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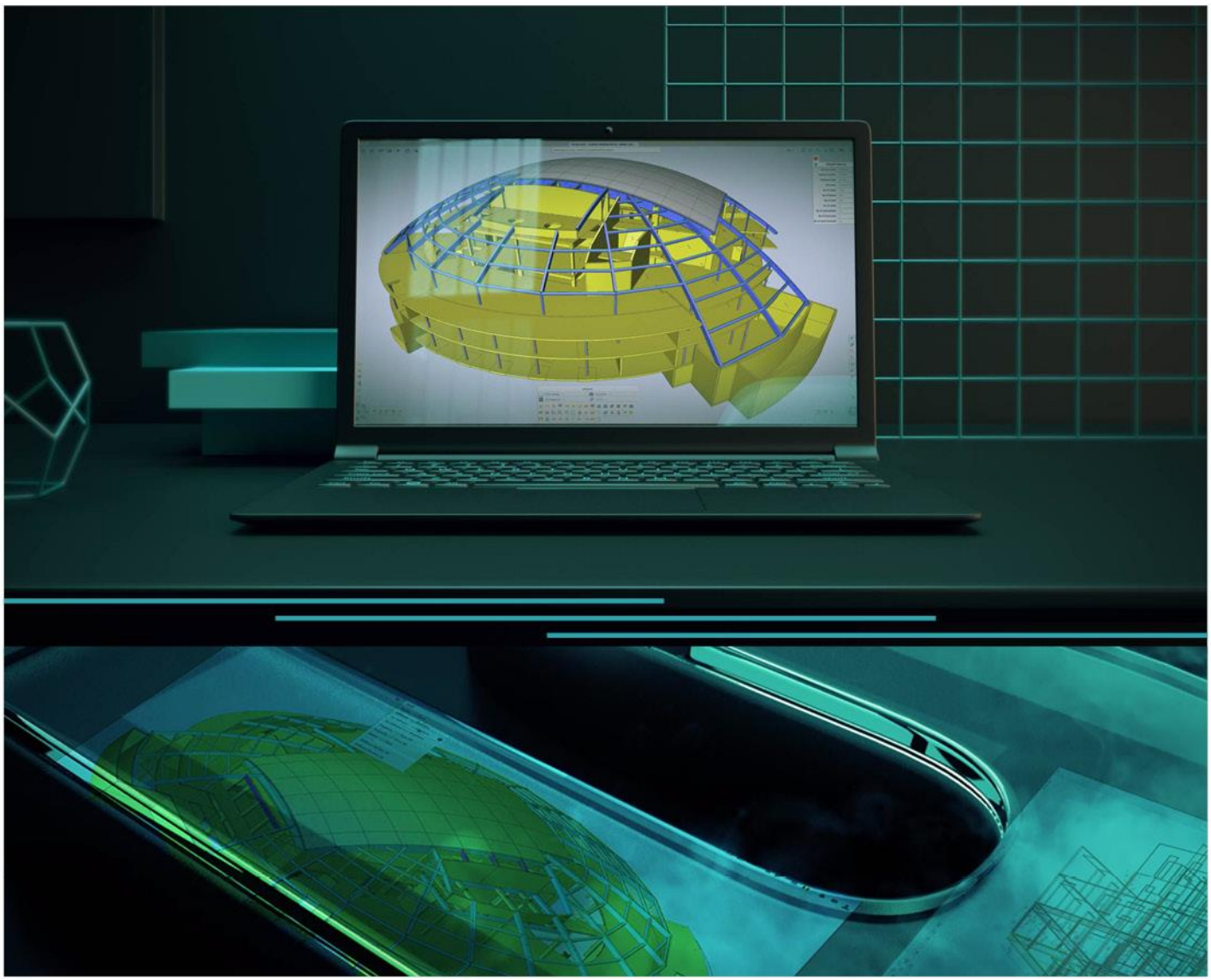

Tutorial

Loads and combinations

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Chapter 1: The model

This tutorial assumes that the modelling of a structure is understood and focusses on implementing load cases, groups and combinations.

The example that will be used in this tutorial is a small bridge deck with a sidewalk and a road over which only one car can drive at a time.

1.1. Load cases and load groups

The table below shows the different load cases, types and load groups.

Load case	Type	Load group	type
self-weight	P	/	/
LC 1: Permanent loads	P	LG 1	
LC 2: Car left	V	LG 2	Exclusive
LC 3: Car right	V	LG 2	Exclusive
LC 4: Pedestrian	V	LG 3	Standard

P = Permanent load
V = Variable load
LC = Load case
LG = Load group

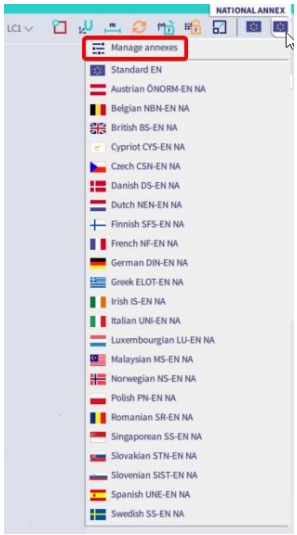
Every load case needs to be added to a load group. These load groups also have a property type which you use to define if loads can occur together in a combination or not. Assume there are two load case A and B in one load group. There are three different types you can choose from:

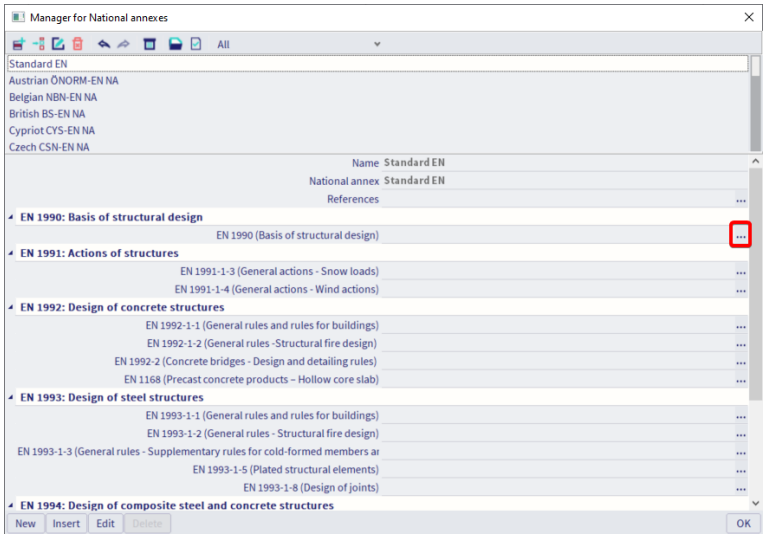
- *Standard* – A and/or B
- *Exclusive* – A or B
- *Together* – A and B

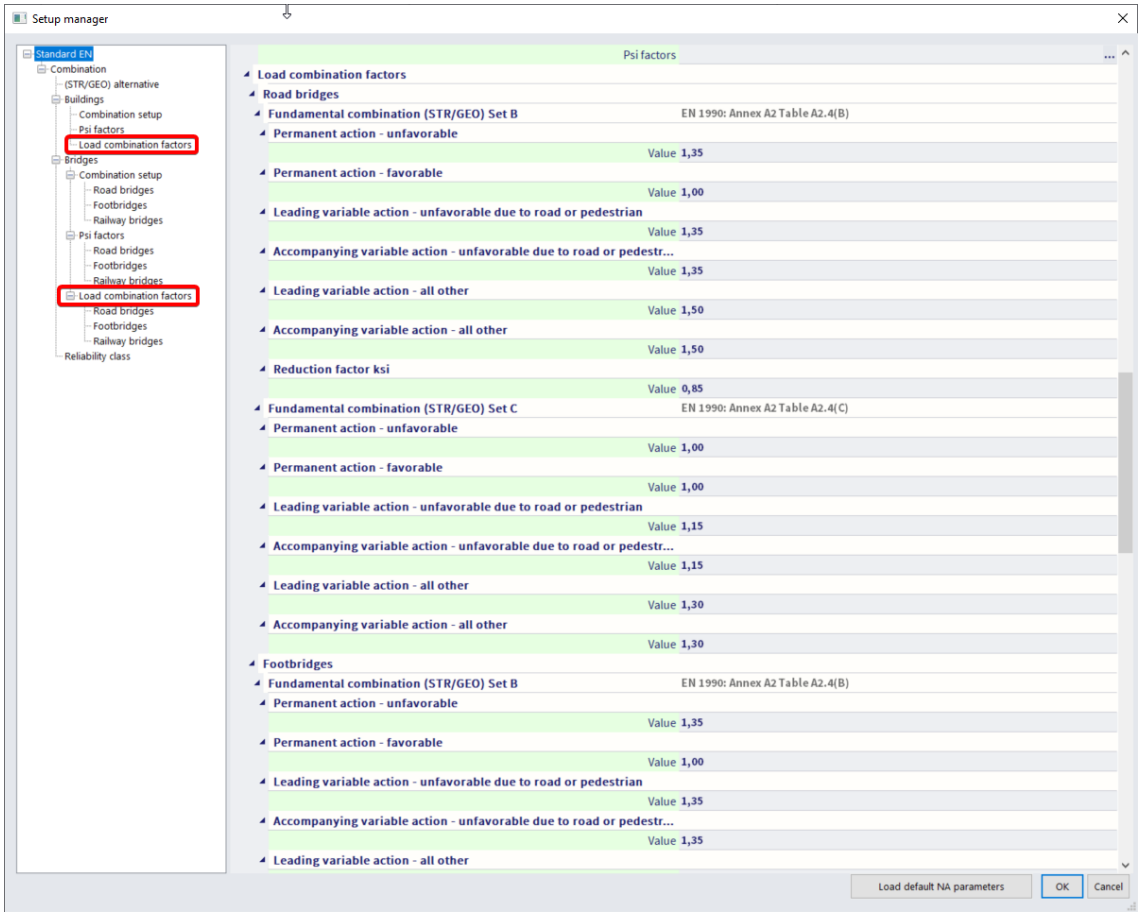
In this example there are 5 different load cases. It is known that only one car can use the bridge at a time, so LC 2 and LC 3 can never occur together. To model this, both load cases should be put in the same load group, LG 2 and the type should be set on exclusive. When creating automatic combinations, LC 2 and LC 3 will never occur in the same combination.

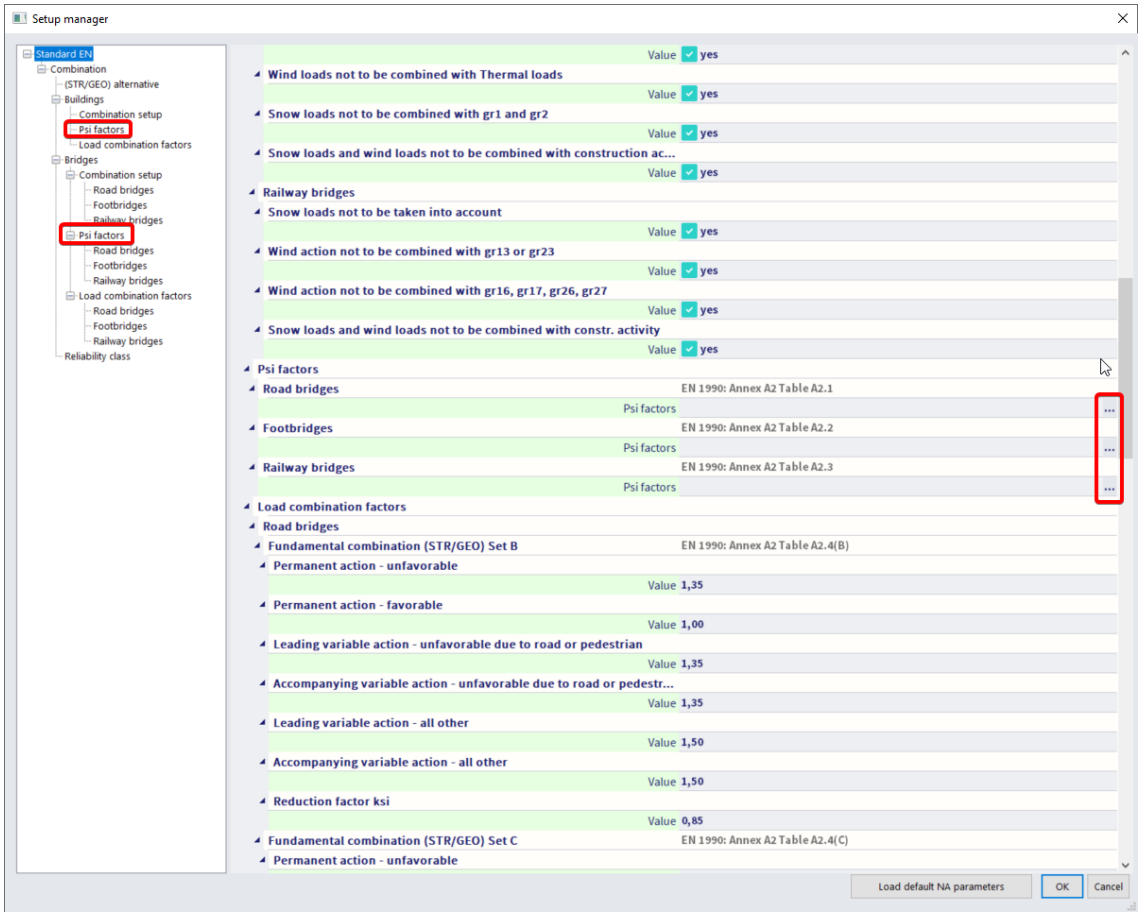
1.1.1. Load combination factors and psi-factors

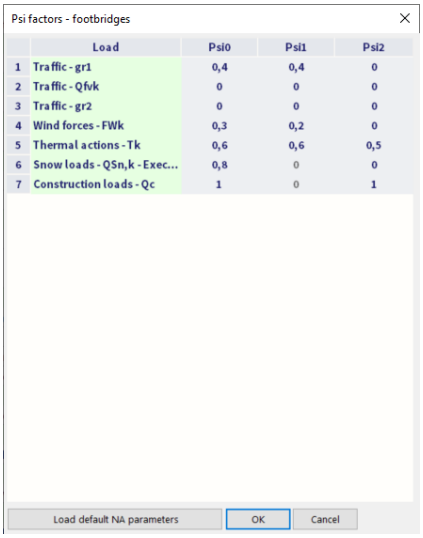
Load combination factors and psi factors can be found in the National Annex manager.






Setup manager
Standard EN
Combination
(STR/GEO) alternative
Buildings
Combination setup
Psi factors
Load combination factors
Bridges
Combination setup
Road bridges
Footbridges
Railway bridges
Psi factors
Road bridges
Footbridges
Railway bridges
Load combination factors
Road bridges
Footbridges
Railway bridges
Reliability class
Psi factors
Load combination factors
Road bridges
Fundamental combination (STR/GEO) Set B
EN 1990: Annex A2 Table A2.4(B)
Permanent action - unfavorable
Value 1,35
Permanent action - favorable
Value 1,00
Leading variable action - unfavorable due to road or pedestrian
Value 1,35
Accompanying variable action - unfavorable due to road or pedestr...
Value 1,35
Leading variable action - all other
Value 1,50
Accompanying variable action - all other
Value 1,50
Reduction factor ksi
Value 0,85
Fundamental combination (STR/GEO) Set C
EN 1990: Annex A2 Table A2.4(C)
Permanent action - unfavorable
Value 1,00
Permanent action - favorable
Value 1,00
Leading variable action - unfavorable due to road or pedestrian
Value 1,15
Accompanying variable action - unfavorable due to road or pedestr...
Value 1,15
Leading variable action - all other
Value 1,30
Accompanying variable action - all other
Value 1,30
Footbridges
Fundamental combination (STR/GEO) Set B
EN 1990: Annex A2 Table A2.4(B)
Permanent action - unfavorable
Value 1,35
Permanent action - favorable
Value 1,00
Leading variable action - unfavorable due to road or pedestrian
Value 1,35
Accompanying variable action - unfavorable due to road or pedestr...
Value 1,35
Leading variable action - all other
Load default NA parameters
OK
Cancel

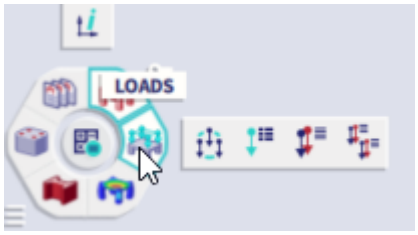

Setup manager
Standard EN
Combination
(STR/GEO) alternative
Buildings
Combination setup
Psi factors
Load combination factors
Bridges
Combination setup
Road bridges
Footbridges
Railway bridges
Psi factors
Road bridges
Footbridges
Railway bridges
Load combination factors
Road bridges
Footbridges
Railway bridges
Reliability class
Value yes
Wind loads not to be combined with Thermal loads
Value yes
Snow loads not to be combined with gr1 and gr2
Value yes
Snow loads and wind loads not to be combined with construction ac...
Value yes
Railway bridges
Snow loads not to be taken into account
Value yes
Wind action not to be combined with gr13 or gr23
Value yes
Wind action not to be combined with gr16, gr17, gr26, gr27
Value yes
Snow loads and wind loads not to be combined with constr. activity
Value yes
Psi factors
Road bridges
EN 1990: Annex A2 Table A2.1
Psi factors
Footbridges
EN 1990: Annex A2 Table A2.2
Psi factors
Railway bridges
EN 1990: Annex A2 Table A2.3
Psi factors
Load combination factors
Road bridges
Fundamental combination (STR/GEO) Set B
EN 1990: Annex A2 Table A2.4(B)
Permanent action - unfavorable
Value 1,35
Permanent action - favorable
Value 1,00
Leading variable action - unfavorable due to road or pedestrian
Value 1,35
Accompanying variable action - unfavorable due to road or pedestr...
Value 1,35
Leading variable action - all other
Value 1,50
Accompanying variable action - all other
Value 1,50
Reduction factor ksi
Value 0,85
Fundamental combination (STR/GEO) Set C
EN 1990: Annex A2 Table A2.4(C)
Permanent action - unfavorable
Load default NA parameters
OK
Cancel



It is possible to change these values if necessary, you can always go back to the factors from the national annex by clicking ‘load default NA parameters’.

Chapter 2: Load cases and load groups

In the process toolbar you can find the functions to add load cases, groups and combinations.



Load groups: 

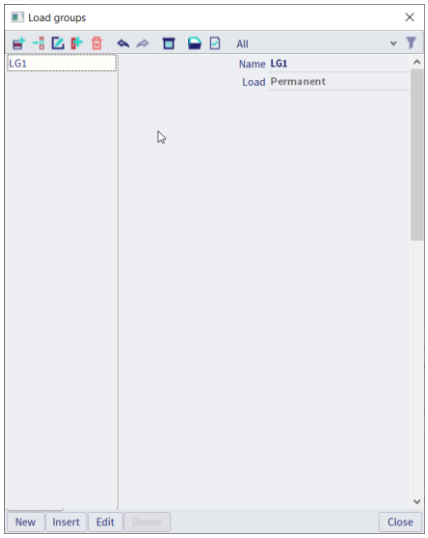
Load cases: 

Combinations: 

Result classes: 

2.1. Load groups

When opening the load groups, you will notice LG 1 is automatically created. This group contains the self-weight. The self-weight will be neglected in this tutorial, so this load group will be used for the other permanent loads.

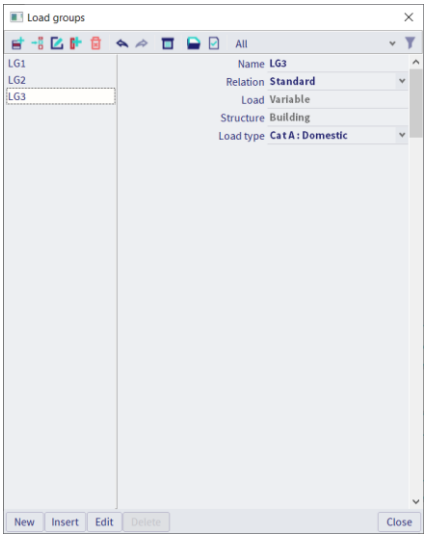


Click on New or  to add a load groups. LG 2 will appear. LG 2 is a group of variable loads who can't occur together so some changes should be done.

- Change load to: 'variable'
- Change relation to: 'exclusive'
- Change load type to 'Cat F: Vehicle < 30kN'

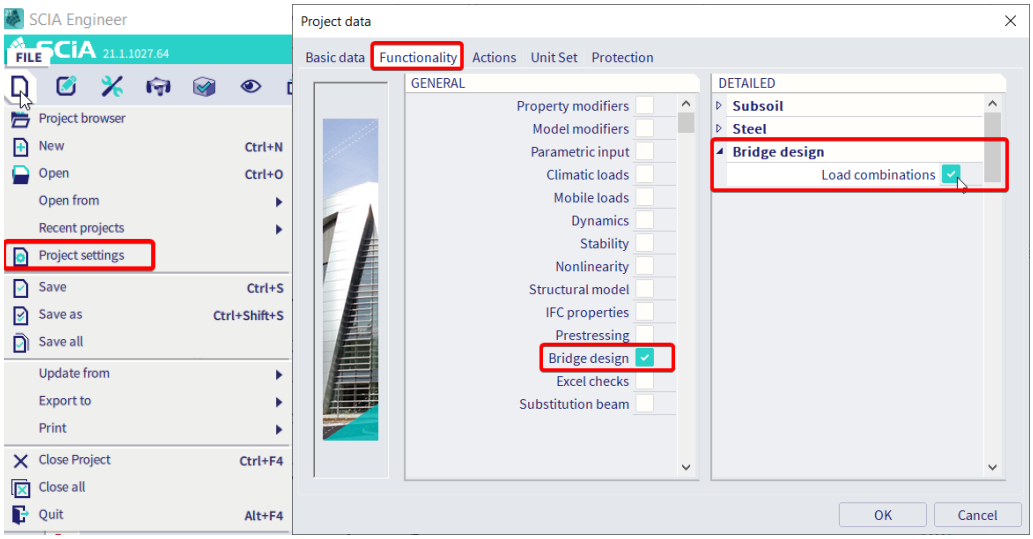
Click on New or  to add a load group. LG 3 will appear.

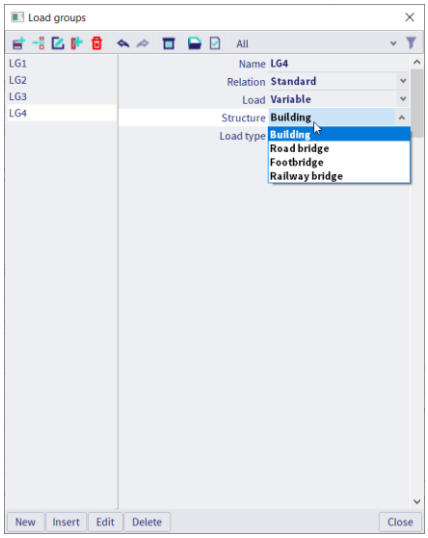
- Change the load to 'variable'
- Change the relation to 'standard'
- Change the load type to 'Cat A: domestic'



2.1.1. Property ‘structure’

In this example the structure will not be changed and you can notice the value is greyed out. To be able to change this value an extra functionality should be toggled on.

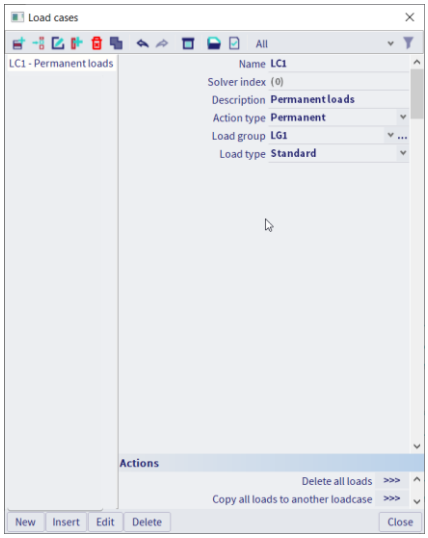




2.2. Load cases

When opening the load cases, you will notice there is one automatically generated. This is the self-weight of the structure. The self-weight will be neglected so a few changes can be made:

- Change the description to ‘Permanent loads’
- Change the load type to ‘standard’
- The load case is already in the right load group LG 1.



By clicking on New or  you can add more load cases. LC 2 will appear.

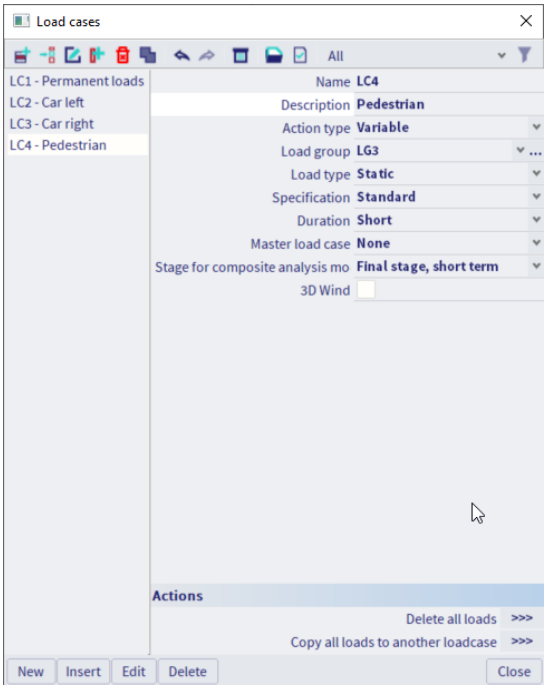
- Change the description to ‘car left’
- Change the action type to ‘Variable’
- This load case should be put in LG 2
- Other settings can be neglected in this tutorial.

By clicking on New or  you can add more load cases. LC 3 will appear.

- Change the description to ‘car right’
- Change the action type to ‘Variable’
- This load case should be put in LG 2
- Other settings can be neglected in this tutorial.

By clicking on New or  you can add more load cases. LC 4 will appear.

- Change the description to ‘Pedestrian
- Change the action type to ‘Variable’
- This load case should be put in LG 3
- Other settings can be neglected in this tutorial.



Chapter 3: Load combinations

In this example the following content of combinations and partial factors will be used:

Content of combination	Partial factors
LC 1	1,2
LC 2	1,5
LC 3	1,0
LC 4	0,5

There are three different types of load combinations

- Linear combination
- EN combination
- Envelope combination

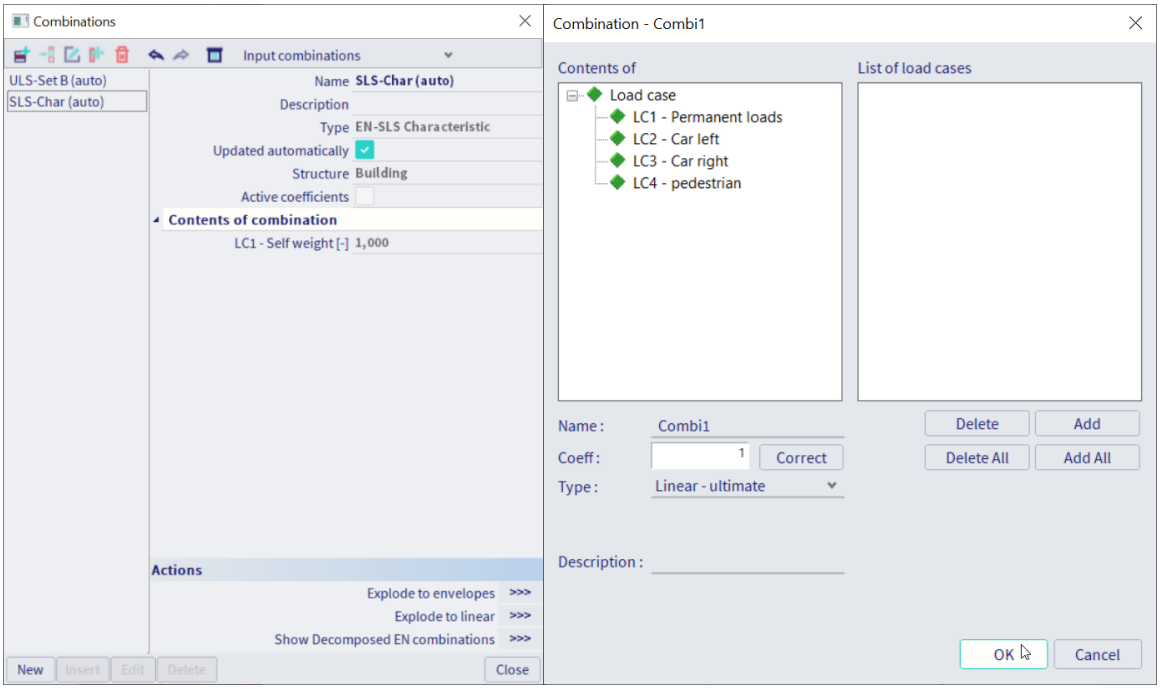
3.1. Linear combination

This type of combination will only generate one combination which you can define yourself. With this option you will **not take into account** the 'relations' defined in the load groups. If you add LC 2 and LC 3 together in this type of combination, you will be looking at a combination where both loads occur together.

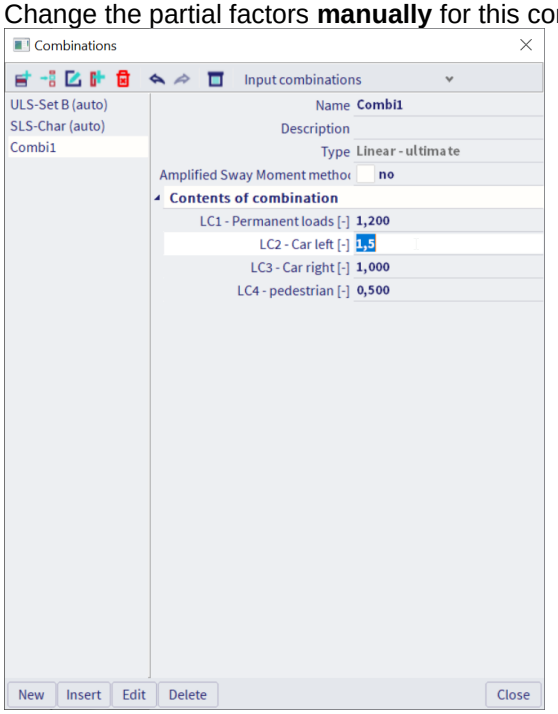
The partial factors are chosen by the user, therefore the 'load type' defined in the load cases will **not be taken into account**.

Open the 'combinations'. You will notice that two EN combinations are made automatically.

- Click New or  to add a new combination.
- Click on 'add all', this will add all the load cases to the combination.
- Set the type as 'linear ultimate'
- Set the name as 'combi1'
- Click 'OK'



- Change the partial factors **manually** for this combination



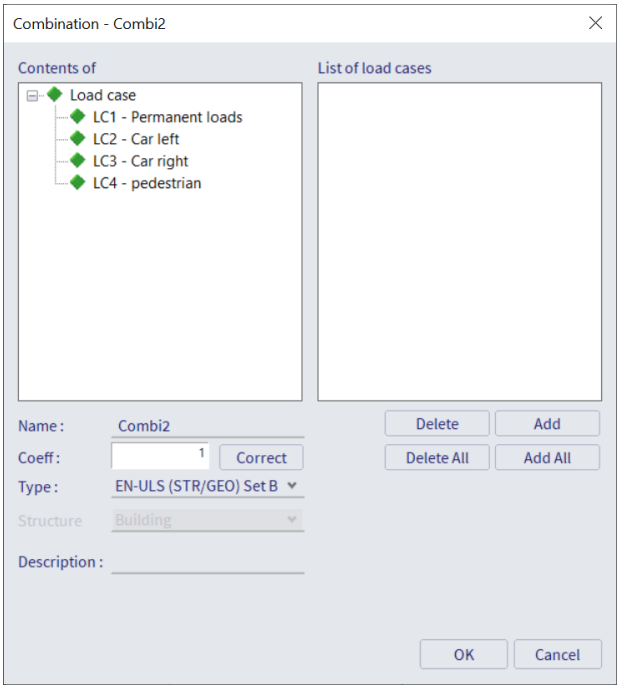
The linear combination Combi1 is: 1*LC1 + 1.5*LC2 + 1*LC3 + 0.5*LC4

3.2. EN combination

This option will create all possible linear combinations according to the **relations** defined in the load groups. The safety factors and Psi-factors are applied according to the Eurocode based on the **type** defined in the load cases.

Open ‘combinations’ and click 

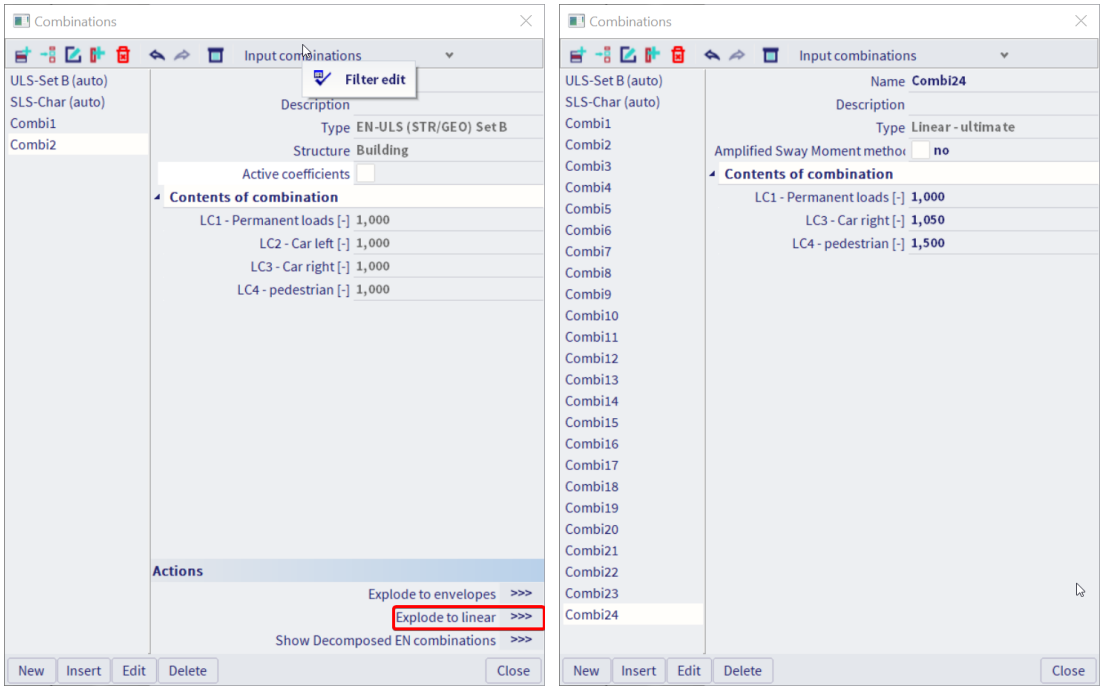
or  to add a new combination.



- Click on ‘add all’ to add all load cases to this combination
- Set the type as EN-ULS to create a new EN combination
- Change the name to Combi2
- Click ‘OK’

Combi2 has become a combination which holds all possible **linear** combinations while taking into account the set relations and the safety factors. This way you do not need to create all possible linear combinations manually.

- It is possible to generate all the linear combinations in Combi2 with the function ‘explode to linear’.



This function will create Combi3-24. If you look into these combinations you will notice that the type is automatically set to Linear Ultimate (chapter 3.1). LC2 and LC3 never occur together in one combination because their relation was set on ‘exclusive’.

In a project it is not necessary to explode an EN-ULS combination into linear combinations. When looking into the results for combination Combi2 the maximal results from all the included linear combinations will be shown.

3.2.1. Property ‘structure’

The property structure in the combinations can be changed the same way as the structure of load groups. When creating a combination with a different structure type you will only be able to add load cases which are put in a load group with the same structure.

For example: if a Load case is added to a load group with structure ‘Footbridge’ you will not be able to add this load case in a combination with structure ‘building’.

3.3. Envelope combination

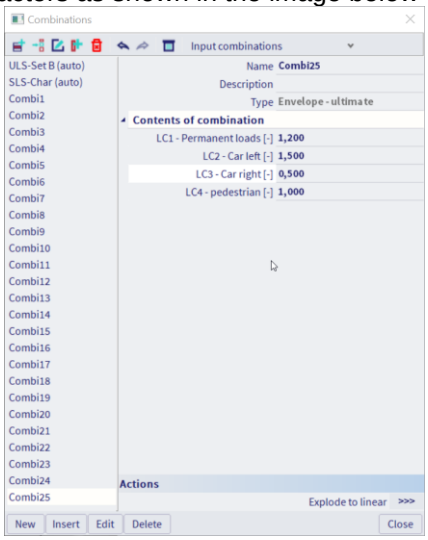
This type of combination will create all possible linear combinations with the chosen load cases. The difference with EN combinations is that the partial safety factors are user defined and not generated according to the Eurocode

Open ‘combinations’ and click New or  to add a new combination.

- Click ‘add all’ to add all load cases to the combination
- Set the type to ‘Envelope – ultimate’
- Change the name to ‘Combi25’
- Click ‘OK’

Combi25 becomes a combination that holds all the possible linear combinations while taking into account the defined relationships and the user defined partial factors.

- Change the partial factors as shown in the image below



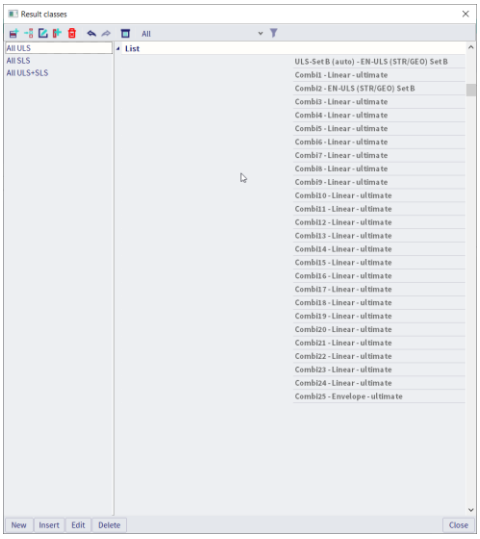
It is also possible to explode this combination to view all the linear combinations it holds. If you do this, Combi26 – 31 will be created. This time the user defined partial factors are used. This combination also makes sure LC2 and LC3 never occur together because their relation was set as ‘exclusive’.

Chapter 4: Result classes

Result classes give you the opportunity to create an enveloping combination with an arbitrary amount of load cases and/or combinations. When looking into the results for a result class, the maximal result will be shown from all the load cases or combination which the class holds.

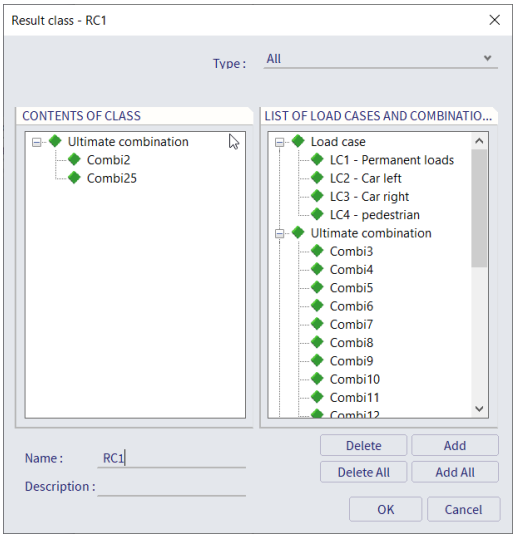
Open ‘result classes’

- Several classes are made automatically
- The class ‘All ULS’ will contain all the created linear, EN and envelope combinations created in chapter 3 and the automatic combination.



Click New or  to add a new result class

- Add Combi2 (EN combination) and Combi25 (Envelope combination) to the result class by selecting them and clicking ‘add’.
- Rename the result class RC1
- Click ‘OK’



The new result class will be added to the list. You can always edit them later.

Chapter 5: Results

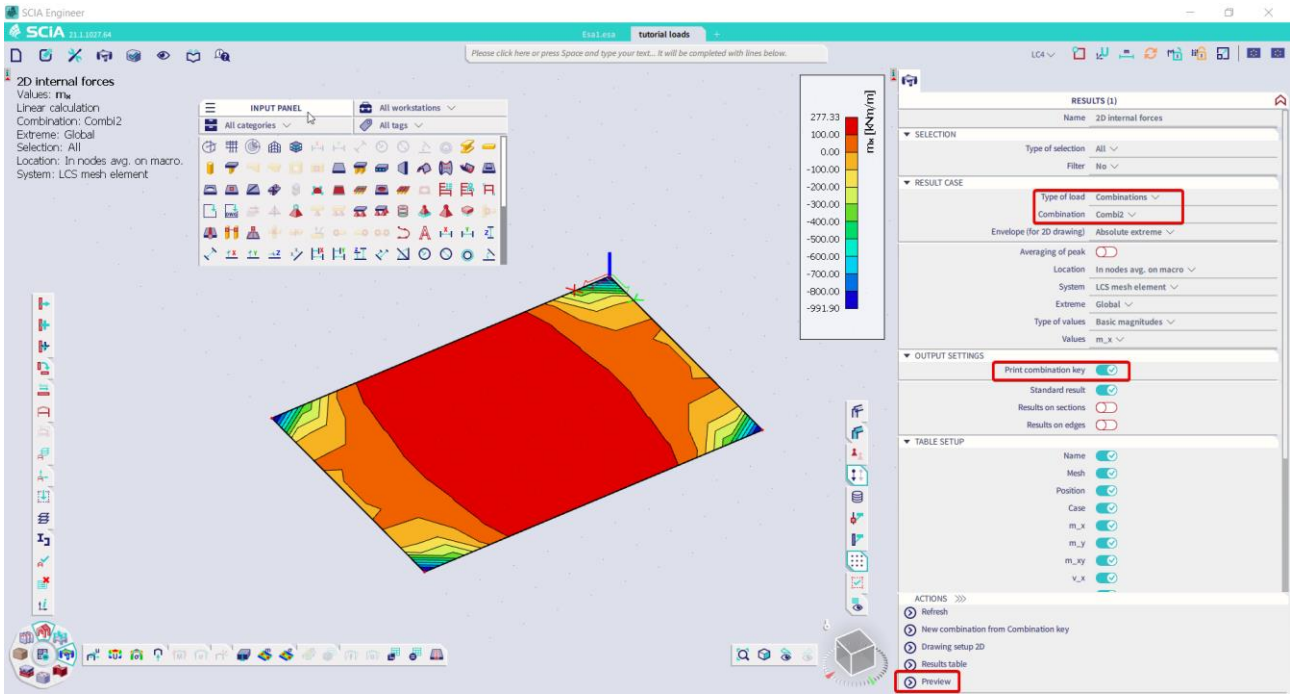
Results are only available after calculation.

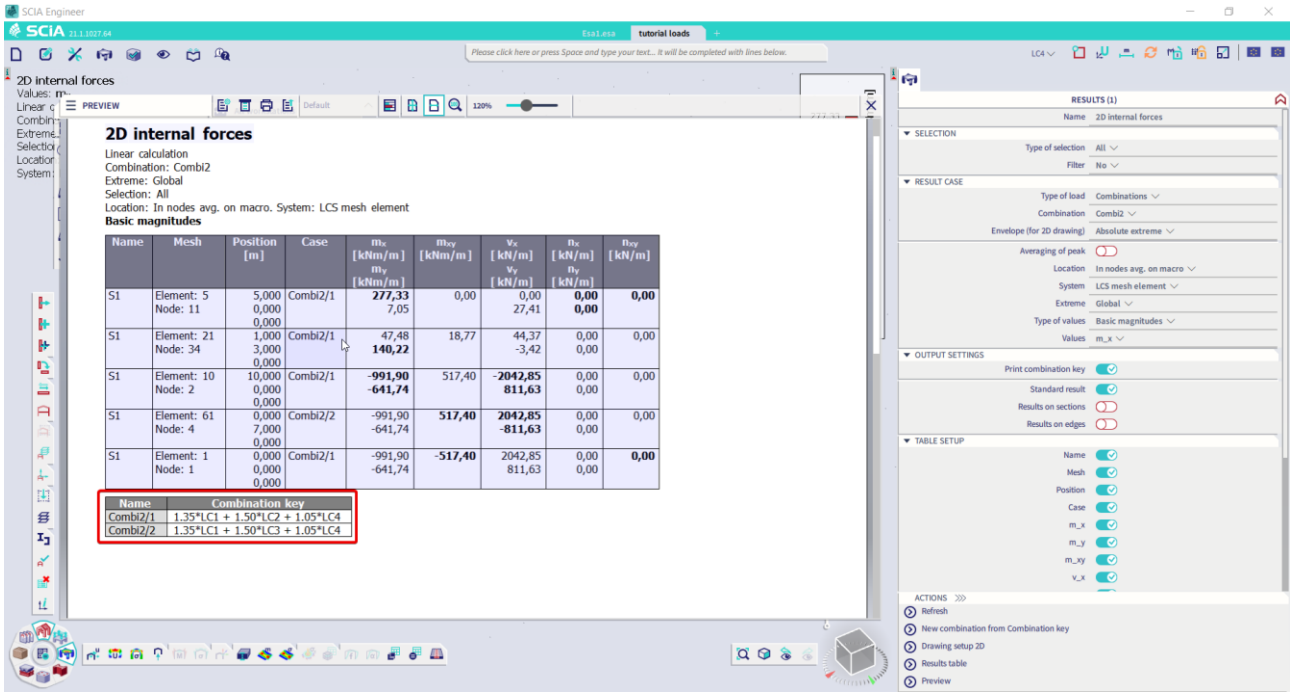
5.1. EN and envelope combinations

The results from EN or envelope combinations show the most positive and negative result on each section. It is only possible to look at the results of specific combinations when the function ‘explode to linear’ was used.

5.2. The most critical combinations

Getting the most critical combinations is only possible with the combination keys shown in the ‘preview’. As an example a piece of the bridge is modelled as a plate and loads are added to the defined load cases. When looking into the results for Combi2 the output is set on ‘print combination key’.





Only the most critical combinations from combi2 are shown here which seems to be the combinations with load case 2 and 3 (car left and car right). The same can be done for result classes or other combinations.