Bridge Design Load Combinations

For LUSAS version:	20.0
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.
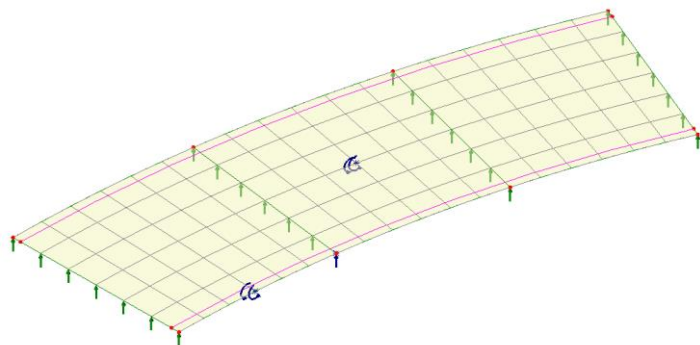
The structure is modelled using thick plate elements, representing a deck of inner radius 75m, outer radius 86m and thickness 0.7m. The deck has a width of 11m consisting of a 10m wide carriageway region and two 0.5m wide verges.

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, 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 Inplane** 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.

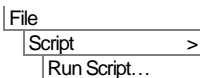| File	
Script	>
Run Script…	

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 was 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 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.

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.

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…

- Select the two lines representing the kerb positions / extent of the traffic lane.

- 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**.

- Click **OK** to return to the main VLO dialog.

Vehicle Selection
☑ SV80
☑ SV100
☑ SV196
☑ SOV250
☑ SOV350
☑ SOV450
☑ SOV600
OK   Cancel   Help
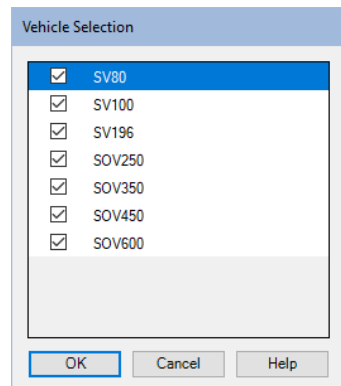
Browse the optional loading parameters

- 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**.

- 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 a few 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 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 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 2. 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 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.

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**

Analyses
 Envelope…

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 Traffic fr**

- **(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.
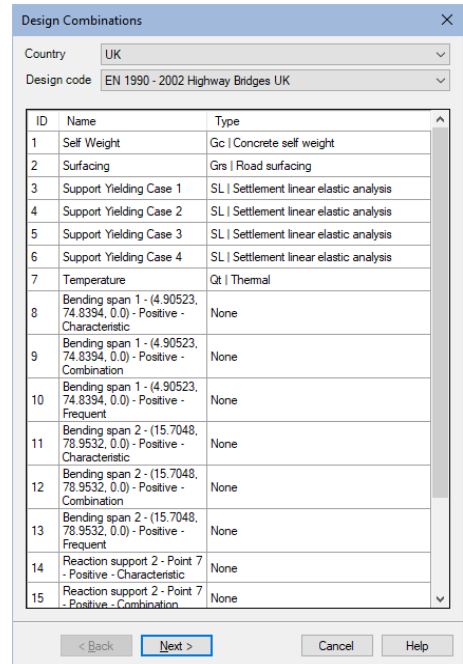
Design
 Design
 Combinations…

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

- Country: **United Kingdom**

- 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.

ID	Name	Type
1	Self Weight	Gc	Concrete self weight
2	Surfacing	Grs	Road surfacing
3	Support Yielding Case 1	SL	Settlement linear elastic analysis
4	Support Yielding Case 2	SL	Settlement linear elastic analysis
5	Support Yielding Case 3	SL	Settlement linear elastic analysis
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	None
9	Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Combination	None
10	Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Frequent	None
11	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Characteristic	None
12	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Combination	None
13	Bending span 2 - (15.7048, 78.9532, 0.0) - Positive - Frequent	None
14	Reaction support 2 - Point 7 - Positive - Characteristic	None
15	Reaction support 2 - Point 7 - Positive - Combination	None

Design Combinations
Country: UK
Design code: EN 1990 - 2002 Highway Bridges UK

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

- 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**
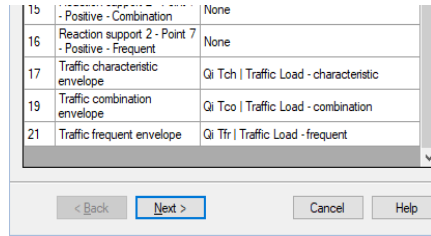
On the Combination options page of the wizard:

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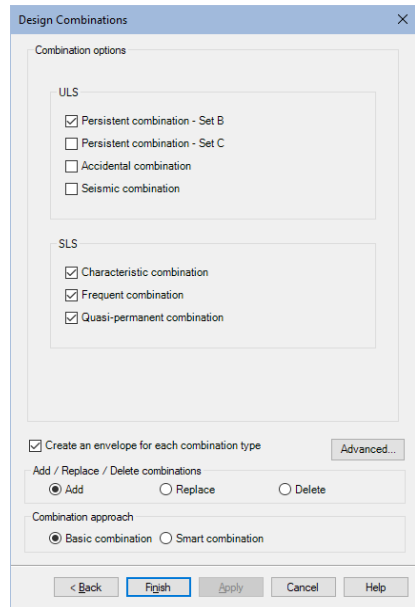
- Press the **Advanced** button, and on the Advanced Options dialog, with the **Permanent actions** tab selected, and for the **SL |Settlement linear elastic analysis** entry only, change **Mutual exclusive** from No to **Yes**, and click **OK**.

- 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.
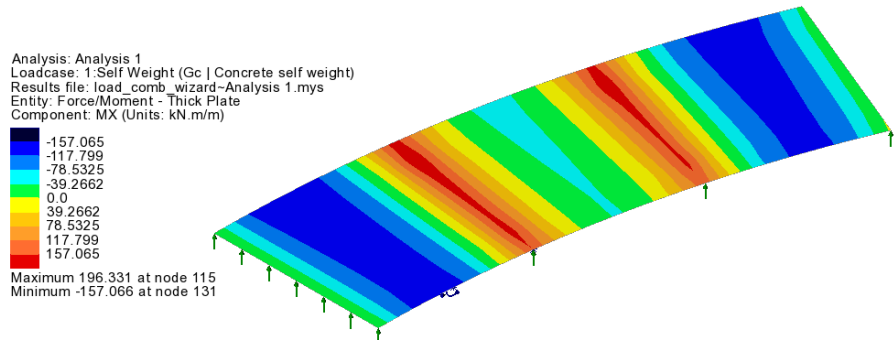
Displaying contours for Max and Min Effects

- 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.

Analysis: Analysis 1
Loadcase: 1:Self Weight (Gc | Concrete self weight)
Results file: load_comb_wizard~Analysis 1.mys
Entity: Force/Moment - Thick Plate
Component: MX (Units: kN.m/m)

-157.065
-117.799
-78.5325
-39.2662
0.0
39.2662
78.5325
117.799
157.065

Maximum 196.331 at node 115
Minimum -157.066 at node 131

Displaying Maximum effects

- In the Treeview, in the ULS Persistent Set B folder, right-click on combination **323:ULS_P_B_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**.

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

|	
	0.0
	141.867
	283.735
	425.602
	567.469
	709.337
	851.204
	993.071
	1.13494E3
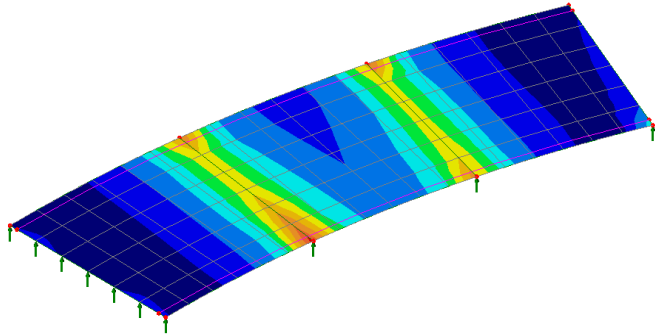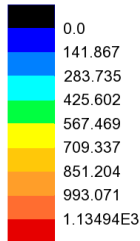
Maximum 1.21455E3 at node 23 of element 23 (101:ULS_P_B_B 79 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tch+1.55*0.6*Qt - Max))
Minimum -62.2538 at node 132 of element 107 (37:ULS_P_B_B 15 (0.95*Gc+0.95*Grs+1.2*SL+1.35*Qi Tch - Max))

From the Contour key it can be seen that maximum values occur in combination **101:ULS_P_B_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 (**79:ULS_P_B_B 47 …**) 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_B 79 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tch+1.55*0.6*Qt - Max)
Entity: Force/Moment - Thick Plate
Component: MX (Units: kN.m/m)

	-643.237
	-428.825
	-214.412
	0.0
	214.412
	428.825
	643.237
	857.65
	1.07206E3
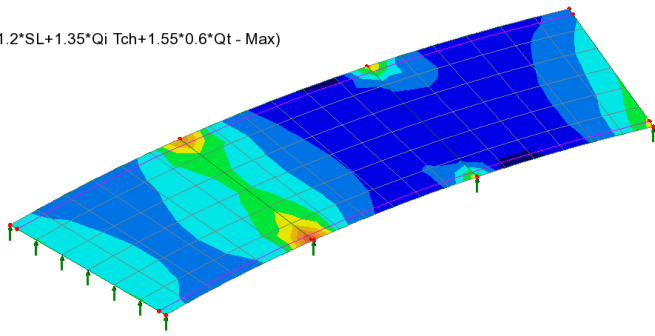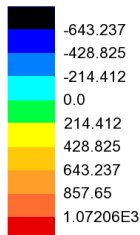
Maximum 1.21455E3 at node 23 of element 23
Minimum -715.16 at node 8 of element 6

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, set combination **324:ULS_P_B_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_B (Min)
Entity: Force/Moment - Thick Plate
Component: MX (Units: kN.m/m)

-1.17753E3
-1.03034E3
-883.147
-735.956
-588.765
-441.574
-294.382
-147.191
0.0
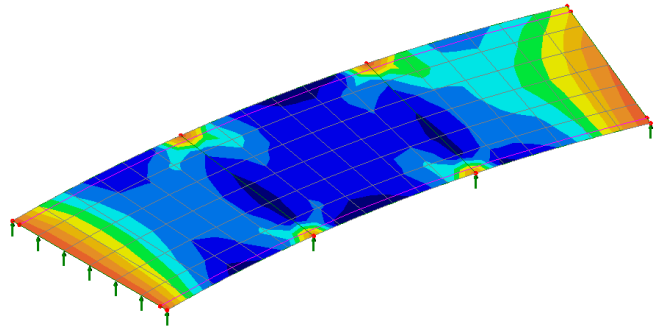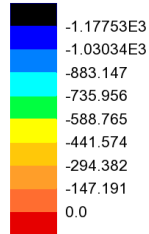
Maximum 27.2968 at node 113 of element 88 (29:ULS_P_B_B 7 (0.95*Gc+0.95*Grs+1.2*SL))
Minimum -1.29742E3 at node 19 of element 17 (280:ULS_P_B_B 258 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qi Tco+1.55*Qt - Min))

From the Contour key minimum values occur in combination **280: ULS_P 258 (1.35*Gc+1.2*Grs+1.2*SL+1.35*Qt Tch-Min).**

- 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**.

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

-1.249E3
-999.197
-749.398
-499.599
-249.799
0.0
249.799
499.599
749.398
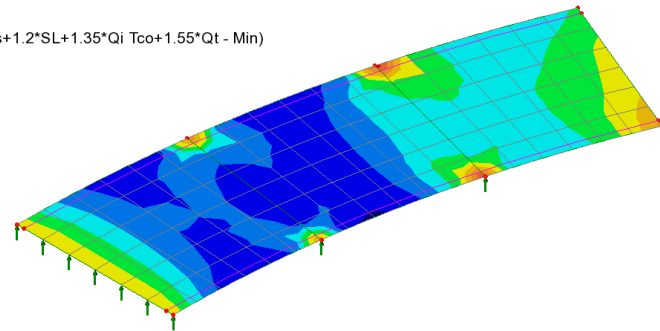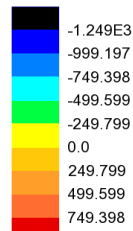
Maximum 950.77 at node 113 of element 88
Minimum -1.29742E3 at node 19 of element 17

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

	Number of combinations created for combination approach	
Combination type	**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.
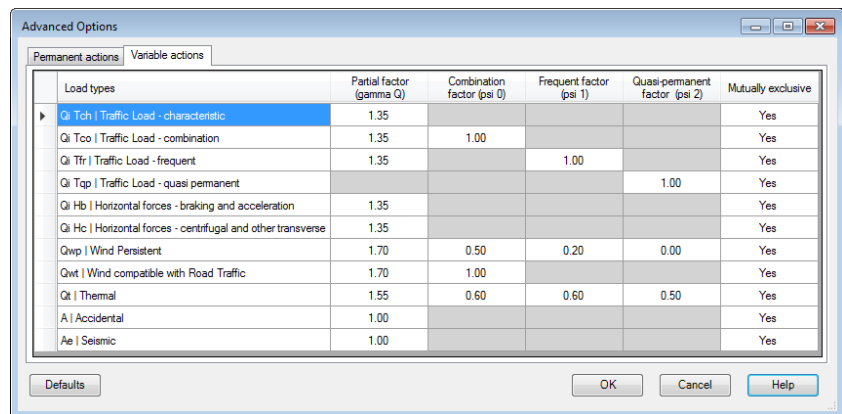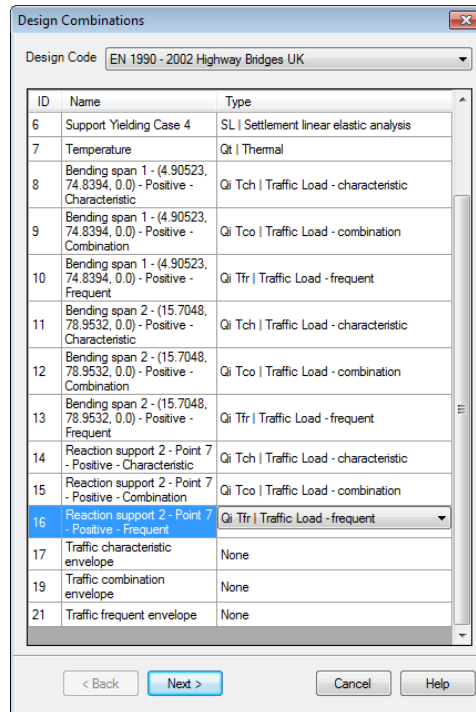
For more information on Basic and Smart Combinations please refer to the Modeller Reference Manual.