



# \ SCIA ENGINEER TUTORIAL Loads and combinations

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#### 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.

#### 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	/	/
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 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.

#### Load combination factors and psi-factors

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

Lav P	] 🔑 🚐 🧭 mà 🖷 🔂 國	Manager for National annexes	^
	Manage annexes	🔍 🖬 📲 🖸 📾 🗢 🗖 🖨 🖸 All 🛛 👻	
	Standard EN	Standard EN	
	Austrian ÖNOPM-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	
	<ul> <li>Cypriot CYS-EN NA</li> </ul>	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	<ul> <li>EN 1991: Actions of structures</li> </ul>	
	Granek ELOTLEN NA	EN 1991-1-3 (General actions - Snow loads)	
		EN 1991-1-4 (General actions - Wind actions)	
	ITISTI IS-EN NA	<ul> <li>EN 1992: Design of concrete structures</li> </ul>	
	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	<ul> <li>EN 1993: Design of steel structures</li> </ul>	
	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)	
	Sopoich LINE EN NA	EN 1993-1-8 (Design of joints)	
	Council of the life life	EN 1994: Design of composite steel and concrete structures	~
	Swedish 55-EN NA	New Insert Edit Delete	ОК

Setup manager		
Standard EN	Psi factors	
Combination	Load combination factors	
(STR/GEO) alternative     Ruildings	A Road bridges	
- Combination setup	Fundamental combination (STR/GEO) Set B EN 1990: Annex A2 Table A2.4(B)	
- Psi factors	Permanent action - unfavorable	
Load combination factors	Value 1.35	
Bridges	A Permanent action - favorable	
- Road bridges	Value 1.00	
Footbridges	A Leading variable action - unfavorable due to read or podertrian	
Railway bridges	Leading variable action - unravorable due to road or pedestriain	
Psi factors     Read bridges	Value 1,35	
Footbridges	Accompanying variable action - unfavorable due to road or pedestr	
Railway bridges	Value 1,35	
-Load combination factors	Leading variable action - all other	
Road bridges	Value 1,50	
Footbridges	Accompanying variable action - all other	
Reliability class	Value 1,50	
	A 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	
	4 Leading variable action - all other	
	- Leading variable action - an other	
	value 1,30	
	Accompanying variable action - all other	
	Value 1,30	
	4 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	

Setup manager					×
Standard EN		Value ves			^
Combination	Wind loads not to be combined with Thermal loads				
- (STR/GEO) alternative		Value ves			
Buildings	for any local state in a second local with set and set	value yes			
Combination setup	Show loads not to be combined with gr1 and gr2				
- Load combination factors		Value ves			
Bridges	Snow loads and wind loads not to be combined with constru	ction ac			
Combination setup		Value 🖌 yes			
- Road bridges 🖌	Railway bridges				
- Footbridges	Snow loads not to be taken into account				
- Bri factors		Value 🔽 yes			
- Road bridges	Wind action not to be combined with gr13 or gr23				
Footbridges	wind action not to be combined with Birs of Birs	Value Ves			
- Railway bridges		value yes			
Load combination factors	Wind action not to be combined with gr16, gr17, gr26, gr27	_			
Road bridges		Value ves			
Footbridges	Snow loads and wind loads not to be combined with constr.	activity			
Ralivay bridges		Value 🔽 yes			
Penability class	Psi factors				A.
	Road bridges	EN 1990: Annex A2 Table A2.1			
	nong pridges	Dei fastere			
	Provide Advance	EN 1000: Annon An Table An A			
1	Footbridges	EN 1990: Annex A2 Table A2.2			
		Psi factors			
4	Railway bridges	EN 1990: Annex A2 Table A2.3			
		Psi factors			
× L	oad combination factors				-
	Road bridges				
	Fundamental combination (STR/GEO) Set B	EN 1990: Annex A2 Table A2.4(B)			
	Bermanent action - unfavorable				
	· remainent action - unavorable	1.1			
		value 1,35			
	Permanent action - favorable				
		Value 1,00			
	Leading variable action - unfavorable due to road or pedes	trian			
		Value 1,35			
	Accompanying variable action - unfavorable due to road or	pedestr			
	······	Value 1 35			
	the discount of the sector will sate as	value 1,00			
	Leading variable action - all other				
		Value 1,50			
	<ul> <li>Accompanying variable action - all other</li> </ul>				
		Value 1,50			
	Reduction factor ksi				
		Value 0.85			
	Fundamental combination (STR/GEO) Set C	EN 1990: Annex &2 Table &2 4(C)			
	Democratic Complication (STR/OCO/ Set C	ER 1330. MILLEX M2 TEME M2.4(C)			
	Permanent action - unfavorable				~
			Load default NA parameters	ОК	Cancel
					-

Psi	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'

### Load cases and load groups

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



#### 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.

Load groups		$\times$
🖶 📲 🖸 📭 🔒 🐟 🛷 🔳 🕞 🖸	) All	~ <b>T</b>
G1	Name LG1	^
	Load Permanent	
R		
New Insert Edit Delete		Close

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 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'



#### 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.



#### 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.

🔳 Loa	d cases						>	<
et -1	🕑 📭	<b>8</b> 5	•	🕒 🖸 🛛 All		¥	Ŋ	ſ
LC1 - Pe	rmanent l	oads		Name	LC1			^
				Solver index	(0)			
				Description	Permanentloads			
				Action type	Permanent		٣	
				Load group	LG1	*		
				Load type	Standard		۷	
			Actions	[ Copy all loa	Delete all loads	>>>		
	-	5.4%	Deter	Copy all loa	ds to another loadcase		-	~
New	Insert	Edit	Delete			C	OS	2

By clicking on New or is 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 is 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.



#### 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

#### 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 **E** 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	<
ULS-Set B (auto) SLS-Char (auto)	<ul> <li>         Image: Input combinations         Name SLS-Char (auto)         Description         Type EN-SLS Characterist         Updated automatically ✓         Structure Building         Active coefficients         Contents of combination         LC1 - Self weight [-] 1,000         </li> </ul>	ic	Contents of       List of load cases         LC1 - Permanent loads       LC2 - Car left         LC2 - Car right       LC4 - pedestrian         LC4 - pedestrian       Delete         Name:       Combi1         Coeff:       1         Correct       Delete All         Type:       Linear - ultimate	
	Actions		Description :	
	Explode to envelop Explode to line	es >>>		
	Show Decomposed EN combinatio	ns >>>		
New Insert Edit	Delete	Close	OK 🗟 Cancel	

Combinations			$\times$
et -: 🖸 🕩 🖯	🔦 🗢 🔲 Input combinations	~	
JLS-Set B (auto)	Name Combi1		
SLS-Char (auto)	Description		
Combi1	Type Linear -	ultimate	
	Amplified Sway Moment method no		
	<ul> <li>Contents of combination</li> </ul>		
	LC1 - Permanent loads [-] 1,200		
	LC2 - Car left [-] 1,5		
	LC3 - Car right [-] 1,000		
	LC4 - pedestrian [-] 0,500		
New Insert E	dit Delete		Close

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

#### **EN** combination

٠

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	New or	r 🔳 to a	dd a new	/ combi	ination.	
	Combination -	- Combi2				×
	Contents of	case (1 - Permanent lo (2 - Car left (3 - Car right (3 - pedestrian	vads	List of load	d cases	
	Name :	Combi2			Delete	Add
	Coeff:	1	Correct		Delete All	Add All
	Type :	EN-ULS (STR/G	EO) Set B 💌			
		Building	V			
	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     X
🖻 📲 🗹 🕩 🖬	🔦 🗢 🔲 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	Combi5 LC3 - Car right [-] 1,050
	LC2 - Car left [-] 1,000	Combis Combiz LC4 - pedestrian [-] 1,500
	LC3 - Car right [-] 1,000	Combia
	LC4 - pedestrian [-] 1,000	Combig
		Combi10
		Combi11
		Combi12
		Combi13
		Combi14
		Combi15
		Combi16
		Combit?
		Combile
		Combi20
		Combi21
	Actions	Combi22
	Explode to envelopes >>>	Combi23
	Explode to linear >>>	Combi24
	Show Decomposed EN combinations >>>	
New Insert Edit	Delete	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.

#### 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'.

#### **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	d a new	/ comb	pinatior	۱.
		Combination -	Combi25				$\times$
		Contents of → Load of → LC2 → LC2 → LC2 → LC2 → LC2	case 1 - Permanent Ic 2 - Car left 3 - Car right 4 - pedestrian	ads	List of load	cases	
		Name : Coeff : Type : Description :	Combi25 1 Envelope - ultir	Correct nate Y		Delete Delete All	Add Add All
						OK	Cancel

- 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

Combinations		$\times$				
🖻 📲 🗹 🕩 🛢	👟 🗢 🔲 Input combinations 🔷 👻					
ULS-Set B (auto)	Name Combi25					
SLS-Char (auto)	Description					
Combi1	Type Envelope - ultimate					
Combi2	<ul> <li>Contents of combination</li> </ul>					
Combi3	LC1 - Permanent loads [-] 1,200					
Combi4	C2 - Car left [-] 1.500					
Combi5	LC3 - Car right [-] 0.500					
Combi6	LC4- pedestrian [-] 1 000					
Combi7	LC4-pedestrian[-] 1,000					
Combi8						
Combi9						
Combi10						
Combi11						
Combi12						
Combi13						
Combi14						
Combi15						
Combi16						
Combi17						
Combi18						
Combi19						
Combi20						
Combi21						
Combi22						
Combi23						
Combi24	Actions					
Combi25	Explode to linear	>>>				
New Insert Edit	Delete	Close				

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'.

#### **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'

Result class - RC1		
	Type :	All
CONTENTS OF CLASS		LIST OF LOAD CASES AND COMBINATIO
Ultimate combination		Load case
Name : RC1		Delete Add
Description :		OK Cancel

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

#### Results

Results are only available after calculation.

#### 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.

#### 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.