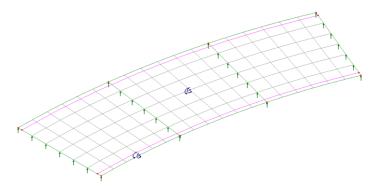
# Bridge Design Load Combinations

For LUSAS version:	18.0
For software product(s):	LUSAS Bridge.
With product option(s):	None.
Note: The example exceed	ls 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:

**Gamma** 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 seen in the reviews.



**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:

Den 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  $\bigcirc$  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:



- Ioad\_comb\_wizard~Analysis 1.out and Ioad\_comb\_wizard~VLO Analysis.out these output files contain details of model data, assigned attributes and selected statistics of the analysis.
- Ioad\_comb\_wizard~Analysis 1.mys and Ioad\_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

14:Reaction support 2 - Point 7 - Positiv     15:Reaction support 2 - Point 7 - Positiv	Name Bending span 1 - (4.90523, 74.8394, 0.0) - Positive - Characte Bending span 2 - (15.7049, 78.9532, 0.0) - Positive - Characteristic Reaction support 2 - Point 7 - Positive - Characteristic
Name Traffic characteristic envelope	× × (17)
	Close Cancel Apply Help

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
- (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.

De	sign
1	Design
0	Combinations

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

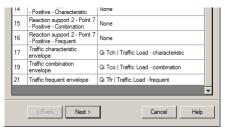
- Design Code: EN 1990 2002 Highway Bridges UK.
- Self Weight: (Gc) | Concrete self weight.
- Surfacing: (Grs) | Road surfacing (Grs).
- Support Yielding Case 1 to 4: (SL) | Settlement linear elastic analysis.
- Temperature: (Qt) | Thermal.
- Do not make any selections for Bending Span 1, 2 or Reaction support 2 VLO loadcase results because, for this example, all pre-defined load types will be assigned to the envelopes that have been defined.

/esig	n Code   EN 1990 - 2002 Hig	nway Bridges UK	_
ID	Name	Туре	
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	1
5	Support Yielding Case 3	SL   Settlement linear elastic analysis	1
6	Support Yielding Case 4	SL   Settlement linear elastic analysis	1
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	L
16	Reaction support 2 - Point 7	None	-

- 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 Action 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.



_	nbinations ation options	>
UL F		
F	S 7 Characteristic combination 7 Frequent combination 7 Quasi-permanent combination	
	e an envelope for each combination type Adv	vanced
Combina	dd C Replace C Delete tion approach assic combination C Smart combination	
	< Back Finish Apply Cancel	Help

- 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 Quasipermanent, 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.

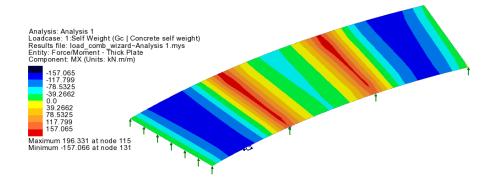
## **Displaying contours for Max and Min Effects**

- 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.

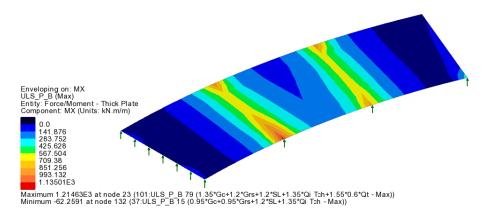
• Select Entity Force/Moment and component MX and click OK

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



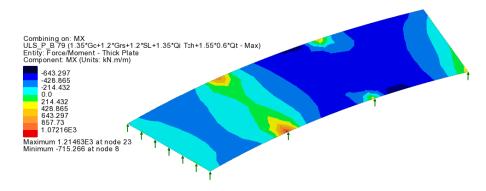
## **Displaying Maximum effects**

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).

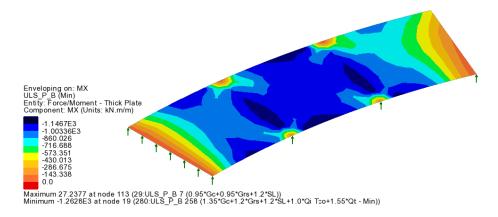
• In the  $\bigcirc$  Treeview, right-click on this combination and choose **Set Active**. On the Set Active dialog leave **Max / min primary component with coincident effects** selected and click **OK**.



**Note.** It can be seen that, in the  $\bigcirc$  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.

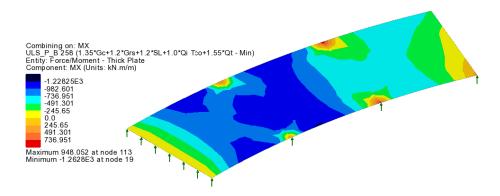
## **Displaying Minimum effects**

• 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.



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**.



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

Save the model file.

This completes the example.

# Discussion

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.

		nations created for n approach
Combination type	Basic combination	Smart combination
Characteristic combination	75	10
Frequent combination	35	8
Quasi-permanent combination	10	4
Persistent	300	12

If 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

ID	Name		Туре		<b>_</b>		
6	Support Yieldin	g Case 4 S	SL   Settlement linear elasti	c analysis			
7	Temperature		Qt   Thermal				
8	Bending span 1 74.8394, 0.0) - Characteristic	I • (4.90523, Positive • (	Di⊺ch   Traffic Load - cha	acteristic			
9	Bending span 1 74.8394, 0.0) - Combination	I • (4.90523, Positive • 0	QiTco Traffic Load - com	bination			
10	Bending span 1 74.8394, 0.0) - Frequent	l - (4.90523, Positive - 1	QiTfr   Traffic Load - frequ	ent			
11	Bending span 2 78.9532, 0.0) - Characteristic	2 - (15.7048, Positive - (	QiTch   Traffic Load - cha	acteristic			
12	Bending span 2 78.9532, 0.0) - Combination	2 · (15.7048, Positive · (	QiTco Traffic Load - com	bination			
13	Bending span 2 78.9532, 0.0] - Frequent	Positive - 0	QiTfr   Traffic Load - frequ	ent			
14	Reaction suppl · Positive · Cha	ort 2 - Point 7 racteristic	Qi Tch   Traffic Load - cha	acteristic			
15	Reaction suppl · Positive · Con	ort 2 - Point 7	QiTco Traffic Load - com	bination			
16	Reaction suppl · Positive · Free	ort 2 - Point 7 quent	QiTfr   Traffic Load - frequ	ent			
17	Traffic characte envelope	eristic	None				
19	Traffic combina	ation	None				
13	Traffic combina envelope Traffic frequent < Back		None Canc	el Help	• •		
	envelope Traffic frequent	t envelope	None		<b>•</b>		
21	envelope Traffic frequent	t envelope	None Cano	el Help	-		21-1
21	envelope Traffic frequent	t envelope	None Cano			iasi-permanent actor (psi 2)	_ [2 Mutually exclusive
21 Options X actions Variable actions	envelope Traffic frequent	t envelope	None Cano	el Help			
21 Options It actions Variable actions diverses ad types	envelope Traffic frequent	Partial factor (gamma Q)	None Cano	el Help			Mutually exclusive
21 Options Xtactons Variable actions  ad types Ch   Traffic Lead - characteristic	envelope Traffic frequent	Partial factor (gamma Q)	Canc Canc r Combination factor (psi 0)	el Help			Mutually exclusive Yes
21 Cptions X actions Variable actions dtppss ch1Traffic Load - contracteristic co1Traffic Load - combination	envelope Traffic frequent	Partial factor (gamma Q) 1.35	Canc Canc r Combination factor (psi 0)	el Help Frequent facto (psi 1)			Mutually exclusive Yes Yes
21 Options X action: Variable actions d type: chi   Tatic Load - characteristic (co   Tatic Load - combination (ri   Traffic Load - Inequent)	emelope Trainic trequent < Beck	Partial factor (gamma Q) 1.35	Canc Canc r Combination factor (psi 0)	el Help Frequent facto (psi 1)		actor (psi 2)	Mutually exclusive Yes Yes Yes
21 21 21 21 21 21 21 21 21 21 21 21 21 2	ervelope Trainic hequent C Beck Eration	Partial factor (gamme 0) 1.35	Canc Canc r Combination factor (psi 0)	el Help Frequent facto (psi 1)		actor (psi 2)	Mutually exclusive Yes Yes No
21 Options  ** actions: Variable actions ad types cch   Traffic Load - characteristic ico   Traffic Load - continuation if   Traffic Load - icousi permanent tib   Horizontal forces - braking and accel	ervelope Trainic hequent C Beck Eration	Partial factor (gamme 0) 1.35 1.35	Canc Canc r Combination factor (psi 0)	el Help Frequent facto (psi 1)		actor (psi 2)	Mutually exclusive Yes Yes No Yes
21 Diptions  * actions: Variable actions  chi   ratic: Load - characteristic coi   Tatlic: Load - combination //ri   Tratlic: Load - combination //ri   Tratlic: Load - combination //ri   Tratlic: Load - casis permanent bit   Horizont  document	ervelope Trainic hequent C Beck Eration	Partial factor (gamma Q) 1.35 1.35 1.35	Combination ractor (pi 0)	el Heb Frequert facto (pi 1) 1.00		actor (psi 2)	Mutually exclusive Yes Yes No Yes Yes Yes
21 Coptions It actions: Variable actions ad types Cent Traffic Load - characteristic Cent Traffic Load - combination In Traffic Load - combination Traffic Load - cause permanent Itib I Microsoft af Gross - braking and accel to I Microsoft af Gross - braking and accel to I Microsoft af Gross - braking and accel to I Microsoft af Gross - centrilugal and oth p I Wind Pensitem	ervelope Trainic hequent C Beck Eration	Partial facto (gamma 0) 1.35 1.35 1.35 1.35 1.35	Cance Cance r Combination fector (pic 0) 1.00 0.50	el Heb Frequert facto (pi 1) 1.00		actor (psi 2)	Mutually exclusive Yes Yes No Yes Yes Yes
21 22 23 24 24 24 25 25 25 25 25 25 25 25 25 25 25 25 25	ervelope Trainic hequent C Beck Eration	Partial factor (gamma Q) 1.35 1.35 1.35 1.35 1.70	Concentration Co	el Heb Frequert facto (pti 1) 1.00		actor (psi 2) 1.00 0.00	Mutually exclusive Yes Yes Yes No Yes Yes Yes Yes

Design Combinations

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