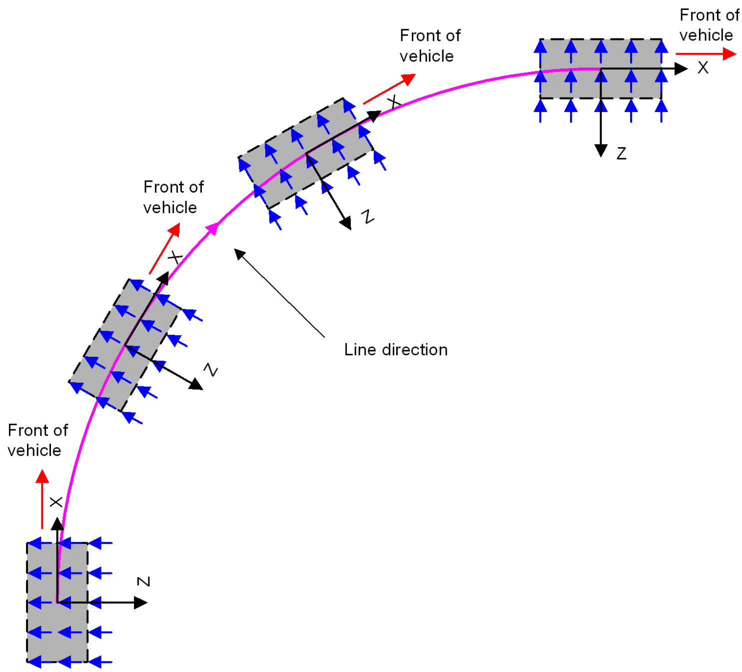


Centrifugal loading

When a centrifugal load is defined for use on a path represented by an arc the point or patch load direction and sign of the vehicle load should be set up to take account of the vertical axis of the model and of the local axes of the vehicle.

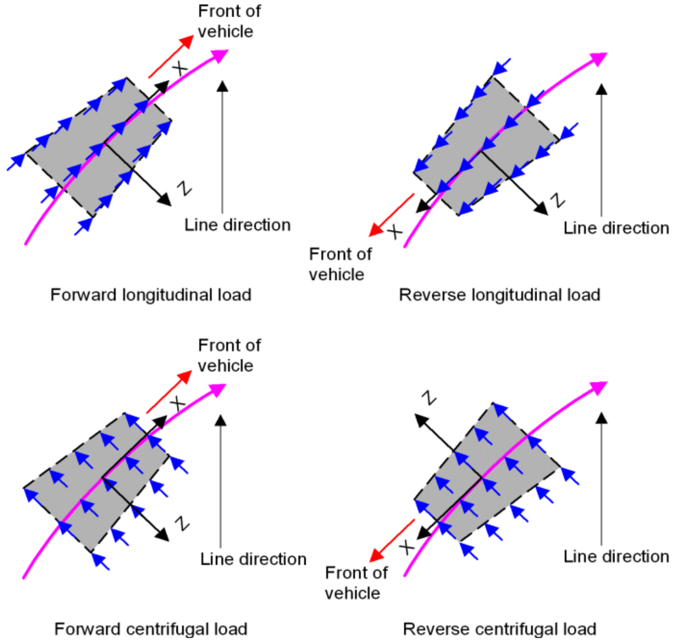
Patch loading

In the following patch load example the vertical axis of the model is set to the Y direction and a vehicle load is moved clockwise around an arc in the ZX plane with centrifugal loading defined as a negative value in the Z direction:



Reversing the vehicle direction by using the Reverse option on the Moving Load dialog will change the orientation of the vehicle configuration so it is rotated 180 degrees such that the vehicle will now pass along the path in the opposite direction with this new orientation. Loads defined in the lateral vehicle directions will be rotated ensuring that the lateral loads for centrifugal loading will be maintained in the correct direction as the vehicle passes along the path.

The following examples (using trapezoidal-shaped patch loading for clarity) show the effect of vehicle direction upon any horizontally defined longitudinal or centrifugal loads:



Point loading

For point loading similar care should be taken to ensure that the vertical axis of the model and the untransformed load directions for longitudinal or centrifugal loading are compatible. Reversing the vehicle direction by using the Reverse option on the Moving Load dialog will ensure that any lateral loads are rotated and, as for patch loading, the centrifugal loading will be maintained in the correct direction as the point load passes along the path.

Moving multiple loads

Discrete loads can be assigned to, and manipulated on a model as a load set or load train by creating a **compound discrete load.**

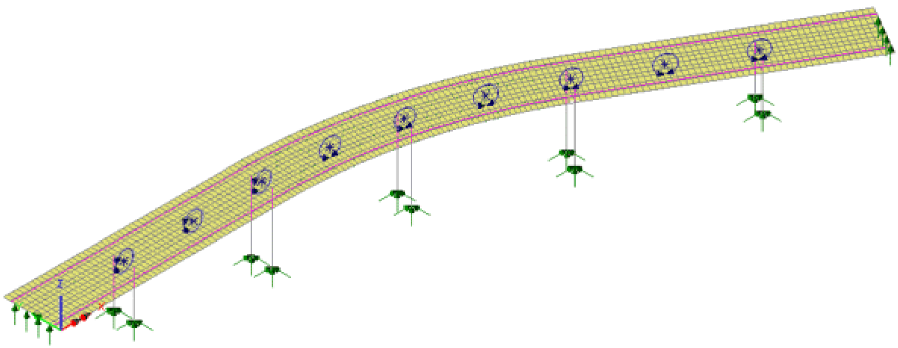
Vehicle Load Optimisation

Overview

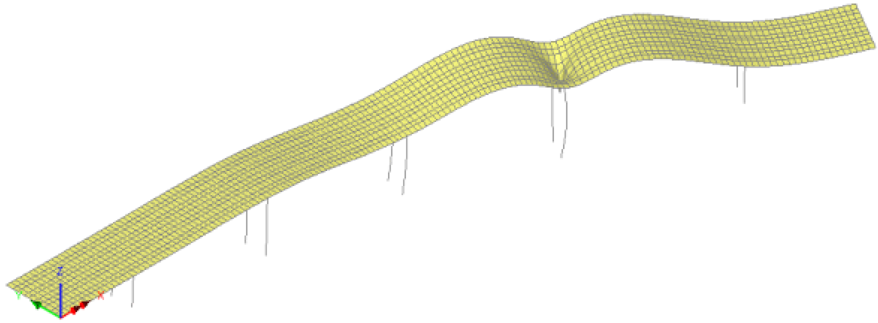
Vehicle load optimisation is used to identify critical vehicle loading patterns on bridges and apply these loading patterns to LUSAS analysis models. It reduces the amount of time spent generating models and leads to more efficient and economic design, assessment or load rating of bridge structures. It is accessed from the **Bridge > Vehicle Load Optimisation** menu item. Prior to using the Vehicle Load Optimisation dialog **influences attributes** must have been assigned to selected positions on a model.

How does it work?

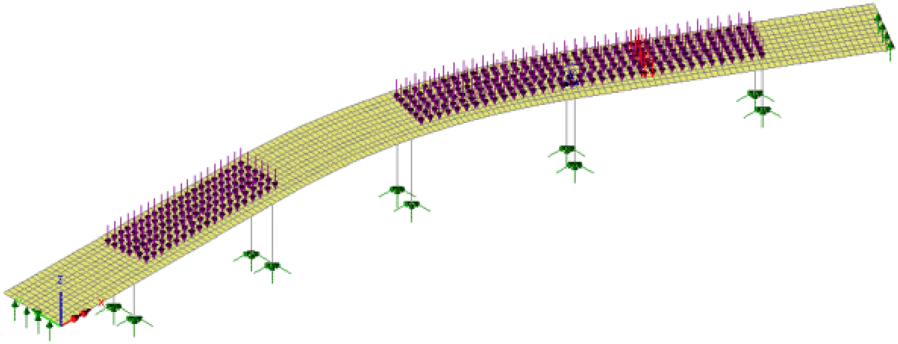
1. One or more positions on the LUSAS model that are to be used for loading evaluation are identified and assigned **influence attributes**. Kerb lines defining the extent of the carriageway are defined. A simple model for analysing traffic loading to Eurocode EN-1991-2 for a number of defined influence points is shown.



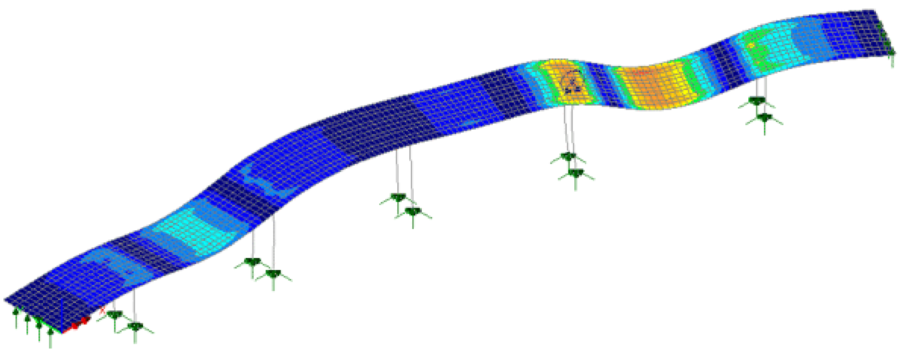
2. An influence surface for each position is automatically calculated and can be optionally displayed.



3. The vehicle load optimisation facility interrogates each influence surface and calculates the critical loading pattern for the chosen effect. The critical loading pattern can be optionally displayed prior to calculating loading effects.



4. The critical loading patterns for each influence surface are then used to calculate the loading effects on the model. Critical loading patterns can be optionally superimposed on deformed or undeformed results plots.

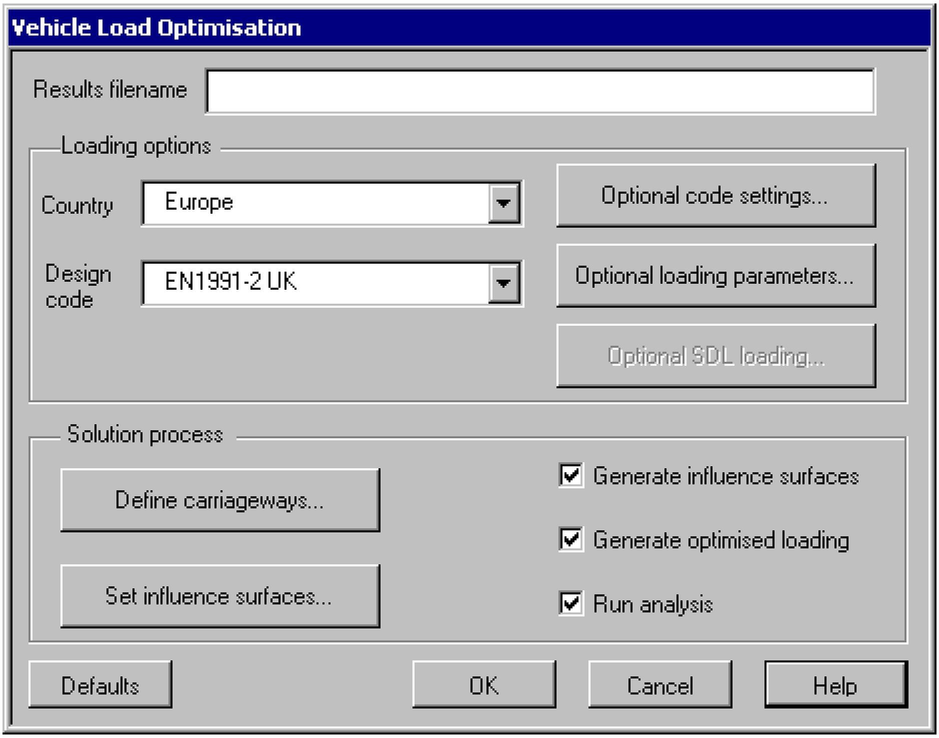


In use

The vehicle load optimisation wizard provides the means of defining parameters for a particular design code for use when generating the most critical loading for each influence surface that has been defined in a model. The actual vehicle load optimisation software that is used to generate this loading depends upon the design code chosen.

- **For traffic loading to Eurocode EN-1991-2, LUSAS Traffic Load Optimisation (TLO) software is used.**
- **For vehicle loading to other supported design codes, Autoloader vehicle load optimisation software is used.**

Design codes supported by LUSAS TLO



Country design codes currently supported by the LUSAS Traffic Load Optimisation (TLO) software option (via incorporation of the National Annexes) include:

- **Ireland** - Eurocode EN1991-2
- **Italy** - Eurocode EN1991-2
- **Poland** - Eurocode EN1991-2
- **Sweden** - Eurocode EN1991-2
- **UK** - Eurocode EN1991-2

A Eurocode EN1991-2 **Recommended values** option is also provided. For this, the values for Nationally Determined Parameters (α_Q, α_q, ψ) and the EN1991-2 informative Annex A Special Vehicles are used by default.

Optional Code Settings

Optional code settings can be specified for all design codes supported by LUSAS TLO. See the online help dialogs for each country load type for details or refer to the relevant help pages in the *Application Manual (Bridge, Civil & Structural).*

Optional Loading Parameters

For design codes supported by LUSAS TLO the following parameters are available for selection:

- **Longitudinal increment** - specifies the increment used when moving the abnormal vehicle along the carriageway. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway,giving more accurate results. A larger increment gives quicker TLO runs but with potentially less accuracy. A generally suitable default value is provided but users can specify an alternative value based upon experience. If an invalid value is specified, a warning is given and the default value used.
- **Transverse increment** - specifies the increment used when moving the vehicle across the carriageway. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway, giving more accurate results. A larger increment gives quicker TLO runs but with potentially less accuracy. A generally suitable default value is provided but users can specify an alternative value based upon experience. If an invalid value is specified, a warning is given and the default value used.
- **Vehicle Direction** - specifies the vehicle direction which is used to calculate the effects of each vehicle. **Forward** means the vehicle is run with axles with the lowest axle positions aligned towards the base point of the carriageway. **Reverse** means the vehicle is run with axles with the highest axle positions aligned towards the base point of the carriageway. **Both** means both cases are run. For an abnormal vehicle, either forward or reverse could produce the greatest effect, dependent upon the shape of the influence surface and the increments used. The default is both directions.

Defining Carriageways

For design codes supported by LUSAS TLO the following parameters are available for selection:

- **Kerb positions -** define the width of each carriageway.

  - **Kerb from Selection**- The kerb positions of carriageways are defined by selecting those lines defining the kerbs on either side of a carriageway on screen prior to displaying the Vehicle Load Optimisation dialog. Multiple straight lines, arcs or any combined sequence of these two feature types that describe the extent of the carriageway can be selected.

Notes

For design codes supported by LUSAS TLO:

- LUSAS TLO vehicle loads can be projected in either the X, Y or Z directions, meaning that models can lie in any of the primary X,Y, Y,Z or Z,X planes.
- When using LUSAS TLO the model does not have to be in the positive x,y quadrant of the view window.
- When using shells, quadratic elements with mid-side nodes are permitted.

See also **Setting-up Influence Surfaces** and the **General Notes** below.

Design codes supported by Autoloader

Country design codes currently supported by LUSAS using the Autoloader vehicle load optimisation software option include:

- **Australia**- the AUSTROADS standard.
- **Finland**- the Finland Highway Loading standard.
- **Israel** - Israel loading.
- **Korea**- the Korea Highway Loading standard.
- **Malaysia**- the JKR Highway Loading standard.
- **Norway**- the Norway Highway Loading standard.
- **South Africa** - TMH7 Loading standard.
- **Sweden**- the BRO standard.
- **UK**- Highways Agency Departmental Standard BD21/97 “Assessment of Highway Bridges and Structures”.
- **UK**- Highways Agency Departmental Standard BD21/01 “Assessment of Highway Bridges and Structures”.
- **UK**- Highways Agency Departmental Standard BD37/88 “Loads for Highway Bridges”, which incorporates BS5400 Part 2:1978.
- **UK**- Highways Agency Departmental Standard BD37/88 “Loads for Highway Bridges”, which incorporates BS5400 Part 2:1978, RU section
- **UK**- Highways Agency Departmental Standard BD37/01 “Loads for Highway Bridges”.
- **USA** - the AASHTO LFD and LRFD standard

Optional Code Settings

Optional code settings can be specified for all design codes supported by Autoloader. See the online help dialogs for each country load type for details or refer to the relevant pages in the *Application Manual (Bridge, Civil & Structural).*

Optional Loading Parameters

For vehicle load optimisation of design codes supported by Autoloader the following parameters are available for selection:

- **Autoloader Vehicle Library** - specifies an alternate file containing the Autoloader Vehicle Library. This enables the user to define another vehicle for a set of Autoloader runs. By default, Autoloader looks for autoload.vec in the working directory.
- **Vehicles** - defines a list of vehicles that can be chosen to calculate the greatest effect. Autoloader tests the vehicle chosen in this list. Each vehicle must be specified in the Autoloader vehicle library. If the field is not specified, HA or equivalent only loading is assumed.
- **Use Multiple Vehicles** - specifies whether a single vehicle is used or a list of vehicles. Each vehicle must be specified in the Autoloader vehicle library. To use this option select the check box next to the label and enter the list of vehicles in the text box with commas separating each name. To deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Vehicle Direction** - specifies the vehicle direction which is used to calculate the effects of each vehicle. **Forward** means the vehicle is run with axles with the lowest axle positions aligned towards the base point of the carriageway. **Reverse** means the vehicle is run with axles with the highest axle positions aligned towards the base point of the carriageway. **Both** means both cases are run. For an abnormal vehicle, either forward or reverse could produce the greatest effect, dependent upon the shape of the influence surface and the increments used. The default is both directions.
- **Longitudinal increment** - specifies the increment used when moving the abnormal vehicle along the carriageway. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway, this gives more accurate results. A larger increment gives quicker Autoloader runs. A generally suitable default value is provided but users can specify an alternative value based upon experience. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Transverse increment** - specifies the increment used when moving the vehicle across the carriageway. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway, this gives more accurate results. A larger increment gives quicker Autoloader runs. A generally suitable default value is provided but users can specify an alternative value based upon experience. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Edit advanced loading options** - further to the basic options provided on this dialog, Autoloader allows more advanced changes to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

Optional Loading Parameters (Advanced)

For vehicle load optimisation of design codes supported by Autoloader the following advanced parameters are available for selection:

- **Use extra parameter file** - specifies another parameter file for Autoloader. This option allows the user to specify a generic set of parameters in another file and use that file in a series of Autoloader runs, for example for a specific project. This additional file can contain anything that the input file can contain. It is read after the entire input file is processed, and any parameter specified within this file will overwrite one specified in the original file. To use this option select the check box next to the label and specify the location of this extra file, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Use alternative KEL** - specifies an alternate value for the Knife Edge Load to use when applying KEL loading. To use this option select the check box next to the label and specify the new value for the KEL loading in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Use UDL Limit** - allows specification of a loaded length, under which the lane in question is not loaded. This can be used in conjunction with HA Alternative to create a situation such as in BD 21/97, where if the loaded length is below 2m, the lane is loaded with a Single Axle Load instead of a UDL + KEL. To use this option select the check box next to the label and specify the UDL limit in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Use Beta Lane Factors** - allows specification of alternate HA lane factors to use when calculating the effects of HA loads. The format is a list of factors. The first factor is used for the lane with the greatest effect, the second is used for the lane with the second highest effect, etc. If there are more lanes than factors, then the last factor in the list is used for any lanes without corresponding factors. It should be noted that for the JKR standard the make up lane is also treated as an HA lane and the user should specify a factor for it bearing in mind that it is quite likely to have the least effect. To use this option select the check box next to the label and specify the alternate HA lane factors in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Use Lane Modification factors -** allows specification of alternate lane modification factors to use when calculating effects. The format is a list of factors. The first value is used when there is one lane loaded, the second when there is two, etc. If there are more lanes than factors, then the last factor in the list is used. This will generally be used when AUSTROADS is applied, but can also be used within the other standards. To use this option select the check box next to the label and specify the alternate lane modification factors in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- **Use Dynamic Load allowance** - allows the dynamic load allowance for gamma factors. This will generally be used when AUSTROADS is applied, but can also be used within the other standards. If an invalid value is specified, Autoloader gives a

warning and uses the default value. To use this option select the check box next to the label and specify the dynamic load allowance for gamma factors in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.

- ❑ **Use Alternative loading intensity curve** - provides the ability to change the relationship between loaded length and intensity of the UDL applied. Each pair of values is a length and an intensity for that length. Autoloader does straight line interpolation between these values. If more accurate loading intensity is required the user should specify as many points as possible. To use this option select the check box next to the label and specify the relationship between loaded length and intensity of the UDL in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.
- ❑ **Use Alternative adjustment factors** - provides the ability to change the relationship between loaded length and the Adjustment factor for BD 21/97. Each pair of values is a length and a factor for that length. Autoloader performs linear interpolation between these values. If a more accurate value is required the user should specify as many points as possible. To use this option select the check box next to the label and specify the new relationship between loaded length and the Adjustment factor in the text box, to deselect this option ensure that the check box is not selected. By default this option will not be selected.

Defining Carriageways

For vehicle load optimisation of design codes supported by Autoloader the following parameters are available for selection:

- ❑ **Carriageway Shape** - specifies whether the carriageway is **curved** or **straight** in plan view
- ❑ **Number of Carriageways** - specifies the number of carriageways to be placed on the deck. Autoloader assumes the kerbs of each carriageway are parallel.
- ❑ **Angle of carriageway** - is only required when the carriageway shape is straight. It specifies the angle of inclination in degrees of the carriageway in an anticlockwise direction relative to the positive x axis.
- ❑ **Kerb positions -** allows entering the positions of the kerbs on each carriageway using two methods:

    - **Kerb from tabular input** - if this option is selected, when the Apply button is clicked a tabular dialog is presented for entering the kerb positions in cartesian coordinates.
    - **Kerb from Selection**- The kerb positions of the carriageways may be defined by selecting those lines defining the kerbs on either side of a carriageway on screen prior to displaying the Vehicle Load Optimisation dialog.

Notes

For vehicle load optimisation of design codes supported by Autoloader:

- For tabular input when the carriageway shape is straight, two points per carriageway are specified. The first of these is the ‘base’ point and is on a kerb at the start of the carriageway. The other point is anywhere on the other kerb.
- For tabular input when the carriageway shape is curved, four points per carriageway must be specified. The first of these is the ‘base’ point and is on a kerb at the start of the carriageway. The next two points are on the same kerb, and are used to calculate the centre of curvature and the radius of curvature. The final point is anywhere on the other kerb. Autoloader uses this data to calculate the width of the carriageway.
- Only straight lines or only arcs that describe the extent of the carriageway can be selected. Combined sequences of these feature types are not supported by Autoloader.
- Autoloader projects vehicle loads in the negative Z axis direction. As a result, models for use with Autoloader must be set up in the x,y plane to ensure that loading can be applied in this direction.
- When using Autoloader the model must be created in the positive x,y quadrant of the view window
- In certain loading situations an upward load may be applied by Autoloader. In the case of a UK design code, this can be a result of a HB loading overhanging a lane where HA loading is applied. The upward load is applied to cancel the excess of HA loading. The loading standard BD 37/88 "Loads for Highway Bridges", clause 6.4 deals with this loading situation in more detail.
- When using a grillage with the Vehicle Load Optimisation facility each of the lines representing a section of the deck must be meshed with one element only i.e. each bay of the grillage must have one element assigned. In addition, only lower order elements can be used. Quadratic elements with mid-side nodes are not permitted.
- The use of Autoloader is described fully in the *Autoloader User Manual.*

Setting-up Influence Surfaces

Applicable to vehicle load optimisation of design codes supported by Autoloader and by LUSAS TLO.

The following parameters are available for selection:

- ❑ **Generate all influence surfaces** - allows all the influence surfaces to be considered in the load optimisation.
- ❑ **Search Area to be used for Analysis** - Select the search area from the list available that LUSAS TLO / Autoloader will use for the application of vehicle loads. A search area restricts loading to a specified portion of the model. If a search area is not

specified the generated vehicle loading will be projected onto the whole model ("Default"). For models where multiple intersections of the load projection occur it is necessary to restrict the loading to the required face using a search area.

- **Increment for influence surfaces** - (for vehicle load optimisation of design codes supported by Autoloader only) specify the increment interval used when interpolating influence values to obtain the influence lines for the centrelines of the notional lanes. A generally suitable default value is provided but users can specify an alternative value based upon experience. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway, giving more accurate results. A larger increment gives quicker Autoloader runs but with potentially less accuracy. If an invalid value is specified, a warning will be given and the default value used. Length units as specified on the main dialog should be used.
- **Loaded Influence area** - specifies the area of the influence surface to be loaded. For vehicle load optimisation of design codes supported by the LUSAS Traffic Load Optimisation software option only positive or negative are valid. For vehicle load optimisation of design codes supported by the Autoloader software option, both, positive or negative are valid.

Setting-up Influence Surfaces for AASHTO / Korea

Applicable to vehicle load optimisation by Autoloader only.

Influence selection can be carried out by individual selection or a range. Use the **Add** or **Remove** button to finalise the list. The following parameters are available for selection:

For AASHTO LFD and Korea loading only

- Select the influences that are required to have either one or two knife edge loads (KEL) applied to the loadable lanes. This is applicable for **AASHTO LFD cl 3.11.3 - Lane Loads on Continuous Spans** and the **Korean Lane Loads on Continuous Spans.**

For AASHTO LRFD loading only

- Select the influences that are required to have either the positive or negative HL-93 combination applied to the loadable lanes.

General Notes

Applicable to vehicle load optimisation of design codes supported by Autoloader and by LUSAS TLO.

- If influence surfaces are to be visualised before running the Vehicle Load Optimisation analysis select the **Generate influence surfaces** check box and ensure that the **Generate optimised loading** and **Run analysis** check boxes are not selected. Click the **OK** button. LUSAS will then carry out the influence surface analysis and load the influence surfaces back into the system as result files.

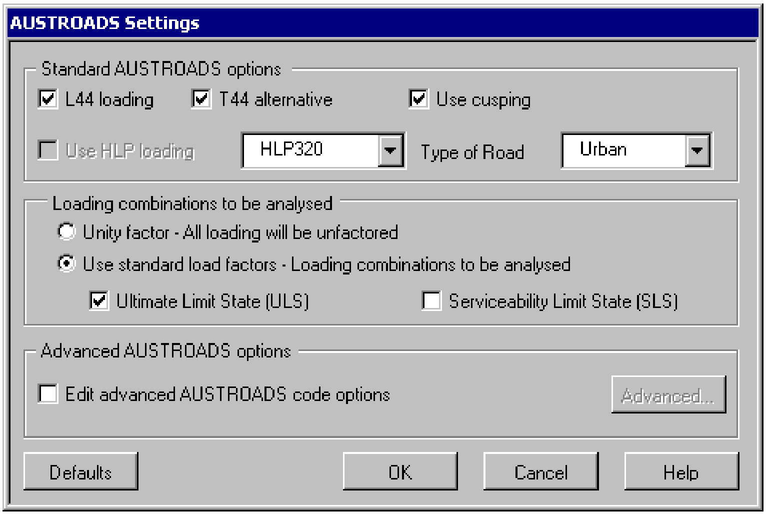
- If you require to run a Vehicle Load Optimisation analysis without solving the LUSAS model with optimised loading select the **Generate influence surfaces** and **Generate optimised loading** check boxes and ensure that **Run analysis** check box is not selected. Click the **OK** button. LUSAS will then carry out the influence surface analysis and run LUSAS TLO / Autoloader based on the influence surfaces. The results from the LUSAS TLO / Autoloader run will then be loaded back into the LUSAS model.
- If you require to run a Vehicle Load Optimisation analysis and solve the LUSAS model with optimised loading select the **Generate influence surfaces**, **Generate optimised loading** and **Run analysis** check boxes. Click the **OK** button. LUSAS will then carry out the influence surfaces analysis and run LUSAS TLO / Autoloader based on the influence surfaces. The results from the LUSAS TLO / Autoloader run will then be loaded back into the LUSAS model, the model will be solved for the optimised loading, and the results of this analysis loaded back into the system.
- The time taken to evaluate critical vehicle loading effects for a structure depends upon a number of factors. The design code; the types and numbers of vehicles to be considered; the number of lanes; whether any remaining areas exist after lane loading is positioned according to particular design codes; the number of spans; the mesh size; the values used for longitudinal and transverse load increments; whether one-way or two-way vehicle direction is specified; and the number of influence points to be evaluated, all combine to dictate the overall solution time. A good assessment of the time that will be required to evaluate a particular loading scheme for a large number of influence points can be achieved by initially timing how long it takes for just one influence point to be evaluated.

Worked examples

- The use of the LUSAS Traffic Load Optimisation facility is described in the worked example Bridge Slab Traffic Load Optimisation. See *Application Examples Manual (Bridge, Civil&Structural*
- The use of the Autoloader vehicle load optimisation facility is described in the worked example Grillage Load Optimisation.See *Application Examples Manual (Bridge, Civil&Structural*

Supported Design Codes

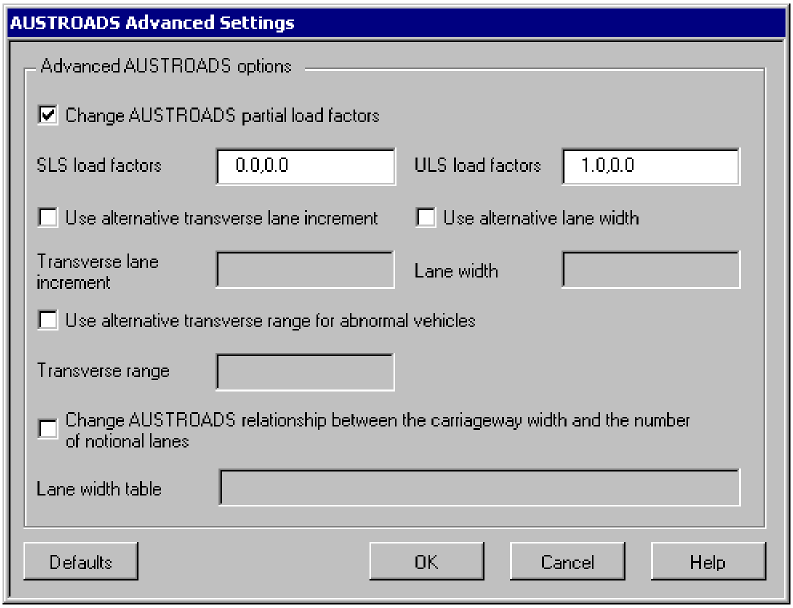
Australia AUSTROADS Settings



The following AUSTROADS options are available:

- **L44 loading** – Choose this option to load the structure with the standard L44 loading as specified in AUSTROADS clause 2.3.3. This loading consists of a uniformly distributed load of 12.5kN/m for lengths up to 150m. This load will be applied in conjunction with a 150kN concentrated load distributed over the 3m lane width. Note that the most adverse loading effect will be generated based on the influence analysis. This may produce continuous or discontinuous load patches.
- **T44 alternative** – Choose this option to load the structure with an alternative T44 truck loading as specified in AUSTROADS.
- **Use HLP loading** – Choose from the Heavy Load Platform (HLP) loading options shown on the drop-down list. For further information on these loadings, refer to AUSTROADS clause 2.3.4
- **Use Cusping** – Specifies whether or not to apply cusping when working out loadable areas. By default, this option will be selected.
- **Type of Road** - can be set to be Rural or Urban.
- **Load combinations** to be analysed can be either set to unity or the standard loadcases can be chosen from the list as defined in AUSTROADS.
- **Edit advanced AUSTROADS code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the use standard load factors is chosen and the check box next to the label is selected and click on the Advanced button. Note that it is unlikely that these advanced options will be required for the majority of work.

Australia AUSTROADS Advanced Settings



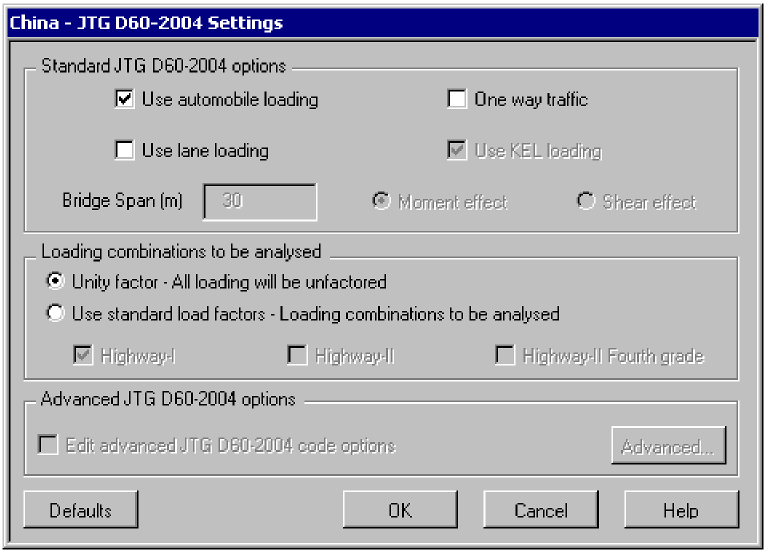
The following AUSTROADS advanced options are available for selection:

- **Change AUSTROADS partial load factors** - To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default, this option will be deselected. Only two values for each loading combination are required. The first value refers to L44/T44 loading only. The second value refers to the HLP with L44/T44 or HLP only.
- **Use alternative transverse lane increment** – Specifies the increment interval used when moving lanes across the carriageway within the AUSTROADS standard. The smaller the increment, the more accurate the vehicle loading is positioned on the carriageway. The larger increment, the more quickly the Autoloader analysis will run. The default values if not selected in 0.25m. By default, this option is deselected.
- **Use alternative lane width** – This option specifies the L44 lane width. The default value used is 2.5m.
- **Use alternative transverse range for abnormal vehicles** – This defines a range through which the centerline of the abnormal vehicle can travel for a carriageway. If no transverse ranges are defined, then the abnormal vehicle is tested in any position on any carriageway. If the transverse range is defined, then the abnormal vehicle is considered within that range on that carriageway. If the transverse range is not defined for a particular carriageway, then the abnormal vehicle will not be placed upon that carriageway. This is to account for the lateral position of the HLP vehicle on the carriageway.

The first value indicates the carriageway number and the next two values specify the range for testing the vehicle. For example, “1,2,4” indicates that the abnormal vehicle will only be tested between 2m and 4m from the edge of the first carriageway.

- **Change AUSTROADS relationship between carriageway width and the number of notional lanes**. Each 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table.

China - JTG D60-2004 settings

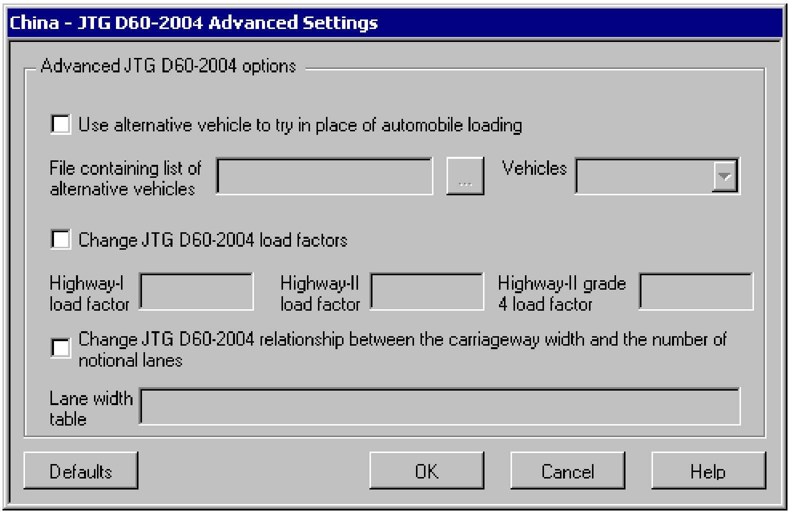


The following JTG D60-2004 options are available for the selection:

- **Use automobile loading** – Choose this option to load the structure with the standard automobile arrangement as specified in JTG D60-2004 Table 4.3.1-2
- **Use lane loading** – This option will apply lane loading as specified in JTG D60-2004 clause 4 - 1).
- **Knife edge loading (KEL)** - Choose to also apply the knife edge load. Choose the effect required by the KEL as either moment or shear. The KEL will be factored by 1.2 for the shear effect option. The bridge span is required to calculate the intensity of the KEL.
- **Loading combinations to be analysed** can be either set to unity or the standard loadcases can be chosen from the list.
- **Edit advanced JTG D60-2004 code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the use standard load factors is chosen and the check box next to the label is selected and click on the Advanced button.

However, note that it is unlikely that these advanced options will be required for the majority of work.

China JTG D60-2004 Advanced Settings



The following JTG D60-2004 advanced options are available for selection:

- **Use Alternative vehicle** - defines a list of vehicles to be tried as an alternative to automobile loading. When loading a lane, Autoloader tries to place vehicles from this list within the lane. Each vehicle must be specified in the Chinese Autoloader vehicle library. By default this option is deselected.
- **Change JTG D60-2004 Partial Load factors** - To use this option select the check box next to the label and enter the new factors to be used. By default this option is deselected.
- **Change relationship between carriageway width and the number of notional lanes.** Each 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table. By default this option is deselected.

Eurocode Traffic Loading

Traffic loading on bridges to the Eurocodes is specified in two main documents:

- **EN1991-2:2003 Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges**
- **EN1990:2002 +A1:2005 Eurocode: Basis of Structural design**

However, the Eurocodes allow a choice of safety related parameters and of certain country-specific data, known collectively as Nationally Determined Parameters (NDPs), which are published in National Annexes that accompany each Eurocode part.

National Annexes supported

Selecting one of the available National Annexes on the main Vehicle Load Optimisation dialog sets default values for NDPs (α_Q, α_q, ψ) and offers traffic load options (e.g. traffic classes, Load Model 3 special vehicles and complementary load models) appropriate to that National Annex. Values may, in any case, be modified to meet specific requirements through the options on the various dialogs.

The following National Annexes are currently supported by LUSAS Traffic Load Optimisation software by first picking the Europe country option:

- **Ireland**
- **Italy**
- **Poland**
- **Recommended Values**
- **Sweden**
- **UK**

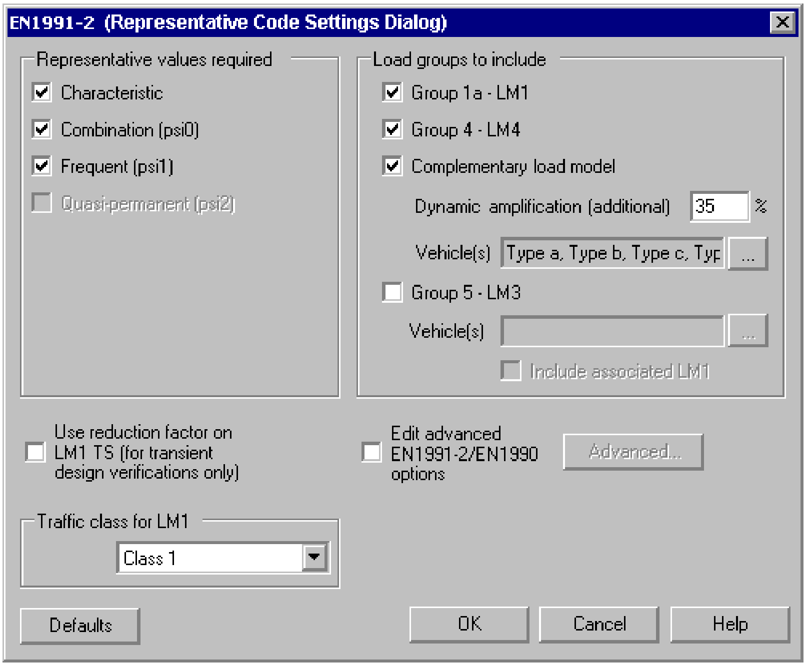
The Recommended Values option sets defaults and offers traffic options based only on recommendations in the main Eurocode documents. This option, with or without modification of values, may be of particular use for countries where a National Annex is not yet published or not yet supported.

Notes

- The scope of the vehicle load optimisation to Eurocodes is the same as for previously implemented codes of practice, that is, restricted to vertical highway traffic loading and global effects. Railway loads and fatigue loading are not currently included.

EN1991-2 Optional Code Settings

This is a representative dialog for all countries supported. Options available depend upon the design code and National Annex supported.



The Optional Code Settings dialog allows the Representative Values required to be selected and the Load Groups that are to be included defined. Factors used in the calculations may be viewed and modified by accessing the Advanced dialog.

Representative values required

The various levels of Representative Values in the Eurocodes are represented on this dialog as follows:

- **Characteristic values** See EN1990:2002 clause 1.5.3.14. Characteristic traffic actions are defined by Table 4.4a in EN1991-2:2003. This includes Group 1a (LM1 with no ψ value used) and Group 5 (generally LM3 with no ψ value together with LM1 with ψ_1 – but depends on National Annex). Characteristic values are used in for the leading variable action ($Q_{k,1}$) in ULS design checks (EN1990 equation 6.9a) and Irreversible SLS checks (equation 6.14a).
- **Combination values** Combination traffic actions are defined by use of ψ_0 from EN1990 table A2.1 (See EN1990 clause 1.5.3.16). It should be noted that ψ_0 for Group 5 is zero, therefore the Optional Code Settings dialog identifies Group 1a (LM1) loading alone as appropriate for the Combination case. Combination values are used for the accompanying variable action ($Q_{k,i}$) in ULS design checks (EN1990 equation 6.9a) and Irreversible SLS checks (equation 6.14a).
- **Frequent values** Frequent traffic actions are defined by Table 4.4b in EN1991-2 or by use of ψ_1 from EN1990 table A2.1 (See EN1990 clause 1.5.3.17) – these two sources are in harmony. It should be noted that ψ_1 for Group 5 is zero, therefore the Optional

Code Settings dialog identifies Group 1a (LM1) loading alone as appropriate for the Frequent case. Frequent values are used for the leading variable action ($Q_{k,1}$) in reversible SLS checks (equation 6.15a).

- **Quasi-permanent values** Defined by use of ψ_2 from EN1990 Table A2.1 (See EN1990 clause 1.5.3.18). In all the National Annexes currently implemented and in the Recommended Values settings ψ_2 is zero for all traffic actions, therefore Quasi-permanent cases cannot be defined in the Optional Code Settings dialog.

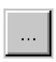
The dialog allows selection of the Representative Values for which the most onerous effect will be calculated.

Notes

- EN1991-2 does not refer to Combination values specifically; presumably the assumption is that traffic will never be an accompanying action but always a leading action. However the combination values are defined adequately using EN1990 Table A2.1 ψ_0 values and are therefore available should they be required.

Load Groups to include

According to the Representative Values selected, one or more Load groups are available to be included in the analysis. As indicated in the section above, Group 5 loads are typically only available when the Characteristic Values are being sought. The dialog includes only the Load Groups from EN1991-2 Table 4.4a and 4.4b that are relevant:

- **Group 1a** comprises Load Model 1 (LM1) tandem system and uniformly distributed loads with the appropriate α, ψ and transient factors where appropriate. Note that for global analysis the tandem system is placed on the centreline of the lane (EN1991-2 clause 4.3.2(1)(a)), however the simplified rules in 4.3.2(6) are not used. Complete tandem systems are used (EN1991-2 clause 4.3.2(1)(a)) and the most onerous length of lane for application of the uniformly distributed load is determined for each lane in turn by integration of the influence surface across the lane width. Footway, cycle track and horizontal loads are excluded from the scope of the optimisation facility.
- **Group 4** comprises Load Model 4, which represents Crowd loading - see EN1991-2 clause 4.3.5. Crowd loading is applied in the carriageway area; footway and cycle track loads are excluded from the scope of the optimisation facility.
- **Complementary load model** Options associated with complementary load models will be available where such a load model is specified in the selected National Annex, according to the Representative Values for which that load model applies.
- **Group 5** is relevant only for Characteristic Values and comprises LM3 (special vehicles) combined with LM1 reduced according to rules given in the National Annex, or – in the case of the Recommended Values option – rules given in the informative Annex A to EN1991-2.
- **Vehicle(s)** Clicking the  button allows selection of one or more special vehicles as defined in the selected National Annex.
- **Include associated LM1** This check box may be unchecked in order to obtain a result for LM3 special vehicles alone, however, the default is for LM1 to be included.

For all load groups, the lane division is according to EN1991-2 Table 4.1, with the remaining area (EN1991-2 clause 4.2.5(2)) being placed either side of the lanes or between any of the lanes in the carriageway area to produce the most onerous arrangement. Likewise, lane ranking is so as to produce the most onerous effect for the influence under consideration (as EN1991-2 clause 4.2.4(2)).

Reduction factor for transient design verifications

EN1991-2 clause 4.5.3(2) may be invoked with this check box if required.

Traffic Class for LM1

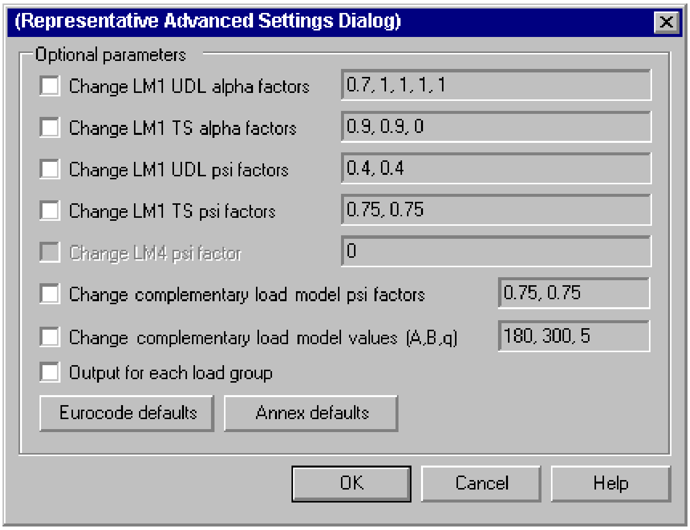
As per EN1991-2 clause 4.3.2 (3) note 2, some National Annexes require a traffic class to be specified for the selection of αQ and αq factors. Where this is the case, the “Traffic Class” box appears on this dialog: for National Annexes where no traffic classes are specific, and for the Recommended Values option, the “Traffic Class” box does not appear on the dialog. See the notes for the relevant National Annex for more information.

Load Groups excluded from appearing on this dialog

- **Group 1b** comprises only Load Model 2 which is for local verifications (“short structural members” to EN1991-2 clause 4.3.1(2)(b)) and so is excluded from the scope of the traffic load optimiser and does not appear on this dialog.
- **Group 2** is relevant only for the Characteristic Values and comprises LM1 (with smaller ψ factors compared to Group 1a) together with horizontal forces. Since horizontal forces are excluded from the scope of the traffic load optimisation software, Group 2 cannot dominate Group 1a and accordingly does not appear on this dialog. Users who wish to combine traffic load patterns with horizontal forces determined outside of the optimisation facility can obtain Characteristic Group 2 results by using Frequent Group 1a, which uses the same factors.
- **Group 3** comprises footway and cycle track loads only, which are excluded from the scope of the optimiser and so Group 3 does not appear on this dialog.

EN1991-2 Optional Code Settings Advanced

A representative dialog for all countries supported is shown. Options available depend upon the design code and National Annex supported.



The Optional Code Settings Advanced dialog is used to view and modify α_Q, α_q and ψ factors or parameters associated with national complementary load models (if applicable) and to request additional output.

- Adjustment factors (α) for Load Model 1 UDL are in the format α_{q1}, α_{q2}, α_{q3}, α_{qn}, α_{qr}.
- Adjustment factors for Load Model 1 Tandem System are in the format α_{Q1}, α_{Q2}, α_{Q3}.

The numerical subscripts in the above denote lane rank, starting with lane 1 (see EN1991-2 clause 4.2.4(4)).

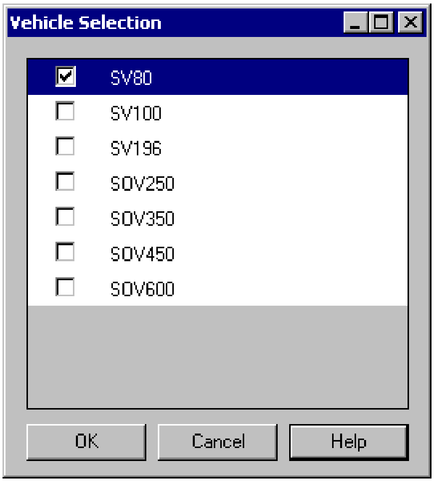
- Multi-component (ψ) factors for Load Model 1 UDL and Tandem Systems are in the format: ψ_0, ψ.

For countries where the National Annex specifies a complementary load model under EN1991-2 clause 4.2.1(1) Note 2 , additional options such as axle loads and multi-component factors may be given in this dialog. See the notes for the relevant National Annex for more information.

By default, the most onerous load patterns returned to the model after the optimisation process are based on a comparison of all selected Load Groups (including any complementary load model). If it is desirable to view the most onerous of each load group, the **Output for each load group** check box should be used.

The **Eurocode defaults** and the **Annex defaults** buttons permit the viewing of Recommended Values from EN1991-2 or the values stated in the National Annex selected on the main dialog (apart from when the “Recommended Values” option was selected from the main dialog). Using the checkboxes factors may also be entered manually to suit project requirements. In some cases values may be modified to suit national requirements until a particular National Annex is fully implemented and available for those countries not currently supported.

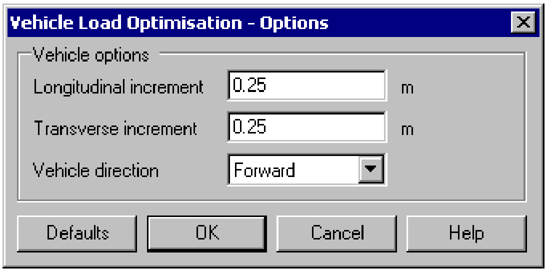
EN1991-2 Special Vehicle Selection



By clicking the ... button on the Optional Code Settings dialog a Special Vehicle Selection dialog is displayed. This allows the selection of one or more special vehicles appropriate to the previously chosen National Annex or, where relevant, the EN1991-2 informative Annex A.

See the notes for the relevant National Annex (or "Recommended Values" for more information).

EN1991-2 Optional Loading Parameters (all supported countries)



The optional loading parameters dialog allows longitudinal and transverse increments to be set which will determine the accuracy with which the most onerous load locations are calculated. A smaller increment will result in higher accuracy but with an extended processing time.

Vehicle direction (for non-symmetric special vehicles) may be given as **Forward, Reverse** or **Both**. The default is **Both**. Symmetric vehicles are not affected by this setting (and the analysis is run only once for symmetric vehicles).

Notes on implemented National Annexes

Notes relating to the implementation of the National Annexes are provided for the following European EN1991-2 design code options:

- ❑ **Ireland**
- ❑ **Italy**
- ❑ **Poland**
- ❑ **Recommended Values**
- ❑ **Sweden**
- ❑ **UK**

Italy

Selecting **EN1991-2 Italy** on the main Vehicle Load Optimisation dialog sets default values for NDPs and offers traffic load options according to Italian National Annexes published by UNI:

- **UNI-EN-1991 – 2 – Eurocodice 1 – Azioni sulle strutture – Parte 2 – Carichi da traffico sui ponti: Appendice nazionale (27 luglio 2007)**
- **UNI-EN-1990 – Criteri generali di progettazione strutturale – Appendice A2 – Applicazioni ai ponti: Appendice nazionale (27 luglio 2007)**

Load model 1

Adjustment factors for Load Model 1 (α_Q, α_q) correspond to traffic class is view of EN1991-2 clause 4.3.2 (3) note 2. Selecting traffic class 1 or class 2 on the dialog results in adjustment factors of 1.0 or 0.8 respectively in accordance with UNI-EN1991-2.

Load model 3

In relation to EN1991-2 clause 4.3.4(1), the Italian National Annex states “When significant, use the special vehicles and rules for application provided in Annex A (informative)”. Accordingly, Load Model 3 special vehicles are taken from EN1991-2 Annex A (informative) Tables A1 and A2. The notes and restrictions for this load model described under “Recommended Values” also apply to EN1991-2 Italy.

Complementary load model

According to EN1991-2 clause 4.2.1(1) Note 2, a complementary load model may be specified in the National Annex. No such complementary load model is described in the Italian National Annex.

Psi factors

Multi-component (ψ) factors are taken from EN1990 Table A2.1 since the Italian National Annex states that the recommended values should be adopted. Infrequent values are not required (A2.2.2(1) note) and quasi-static values are not calculated since $\psi 2$ is given as zero for all traffic loads (EN1990 Table A2). Group 4 loading is not included in the calculation of Frequent values for the reason described under “Recommended Values”.

Restrictions on use

The traffic load models in EN1991-2 are applicable for bridges with loaded lengths less than 200m (clause 4.1(1)). In general the use of Load Model 1 is safe-sided for loaded lengths over 200m (4.1(1) note 1). The Italian National Annex defines a load model which is less conservative than Load Model 1 for structures with loaded lengths > 300m. This alternative Load model is not implemented. Calculation of the most onerous load pattern will proceed using the selected EN1991-2 load models regardless of the loaded length and therefore patterns generated may be over-conservative for very long loaded lengths.

Ireland

Selecting **EN1991-2 Ireland** on the main Vehicle Load Optimisation dialog sets default values for NDPs and offers traffic load options according to Irish National Annexes published under the authority of the NSAI. Traffic loading on bridges to the Eurocodes is specified in two main documents:

- **NA to IS EN1991-2:2003 (effective from 9 September 2009)**
- **NA to IS EN 1990:2002+A1:2005 (effective from 29 March 2010)**

Load model 1

Adjustment factors for Load Model 1 (α_Q, α_q) are taken from NA to IS EN1991-2 Table NA.1. According to EN1991-2 clause 4.3.2 (3) note 2, adjustment factors may correspond to classes of traffic. However, the adjustment factors in Table NA.1 are not dependent upon a selected traffic class and accordingly no traffic class options are offered on the dialog.

Load model 3

- Load Model 3 special vehicles (three SV and four SOV model vehicles) are described in NA to IS EN1991-2 Fig NA.1 to NA.3 inclusive. One or more vehicles may be selected for use in the calculation of the most onerous load pattern. The selected vehicles are considered one at a time, being placed, together with associated Load Model 1 (switched on by default) according to the rules set out in clause NA.2.16.3.

- Each SV has a central axle spacing which varies (3 possible values). All such axle spacings are considered in calculation of the most onerous load effect. Each SOV has an axle spacing which varies continuously from 1.5 to 40m. By default, this axle spacing is calculated to an accuracy set in the Optional Loading Parameters dialog.
- Dynamic amplification factors (Table NA.2) are included in the calculation of the most onerous Group 5 load pattern and the wheel loads are accordingly factored within the vehicle (discrete point) loading attributes generated when the optimisation process is complete.
- When Group 5 is included, the SV80 is selected as a default. This vehicle is intended to model the effects of typical abnormal vehicles with a maximum gross weight of 80 tonnes and a maximum basic axle load of 12.5 tonnes (NA.2.16.1.1). Project requirements would dictate if this is the appropriate vehicle and the vehicle selection may need to be adjusted or expanded.

Complementary load model

According to EN1991-2 clause 4.2.1(1) Note 2, a complementary load model may be specified in the National Annex. No such complementary load model is described in the Irish National Annex.

Psi factors

Multi-component (ψ) factors are taken from NA to IS EN1990 Table NA.7. Infrequent values are not required (NA.2.3.3.1) and quasi-static values are not calculated since $\psi 2$ is given as zero for all traffic loads (Table NA.7). Group 4 loading is not included in the calculation of Frequent values (note (2) to Table NA.7).

Restrictions on use

The traffic load models in EN1991-2 are applicable for bridges with loaded lengths less than 200m (clause 4.1(1)). In general the use of Load Model 1 is safe-sided for loaded lengths over 200m (4.1(1) note 1). The Irish National Annex states that Load Model 1 may be used for loaded lengths up to 1500m (NA to IS EN1991-2 clause NA2.6) and no information on load models appropriate beyond that length is given. Calculation of the most onerous load pattern will proceed regardless of the loaded length and therefore patterns generated may be inappropriate for very long loaded lengths.

Poland

Selecting **EN1991-2 Poland** on the main Vehicle Load Optimisation dialog sets default values for NDPs and offers traffic load options according to recommendations in EN1991-2 and EN1990, and offers traffic load options from the informative Annex A to EN1990. This is because PN-EN 1991-2:2007 and PN-EN 1990:2004/A1:2008 published by PKN state that

European Norms have the status of Polish Norms, with no modification from the English version of the European Norms.

All notes on “Recommended Values” are therefore also applicable to “EN1991-2 Poland”.

Recommended Values

Selecting **EN1991-2 Recommended Values** on the main Vehicle Load Optimisation dialog sets default values for NDPs according to recommendations in EN1991-2 and EN1990, and offers traffic load options from the informative Annex A to EN1990. The default values may be modified as necessary making the “Recommended Values” option useful for countries where a National Annex is not yet published or is not yet supported.

Load model 1

Adjustment factors for Load Model 1 (α_Q, α_q) are taken as 1.0, based on EN1991-2 clause 4.3.2 (3) note 1. With respect to note 2, no traffic class options are offered on the dialog but the adjustment factors may be modified in the optional code settings “advanced” dialog.

Load model 3

- Load Model 3 special vehicles are taken from EN1991-2 Annex A (informative) Tables A1 and A2. Each table lists 17 vehicles, however a conflict in the last lines of the two tables means that effectively 18 vehicles are described and accordingly there are 18 vehicles of fixed axle spacing listed in the dialog. One or more vehicles may be selected for use in the calculation of the most onerous load pattern. The selected vehicles are considered one at a time, being placed, together with associated Load Model 1 (switched on by default) according to the rules set out in clause A.3 considering low speed transit only (clauses A.3(5) and A.3(7) are not applied).
- When Group 5 is included, the SV1800200 is selected as a default. This vehicle has a gross weight of 180 tonnes and an axle load of 20 tonnes, and is selected only as an example – on the basis that the heaviest vehicles in the Annex are exceptional and the least heavy are covered by the effects of Load model 1 (clause A.2 (2), note 2). Project requirements would dictate the appropriate vehicle and so the vehicle selection may need to be modified.
- Dynamic amplification (clause A.3(5)) is not used for low speed transit and so is not included in the calculation of the most onerous Group 5 load pattern.

Psi factors

Multi-component (ψ) factors are taken from EN1990 Table A2.1. Infrequent values are not currently implemented (note 2 under table A2.1 is not applied) and quasi-static values are not calculated since $\psi 2$ is given as zero for all traffic loads (Table A2.1). In EN1990 Table A2.1, the frequent value of Group 4 loading is indicated with $\psi 1$ factor. However in EN1991-2 Table 4.4a and 4.4b, Group 4 loading is not required in the calculation of Frequent values. This conflict is resolved by excluding Group 4 from the calculation of frequent values.

Restrictions on use

The traffic load models in EN1991-2 are applicable for bridges with loaded lengths less than 200m (clause 4.1(1)). In general the use of Load Model 1 is safe-sided for loaded lengths over 200m (4.1(1) note 1). Calculation of the most onerous load pattern will proceed regardless of the loaded length and therefore patterns generated may be inappropriate for very long loaded lengths.

Sweden

Selecting **EN1991-2 Sweden** on the main Vehicle Load Optimisation dialog sets default values for NDPs and offers traffic load options according to Swedish standards:

- **Specifikation SIS/PAS NA, EN 1991-2:2003 Swedish National Annex NA to Eurocode EN 1991-2:2003 – Traffic loads on bridges, Utgåva 1 (First Edition), Publicerad: maj 2007**
- **VV2009:19 Updated rules for use of Eurocodes on highway projects; Utkom från trycket den 26 juni 2009**
- **VV2009:27 TK Bro; Datum 2009-07-01**

Load model 1

Adjustment factors for Load Model 1 (αQ, αq) are taken from SIS/PAS NA to EN 1991-2:2003 clause 4.3.2(3); the same values are given in VVFS 2009:19 Chapter 6, clause 4, Tabell 7.1. According to EN1991-2 clause 4.3.2 (3) note 2, adjustment factors may correspond to classes of traffic. However, the adjustment factors in the Swedish documents are not dependent upon a selected traffic class and accordingly no traffic class options are offered on the dialog.

Load model 3

Load Model 3 special vehicles. TK Bro VV2009:27 clause B.3.4.1.3(e) states that other load models do not apply. However SIS/PAS NA to EN 1991-2 clause 4.3.4(1) allows for the client to specify values for the individual project; VV2009:19 Chapter 6 clause 2 says the same. For flexibility to Load Model 3 special vehicles from EN1991-2 Annex A (informative) Tables A1 and A2 are available (although Group 5 is switched off by default). The notes and restrictions for this load model described under “Recommended Values” also apply to EN1991-2 Sweden.

Complementary load model

According to EN1991-2 clause 4.2.1(1) Note 2, a complementary load model may be specified in the National Annex. SIS/PAS NA to EN1991-2 describes a Swedish complementary load model; TK Bro VV2009:27 clause B.3.4.1.3(d) refers us to VV2004:43

(superseded by VV2009:19) and VV2009:19 Chapter 6, clause 3 (page 13) repeats the information from the SIS/PAS National Annex.

- The Swedish complementary load model consists of 12 vehicles (type a to type l inclusive). One or more vehicles may be selected for use in the calculation of the most onerous load pattern. The selected vehicle types are considered one type at a time. A single vehicle is placed in the most onerous lane (with lane factor 1.0) with another vehicle of the same type placed in the second most onerous lane (with lane factor 0.8). Uniformly distributed load (q) is placed in adverse areas of lanes 1 and 2 if appropriate and also in adverse areas of other lanes.
- A number of the complementary load model vehicles have an axle spacing which varies continuously from a stated minimum value, with no set maximum value. By default, this axle spacing is calculated to an accuracy set in the Optional Loading Parameters dialog.
- All complementary load vehicles have axle width which may vary between 1.7 and 2.3m (measured to the centre of action of each wheel load). By default the widths 1.7m, 2.0m and 2.3m are tested and the most onerous used.
- A dynamic amplification factor is applied to the vehicles (not the uniformly distributed load, q) in the calculation of the most onerous Swedish complementary load model load pattern and the wheel loads are accordingly factored within the vehicle (discrete point) loading attributes generated when the optimisation process is complete. The dynamic factor entered on the dialog should be calculated from the equation in SIS/PAS NA or VV2009:19 Chapter 6, clause 3. The default value of 35% reflects the maximum allowable value.
- Using the Optional Code Settings Advanced dialog, it is possible to view and modify the values used for A, B and q in the complementary load model.
- When the Swedish Complementary Load model is included, all 12 vehicles are selected by default. This means that the most onerous of the 12 will be identified so that the structural element under consideration can be “designed for the type vehicle that causes the most unfavourable influence” (EN1991-2 clause 4.2.1(1) Note 2). The number of vehicles selected for the optimisation may be reduced using the dialog provided, as appropriate to project requirements.
- It is noted that the Swedish complementary load model vehicles are identical to the “classification loads” of VV2009:61 Clause 2.3.2.2.1 (and Annex 2). However, for classification, VV2009:61 Clause 1.1.5.3 requires the engineer to calculate the maximum values of load magnitudes “A” and “B” which can be carried (also referring to VV2009:62 (MB803) for exceptional loads). Such a calculation is not automated although values of A and B can be modified as described above.

Psi factors

Multi-component (ψ) factors are generally taken from EN1990 Table A2.1 since the note under VVFS 2009:19 Chapter 7, clause 5, Tabell A2.(S) states that “at least the recommended levels apply”. Infrequent values are not required (SIS/PAS NA, EN 1991-2:2003 clause 2.2(2)) and quasi-static values are not calculated since ψ2 is given as zero for all traffic loads

(EN1990 Table A2). Group 4 loading is not included in the calculation of Frequent values for the reason described under “Recommended Values”.

Multi-component (ψ) factors for the Swedish Complementary load model are taken from TK Bro VV2009:27 Clause B.2.1.2.2. Based on the values given (ψ0 and ψ1 but ψ2 =0), the complementary load model is included in the calculation of characteristic, combination and frequent values, but quasi-static values are not required.

Obtaining most onerous load patterns

The most onerous load patterns returned to the model after the optimisation process are based on a comparison of the Swedish complementary load model (using the selected type vehicles) and any other selected Eurocode load models (Group 1a, Group 4, Group 5). If it is desirable to view the most onerous of each load group, the check box on the Optional Code Settings Advanced dialog should be used.

Restrictions on use

The traffic load models in EN1991-2 are applicable for bridges with loaded lengths less than 200m (clause 4.1(1)). In general the use of Load Model 1 is safe-sided for loaded lengths over 200m (4.1(1) note 1). In TK Bro VV2009:27 clause B.3.4.1.3(b), a load model for bridges of span >200m [sic] is given. This alternative Load model is not implemented. Calculation of the most onerous load pattern will proceed using the EN1991-2 load models and the Swedish Complementary load model, as selected, regardless of the loaded length and therefore patterns generated may be inappropriate for very long loaded lengths.

United Kingdom

Selecting **EN1991-2 UK** on the main Vehicle Load Optimisation dialog sets default values for NDPs and offers traffic load options according to UK National Annexes published by BSI:

- **UK NA to BS EN1991-2:2003 incorporating corrigendum No 1 (May 2008)**
- **UK NA to BS EN 1990:2002+A1:2005 incorporating National Amendment No. 1 (June 2009)**

Load model 1

Adjustment factors for Load Model 1 (αQ, αq) are taken from NA to BS EN1991-2 Table NA.1. According to EN1991-2 clause 4.3.2 (3) note 2, adjustment factors may correspond to classes of traffic. However, the adjustment factors in Table NA.1 are not dependent upon a selected traffic class and accordingly no traffic class options are offered on the dialog.

Load model 3

Load Model 3 special vehicles (three SV and four SOV model vehicles) are described in NA to BS EN1991-2 Fig NA.1 to NA.3 inclusive. One or more vehicles may be selected for use in the calculation of the most onerous load pattern. The selected vehicles are considered one at a time, being placed, together with associated Load Model 1 (switched on by default) according to the rules set out in clause NA.2.16.4.

Each SV has a central axle spacing which varies (3 possible values). All such axle spacings are considered in calculation of the most onerous load effect. Each SOV has an axle spacing which varies continuously from 1.5 to 40m. By default, this axle spacing is calculated to an accuracy set in the Optional Loading Parameters dialog.

Dynamic amplification factors (Table NA.2) are included in the calculation of the most onerous Group 5 load pattern and the wheel loads are accordingly factored within the vehicle (discrete point) loading attributes generated when the optimisation process is complete.

When Group 5 is included, the SV80 is selected as a default. This vehicle is intended to model the effects of STGO Category 2 vehicles with a maximum gross weight of 80 tonnes and a maximum basic axle load of 12.5 tonnes (NA.2.16.1.1). Project requirements would dictate if this is the appropriate vehicle and the vehicle selection may need to be adjusted or expanded.

According to EN1991-2 clause 4.2.1(1) Note 2, a complementary load model may be specified in the National Annex. No such complementary load model is described in the UK National Annex.

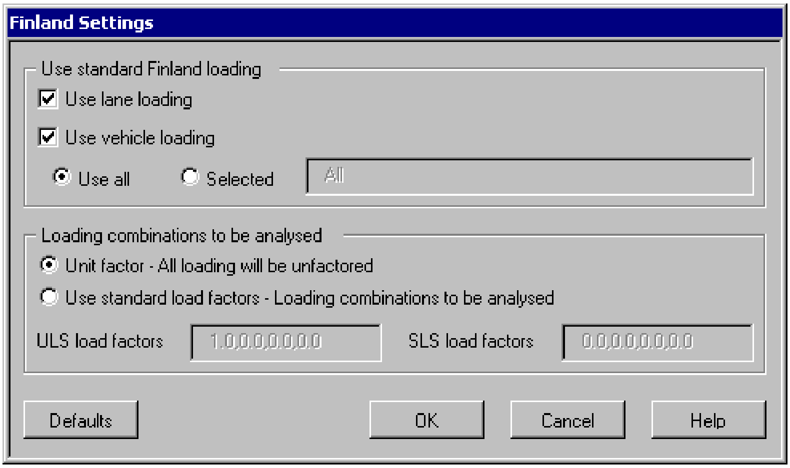
Psi factors

Multi-component (ψ) factors are taken from NA to BS EN1990 Table NA.A2.1. Infrequent values are not required (NA.2.3.6.2) and quasi-static values are not calculated since $\psi 2$ is given as zero for all traffic loads (Table NA.A2.1). Group 4 loading is not included in the calculation of Frequent values (note b to Table NA.A2.1).

Restrictions on use

The traffic load models in EN1991-2 are applicable for bridges with loaded lengths less than 200m (clause 4.1(1)). In general the use of Load Model 1 is safe-sided for loaded lengths over 200m (4.1(1) note 1). The UK National Annex states that Load Model 1 may be used for loaded lengths up to 1500m (NA to BS EN1991-2 clause NA2.6) and no information on load models appropriate beyond that length is given. Calculation of the most onerous load pattern will proceed regardless of the loaded length and therefore patterns generated may be inappropriate for very long loaded lengths.

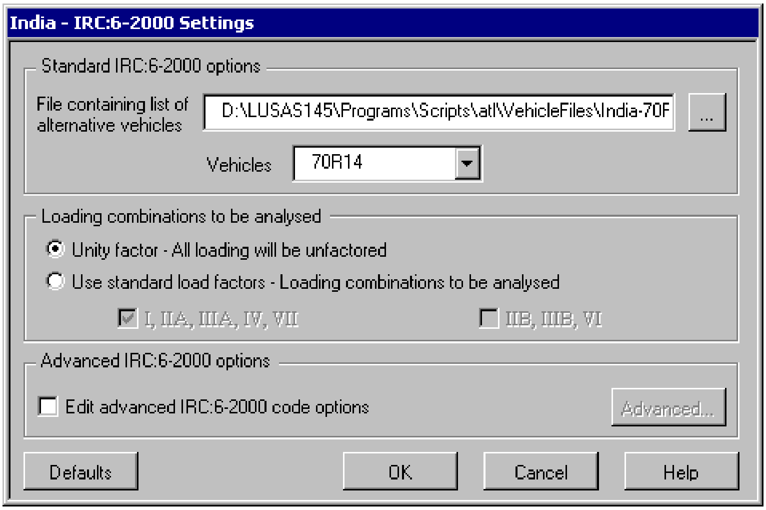
Finland Settings



The following Finland options are available for selection:

- **Use lane loading** - Specifies whether to apply the uniformly distributed load (UDL) to the lanes of the bridge. To use this option select the checkbox. To deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Use vehicle loading** – This gives the option to define a list of vehicles as defined in the Autoloader vehicle library file (*.vec), normally found in the “<LUSAS Installed location>\Programs\Scripts\atl\VehicleFiles” directory. These vehicles will be tried as an alternative to UDL loading. When loading a lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than the UDL loading, the vehicle will be placed in the lane instead. To use this option select the checkbox and select the “Selected” option and enter the vehicle name(s), separated by a comma, that you require as an alternative to UDL loading. Selecting “Use all” will attempt to use all the vehicles defined in the Autoloader vehicle library file. To deselect this option ensure that the checkbox is not selected. By default this option will be selected with all vehicles chosen for the Autoloader analysis.
- **Loading combinations to be analysed** – “SLS Load factors” and the “ULS Load factors” textbox allows the default partial load factors to be overridden for the Serviceability Limit State (SLS) and Ultimate Limit State (ULS) load factors. To use this option select “Use standard load factors” and enter the new factors. The default values will be displayed in the textbox for overriding. The use of “Unity factor” will apply a factor of 1.0 to all loading produced from Autoloader so that this can be factored later. By default this option will be selected.

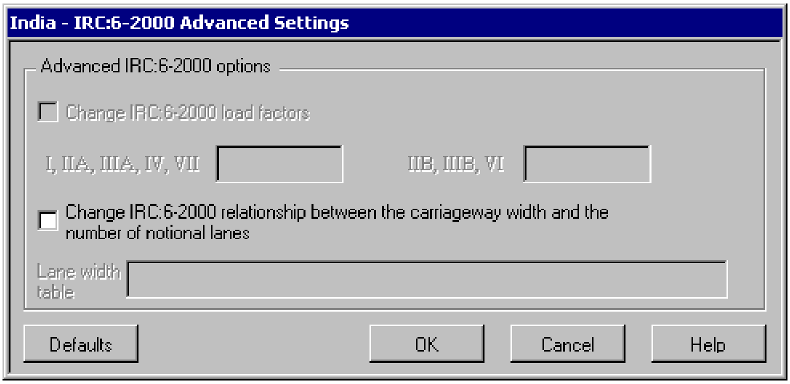
India IRC:6-2000 Settings



The following IRC:6-2000 options are available:

- **File containing list of alternative vehicles** – Choose a vehicle definition file (*.vec) that will populate the "Vehicle" list allowing a vehicle to be chosen for analysis with Autoloader.
- **Vehicles** – Select from the list the vehicle to be applied to the bridge deck.
- **Load combinations** to be analysed can be either set to unity or the standard loadcases can be chosen from the list as defined in IRC:6-2000.
- **Edit advanced IRC:6-2000 code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the use standard load factors is chosen and the check box next to the label is selected and click on the Advanced button. Note that it is unlikely that these advanced options will be required for the majority of work.

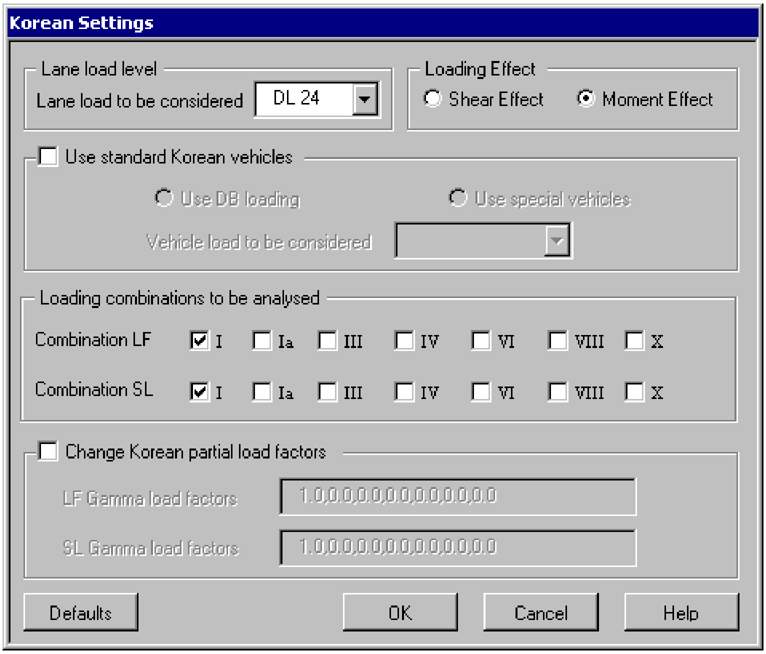
India IRC:6-2000 Advanced Settings



The following IRC:6-2000 advanced options are available for selection:

- **Change IRC:6-2000 load factors** - To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default, this option will be deselected. Only one value for each loading combination is required. For further information on these load combinations refer to Table 1 of IRC:6-2000.
- **Change IRC:6-2000 relationship between carriageway width and the number of notional lanes** – Allows the relationship between the carriageway width and the number of notional lanes to be changed. Each three values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table. To use this option select the check box next to the label and enter the values into the text box. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

Korean Settings



The following Korean options are available for selection:

- **Lane Load Level** - specifies the level of Korean patch loading to be applied. If "None" is chosen no patch loading will be applied and no "Loading Effect" is required. By default this option will be selected.
- **Loading Effect** - allows the specification of the effect to be investigated. By default the "Moment" effect will be selected. If "None" is selected from the "Lane Load Level" this option will be disabled.
- **Use Standard Korean Vehicles** - defines a list of vehicles that can be chosen to calculate the greatest effect. Autoloader tests the vehicle chosen in this list. By default this option will be disabled.
- **Change Korean Partial Load factors** - SL Gamma Load Factors and LF Gamma Load Factors allow the user to specify the partial load factors for the Service Load State and LF Load Factor Design respectively. The list is ordered as follows:

  SL / LF I
  SL / LF IA
  SL / LF III
  SL / LF IV
  SL / LF VI
  SL / LF VIII
  SL / LF X

Note that only loading combinations LF and SL I will only be loaded. To utilise other load combinations that have been generated by Autoloader use the File > Open… menu commands and locate the <filename>_x_lfx / slx.vbs files where x is replaced by the combination number e.g. 1a.

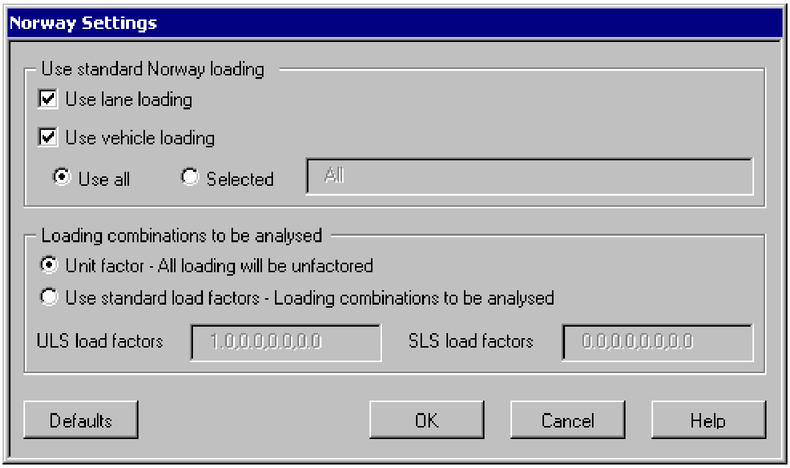
To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

Lane Loads on Continuous Spans :

"For the determination of maximum negative moment in the design of continuous spans, the lane load shall be modified by the addition of a second, equal weight concentrated load placed in one other span in the series in such position to produce the maximum effect. For maximum positive moment, only one concentrated load shall be used per lane, combined with as many spans loaded uniformly as required to produce maximum moment."

In the current Vehicle Load Optimisation only one concentrated load KEL (Knife Edge Load) is applied. Please contact LUSAS Technical Support for details on how to overcome this limitation.

Norway Settings



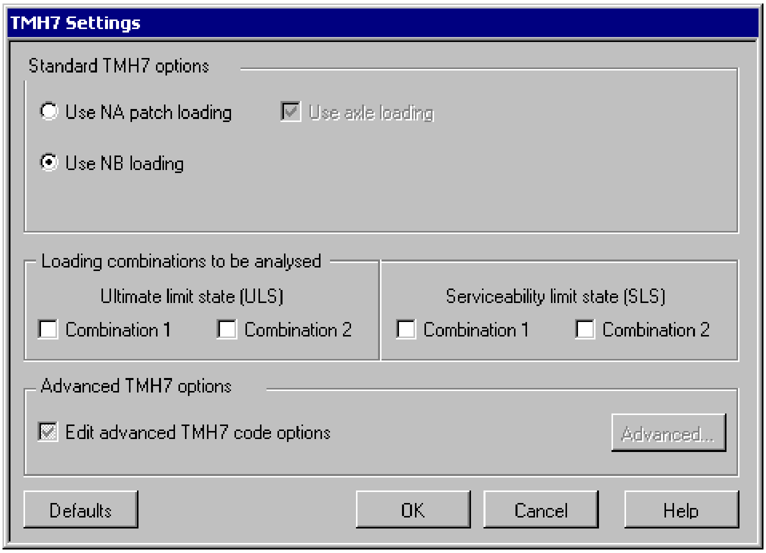
The following Norway options are available for selection:

- **Use lane loading** - Specifies whether to apply the uniformly distributed load (UDL) to the lanes of the bridge. To use this option select the checkbox. To deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Use vehicle loading** – This gives the option to define a list of vehicles as defined in the Autoloader vehicle library file (*.vec), normally found in the “<LUSAS Installed location>\Programs\Scripts\atl\VehicleFiles” directory. These vehicles will be tried as an alternative to UDL loading. When loading a lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than the UDL loading, the

vehicle will be placed in the lane instead. To use this option select the checkbox and select the "Selected" option and enter the vehicle name(s), separated by a comma, that you require as an alternative to UDL loading. Selecting "Use all" will attempt to use all the vehicles defined in the Autoloader vehicle library file. To deselect this option ensure that the checkbox is not selected. By default this option will be selected with all vehicles chosen for the Autoloader analysis.

- **Loading combinations to be analysed** – "SLS Load factors" and the "ULS Load factors" textbox allows the default partial load factors to be overridden for the Serviceability Limit State (SLS) and Ultimate Limit State (ULS) load factors. To use this option select "Use standard load factors" and enter the new factors. The default values will be displayed in the textbox for overriding. The use of "Unity factor" will apply a factor of 1.0 to all loading produced from Autoloader so that this can be factored later. By default this option will be selected.

TMH7 Settings



The following South African TMH7 options are available for selection:

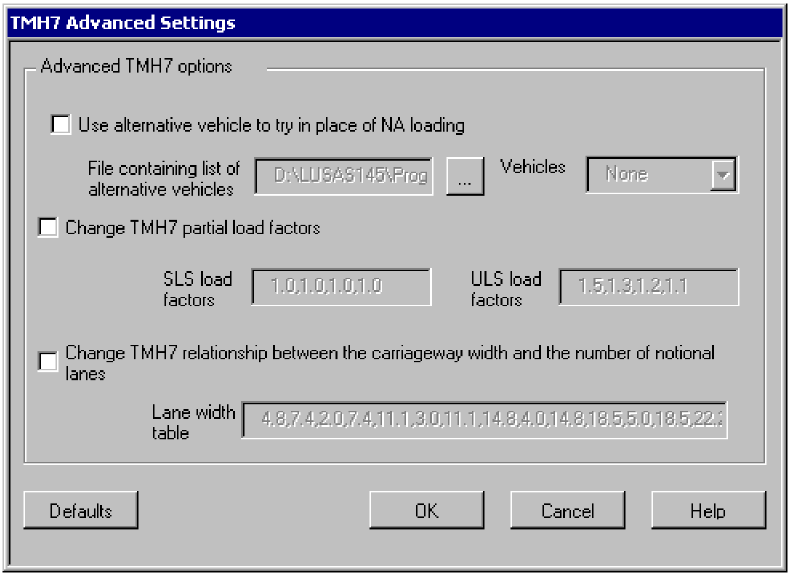
- **Use NA loading** - specifies whether to apply the NA loading (which includes axle loading).
- **Use NB loading** - specifies whether to apply a single abnormal vehicle. If selected, the abnormal vehicles are applied to the carriageway. If not selected, then NA loading only is applied.
- **Use axle loading** - specifies whether to apply axle loads. If selected, axle loads are applied to areas with NA loading, according to the standard in use. If not selected, no axle loads are applied. If **Use NA loading** is not selected then **Use axle loading** will not be enabled.

- **Edit advanced TMH7 code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. Note, however, that it is unlikely that these advanced options will be required for the majority of work.

Notes

- Autoloader should be used for global bridge design. Local effects due to accidental wheel loads are not considered and so these effects should be assessed separately.
- The load sequence number is always assumed to be unity.
- The implementation of the South African loading code assumes that the transverse distribution has no significant effect and therefore the NA loading will be distributed over the full width of the notional lane.

TMH7 Advanced Settings



The following South African TMH7 advanced options are available for selection:

- **Use alternative vehicle to try in place of NA loading** - defines a list of vehicles to be tried as an alternative to NA loading. When loading an NA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than NA loading, uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library.
- **Change TMH7 partial load factors** - SLS Load factors allows specification of the partial load factors for the Serviceability Limit State and ULS Load factors allow

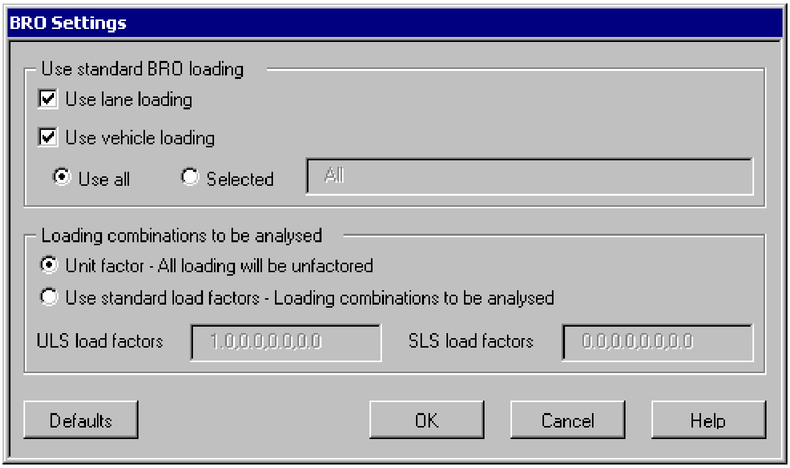
specification of the partial load factors for the Ultimate Limit State. The list is ordered as follows:

- NA alone (combination 1)
- NA alone (combination 2)
- NB with NA or NB alone (combination 1)
- NB with NA or NB alone (combination 2)

❑ **Use TMH7 partial load factors** - SLS Load factors allows specification of the partial load factors for the Serviceability Limit State and ULS Load factors allow specification of the partial load factors for the Ultimate Limit State.

❑ **Change TMH7 relationship between carriageway width and the number of notional lanes**. Each set of 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width Autoloader works its way down the table, checking the calculated width against the values in the table.

BRO94 Settings



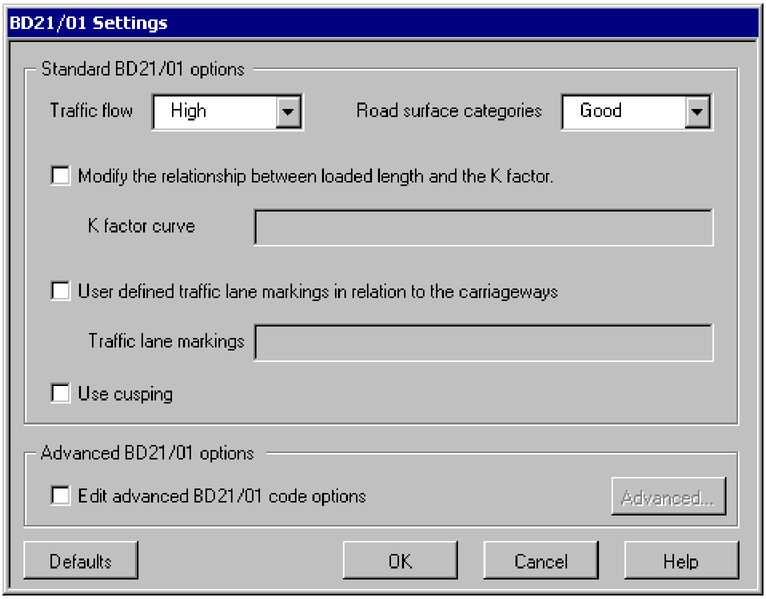
The following BRO 94 options are available for selection:

❑ **Use lane loading** - Specifies whether to apply the uniformly distributed load (UDL) to the lanes of the bridge. To use this option select the checkbox. To deselect this option ensure that the check box is not selected. By default this option will be selected.

❑ **Use vehicle loading** – This gives the option to define a list of vehicles as defined in the Autoloader vehicle library file (*.vec), normally found in the “<LUSAS Installed location>\Programs\Scripts\atl\VehicleFiles” directory. These vehicles will be tried as an alternative to UDL loading. When loading a lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than the UDL loading, the vehicle will be placed in the lane instead. To use this option select the checkbox and select the “Selected” option and enter the vehicle name(s), separated by a comma, that you require as an alternative to UDL loading. Selecting “Use all” will attempt to use all the vehicles defined in the Autoloader vehicle library file. To deselect this option ensure that the checkbox is not selected. By default this option will be selected with all vehicles chosen for the Autoloader analysis.

- **Loading combinations to be analysed** – "SLS Load factors" and the "ULS Load factors" textbox allows the default partial load factors to be overridden for the Serviceability Limit State (SLS) and Ultimate Limit State (ULS) load factors. To use this option select "Use standard load factors" and enter the new factors. The default values will be displayed in the textbox for overriding. The use of "Unity factor" will apply a factor of 1.0 to all loading produced from Autoloader so that this can be factored later. By default this option will be selected.

BD21/01 Settings



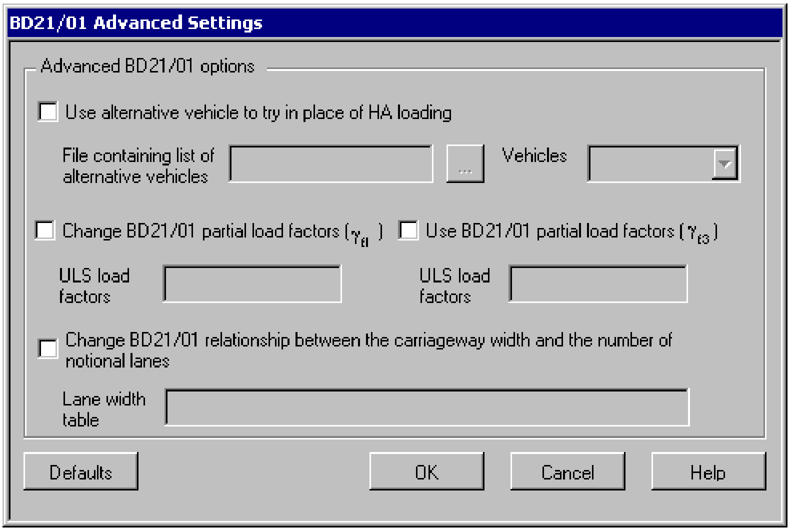
The following BD21/01 options are available for selection:

- **Traffic flow**- specify the traffic level, as defined in the BD21/01 standard, as **High**, **Medium** or **Low**. This option has no effect in any of the other standards. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Road surface category**- specify the quality of road surface, as defined in the BD21/01 standard, as **Good** or **Poor.**This option has no effect in any of the other standards. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Modify the relationship between loaded length and the K factor**- change the relationship between loaded length and the K factor. Each pair of values consists of a length and a factor for that length. Autoloader performs a linear interpolation between these values. If a more accurate value is required you should specify as many points as

possible. To use this option select the check box next to the label and enter the new relationship between loaded length and the K factor, to deselect this option ensure that the check box is not selected. By default this option will be selected.

- **User to define marked traffic lanes in relation to the carriageways**- define marked traffic lanes in relation to the carriageway(s). Each set of values consists of a carriageway number, and two sets of x and y values, through which points the lane edges pass. The traffic lane is assumed to be parallel to the carriageway kerbs. To use this option select the check box next to the label and enter the new relationship between marked traffic lanes in relation to the carriageway. To deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Edit advanced BD21/01 code options**-further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

BD21/01 Advanced Settings

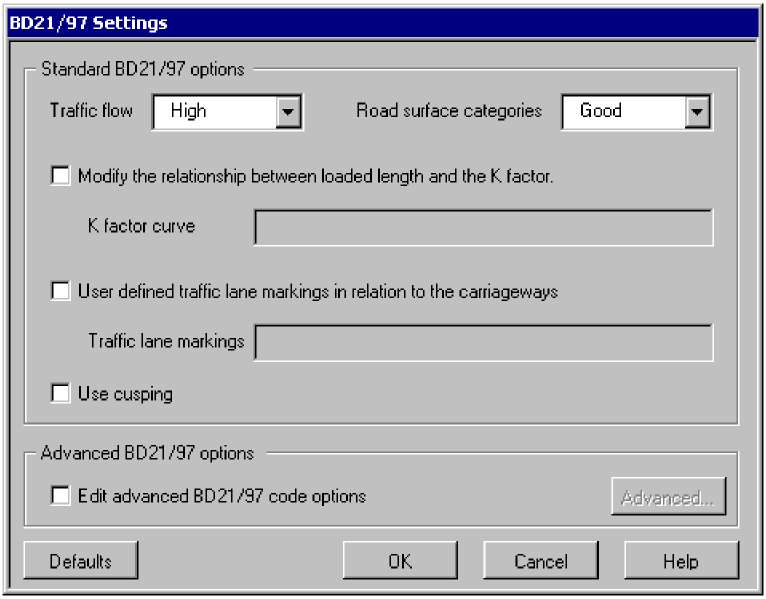


The following BD 21/01 advanced options are available for selection:

- **Use Alternative vehicle**- defines a list of vehicles to be tried as an alternative to HA loading. When loading an HA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than HA loading, it uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library. To use this option select the check box next to the label and enter the vehicle name that you require as an alternative to HA loading, to deselect this option ensure that the check box is not selected. By default this option will be deselected.

- **Change BD21/01 Partial Loadfactors** -ULS Load factors allow you to specify the partial load factors for the Ultimate Limit State. To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.
- **Change relationship between carriageway width and the number of notional lanes**. Each 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table. To use this option select the check box next to the label and enter the values into the text box. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

BD21/97 Settings



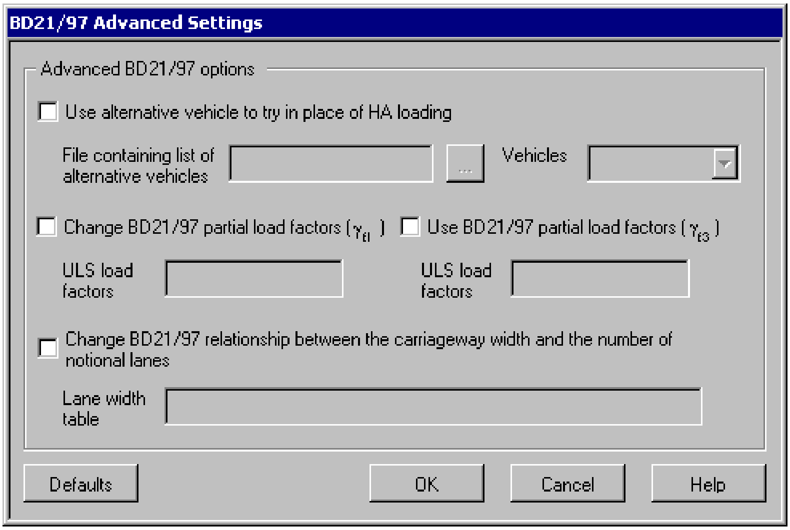
The following BD 21/97 options are available for selection:

- **Traffic flow**- specify the traffic level, as defined in the BD 21/97 standard, as **High**, **Medium** or **Low**. This option has no effect in any of the other standards. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Road surface category**- specify the quality of road surface, as defined in the BD 21/97 standard, as **Good** or **Poor.** This option has no effect in any of the other standards. If an invalid value is specified, Autoloader gives a warning and uses the default value.
- **Modify the relationship between loaded length and the K factor**- Each pair of values consists of a length and a factor for that length. Autoloader performs a linear interpolation between these values. If a more accurate value is required you should

specify as many points as possible. To use this option select the check box next to the label and enter the new relationship between loaded length and the K factor, to deselect this option ensure that the check box is not selected. By default this option will be selected.

- **User to define marked traffic lanes in relation to the carriageways**- Each set of values consists of a carriageway number, and two sets of x and y values, through which points the lane edges pass. The traffic lane is assumed to be parallel to the carriageway kerbs. To use this option select the check box next to the label and enter the new relationship between marked traffic lanes in relation to the carriageway. To deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Edit advanced BD 21/97 code options**-further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

BD21/97 Advanced Settings



The following BD 21/97 advanced options are available for selection:

- **Use Alternative vehicle**- defines a list of vehicles to be tried as an alternative to HA loading. When loading an HA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than HA loading, it uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library. To use this option select the check box next to the label and enter the vehicle name that you require as an alternative to HA loading, to deselect this option ensure that the check box is not selected. By default this option will be deselected.

- **Change BD21/97 Partial Loadfactors** -ULS Load factors allow you to specify the partial load factors for the Ultimate Limit State. To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.
- **Change relationship between carriageway width and the number of notional lanes**. Each 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table. To use this option select the check box next to the label and enter the values into the text box. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

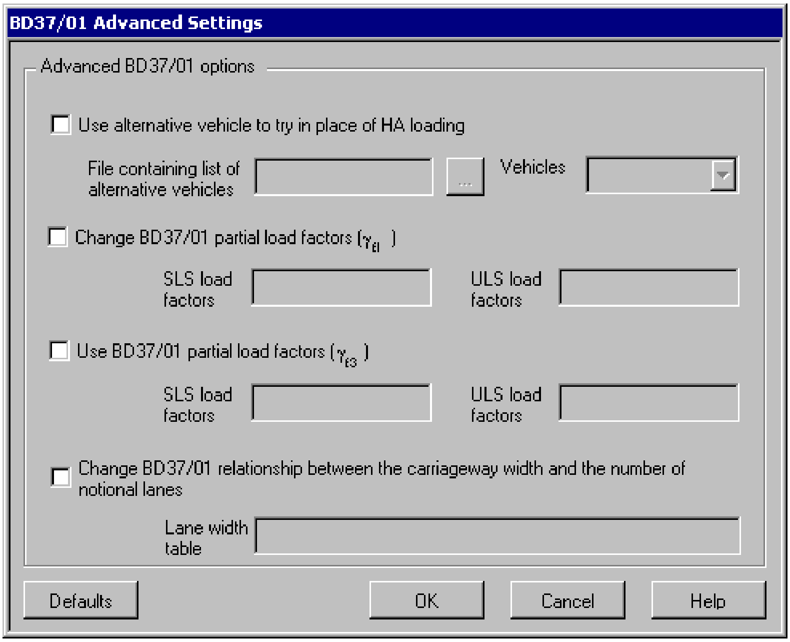
BD37/01 Settings

The following BD37/01 options are available for selection:

- **Use HA Loading** - specifies whether to apply the HA loading (which includes KEL loading). To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Use HB Loading** - specifies whether to apply an abnormal vehicle. If selected, the abnormal vehicles are applied to the carriageway. If not selected, then HA loading only is applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Use KEL Loading** - specifies whether to apply Knife Edge Loads. If selected, Knife Edge Loads are applied to areas with UDL loading, according to the standard in use. If not selected, no KEL'S are applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected, however if Use HA loading is not selected then Use KEL Loading will not be enabled.
- **Use Cusping** - specifies whether to apply cusping when working out loadable areas. If selected, cusping is applied. If not selected, cusping is not applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.
- **One Way Traffic** - BD37/01 specifies that a bridge carrying traffic in one direction only would result in the doubling of the N value in the calculation of the HA lane factors (ref. BD37/01, Table 14, Note 2). If ONEWAY is selected, then the value of N used in the table is doubled. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will not be selected
- **Number of HB Units** - specifies the number of HB Units to use. In cases where an abnormal vehicle uses HB Units, the values of the weights of the axles are multiplied by the number of HB Units. By default the number of HB units is set as 45, to change this value enter the new value in the text box.

- **Edit advanced BD37/01 code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

BD37/01 Advanced Settings



The following BD37/01 advanced options are available for selection:

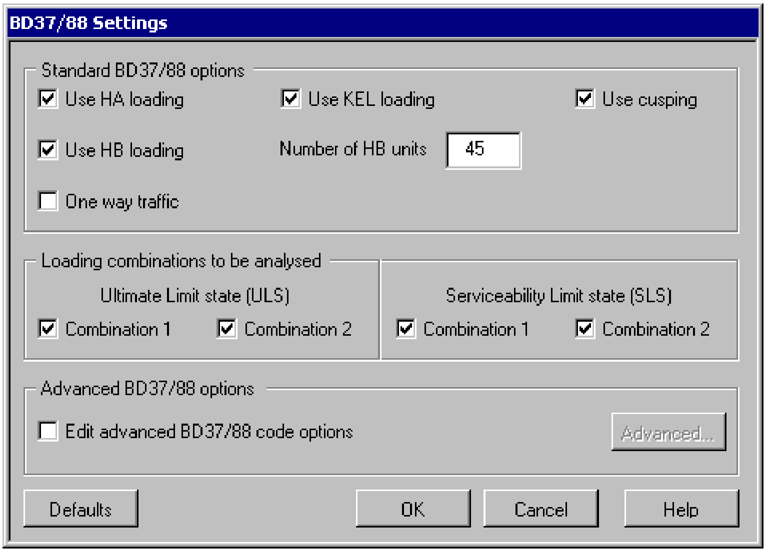
- **Use Alternative vehicle**- defines a list of vehicles to be tried as an alternative to HA loading. When loading an HA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than HA loading, uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library. To use this option select the check box next to the label and enter the vehicle name that you require as an alternative to HA loading. To deselect this option ensure that the check box is not selected. By default this option will be deselected.
- **Change BD37/01 Partial Loadfactors** -SLS Load factors allow specification of the partial load factors for the Serviceability Limit State and ULS Load factors specification of the partial load factors for the Ultimate Limit State. The list is ordered as follows:
  - HA alone (combination 1)
  - HA alone (combination 2)

- HB with HA or HB alone (combination 1)
- HB with HA or HB alone (combination 2)

To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

- **Change relationship between carriageway width and the number of notional lanes**. Each 3 values are taken as a lower limit, an upper limit and a number of notional lanes. After calculating the carriageway width Autoloader works its way down the table, checking the calculated width against the values in the table. To use this option select the check box next to the label and enter the values into the text box. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

BD37/88 Settings

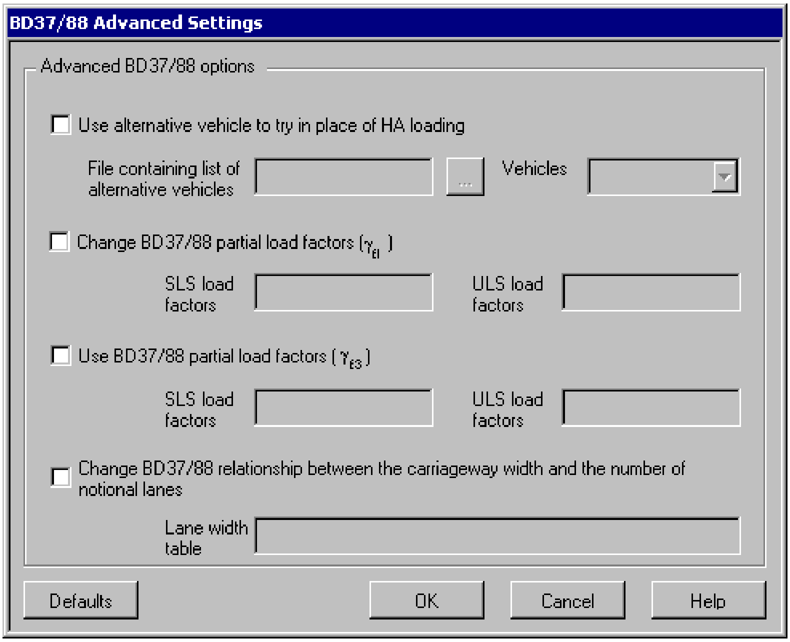


The following BD37/88 options are available for selection:

- **Use HA Loading -** specifies whether to apply the HA loading (which includes KEL loading). To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.
- **Use HB Loading** - specifies whether to apply an abnormal vehicle. If selected, the abnormal vehicles are applied to the carriageway. If not selected, then HA loading only is applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.

- **Use KEL Loading** - specifies whether to apply Knife Edge Loads. If selected, Knife Edge Loads are applied to areas with UDL loading, according to the standard in use. If not selected, no KEL'S are applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected, however if Use HA loading is not selected then Use KEL Loading will not be enabled.
- **Use Cusping** - specifies whether to apply cusping when working out loadable areas. If selected, cusping is applied. If not selected, cusping is not applied. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will be selected.
- **One Way Traffic** - BD37/88 specifies that a bridge carrying traffic in one direction only would result in the doubling of the N value in the calculation of the HA lane factors (ref. BD37/88, Table 14, Note 2). If ONEWAY is selected, then the value of N used in the table is doubled. To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected. By default this option will not be selected
- **Number of HB Units** - specifies the number of HB Units to use. In cases where an abnormal vehicle uses HB Units, the values of the weights of the axles are multiplied by the number of HB Units. By default the number of HB units is set as 45, to change this value enter the new value in the text box.
- **Edit advanced BD37/88 code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

BD37/88 Advanced Settings



The following BD37/88 advanced options are available for selection:

- **Use Alternative vehicle** defines a list of vehicles to be tried as an alternative to HA loading. When loading an HA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than HA loading, uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library. To use this option select the check box next to the label and enter the vehicle name that you require as an alternative to HA loading. To deselect this option ensure that the check box is not selected. By default this option will be deselected.
- **Change BD37/88 Partial Loadfactors** SLS Load factors allows specification of the partial load factors for the Serviceability Limit State and ULS Load factors allow specification of the partial load factors for the Ultimate Limit State. The list is ordered as follows:

  HA alone (combination 1)

  HA alone (combination 2)

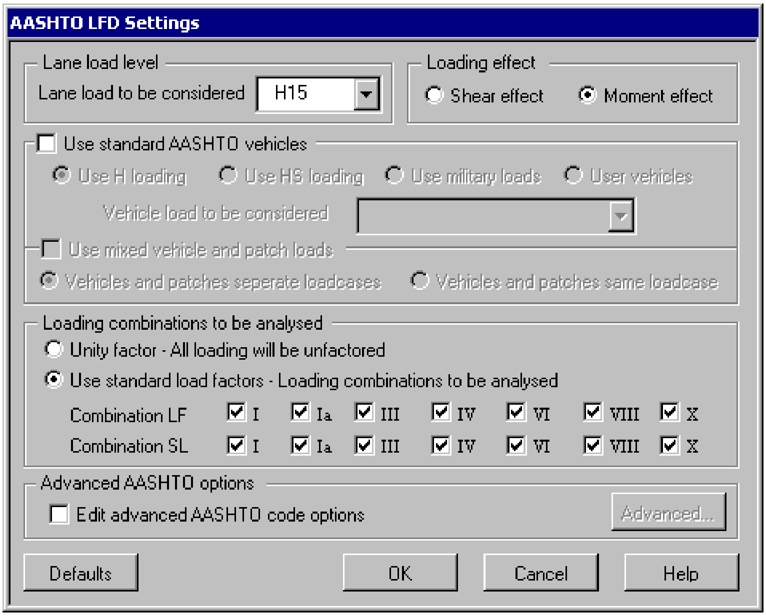
  HB with HA or HB alone (combination 1)

  HB with HA or HB alone (combination 2)

  To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.
- **Change relationship between carriageway width and the number of notional lanes**. Each 3 values are taken as a lower limit, an upper limit and a number of

notional lanes. After calculating the carriageway width Autoloader works its way down the table, checking the calculated width against the values in the table. To use this option select the check box next to the label and enter the values into the text box. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

AASHTO LFD Settings



The following AASHTO LFD options are available for selection:

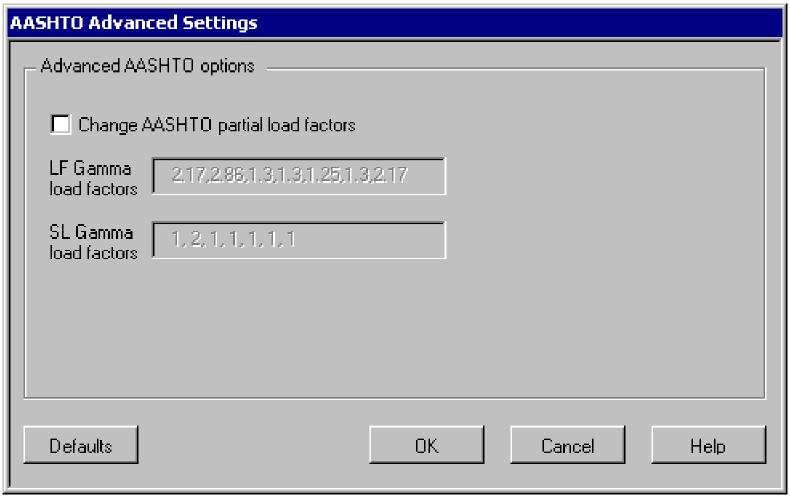
- **Lane Load Level** - specifies the level of AASHTO LFD patch loading to be applied (ref AASHTO LFD cl. 3.7.2 et al). By default this option will be selected.
- **Loading Effect** - allows the specification of the effect to be investigated. This will apply the relevant KEL in accordance with AASHTO LFD fig 3.7.6B. By default the "Moment" effect will be selected.
- **Use Standard AASHTO Vehicles** - defines a list of vehicles that can be chosen to calculate the greatest effect. Autoloader tests the vehicle chosen in this list. These vehicles are as that defined in AASHTO LFD cl. 3.7.2. By default this option will be disabled.
- **Use mixed vehicle and patch loads** - defines if the analysis should consider vehicles and patch loads together on the same carriageway when defining the loading patterns. If this option is not selected and the use standard AASHTO vehicles option is selected, the analysis will load the carriageway with vehicles loads only. With this option selected the choice of defining vehicles and patches in separate loadcases or mixed in the same loadcases can be chosen.

- **Load combinations to be analysed** can be either set to unity or the standard loadcases can be chosen from the list.
- **Edit advanced AASHTO code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the use standard load factors is chosen and the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

AASHTO LFD cl 3.11.3 - Lane Loads on Continuous Spans :-

"For the determination of maximum negative moment in the design of continuous spans, the lane load shall be modified by the addition of a second, equal weight concentrated load placed in one other span in the series in such position to produce the maximum effect. For maximum positive moment, only one concentrated load shall be used per lane, combined with as many spans loaded uniformly as required to produce maximum moment."

AASHTO Advanced Settings



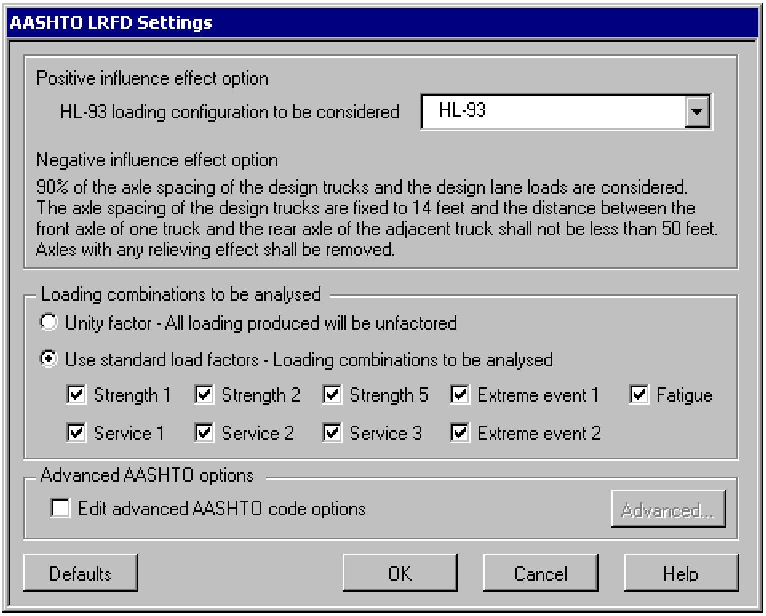
The following AASHTO options are available for selection:

- **Change AASHTO Partial Load factors** - SL Gamma Load Factors and LF Gamma Load Factors allow specification of the partial load factors for the Service Load State and LF Load Factor Design respectively. The list is ordered as follows:

  SL / LF I
  SL / LF IA
  SL / LF III
  SL / LF IV
  SL / LF VI
  SL / LF VIII
  SL / LF X

To use this option select the check box next to the label and enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

AASHTO LRFD Settings



The following AASHTO LRFD options are available to select:

For the positive influence effect the following HL-93 loading configurations can be considered.

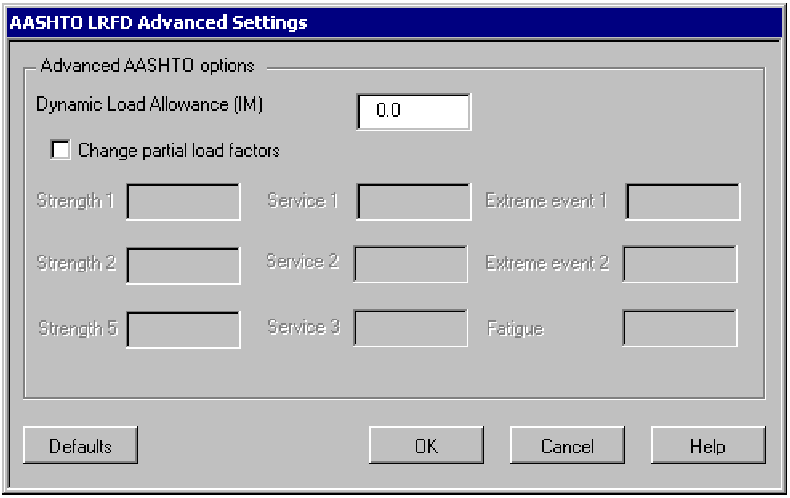
- **HL-93**
- **Design Truck + Design Lane**
- **Design Tandem + Design Lane**

Selecting **HL-93** will run the both combination of the design lane and design truck or design tandem and will give the loading arrangement that will give the most adverse effect for the chosen influences. The other two options allow the specific HL-93 combination to be run individually.

Load combinations to be analysed can be either set to unity or the standard loadcases can be chosen from the list.

- **Edit advanced AASHTO code options** - further to the basic code options provided on this dialog, Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the use standard load factors is chosen and the check box next to the label is selected and click on the Advanced button. However, note that it is unlikely that these advanced options will be required for the majority of work.

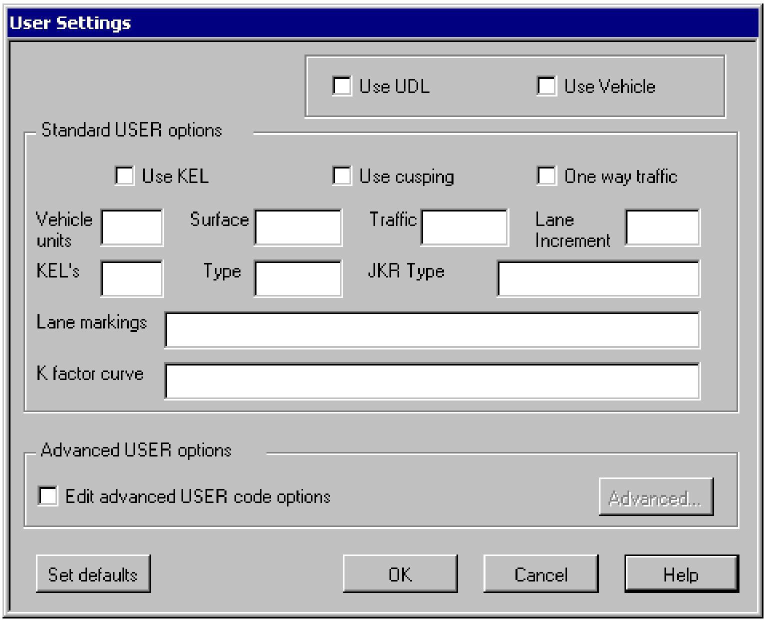
AASHTO LRFD Advanced Settings



The following AASHTO LRFD options are available for selection:

- **Change AASHTO LRFD Partial Load factors** - allow the specification of the partial load factors for the nine load combinations. The default values are shown in the dialog by default.
- Enter the new factors to be used. To deselect this option ensure that the check box is not selected. By default this option will be deselected.

User Settings

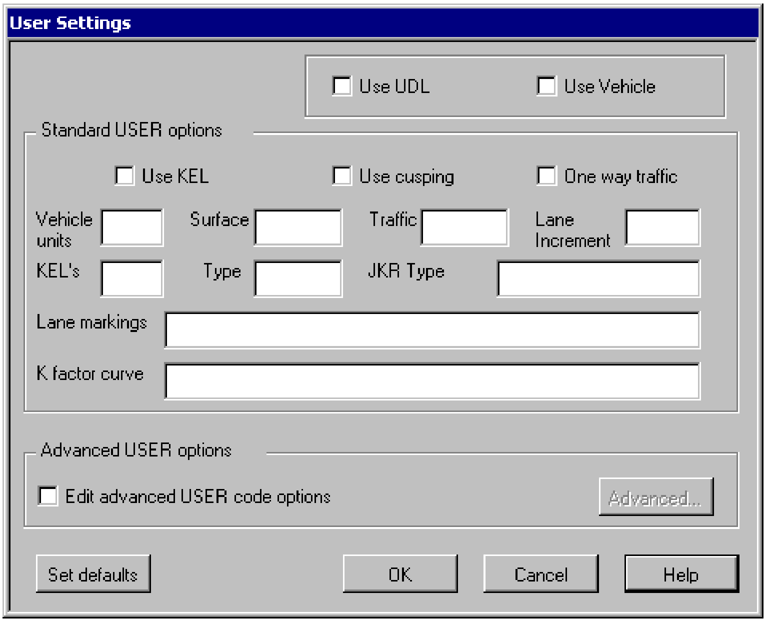


The following options are available for selection:

- **Use UDL -** specifies whether to apply the HA loading (which includes KEL loading). To use this option select the check box next to the label, to deselect this option ensure that the check box is not selected.
- **Use vehicle** - specifies whether to apply an abnormal vehicle. If selected, the abnormal vehicles are applied to the carriageway. If not selected, then HA loading only is applied.
- **Use KEL** - specifies whether to apply Knife Edge Loads. If selected, Knife Edge Loads are applied to areas with UDL loading, according to the standard in use. If not selected, no KEL'S are applied.
- **Use cusping** - specifies whether to apply cusping when working out loadable areas. If selected, cusping is applied. If not selected, cusping is not applied.
- **One way traffic** - specifies that a bridge carrying traffic in one direction only would result in the doubling of the N value in the calculation of the HA lane. If ONEWAY is selected, then the value of N used in the table is doubled.
- **Vehicle units** - specifies the number of HB Units to use. In cases where an abnormal vehicle uses HB Units, the values of the weights of the axles are multiplied by the number of HB Units.
- **Surface** - allows the user to specify the quality of road surface, as defined in the BD 21/97 standard, as **Good** or **Poor.** This option has no effect in any of the other standards. If an invalid value is specified Autoloader gives a warning and uses the default value.

- **Traffic flow** - specify the traffic level as defined in the BD 21/97 standard as **High**, **Medium** or **Low**. This option has no effect in any of the other standards. If an invalid value is specified Autoloader gives a warning and uses the default value.
- **Lane increment** - specifies the increment interval used when moving lanes across the carriageway within the JKR standard. The smaller the increment, the more accurately the position of the vehicle will be calculated on the carriageway, this gives more accurate results. A larger increment gives quicker Autoloader runs. The user must choose through experience an appropriate value. If an invalid value is specified Autoloader gives a warning and uses the default value.
- **KEL's** - specifies the number of KEL's to apply within a specified design lane. This will generally be used when AUSTROADS is applied, but can also be used within the other standards. If an invalid value is specified Autoloader gives a warning and uses the default value.
- **Type** - allows the user to specify either an urban road or a rural road, as defined in the AUSTROADS standard. This option has no effect in any of the other standards. If an invalid value is specified Autoloader gives a warning and the default value is used.
- **JKR Type** - specify either controlled or uncontrolled vehicle movement, as defined in the JKR standard. This option has no effect in any of the other standards. If an invalid value is specified Autoloader gives a warning and uses the default value.
- **Lane markings** - define marked traffic lanes in relation to the carriageway(s). Each set of values consists of a carriageway number and two sets of x and y values, through which the lane edges pass. The traffic lane is assumed to be parallel to the carriageway kerbs.
- **K factor curve** - change the relationship between loaded length and the K factor. Each pair of values consists of a length and a factor for that length. Autoloader performs linear interpolation between these values. If a more accurate value is required as many points as possible should be defined.
- **Edit advanced User code options** - further to the basic code options provide on this dialog Autoloader allows more advanced changes to the code to be made. To access this functionality ensure that the check box next to the label is selected and click on the Advanced button.

User Advanced Settings



The following User advanced options are available for selection:

- **File containing Alternative vehicle** - defines a list of vehicles to be tried as an alternative to HA loading. When loading an HA lane, Autoloader tries to place vehicles from this list within the lane, and if the effect is greater than HA loading, uses that vehicle instead. Each vehicle must be specified in the Autoloader vehicle library.
- **SLS Load factors** - specify the partial load factors for the Serviceability Limit State
- **ULS Load factors** - specify the partial load factors for the Ultimate Limit State.
- **SL** - specify the partial load factors for the Service Load State.
- **LF** - specify the partial load factors for the Load Factor Design.
- **Lane width** - specifies the L44 lane width. If an invalid value is specified Autoloader gives a warning and uses the default value.
- **Pedestrian load** - specify an alternate value for the Pedestrian Load.
- **Lane width table** - Each 3 values are taken as a lower limit, an upper limit, and a number of notional lanes. After calculating the carriageway width, Autoloader works its way down the table, checking the calculated width against the values in the table.

Prestress Loading

Overview

The single and multiple tendon prestress wizards calculate equivalent nodal loading due to tendon prestressing or post tensioning and assign these forces automatically (and using **search areas)** to selected lines (and hence nodes and elements) of the model for the current active loadcase.

- The single tendon prestress wizard supports beam, tendon, plane stress and solid element modelling of concrete.
- The multiple tendon wizard only supports beam element modelling of concrete.

For both the single and multiple tendon prestress wizards the computation of tendon forces can be carried out in accordance with AASHTO-LRFD, BS5400, Eurocode EN1992 and JTG D62-2004 codes.

Prestress loading options are accessed from the **Bridge > Prestress Wizard** menu item.

Which to use?

- **Single tendon prestress wizard** does not take into account any stressing or unstressing of any other tendons. It is for use with beam, tendon, plane stress and solid element modelling of concrete.
- **Multiple tendon prestress wizard** takes into account elastic shortening due to stressing of other tendons according to the design code or user-defined percentage losses. As such it is more suited to staged construction analysis. It is for use with beam element modelling of concrete. If the option to ignore effects due to elastic shortening is chosen the loading computed will be the same as that calculated by the single tendon wizard.

Single Tendon Prestress Wizard

The single tendon prestress wizard generates tendon loads as either beam element loads or as discrete loads, depending upon the analysis type chosen. Direct import of tendon forces may also be defined via an Excel spreadsheet. The single tendon wizard does not take into account any individual stressing or unstressing of any other tendons. For sets of tendons it may be used if all tendons are stressed at the same time.

A model may contain many tendons and the single tendon prestress wizard can be used separately on each to derive equivalent nodal loading on the mesh for all the tendons used. Structural concrete surrounding a tendon may either be modelled as a series of beam elements, or by a set of plane stress or solid elements. For examples see the analysis types supported below.

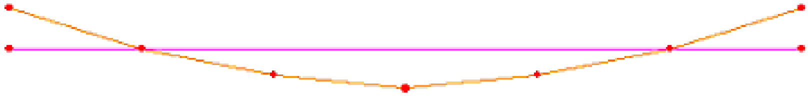
Usage

To use the single tendon prestress wizard first select the spline or combined line defining the tendon and then, but only if carrying out a beam analysis, additionally use the **Shift** key to select the beam(s) prior to selecting the Prestress menu option. The prestress wizard computes the equivalent forces due to the prestress tendon in accordance with a chosen code and assigns them to the current active loadcase of the beam, plane stress or solid elements automatically. After load assignment the forces resulting from the tendon will be shown. Using this simplified force approach, the effects of prestress can be defined in a separate linear loadcase that can be combined with the other loadcases to compute the overall structural behaviour.

Analysis Type

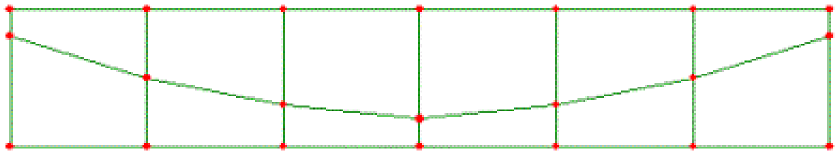
Four analysis types are supported; Beam, Tendon, Plane Stress and Solid.

- **Beam** For beam analysis loading calculations the tendon profile must be defined as a spline. No elements need to be assigned to this spline but thick beam elements should be assigned to the line representing the concrete beam. Beams may be straight or curved and may consist of multiple lines defining each span. Tendon alignment / realignment is independent of the underlying mesh arrangement. With this analysis type the tendon is not included in the analysis model. Lines defining tendon profiles are essentially used solely to derive the forces on surrounding elements defining the structural concrete and, as such, these tendons are not included in an analysis model. Once used in this way, tendons may be grouped together and made invisible to simplify subsequent model displays.



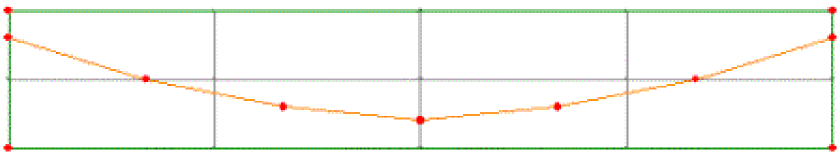
Analysis type: Beam

- **Tendon** For tendon analysis loading calculation the tendon is included in the analysis model. Thick beam elements should be assigned to the lines defining the tendon profile (which must for this analysis type only be defined as a combined line) and the concrete beam surrounding the tendon should be modelled with Plane Stress or 3D Solid elements. Note that when using a combined line sufficient points must be used to accurately represent the tendon profile as a series of straight lines. Tendon alignment / realignment is dependent on the underlying mesh arrangement. This analysis method does not allow for tendon realignment as easily as the Plane Stress / Solid analysis option.

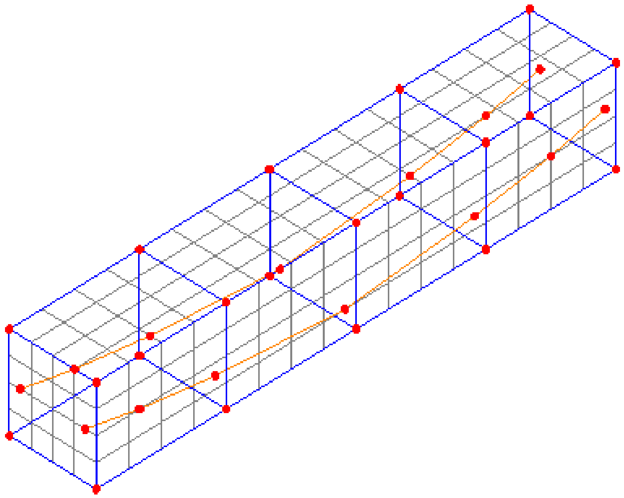


Analysis type: Tendon

- **Plane Stress / Solid** For this analysis type the tendon profile must be defined as either a single line, single arc or a spline. No elements need to be assigned to the spline but plane stress / solid elements must be assigned to the surrounding concrete. The lines representing the tendon are not included in the analysis model. Tendon alignment / realignment is, therefore, independent of the underlying mesh arrangement. Lines defining tendon profiles are essentially used solely to derive the forces on surrounding elements defining the structural concrete and, as such, these tendons are not included in an analysis model. Once used in this way, tendons may be grouped together and made invisible to simplify subsequent model displays. Examples of the use of the plane stress and solid methods are shown below.



Analysis type: Plane Stress



Analysis type: Solid

Notes

- An optional report can be generated in HTML file format in your project directory that contains a summary of the tendon properties, tendon geometry and prestress losses for a selected tendon.
- Graph datasets can be optionally created to allow subsequent graphing to be carried out using the Graph Wizard.
- When the prestress definition is computed two graph datasets are created to enable the tendon losses to be visualised against the tendon length. These can be seen in the Utilities Treeview.
- Tendon forces can also be computed directly by the user and imported from a spreadsheet. If this option is selected a filename for the spreadsheet is entered and when the OK button is clicked the tendon geometry is written to the spreadsheet. When this has been done the spreadsheet is displayed and the tendon forces can be added by manually editing the spreadsheet. The forces are then read into Modeller and the procedure follows that described above for the codes.
- If tendon realignment is required the previously assigned discrete loading properties should be removed from the model and the Prestress loading wizard re-run to calculate the new discrete loading properties for the new tendon alignment.
- Use of the single tendon prestress facility is described in the example ‘Linear Analysis of a Post Tensioned Bridge’. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.

Codes supported

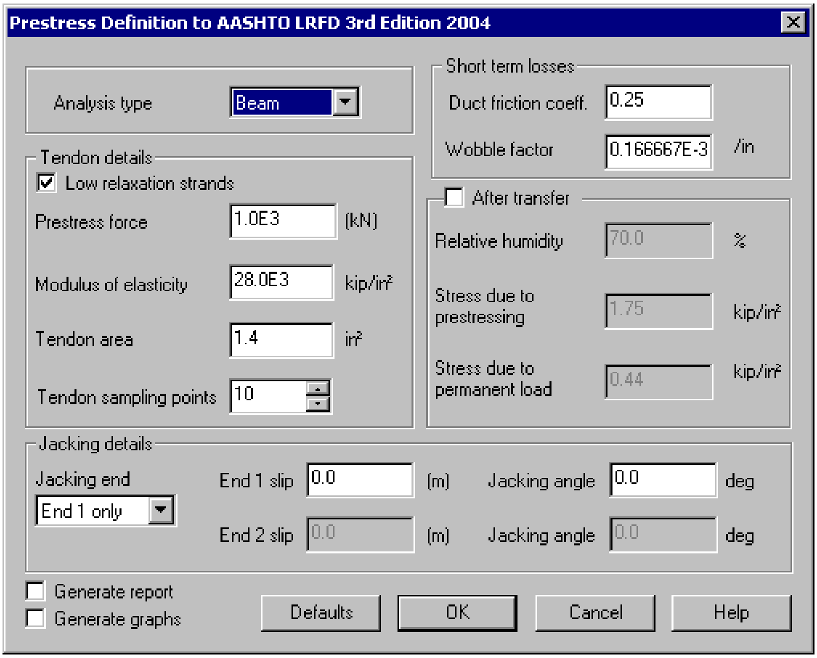
Prestress definition varies slightly according to the design code selected and is explained in separate headings. The following design codes are supported:

- **AASHTO LRFD**
- **BS5400**
- **EN1992 Eurocode 2**
- **JTG D62-2004**

Prestress definition can also be imported from a spreadsheet.

Single Tendon Prestress to AASHTO

Prior to using the **single tendon prestress wizard** first select the spline or combined line defining the tendon and then, but only if carrying out a beam analysis, additionally use the **Shift** key to select the beam(s) prior to selecting the Prestress menu option.



Analysis type

General **single tendon prestress wizard** information provides details on the analysis types supported.

Tendon details

- Low relaxation strands **This option is used in the calculation of the steel relaxation losses. When selected, 30% of the steel relaxation loss is applied - as specified in clause 5.9.5.4.1**
- Prestress force **units are displayed on the dialog according to the model units in use.**
- Modulus of Elasticity **should be specified.**
- Tendon area **for the single tendon being defined.**
- Tendon sampling points **are the locations along a spline at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the spline have no bearing on any calculations that are carried out, they are simply used to ensure a good tendon profile is obtained.**

Short term losses

- Duct Friction coefficient **should be obtained from design code**
- Wobble factor **is defined per metre length and should be obtained from design code.**

After transfer

- Relative humidity
- Stress due to prestressing
- Stress due to permanent load

Jacking details

Jacking end slip and jacking angle can be defined for end 1 only, end 2 only, or for both ends of the tendon. End 1 is the start of the spline used to define the tendon.

The jacking angle is the angle between the direction of the tendon at the anchorage and the direction that the jack is set to pull in. If the jack pulls the cable axially the jacking angle would be zero.

Generate report

Generating a report creates an HTML file in your project directory containing a summary of the tendon properties, tendon geometry and prestress losses for the selected tendon.

Generate graphs

Generates graph datasets in the Utilities Treeview to allow subsequent graphing to be carried out using the Graph Wizard.

Defaults

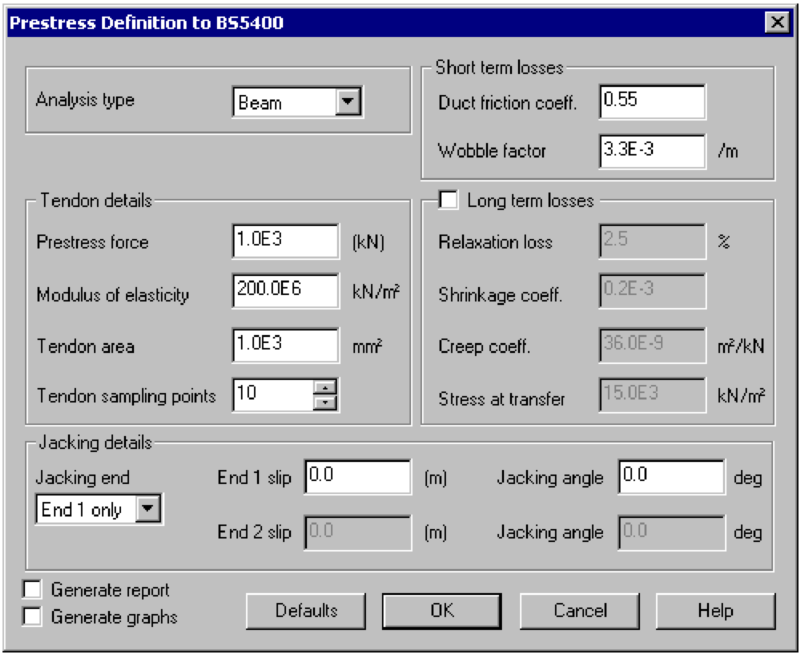
The defaults button sets all previously entered values to those specified when the dialog is first displayed.

Notes

- If tendon realignment is required the previously assigned discrete loading properties should be removed from the model and the Prestress loading wizard re-run to calculate the new discrete loading properties for the new tendon alignment.
- Use of the single tendon prestress facility is described in the example 'Linear Analysis of a Post Tensioned Bridge'. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.

Single Tendon Prestress to BS5400

Prior to using the **single tendon prestress wizard** first select the spline or combined line defining the tendon and then, but only if carrying out a beam analysis, additionally use the **Shift** key to select the beam(s) prior to selecting the Prestress menu option.



Analysis type

General **single tendon prestress wizard** information provides details on the analysis types supported.

Tendon details

- **Prestress force** units are displayed on the dialog according to the model units in use.
- **Modulus of Elasticity** should be specified.
- **Tendon area** for the single tendon being defined.
- **Tendon sampling points** are the locations along a spline at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the spline have no bearing on any calculations that are carried out. They are simply used to ensure a good tendon profile is obtained.

Short term losses

- **Duct Friction coefficient** should be obtained from design code
- **Wobble factor** is defined per metre length and should be obtained from design code.

Long term losses

- **Relaxation loss**
- **Shrinkage Coefficient**
- **Creep coefficient**
- **Stress at transfer**

Jacking details

Jacking end slip and jacking angle can be defined for end 1 only, end 2 only, or for both ends of the tendon. End 1 is the start of the spline used to define the tendon.

The jacking angle is the angle between the direction of the tendon at the anchorage and the direction that the jack is set to pull in. If the jack pulls the cable axially the jacking angle would be zero.

Generate report

Generating a report creates an HTML file in your project directory containing a summary of the tendon properties, tendon geometry and prestress losses for the selected tendon.

Generate graphs

Generates graph datasets in the Utilities Treeview to allow subsequent graphing to be carried out using the Graph Wizard.

Defaults

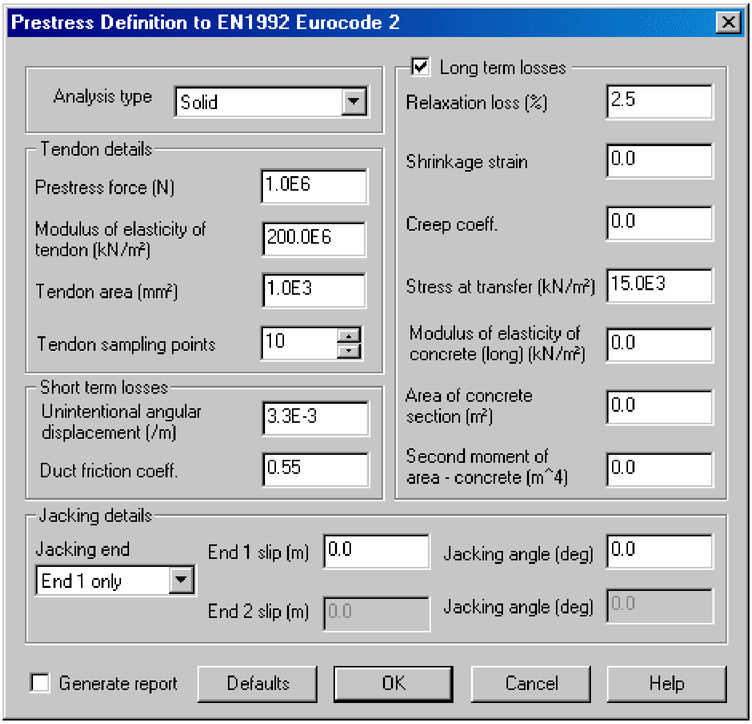
The defaults button sets all previously entered values to those specified when the dialog is first displayed.

Notes

- If tendon realignment is required the previously assigned discrete loading properties should be removed from the model and the Prestress loading wizard re-run to calculate the new discrete loading properties for the new tendon alignment.
- Use of the single tendon prestress facility is described in the example 'Linear Analysis of a Post Tensioned Bridge'. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.

Single Tendon Prestress to EN1992 Eurocode 2

Prior to using the single tendon prestress wizard first select the spline or combined line defining the tendon and then, but only if carrying out a beam analysis, additionally use the **Shift** key to select the beam(s) prior to selecting the Prestress menu option.



Analysis type

General **single tendon prestress wizard** information provides details on the analysis types supported.

Tendon details

- **Prestress force** units are displayed on the dialog according to the model units in use.
- **Modulus of Elasticity** should be specified.
- **Tendon area** for the single tendon being defined.
- **Tendon sampling points** are the locations along a spline at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the spline have no bearing on any calculations that are carried out, they are simply used to ensure a good tendon profile is obtained.

Short term losses

- **Unintentional angular displacement** is defined per metre length and should be obtained from design code.
- **Duct Friction coefficient** should be obtained from design code

Long term losses

- **Relaxation loss**
- **Shrinkage strain** - should be 'per mil' in accordance with the code, rather than actual strain
- **Creep coefficient**
- **Stress at transfer**
- **Modulus of elasticity of concrete (long)** should be defined. This is the Modulus of Elasticity for concrete (Ecm, 28 days). A likely range of values would be 24-42Mpa.
- **Area of concrete section**
- **Second moment of area - concrete**

Jacking details

Jacking end slip and jacking angle can be defined for end 1 only, end 2 only, or for both ends of the tendon. End 1 is the start of the spline used to define the tendon.

The jacking angle is the angle between the direction of the tendon at the anchorage and the direction that the jack is set to pull in. If the jack pulls the cable axially the jacking angle would be zero.

Generate report

Generating a report creates an HTML file in your project directory containing a summary of the tendon properties, tendon geometry and prestress losses for the selected tendon.

Generate graphs

Generates graph datasets in the Utilities Treeview to allow subsequent graphing to be carried out using the Graph Wizard.

Defaults

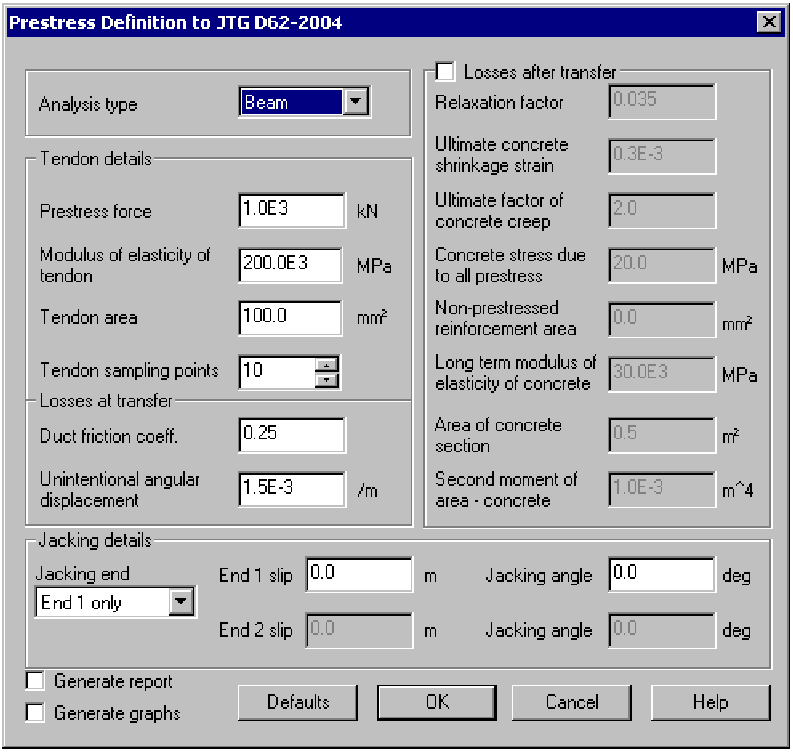
The defaults button sets all previously entered values to those specified when the dialog was first displayed.

Notes

- If tendon realignment is required the previously assigned discrete loading properties should be removed from the model and the Prestress loading wizard re-run to calculate the new discrete loading properties for the new tendon alignment.
- Use of the single tendon prestress facility is described in the example ‘Linear Analysis of a Post Tensioned Bridge’. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.

Single Tendon Prestress to JTG D62-2004 code

Prior to using the single tendon prestress wizard first select the spline or combined line defining the tendon and then, but only if carrying out a beam analysis, additionally use the **Shift** key to select the beam(s) prior to selecting the Prestress menu option.



Analysis type

General **single tendon prestress wizard** information provides details on the analysis types supported.

Tendon details

- **Prestress force** units are displayed on the dialog according to the model units in use.
- **Modulus of elasticity of tendon** Young's modulus of prestress reinforcement.
- **Tendon area** Steel area for the single tendon being defined.
- **Tendon sampling points** Locations along a spline at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the spline have no bearing on any calculations that are carried out. They are simply used to ensure a good tendon profile is obtained.

Losses at transfer

- **Duct Friction coefficient** The friction coefficient between the tendon (prestress reinforcement) and the duct (pipe). See JTG D62-2004 Table 6.2.2.
- **Unintentional angular displacement** also known as the influence factor of load deviation or wobble. This is defined per metre length. See JTG D62-2004 Table 6.2.2.

Losses after transfer

- **Relaxation factor** See JTG D62-2004 Section 6.2.6.
- **Ultimate concrete shrinkage strain** See JTG D62-2004 Table 6.2.7.
- **Ultimate factor of concrete creep** See JTG D62-2004 Table 6.2.7
- **Concrete prestress due to all prestress** The stress in concrete due to prestress at the centroid of all tendons. See JTG D62-2004 section 6.1.5.
- **Non-prestressed reinforcement area** The sectional area of general (non prestressed) reinforced reinforcement
- **Long-term modulus of elasticity of concrete** The long-term Young's modulus of concrete.
- **Area of concrete section** The net sectional area of concrete after the area of the pipes (ducts) and other weakened parts have been removed.
- **Second moment of area- - concrete** Moment of inertia of concrete section

Jacking details

Jacking end slip and jacking angle can be defined for end 1 only, end 2 only, or for both ends of the tendon. End 1 is the start of the spline used to define the tendon.

The jacking angle is the angle between the direction of the tendon at the anchorage and the direction that the jack is set to pull in. If the jack pulls the cable axially the jacking angle would be zero.

Generate report

Generating a report creates an HTML file in your project directory containing a summary of the tendon properties, tendon geometry and prestress losses for the selected tendon.

Generate graphs

Generates graph datasets in the Utilities Treeview to allow subsequent graphing to be carried out using the Graph Wizard.

Defaults

The defaults button sets all previously entered values to those specified when the dialog was first displayed.

Notes

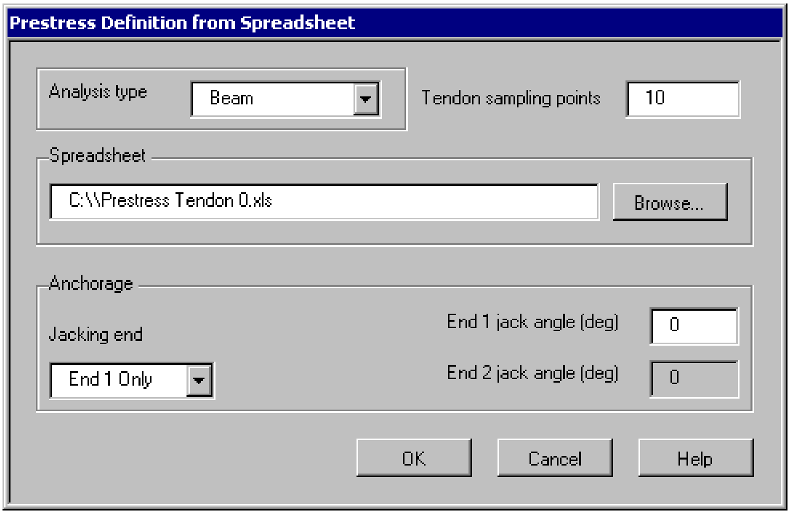
- The prestress definition dialog expects input units to be the same as the current model unless otherwise stated on the dialogs. When the prestress loads are calculated the prestress forces are converted into the current model units. The current model units can be found on the status bar of LUSAS Modeller.
- The loss due to elastic compression of concrete is computed using the simplified formula in JTG D62-2004 Appendix E
- Guidance on the deformation of the anchorage device is provided in JTG D62-2004 Table 6.2.3.
- Use of the single tendon prestress facility is described in the example ‘Linear Analysis of a Post Tensioned Bridge’. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.
- Tendon forces can also be computed directly by the user and imported from a spreadsheet.

Single Tendon Prestress Definition from Spreadsheet

As an alternative to using one of the supplied single tendon prestress design code options, tendon forces can be computed directly by a user and imported from a spreadsheet. To aid with this, a spreadsheet is created by LUSAS containing geometric properties for a particular selected tendon meaning that only the tendon loading data needs initially to be entered by a user.

Usage

Prior to using this facility the line, arc, spline or combined line defining the tendon must be selected and then, but only if carrying out a beam analysis, the **Shift** key must be used to additionally select the beam(s) prior to selecting the **Bridge > Single Tendon > Prestress Definition from Spreadsheet > Spreadsheet Import** menu option.



Analysis type

General **single tendon prestress wizard** information provides details on the analysis types supported.

Tendon details

- **Tendon sampling points** are the locations along a spline at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the spline have no bearing on any calculations that are carried out. They are simply used to ensure a good tendon profile is obtained.

Spreadsheet

A filename for the spreadsheet is automatically entered for creation in the current working directory. When the **OK** button is clicked the previously selected tendon geometry is written to the spreadsheet along with angle and cable length data. The spreadsheet is then automatically opened to allow tendon forces to be manually added. Detailed notes are included on the spreadsheet along with two buttons. One is to be clicked when the tendon forces have been added, the other cancels all input. On pressing the **Click here when tendon forces have been added** button the forces are then read into Modeller and the procedure follows that described for any of the design codes. An example spreadsheet is shown below.

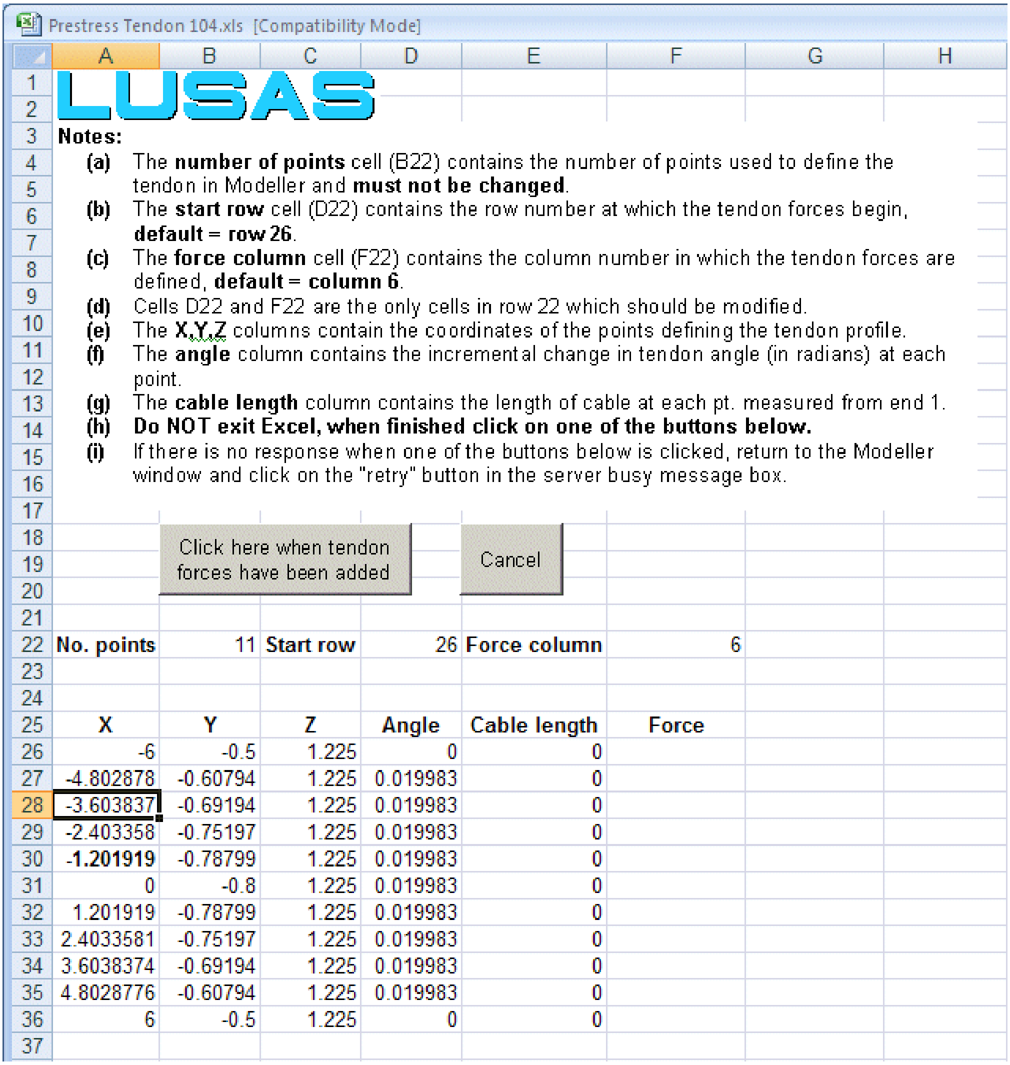
Jacking details

Jacking end slip and jacking angle can be defined for end 1 only, end 2 only, or for both ends of the tendon. End 1 is the start of the spline used to define the tendon.

Generate report

Generating a report creates an HTML file in your project directory containing a summary of the tendon properties, tendon geometry and prestress losses for the selected tendon.

Example Spreadsheet



Prestress Tendon 104.xls [Compatibility Mode]

LUSAS

Notes:

(a) The **number of points** cell (B22) contains the number of points used to define the tendon in Modeller and **must not be changed**.

(b) The **start row** cell (D22) contains the row number at which the tendon forces begin, **default = row 26**.

(c) The **force column** cell (F22) contains the column number in which the tendon forces are defined, **default = column 6**.

(d) Cells D22 and F22 are the only cells in row 22 which should be modified.

(e) The **X,Y,Z** columns contain the coordinates of the points defining the tendon profile.

(f) The **angle** column contains the incremental change in tendon angle (in radians) at each point.

(g) The **cable length** column contains the length of cable at each pt. measured from end 1.

(h) **Do NOT exit Excel, when finished click on one of the buttons below.**

(i) If there is no response when one of the buttons below is clicked, return to the Modeller window and click on the "retry" button in the server busy message box.

Click here when tendon forces have been added | Cancel

	A	B	C	D	E	F	G	H
22	**No. points**	11	**Start row**	26	**Force column**	6		
23								
24								
25	**X**	**Y**	**Z**	**Angle**	**Cable length**	**Force**		
26	-6	-0.5	1.225	0	0			
27	-4.802878	-0.60794	1.225	0.019983	0			
28	-3.603837	-0.69194	1.225	0.019983	0			
29	-2.403358	-0.75197	1.225	0.019983	0			
30	**-1.201919**	-0.78799	1.225	0.019983	0			
31	0	-0.8	1.225	0.019983	0			
32	1.201919	-0.78799	1.225	0.019983	0			
33	2.4033581	-0.75197	1.225	0.019983	0			
34	3.6038374	-0.69194	1.225	0.019983	0			
35	4.8028776	-0.60794	1.225	0.019983	0			
36	6	-0.5	1.225	0	0			
37								

Notes

- If tendon realignment is required the previously assigned discrete loading properties should be removed from the model and the Prestress Definition from from Spreadsheet option re-run to calculate the new geometric properties for the new tendon alignment.

Multiple Tendon Prestress Wizard

The multiple tendon prestress wizard is for use with beam elements. It takes account of short and long term losses and can take into account elastic shortening due to stressing of other tendons according to the design code or user-defined percentage losses. If the option to ignore effects due to elastic shortening is chosen the loading computed will be the same as that calculated by the single tendon wizard.

The multiple tendon prestress wizard can be used for single tendon equivalent nodal loading calculation but it is primarily for use with multiple tendons and particularly for staged construction where it can calculate and allow for the changing effects of the casting sequence on the tendon properties.

Usage

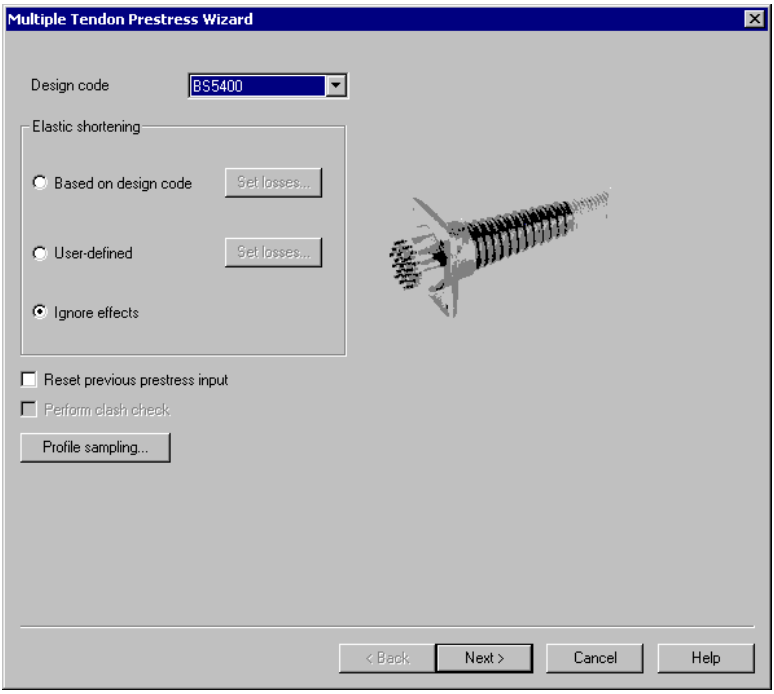
The Multiple Tendon Prestress Wizard consists of five pages to assist with tendon definition and assignment and involves the following steps:

1. **Selection of design code**
2. **Definition of tendon profile**
3. **Definition of tendon properties according to the design code selected**
4. **Definition of tendon loading**
5. **Tendon assignment to loadcases and lines in the model**

Notes

- Before the tendon assignment can be undertaken any lines in the model that are to be assigned tendon properties must be meshed with beam elements.
- Re-running the Multiple Tendon Prestress Wizard deletes all previously created data before re-calculating for a modified model.
- Use of the multiple tendon prestress facility is described in the example 'Segmental Construction of a Post Tensioned Bridge'. See the *Application Examples Manual (Bridge, Civil & Structural)* for details.

Selection of Design Code



Design code

Prestress definition varies slightly according to the design code selected and is explained for each. The following design codes are supported:

- **AASHTO LRFD**
- **BS5400**
- **EN1992 Eurocde 2**
- **JTG D62-2004**

Elastic shortening

- Selecting **Based on design code** will allow the elastic shortening to be calculated as described in the selected design code.
- Selecting the **User defined** option enables the **Set losses…** button. This allows the percentage of applied load remaining after attaching subsequent tendons to be specified. The wizard analyses the assignments in order to correctly determine how to apply elastic shortening. When using elastic shortening several loads may be created for each tendon as the load intensity depends on previous tendon assignments.

- When BS5400 is chosen in combination with this option the **Set losses…** button is enabled. This allows the average overall tendon force loss to be entered as a percentage. This percentage loss is applied to all loading that is assigned to the model. Part IV clause 6.7.2.3 of BS5400 details what is required for elastic shortening.
- When this option is chosen with the design code set to either **AASHTO LRFD** or **EN1992 Eurocode 2** this **Set losses…** button will remain disabled and the elastic shortening will be calculated automatically.
- For AASHTO LRFD the elastic shortening is calculated as described in clause 5.9.5.2.3b. Note that the loss due to elastic shortening in post-tensioned members other than slab systems may be taken as:

$$\Delta f_p ES = \frac{N-1}{2N}\frac{E_p}{E_{cf}} f_{cgp}$$

- EN1992 Eurocode 2 elastic shortening is calculated as described in clause 4.2.3.5.5(6).

$$\Delta P_c = 0.5\left(\frac{E_s}{E_{cm}}\right)\sigma_c$$

- ❑ Selecting **Ignore effects** will not apply any elastic shortening effects to the tendons.
- ❑ **Reset previous prestress input** If previous prestress data has been stored in the model, the Reset previous input data option causes the prestress wizard to ignore previous input and allow new data to be entered. If the wizard is cancelled at any time, the previous data saved in the model file will not be lost. Data will only be overwritten when the finish button is chosen on the final dialog.
- ❑ **Perform clash check** Not available.

Profile sampling

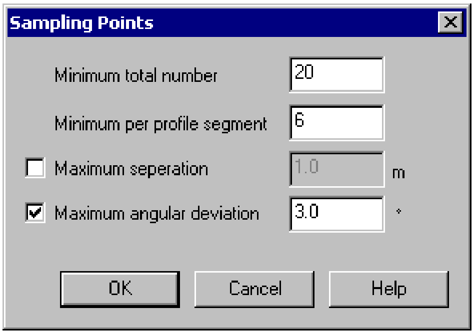
- Defines the locations along a tendon profile at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the line, arc or spline have no bearing on any calculations that are carried out. They are simply used to ensure a good tendon profile is obtained.

Notes

- The wizard expects the input units to be the same as the current model unless otherwise stated on the dialogs.
- When the prestress loads are calculated the prestress forces are converted into the current model units.

- The current model units can be found on the status bar of LUSAS Modeller.

Tendon Profile Sampling Points



For each line segment (that is for each line, arc or spline) of each tendon profile, tendon sampling points are calculated according to values specified on the Sampling Points dialog. Tendon sampling points are the locations along a tendon profile at which calculated equivalent tendon loads will be applied to the model. Note that the original points used to define the line, arc or spline have no bearing on any calculations that are carried out. They are simply used to ensure a good tendon profile is obtained.

- **Minimum total number** specifies the minimum number of sampling points that will be accepted throughout the tendon profile.
- **Minimum per profile segment** specifies the minimum number of sampling points that will be accepted per line segment of the tendon profile.
- **Maximum separation** specifies the largest distance between sampling points (in modelling units) that will be accepted along each line segment of tendon profile.
- **Maximum angular deviation** specifies the maximum angle of deviation between segments that will be accepted.

From the Minimum total number, Minimum per profile segment and Maximum separation value entries specified a calculated number of sampling points for each line segment will be arrived at. The Maximum angular deviation value will introduce additional sampling points in line segments where the line segment curvature is high.

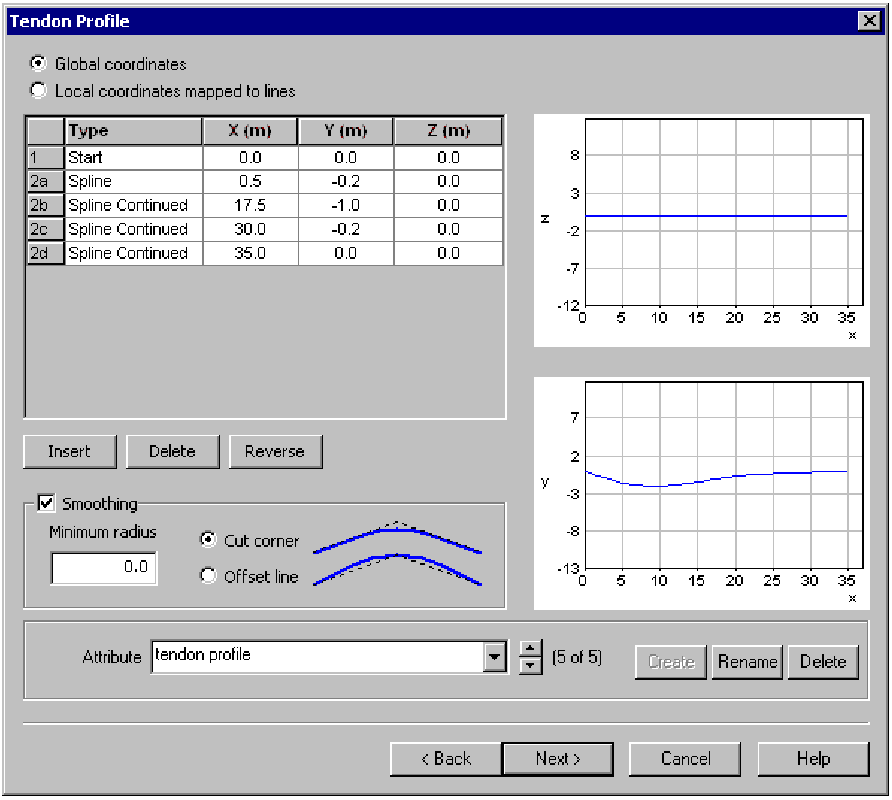
Notes

- Note that the maximum separation distance is input and displayed in current model units. This implies that, for a new model, if imperial units have been chosen, the default is 39.37 inches (1m). Consistently with other inputs in Modeller, changing the units after entering a value changes the meaning, not the numerical value that was previously input.

Definition of Tendon Profile

This page of the **multiple tendon prestress wizard** allows tendon profile geometry to be defined or copied and pasted from a spreadsheet. It also shows tendon profile coordinates and allows specification of line segment type when a tendon profile has been previously generated by defining lines, arcs or splines in Modeller. Previously defined tendon profiles are read from the Utilities Treeview and can be selected by name in order to view stored data.

Tendon profiles are stored and viewed in the Utilities Treeview. Like other utilities, tendon profiles are not directly assignable to geometry and can only be edited using this dialog.



- To create tendon profiles enter a title and select the **Create** button. Coordinate data can then be entered for this new profile in the blank grid. Use **Rename** and **Delete** to change and remove tendon profile names from the Utilities Treeview.

Defining tendon profile by coordinates

Tendon profile setting-out information is defined by adding rows to a table and specifying the coordinates of each defining point along the tendon. The profile coordinates can be entered in either local or global coordinates. Entering in local coordinates will transform the profile to global coordinates when assigned to lines. As the coordinates are entered the tendon shape that they define is visualised in the adjacent graphs.

- **Type** Clicking on the additional input button in this cell of the table allows the type of line to be specified. Options are Straight, Arc Bulge, Arc Centre, Spline, Parabola Bulge, and Spline Continued.
- **Insert**, **Delete** and **Reverse** buttons provide the means to create a new above a selected row, to delete rows, and to reverse the order of all of the rows in the table. Use the tab key to create a new row at the bottom of the table.

Defining tendon profile by spreadsheet import

Tendon geometry and line segment information can be imported from a spreadsheet using standard copy and paste facilities. Both 4 column (type and coordinate data) and 3 column (coordinate data only) widths are supported. With 4 column import the data in the first column is expected to be text. 3 column data is expected to numeric and will paste into the coordinate cells wherever it is pasted.

Defining tendon profile in Modeller

Lines, arcs and splines which represent a tendon can be defined in LUSAS Modeller and then be selected prior to accessing this dialog. Line segments will be listed in the table with their setting-out information.

Smoothing

Smoothing allows the definition of a minimum radius around or through which two intersecting tendon definition lines will be shaped. There are two options:

- **Cut corner** adds a radius transition between two lines inside of their defined intersection point
- **Offset line** adds a radius transition between two lines through their defined intersection point

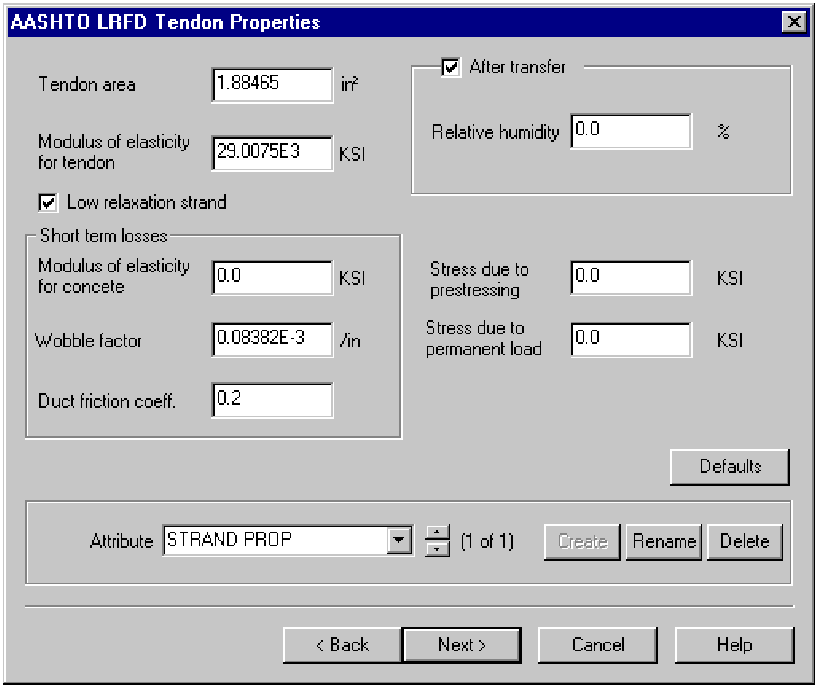
Notes

- Selecting the top left row / column box will allow you to copy and paste data from a spreadsheet using Ctrl + C and Ctrl + V keyboard shortcuts.
- If the line to which the tendon is assigned is an arc and the tendon profile is generated with a straight local x-axis this will be “wrapped” to follow the path of the assigned arc, therefore there is no need to arc the tendon profile. In this situation it may be better to specify the profile as an arc in global coordinates.

- Tendon profiles can also be defined in isolation and outside of the multiple tendon prestress wizard by using the **Bridge** > **Prestress Wizard** > **Tendon Profile** menu item.

Defining AASHTO LRFD Tendon Properties

This page of the **multiple tendon prestress wizard** allows tendon properties including short and long and term losses to be entered.



- To create tendon property enter an attribute name and select the **Create** button. Then enter tendon property data as described below:

Tendon details

- ❑ **Tendon area**
- ❑ **Modulus of elasticity for tendon**
- ❑ **Low relaxation strand** This option is used in the calculation of the steel relaxation losses. When selected, 30% of the steel relaxation loss is applied - as specified in clause 5.9.5.4.1.

Short term losses

- ❑ **Modulus of elasticity for concrete**

- ❑ **Wobble factor** is defined per metre length and should be obtained from the design code.
- ❑ **Duct friction coefficient** should be obtained from the design code

After transfer

- ❑ **Relative humidity**
- ❑ **Stress due to prestressing** is defined as the compressive stress at the centroidal axis due to prestress loading only. See notes.
- ❑ **Stress due to permanent load** is defined as the compressive stress at the centroidal axis due to permanent loads on the prestressed member only. See notes.

Defaults

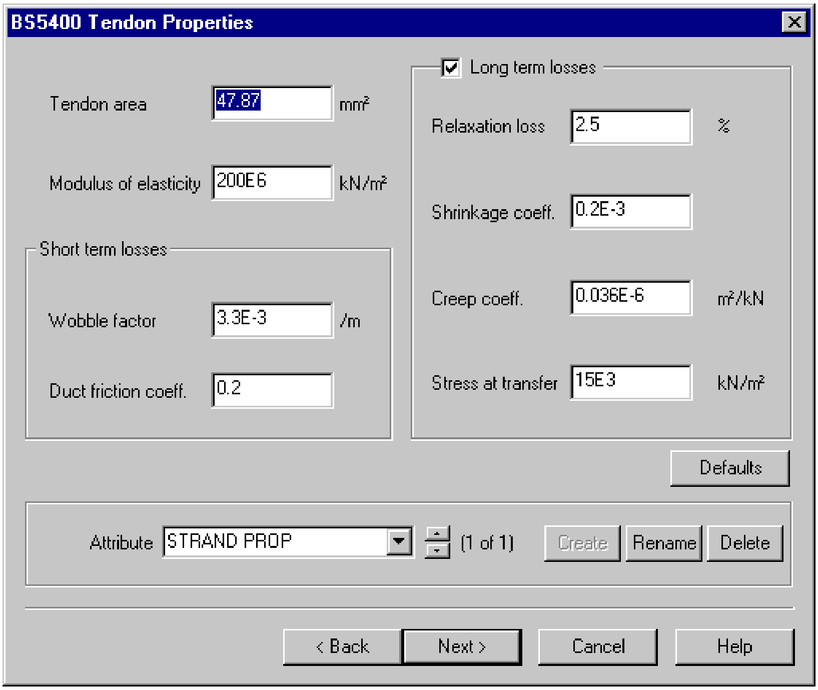
The defaults button sets all previously entered values to those specified when the dialog was first displayed.

Notes

- The prestress definition dialog expects input units to be the same as the current model unless otherwise stated on the dialogs. When the prestress loads are calculated the prestress forces are converted into the current model units. The current model units can be found on the status bar of LUSAS Modeller.
- **Stress due to prestressing** and **Stress due to permanent load** values are used for the elastic shortening calculation based on the design code, as defined on the Wizard's first page, and are also used for the calculation of long term losses.

Defining BS5400 Tendon Properties

This page of the **multiple tendon prestress wizard** allows tendon properties including short and long and term losses to be entered.



- To create tendon property enter an attribute name and select the **Create** button. Then enter tendon property data as described below:

Tendon details

- ❑ **Tendon area**
- ❑ **Modulus of elasticity**

Short term losses

- ❑ **Wobble factor** is defined per metre length and should be obtained from design code.
- ❑ **Duct friction coefficient** should be obtained from design code

Long term losses

- ❑ **Relaxation loss** is a percentage of the prestress force.
- ❑ **Shrinkage Coefficient**
- ❑ **Creep coefficient**
- ❑ **Stress at transfer** is defined as the compressive stress at the centroidal axis due to prestress.

Defaults

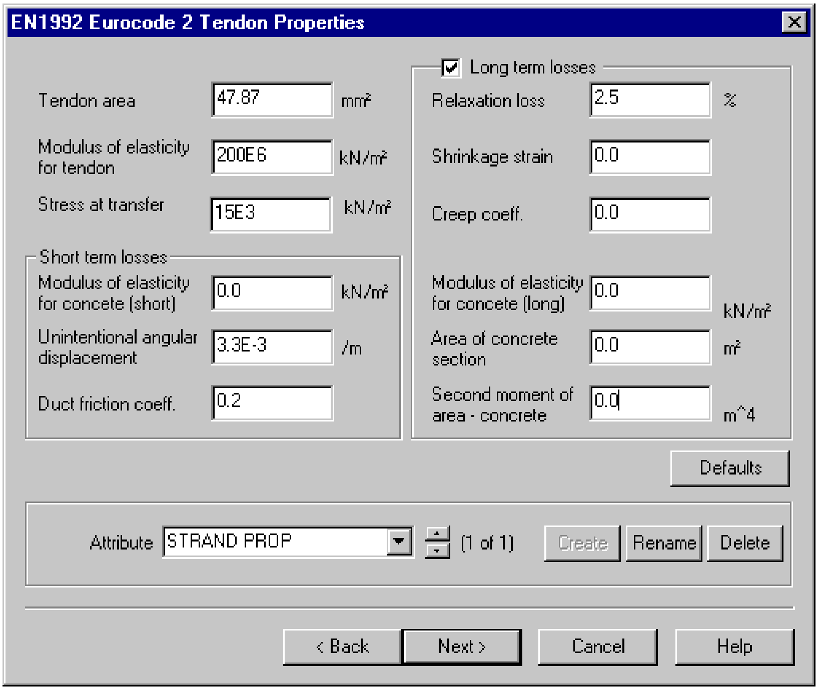
The defaults button sets all previously entered values to those specified when the dialog was first displayed.

Notes

- The prestress definition dialog expects input units to be the same as the current model unless otherwise stated on the dialogs. When the prestress loads are calculated the prestress forces are converted into the current model units. The current model units can be found on the status bar of LUSAS Modeller.

Defining EN1992 Eurocode 2 Tendon Properties

This page of the **multiple tendon prestress wizard** allows tendon properties including short and long and term losses to be entered.



- To create tendon property enter an attribute name and select the **Create** button. Then enter tendon property data as described below:

Tendon details

- **Tendon area**
- **Modulus of elasticity of tendon**
- **Stress at transfer** is defined as the compressive stress at the centroidal axis due to prestress. This value is used for the elastic shortening calculation based on the design code, as defined on the Wizard's first page, and is also used for the calculation of long term losses.

Short term losses

- **Modulus of elasticity of concrete (short)** should be defined. This is the Modulus of Elasticity for concrete at stressing. A likely range of values would be 24-37Mpa.
- **Unintentional angular displacement** is defined per metre length and should be obtained from design code.
- **Duct friction coefficient** should be obtained from the design code.

Long term losses

- **Relaxation loss** is a percentage of the prestress force. Loss of prestress is calculated as specified in clause 4.2.3.5.5 of Eurocode 2. Time dependant losses are calculated using:

$$\Delta\sigma_{p,c+s+r} = \frac{\varepsilon_{s(t,t_0)} E_s + \Delta\sigma_{pr} + \alpha\phi(t,t_0)(\sigma_{cg} + \sigma_{cgo})}{1 + \alpha \frac{A_p}{A_c}\left[\left(1 + \frac{A_c}{I_c} Z_{cp}^2\right)(1 + 0.8\phi(t,t_0))\right]}$$

- **Shrinkage strain** - This should be 'per mil' in accordance with the code, rather than actual strain.
- **Creep coefficient**
- **Modulus of elasticity of concrete (long)** should be defined. This is the Modulus of Elasticity for concrete (Ecm, 28 days). A likely range of values would be 24-42Mpa.
- **Area of concrete section**
- **Second moment of area - concrete**

Defaults

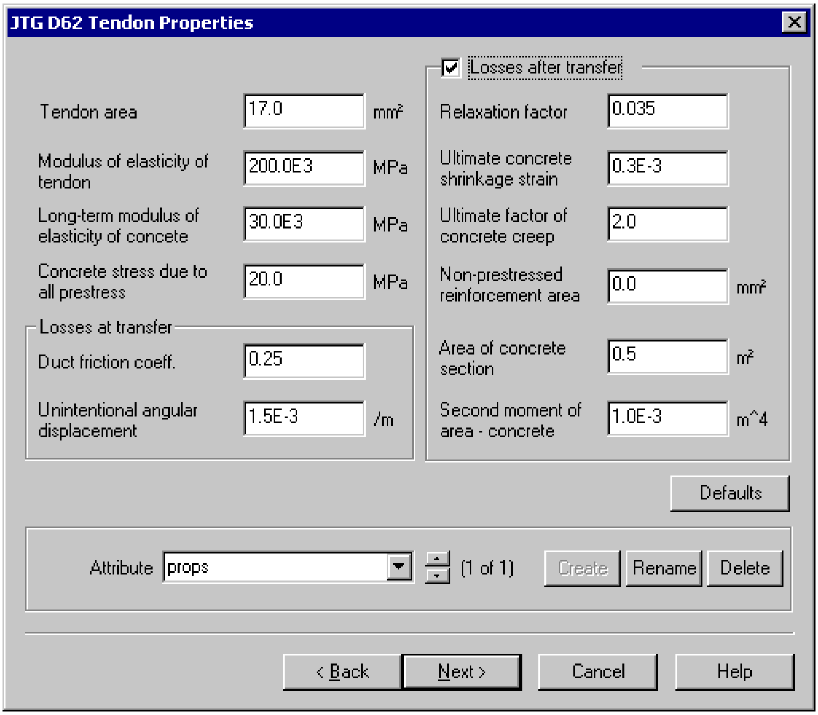
The defaults button sets all previously entered values to those specified when the dialog was first displayed.

Notes.

- The prestress definition dialog expects input units to be the same as the current model unless otherwise stated on the dialogs. When the prestress loads are calculated the prestress forces are converted into the current model units. The current model units can be found on the status bar of LUSAS Modeller.

Defining JTG D62-2004 Tendon Properties

This page of the **multiple tendon prestress wizard** allows tendon properties including short and long and term losses to be entered.



- To create tendon property enter an attribute name and select the **Create** button. Then enter tendon property data as described below:

Tendon details

- ❑ **Tendon area**
- ❑ **Modulus of elasticity of tendon** Young's modulus of prestress reinforcement.
- ❑ **Long-term modulus of elasticity of concrete** The long-term Young's modulus of concrete.

- **Concrete stress due to all prestress** The stress in concrete due to prestress at the centroid of all tendons. See JTG D62-2004 section 6.1.5.

Losses at transfer

- **Duct friction coefficient** The friction coefficient between the tendon (prestress reinforcement) and the duct (pipe). See JTG D62-2004 Table 6.2.2.
- **Unintentional angular displacement** also known as the influence factor of load deviation or wobble. This is defined per metre length. See JTG D62-2004 Table 6.2.2.

Losses after transfer

- **Relaxation factor** See JTG D62-2004 Section 6.2.6.
- **Ultimate concrete shrinkage strain** See JTG D62-2004 Table 6.2.7.
- **Ultimate factor of concrete creep** See JTG D62-2004 Table 6.2.7
- **Concrete prestress due to all prestress** The stress in concrete due to prestress at the centroid of all tendons. See JTG D62-2004 section 6.1.5.
- **Non-prestressed reinforcement area** The sectional area of general (non prestressed) reinforced reinforcement
- **Area of concrete section** The net sectional area of concrete after the area of the pipes (ducts) and other weakened parts have been removed.
- **Second moment of area- - concrete** Moment of inertia of concrete section

Defaults

The defaults button sets all previously entered values to those specified when the dialog was first displayed.

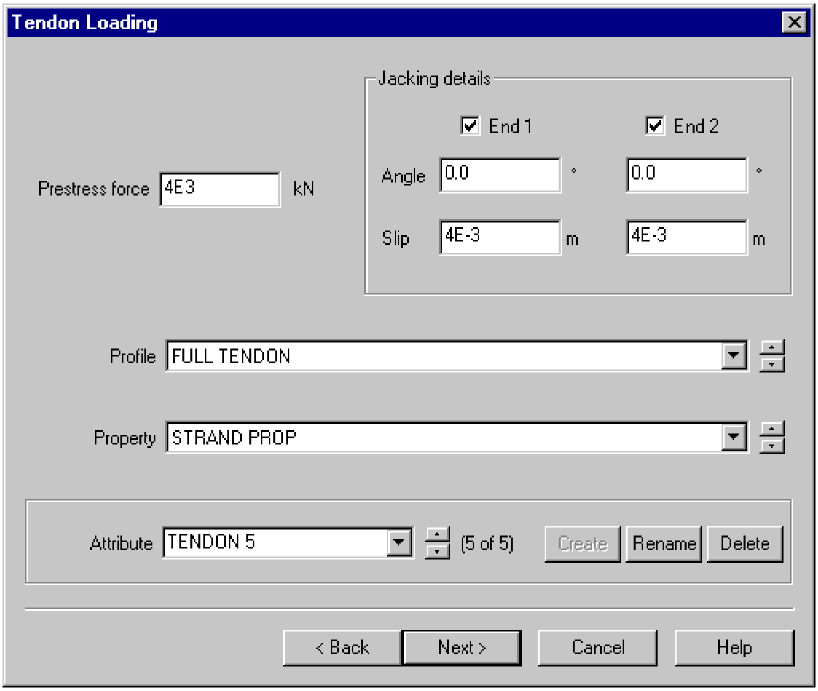
Notes

- The prestress definition dialog expects input units to be the same as the current model unless otherwise stated on the dialogs. When the prestress loads are calculated the prestress forces are converted into the current model units. The current model units can be found on the status bar of LUSAS Modeller.
- The loss due to elastic compression of concrete is computed using the simplified formula in JTG D62-2004 Appendix E.
- Guidance on the deformation of the anchorage device is provided in JTG D62-2004 Table 6.2.3.

Definition of Tendon Loading

This page of the **multiple tendon prestress wizard** allows a tendon load to be associated with previously entered profiles and properties.

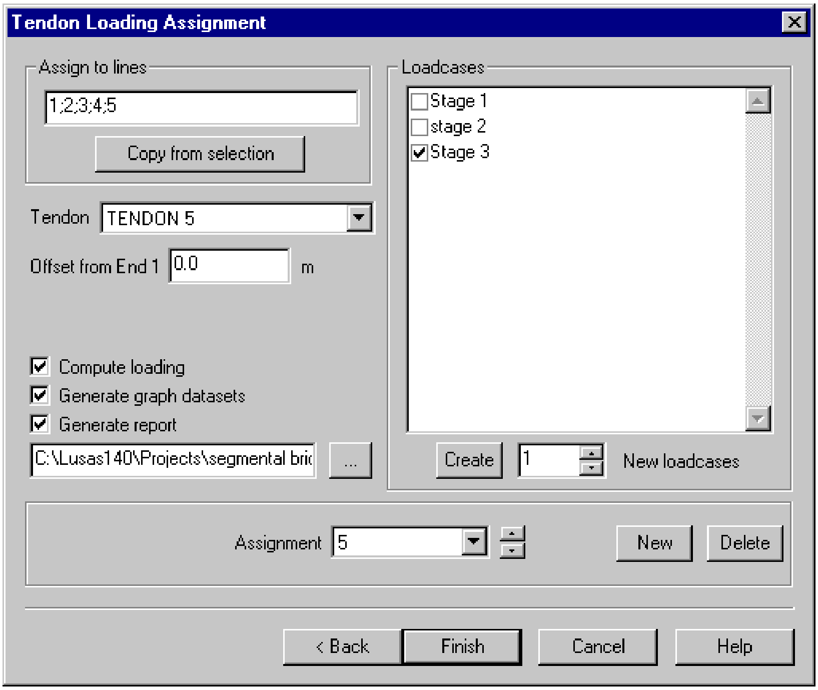
The tendon profile and property drop-down lists are populated with entries present in the Utilities Treeview.



- To create tendon load enter a dataset title and select the **Create** button. Tendon load data can then be entered.
- The tendon force must be defined in addition to jacking details. Anchorage losses are defined as slippage from either or both ends.

Tendon Loading Assignment

This last page of the **multiple tendon prestress wizard** allows the assignment of the tendon loads that have been defined in the previous dialog.



Assigning tendon loads to loadcases

- Tendon loads can be assigned to single or multiple loadcases using the checklist box. Selecting a loadcase will automatically select all subsequent loadcases. To switch the subsequent loadcases off select the loadcase following the chosen loadcase and this will toggle the activation of the subsequent loadcases.
- New loadcases for tendon assignment can be created by entering a number and selecting the **Create** button. These will not be generated in the model until the tendon calculation is complete.

Assigning tendon loads to lines

- Before any tendon assignments can be carried out any lines in the model that are to be assigned tendon properties must be meshed with beam elements.
- Tendon loads can be assigned to lines entered in the line numbers box directly, or by selecting the lines on the model and clicking **Copy from selection**. These lines may be straight or curved and may consist of multiple lines defining each span.

- Checks are made on saving that the lines selected for assignment form a single continuous open-ended path. Unconnected lines, multiple paths, branching and/or a closed loop are reported as an error.
- Line numbering and line direction determines the tendon profile direction for the superimposed tendon. Line direction must be consistent along the selected lines representing the beam assignments. Any inconsistencies in line direction will cause an error. Use the **Offset fromEnd 1** to allow the selected tendon profile to be displaced along the starting point of tendon jacking.

Computing loading

- **Compute loading** when checked causes the loading calculation and assignments to be carried out on finishing the wizard. When not checked no calculations will take place but the data entered, as long as it is valid, will be stored to the model. This is useful if it is required to exit the wizard during the process of entering data. The **Next>** button on the preceding dialogs can be clicked to get to this final page to enter a single assignment and then exit the wizard assured that the current entered data will be stored to the model.

Generating graphs of tendon losses

- **Generate graph datasets** should be selected if a graphical visualisation of the tendons is required. When the prestress definition is computed graph datasets will be created to enable the tendon losses to be visualised against the tendon length.

Generating reports of tendon assignments

- Check the **Generate report** box if a HTML report is required. If selected, a HTML document will be created in the current working folder (or the specified directory) and automatically displayed in the default web browser at the end on the calculation. This report gives a table of contents of all the tendon calculations. Summaries for the tendon properties and profile are given followed by the prestress losses and the prestress load components as used in the LUSAS loading attributes. This report is useful for quality assurance purposes.

Completing the Wizard

- Clicking the **Finish** button will save all of the entered data to the model and, if selected, compute the tendon forces and assign them to the relevant loadcases.

Prestress Wizard-created data

- In using the Prestress Wizard, prestress loading is added to the analysis model as equivalent discrete point loading. In doing so, search areas are created and used automatically by the prestress wizard to define the target geometry to be loaded. By right-clicking on a tendon loading assignment in the Attributes Treeview the search area used for that assignment may be visualised.
- Load factors are used to represent elastic shortening and these can be seen for each stage in the Loadcase Treeview.
- Graphing datasets (which allow of graphing of prestress losses etc) are added to the Utilities Treeview.
- Tendon profiles defined by the Prestress Wizard are added to the Utilities Treeview.

Editing Prestress Wizard-created data

- If any tendon assignments need modifying, the Multiple tendon prestress wizard may be re-run (previously entered values will be retained) and the Next button can be clicked to get to the tendon loading assignment page. Incorrect assignments can be deleted or simply corrected as required before clicking the Finish button to recalculate the equivalent tendon loading on the model.
- Editing of tendon profile data in the Utilities Treeview. (that is, outside of the wizard) is permitted but all attributes that require re-calculating by re-running the prestress wizard will be marked with the symbol . Re-running the prestress wizard will update all values accordingly.
- Editing of any attribute data calculated and generated by the prestress wizard is not permitted.

Deletion of prestress attributes

- Deletion of individual prestress attributes is not permitted since it will invalidate any calculations (e.g. elastic shortening) that have been made. Deletion of all prestress attributes (i.e profiles, properties) is possible and is achieved by selecting the **Delete all** menu item on the context menu for each item.
- Re-running the Multiple Tendon Prestress Wizard deletes all previously created data before re-calculating for a modified model.

Load Combination Wizards

In addition to Basic or Smart load combinations that can be defined for any design code, loading combinations can be defined using load combination wizards for the BD37/88, BRO or the Korean Highway codes.

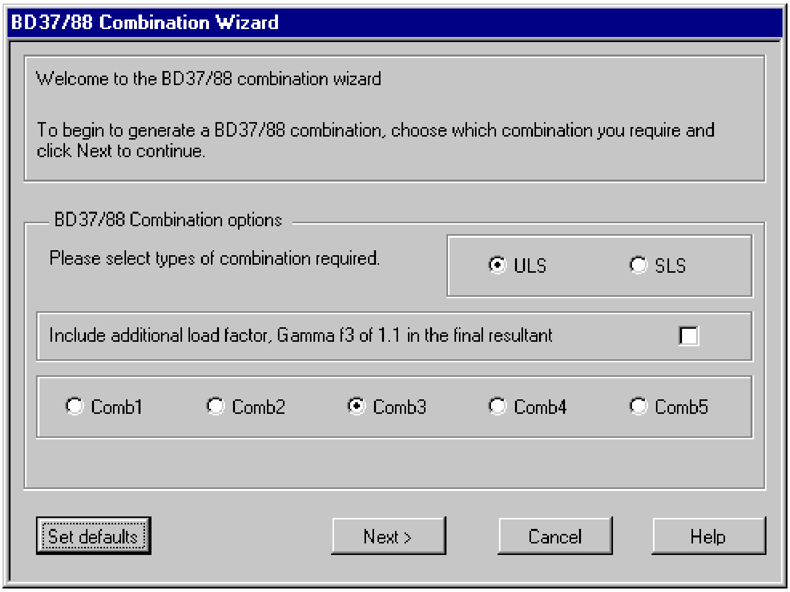
Load combination wizards should only be used in conjunction with a corresponding predefined load template. Load templates are selected from the New Model dialog and predefine the possible characteristic loadcases. Loads are assigned to these characteristic loadcases and the combination generator then combines these loadcases and creates load combinations to give the resultant maximum and minimum ULS or SLS loadcases in accordance with the chosen design code.

Notes:

- If a model exists which has not been created from the appropriate startup template all loading should be removed and the loadcases should be defined using the vbs file **<Code>Loadcases.vbs** which is located in the **\<Lusas Installation Folder>\Programs\Scripts\Treeview** directory.
- The loads should be applied to the model as un-factored loads as the load factors are placed into the combination automatically by the combination wizard in accordance with the code. The factors taken into account within the combinations are those stated within the appropriate code.
- The use of bridge load combinations is described in the BRO Slab Analysis example. See the *Application Examples Manual* for LUSAS Bridge.

BD37/88 Combinations

The BD37/88 combination wizard allows combinations to be generated in accordance with the UK Highways Agency Department Standard BD37/88. In order to use the combination wizard a model must have been created using the BD37/88 startup template, with loads assigned to the required loadcases as named in the template. The factors taken into account within the combinations are those stated within Table 1 of BD37/88.

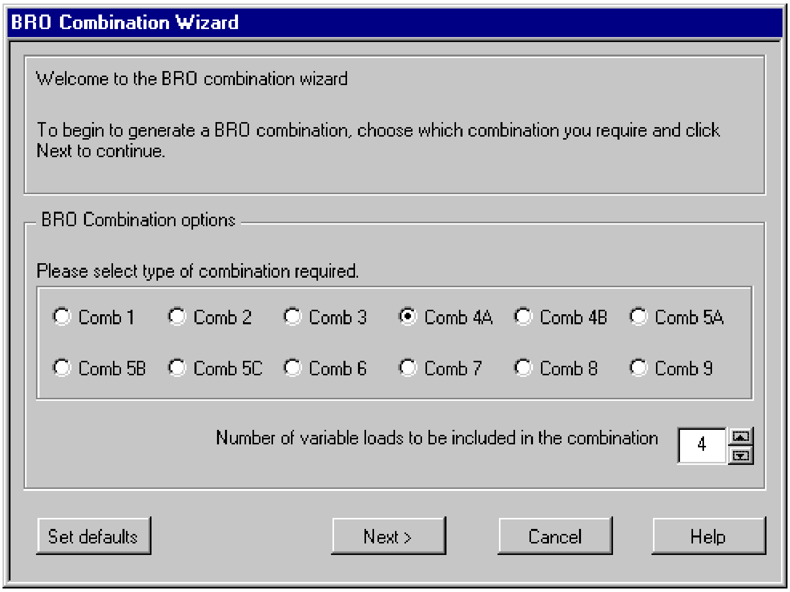


To use the combination wizard:

- Specify which limit state combination is required, **ULS** (Ultimate Limit State) or **SLS** (Serviceability Limit State)
- Specify if the additional factor Gamma f3 is to be included in the final combination. This should only be used for concrete structures designed to BS5400 part4.
- Specify the combination required.

BRO Combinations

The BRO combination wizard allows combinations to be generated in accordance with the Swedish Highways Agency Department Standard BRO. In order to use the combination wizard a model must have been created using the BRO startup template, with loads assigned to the required loadcases as named in the template. The factors taken into account within the combinations are those stated within BRO.



To use the combination wizard:

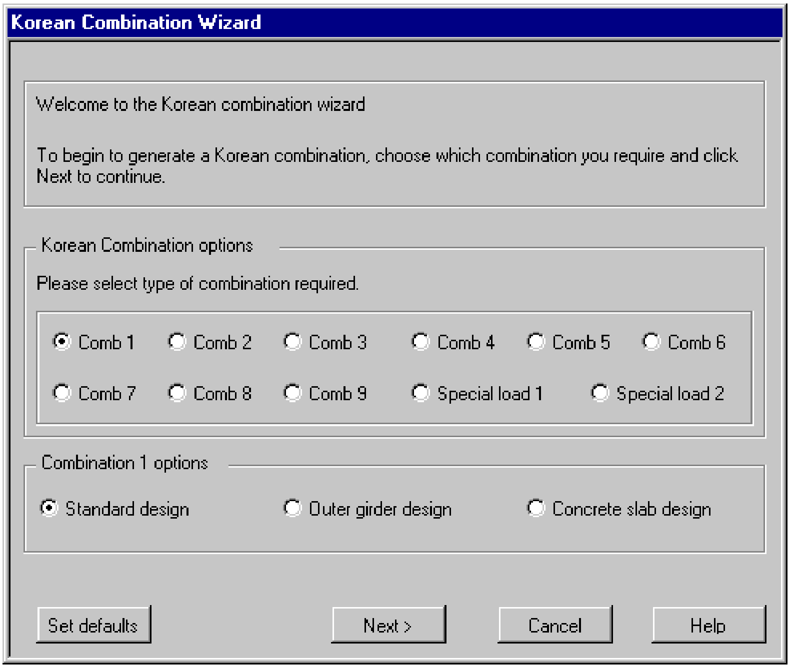
- Specify the combination required.
- Specify the number of variable loadcases to be considered in the variable loadcases combination.

Korean Highway Code Combinations

The Korean combination wizard allows combinations to be generated in accordance with the Korean Highways code. In order to use the combination wizard a model must have been created using the Korean (Bridge) startup template, with loads assigned to the required loadcases as named in the template.

The factors taken into account within the combinations are those stated within the following Table:

Combination Name	Loading Combination and factors
1	U=1.3D+2.15(L+I)+1.3CF+1.7H+1.3Q
2	U=1.3D+1.7H+1.3Q+1.3W
3	U=1.3D+1.3(L+I)+1.3CF+1.7H+1.3Q+1.3(0.5W+WL+BK)
4	U=1.3D+1.3(L+I)+1.3CF+1.7H+1.3Q+1.3G
5	U=1.25D+1.65H+1.25Q+1.25W+1.25G
6	U=1.25D+1.25(L+I)+1.25CF+1.65H+1.25Q+1.25(0.5W+WL+BK)+1.25G
7	U=1.0(D+H+Q+E)
8	U=1.3D+1.3(L+I)+1.3CF+1.7H+1.3Q+1.3CO
9	U=1.2D+.55H+1.2Q+1.2CO
Special load 1	U=1.3D+2.85(L+I)
Special load 2	U=1.3D+1.3(L+I)+1.3CF+1.7H+1.3Q



To use the combination wizard:

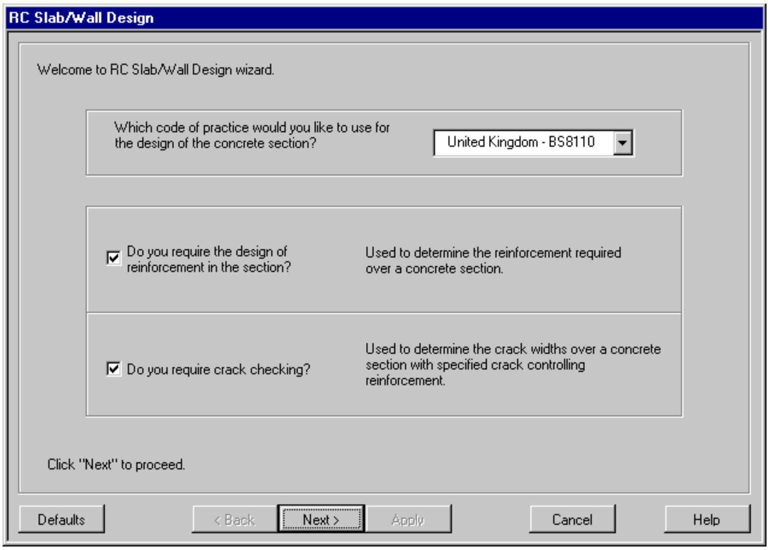
- Specify the combinations required.

- If Combination 1 is being considered specify which of the three options is required; Standard design, Outer girder design or Concrete slab design.

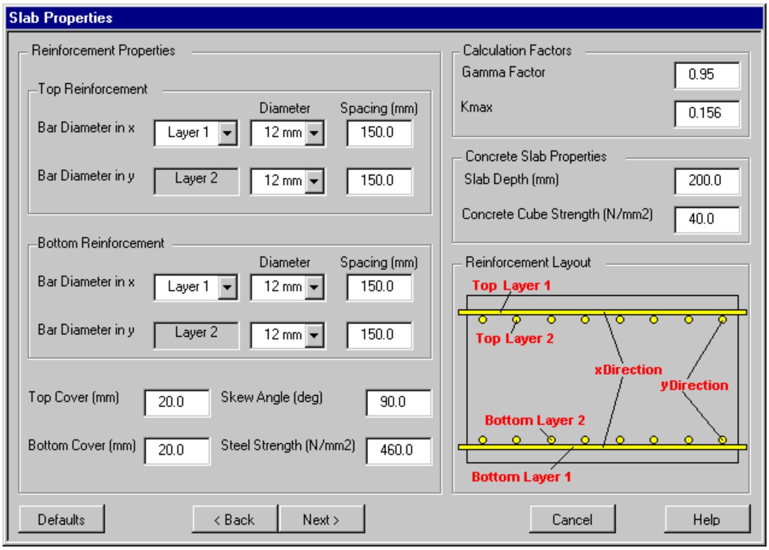
RC Slab/Wall Design

The RC Design menu item enables the reinforcement required in slabs and walls to be computed in accordance with BS8110. Calculation of crack widths can be carried out in accordance with BS5400, BS8110 and BS8007. The wizard uses the Wood and Armer moments to compute the steel area required. If regular bar spacing is specified the appropriate bar sizes can be computed and contoured.

- To use the RC Slab/Wall wizard prepare a slab model in the usual way and run the analysis. If using shell elements ensure that all the elements are orientated with the surface normal pointing upwards (towards the top of the slab). With the results loaded select the **RC Design> Slab/Wall** item from the Bridge or Civil menu.



Slab Properties



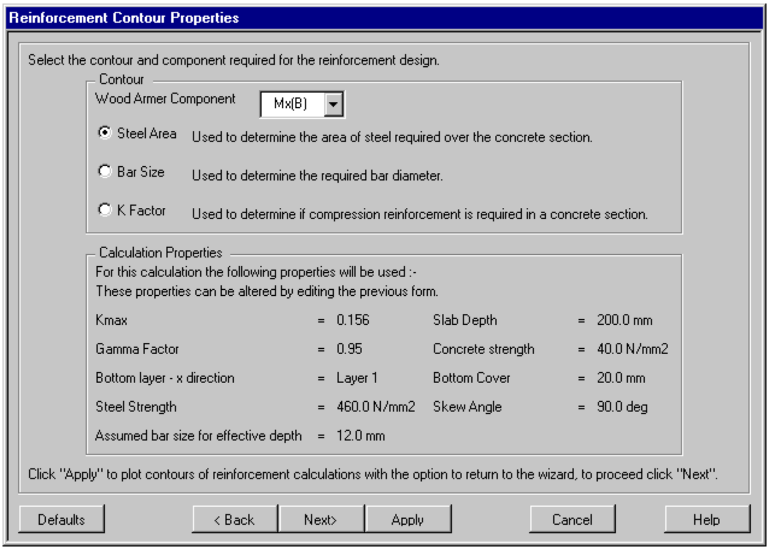
- Slab thickness, concrete cube strength, bar sizes and cover for the top and bottom reinforcement are defined
- Gamma factor is 1/gm (partial material factor) which by default is set to 0.95.
- Kmax is the maximum allowable K factor as specified in BS8110 : Part 1 clause 3.4.4.4. with a default of 0.156.
- The skew angle is required for the Wood and Armer calculation. The angle is measured in an anti-clockwise direction from the element local x axis (bar in x direction) to the direction of the y bar.
- All units will be converted to the relevant model units.

Reinforcement Design

The reinforcement required in slabs or walls are computed in accordance with the following codes:

- **BS8110 "Structural use of Concrete"**
- **BS8007 "Design of Concrete Structures for Retaining Aqueous Liquids".**
- **BS5400 in combination with BD24/92 "Design of Highway Bridges and Structures - Part 4"** limits the redistribution of elastic ultimate moments to less than 10%. BS8110 allows for a possible redistribution greater than 10% (K and K' factor). It is for this reason that the reinforcement design is approximate when using BS5400.

The use of Wood and Armer moments is used to compute the required contour.



- To display contours of the K factor, reinforcement area or bar sizes required enter the concrete cube strength and steel characteristic strength and set the appropriate top and bottom bar sizes, cover and skew angle.
- To enable the effective depth to be computed the top and bottom cover and top and bottom bar size are input. The effective depth is used to establish if compressive reinforcement is required using the equation:

$$K = \frac{M}{bd^2 fcu}$$

If K is greater than K_{max} a warning message is issued.

The area of reinforcement is computed in mm^2/m width using the equation:

$$Ast = \frac{M}{\gamma \, f_y \, z}$$

where:

z is the lever arm

γ is the Gamma factor which has a default value of 0.95.

K_{max} is the maximum allowable K factor as specified in BS8110 : Part 1 clause 3.4.4.4. with a default of 0.156.

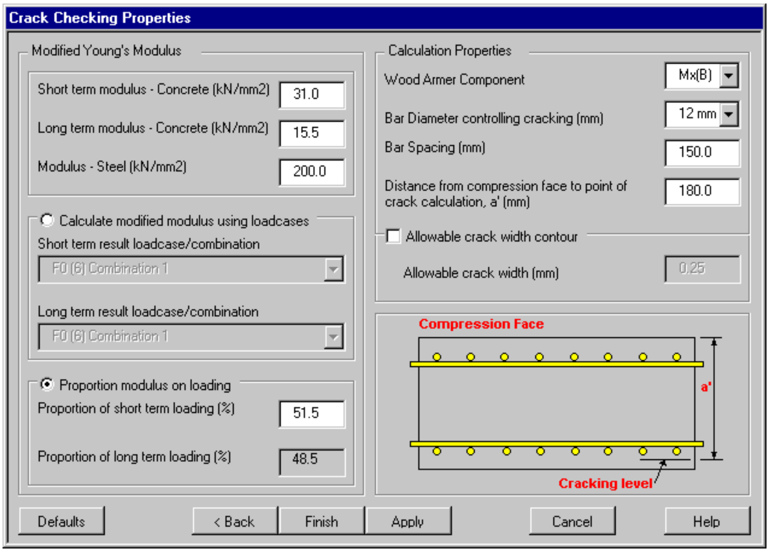
The skew angle is required for the Wood and Armer calculation. The angle is measured in an anti-clockwise direction from the element local x axis (bar in x direction) to the direction of the y bar.

All units will be converted to the relevant model units.

Crack Checking

All of the listed codes of practice use the same principles for calculating crack width; however, there are some differences:

- BS8110 Part 1, in the first instance, is concerned with the deflection of concrete members. Limits for deflection are given in the form of span-to-depth ratios. Flexural cracking is controlled by the bar spacing and detailed rules are given. If greater spacings are used then Part 2 “Special Situations” Section 3.8 can be used to calculate crack widths. This calculation gives an alternative approximate method, which is similar to that of BS5400 except the tension stiffening effect is ignored.
- BS8007 uses the same method as described in BS8110, however, to allow for a more rigorous check the allowable crack width is reduced from 0.25mm, as given in BS8110, to 0.2mm or 0.1mm.
- BS5400 Part 4 clause 5.8.8.2 details a rigorous check of crack widths that allows for the stiffening effect of concrete in the tension zone. This means that the calculation of the strain at the level of cracking consideration, ε_m, requires the moment in the section under permanent and live loads. There is no limit state of excessive deflection in the form of span-to-depth ratios.



- The crack checking facility provides contours of crack widths in a particular direction and level, i.e. Mx(B), My(T) etc. Crack checking can follow on from a slab analysis or it can be carried out as a singular process.
- To carry out crack checking a proportioned value of Young's modulus for the long and short term loading effects is required. An option exists to examine the model and extract Wood-Armer moment results at nodes for each of the specified loadcases; a proportioned value of Young's modulus is then computed using these moments. Alternatively, percentages of short and long term loading for an active Loadcase can be specified.

Plotting contours of crack widths

Two options are available for the contours of crack width:

- A contour can be plotted over the entire structure based on calculated nodal values
- A plot of allowable crack widths can be displayed. This option will compare the calculated value with a user specified value and plot contours of pass or fail i.e. blue for pass and red for fail. The default value for the allowable crack width is 0.25mm.

If a prior slab design has been carried out, and crack checking reveals non compliance, the **Back** button provides the option to return to the slab designer to repeat the operation.

When visualisation of slab design results has been completed **RC Design> Off** should be selected from the Bridge menu to reset the results options.

The use of the RC Design facility is described in the example "Simple Slab Design". See the *Application Examples Manual* for LUSAS Civil & Structural.

Crack Checking Theory

There are two methods for calculating a combined Young's modulus of concrete for short and long term loadings. One is to have two different loadcases that have all short term loadings (associated with the short term modulus) and long term loadings (associated with the long term modulus). The other is by proportioning the active loadcase results.

A combined Young's Modulus can then be used for calculating crack sizes. The following Young's modulus calculation can be used for all codes of practice.

To calculate a combined modulus this is proportioned on the loading levels using the equation:-

$$E_{conc} = \frac{E_s E_l}{E_l R + E_s (1 - R)}$$

where,

E_s = Short term modulus concrete

E_l = Long term modulus concrete

M_s = short term moment due to live loads

M_l = long term moment due to permanent loads

For the proportioned loading, based on the active loadcase, the entered values will determine the ratio, and be used to calculate E_{conc}.

Modular ratio, $$\alpha e = \frac{E_{steel}}{E_{conc}}$$

where,

E_{conc} = Modulus of concrete calculated above

E_{steel} = Modulus of steel reinforcement

The area of steel controlling cracking is specified by "Bar diameter controlling cracking". Where that axis of the design moment and the direction of the tensile reinforcement resisting that moment are not normal to each other (e.g. in a skew slab), A_s should be chosen from the list that closely matches the skewed reinforcement area. BS5400 specifies this as

$$A_s = \sum \left(A_t \cos^4 \alpha_1 \right)$$

where,

A_t = Area of reinforcement in a particular direction

α_1 = Angle between the axis of the design moment and the direction of the tensile reinforcement, A_t, resisting that moment.

After the modulus is determined, the depth to the neutral axis of the section, x, has to be calculated

$$x = \frac{\alpha e As}{b}\left[\left(1 + \frac{2bd}{\alpha e As}\right)^{\frac{1}{2}} - 1\right]$$

A_s = Area of tension reinforcement controlling the cracking,

b = breadth of section

d = effective depth of section

The stress at level of the reinforcement is then

$$fst = \frac{M}{\left(d - \frac{x}{3}\right)Ast}$$

The strain at the level of the reinforcement is

$$\varepsilon s = \frac{fst}{Esteel}$$

The strain at the level of cracking ignoring stiffening effect, ε_1

$$\varepsilon 1 = \varepsilon s\left(\frac{a' - x}{d - x}\right)$$

where,

a' = distance from the compression face to the point of cracking level

For BS5400, more rigorous check for cracking, M_q is the same as $M_{s,}$ short term moment due to live load effects and M_g is M_l, long term moment due to permanent loads. The strain at the level of cracking with stiffening effect, $\varepsilon_{m,}$ is therefore:-

$$\varepsilon m = \varepsilon 1 - \left[\frac{3.8bh(a' - x)}{\varepsilon m Ast(h - x)}\right]\left[\left(1 - \frac{Mq}{Mg}\right)10^{-9}\right] \leq \varepsilon 1$$

where,

b_t = width of section at the level of centroid of the tension steel

h = Overall section depth

d_c = depth of concrete in compression

The design crack width is given by:

$$\frac{3acr\varepsilon m}{1 + 2(acr - Cnorm)/(h - x)}$$

where,

a_{cr} = the distance from the point of crack consideration to the surface of the nearest bar controlling the crack width.

h = Depth of the section

C_{norm} = Cover provided to the reinforcement.

For BS8007 the same procedure is used however the following calculations are different :-

$$\varepsilon m = \varepsilon 1 - \varepsilon 2$$

where ε_1 is as above and ε_2 for a limiting design crack width of 0.2mm is

$$\varepsilon m = \frac{b(h-x)(a'-x)}{3EsAs(d-x)}$$

For a limiting design crack width of 0.1mm, ε_2 is

$$\varepsilon m = \frac{1.5b(h-x)(a'-x)}{3EsAs(d-x)}$$

BS8110 uses the calculation of ε_m as given for BS8007 0.2mm crack width. However, the allowable crack width is increased to 0.25mm.

If the allowable crack width option is chosen the calculation will be based on either of the above equations depending on the allowable size entered. If this is not specified the equation for a crack size of 0.2mm will be used.

Rail Track-Structure Interaction Analysis

Overview

The LUSAS Rail Track Analysis software option permits track/bridge interaction analysis to the International Union of Railways Code UIC774-3. Dialogs that enable model building, definition of loading and post-processing of results are accessed from the **Bridge** (or Civil) **> Rail Track Analysis UIC774-3** menu item.

Track and bridge interaction models are built automatically in LUSAS from geometric, material property, and loading data defined in a MS Excel spreadsheet. Both thermal loading to the track and train loading due to acceleration and braking forces can be defined. In accordance with the UIC774-3 code of practice, a user-specified element length is used to define the longitudinal embankment and bridge features. Rail clips, ballast movement, bearings and pier stiffness are all included in the analysis model. The model building dialogs allow for either one train crossing one or more structures, or for multiple trains crossing the same structure

When running an analysis, deck temperature loading can be considered in isolation for subsequent analysis of multiple rail configurations, or a full analysis can be carried out considering the combined temperature in the deck and rail loading. Because the response of the ballast and/or clips is nonlinear a nonlinear analysis always needs to be carried out.

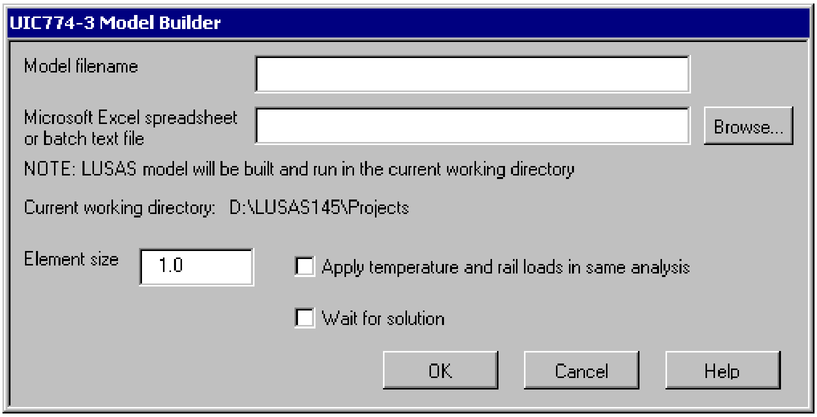
Results can be produced in either Excel spreadsheet or standard LUSAS results file format. User-defined load combinations can be specified. Spreadsheet results include deformations, forces/moments and axial stresses in the rails of the tracks and deformations and forces / moments in the deck structure.

The use of individual dialogs are explained in the following topics. For more detailed information refer to the Rail Track Analysis Manual.

A worked example, **Track-Structure Interaction to UIC774-3**, examines the track-structure interaction between a braking train and a single span bridge to replicate (as far as the original test data allows) testcase E1-3 which can be found in Appendix D.1 of the UIC774-3 Code of

Practice. This example can be found in the *Application Example Manual (Bridge, Civil & Structural).*

UIC774-3 Model Builder



To use the UIC774-3 analysis option a spreadsheet describing the model geometry, properties and loading should have been defined. To do this use the template located in the <Lusas Installation Folder>\Programs\Scripts\User directory and enter the required information into the appropriate locations. All units for the analysis are metric and are listed for the sections within this spreadsheet.

Note: Each 'rail' in the Geometric Properties definition represents a single track on the structure and therefore should have geometric properties equal to double that of a single rail. Up to two tracks can be present on the structure.

Analysing a Single Structure

If a single analysis is being carried out then a model filename should be specified with or without the *.mdl extension. A directory should not be specified with this model filename as the current working directory is used for saving the model.

The Microsoft Excel filename should be entered or located using the Browse… button

Batch Processing Multiple Structures

If multiple models are to be built and analysed the batch processing facilities can be used. For this a batch text file (with a *.txt extension) should be created that contains the name of one valid Excel spreadsheet per line that defines the models. If the spreadsheet exists and contains valid data then the model will be built and solved in the same directory as the Excel spreadsheet. The number of Excel spreadsheets is unlimited.

The batch text filename should be entered into the dialog or located using the Browse… button and choosing Batch text file (*.txt) as the file type. No model filename should be entered as this will be defined by the basename of the Excel spreadsheet in the batch text file.

Common Input for Single or Multiple Structures

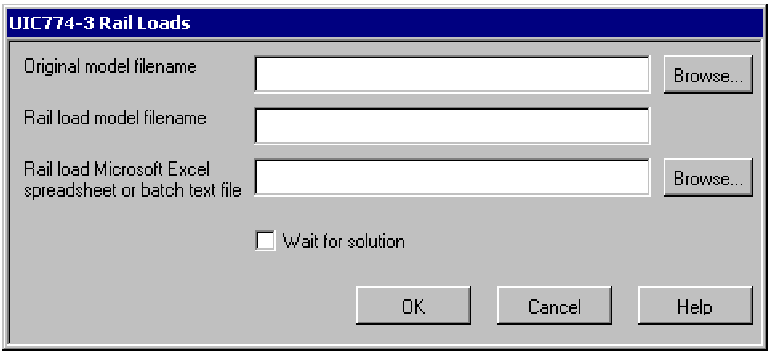
The element size must be specified and this should be in the range 0 < element size <= 2 m for compliance with the UIC774-3 code of practice.

By default, only the temperature loading is applied to the decks of the structure which allows multiple train load configurations to be applied to the same structure. If, however, the combined deck temperature and rail loading is to be solved in a single analysis then the Apply temperature and rail loads in same analysis option should be selected.

If the option to wait for the solution is selected then all of the analyses will be run from Modeller and nothing can be carried out in the current Modeller window until the solution has finished. For relatively small structures or analyses with a limited set of parametric trainset loading locations this is may be fine. If a large number of parametric trainset loading locations are included in an analysis and/or a large number of models are being built using the batch processing then waiting for the solution can take a considerable amount of time.

On clicking the OK button the model(s) will be built and solved automatically by the software. A log file called UIC774-3_BuildModel.log will be created in the current working directory if batch processing is used to report any errors encountered during the batch process.

UIC774-3 Rail Loads



If only the temperature effects have been applied to the model using the UIC774-3 Model Builder dialog then single or multiple rail configurations can be applied using this dialog.

Note: Attempting to use this dialog on a model that has not been created using the model builder dialog or that has loading other than temperature loads will generate an error message.

Analysing a Single Structure with One Rail Load Configuration

If a single rail load configuration is to be analysed for a single structure either enter the filename of the existing LUSAS temperature model created using the model builder or select it using the Browse… button. Enter the filename for the new model (omitting any path description as the model will be saved in the current working directory). This filename can be the same as the original model but it is recommended that an alternative filename is used so the original model remains unchanged. Finally enter the filename for the Excel spreadsheet that contains the rail load configuration description or select it using the Browse… button.

Analysing a Single Structure or Multiple Structures with Multiple Rail Load Configurations

If multiple models and / or multiple rail load configurations are to be analysed then only the batch text file should be entered or selected using the Browse… button and choosing Batch text file (*.txt) as the file type. The batch text file should be TAB delimited and contain the filename of the original model file, the filename of the new model to be created and the filename of the Excel spreadsheet containing the rail loading, e.g.

Viaduct 1.mdl Viaduct 1_RailConfig1.mdl Viaduct 1_RailConfig1.xls

Viaduct 1.mdl Viaduct 1_RailConfig2.mdl Viaduct 1_RailConfig2.xls

Viaduct 1.mdl Viaduct 1_RailConfig3.mdl Viaduct 1_RailConfig3.xls

Viaduct 2.mdl Viaduct 2_RailConfig1.mdl Viaduct 2_RailConfig1.xls

Viaduct 2.mdl Viaduct 2_RailConfig2.mdl Viaduct 2_RailConfig2.xls

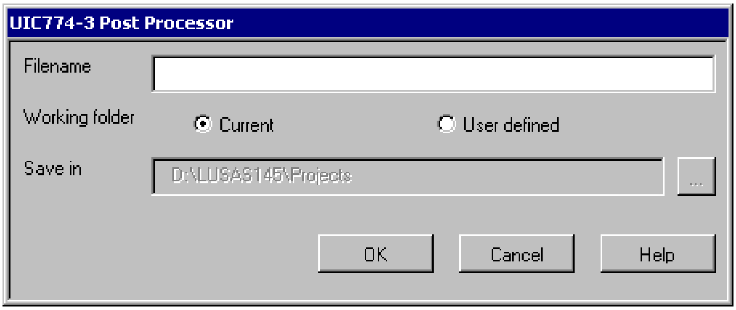
In the above example, two different viaduct temperature models have been selected and three rail load configurations chosen for the first and two for the second models. The number of entries in the batch text file is unlimited.

Common Input for Single or Multiple Structures / Rail Loads

If the option to wait for the solution is selected then all of the analyses will be run from Modeller and nothing can be carried out in the current Modeller window until the solution has finished. For relatively small structures or analyses with a limited set of parametric trainset loading locations this is may be fine. If a large number of parametric trainset loading locations are included in an analysis and/or a large number of models are being built using the batch processing then waiting for the solution can take a considerable amount of time.

On clicking the OK button the combined temperature and rail load model(s) will be built from the original temperature model(s) and solved automatically by the software. A log file called UIC774-3_RailLoads.log will be created in the current working directory and will report any errors encountered during the batch process.

UIC774-3 Post-Processor



The models created by the UIC774-3 model building software can be post-processed in Microsoft Excel with the post-processing dialog. This allows the extraction of the results along with automatic generation of graphs and enveloping in Microsoft Excel. In addition, if enveloping is performed in Microsoft Excel then additional summary tables are generated for key quantities that need to be checked for compliance with UIC774-3 under clause 1.7.2 of the Code of Practice.

On startup of the dialog, if valid UIC774-3 model groups are found, namely "Track 1", "Track 2" and "Decks" then the results can be extracted using these groups or for individual selected rail nodes. If, however, these groups are not found then the current selection will be used if it contains lines with thick 3D engineering beams assigned. If no valid groups or selection are found then the post-processor will report an error.

To use the post-processor, enter the filename for the Excel file that will be created. The directory in which to place the Microsoft Excel file can be selected but is, by default, the current working directory.

On clicking OK the post-processor will extract the results from all of the results loadcases. If envelopes or basic combinations are defined in the model then the option to process envelopes and generate the additional summary tables will not be available and all envelopes (without association) and basic combinations defined in the model file will be extracted. If the groups are being processed and no envelopes or basic combinations are defined in the model then the option to process the envelopes in Microsoft Excel will become available. If multiple results files are loaded, for example if multiple rail load configurations have been analysed and the results loaded into Modeller, then the results for all of these results files will be extracted into the Microsoft Excel spreadsheet.

On opening the spreadsheet, if the model originally contained the UIC774-3 groups ("Track 1", "Track 2" and "Decks") then the results for each item will be placed into a separate worksheet within the spreadsheet. If the selection was used for post-processing a single worksheet will be placed into the Microsoft Excel spreadsheet. Additional worksheets will also be generated if enveloping is carried out in Microsoft Excel. If individual rail nodes were selected and post-processed the spreadsheet will contain a separate worksheet for each node that lists the rail stresses seen at the location of the node for all results processed.

Frame Results

Overview

The Frame Results processor (currently for restricted use only) allows the automatic tabulation of results for 2D and 3D frames to Microsoft Excel. Results from all loadcases, envelopes, basic combinations and smart combinations are output into a formatted spreadsheet for the parts selected.

To use

In order to use this facility the model must consist of 2D or 3D engineering thick beams (BEAM, BMS3 and BTS3 elements). In addition, only straight lines or combined lines containing only straight lines with these elements can be post-processed at present. Models can contain arcs and splines but results for these parts cannot be extracted using this facility.

Multiple straight lines can be selected for processing but should not contain any branching or closed loops. The lines will be grouped into line sets governed by their connectivity and output to the spreadsheet. For each line set a separate table and page is generated in the spreadsheet.

In addition to the results, Quality Assurance information about the LUSAS analysis is included at the top of each page along with a logo. The logo is defined by the **report_logo.bmp** bitmap image in the **\<Lusas Installation Folder>\Programs\Scripts\User** directory. This logo can be replaced to allow your own company logo to be automatically included on the spreadsheet.

The results can be output as individual line fractions (the default) or as chainage distances from the start of the first line in the selection to the end of the last line.

Limitations:

- Ensure that only post-processing beam elements is done when using this facility
- Only 2D or 3D thick engineering beam (BEAM, BMS3 and BTS3) elements are supported
- Output is only generated at the end nodes of the beam elements and may omit peak results and / or discontinuities of forces / moments that occur within elements due to internal beam loads.
- Output is reported in the Microsoft Excel Spreadsheet as values at each mesh node and these are stated at fractional distances along the parent line feature.

- Only straight lines or combined lines containing only straight lines are supported
- Only a single results file is supported
- Only Microsoft Excel is supported
- For outputting by line fractions the order of the output is moments followed by forces instead of the normal forces then moments based upon user requests.