

Tutorial Loads and combinations

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Table of Contents

Table of Cont	ents3	}
Chapter 1:	The model4	ļ
1.1.	Load cases and load groups	4
1.1	1.1. Load combination factors and psi-factors	4
Chapter 2:	Load cases and load groups7	,
2.1.	Load groups	7
2.2.	Load cases	9
Chapter 3:	Load combinations12	2
3.1.	Linear combination	12

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	Туре	Load group	type
self-weight	Р	1	1
LC 1: Permanent loads	Р	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 loadV = Variable loadLC = Load caseLG = 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.

LC1 ~ 🗋 🐙 🚐 🥪 🏫 🖬 🔝 國	Manager for National annexes	×
	🖶 📲 🖸 📵 🐟 🛷 🛅 🔛 🗛 🖬 🔍 🗛 👘	
Standard EN	Standard EN	
Austrian ÖNORM-EN NA	Austrian ÖNORM-EN NA	-
	Belgian NBN-EN NA	
Belgian NBN-EN NA	British BS-EN NA	
British BS-EN NA	Cypriot CYS-EN NA	
Cypriot CYS-EN NA	Czech CSN-EN NA	
Czech CSN-EN NA	Name Standard EN	^
Danish DS-EN NA	National annex Standard EN	
Dutch NEN-EN NA	References	
Finnish SFS-EN NA	 EN 1990: Basis of structural design 	
French NF-EN NA	EN 1990 (Basis of structural design)	
German DIN-EN NA	 EN 1991: Actions of structures 	
Greek ELOT-EN NA	EN 1991-1-3 (General actions - Snow loads)	
Irish IS-EN NA	EN 1991-1-4 (General actions - Wind actions)	
	 EN 1992: Design of concrete structures 	
Italian UNI-EN NA	EN 1992-1-1 (General rules and rules for buildings)	
Luxembourgian LU-EN NA	EN 1992-1-2 (General rules -Structural fire design)	
Malaysian MS-EN NA	EN 1992-2 (Concrete bridges - Design and detailing rules)	
Norwegian NS-EN NA	EN 1168 (Precast concrete products – Hollow core slab)	
Polish PN-EN NA	 EN 1993: Design of steel structures 	
Romanian SR-EN NA	EN 1993-1-1 (General rules and rules for buildings)	
Singaporean SS-EN NA	EN 1993-1-2 (General rules - Structural fire design)	
Slovakian STN-EN NA	EN 1993-1-3 (General rules - Supplementary rules for cold-formed members ar	
Slovenian SIST-EN NA	EN 1993-1-5 (Plated structural elements)	
Spanish UNE-EN NA	EN 1993-1-8 (Design of joints)	
Swedish SS-EN NA	EN 1994: Design of composite steel and concrete structures	×
	New Insert Edit Delete	ОК

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	,30 :N 1990: Annex A2 Table A2.4(B) ,35 ,00

	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 cor			
- Show loads and while loads not to be combined with con	Value ves		
A Railway bridges	value value		
 Snow loads not to be taken into account 			
- Show loads not to be taken into account	Value 🗸 yes		
Wind entire not to be combined with esta as es22	value ves		
 Wind action not to be combined with gr13 or gr23 	Mala and		
	Value 🗸 yes		
 Wind action not to be combined with gr16, gr17, gr26, gr 	_		
	Value 🗸 yes		
Snow loads and wind loads not to be combined with cor			
	Value 🔽 yes		
Psi factors			
A 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			
A 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 period			
- Leading variable action - unravorable due to road of pe	Value 1,35		
Accompanying variable action - unfavorable due to roa			
Accompanying variable action - unravorable due to roa			
	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	ОК

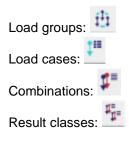
	factors - footbridges			×
	Load	Psi0	Psi1	Psi2
1	Traffic - gr1	0,4	0,4	0
2	Traffic - Qfvk	0	0	0
3	Traffic - gr2	0	0	0
4	Wind forces - FWk	0,3	0,2	0
5	Thermal actions - Tk	0,6	0,6	0,5
6	Snow loads - QSn,k - Exec	0,8	0	0
7	Construction loads - Qc	1	0	1

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

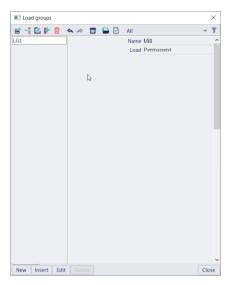
In the process toolbar you can find the functions to add load cases, groups and combinations.





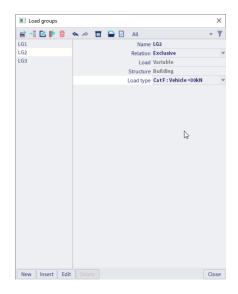
2.1. Load groups

When opening the load groups, you will notice LG 1 is automatically created. This group contains the selfweight. 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 it 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'



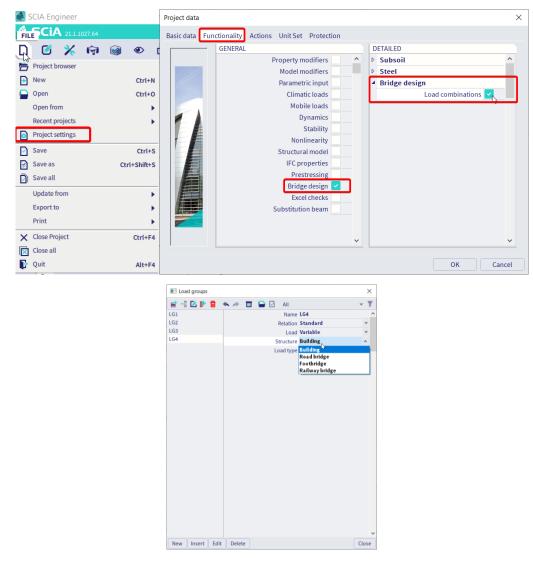
Click on New or it to add a load group. LG 3 will appear.

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



2.1.1. Property 'structure'

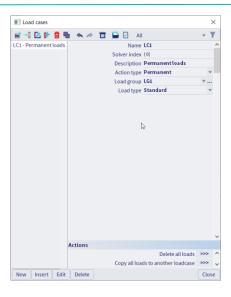
In this example the structure will not be changed and you can notice the value is greyed out. To be able to change this value an extra functionality should be toggled on.



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:

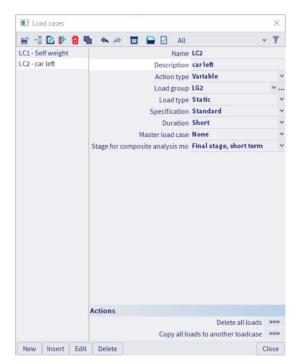
- Change the description to 'Permanent loads'
- Change the load type to 'standard'
- The load case is already in the right load group LG 1.

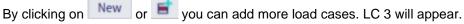


By clicking on

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.



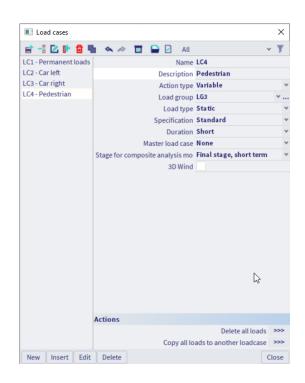


- Change the description to 'car right'
- Change the action type to 'Variable'
- This load case should be put in LG 2
- Other settings can be neglected in this tutorial.

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 <u>one</u> 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 it 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'

Combinations		\times	Combination - Combi1 X	
ULS-Set B (auto) SLS-Char (auto)	 Input combinations Name SLS-Char (auto) Description Type EN-SLS Characteristic Updated automatically Structure Building Active coefficients Contents of combination LC1 - Self weight [-] 1,000 		Contents of List of load cases LC1 - Permanent loads LC2 - Car left LC3 - Car right LC4 - pedestrian LC4 - pedestrian Delete Name : Combi1 Coeff : 1 Coeff : 1 Coeff : 1 Delete All Add All Type : Linear - ultimate	
	Actions Explode to envelopes	>>>		
		>>>		
	Show Decomposed EN combinations		OK 🗟 Cancel	
New Insert Edit	Delete	ose	OK W Caller	

Combination	IS			×
🛃 📲 🖸 🕩		Input combinations	~	
ULS-Set B (auto)		Name Com	oi1	
SLS-Char (auto)		Description		
Combi1		Type Linea	ır - ultimate	
	Amplified	Sway Moment method n	0	
	 Conten 	ts of combination		
	LC	1 - Permanent loads [-] 1,200	,	
		LC2 - Car left [-] 1,5		
		LC3 - Car right [-] 1,000	1	
		LC4 - pedestrian [-] 0,500	,	
	Edit Delete			Close

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 clic	New	or 📑	to add a	new co	ombinatio	on.
	Combination -	- Combi2				×
		case 21 - Permanent lo 22 - Car left 33 - Car right 24 - pedestrian	ads	List of load	cases	
	Name : Coeff :	Combi2	Correct		Delete Delete All	Add Add All
	Type : Structure Description :	EN-ULS (STR/G	EO) Set B 👻			
	Description :				ОК	Cancel

- 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'.

Combinations	×	Combinations
📑 📲 🗹 🕩 🖬	🔦 🗢 🔲 Input combinations 🔹 👻	📑 📲 🔀 📴 🐟 🗢 🔲 Input combinations 🔹 👻
ULS-Set B (auto)	💎 Filter edit	ULS-Set B (auto) Name Combi24
SLS-Char (auto)	Description	SLS-Char (auto) Description
Combi1	Type EN-ULS (STR/GEO) Set B	Combi1 Type Linear - ultimate
Combi2	Structure Building	Combi2 Amplified Sway Moment method no
	Active coefficients	Combi3 Contents of combination
	Contents of combination	Combi4 LC1 - Permanent loads [-] 1,000
	LC1 - Permanent loads [-] 1,000	Combis LC3 - Car right [-] 1,050
	LC2 - Car left [-] 1,000	Combi6 LC4 - pedestrian [-] 1,500
	LC3 - Car right [-] 1,000	Combia
	LC4 - pedestrian [-] 1,000	Combia
		Combio Combio
		Combil1
		Combi12
		Combi13
		Combi14
		Combi15
		Combi16
		Combi17
		Combi18
		Combi19
		Combi20
	Actions	Combi21 Combi22
	Explode to envelopes >>>	Combi23
	Explode to linear >>>	Combi24
	Show Decomposed EN combinations >>>	
New Insert Edit	t Delete Close	New Insert Edit Delete Close

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

Open 'combinations'

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

Combination - Combi25	
Contents of	List of load cases
 Coad case CL1 - Permanent loads C2 - Car left C3 - Car right C4 - pedestrian 	
Name : Combi25	Delete Add
Coeff: Correc	ct Delete All Add All
Type : Envelope - ultimate	<u> </u>
Description :	

- 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



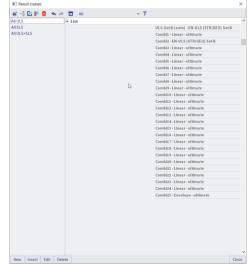
It is also possible to explode this combination to view all the linear combinations it holds. If you do this, Combi26 – 31 will be created. This time the user defined partial factors are used. This combination also makes sure LC2 and LC3 never occur together because their relation was set as 'exclusive'.

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.

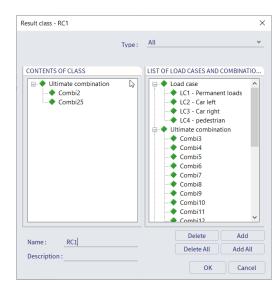
Open 'result classes'

- 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 it 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

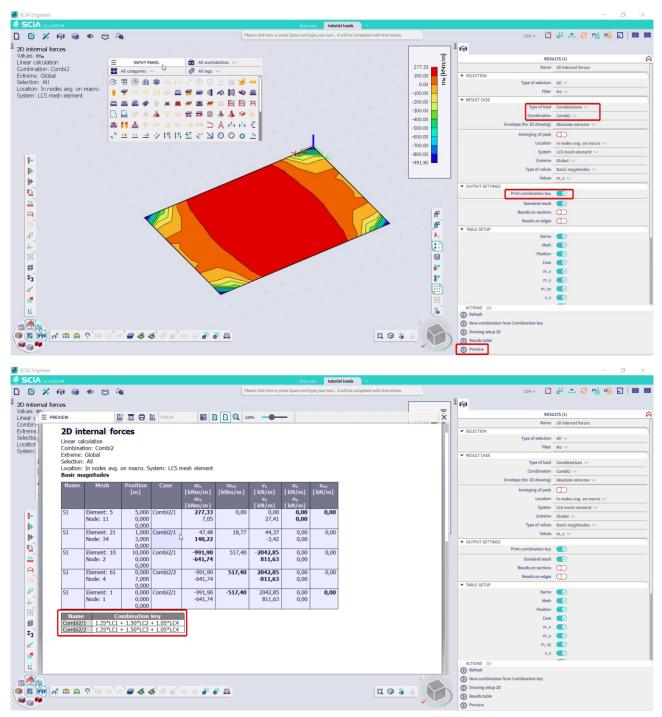
Results are only available after calculation.

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.