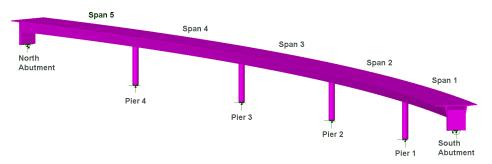
# Vehicle Load Optimisation of a Box Beam Bridge

For LUSAS version:	20.0
For software product(s):	Bridge and Bridge Plus
With product option(s):	LUSAS Vehicle Load Optimisation

# **Description**

A 5-span concrete box curved bridge with end spans of 45m and three internal spans of 50m is modelled with beams to illustrate the use of the Direct Method Influence (DMI) attributes and Vehicle Load Optimization (VLO) facilities in LUSAS.



A pre-defined base model with assigned mesh, material and support attributes is supplied for use with this example.

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

#### **Objectives**

The required steps in the analysis consist of:

- □ Run a Direct Influence Method Analysis to calculate the effects of a unit load
- Define influence attributes and assign them onto the model
- □ Create influence surfaces
- □ Create optimised vehicle loading results with VLO

#### Keywords

**3D**, Beam, Bridge, Concrete, Box Girder, Direct Method Influence, Vehicle Load Optimisation

#### **Associated Files**

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



**curved\_bridge.lvb** creates an initial basic beam model of the bridge.

# Modelling



**Note.** Model and results images included in this example were captured in an earlier version and may differ in appearance from those seen and obtained from this version.

## **Running LUSAS Modeller**

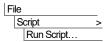
For details of how to run LUSAS Modeller, see the heading *Running LUSAS Modeller* in the Examples Manual Introduction.

# **Creating a Model**

- File New...
- Enter a file name of **curved\_bridge**.
- Use the default User-defined working folder.
- Ensure an Analysis type of **3D** is set.
- Click the **OK** button.



**Note.** There is no need to enter any other new model details when the intention is to run a script to build an initial model, since the contents of the script will overwrite any other settings made.

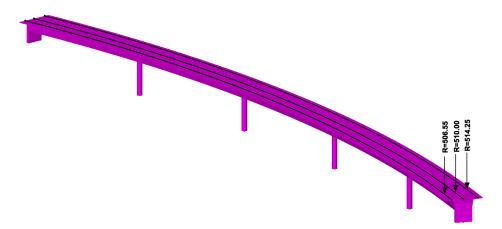


To create the model, open the read-only file **curved\_bridge.lvb** that was downloaded and placed in a folder of your choosing.

## **Model Description**

The 5-span, box girder bridge has spans of 45m, 50m, 50m, 50m and 45m, all set-out to a horizontal curvature of 510m radius. For simplicity the cross section of the bridge is considered constant across its length, and the deck is supported on 5.5m high abutments and 12.5m high circular pier columns, which are considered fully integral with it. The box girder of the deck, including cantilever outstands, is 11.5 m wide. The carriageway itself is 7.7m wide, with space for a footway on the inside and hard standing margin on the outside.

The deck is modelled as a series of beams along the centreline of the carriageway at a radius of 510m. The kerb lines defining the extent of the loadable carriageway are defined at the deck level, above the nodal line, using lines of 506.55m radius and 514.25m radius – a difference of 7.7m, which relates to the width of the carriageway.



For the purposes of this example the geometric lines of this model have been assigned a line mesh of thick beam elements with a specified element length of 5m. A cylindrical coordinate system has been used to orientate the abutments and piers supports. Concrete EU  $f_{ck}$ =50MPa has been assigned to all members. Pin supports restrain the base of the piers and other pin supports, having the additional fixity, THY, are used at the abutments. A local cylindrical coordinate system has been assigned to the end points to orientate the supports as needed.

The Direct Method Influence method is to be used for vehicle load optimisation analysis instead of the Reciprocal Theorem because it allows the structure to be analysed as a simple line-beam model.

#### **Defining a reference path**

A reference path is to be created for use as a centreline for the bridge and also to define a grid which will be used for the loading locations required to create influence shapes in Direct Method Influence Analysis. The use of a reference path is recommended for most vehicle loading and load optimisation situations.

- In the 🔯 Treeview right-click on **Deck** and click **Select Members** to select the lines representing the bridge centreline.
- Change the name to be **Bridge Centreline** and click **OK**. A corresponding path definition entry will be created in the  $\sqrt{2}$  Treeview.

**Note.** The direction of the reference path will control the order of any created influence entries in the  $\bigcirc$  Treeview.

#### **Defining a search area**

A search area is to be used to limit the area or features over which loads are applied, so that the effect of the load on certain features may be removed from the analysis. It is strongly recommended to define a search area for VLO analyses.

- Change the name to **Deck** and click **OK**.
- In the still selected, drag and drop the newly defined **Deck** search area on to the model to assign the attribute.

#### **Direct Method influence analysis**

Direct Method influence analysis is a means of creating an influence where the effect of a specified point load is assessed at each node or grid location on a loadable area of a structure. The value of the load effect of interest at each specified location is then used to construct an influence line or surface for that location. The direct method influence enables the construction of influence surfaces for any results component at any node in the structure.

Direct Method influence analysis can be carried out either by defining and assigning influence attributes to the model before carrying out an influence analysis (as has to be done for the Reciprocal Theorum Method), or by pre-solving for the nodes in a search area, or for the points on a loading grid, (without having any influence attributes assigned to the model) to evaluate the effect of a unit load at the beginning. This optional approach caches the results for each node or loading point on the grid so that they are available when an influence attribute is assigned to the model at a later stage, allowing influence shapes to be generated for chosen locations at any time. Note that for a line beam analysis, as used in this worked example, Direct Method influence attributes must be used.

Utilities Reference Path...



Attributes Search Area...

### **Defining a Direct Method influence analysis**

Analyses Direct Method Influence Analysis General...

• Choose **Deck** as the **Search area** in order to apply a prescribed unit load only on the deck beams.

For a line beam model, where the geometric section represents a beam with a loadable top slab, a loading grid of points should be defined to represent the slab. This virtual grid is equivalent to the nodes or points present in a shell or plate model and is used to create an influence surface for each location of interest.

- Ensure that **Grid** is selected.
- Ensure that the chosen Centreline is the previously defined **Bridge Centreline** reference path.
- Set a Transverse width of **11.5**. This is the width of the grid to be loaded for influence analysis.
- Press the **Grid Settings** button and make sure that **Match nodes in search area** (line beam only) is selected. Click OK to return to the previous dialog.
- Change the name to **DMI My** and click **OK** to exit the dialog.



**Note.** The Grid Settings advanced dialog controls the spacing and number of load locations within the defined width and search area length. For line beam models the most accurate results are obtained when the grid spacing along the centreline of the loading grid is set to match the longitudinal spacing (and hence number of nodes) of the underlying beam mesh.



**Note.** When the 'Match nodes in search area option' is used for line beams models, only 1 transverse point is used to define the extent of the loading grid to each side of the line beam. Using a larger number of transverse points across a single beam will not make the analysis more accurate and is not required because results are only calculated for the two extreme fibres. If a very fine grid was defined the solution stage may take some time, as the solution time is proportional to the mesh and grid density.

The defined grid that is now shown on the model will be used by an influence analysis to apply a unit load at each grid point.

The grid can be displayed or hidden on the screen.

• In the 🕒 Treeview right-click on **DMI My** and select **Show Grid** to un-tick the entry and make the grid invisible.



**Note.** A Direct Method Influence analysis can include any number of influence types or can include only particular influence assignments for a particular span or section of the model. Here, an analysis for just one influence type (My) is being used for all spans.

#### **Solving for a Unit loadcase**

• Press the Solve Now 📃 button. On the Solve Now dialog ensure that both Analysis 1 (which includes the self-weight loadcase that assumes the bridge is wished-in-place for the purposes of this example) and also DMI My are checked and press OK to run the analysis.

This applies a unit load to each loading point on the grid and caches the results for each point so that they are available when an influence shape is required to be generated.

#### If the analysis is successful...

A results loadcase for Analysis 1 and a DMI My analysis entry are added to the  $\mathfrak{L}$  Treeview.

#### **Defining Direct Method influence attributes**

Now that the influence analysis has been solved the definition of influence attributes can be done prior to assigning to nodes in the structure.

- Select Entity as **Force/Moment** 
  - Ensure the Direction is Local
  - Select My as the Component of interest.
  - Enter My Influence as the name and press OK to close the dialog.

Once created, an influence attribute is held in the  $\clubsuit$  Treeview for assignment to selected nodes or points. Note that subsequent assignment of the same attribute to other nodes or points of interest on a model will use the same influence type settings that were initially made.

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Attributes
Influence >
Direct
Method...

## Assigning Direct Method influence attributes to the deck

Influence assignments will be made to all nodes along lines representing the deck.

- In the D Treeview turn off the display of the Utilities layer This turns-off the display of the reference path.
- In the 🔀 Treeview right-click on **Deck** and click **Set as Only Visible** to display only the lines representing the bridge centreline.
- Hold-down the N key (to select just the Nodes) and make a box-selection with the cursor to enclose the five lines representing the deck. 49 nodes will be selected.
- Drag and drop the **My Influence** attribute from the streeview onto the view window to assign it to the selected nodes.

Influence loadcases (as yet unsolved) will be added to the **DMI My** analysis in the Treeview, indicating the name and position of the influence attribute assigned. Note that where a node coincides with its parent geometry the geometry name will appear as part of the influence assignment name.

• With no features selected right-click the view window and select All visible.

## Finding assigned influence locations

In models with lots of elements, nodes and attributes you can quickly locate an assigned influence location in the view window by selecting this context menu item for an influence attribute:

• In the C Treeview, right-click on My Influence (My) – (495.947, 118.896, 0.0) and choose Find.

A temporary indicator will appear, highlighting the node with the assigned influence attribute, and showing it to be in the middle of span 3.

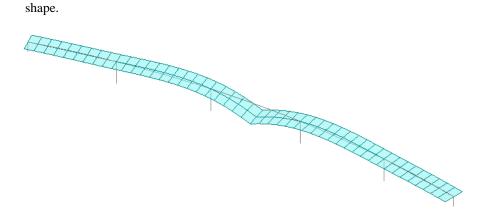
#### **Visualising influence shapes**

• In the C Treeview, right-click **My Influence** (**My**) – (**495.947**, **118.696**, **0.0**) and now choose **Set Active** to view the influence shape for My at the centre of span 3. Click **Yes** to Solve and open the results, if asked.

Note that the results loadcase must be set active, and the next step must be completed before the influence shape will be drawn.

• With no features selected right-click in a blank part of the view window and select the **Influence shape** option.

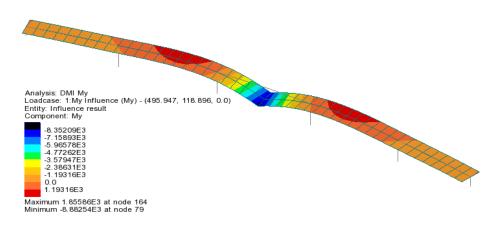
• In the Treeview turn the **Geometry** off, to leave a view of the chosen influence shape.



### **Contouring influence results**

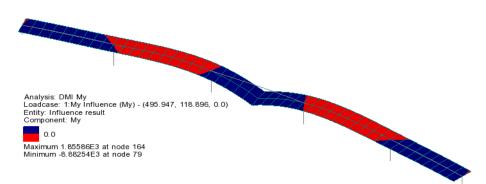
After the influence attributes have been defined and assigned, contours can be added to the view to indicate just what effect the degree and direction of influence loading applied along the surface will have on the assigned node.

- With no features selected right-click in a blank part of the Graphics window and select the **Contours** option to add the Contours layer to the Treeview.
- Select the Entity **Influence result**. Note that the Component **Inf** and Display of **Nodal** will be automatically selected.
- To plot the contour on the influence shape, select the **Contour Display** tab, click the **Appearance** tab, and tick **Deform.**
- Press **OK** to exit the dialog.



The contours can be simplified to indicate which areas of the structure, when loaded, will have a positive, or negative influence for the selected influence assignment.

- Double-click the **Contours** layer to the 📴 Treeview to open the properties dialog
- Select the **Appearance** tab, press the radio button for the **Red/Blue** option, and click **OK**.





**Note.** For this influence analysis, carried out using Direct Method Influence attributes, vehicle loading placed onto the negative areas (blue) will create a negative moment for the influence shape for this chosen influence location. Vehicle loading placed onto the positive areas (red) will create a positive moment for the influence shape for this chosen influence location. The Vehicle Load Optimisation facility will make use of these areas in its positioning of traffic loading patterns.

## Vehicle Load Optimisation (VLO)

Now that influence attributes have been defined and assigned, the VLO facility can be used to define optimised traffic loading for the bridge for these influence assignments, based on a chosen code of practice. In this example EN1991-2 UK will be used. Note that unlike Reciprocal Theorum influence attributes, Direct Method influence attributes can be assigned to the whole model regardless of whether nodes lie in a positive or negative region of an influence shape.

- In the D Treeview, turn off **Contours** and **Influence shape** and **Annotation**
- In the 🖵 Treeview, turn on **Geometry**

#### Selecting kerb lines



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**Note.** In this model, the lines defining the extent of the loadable carriageway have been defined as Combined Lines which cannot be directly used by the VLO facility. But, and as a general rule, any lines representing kerbs should always be saved as a Group to aid easy selection. This has been done for this example and the points and lines representing the kerbs can then be selected indirectly by selecting the Group in which they are members.

- In the Groups 🔯 Treeview, right-click on the **Kerblines** group, and then select **Select Members** to select the lines representing the extent of the carriageway.
- Bridge Vehicle Load Optimisation VLO Run
- Select **United Kingdom** from the Country drop down list and choose **EN1991-2 UK 2009** as the Design code.

For simplicity only the effects of a characteristic LM1 load will be considered in this example.

- Press **Optional Code settings** and ensure that **Characteristic** is the only one of the representative values required, and **Group 1a –LM1** is the only one of the load groups to be included. Press **OK** to exit the dialog.
- On the main VLO dialog, press **Define carriageways**. Ensure **Kerbs from selection** is selected and press **Apply** to exit the dialog.
- On the main VLO dialog, press **Set influence surfaces** and on the next dialog select **Include all influence surfaces**.
- Ensure that the **Positive** and **Negative** checkboxes are selected for all the My Influences included (see note below). This means that the VLO analysis will produce loading patterns for positive and negative effects of My.



**Note.** Clicking in the header cell of a column will select the whole column so that checking (ticking) one entry will check (tick) all in that column.

- Press **OK** to return to the main VLO dialog.
- Ensure the option to **View onerous effect table** is selected.
- Ensure the option to Create loading patterns for All chosen influences is <u>not</u> selected.
- To specify a non-default analysis name, choose **New** from the drop-down list, and enter the analysis name to be **VLO DMI My**
- Change the VLO run Name to be LM1 All
- Press **OK** to exit the dialog and generate optimised loading.

After a short time, and at the bottom of the  $\bigcirc$  Treeview, the new VLO DMI My analysis will be created. This contains the LM1 All VLO run, as denoted by this icon  $\clubsuit$ , which includes Characteristic results table entries for the negative and positive My Influence assignments as shown in the following image.

```
VLO DMI My

My

My

My

Negative - Characteristic

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Characteristic
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VLO results tables will also appear on tabbed results pages for the negative and positive influence assignments that have been made, and with the most onerous influence assignment in each set of tabbed results shown highlighted in red.



**Note.** Because the option to 'Create loading patterns' was <u>not</u> chosen on the main VLO dialog, no loading folders will initially appear for an influence in the  $\bigcirc$  Treeview, but the VLO results table will show 'Create Loading' alongside all influence assignment entries, loading patterns to be created, as necessary, one at a time.

• First, in the 🔀 Treeview right-click on **Kerblines** and click **Invisible** to hide the lines representing the kerbs.

## **Filtering influence results**

• In the VLO results table, ensure that the My Influence (My) – Negative – Characteristic tab is selected.

By default, results in tables are listed for all visible nodes in order of descending effect showing the most onerous value at the top of the listing in red. If desired, and by selecting a feature on the model, only those results applicable for a particular feature may be shown. One way of seeing this is to arrange the View and Results Table windows side-by-side and to select the individual lines representing each span of the model in turn as follows:

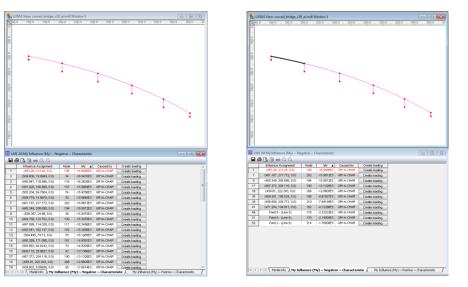
If necessary, ensure that tabbed documents are being viewed.

• Click, hold-down and drag the tab named LM1 All My Influence... towards the bottom of the view window until a highlighted region, that represents the new position of the view window, appears, and then release.

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1         The Subscript (0)         Performance (0)           2         The Subscript (0)         Performance (0)         Performance (0)           3         The Subscript (0)         Performance (0)         Performance (0)           4         The Subscript (0)         Performance (0)         Performance (0)		5 6 7 5 9 10	(481 900, 166 869, 0.8) (555 204, 09.7504, 0.0) (555 778, 14.8978, 0.8) (461 197, 217 772, 0.8) (455 349, 200 500, 0.0) (509 307, 24 99, 0.8)	157 -15 74 -15 30 -11 202 -15 134 -15	5.998983 OR14-CHAR 5.976853 GR14-CHAR 5.964853 GR14-CHAR 5.961253 OR14-CHAR	Create leading Create leading				
1         Implement Prof.         IDEL 27, 27, 28, 455, 41           1         Implement Prof.         IDEL 28, 28, 454, 41           1         Implement Prof.         IDEL 28, 454, 454, 454           1         Implement Prof.         IDEL 28, 454, 454, 454, 454           1         Implement Prof.         IDEL 28, 454, 454, 454, 454, 454, 454, 454, 45		5 6 7 5 9 10	(505.204, 09.7004, 0.5) (508.779, 14.8678, 0.5) (461.957, 217.772, 0.5) (465.349, 200.808, 0.0) (509.307, 24.99, 0.5)	74 -15 30 -11 202 -15 194 -55	5.9702E3 GRIA-CHAR 5.9642E3 GRIA-CHAR 5.9612E3 GRIA-CHAR	Create leading				
<ul> <li>1 (n) (Allers (n)) (400.25, pp. 143, 0.0)</li> <li>2 (n) (Allers (n)) (400.25, pp. 144, 0.0)</li> <li>3 (n) (Allers (n)) (400.25, pp. 144, 0.0)</li> <li>3 (n) (Allers (n)) (400.25, pp. 144, 0.0)</li> </ul>		4 7 5 9 10	(\$05.775, 14.5575, 0.0) (461.167, 217.772, 0.0) (405.349, 205.555, 0.0) (509.307, 24.59, 0.0)	30 -11 202 -15 194 -15	5.96483 GRIA-CHAR 5.961253 GRIA-CHAR					
-1. 219 (character) (c). (4001, 3011, 400, 401 -2. 219 (character) (4000, 4010, 4010, 4010 -2. 219 (character) (4000, 4010, 4010, 4010) -2. 219 (character) (4000, 401		7 8 9 10	(461.167, 217.772, 0.8) (465.349, 205.888, 0.8) (508.387, 24.99, 0.8)	202 -15 194 -15	5.9612E3 OR1A-CHAR					
<ul> <li>Taylor Shakarao (My) - (4000,500,1142,020,014)</li> <li>Taylor Shakarao (My) - (4000,490,1140,020,014)</li> <li>Taylor Shakarao (My) - (4000,490,1140,000,014)</li> <li>Taylor Shakarao (My) - (4000,500,1130,120,016)</li> <li>Taylor Shakarao (My) - (4000,500,1130,120,1100,1100,1100,1100,1100,110</li></ul>		9 10	(405.349, 205.686, 0.0) (509.307, 24.99, 0.0)	194 -15		Create leading				
-21 Terry (Hamore (Hr) - (He), 728, 123,732, 0.01 -21 Terry (Hamore (Hr) - (He), 521, 521,872, 0.01 -21 Terry (Hamore (Hr) - (He), 525, 123,475, 0.01 -21 Terry (Hamore (Hr) - (He), 625, 123,474, 0.01 -21 Terry (Hamore (Hr) - He), 625, 124,474, 0.01 -21 Terry (Hamore (Hr) - He), 625, 124,67 -114,114,114,114,114,114,114,114,114,114		9 10	(509.307, 24.99, 0.0)							
	- 1				5.2012E3 GRIA-CHAR	Create leading				
- 11 194 3rduence (Hy) - (Hi2 236, 133,429, 0.0) - 11 194 3rduence (Hy) - (Hi0 166, 133,429, 0.0) - 11 194 3rduence (Hy) - Hant 5 - Line (S) - 11 194 3rduence (Hy) - Hant 5 - Line (S)	- 1				5.9470E3 OR1A-CHAR	Creals leading				
- 37 10% Influence (Hy) - (460.006, 138.249, 0.0) - 37 10% Influence (Hy) - Read 5 - Sure 51 - 37 10% Influence (Hy) - Read 5 - Sure 51 - 37 10% Influence (Hy) - Read 5 - Sure 51	- 1	11	(494,758, 123,752, 0.0)		5.3478E3 GRIA-CHAR	Create leading				
<ul> <li>u<sup>3</sup> 10% Influence (My) - Point 5 - Quie 51</li> <li>u<sup>3</sup> 10% Influence (My) - Point 5 - Quie 40</li> </ul>	- 1		(497,089, 114,828, 0.8)		5.345823 GRIA-CHAR	Create laading				
- s? 10% infuence (%) -Point 5 - (Line 4)		12	(483.541, 162.137, 0.0)		\$ 2006E3 ORIA-CHAR	Create leading				
		12	(504.495, 74.73, 0.0)		5.190523 GRIA-CHAR	Create leading				
		14	(480,289, 171,586, 0.0)	161 -14	4.9391E3 ORTALCHAR	Create leading				
- 1,1 109 016400 (My) - (400.1, 147.047, 0.0) - 1,1 109 0164000 (My) - (400.627, 152.625, 0.0)		15	(\$85.063, 64.8242, 0.0)	70 -14	4.9205E3 GRIA-CHAR	Create neding				
1.9% britance (My) - (485, 107, 157, 388, 0.0)		16	(500 118, 20 5027, 0.0)	42 -12	3.138823 GRIA-CHAR	Create laading				
57 15% 3rfbarros (%) - (453,541, 352,137, 0.0)		17	(487 372, 204 116, 0.0)	190 .17	1 1339E3 OP1A CHAR	Create bading				
- 1 <sup>4</sup> 1My Svhamor (My) - (481.928, 366.869, 0.0)			(100.01.000.000.0.0.		0-330000	disab basing				_
- 2 <sup>4</sup> 15My Drhamor (My) - (400.269, 371.536, 0.0)		19	(545 902 9 99906 0.8)		2.8514E3 OR1A-CHAR	Create leading				
- 2 <sup>1</sup> 15Hy 3rduence (Hy) - (470-564, 126-286, 0.0)		20	(493 521, 120 597, 0.0)		2 6013E3 GRIA CHAR	Create leading				
- L <sup>1</sup> 1Phy Influence (Hy) - (476.812, 380.969, 0.0)		21	(496 163, 109 149, 0.8)		2.5979E3 GRIA-CHAR	Create leading				
- 2 <sup>4</sup> 199y Influence (My) - (475.015, 385.635, 0.0)		22								
<ul> <li>_1<sup>3</sup> 1My Infuence (My) - Point 6 - (Line 6)</li> <li>_1<sup>3</sup> 1My Infuence (My) - Point 6 - (Line 6)</li> </ul>			(485.107, 197.388, 0.0)		2.5789E3 OR1A-CHAR	Create leading				
- 1 <sup>-1</sup> 104 (monte (H)) - (471.284, 194.913, 0.0)		23	(\$63,738,79,6723,0,8)		2.5727E3 GRIA-CHAR	Create leading				
-17 19% 2% even (%) - (%) 351, 295 524, 0.0		24	(478.584, 176.286, 0.8)		2.0629E3 ORIA-CHAR	Create leading				
57 10% brillaence (Ma) - (467, 372, 204, 118, 0.0)		26	(\$96.475, \$9.8617, 0.0)		2.0471E3 GRIALCHAR	Create loading				
- 2" 19ty 3xhuence (My) - (465.349, 208.658, 0.0)		28	(469.351, 199.524, 0.0)		KTR27E3 GELA-CHAR	Create leading				
- 1,7 13Ny Infuence (Ny) - (463.28, 213.24, 0.0)		27	(508.799, 34.8725, 0.0)	46 -83	67748E3 OR1A-CHAR	Create leading				
- k <sup>7</sup> 15Ny Influence (My) - (461, 167, 217, 772, 0.0)		28	(499.229, 104.26, 0.0)	100 -8.	40554E3 GRIA-CHAR	Create leading				
- 1. <sup>4</sup> 1.04y Influence (Hy) - (459.01, 222.393, 0.0)		20	(482.238, 133.429, 0.0)	128 -8.	40127E3 ORTA-CHAR	Create leading				
- L <sup>4</sup> 1/My Influence (Hy) - (456-809, 226.772, 0.0)		30	(502 933, 84 607, 0.0)	26	JATTHE GRIALCHAR	Create loading				
L <sup>1</sup> 1PN/influence (Ny) - Paint 2 - (Line 4)		31	(455.627.152.625.0.0)		3332123 GRIA-CHAR	Create leading				
		32	(476 812 100 969 0.0)		69745E3 ORIA-CHAR	Create leading				
- III Hy Influence (Hy) ~ Positive ~ Characteristic		22	(527 007 54 0905 0.0)		CONTES GRIA-CHAR	Create leading				
- III My Infuence (Hy) - Negative - Characteristic		34	(456.009, 228.772, 0.4)		SATIFIES ORTA-CHAR	Create leading				
S Nodel properties		3	(\$99,975, 4,99992, 0,9)		64192E3 ORTA-CHAR			/		
•						Create leading				
ana 1	- 4	36	(550.227, 99.3605, 0.0)		6013523 GRIA-CHAR	Create loading		$\sim$		
	- Specify	37	(492 905, 138 248, 0.0)		64292E3 OR1A-CHAR	Creeks Itadicu				-
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• Then click on the tab 'Curved\_bridge\_vlo' to position the model view above the results table, as shown in the following image.

Window Layout Tabbed documents



Unfiltered influence results show results for all features (all spans)

Influence results filtered to show only those results for a selected feature (span 5)

• In the model view window, select each of the lines representing the spans in turn to filter the results in the table and see that the most onerous effect (denoted by the red text) occurs in span 5.

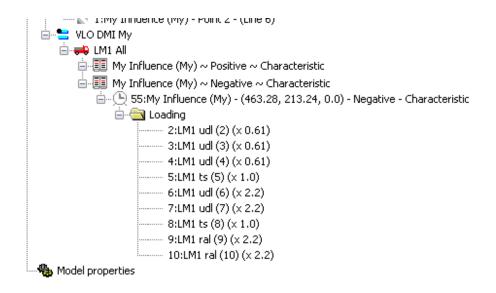
## **Creating loading patterns**

For this worked example, the most onerous loading effect for the influence assignment of interest will be created individually by pressing the 'Create Loading' button alongside the appropriate entry in the onerous results table.

With the line representing span 5 still selected:

• In the VLO results table ensure that the **My Influence** (**My**) – **Negative** – **Characteristic** tab is selected and press the **Create loading** button for the most onerous negative result entry (shown in red at the top of the table in the preceding images).

A loadcase entry and a Loading folder will appear for the VLO results table entry in the Analyses  $\bigcirc$  Treeview for that influence. When expanded, it will appear as shown in the following image.



• Leave the results table open to create additional loading patterns.

#### **Check the loading visualisation settings**

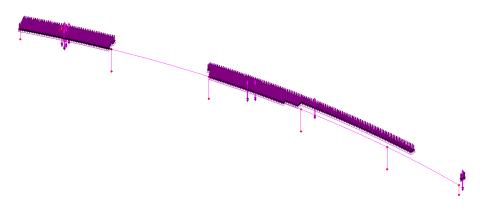
Before visualising the loading, it is prudent to check or correct the settings required.

- Click in the Model view window to make that view active (instead of the table of results view) and if necessary, use the dynamic zoom to enlarge the model.
- In the 🖵 Treeview double-click **Attributes**
- Select the Loading tab and press Settings... button
- Ensure Show discrete loading by definition is selected and press OK to exit the dialog.
- Press **OK** to return to the model.

#### **Negative effects**

- In the 💭 Treeview, and <u>from within the VLO DMI analysis section</u>, select the **My Influence** (**My**) – (**463.28**, **213.24**, **0.0**) – **Negative** - **Characteristic** loadcase and choose **Set Active**.
- Press ito visualise loading.

The optimised loading for the characteristic case of EN1991-2 UK that gives the maximum My effect in the mid-span of span 5 for negative influence will be displayed.



#### **Positive effects**

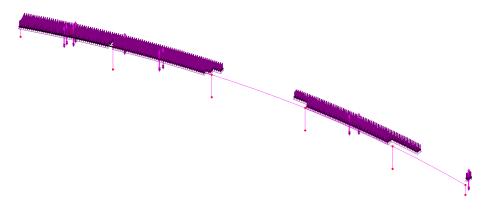
With the line representing span 5 still selected:

• Go back to the VLO results table and select the **My Influence** (**My**) – **Positive** – **Characteristic** tab and press the **Create loading** button for the most onerous positive result entry for the line selected. Note that this entry is not the most onerous value for the bridge as a whole because it is not shown in red.

A loadcase entry and a Loading folder will appear for the VLO results table entry in the Treeview for that influence.

• In the C Treeview, and from within the VLO DMI analysis section, select the My Influence (My) – Point 6 - (Line 6) – Positive - Characteristic and choose Set Active.

The optimised loading for the characteristic case of EN1991-2 UK that gives the maximum My effect positive influence for the selected span will be displayed.



After further inspection (by selecting the line of each span and looking at the filtered results in the onerous results table) it can be seen that the most onerous results for hogging are actually obtained for span 3 at pier 2 (Point 4).

• First press it to turn-off the display of the loading patterns.

#### **Solving optimised loading arrangements**

So, as seen, the VLO run includes loading arrangements that can be optionally visualised but produces no structural results. Results are available only after the VLO analysis has been solved. So:

• With the model view window active, press the Solve Now 📃 button.

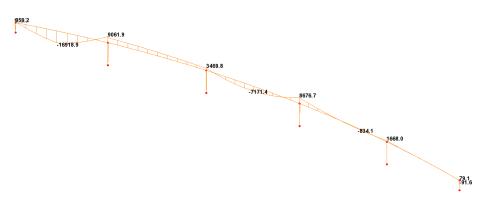
Only the VLO analysis has to be solved in order to produce the results for the optimised loading arrangements for each influence assignment. The Solve Now dialog indicates that the VLO DMI My analysis results are not up to date and that they need to be solved. The other two analyses are unselected by default, as their results are up to date.

• Press **OK** to solve the VLO run.

The results will be loaded on top of the current model, with the last viewed VLO DMI My analysis loadcase set active by default.

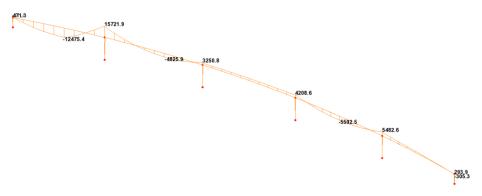
#### **Plotting bending moments**

- In the Treeview, and from within the VLO DMI My analysis section, select the My Influence (My) (463.28, 213.24, 0.0) Negative Characteristic results loadcase and choose Set Active.
- In the Treeview turn off the Geometry and Attributes layers.
- With no features selected right-click in a blank part of the Graphics window and select the **Diagrams** option to add the **Diagrams** layer to the Treeview
- In the diagram properties drop-down menu, pick **Force/Moment** from the entity and **My** from the component drop down list.
- From the **Diagram Display** tab <u>deselect</u> the **Use for labels too** option, select **Decimal places** and change the value to **1**
- Press the Label font... button and change the style to Bold
- Press OK to return to the properties dialog, and then press OK exit.



The preceding diagram shows the worst-case sagging moment, My, for span 5, due to characteristic LM1 loading.

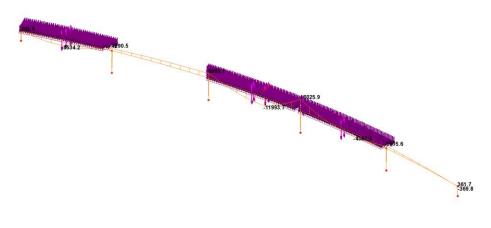
In the C Treeview, and from within the VLO DMI analysis section, select the My Influence (My) – Point 6 - (Line 6) – Positive - Characteristic and choose Set Active.



The preceding diagram shows the worst-case hogging moment, My, for span 5, which occurs at pier 4, due to characteristic LM1 loading.

Using the procedures described in this example, lines representing each span can be selected, onerous loading patterns can be created, loadcases solved, and the corresponding results for each span can be inspected.

By inspection it can be seen that the worst-case hogging moment, My, for any pier, due to characteristic LM1 loading, occurs at Pier 2 (Point 4) as shown below.



This completes the example.

## Discussion

This example just shows how a single influence component (My) can be defined and assigned as an attribute to nodes within the lines representing the deck. Other influence attributes such Mx, for investigating torsional effects, could be assigned to nodes in the deck also, with loading and results effects being obtained in exactly the same way. Investigation of axial forces at pier heads can also achieved in a similar fashion, but by making assignments only to the points at those locations.

#### VLO analysis naming conventions

One Direct Method Analysis entry could contain a single Vehicle Load Optimisation run, for all assigned influence components of interest, but for large models this could result in a great deal of unstructured data within the Analyses  $\bigcirc$  treeview that is not easily viewable.

It is often better to have a single Direct Method Analysis entry containing multiple VLO run entries of suitable names such as Deck, or Pier, even including additional references to load types, since this will simplify the viewing and provide a 'structure' to the data in the Analyses  $\bigcirc$  treeview and also make the identification of results loadcases easier when results processing.

Appending an influence component name to a Direct Method Analysis entry or a VLO Run name (if they only contain assignments for a single influence type) may also be useful if many entries are present in the Analyses  $\bigcirc$  treeview, and some of these entries are contracted when other entries are being viewed.