Bridge Design Load Combinations

For LUSAS version:	19.0
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 by a wizard 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 a number of design codes that are supported.

The example uses a supplied LUSAS 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.
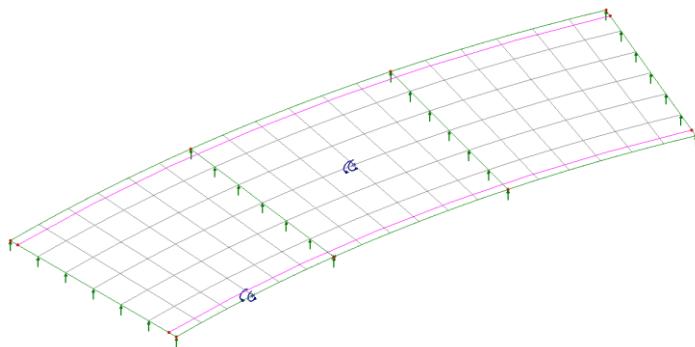
The structure is modelled using thick plate elements, representing a deck of inner radius 75m, outer radius 86m and thickness 0.7m. The deck has a width of 11m consisting of a 10m wide carriageway region and two 0.5m wide verges.

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, Positive Effects, Negative Effects

Associated Files

❑ **load_comb_wizard_preliminary.mdl** Model file of the structure.

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.

Loading the Model

File
Open…

• To start this example open the read-only file **load_comb_wizard_preliminary.mdl** located in the *\<LUSAS Installation Folder>\Examples\Modeller* directory.

Depending upon your access rights it may be necessary to copy this file to another folder before it can be opened, and remove the read-only protection before it can be saved to the new folder. Once opened:

The basic bridge geometry will be displayed.

File
Save As…

• Save the file to a suitable folder as **load_comb_wizard**

Loadcases considered

Traffic loadcases in the model were created using the LUSAS Traffic Load Optimization (TLO) facility for the EN1991-2 UK National Annex. The Muller-Breslau (reciprocal) theorem was used and influence surfaces defined for:

❑ **Edge mid-span bending span 1**

❑ **Mid-span bending span 2**

❑ **Maximum reaction at an internal support**

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

The following characteristic loadcases were assigned to the model:

- ❑ Dead Load

- ❑ Surfacing

- ❑ Settlement

- ❑ Thermal actions

- ❑ Traffic loading to EN1991-2 UK

The Vehicle Load Optimisation (VLO) loadings and loadcases can be seen in the ⚛ and 🕑 Treeviews.

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.

Running the Analysis

With the model loaded:

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

Note. There is no need to solve the Reciprocal Influence Analysis because influence shapes will not be examined in this example.

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. In addition, two files will be created in the Associated Model Data directory for each analysis where the model file resides:

- ❑ **load_comb_wizard~Analysis 1.out** and
  load_comb_wizard~VLO Analysis.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.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.

Analyses
Envelope…

To create the Characteristic loadcase envelope hold down the **Ctrl** key whilst selecting the following:

- **(8) Bending span 1 - (4.90523, 74.8394, 0.0) - Positive – Characteristic**

- **(11) Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Characteristic**

- **(14) Reaction support 2 - Point 7 - Positive – Characteristic**

- Press the Add to ⮞⮞ button to add the selected datasets to the envelope.

- Change the name to **Traffic characteristic envelope** and click **OK**

Analyses
Envelope…
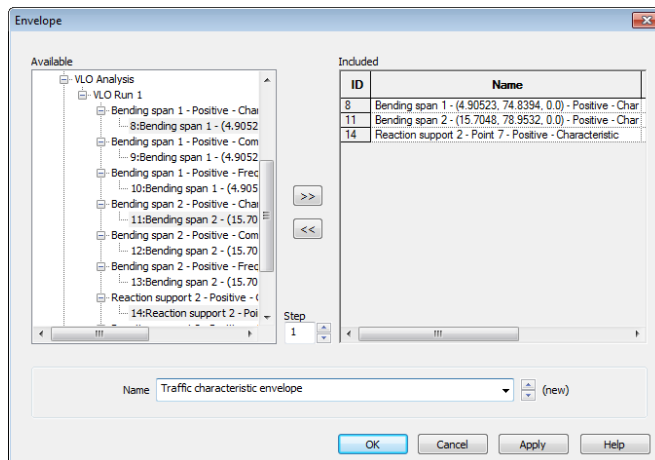
To create the Combination loadcase envelope hold down the **Ctrl** key whilst selecting the following:

- **(9) Bending span 1 - (4.90523, 74.8394, 0.0) - Positive – Combination**

- **(12) Bending span 2 - (15.7048, 78.9532, 0.0) - Positive – Combination**

- **(15) Reaction support 2 - Point 7 - Positive – Combination**

- Press the Add to [>>] button to add the selected datasets to the envelope.

- Change the name to **Traffic combination envelope** and click **OK**

To create the Frequent loadcase envelope hold down the **Ctrl** key whilst selecting the following:

- **(10) Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Frequent**

- **(13) Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Frequent**

- **(16) Reaction support 2 - Point 7 - Positive - Frequent**

- Press the Add to [>>] button to add the selected datasets to the envelope.

- 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.

The Load Combination dialog will appear. From each drop-down list, select the following:

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

- **Self Weight: (Gc) | Concrete self weight.**

- **Surfacing: (Grs) | Road surfacing (Grs).**

- **Support Yielding Case 1 to 4: (SL) | Settlement linear elastic analysis**.

- **Temperature: (Qt) | Thermal**.

- Do not make any selections for Bending Span 1, 2 or Reaction support 2 VLO loadcase results because, for this example, all pre-defined load types will be assigned to the envelopes that have been defined.

5
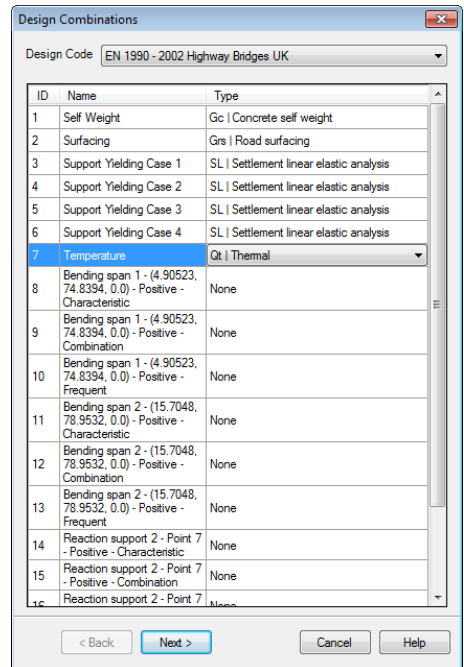
- Scroll to the bottom of the dialog and make the following assignments:

- Traffic characteristic envelope: **Qi Tch | Traffic Load - characteristic.**

- Traffic combination envelope: **Qi Tco | Traffic Load – combination.**

- Traffic frequent envelope: **Qi Tfr | Traffic Load - frequent.**

- Click **Next**

On the Combination options page of the wizard:

- For ULS ensure that the **Persistent combination** is selected

- For SLS check the **Characteristic combination**, **Frequent combination** and **Quasi-permanent combination** check boxes.

- Ensure that **Create an envelope for each combination type** is selected.

- Press the **Advanced** button, and on the Advanced Options dialog, with the **Permanent actions** tab selected, and for the **SL |Settlement linear elastic analysis** entry only, change **Mutual exclusive** from No to **Yes**, and click **OK**.

- Back on the main dialog, and for the Add / Replace / Delete Combinations option, ensure **Add** is enabled.

- For the Combination approach, ensure **Basic Combination** is selected.

- Click **Finish** to generate the design load 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 Persistent (Eq 6.10) load combinations. A Max and Min envelope of the relevant loads is also created in each combination folder.

Note. For the 'SL | Settlement linear elastic analysis' load type, setting the mutually exclusive option to 'Yes' means that each loadcase will be considered individually in the

combinations. Setting the mutual exclusive option to 'No', would mean that the cumulative effects of the settlement at each support would be considered in the combinations.

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.

- 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** and component **MX** and click **OK**

The Contour results for Loadcase 1 − Self Weight will be displayed.
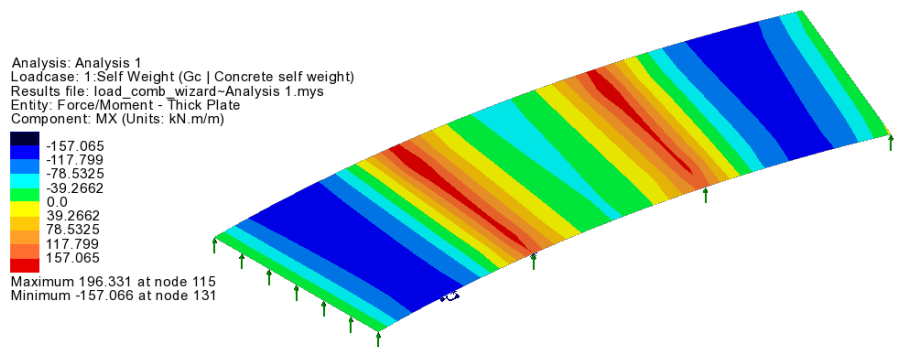
Displaying Maximum effects

- In the 🔍 Treeview, in the ULS Persistent Set B folder, right-click on combination **323:ULS_P_B (Max)** and select the **Set Active** option to view the worst positive effects (i.e. hogging moments and reactions). On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.
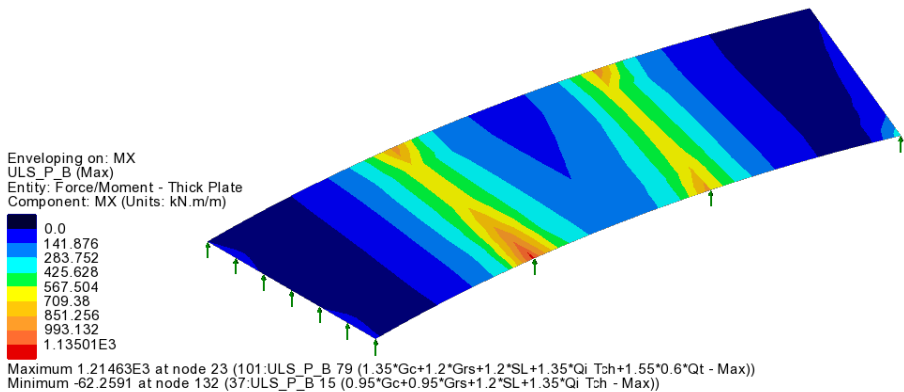
From the Contour key it can be seen that maximum values occur in combination **101:ULS_P_B 79 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tch+1.55*0.6*Qt - Max).**

- In the ⏰ Treeview, right-click on this combination and choose **Set Active**. On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.
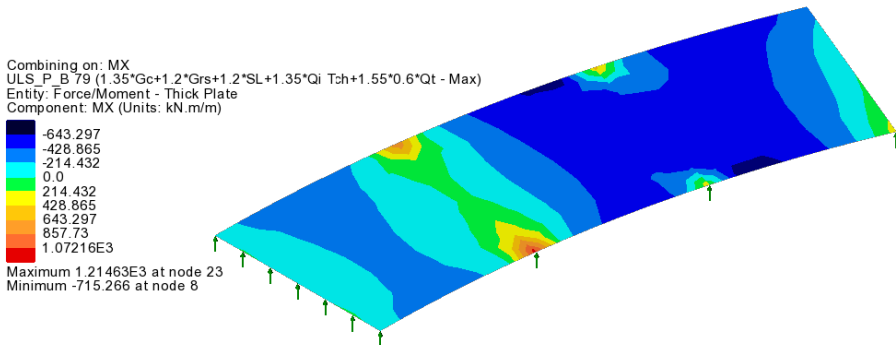
Note. It can be seen that, in the ⏰ Treeview, many of the combination descriptions in brackets are repeated four times. This is because the settlement at each support is considered in turn for combinations involving settlement.

Displaying Minimum effects

- Set combination **324:ULS_P_B (Min)** in the ULS Persistent folder active to view worst negative effects (i.e. sagging moments). On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.

Enveloping on: MX
ULS_P_B (Min)
Entity: Force/Moment - Thick Plate
Component: MX (Units: kN.m/m)

-1.1467E3
-1.00336E3
-860.026
-716.688
-573.351
-430.013
-286.675
-143.338
0.0

Maximum 27.2377 at node 113 (29:ULS_P_B 7 (0.95*Gc+0.95*Grs+1.2*SL))
Minimum -1.2628E3 at node 19 (280:ULS_P_B 258 (1.35*Gc+1.2*Grs+1.2*SL+1.0*Qi Tco+1.55*Qt - Min))
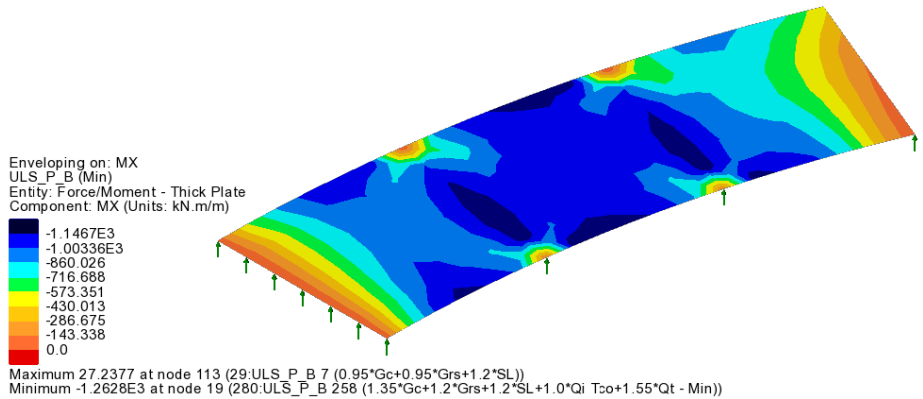
From the Contour key it can be seen that minimum values occur in combination **280: ULS_P 258 (1.35*Gc+1.2*Grs+1.2*SL+1.0*Qt Tco+1.55*Qt-Min).**

- Right click on this combination and choose **Set Active.** On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.

Combining on: MX
ULS_P_B 258 (1.35*Gc+1.2*Grs+1.2*SL+1.0*Qi Tco+1.55*Qt - Min)
Entity: Force/Moment - Thick Plate
Component: MX (Units: kN.m/m)

-1.22825E3
-982.601
-736.951
-491.301
-245.65
0.0
245.65
491.301
736.951

Maximum 948.052 at node 113
Minimum -1.2628E3 at node 19
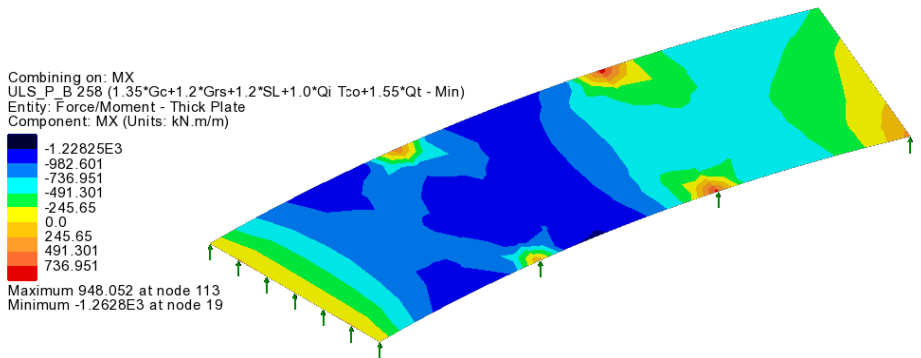
Additional results processing can be carried out for the SLS Characteristic, SLS Frequent and SLS Quasi permanent combinations in a similar manner.

Save the model

File
  Save

💾 Save the model file.

This completes the example.

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 relieving factor and added together. This generally produces significantly fewer load combinations in total, but note that the variable and permanent load factors actually used to create each max or min smart combination are not reported.

Combination type	Number of combinations created for combination approach	
	Basic combination	**Smart combination**
Characteristic combination	75	10
Frequent combination	35	8
Quasi-permanent combination	10	4
Persistent	300	12

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. These reside 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.

Examples of the alternative settings made are shown on the following dialogs.

Design Combinations

Design Code: EN 1990 - 2002 Highway Bridges UK

ID	Name	Type
6	Support Yielding Case 4	SL | Settlement linear elastic analysis
7	Temperature	Qt | Thermal
8	Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Characteristic	Qi Tch | Traffic Load - characteristic
9	Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Combination	Qi Tco | Traffic Load - combination
10	Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Frequent	Qi Tfr | Traffic Load - frequent
11	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Characteristic	Qi Tch | Traffic Load - characteristic
12	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Combination	Qi Tco | Traffic Load - combination
13	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Frequent	Qi Tfr | Traffic Load - frequent
14	Reaction support 2 - Point 7 - Positive - Characteristic	Qi Tch | Traffic Load - characteristic
15	Reaction support 2 - Point 7 - Positive - Combination	Qi Tco | Traffic Load - combination
16	Reaction support 2 - Point 7 - Positive - Frequent	Qi Tfr | Traffic Load - frequent
17	Traffic characteristic envelope	None
19	Traffic combination envelope	None
21	Traffic frequent envelope	None

[< Back] [Next >] [Cancel] [Help]

Advanced Options

Permanent actions | Variable actions

Load types	Partial factor (gamma Q)	Combination factor (psi 0)	Frequent factor (psi 1)	Quasi-permanent factor (psi 2)	Mutually exclusive
Qi Tch | Traffic Load - characteristic	1.35				Yes
Qi Tco | Traffic Load - combination	1.35	1.00			Yes
Qi Tfr | Traffic Load - frequent	1.35		1.00		Yes
Qi Tqp | Traffic Load - quasi permanent				1.00	Yes
Qi Hb | Horizontal forces - braking and acceleration	1.35				Yes
Qi Hc | Horizontal forces - centrifugal and other transverse	1.35				Yes
Qwp | Wind Persistent	1.70	0.50	0.20	0.00	Yes
Qwt | Wind compatible with Road Traffic	1.70	1.00			Yes
Qt | Thermal	1.55	0.60	0.60	0.50	Yes
A | Accidental	1.00				Yes
Ae | Seismic	1.00				Yes

[Defaults] [OK] [Cancel] [Help]

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