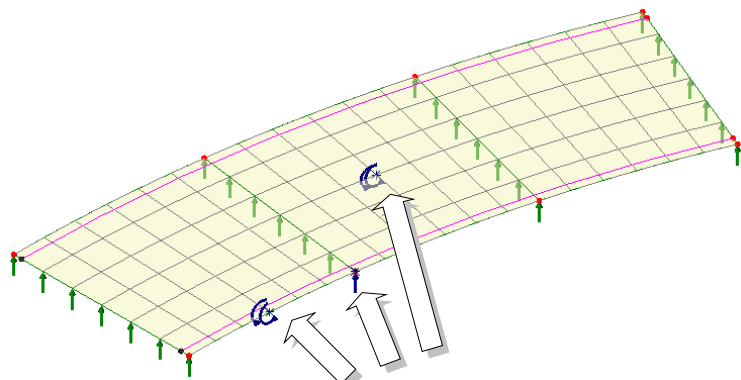# Bridge Slab Traffic Load Optimisation (Reciprocal Influence Method)

For LUSAS version:	21.0
For software product(s):	LUSAS *Bridge* and LUSAS *Bridge Plus*
With product option(s):	Vehicle Load Optimisation.

Description

This example uses the LUSAS Vehicle Load Optimisation (VLO) software option and the Reciprocal Influence Method to aid in the linear static analysis of a 3-span curved concrete bridge deck subject to Eurocode traffic loading.

Points of interest for influence surface generation

The structure is modelled using thick plate elements, representing a deck of inner radius 75m, outer radius 86m and thickness 0.7m. The deck has a width of 11m consisting of a 10m wide carriageway region and two 0.5m wide verges. The live loading is to be calculated for three defined influence surfaces using the LUSAS VLO software option.

Units used are kN, m, t, s, C throughout.

Note. LUSAS VLO is a software option for LUSAS *Bridge*. It extends the vehicle loading capabilities in LUSAS *Bridge* and produces worst-case traffic load effects more easily and much faster than by manual methods. LUSAS VLO generates the most onerous traffic load patterns according to a selected code of practice, based upon influence surfaces for specified load effects (moments, shears, reactions, stresses etc) at selected locations in the structure. A number of Eurocode National Annexes and other codes are supported. This example analyses a bridge deck using EN1991-2 Recommended Values. Subsequent analysis for comparison purposes is carried out using the UK and Swedish National Annex options.

Note. A separate example titled "Bridge Slab Traffic Load Optimisation (Direct Envelope Method)" shows the use of a different method which provides an optimised load effect of interest (e.g. My) at all locations in a feature (a line or surface) for which the Influence Envelope attribute has been assigned, and optionally for coexistent load effects (e.g. Fx, Fy, Fz, Mx, Mz) at those assigned locations.

Note. The reciprocal theorem method described in this example provides less functionality than the Direct Method, but it is faster when only a limited number of influences are required at strategic locations on a bridge deck (as in this example).

Modelling Objectives

The operations in the creation of the model are as follows:

- ❑ Sweep a curved deck from a line.
- ❑ Mesh the Surfaces with thick plate elements (regular mesh).
- ❑ Define and assign geometric properties to describe the slab thickness.
- ❑ Define and assign material properties.
- ❑ Define and assign bearing supports.
- ❑ Define and assign dead loading.
- ❑ Define three influence surfaces which will allow calculation of the most onerous traffic load pattern for:
    1. Mid-span bending, inner curve, first span.
    2. Mid-span bending, mid-node, second span.
    3. Reaction at the first internal support.
- ❑ Use LUSAS VLO to calculate the most onerous traffic load pattern for the three influence surfaces.

Keywords

2D, Plate, Slab, Modelling, Eurocode, Element Axes, Influence Surface, Reciprocal Method, LUSAS VLO, Vehicle Load Optimisation, Load Combination, Bending Moments, Reactions, Transformed Results, Peak Values

Associated Files

Associated files can be downloaded from the user area of the LUSAS website.

❑ **deck_modelling.lvb** carries out the modelling of the slab deck, including influence locations, for subsequent use with the LUSAS VLO software option.

Vehicle load optimisation in LUSAS

Vehicle load optimisation (VLO) makes use of influence surfaces and influence analysis to identify the most onerous vehicle loading patterns on bridges for a chosen design code and to apply these loading patterns to LUSAS models. A vehicle load optimisation wizard provides the means of defining parameters, for a particular design code, to generate the most critical traffic loading pattern for each influence shape under consideration. In this example, the bridge deck is loaded according to EN1991-2 Recommended Values.

Modelling

Running LUSAS Modeller

For details of how to run LUSAS Modeller see the heading *Running LUSAS Modeller* in the *Introduction to LUSAS Worked Examples* document.

Note. This example is written assuming a new LUSAS Modeller session has been started. If continuing from an existing Modeller session select the menu command **File>New** to start a new model file. Modeller will prompt for any unsaved data and display the New Model dialog.

Creating a new model

- Enter a File name of **Deck**

- Use the default User-defined working folder.

- Ensure an Analysis type of **Structural** is set.

- Select an Analysis Category of **2D Grillage/Plate**

- Set Model units of **kN,m,t,s,C**

- Leave the Timescale units as **Seconds**

- Select a Startup template of **2D Plate**.

- Ensure the Layout grid is set as **None**

- Enter the Title to be **Deck analysis using traffic load optimisation**
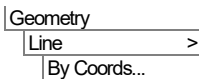
- Click the **OK** button.

The Attributes 🔴 treeview will be populated with potentially useful basic line mesh, geometric and support entries appropriate to the settings made on the new model dialog.

Note. The Undo button 🔙 may also be used to correct a mistake. The undo button allows any number of actions since the last save to be undone.

Geometry

In this model, one span of the complete bridge deck is modelled in its entirety (including specifying geometric properties, material, supports, etc.) before it is then copied to form the complete 3-span structural model.
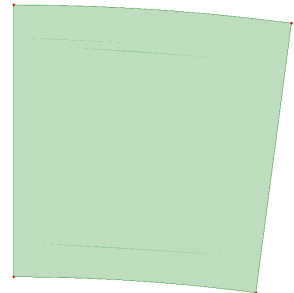
Geometry	
Line	>
By Coords...	

Enter coordinates of (**0,75**) and (**0,86**) to define a Line representing the end of the deck.

- Click the **OK** button to finish.

- Select the Line just drawn.

Geometry	
Surface	>
By Sweeping…	
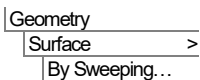
Select the **Rotate** option and enter an angle of **-7.5** degrees to rotate about the **Z-axis** about the origin **0,0**

- Click **OK** to sweep the Line to create a surface.

Meshing

This analysis will consider only out-of-plane bending effects, and no in-plane behaviour therefore plate elements will be used. Note that when thick plates are used care must be taken to ensure that results are transformed correctly when plotting contours and values of bending moments.

- With the whole model selected, drag and drop the surface mesh dataset **Thick plate, linear order** from the 🔴 Treeview onto the selected features.

The default number of line mesh divisions of 4 divisions per line will be drawn. This gives a somewhat coarse mesh so the default number of line mesh divisions will now be changed.
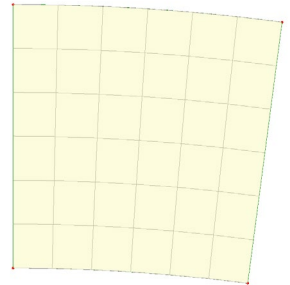
File
　Model Properties...

- With the **Meshing** tab selected, set the default number of mesh divisions to **6** and click **OK**

The new mesh divisions will be displayed.

Geometric Properties

Attributes
　Geometric　　>
　　Surface...

- Enter a thickness of **0.7**

The eccentricity box should, in this case, be left blank. Using an eccentricity would infer some in-plane effects, when, as described above, this analysis is intended to consider only out-of-plane effects. In 3D structures where behaviour is dependent upon both flexural and membrane effects, shell elements may be used.

- Enter the dataset name as **Slab thickness** and click **OK**

- With the whole model selected, drag and drop the geometric dataset **Slab thickness** from the 🔴 Treeview onto the selected features.

Geometric property assignments are visualised by default.

Material Properties

- With the whole model selected, drag and drop the material dataset **Concrete (Ungraded | Concrete)** from the 🔴 Treeview onto the selected features and assign to the selected surfaces by clicking the **OK** button.
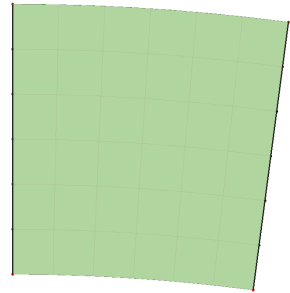
Supports

Attributes
　Support

- Set the Translation in the **Z**-direction to be **Fixed.**

- Enter a name of **Fixed in Z** and click **OK.**

- Select the two lines on the left and right of the surface.

- Drag and drop the support dataset **Fixed in Z** from the ⚬ Treeview onto the selected Lines.

- Ensure the **Assign to lines** and **All analysis loadcases** options are selected and click **OK**
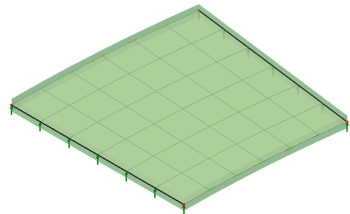
The supports will be visualised on the model.

To check the location and direction of the supports:

⊕ Use the isometric view button to rotate the model.

- To complete the full model of the bridge deck, select the whole model using the **Ctrl** and **A** keys together.

Geometry	
Surface	>
Copy...	

🎚️ Select the **Rotate** option and copy the features selected through an angle of **-7.5** degrees about the **Z-axis** and about the origin **0,0**

- Enter the number of copies as **2** and click the **OK** button.

The full 3-span model of the bridge deck will be created.
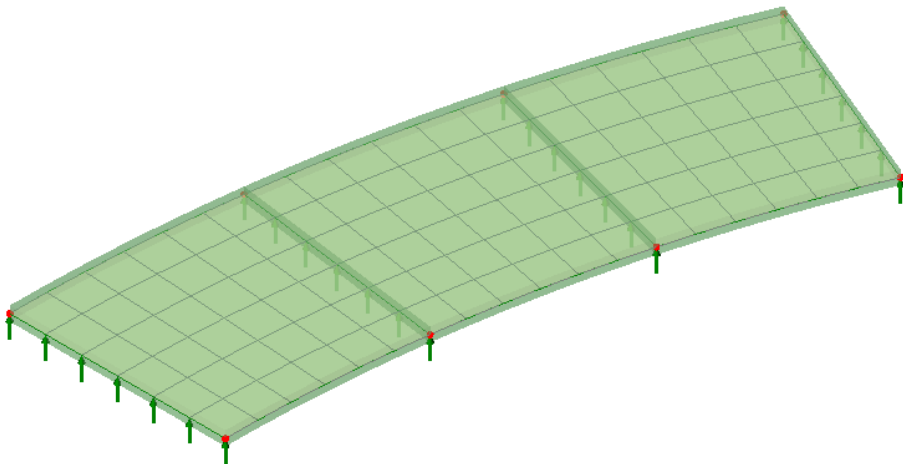
Note. Many of the more common tasks are provided in a context menu for the View window. With the model geometry selected clicking the right-hand mouse button within the view will display a context menu with **Copy**, **Delete**, **Move** and **Sweep**.

Self-Weight

- With the whole model selected, drag and drop the loading dataset **BFP1 (Gravity – vertical)** from the 🟣 Treeview onto the selected features. Ensure the **Assign to surfaces** option is selected and click **OK** to assign to **Analysis 1**, **Loadcase 1**.

The gravity loading will be visualised on the model.
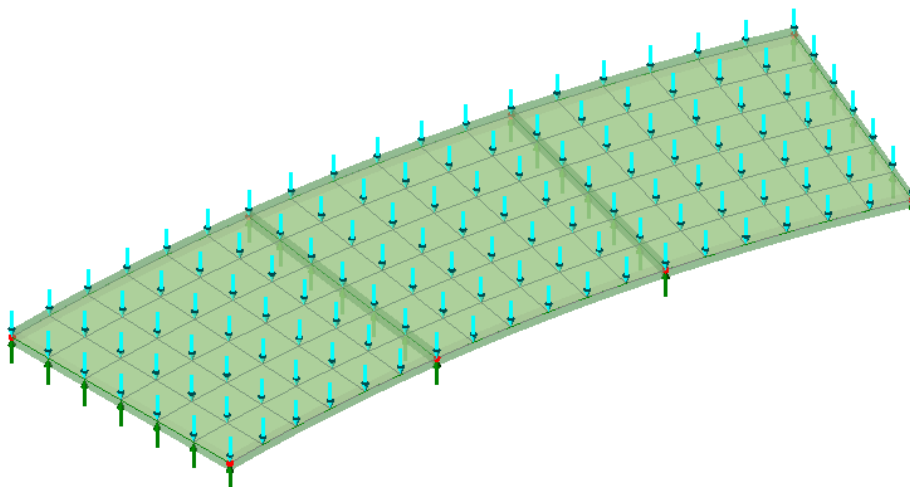
- In the 🔍 Treeview, using the right-hand mouse button, select **Loadcase 1** and select the **Rename** option. Change the loadcase name to **Self Weight**

Defining a local coordinate system

Since this model is a curved deck a cylindrical local coordinate system will be used for the direction definition. Specifying a direction definition sets the vertical, longitudinal and transverse axes for a model to assist with model orientation and the calculation of particular effects. A local direction definition is used for aligning influence attributes along a singly curved bridge deck.

Attributes
Local Coordinate…

- Select the **Cylindrical** option and ensure that the **Z-axis** option is set. Enter a dataset name of **Cylindrical about Z-axis** and click **OK**

To use this local coordinate system:

Tools
Direction definition…

- In the Longitudinal section of the dialog set the **Local axis** to be **Cylindrical about Z-axis** for **Theta** and click **OK**.

Influence Attributes

In order to use the vehicle load optimisation facility, it is necessary to identify what quantity is to be optimised and at what location in the structure. This is achieved by specifying appropriate influence surfaces, which is done by defining and assigning influence attributes to the model. LUSAS generates influence surfaces for each of the chosen locations and load effects, and in this case, by using the Muller-Breslau (reciprocal) theorem. Note that Direct Method influence attributes are also available and provide different capabilities. See the online help for more details.

To make it easier to select the nodes required to define the influence parameters the geometric and load visualisation will be removed from the display.

Select the fleshing on/off button to turn-off the geometric visualisation.

Select the loading on/off button to turn-off the loading visualisation.

- Right-click and turn off the display of the **Geometry** layer in the Treeview.

For this example, three influence surfaces will be defined.

Influence Surface Definition - Edge Mid-span Bending

The first influence attribute to be defined will be used to investigate mid span edge bending in the first span.

Attributes
  Influence   >
    Reciprocal
    Theorem...

- Select a **Moment** influence type **About transverse** influence direction for a **Negative** displacement direction (because the maximum sagging moment is of interest).

- Enter the influence attribute name as **Bending span 1** and click **OK**.
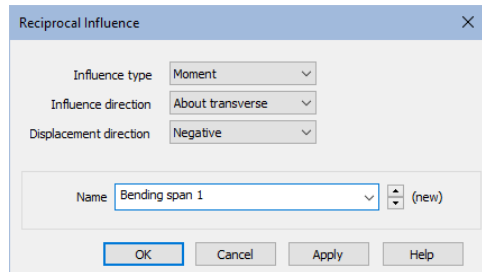
- Select the mid-span node at the inside edge of the first span.

- Drag and drop the influence attribute **Bending span 1** from the Treeview onto the selected node.
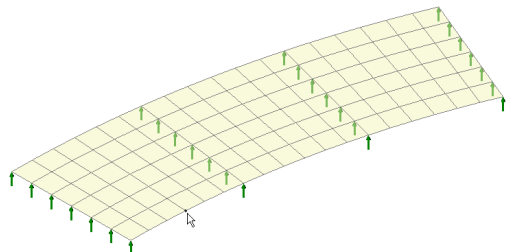
This adds an influence assignment

(with a corresponding coordinate) to the 🕒 Treeview.

For this example, and for speed and clarity reasons, only one node will be selected for each influence attribute.

⚠️ **Caution.** Reciprocal influence attributes can be assigned to as many nodes or points on the model as necessary <u>but should only be assigned to those nodes or points for which they are applicable</u>. For example, the Bending span 1 influence attribute (defined for a negative displacement direction) should only be assigned to those nodes in the first span of the bridge for which a negative influence shape applies. For nodes where a positive influence shape exists a Reciprocal influence attribute with a positive displacement direction should be assigned. In general, when using Reciprocal influence attributes, the influence shapes for nodes of interest should be viewed after a solution is obtained to ensure that they have been defined for the influence shape seen.

📝 **Note.** A benefit of using Direct Method influence attributes over reciprocal theorem ones is that they can be assigned to the whole model regardless of whether nodes lie in a positive or negative region of an influence shape.

Influence Surface Definition – Mid-span Bending Span 2

The second influence attribute to be defined will be used to investigate mid-span bending in the middle of the slab in the second span.

Attributes	
Influence	>
Reciprocal Theorem...	

- Select a **Moment** influence type **About transverse** influence direction for a **Negative** displacement direction (because we are interested in the maximum sagging moment).

- Enter the influence attribute name as **Bending span 2** and click **OK**.

- Select the node at mid-span of the second span.

- Drag and drop the influence attribute **Bending span 2** from the 🔵 Treeview onto the selected node.
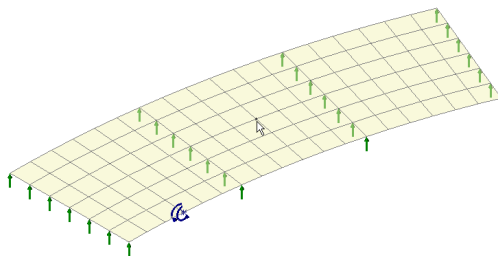
This adds the influence assignment to the 🕒 Treeview.

📝 **Tip.** For this example, giving influence attribute names that relate to each span and support (rather than just defining one influence attribute called 'Bending' or 'Reaction' enables easier identification of the influence results in the 🕒 Treeview.

Influence Surface Definition - Maximum Reaction

The third influence attribute to be defined will be used to investigate the maximum reaction at the inner edge of the second line of supports.

Attributes
  Influence   >
    Reciprocal
    Theorem...

- Select a **Reaction** influence type in the **Vertical axis** influence direction for a **Positive** displacement direction.

- Enter the influence attribute name as **Reaction support 2** and click **OK**.

- Select the node at the edge of the first support as shown.

- Drag and drop the influence attribute **Reaction support 2** from the Treeview onto the selected node.
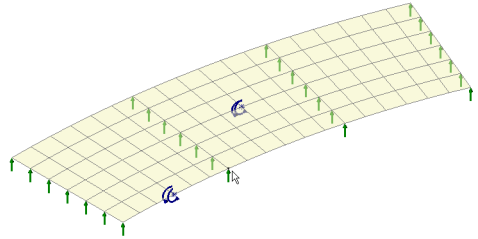
Checking the Defined Influence Points

Select the Home button to return to a plan view of the model.

The influence visualisations will now be as shown.
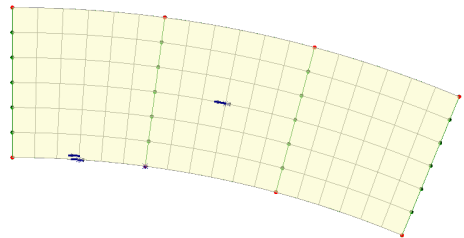
Define the Kerb Lines

Kerb lines are used to define the extent of a loadable carriageway.

- Turn on the display of the **Geometry** layer in the Treeview.

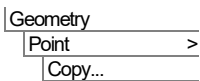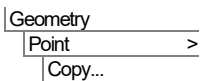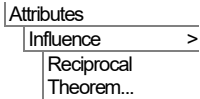- Select the Point at the left-bottom corner of the deck.

Geometry
  Point   >
    Copy...

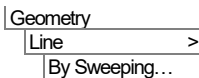Enter a translation of **0.5** in the **Y** direction. Click **OK**.

- Select the Point just created.

Geometry
  Point   >
    Copy...

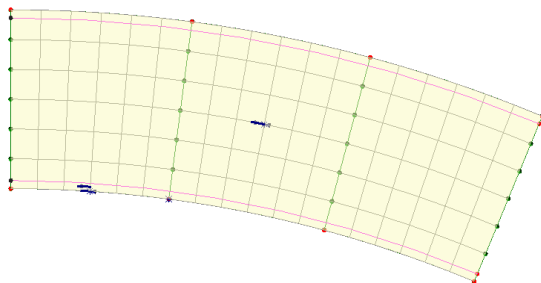Enter a translation of **10** in the **Y** direction. Click **OK**.

- Select the two Points that have been created.

 Select the **Rotate** option and enter an angle of **-22.5** degrees to rotate about the **Z-axis** about the origin **0,0**

- Click **OK** to sweep the Points to create a two lines representing the kerbs.

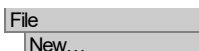## Save the model

 Save the model file.

This completes the preparation of the model for influence analysis.

Rebuilding the Model

If errors have been made in the modelling of this example that for some reason you cannot correct, a file is provided to re-create the model information correctly, allowing a subsequent analysis to be run successfully. You may download this file from the user area of the LUSAS website.
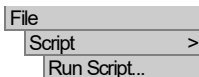
❑ **deck_modelling.lvb** carries out the modelling of the example including the loading.

 Start a new model file. If an existing model is open Modeller will prompt for unsaved data to be saved before opening the new file.

- Enter the file name as **deck**

- To recreate the model, select the file **deck_modelling.lvb** that was downloaded and placed in a folder of your choosing.
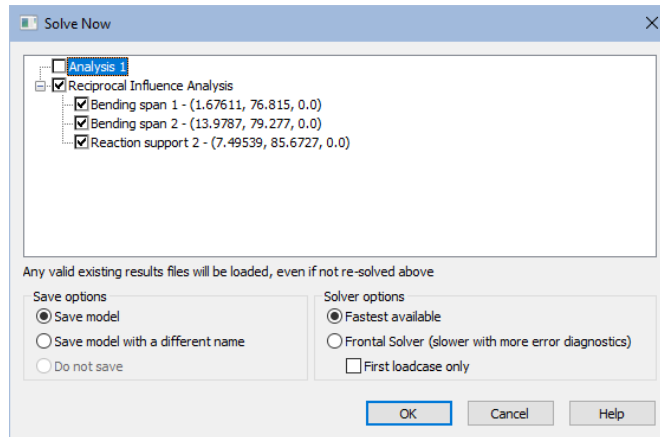
Running a Reciprocal Influence Analysis

If it is required to visualise influence surfaces and confirm they are correct before they are used to generate optimised loading patterns, this can be optionally done by solving a Reciprocal Influence Analysis in isolation from any other analyses.

- Press the Solve Now button and <u>deselect</u> the **Analysis 1** option to leave just the **Reciprocal Influence Analysis** check box ticked. Click the **OK** button.

- When solved, the 🕒 Treeview will contain one results file for each influence surface.
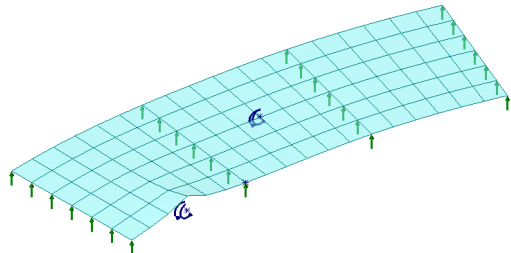
Visualising Influence Surfaces
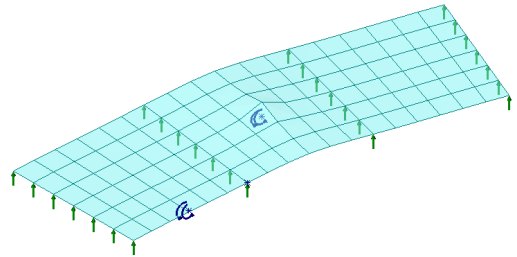
⊕ Rotate the model to an isometric view.

- From the 🕒 Treeview right-click on the Reciprocal Influence Analysis results loadcase **Bending span 1** and select the **Set Active** option. An **Influence Shape** entry will be added to the 🔲 Treeview.

- Ensure the **Influence Shape** layer is present and turned on.

- If present, turn-off the display of the **Mesh** and **Geometry** layers from the 🔲 Treeview.

- In the 🔲 Treeview double-click on the **Attributes** entry, find and right-click on the **Supports** tab, and select the **All** button. Select the option **From results file** and click **OK.**

Bending span 1 (moment) influence surface

- From the 🕒 Treeview right-click on the Reciprocal Influence Analysis results loadcase **Bending span 2** and select the **Set Active** option.

**Bending span 2 (moment) influence
surface**

- From the 🕒 Treeview right-click on the Reciprocal Influence Analysis results loadcase **Reaction support 2 (reaction)** and select the **Set Active** option.

**Reaction support 2 (reaction)
influence surface**
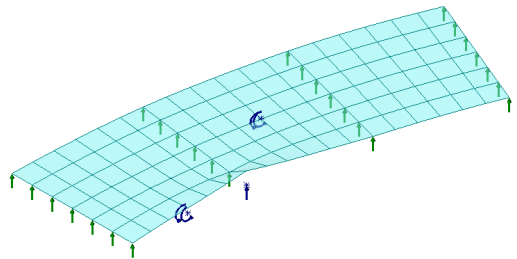
Using the Vehicle Load Optimisation facility to calculate the most critical loading patterns

The vehicle load optimisation software option automates the creation of traffic load patterns in accordance with a selected design code for locations specified on the model. The example as written uses EN1991-2 Recommended Values, which is supported by the LUSAS VLO software option. Other EN1991-2 National Annexes may be chosen. Results for selected other National Annexes are shown at the end of the example.

- Turn-off the display of the **Influence shape** layer and turn back on the display of the **Mesh** and **Geometry** layers from the 🗔 Treeview.

Select the kerb lines

Prior to running the vehicle load optimisation, the kerb positions defining the extent of the loadable area of carriageway must be selected.

- **Select the two lines** representing the kerb positions / extent of the traffic lane.
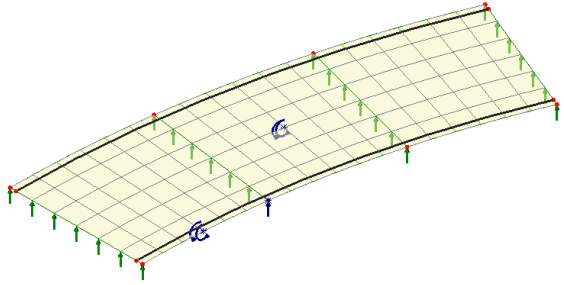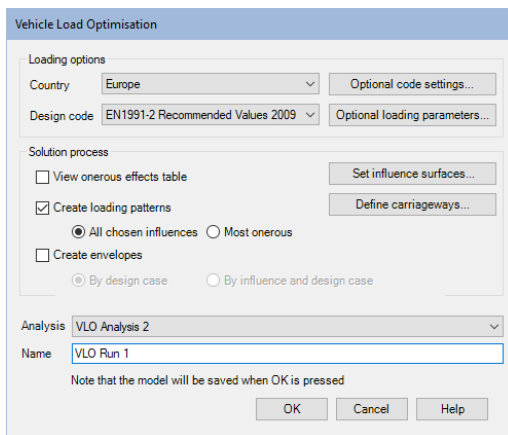
Define Vehicle Load Optimisation parameters

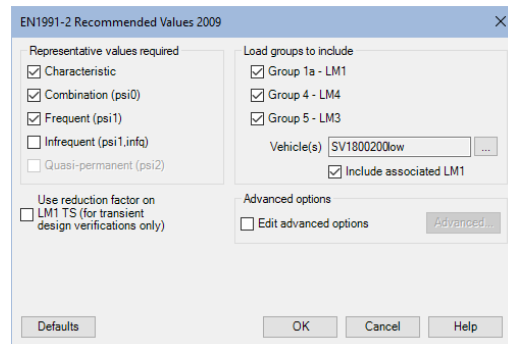Bridge
 Vehicle Load
 Optimisation…
  VLO Run

- Select **Europe** from the Country drop down list.

- Select **EN1991-2 Recommended Values 2009** from the Design code drop down list.

- <u>Deselect</u> the **View onerous effects** table.

- Select **Create loading patterns** for **All chosen loadcases**

- **VLO Analysis 2** will be automatically entered for the Analysis entry in the 🕑 Treeview. (Note that an alternative name can be entered by selecting the New option from the drop-down list).

- Ensure the Name is set as **VLO Run 1**

Browse the optional code settings

- Select the **Optional code settings** button and the optional loading parameters dialog will appear for the design code selected.

On this dialog any representative values that are required and load groups that are to be included can be specified. Special vehicle types can be specified, and advanced settings can be defined.

Note that a single special vehicle (**SV1800200low**) is specified as a default in these recommended values and that a vehicle(s) appropriate to the structure being designed should be specified in practice.

- For this example leave the dialog as it is but <u>un-check</u> the **Infrequent** option, then click the **OK** button to accept the remaining default values and return to the main VLO dialog.

Browse the optional loading parameters

- On the main VLO dialog, select the **Optional loading parameters** button

- On this Options dialog ensure the **Longitudinal increment** is set to **0.25**, the **Transverse increment** is set to **0.25** and the Vehicle direction is set to **Both.**

- The option to **Use rationalised placement method** should be set.

- Click **OK** to return to the main Vehicle Load Optimisation dialog.

Define the carriageways

- On the main VLO dialog, select the **Define carriageways…** button.

Because the kerb lines have been selected the carriageway shape and angle of carriageway are known. **Kerbs from selection** will be automatically selected.

- Click **Apply** to return to the main Vehicle Load Optimisation dialog.

Define the influence surfaces

- On the main Vehicle Load Optimisation dialog, select the **Set influence surfaces** button.

- Ensure the **Include all influence surfaces** option is selected.

- Ensure the **Positive** checkbox option is selected for each influence.

Note. For an influence analysis carried out using Reciprocal Method attributes, the influence shape for a chosen influence location will determine whether Positive or Negative should be chosen. For this example, vehicle loading placed onto the positive areas will create the maximum negative moment required.

- Click **OK** to return to the main load optimisation dialog.

- Press the **OK** button on the main VLO dialog to run the vehicle load optimisation analysis.

This loading optimisation will take just seconds on the latest computers, and when successfully completed, Characteristic, Combination and Frequent results table entries

and results loadcases and Loading folders will appear in the 🔍 Treeview for each influence as shown in the following image.
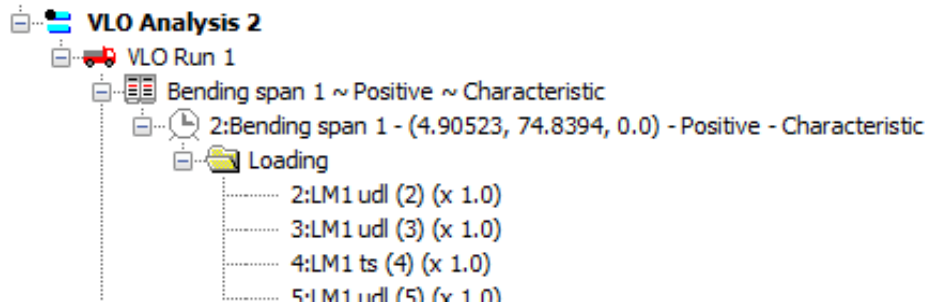
Note. If 'Create loading patterns' was not selected on the main VLO dialog the most onerous loading effects can be created individually when viewing VLO results table entries by using a 'Create Loading' button that appears instead of the 'Loading Created' one.

So, as can be seen, the VLO run currently includes loading arrangements for influence locations but no results. Whilst loading patterns can be visualised, results are available only after the VLO analysis has been solved.

Visualising Load Definitions

- In the 🪟 Treeview ensure the **Influence shape** layer is turned-off, and the **Mesh** layer is turned on.

- In the 🪟 Treeview turn-off the display of the G**eometry** layer.

Select the loading on/off button to **turn-on** the loading visualisation.

If necessary, select the supports on/off button to **turn-on** the support visualisation.

The load definition may be visualised for each loadcase as follows:

### Viewing Characteristic Loading for Edge Mid-span 1

- In the 🔍 Treeview, expand the **VLO Analysis 2** entry, expand the **VLO Run 1** entry, and expand the **Bending span 1 – Positive – Characteristic** entry.

- Right-click on the loadcase **Bending span 1 - (x,y) – Positive - Characteristic** and pick the **Set Active** option.
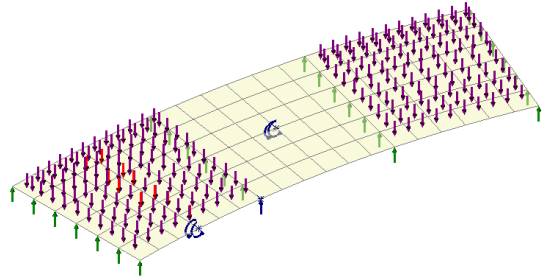
Here, it can be seen that Group 1a dominates and the load pattern is made up of LM1 tandem systems and LM1 UDL patches. The 10m carriageway width accommodates three 3m wide lanes. With reference to EN1991-2:2003 table 4.2 and clause 4.2.4 (4), Lane Number 1, with the heaviest tandem and udl loads, is positioned adjacent to the influence definition on one side of the deck. Moving away from the location of interest, lanes 2 and 3 appear in order. The remaining area (1m wide) appears on the far side of the bridge deck. Spans 1 and 3 only are loaded (span 2 is not part of the adverse area).

Viewing Characteristic Loading for Mid-span Bending Span 2

- In the 🔍 Treeview right-click on the loadcase **Bending span 2 - (x,y) – Positive - Characteristic** and pick the **Set Active** option.
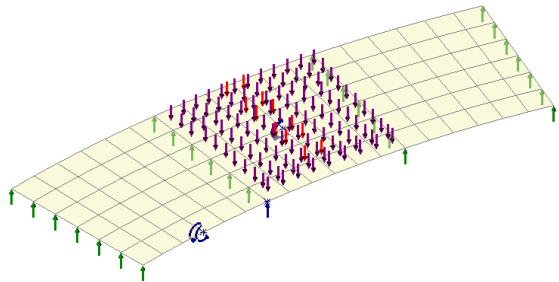
Here, again, Group 1a dominates and the load pattern is made up of LM1 tandem

systems and LM1 udl patches. Lane Number 1, with the heaviest tandem and udl loads, is positioned adjacent to the influence definition, near the middle of the deck. Lanes 2 and 3 appear each side of Lane 1 and the 1m wide remaining area appears on the opposite side of the bridge deck compared to that when considering the previous loadcase. This illustrates how the ranking and location of lanes is modified as appropriate (EN1991-2:2003 clause 4.2.4(2)). Span 2 only is loaded (spans 1 & 3 are not part of the adverse area).

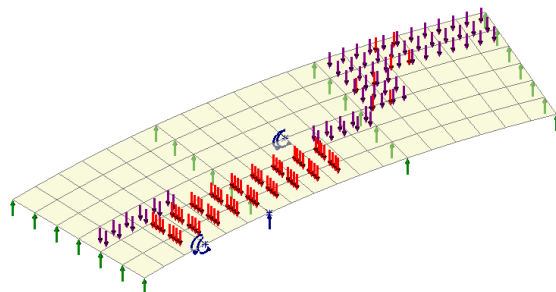### Viewing Characteristic Loading for Reaction at Support 2

- In the 🔍 Treeview right-
  click on the loadcase
  **Reaction support 2 - (*x,y*) –
  Positive - Characteristic**
  and pick the **Set Active**
  option.

In this last example, giving
maximum reaction at the inner
support, Group 5 dominates and
the load pattern is made up of LM3 with associated LM1 tandems and udl patches. The
SV1800/200 is positioned adjacent to the influence definition, near the edge of the deck
over spans 1 and 2. This is considered to be Lane Number 1 (EN1991-2:2003 Annex A
clause A.3). Lanes 2 and 3 appear on the far side of the deck and are loaded only in the
adverse area, which happens to be in span 3. The 1m wide remaining area appears
between lanes 1 and 3, illustrating yet another arrangement of lane rank and location,
used to generate the most onerous traffic load pattern.

Note. As previously stated, the VLO run creates loading arrangements but no results.
Results are available only after the VLO analysis has been solved.

Running a VLO Analysis

Only the VLO analysis has to be solved in order to produce the results for the
optimised loading arrangements for each influence assignment.

- Press the **Solve Now** 🟰 button.

The Solve Now dialog indicates
that the Analysis 1 (self-weight
loading) and the Reciprocal
Influence Analysis results are up
to date and that they do need to
be solved again.

VLO Analysis 2 is checked
because the VLO run has not
been solved yet.

Note. As well as showing the
status of each analysis, the Solve
Now dialog also allows analyses to be solved in isolation from each other, if desired, so
that self-weight (defined in Analysis 1) could be solved separately from the live
loading.
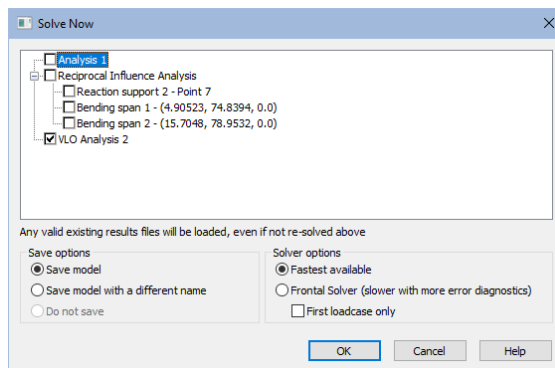
Viewing Load Combinations

The LUSAS VLO facility outputs a design value – Characteristic, Combination or Frequent, with the meaning of each given in the VLO Help. In this example the vehicle loading is assumed to be the dominant effect and all other variable actions (wind, snow, temperature etc.) are being ignored. For this case, and in accordance with EN1990 6.4.3.2(3) equation 6.10, the loads can be combined as γ_G*[dead loads] + γ_Q*[traffic loads]. According to clause A2.3.1(4), for the design of structural members not involving geotechnical actions, the γ factors can be found in Table A2.4(B) as γ_G = 1.35 and γ_q = 1.5 for traffic. So, to define a basic combination:

Analyses
  Basic Combination

On the Combination Properties dialog:

- From the **loadcase** listing add **Self Weight** to the included panel.

- Add **Bending span 1 - (*x,y*) – Positive - Characteristic** to the included panel.

- In the grid, enter factors of **1.35** for self-weight loadcase and **1.5** for the Bending span 1 loadcase.

- Change the combination name to **Combination Bending Span 1** and click the **OK** button to update the combination in the 🕒 Treeview.

Plotting Contours of Moment and Peak Values

- In the 🕒 Treeview right-click on the loadcase **Combination Bending span 1** and pick the **Set Active** option.

- With no features selected click the right-hand mouse button in a blank part of the graphics window and select the **Contours** option to add the contours layer to the 🔲 Treeview. Note that by default, and in accordance with established theory, thick plate element results are given along a chosen global axis. Because we wish to look at radial results along the deck the cylindrical local coordinate system must be selected in order to make the appropriate results components available for selection.

- Select Entity **Force/Moment** and then select the **Transformed** button and select the **Specified local coordinate** option. Ensure **Cylindrical about Z-axis** is selected in the drop-down list. Ensure **Shell plane for resultants** is set to **r/theta** and click **OK.**

- Now, as a result of transforming the results, a new component is available in the Component drop down list. Selected moments in the theta direction **Mt**

- Click the **OK** button to display contours of moments in the longitudinal direction.

- With no features selected
  click the right-hand mouse
  button in a blank part of
  the graphics window and
  select the **Values** option to
  add the values layer to the
  Treeview.
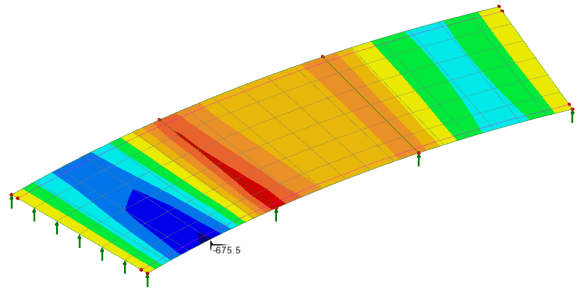
The values properties dialog
will be displayed.

- Select Entity **Force/Moment** and Component moments in the theta direction **Mt**,
  and then select **Averaged nodal.**

- Select the **Values Display** tab.

- Deselect the **Maxima** option since the sagging moment is negative (Minima will
  then be automatically selected). Change the percentage of values to display to **1**

- Set the number of significant figures to **4**

- Click the **OK** button to display contours of moments in the longitudinal direction
  with the bending moment value displayed.

Plotting stress contours and peak values for other load combinations and for other
influence points of interest may be obtained in a similar manner to that described
above.

Save the model

File
Save

Save the model file.

Note. When the model file is saved after results processing, all load combinations,
envelopes, and graph datasets, if defined, are also saved and therefore do not have to be
re-created if the model is amended and a re-analysis is done at a later date.

This completes the example.

Discussion

## Traffic Load Optimisation for EN1991-2 design codes

To illustrate general usage this example analysed traffic load optimisation to EN1991-2 using the Recommended Values design code option.

By re-selecting the lines representing the kerbs on the Geometry layer and selecting an appropriate design code on the main Vehicle Load Optimisation dialog and re-running the traffic load optimisation analysis, the results for other supported EN1991-2 Design Code and National Annexes values can be similarly obtained.

When re-running the LUSAS VLO facility on the existing model care should be taken to ensure that the correct loadcase is included in the load combination and that the correct load factor has been specified.

## Traffic Load Optimisation for EN1991-2 UK 2009

By following a similar procedure to that previously described the optimised load definitions for EN1991-2 UK (using a single SV80 special vehicle) can be obtained along with a contour plot for a basic combination of self-weight and combination results for bending in span 1, as shown in the following images.
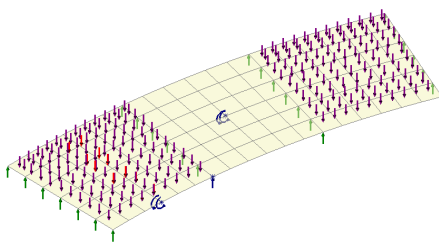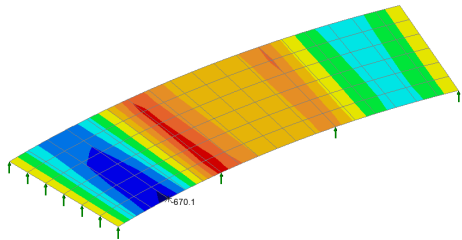

Optimised Characteristic Loading for
Influence Point at Edge Mid-span 1
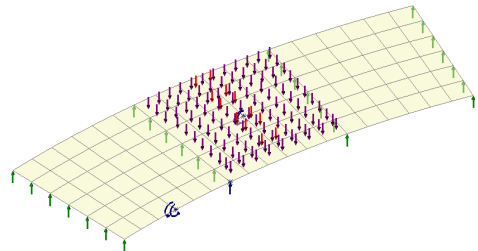
Optimised Characteristic Loading for
Influence Point at Mid-span Bending Span 2
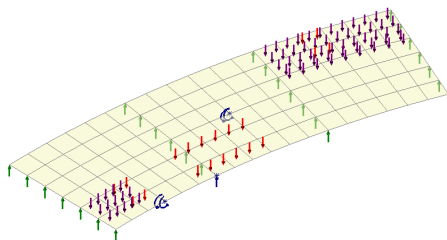
Optimised Characteristic Loading for the
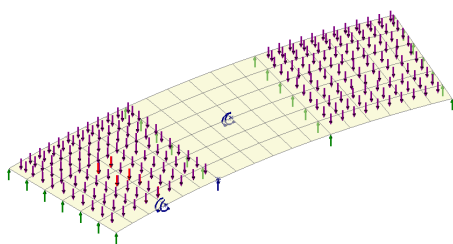Influence Point at Reaction at Support 2

Combination results for Influence Point
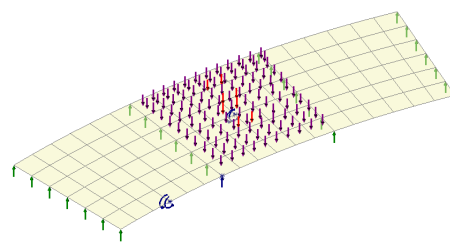at Edge Mid-span 1

Here, the two bending influences show Group 1A loading to be dominant. The LM1 tandem and LM1 udl are however different in value to those in the earlier example due to the use of the appropriate adjustment factors from NA to BS EN1991-2 Table NA.1. The reaction influence shows the Group 5 to be dominant. The UK SV80 appears in Lane Number 1, with associated LM1 also appearing in Lane Number 1, with a minimum 5m distance from the SV to the first axle of the LM1 TS. Lane rank and location are similar to those described in the earlier example.

## Traffic Load Optimisation for EN1991-2 Sweden 2009

By following a similar procedure to that previously described the optimised load definitions for EN1991-2 Sweden (using all Complementary load model loads from 'a' to 'l') can be obtained along with a contour plot for a basic combination of self-weight and combination results for bending in span 1, as shown in the following images.
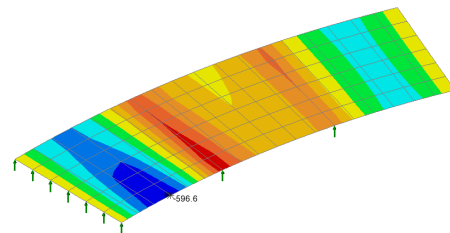

Optimised Characteristic Loading for the
Influence Point at Edge Mid-span 1

Optimised Characteristic Loading for the
Influence Point at Mid-span Bending Span 2
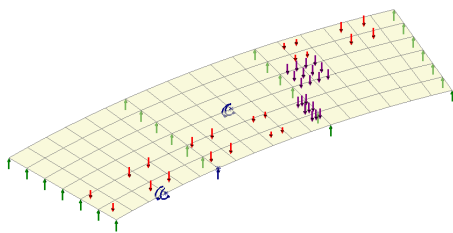
Optimised Characteristic Loading for the
Influence Point at Reaction at Support 2

Combination results for the Influence Point at
Edge Mid-span 1

Here, the two bending influences show Group 1A loading to be dominant. In accordance with SIS/PAS NA to EN 1991-2:2003 clause 4.3.2(3) and VVFS 2009:19 Chapter 6, clause 4, Table 7.1, adjustment factors for the LM1 tandem and LM1 udl are applied – hence there is no LM1 tandem in Lane Number 3 (factor $\alpha_{q3}=0$). Other comments on the EN1991-2 load patterns above also apply here. The reaction influence shows the Swedish Complementary Load Model to be dominant. Type L vehicles appear in Lanes 1 & 2, with udl q appearing in Lane 3 and no loading in the "remaining area". Lane rank and location are similar to those described in the earlier example.