CM01 – Concrete and Masonry Structures 1

HW2 – Calculation of internal forces

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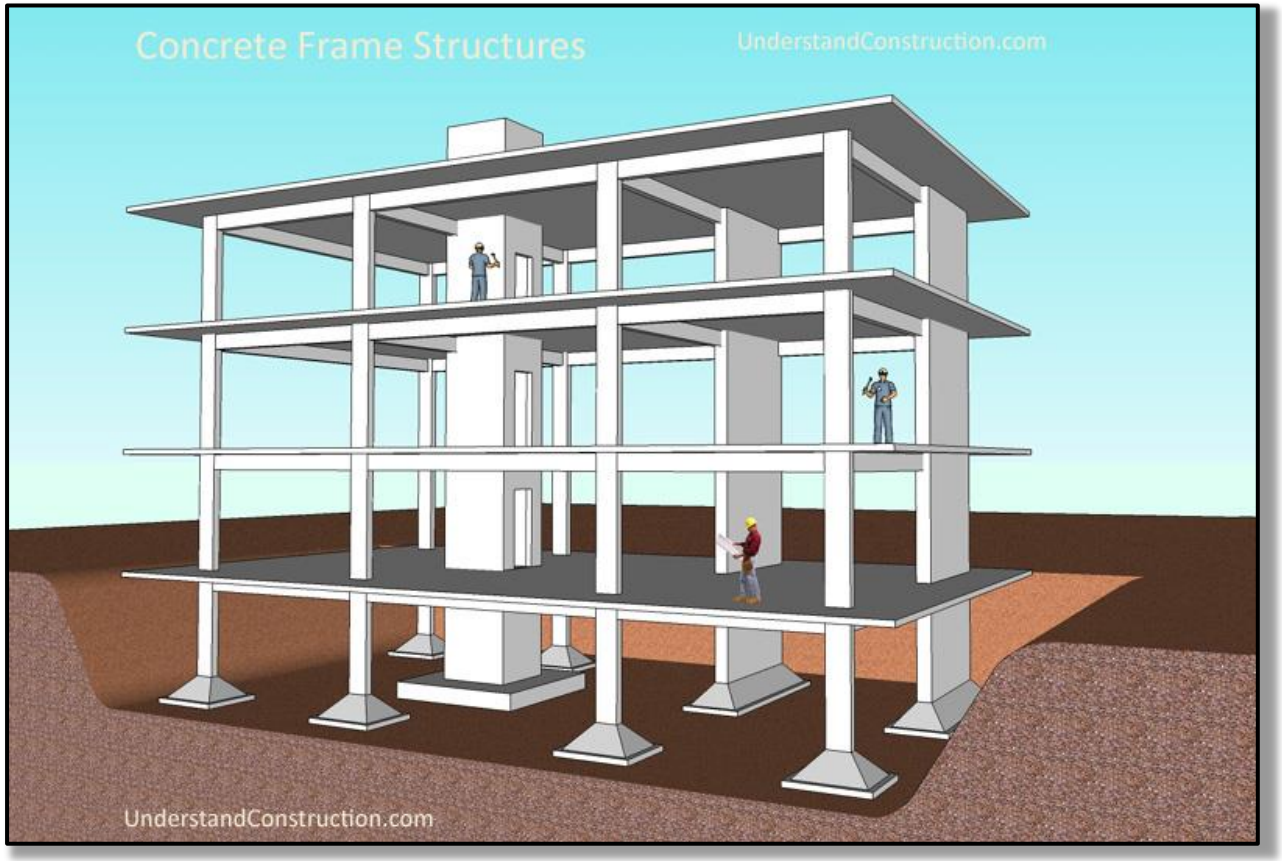
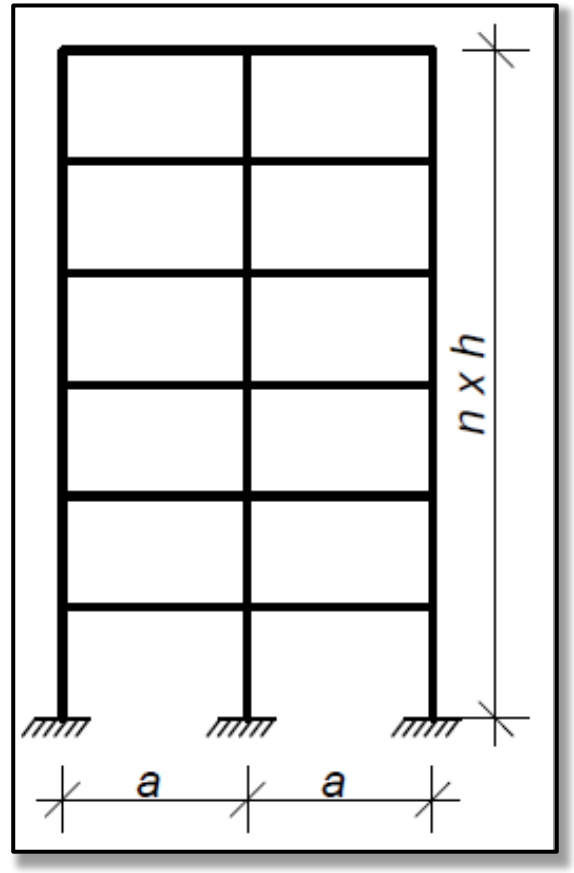
Task 1

Task 1 – Frame structure

In Task 1, frame structure will be designed.

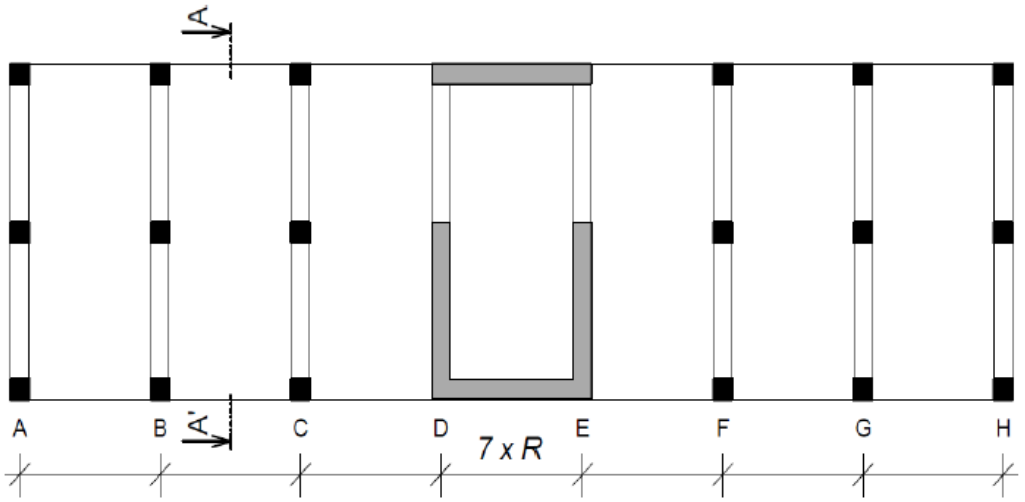




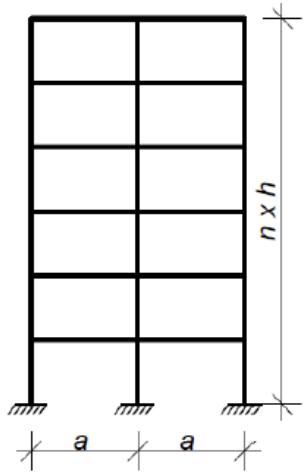
Task 1 – Assignment

Scheme of the stucture:

Plan:



Section A -A´:



Individual parameters (parameters in **bold** you can find on teacher's website):

Geometry: ***R***, ***a*** [m] – horizontal dimensions, ***h*** [m] – floor height, ***n*** – number of floors

Materials: Concrete – **concrete class**
Steel B 500 B (f_{yk} = 500 MPa)

Loads: Other permanent load of typical floor $(g\text{-}g_0)_{floor,k}$ [kN/m^2]
Other permanent load of the roof $(g\text{-}g_0)_{roof,k}$ [kN/m^2]
Live load of typical floor $q_{floor,k}$ [kN/m^2]
Live load of the roof $q_{roof,k}$ = 0,75 kN/m^2
Self-weight of the slab according to calculated depth

Another parameters: ***S*** – Exposure class related to environmental conditions
Z – Working life of the structure

Task 1 – Assignment goals

Our goal will be to:

- Design the dimensions of all elements.
- **Do detailed calculation of 2D frame – calculation of bending moments, shear and normal forces using FEM software.**
- Design steel reinforcement in the members.
- Draw layout of the reinforcement.

Calculation of internal forces in 2D frame

Calculation of internal forces in 2D frame

In this part of the task, we will **calculate internal forces in the frame structure** (2D transverse section of the building).

We will use the **IdeaStatica software** for the calculation of internal forces*.

*In your homework, you can use any other software if you are familiar with it, or calculate the forces manually.

Calculation of internal forces in 2D frame

This part consists of the following steps:

- **calculate beam loading**,
- download and **install IdeaStatica 21.0**,
- **model the frame**, **calculate internal forces**, and **create a report** in IdeaFrame module.

Calculation of internal forces in 2D frame

Beam loading

Beam loading

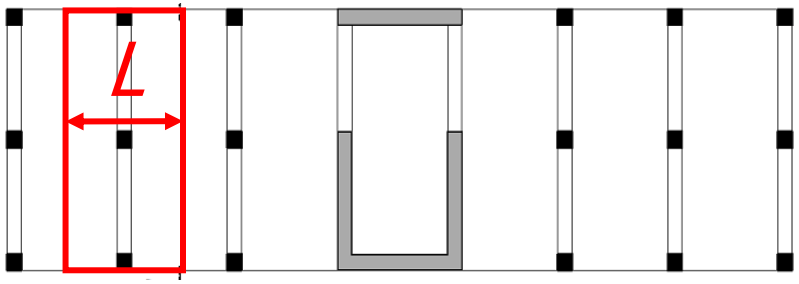
First, we must determine the loads acting on the beams, which we will later input into Idea software.

Manually calculate 4 values of linear loads per 1 meter of the beam (in kN/m):

- Characteristic permanent load in typical floor $g_{k,t}$,
- Characteristic permanent load on the roof $g_{k,r}$,
- Characteristic variable load in typical floor $q_{k,t}$,
- Characteristic variable load on the roof $q_{k,r}$,

self-weight of the slab + other permanent load

Linear load [kN/m] = area load [kN/m2] * L [m].



Beam loading

Floor slab load							
Load type	Load name	h	ρ	ρ_{pl}	f_k	γ	f_d
-	-	mm	kg/m^3	kg/m^2	kN/m^2	-	kN/m^2
DEAD (G)	slab self weight	190	2500	475	4.75	1.35	6.41
	other permanent load	*from assignment*			0.50		0.68
	Σ				5.25		7.09
LIVE (Q)	variable	*from assignment*			3	1.5	4.50
	Σ				3		4.50
SUM					**f_k =**	**8.25**	**f_d =** **11.59**

Floor beam load						
Load type	Load name	$f_{a,k}$	tributing width	$f_{lin,k}$	γ	$f_{lin,d}$
-	-	kN/m^2	m	kN/m	-	kN/m
DEAD (G)	slab dead load	5.25	6.5	34.13	1.35	46.07
	beam self weight	*calculated automatically by Idea*		0.00		0.00
	Σ			34.13		46.07
LIVE (Q)	slab live load	3	6.5	19.50	1.5	29.25
	Σ			19.50		29.25
SUM				**f_k =** **53.63**		**f_d =** **75.32**

Slab span: R = 6.5 m

Roof slab load							
Load type	Load name	h	ρ	ρ_{pl}	f_k	γ	f_d
-	-	mm	kg/m^3	kg/m^2	kN/m^2	-	kN/m^2
STÁLÉ (G)	slab self weight	190	2500	475	4.75	1.35	6.41
	other permanent load	*from assignment*			2.00		2.70
	Σ				6.75		9.11
PROM. (Q)	variable	*from assignment*			0.75	1.5	1.13
	Σ				0.75		1.13
SUM					**f_k =**	**7.50**	**f_d =** **10.24**

Roof beam load						
Load type	Load name	$f_{a,k}$	tributing width	$f_{lin,k}$	γ	$f_{lin,d}$
-	-	kN/m^2	m	kN/m	-	kN/m
DEAD (G)	slab dead load	6.75	6.5	43.88	1.35	59.23
	beam self weight	*calculated automatically by Idea*		0.00		0.00
	Σ			43.88		59.23
LIVE (Q)	slab live load	0.75	6.5	4.88	1.5	7.31
	Σ			4.88		7.31
SUM				**f_k =** **48.75**		**f_d =** **66.54**

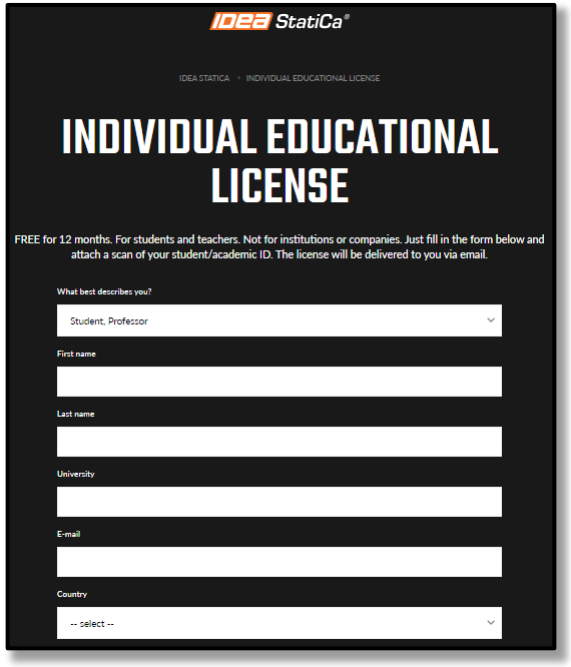
Slab span: R = 6.5 m

Calculation of internal forces in 2D frame

Download and install of IdeaStatica 21.0

Download and install of IdeaStatica 21.0

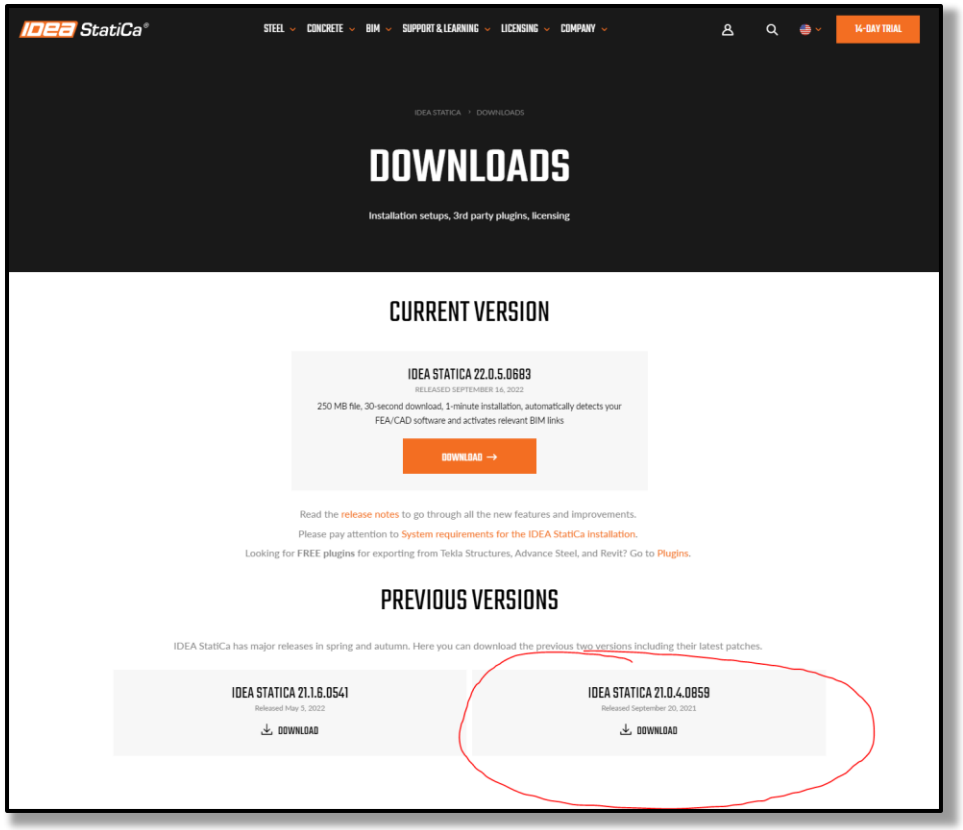
First, apply for the **student license** of IdeaStatica. When applying, **use your school student email** (e.g., “name.surname@estp.fr”).



Wait (up to 3 days) until you receive an activation email with your login credentials.

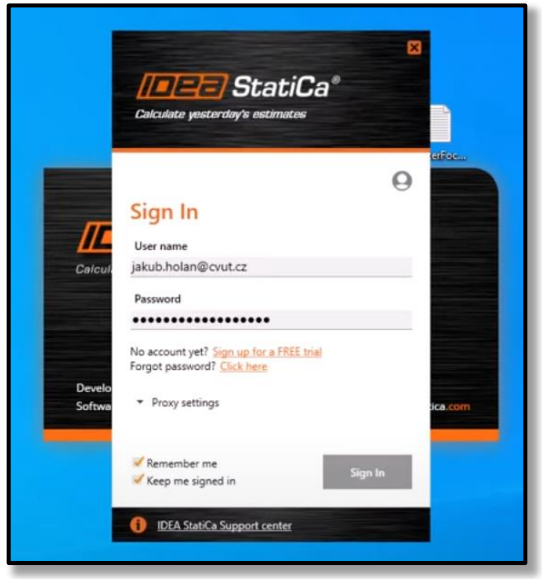
Download and install of IdeaStatica 21.0

For our task, we will use the IdeaFrame module. This module is available only in **IdeaStatica 21.0** so we will download and install this version. Do NOT download any other version as they do not have the IdeaFrame module!

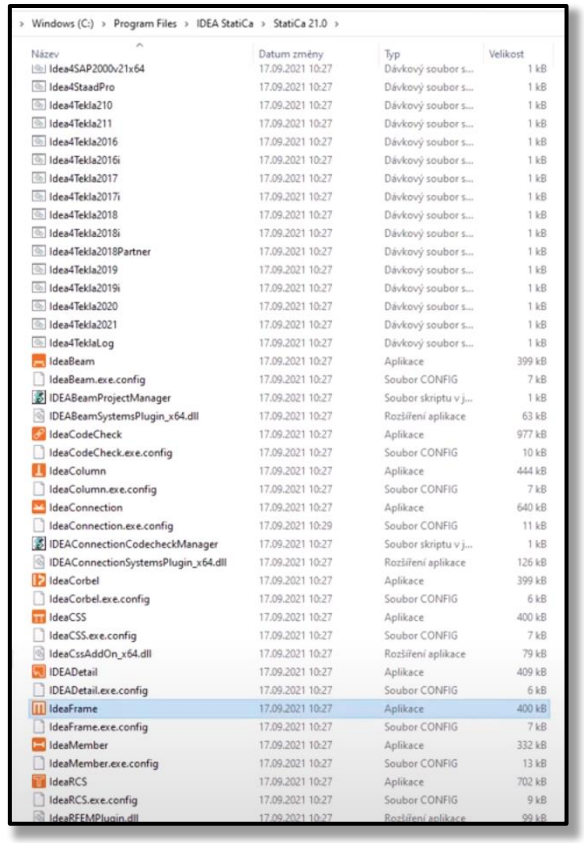


Download and install of IdeaStatica 21.0

After installing IdeaStatica 21.0., **run the software and log in using your credentials** from the activation email.



And also check, whether the **IdeaFrame module is installed**.

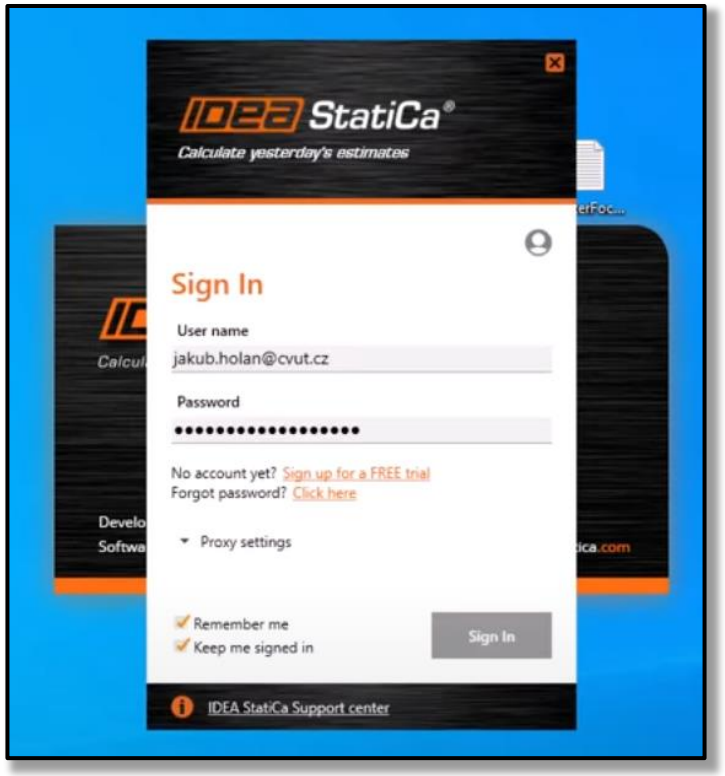


Calculation of internal forces in 2D frame

Modelling of the frame in IdeaFrame module

Initialization of the program

Run the program and fill in the login details from activation e-mail.

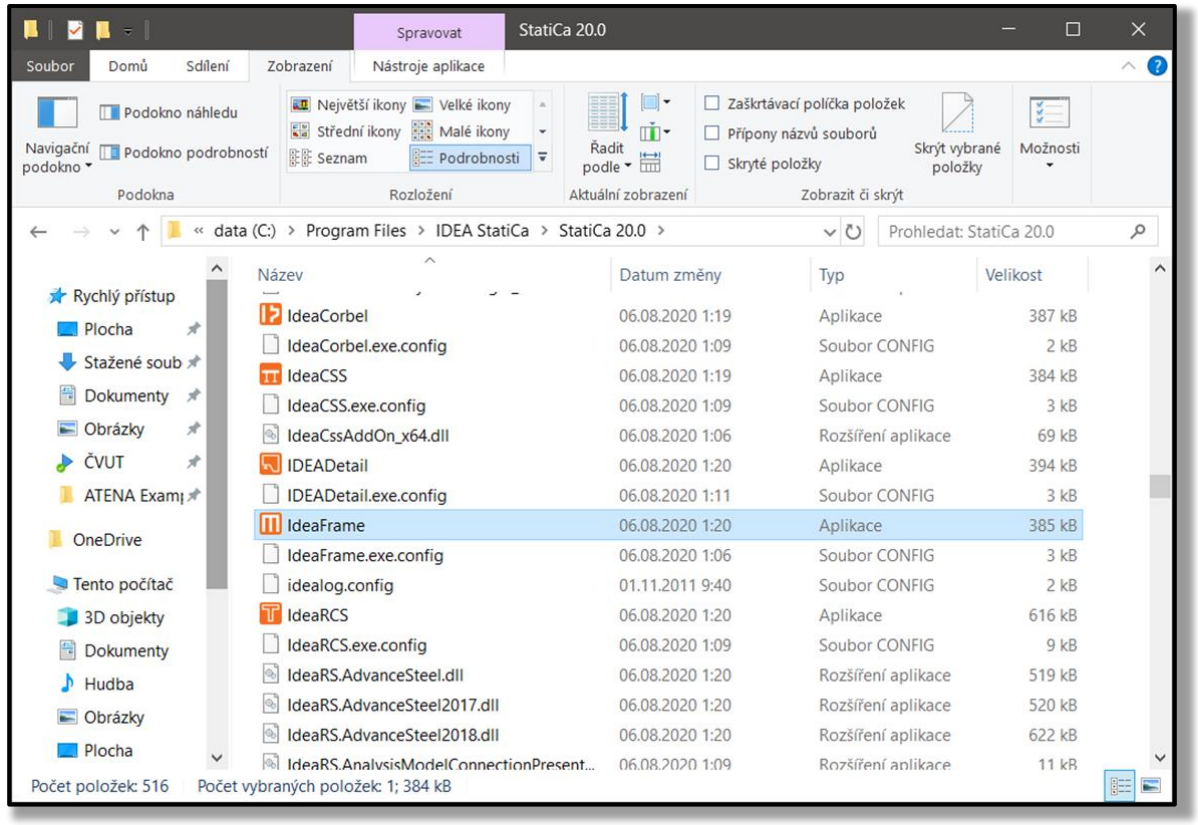


Initialization of IdeaFrame

IdeaFrame module is **NOT accessible from main window**.

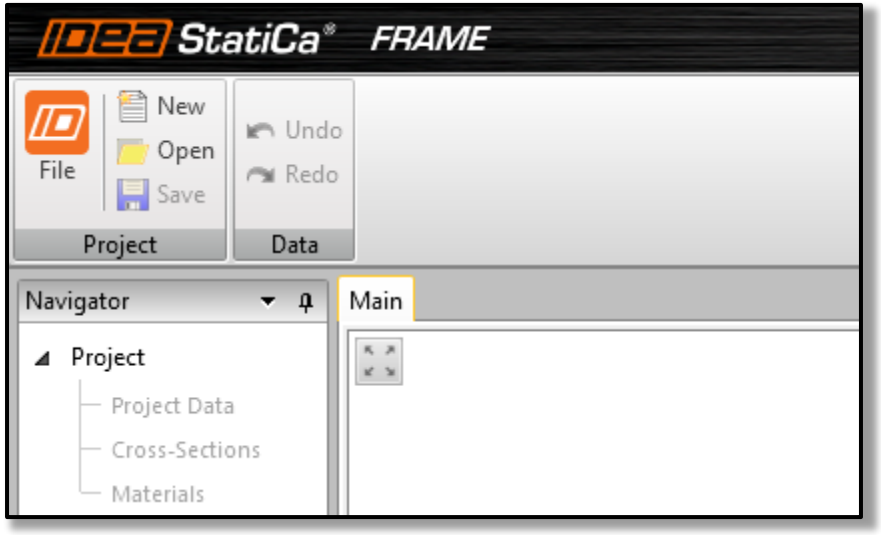
Initialization of IdeaFrame

You have to locate IdeaStatica folder in your computer and **run the IdeaFrame.exe file directly**.



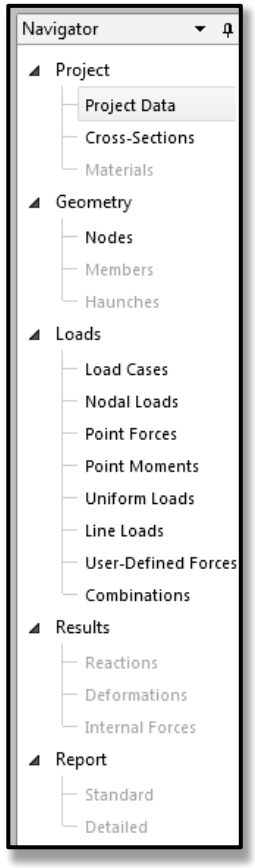
New project

Create new project.

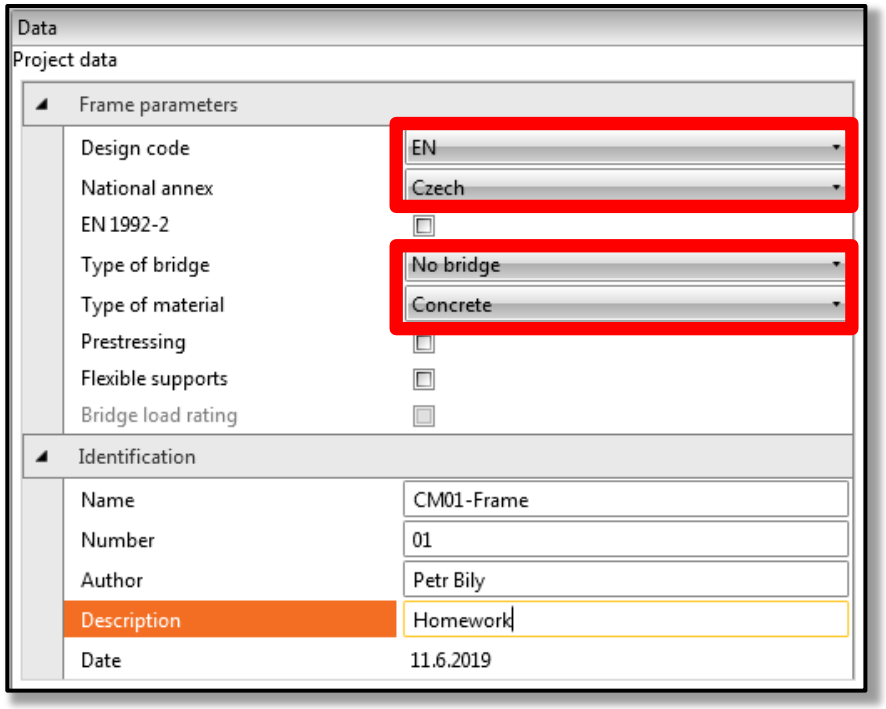


Project data

Use *Navigator* menu to enter *Project data* properties:



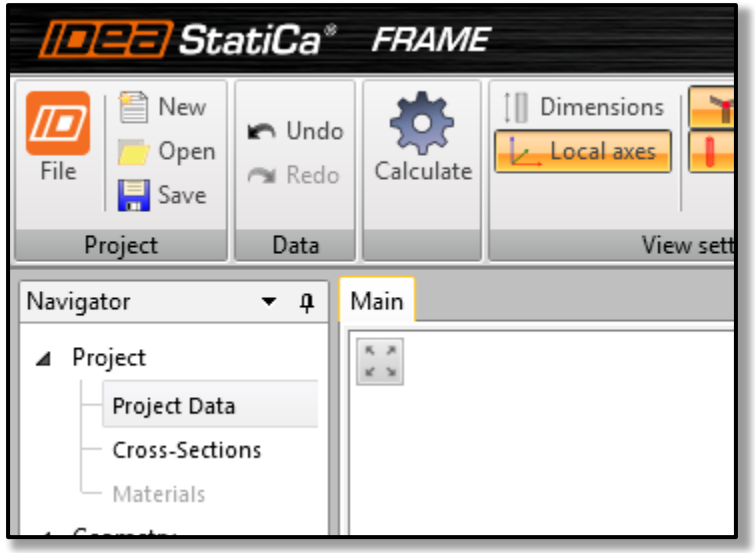
Change Project data as follows:



Save

Save and name your project.

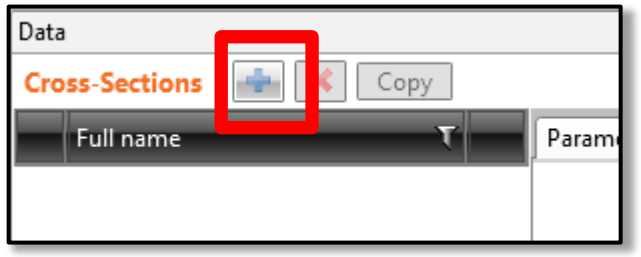
Save your project regularly to avoid losing unsaved data!

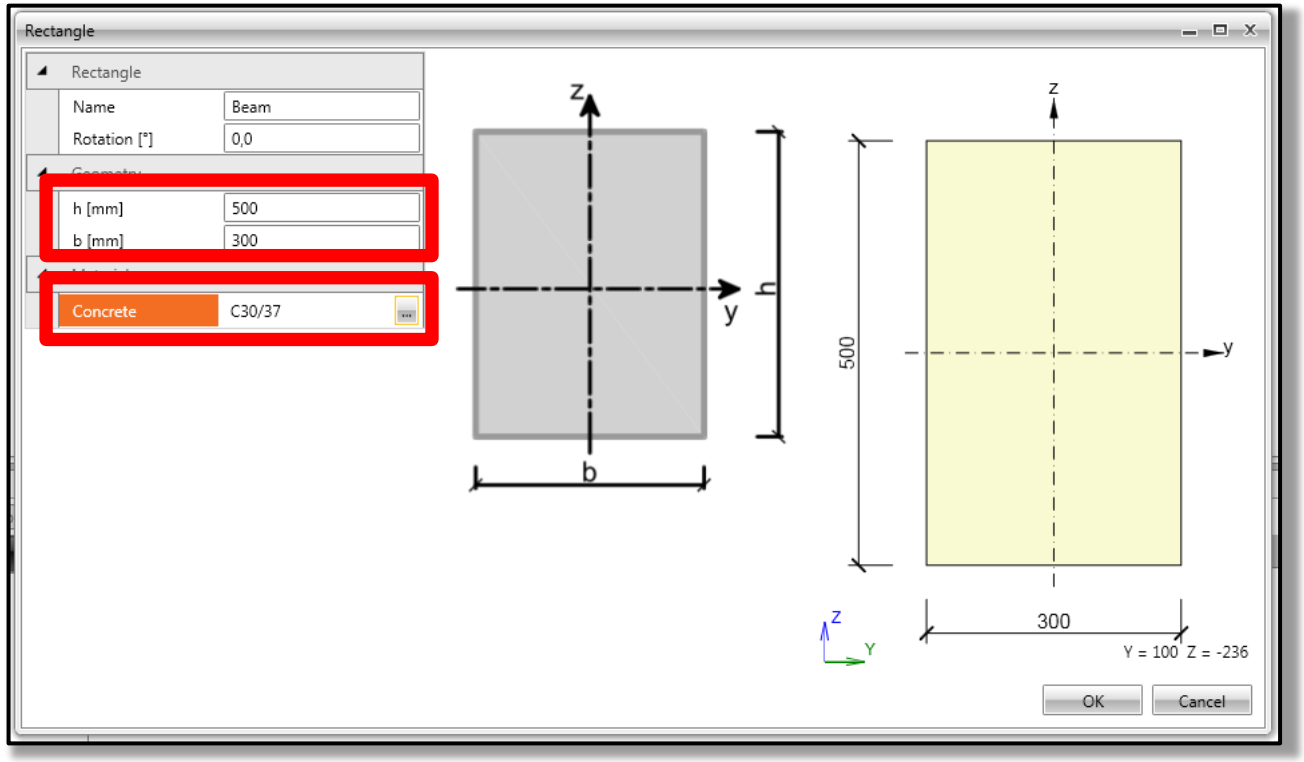


Cross-sections

Go to: Navigator ⟶ Project ⟶ Cross-Sections.

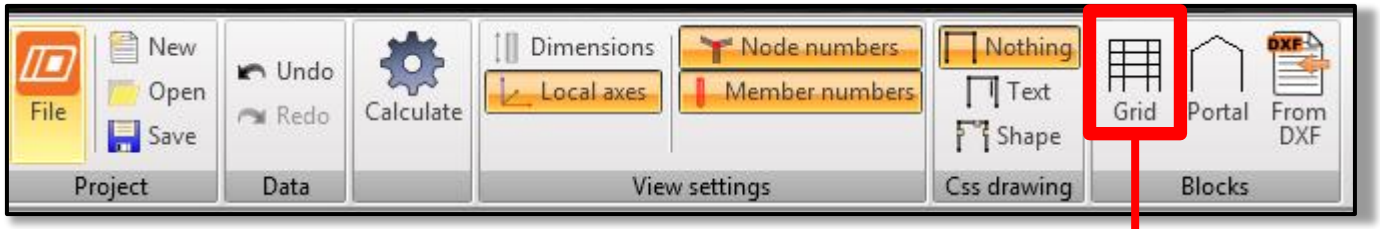
Enter cross-sections of **your** beam and column as designed in homework HW1 (name, dimensions, material).

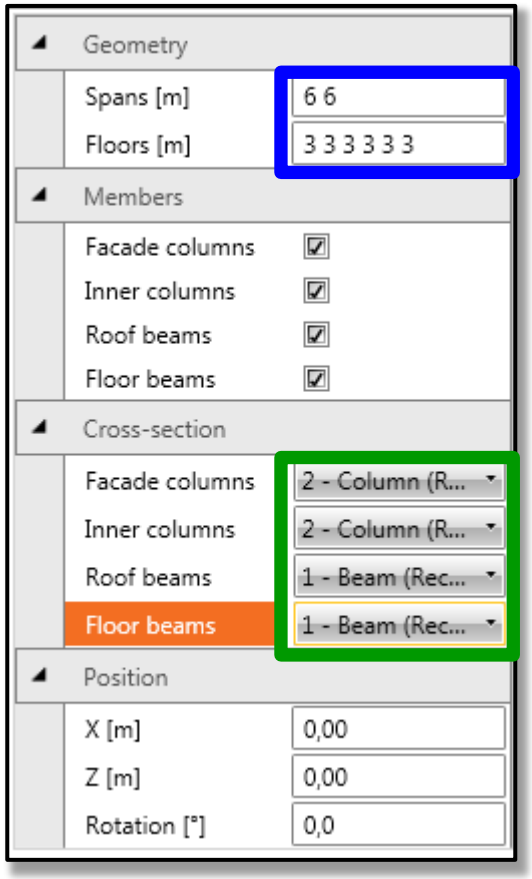




Creating the frame

Go to: Navigator ⟶ Geometry ⟶ Nodes.
Use Grid block to create the frame.





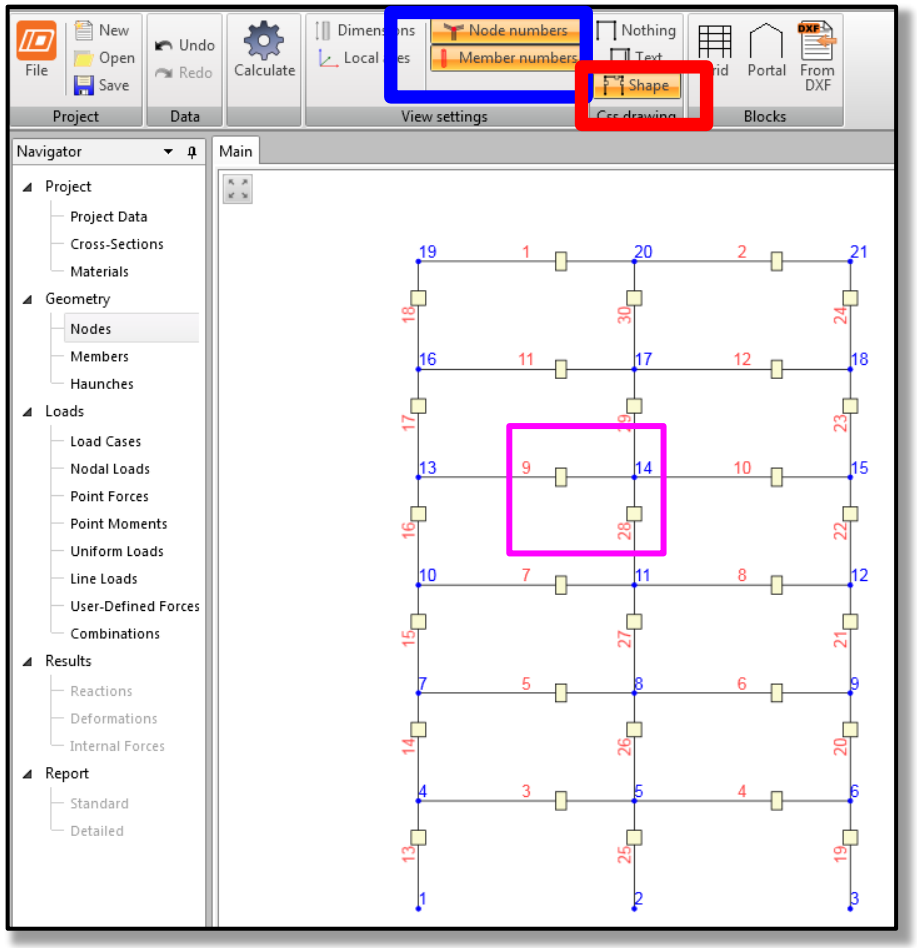
Set dimensions and number of spans/floors (divide the numbers simply by spacebar).

Select cross-sections of columns and beams.

Creating the frame

Display Shapes to check whether you entered the cross-sections correctly.

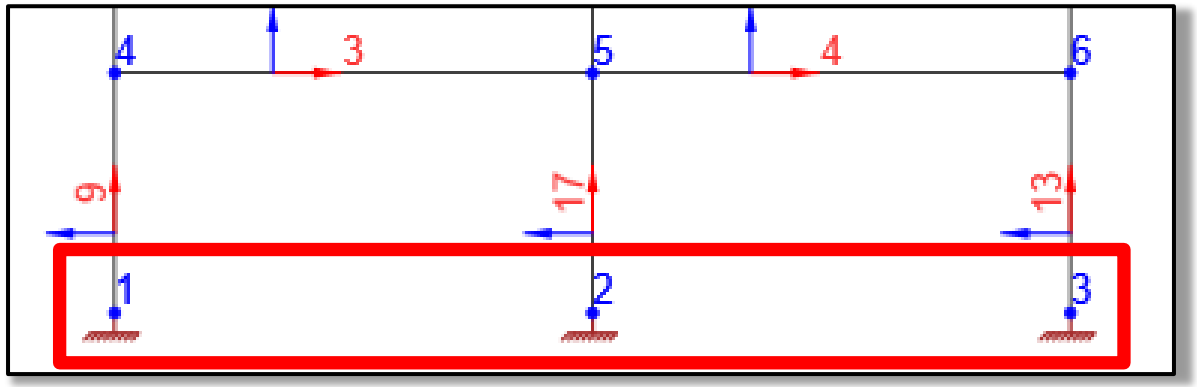
Display Node numbers and Member numbers.



Supports

We must also define the supports of the frame (rigid supports in column bases).

In Data window, check all nodal supports for the nodes in column bases.



Data

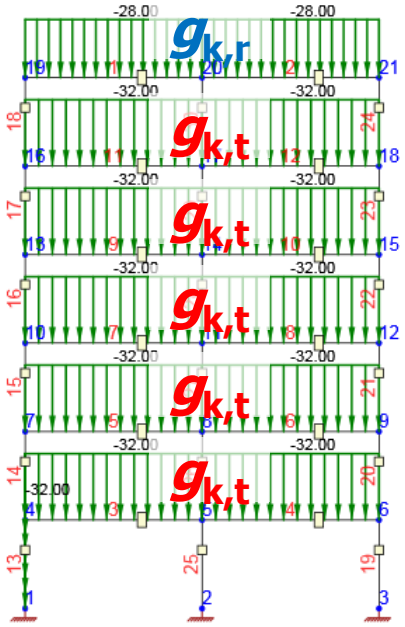
Nodes | Cleanup

Node	X [m]	Z [m]	Nodal Support X	Z	Ry
1	0,00	0,00	☑	☑	☑
2	6,00	0,00	☑	☑	☑
3	12,00	0,00	☑	☑	☑
4	0,00	3,00	☐	☐	☐

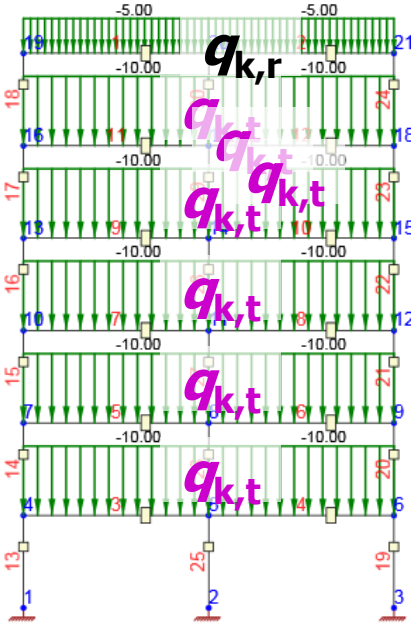
Load cases

We must consider **4 load cases**:

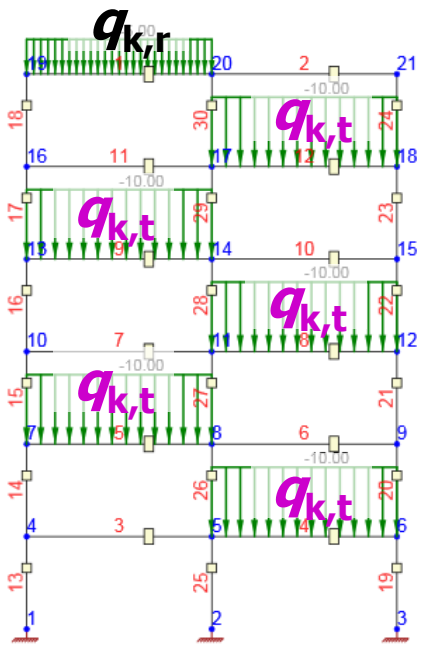
- SW: Self-weight of the frame – calculated automatically by IdeaStatica,
- LC1: Full permanent load,
- LC2: Full variable load,
- LC3: Checkerboard variable load.



LC1: Full permanent load



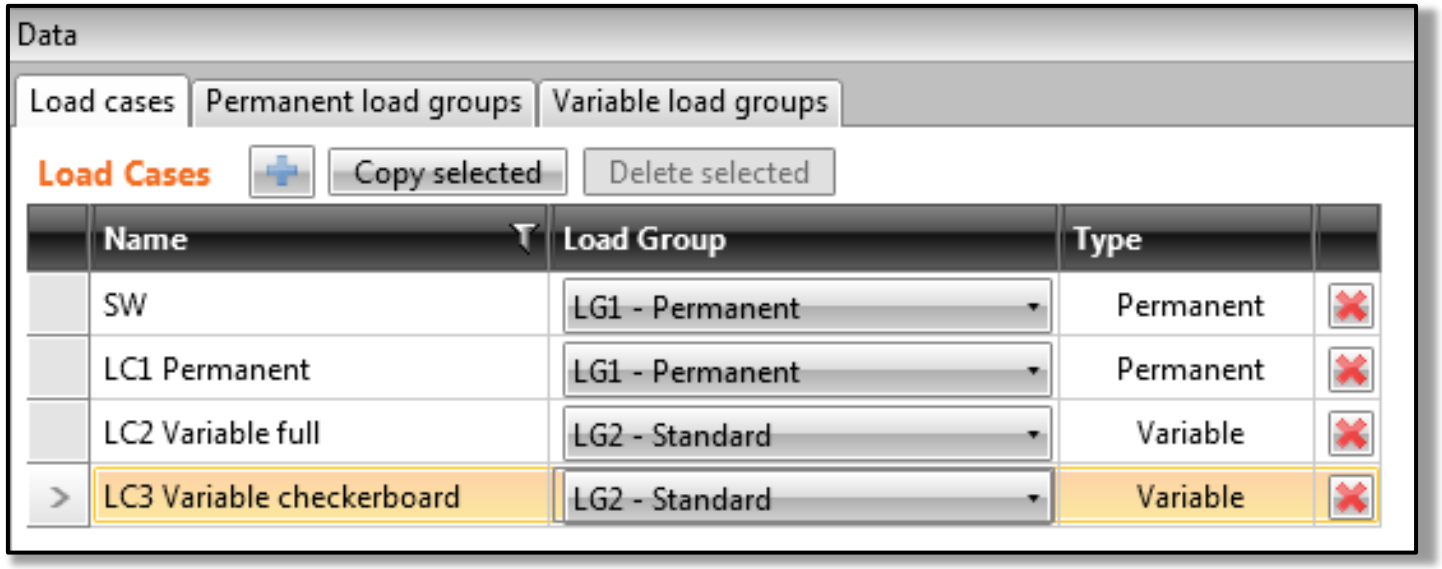
LC2: Full variable load



LC3: Checkerboard variable load

Load cases

Go to: Navigator ⟶ Loads ⟶ Load cases.
Create the 3 load cases (SW* is already created automatically) and adjust Load Group and Type as follows:



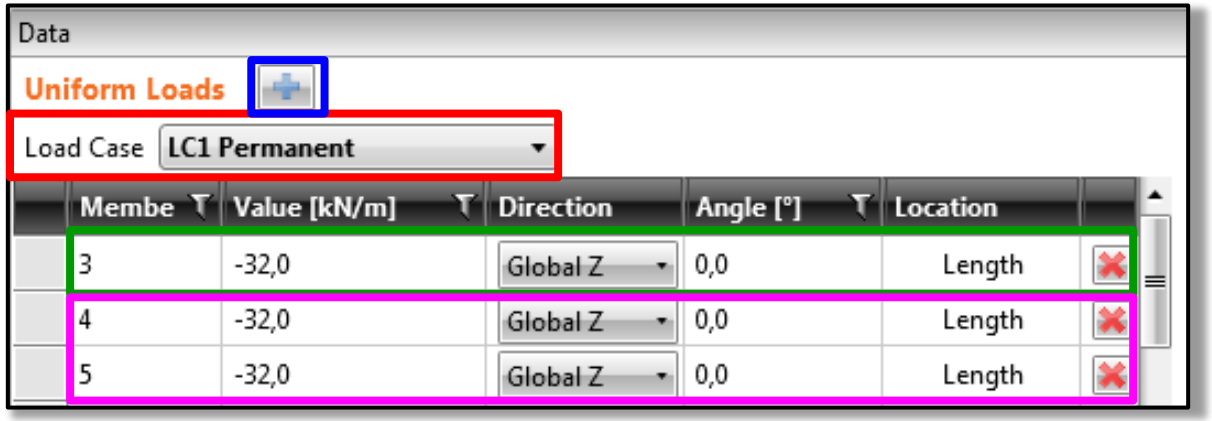
*SW = self-weight of the modeled structure (frame)

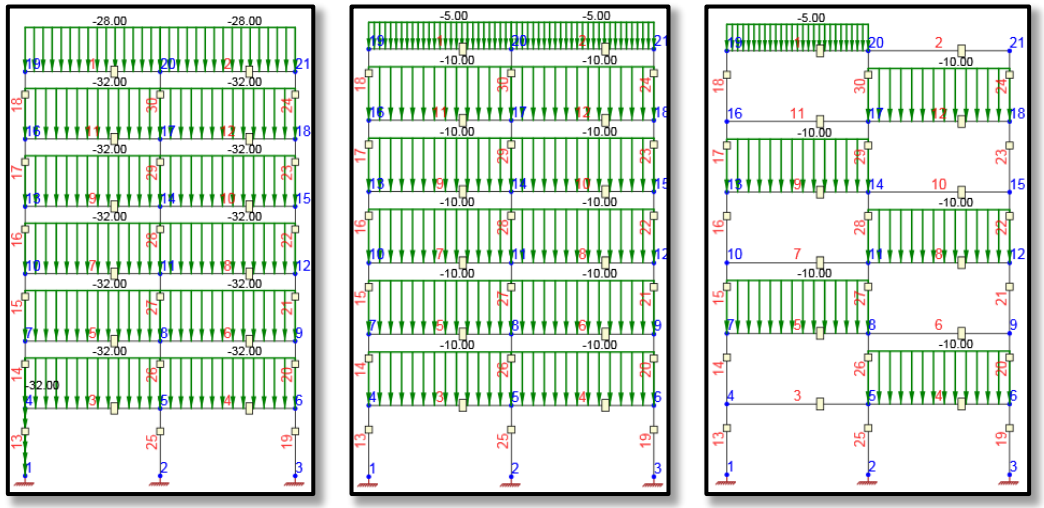
Inputting loads

Go to: Navigator ⟶ Loads ⟶ Uniform loads.

1) Select LC1.
2) Enter new load.
3) Enter member number.
4) Enter load value (with „minus“).
5) Select vertical direction (Z).
6) Repeat for other members.

Repeat for LC2 and LC3.

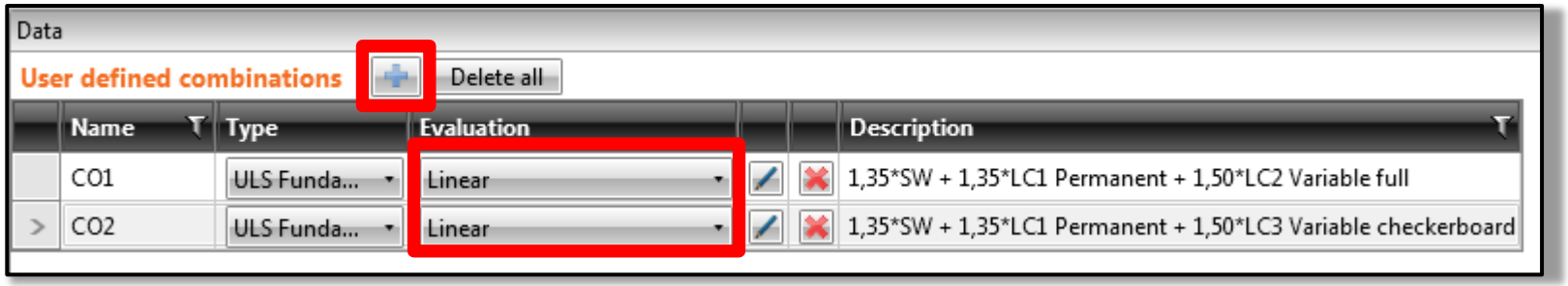




Load combinations

Go to: Navigator ⟶ Loads ⟶ Combinations.
Create 2 load combinations and set them to “Linear”:

- CO1 Full (SW + LC1 + LC2),
- CO2 Checkerboard (SW + LC1 + LC3).

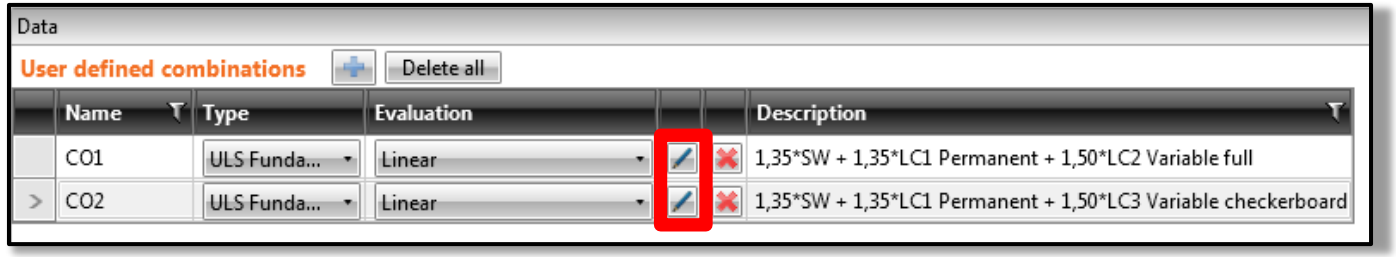


Why do we do Full and Checkboard loads/combinations?

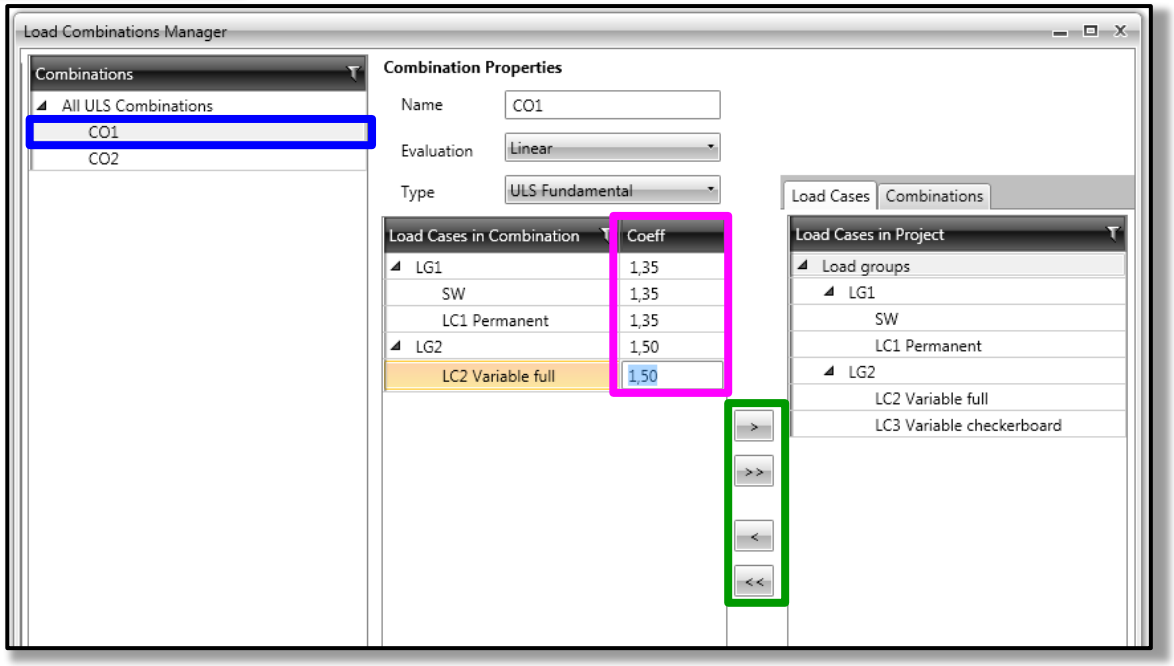
- Full generates extreme N and support M,
- Checkerboard generates extreme V and midspan M.

Load combinations

Edit the combinations.

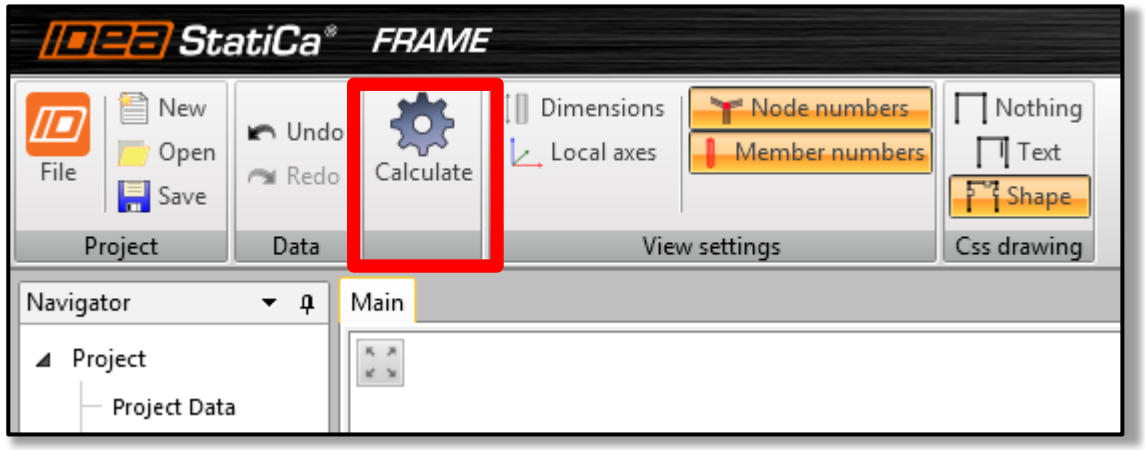


1) Select the combination.
2) Add/remove load cases to the combination.
3) Adjust the coefficients (1.35 for permanent loads, 1.5 for variable loads)



Calculation

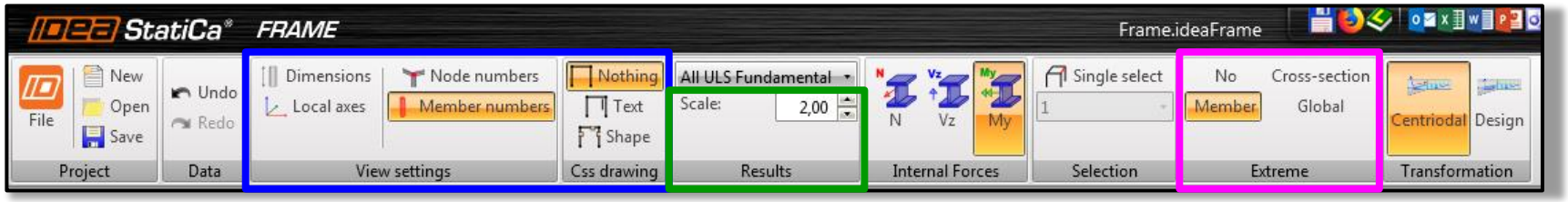
Calculate the internal forces.



Results – settings

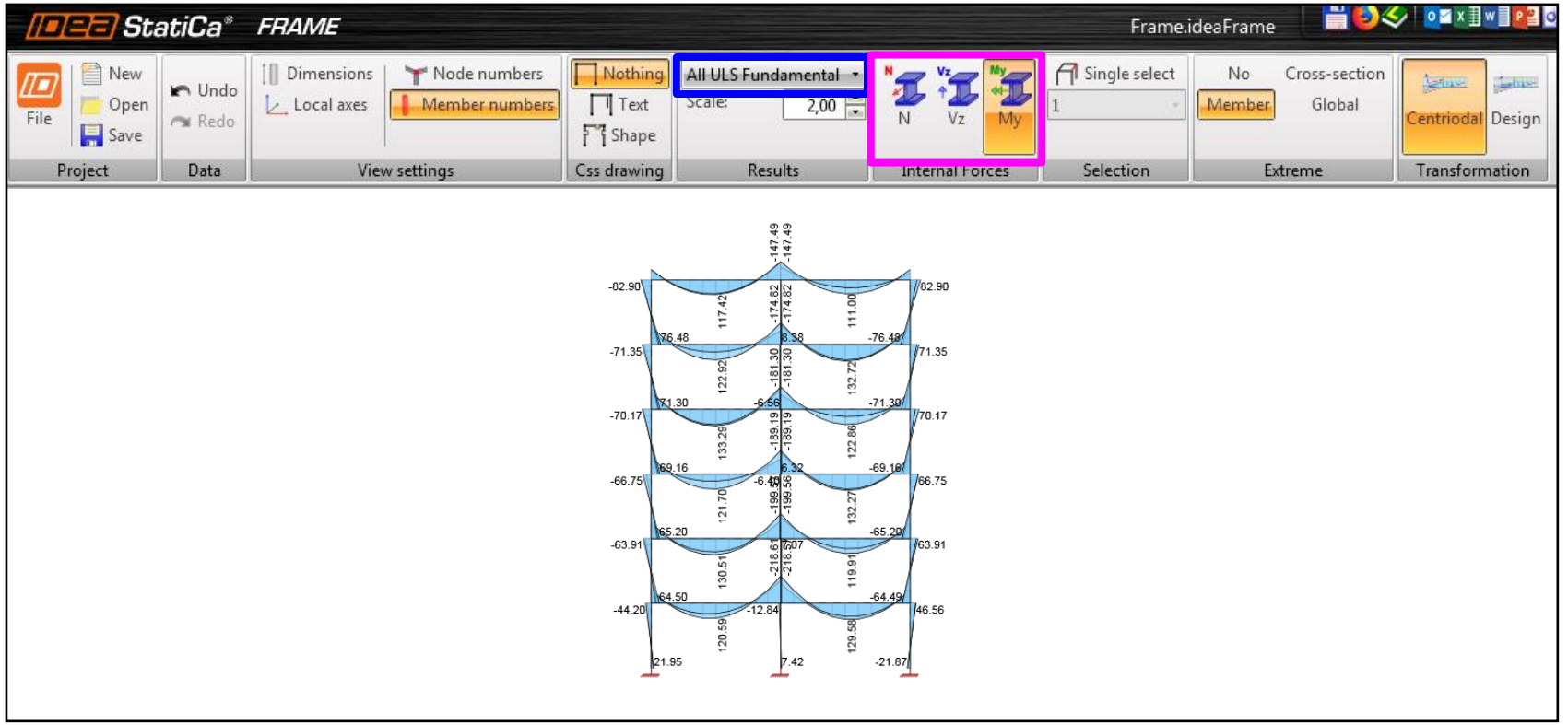
Go to: Navigator ⟶ Results ⟶ Internal forces.

1) Turn off all labels except Member numbers.
2) Adjust the result scale.
3) Display extreme values on members.



Results

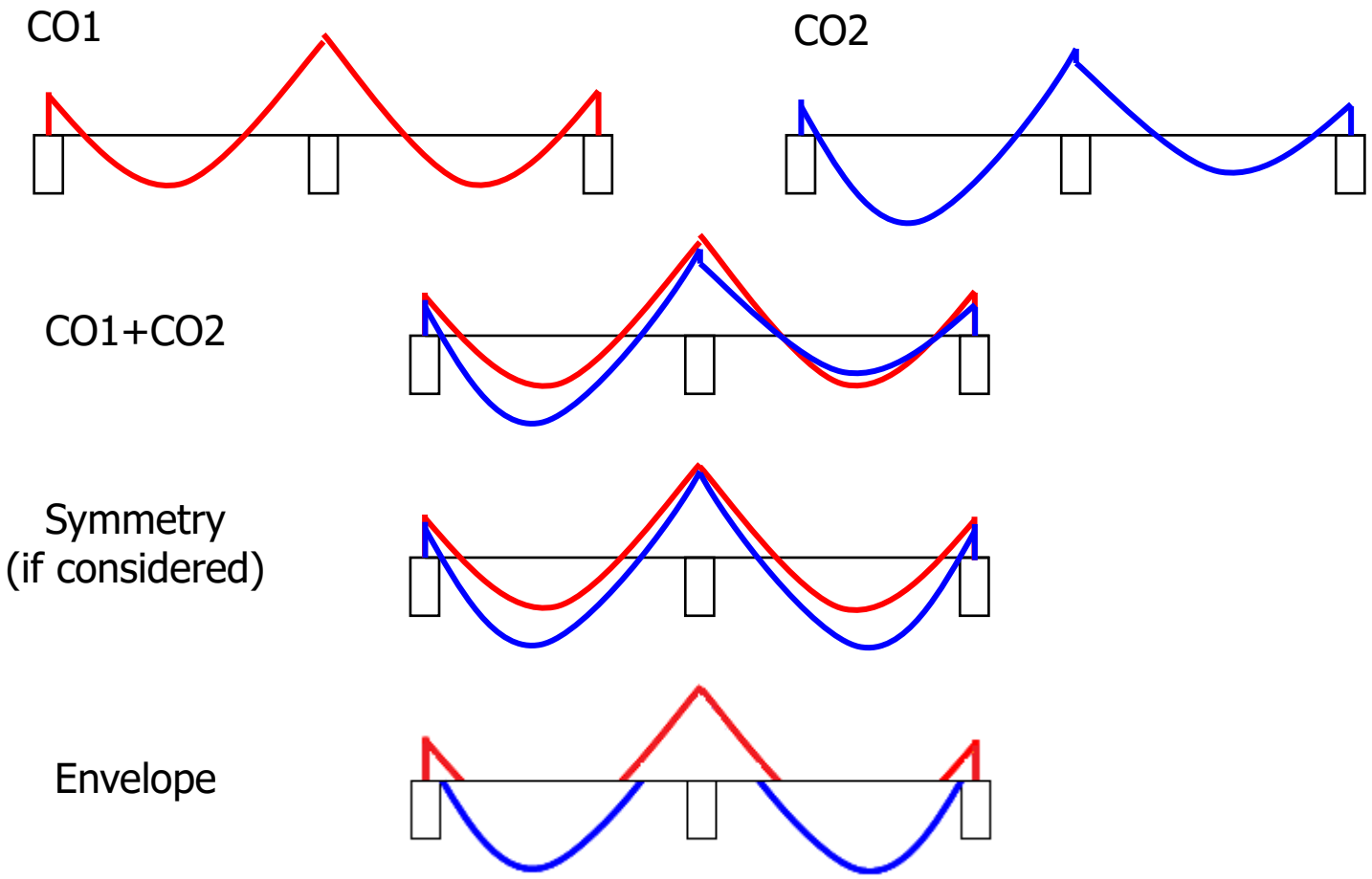
1) Select load combination to display – CO1, CO2 or All ULS (“envelope” of CO1 and CO2)*.
2) Select internal force to display.



*Check all three combinations and all three internal forces for obvious errors.

Envelope

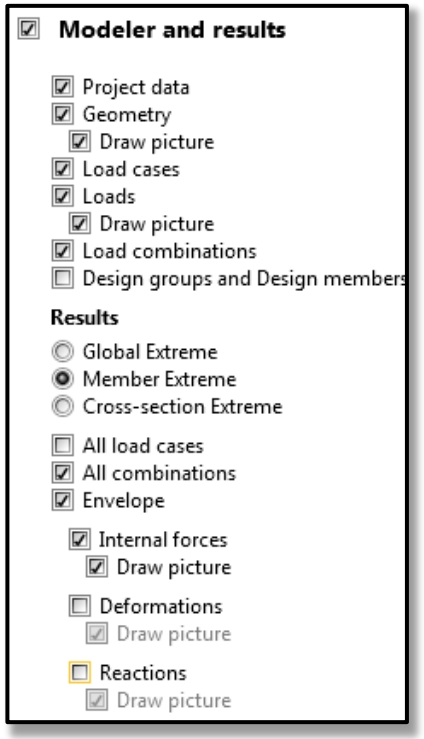
What is an “envelope” of an internal force?



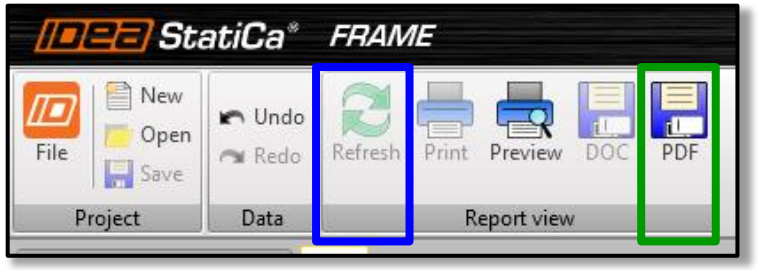
Report

Go to: Navigator ⟶ Report ⟶ Detailed.

In the menu on the right, select the following:



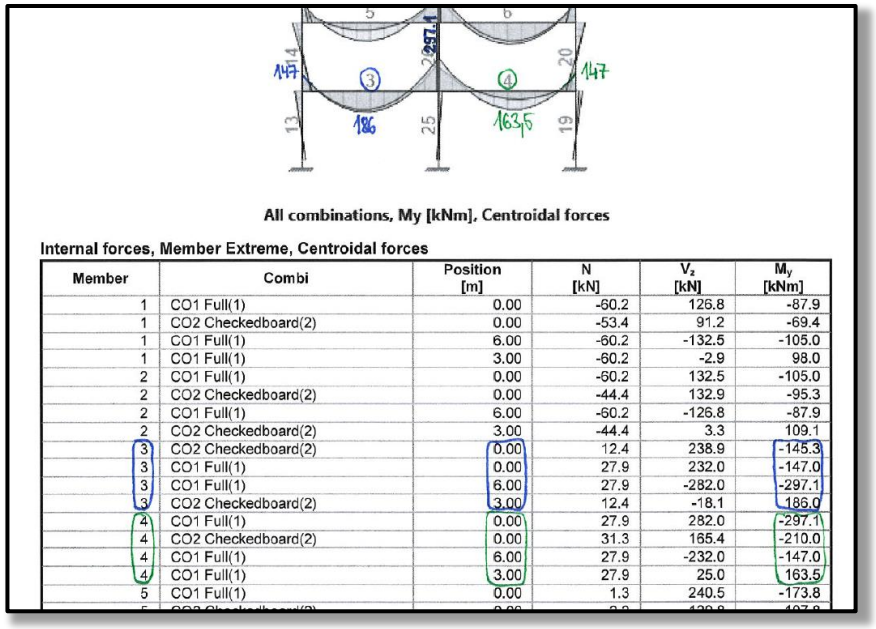
Then refresh the report and export the report.



Report

Print the report.

In the printed report, **manually add the values of the bending moments** to the schemes of the **bottom floor beam** for all combinations (you will find the values in the tables):



All combinations, My [kNm], Centroidal forces

Internal forces, Member Extreme, Centroidal forces

Member	Combi	Position [m]	N [kN]	V_z [kN]	M_y [kNm]
1	CO1 Full(1)	0.00	-60.2	126.8	-87.9
1	CO2 Checkedboard(2)	0.00	-53.4	91.2	-69.4
1	CO1 Full(1)	6.00	-60.2	-132.5	-105.0
1	CO1 Full(1)	3.00	-60.2	-2.9	98.0
2	CO1 Full(1)	0.00	-60.2	132.5	-105.0
2	CO2 Checkedboard(2)	0.00	-44.4	132.9	-95.3
2	CO1 Full(1)	6.00	-60.2	-126.8	-87.9
2	CO2 Checkedboard(2)	3.00	-44.4	3.3	109.1
3	CO2 Checkedboard(2)	0.00	12.4	238.9	-145.3
3	CO1 Full(1)	0.00	27.9	232.0	-147.0
3	CO1 Full(1)	6.00	27.9	-282.0	-297.1
3	CO2 Checkedboard(2)	3.00	12.4	-18.1	186.0
4	CO1 Full(1)	0.00	27.9	282.0	-297.1
4	CO2 Checkedboard(2)	0.00	31.3	165.4	-210.0
4	CO1 Full(1)	6.00	27.9	-232.0	-147.0
4	CO1 Full(1)	3.00	27.9	25.0	163.5
5	CO1 Full(1)	0.00	1.3	240.5	-173.8

The report **will not be accepted without this** manual amendment!

Video

The whole process of modelling in IdeaFrame is shown in this video.

Next week

Next week

Next week we will focus on **design and assessment of reinforcement of the beam**.

thank you for your attention

Recognitions

I thank **Assoc. Prof. Petr Bílý** for his original seminar presentation and other supporting materials from which this presentation was created.