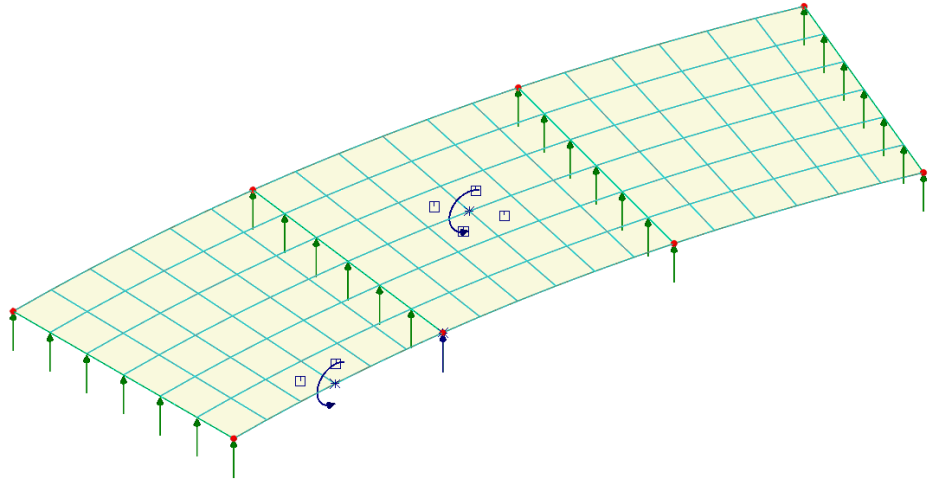
Bridge Design Load Combinations

For LUSAS version:	24.0
For software product(s):	LUSAS *Bridge*.
With product option(s):	None.
Note: The example exceeds the limits of the LUSAS Teaching and Training Version.	

Description

In this example design combinations are generated based on the assignment of design code specific load types. These load types are used to apply the correct factors for the limit state selected. EN1990 is just one of several design codes that are supported.

The example considers a bridge model that contains EN1991-2 loadings and loadcases for the UK National Annex. Worst-case positive and negative effects are investigated for three influence point locations on the model: at edge mid-span 1, the middle of span 2, and an internal support.



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.

Objectives

- Generation of load combination for a road bridge in accordance with EN 1990 using the UK National annex.

Keywords

2D, Slab, Vehicle Load Optimisation (VLO), Design Combinations, EN 1990 Bridges, Direct Method Influence, Positive Effects, Negative Effects

Associated Files

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

- **load_comb_wizard.lvb** creates an initial model of the structure for further development.

Modelling

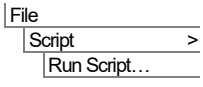
Running LUSAS Modeller

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

Creating a New Model

- Enter a file name of **load_comb_wizard**.
- Use the default **User-defined** working folder.
- Ensure an Analysis type of **2D Grillage/Plate** 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 required for this example, open the script file **load_comb_wizard.lvb** that was downloaded and placed in a folder of your choosing.

The basic bridge geometry will be displayed.

Loadcases considered

The following characteristic loadcases were assigned to the model created by the script.

- Dead Load
- Surfacing
- Settlement
- Thermal actions

Traffic loading in the model needs to be created using the LUSAS Vehicle Load Optimization (VLO) facility for the EN1991-2 UK National Annex. Influence surfaces (generated from the assignment of direct method influence attributes) have already been defined for:

- **Edge mid-span bending span 1**
- **Mid-span bending span 2**
- **Maximum reaction at an internal support**

Characteristic, Combination & Frequent loadcases are created in a separate analysis.

Note. For bridge loading codes the load combination wizard has been developed for use with traffic loads output from the Vehicle Load Optimisation facility. If VLO is not used to generate the traffic loads, appropriate load combinations should be created with the same lane factors, modifications factors and load factors applied as are applied in the VLO.

Vehicle load optimisation

Vehicle load optimisation settings cannot be supplied as part of a model script, so need to be defined here.

Analyses
Vehicle Load Optimisation
VLO Run…

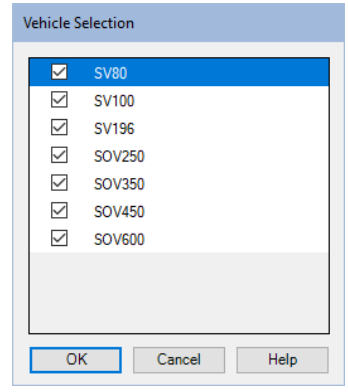
- Select **Europe** from the country drop-down list.
- Select **EN1991-2 UK 2009** from the Design code drop down list.
- Deselect the **View onerous effects** table.
- Select **Create loading patterns** for **All chosen influences**
- **VLO Analysis 2** will be automatically entered for the Analysis entry in the Analyses 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 the design code's Optional Settings 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 (SV80) is specified as a default and that a vehicle(s) appropriate to the structure being designed should be specified in practice.

- On the 'Load groups to include' panel press the ... button beside the Vehicle(s) text box.
- On the Vehicle Selection dialog ensure that all vehicles are checked (ticked) and press **OK**.
- Turn off the **Output for each load group** option to not create influence design loadcases for each load group that is ticked. This provides an overview of the combined effects of all the load groups selected, as opposed to a breakdown of effects group by group. It also helps to simplify the creation of envelopes just for this example.
- Click **OK** to 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** and the **Transverse increment** is set to **0.25**.
- Ensure **Use rationalised placement method** is checked on. If necessary, visit the help pages to find out more about this option.
- Click **OK** 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 **Negative** checkbox is selected for bending influences while **Positive** is selected for the reaction influence.

Note. We are looking for negative moment (sagging) in the spans, and a positive vertical reaction.

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

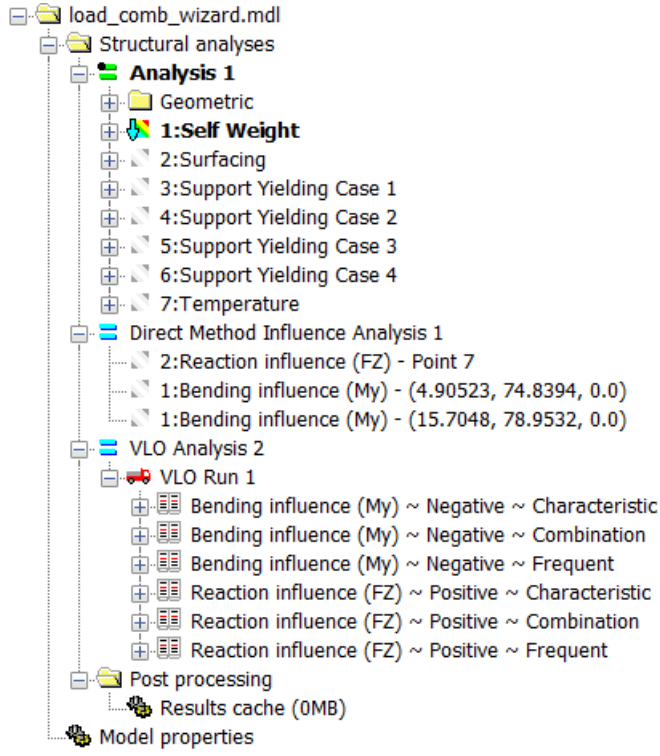
Select the highway

- On the main VLO dialog, ensure the selected highway is **Highway1**.

Run the optimisation

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

This loading optimisation will take a short while to compute, but when successfully completed, Characteristic, Combination and Frequent results table entries and 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 for selected 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 but no results. Whilst loading patterns can be visualised, results are available only after the VLO analysis has been solved.

Running the Analysis

With the model loaded:


Open the **Solve Now** dialog. Ensure that only **Analysis 1** and **VLO Analysis 2** are selected and press **OK** to begin the analysis.


Note. There is no need to solve the Direct Method Influence Analysis as it has already been solved by the Vehicle Load Optimiser.

A LUSAS Datafile will be created from the model information. The LUSAS Solver uses this datafile to perform the analysis.

If the analysis is successful...

Analysis loadcase results are added to the  Treeview for Analysis 1 and VLO Analysis 2. In addition, these files will be created in the LUSASFiles32\<model_name> folder for each analysis where the model file resides:

- **load_comb_wizard~Analysis 1.out** and **load_comb_wizard~VLO Analysis 2.out** these output files contain details of model data, assigned attributes and selected statistics of the analysis.
- **load_comb_wizard~Analysis 1.mys** and **load_comb_wizard~VLO Analysis 2.mys** these are the LUSAS results file which are loaded automatically into the  Treeview to allow results processing to take place.

Viewing the Results

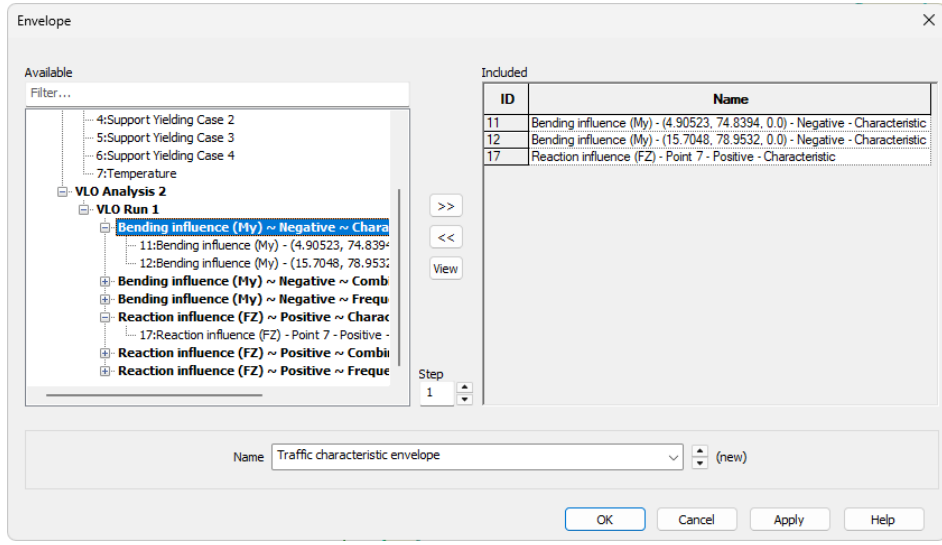
Traffic Envelopes

An envelope is to be created for each of the Characteristic, Combination & Frequent loadcases.

To create the Characteristic envelope:

Analyses
Envelope…

- On the Envelope dialog, and from the Available panel, select the **Bending influence (My) ~ Negative ~ Characteristic** entry and press the 'Add to' button >> to add the two bending influence loadcases associated with it to the Included panel.



- Select the **Reaction influence (FZ) ~ Positive ~ Characteristic** entry from the Available panel and press the 'Add to' button >> to add the single reaction influence loadcase associated with it to those already included.
- Change the name to **Traffic characteristic envelope** and click **OK**

To create the Combination loadcase envelope:

Analyses
Envelope…

- From the Available panel, select the **Bending influence (My) ~ Negative ~ Combination** entry and press the 'Add to' button >> to add the two bending influence loadcases associated with it to the Included panel.
- Select the **Reaction influence (FZ) ~ Positive ~ Combination** entry from the Available panel and press the 'Add to' button >> to add the single reaction influence loadcase associated with it to those already included.
- Change the name to **Traffic combination envelope** and click **OK**

To create the Frequent loadcase envelope:

Analyses
Envelope…

- From the Available panel, select the **Bending influence (My) ~ Negative ~ Frequent** entry and press the 'Add to' button  to add the two bending influence loadcases associated with it to the Included panel.
- Select the **Reaction influence (FZ) ~ Positive ~ Frequent** entry from the Available panel and press the 'Add to' button  to add the single reaction influence loadcase associated with it to those already included.
- Change the name to **Traffic frequent envelope** and click **OK**

Load Combinations

The design load combinations wizard allows you to assign a predefined load type to each loadcase, envelope or basic combination based on a chosen design code. Doing so allows different combinations for those load types to be generated.

Design
Design Combinations
Set/Edit Combination Design Code…

From the drop lists select the following:

- Country: **UK**
- Design Code: **EN 1990 – 2002 Highway Bridges UK.**

Then, click **OK**.

Design
Design Combinations
Generate Design Combinations…

The Design Code Combinations dialog will appear.

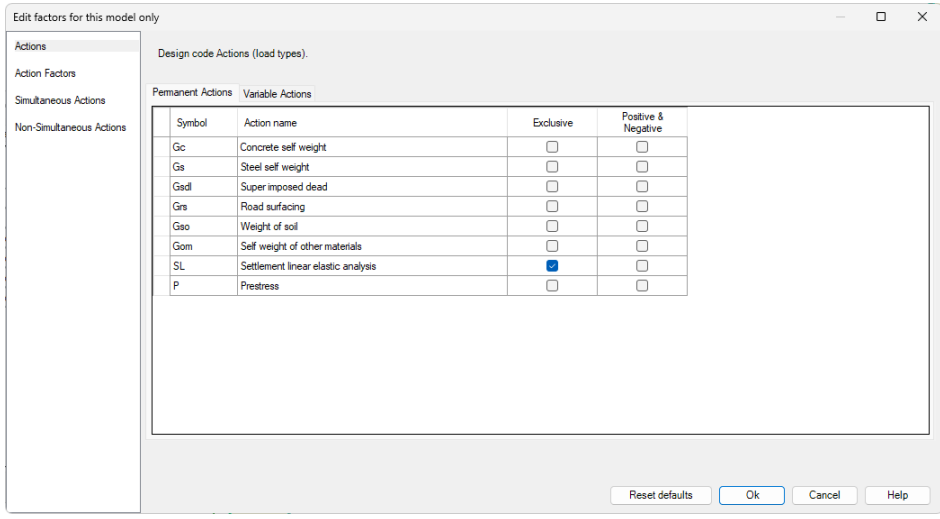
Add Permanent actions

- Select the **Permanent Actions** tab.
- Click the **Add loadcases** button, then select the six loadcases listed below and press the 'Add to'  button to include them in the design combination.

Loadcase	Action
Self Weight	**Gc | Concrete self weight**
Surfacing	**Grs | Road surfacing**
Support Yielding Case 1	**SL | Settlement linear elastic analysis**
Support Yielding Case 2	**SL | Settlement linear elastic analysis**
Support Yielding Case 3	**SL | Settlement linear elastic analysis**
Support Yielding Case 4	**SL | Settlement linear elastic analysis**

- Once added, for each one, choose the appropriate option from the **Action** drop-down menu.

- Click the **Edit factors** button, then choose **Actions** from the list on the left side of the dialog box.



- Open the **Permanent Actions** tab, enable the **Exclusive** option for the **Settlement linear elastic analysis** actions, and then click **OK**.

Add Variable actions

- Back on the main Design Code Combinations dialog, select the **Variable Actions** tab.

- Click the **Add loadcases** button, then select the four loadcases listed below and press the 'Add to'  button to include them in the design combination.

Loadcase	Action
Temperature	**Qt | Thermal**
Traffic characteristic envelope	**Qi Tch | Traffic Load - characteristic**
Traffic combination envelope	**Qi Tco | Traffic Load – combination**
Traffic frequent envelope	**Qi Tfr | Traffic Load - frequent**

- Once added, for each one, choose the appropriate option from the **Action** drop-down menu.

Generating combinations

- Select the **Combinations to Generate** tab.
- Include **ULS Fundamental Set B (Eq. 6.10)**, **SLS Characteristic**, **SLS Frequent**, and **SLS Quasi-Permanent**.
- Ensure that **Basic Combinations** is selected.
- Ensure that **Create envelope for each combination** is selected.
- Click **Generate combinations**.

On completion a 'Design Combinations – Basic' parent folder is created in the Treeview, containing folders holding the SLS Characteristic, SLS Frequent, SLS Quasi-Permanent, and ULS Fundamental Set B (Eq 6.10) load combinations. An envelope of the relevant loads is also created in each combination folder.

Note. For the **SL | Settlement linear elastic analysis** action type, selecting the **Exclusive** option ensures that each settlement loadcase is considered individually within the combinations. If the **Exclusive** option is not selected, the combinations will instead account for the cumulative effects of settlement.

Note. The **Review Combinations** button displays the combinations to be generated, including the factors applied to each loadcase and the corresponding combination expressions.

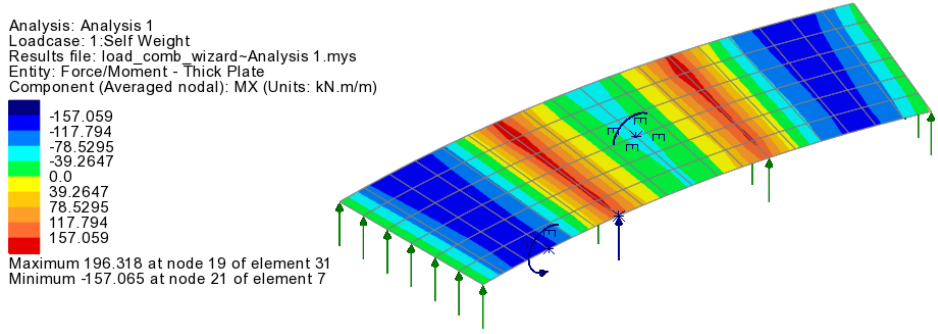
Displaying contours for Max and Min Effects

- If present, turn-off the display of the **Geometry** layer, and ensure the **Attributes** layer is turned on in the Treeview.
- Turn on the display of the supports.
- With no features selected, click the right-hand mouse button in a blank part of the graphics area and select the **Contours** option to add the contours layer to the Treeview.

The contours properties dialog will be displayed.

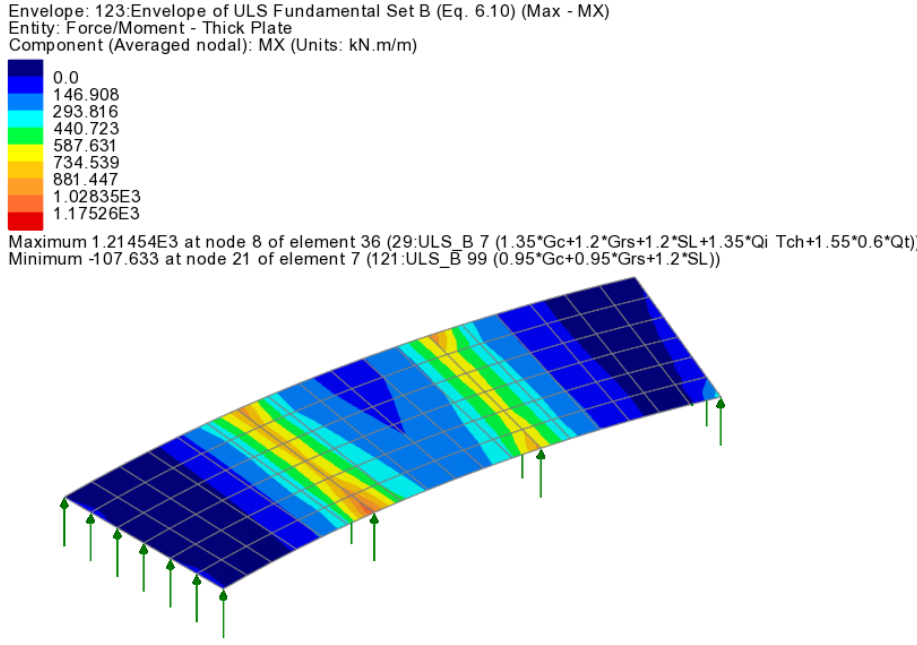
- Select Entity **Force/Moment - Thick Plate** and component **MX** and click **OK**

The Contour results for Loadcase 1 – Self Weight will be displayed.



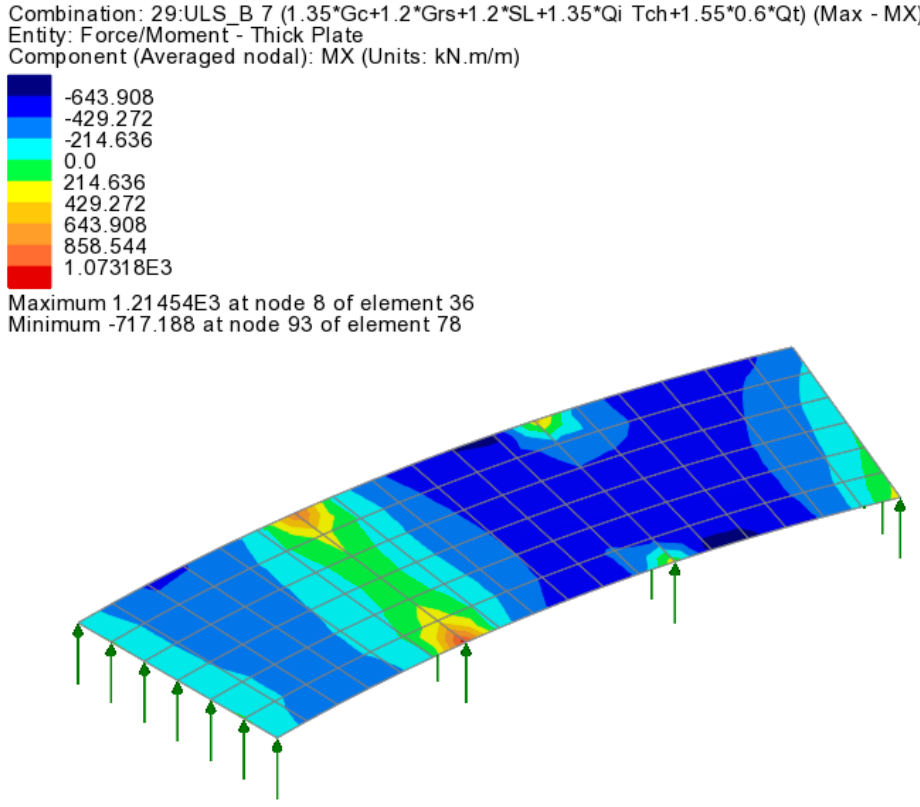
Displaying Maximum effects

- In the Treeview, scroll to the bottom, and in the **ULS Fundamental Set B (Eq. 6.10)** folder, right-click on **Envelope of ULS Fundamental Set B (Eq. 6.10)**, and select the **Set Active** option. In the dialog that appears, select the **Maximum values** option and ensure that the **Force/Moment – Thick Plate** entity and the **MX** component are used. Then, click **OK**.



From the Contour key, the maximum value occurs in combination **29:ULS_B 7 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tch+1.55*0.6*Qt).**

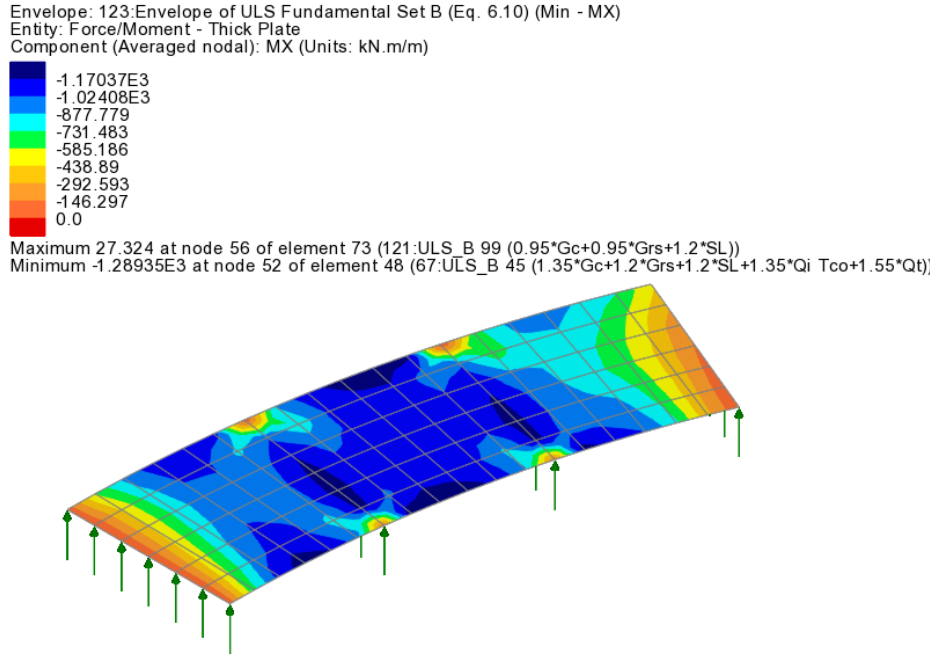
- In the Treeview, right-click on this combination (**29:ULS_B 7 etc…**) and choose **Set Active**. On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.



Note. In the Treeview, many of the combination descriptions in brackets are repeated four times. This is because the settlement at each support is considered in turn for combinations involving settlement.

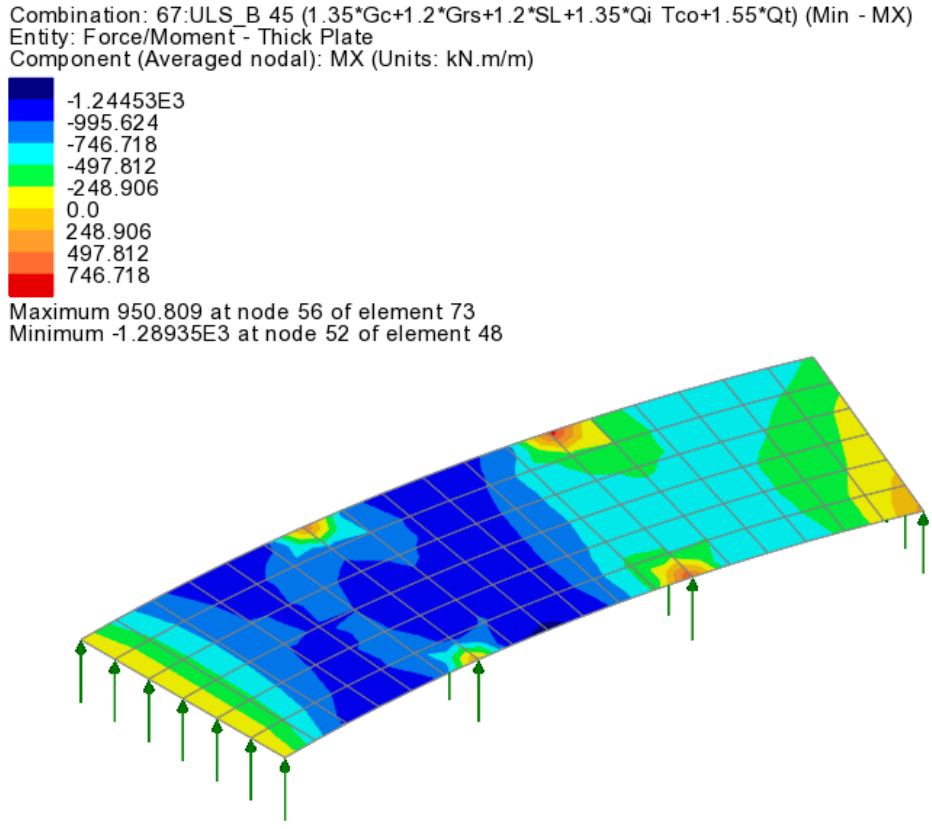
Displaying Minimum effects

- In the Treeview, scroll to the bottom, and in the **ULS Fundamental Set B (Eq. 6.10)** folder, right-click on **Envelope of ULS Fundamental Set B (Eq. 6.10)**, and select the **Set Active** option. In the dialog that appears, select the **Minimum values** option and ensure that the **Force/Moment – Thick Plate** entity and the **MX** component are used. Then, click **OK**.



From the Contour key, the minimum value occurs in combination **67: ULS_B 45 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tco+1.55*Qt).**

- In the Treeview, right-click on this combination (**67:ULS_B 45 etc…**) and choose **Set Active.** On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.



Additional results processing can be carried out for the SLS Characteristic, SLS Frequent and SLS Quasi-Permanent combinations in a similar manner.

Save the model

File
Save

 Save the model file.

This completes the example.

A discussion on whether to use basic or smart combinations follows.

Discussion – Basic or Smart Combinations?

Choosing to use a Basic Combination approach (as done in this example) enables the load factors used within each combination to be seen.

At the point where the Combination approach is selected the Smart combination option could alternatively have been chosen, and with this approach the resulting combinations would be placed in a **Design Combinations – Smart** parent folder.

Using the Smart combination approach, the results from individual loadcases are factored with an adverse or beneficial factor and added together. This generally produces significantly fewer load combinations in total but note that the beneficial and adverse load factors used to create each smart combination are not reported.

	Number of combinations created	
Combination type	**Basic combination**	**Smart combination**
Characteristic combination	40	4
Frequent combination	20	3
Quasi-Permanent combination	10	2
ULS Fundamental Set B (Eq. 6.10)	100	3

If the Smart combination approach were to be used in this example, an additional envelope would be created for the 'SL | settlement linear elastic analysis' load type as this is mutually exclusive. This resides in a folder called **Constituents**.

Instead of creating envelopes of the VLO loadcases, each VLO loadcase could be assigned the appropriate load type, i.e. 'Qi Tch | Traffic Load – characteristic', 'Qi Tco | Traffic Load – combination', and 'Qi Tfr | Traffic Load – frequent' and these could then be set to mutually exclusive. This would result in many more combinations being created.

For more information on Basic and Smart Combinations please refer to the Modeller Reference Manual.