AutoCell Build

Architectural Symphony of Cells

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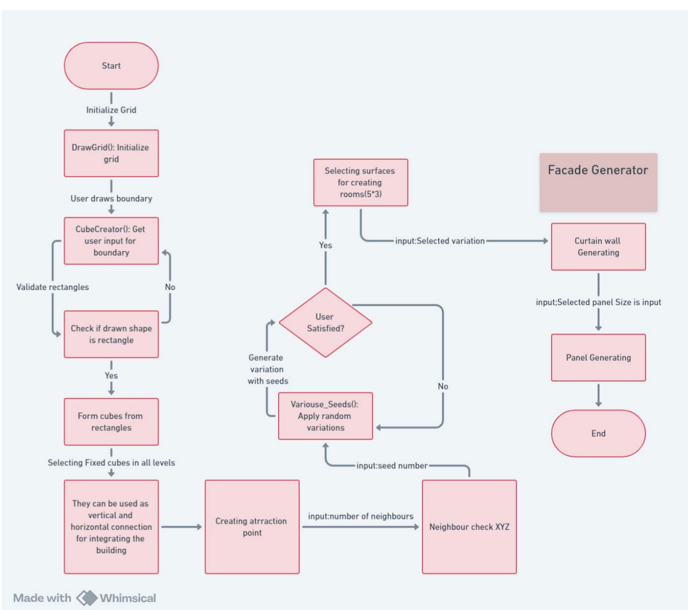
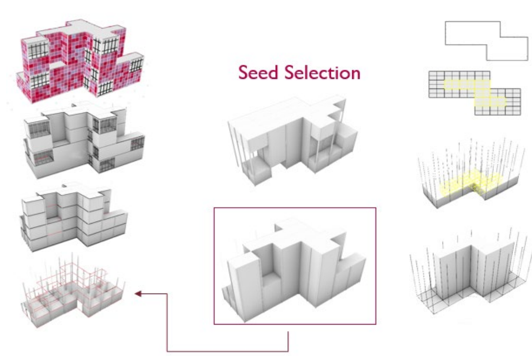
CONCEPT

Inspired by the groundbreaking research of John Frazer(1995) and Herr(2008), as well as the broader scholarly discourse on applying computational techniques in architectural design, we began this project by investigating the idea of computational design thinking using cellular automata. Cellular Automata, with its capability for generating diverse and complex patterns from simple rules, offers a method to break free from these constraints, allowing for the exploration of alternative building morphologies that are both varied and contextually responsive.

In this project, the usage of cellular automata is intended to produce new architectural forms while also promoting a better comprehension of the design process itself. Through a system in which advanced global behaviors emerge from local interactions between elements (cells), designers can investigate a wide range of design options that are naturally tailored to contextual and functional constraints. This is in line with the more general objectives of computational design thinking, which aims to use computation as a basic method of thinking about and solving architectural challenges rather than just as a tool for design.





Code flow chart(1-picture)

Diagram of process(2-picture)

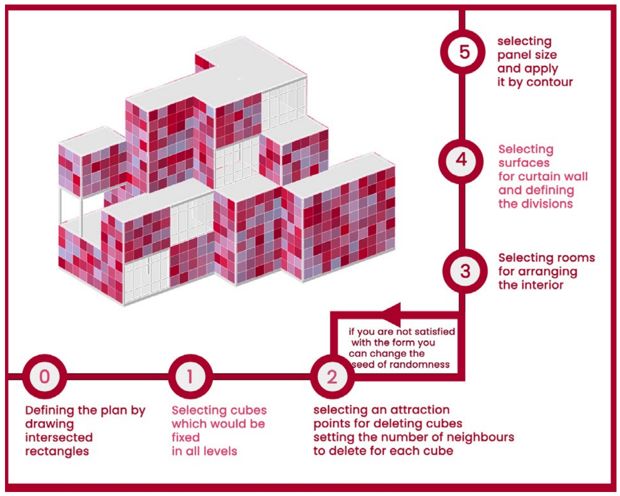
S7 Programming and Simulation

Our project was inspired by the principles of cellular automata, applied in a two-phase design process for architectural modeling within Rhino, leveraging both scripted automation and user input.

Phase 1: Initial Design and Cellular Automata Application

Phase 1 focuses on the initial design layout, allowing users to place fixed elements (cubes) within a defined grid. The program enables dynamic manipulation of this layout by permitting users to specify the number of neighboring elements to remove, with a recommendation for removing 1 or 2 neighbors to achieve the desired outcome. Additionally, attraction points are defined to influence the removal process further, enhancing design flexibility. Users are given the choice to accept the outcome of Phase 1 or to iterate on their design by adjusting the parameters influencing randomness.

To give a detailed explanation of this phase, we began with **Grid Generation**, which involved building a grid in Rhino that served as the basis for the design. This grid simulates the behavior of cellular automata by providing places where users can add or delete cubes. **User Interaction for Fixed Elements** was the next stage. Here, users can choose which cubes in the grid to fixate on while creating a design. This stage adds a degree of complexity and customization, enabling more unique and different designs. Then comes **Neighborhood Definition and Manipulation.** Here, users can specify, from 0 to 6, how many nearby cubes to remove from each selected cube. For best results, it is advised to eliminate one or two neighbors. This stage is essential for producing intriguing structures and patterns that adhere to cellular automata logic. Additional complexity is introduced by allowing users to specify **attraction points**, which influences the deletion of cubes beyond the immediate neighborhood. This feature adds another layer of control over the design, enabling users to create areas of higher or lower density. The next step was **Iteration and Redesign.** After the initial setup, users can choose to either accept the design as is or to iterate by adjusting the parameters that influence randomness. This iterative process is fundamental to reaching a satisfactory design outcome. Lastly, **Preservation of Design State.** Throughout this phase, the code ensures that the results of each iteration are preserved. This allows users to backtrack or proceed from the last known good state, fostering an experimental design approach.



Guide of process(3-picture)

Phase 2: Refinement and Detailing

Phase 2 shifts towards a more automated approach, concentrating on refining the building's structural and aesthetic features. This includes offsetting walls to define the interior space more clearly, enabling room selection, and detailing the facade with window placements. Two variations of windows/curtain walls are offered, alongside two types of paneling options. Finally, the design is colorized using a palette inspired by the red hues of the campus, adding a final touch of customization to the project.

To provide a comprehensive overview of this stage, we started with **Structural Definition**. At a higher degree of detail, you can automatically adjust the wall positions according to the Phase 1 design. The internal space of the building is more clearly defined in this step. **Interior Space Configuration** is the following stage. Users can choose which rooms to include in the interior area here, giving the layout more information and enabling useful space planning inside the building. The focus then shifts to **Facade Design**, where we incorporated different window positioning possibilities. The building's external look is made more diverse by the two different window/curtain wall combinations. Here, both functional and aesthetic factors play a role in the design decisions. The **Paneling** options are last in line. Here Two additional paneling options are added to the facade details, enabling further personalization of the building's appearance. This step considers the facade's prospective performance qualities and personal aesthetic preferences. Lastly, **Colorization.** Taking cues from the campus's red tones, the code finally produces a random color from a predetermined spectrum. This gives the design a distinct visual identity while also connecting the building to its surroundings.

C2 Construction and Dimensioning

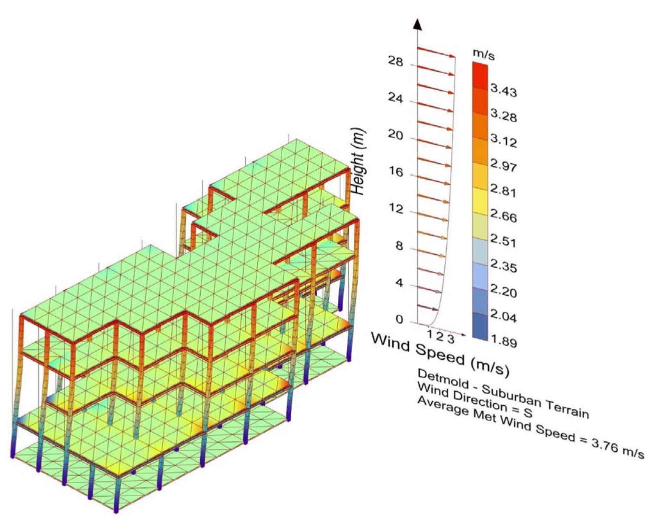
To conduct a comprehensive **structural analysis** of our building structure under various loads, including wind, and to ensure seamless integration with Karamba3D for Finite Element Analysis (FEA), we first carefully arranged the geometric elements (beams, columns, slabs, and supports) into their appropriate layers within Rhino. This organizational approach not only made the workflow more efficient, but also set up our model for a smoother transition into the analysis stage.

We used Grasshopper and the **Elefront** plugin after the initial Rhino setup to automatically reference this layered geometry into our Karamba3D environment. This automation was essential since it removed the need for manual geometry assignment and greatly accelerated the processes leading up to our structural analysis.

Once in Karamba3D, we assigned specific materials and cross-sectional properties to each structural element. We chose steel box columns for their aesthetic appeal in exposed situations, complementing the visual design aspects of our structure with their structural functionality. For the beams, we selected I-beams, favored for their load-carrying efficiency and suitability for spanning significant distances. Concrete slabs formed the horizontal components of our structure, providing robustness and stability. Additionally, we adjusted the eccentricity of these cross-sections to accurately reflect the finite element model, optimizing the behavior of our structure under applied loads.

An important element of our study involved determining how the structure responded to wind load, especially from the south which is a dominant wind in Detmold, we used the **LadyBug** plugin for visualizing wind profiles in different heights which extracts all the Detmold weather information from epw map. We used an external source (website) to compute the exact wind load in one m2 while taking local wind directions and speeds into account to ensure accuracy. After applying this computed load to our model in Karamba3D, we were able to see and examine the structural deformations that resulted. This stage was crucial in helping us comprehend how external factors, such as wind, affect the stability and structural integrity of our design.

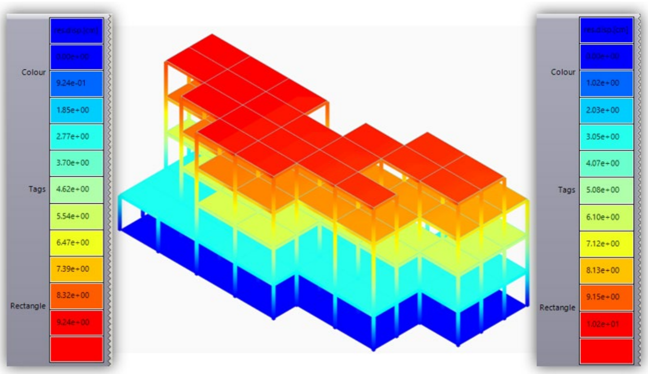
We included the structure's deformation and use in our Karamba3D study. The deformation study identified possible areas of concern and shed light on how the structure moved under wind forces. Conversely, the utilization analysis assisted us in determining the effectiveness of our material use by highlighting design features that were both over- and under-stressed. This thorough examination guaranteed that every part of our construction was effectively constructed, sound structurally, and aesthetically beautiful.



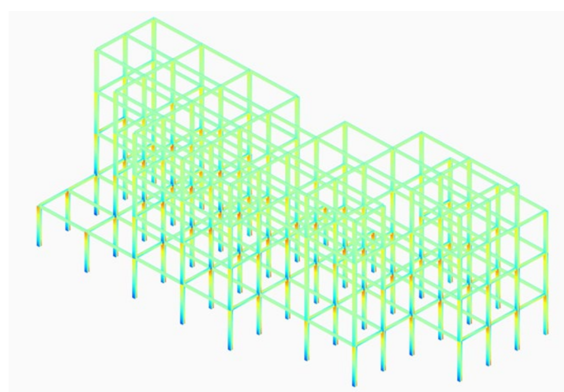
Deformation by wind(4-picture)

To further validate the integrity of our design, particularly at the joints, we utilized Idea Statica. This external analysis tool gave us detailed insights into the performance of structural joints under various loads, ensuring that our connections could withstand the calculated stresses without compromising safety.

In conclusion, we completed a comprehensive and in-depth study of our building structure by utilizing the features of Rhino, Grasshopper, Karamba3D, and other tools like Elefront and Idea Statica. Through this method, we made sure our design was not only aesthetically pleasing but also strong structurally, able to withstand loads from the environment, and optimum for materials. We successfully negotiated the challenges of structural analysis using this rigorous approach, ensuring that our final design complied with all relevant performance and safety regulations.



Displacement *without* **wind load**(5-picture)



Utilization *without* **wind load**(6-picture)

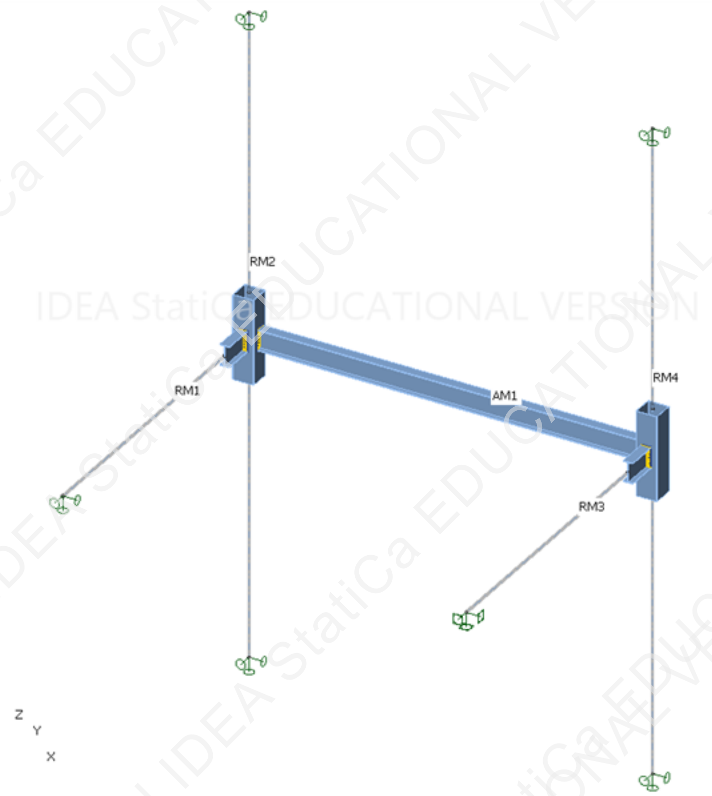
IDEA StatiCa

Project:
Project no:
Author:

Project data

Project name	
Project number	
Author	
Description	
Date	3/30/2024
Design code	EN

Geometry



Analyzed members

AM1

Property	Value
Name	AM1
Members	M2
Cross-section	Iw260x119
Length	5.00 m
ey	0 mm
ez	0 mm
Begin	(0.00; 0.00; 0.00) m
End	(5.00; 0.00; 0.00) m

Related members

RM1

Property	Value
Name	RM1
Members	M3
Cross-section	Iw260x119
Length	4.00 m
ey	0 mm
ez	0 mm
Begin	(0.00; -4.00; 0.00) m
End	(0.00; 0.00; 0.00) m
Support	■ X | ■ Y | ■ Z | □ Rx | □ Ry | □ Rz

RM2

Property	Value
Name	RM2
Members	M4
Cross-section	BoxWeb260x(260/260)
Length	8.00 m
ey	0 mm
ez	0 mm
Begin	(0.00; 0.00; -4.00) m
End	(0.00; 0.00; 4.00) m
Support Begin	■ X | ■ Y | ■ Z | □ Rx | □ Ry | □ Rz
Support End	■ X | ■ Y | ■ Z | □ Rx | □ Ry | □ Rz

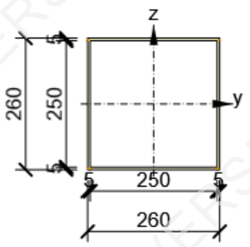
RM3

Property	Value
Name	RM3
Members	M5
Cross-section	Iw260x119
Length	4.00 m
ey	0 mm
ez	0 mm
Begin	(5.00; -4.00; 0.00) m
End	(5.00; 0.00; 0.00) m
Support	■ X | ■ Y | ■ Z | ■ Rx | ■ Ry | ■ Rz

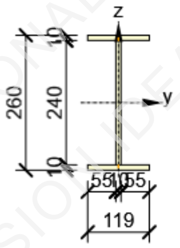
RM4

Property	Value
Name	RM4
Members	M6
Cross-section	BoxWeb260x(260/260)
Length	8.00 m
ey	0 mm
ez	0 mm
Begin	(5.00; 0.00; -4.00) m
End	(5.00; 0.00; 4.00) m
Support Begin	■ X | ■ Y | ■ Z | □ Rx | □ Ry | □ Rz
Support End	■ X | ■ Y | ■ Z | □ Rx | □ Ry | □ Rz

Cross-section



BoxWeb260x(260/260), Material: S 355



Iw260x119, Material: S 355

Loading

LE1 – Type ULS

Line load

Member	Begin [m]	End [m]	X [kN/m]	Y [kN/m]	Z [kN/m]	Location	Width [mm]	Ey [mm]
AM1	0.00	5.00	0.0	0.0	-30.0	Top	100	0

Point load

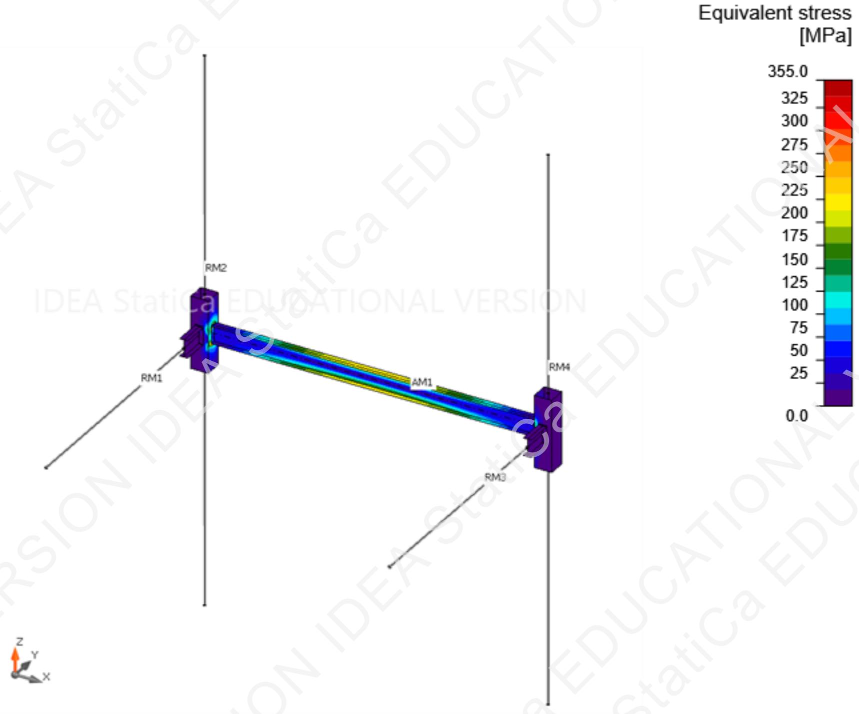
Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kN]	My [kN]	Mz [kN]
RM1 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
RM2 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
RM2 / End	0.0	0.0	0.0	0.0	0.0	0.0
RM3 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
RM4 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
RM4 / End	0.0	0.0	0.0	0.0	0.0	0.0

Results

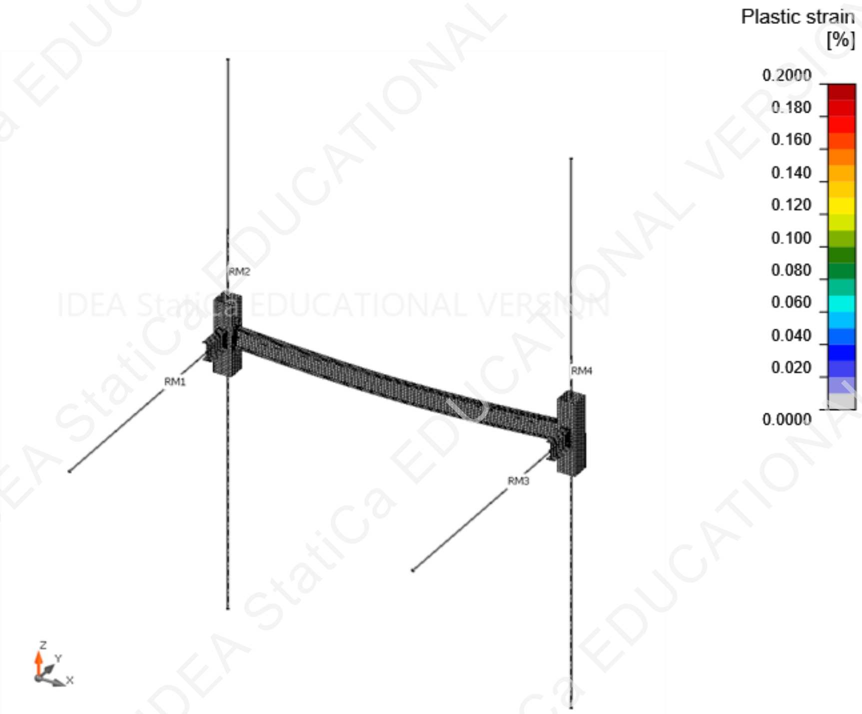
Materially non-linear analysis (MNA)

Summary

Load	Applied loads [%]
LE1	100.0



Eq. stress ,LC1



Plastic strain ,LC1

Design data

Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

Symbol	Explanation
f_y	Yield strength
ε_{lim}	Limit of plastic strain used in 2D plate element check

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

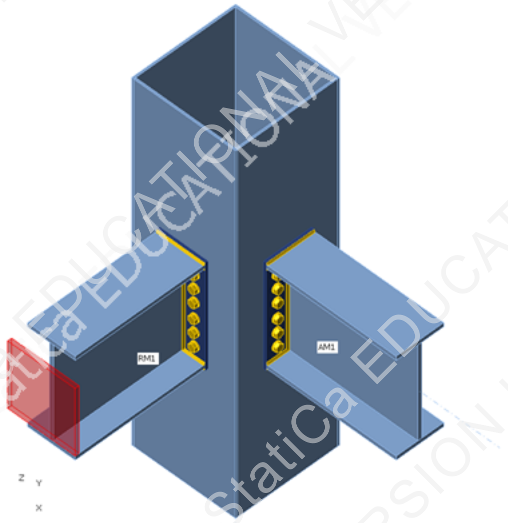
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
AM1	3 - Iw260x119	0.0	0.0	0.0	0	0	0
RM1	3 - Iw260x119	90.0	0.0	0.0	0	0	0
RM2	2 - BoxWeb260x(260/260)	0.0	90.0	0.0	0	0	0

Supports and forces

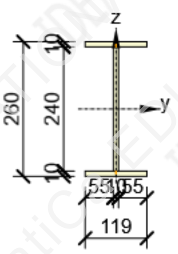
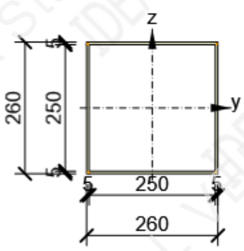
Name	Support	Forces in	X [mm]
AM1 / end		Position	0
RM1 / begin	N-Vy-Vz-Mx-My-Mz	Position	0
RM2 / begin		Position	0
RM2 / end		Position	0



Cross-sections

Name	Material
3 - Iw260x119	S 355
2 - BoxWeb260x(260/260)	S 355

Cross-sections

Name	Material	Drawing
3 - Iw260x119	S 355	
2 - BoxWeb260x(260/260)	S 355	

Bolts

Name	Bolt assembly	Diameter [mm]	f_u [MPa]	Gross area [mm^2]
M12 4.6	M12 4.6	12	400.0	113

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	AM1 / End	-0.2	0.0	0.0	0.0	0.0	0.0
	RM1 / Begin	0.2	0.0	0.0	0.0	0.0	0.0
	RM2 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
	RM2 / End	0.0	0.0	0.0	0.0	0.0	0.0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	-0.2	0.2	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	1.2 < 100%	OK
Welds	0.9 < 100%	OK
Buckling	Not calculated	

Plates

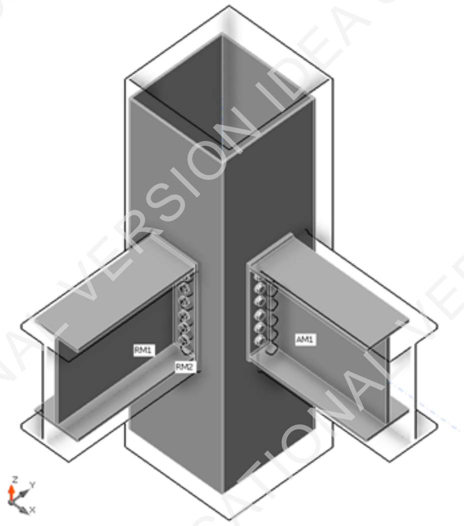
Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
AM1-tfl 1	10.0	LE1	0.6	0.0	0.0	OK
AM1-bfl 1	10.0	LE1	0.6	0.0	0.0	OK
AM1-w 1	10.0	LE1	0.1	0.0	0.0	OK
RM1-tfl 1	10.0	LE1	2.0	0.0	0.0	OK
RM1-bfl 1	10.0	LE1	2.0	0.0	0.0	OK
RM1-w 1	10.0	LE1	1.5	0.0	0.0	OK
RM2-tfl 1	5.0	LE1	0.9	0.0	0.0	OK
RM2-bfl 1	5.0	LE1	3.3	0.0	0.3	OK
RM2-w 1	5.0	LE1	10.2	0.0	1.4	OK
RM2-w 2	5.0	LE1	1.1	0.0	0.0	OK
EP1a	6.0	LE1	2.4	0.0	0.7	OK
EP1b	6.0	LE1	4.7	0.0	1.4	OK

Design data

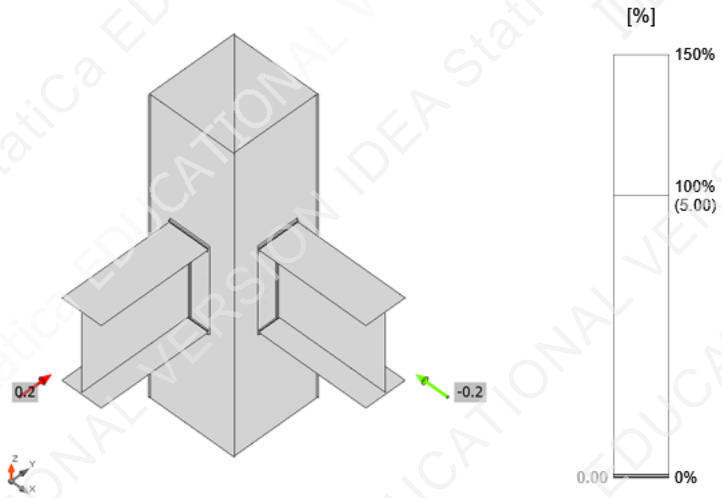
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

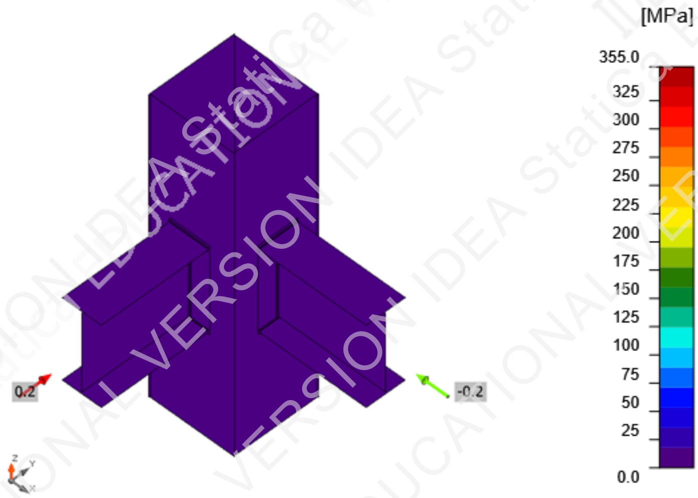
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1



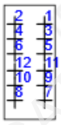
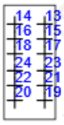
Strain check, LE1



Equivalent stress, LE1

EDUCATIONAL VERSION IDEA StatiCa

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M12 4.6 - 1	LE1	0.1	0.0	48.0	0.3	0.0	0.2	OK	OK
	B2	M12 4.6 - 1	LE1	0.1	0.0	48.0	0.3	0.0	0.3	OK	OK
	B3	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B4	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B5	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B6	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B7	M12 4.6 - 1	LE1	0.1	0.0	48.0	0.3	0.0	0.2	OK	OK
	B8	M12 4.6 - 1	LE1	0.1	0.0	48.0	0.3	0.0	0.3	OK	OK
	B9	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B10	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B11	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B12	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.1	0.0	0.1	OK	OK
	B13	M12 4.6 - 1	LE1	0.3	0.0	39.7	1.2	0.1	1.0	OK	OK
	B14	M12 4.6 - 1	LE1	0.1	0.0	37.4	0.3	0.2	0.4	OK	OK
	B15	M12 4.6 - 1	LE1	0.1	0.0	39.7	0.4	0.1	0.4	OK	OK
	B16	M12 4.6 - 1	LE1	0.0	0.0	37.4	0.1	0.1	0.2	OK	OK
	B17	M12 4.6 - 1	LE1	0.1	0.0	39.7	0.4	0.1	0.3	OK	OK
	B18	M12 4.6 - 1	LE1	0.0	0.0	37.4	0.1	0.1	0.2	OK	OK
	B19	M12 4.6 - 1	LE1	0.3	0.0	39.7	1.2	0.1	1.0	OK	OK
	B20	M12 4.6 - 1	LE1	0.1	0.0	37.4	0.3	0.2	0.4	OK	OK
	B21	M12 4.6 - 1	LE1	0.1	0.0	39.7	0.4	0.1	0.4	OK	OK
	B22	M12 4.6 - 1	LE1	0.0	0.0	37.4	0.1	0.1	0.2	OK	OK
	B23	M12 4.6 - 1	LE1	0.1	0.0	39.7	0.4	0.1	0.3	OK	OK
	B24	M12 4.6 - 1	LE1	0.0	0.0	37.4	0.1	0.1	0.2	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 4.6 - 1	24.3	70.3	16.2

Symbol explanation

$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_\perp$ [MPa]	$\tau_\perp$ [MPa]	$\tau_\parallel$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
EP1a	AM1-tfl 1	◢3.0◣	119	LE1	1.9	0.0	-0.6	-0.8	0.6	0.4	0.0	OK	OK
		◢3.0◣	119	LE1	2.3	0.0	-1.0	0.8	0.9	0.5	0.0	OK	OK
EP1a	AM1-bfl 1	◢3.0◣	119	LE1	2.3	0.0	-1.0	-0.8	-0.9	0.5	0.0	OK	OK
		◢3.0◣	119	LE1	1.9	0.0	-0.6	0.8	-0.6	0.4	0.0	OK	OK
EP1a	AM1-w 1	◢3.0◣	238	LE1	0.4	0.0	0.2	0.2	0.0	0.1	0.0	OK	OK
		◢3.0◣	238	LE1	0.3	0.0	0.1	-0.2	-0.1	0.1	0.0	OK	OK
EP1b	RM1-tfl 1	◢3.0◣	119	LE1	2.2	0.0	-0.6	-1.0	0.7	0.5	0.0	OK	OK
		◢3.0◣	119	LE1	3.8	0.0	-1.8	1.4	-1.4	0.9	0.0	OK	OK
EP1b	RM1-bfl 1	◢3.0◣	119	LE1	3.8	0.0	-1.8	-1.4	1.3	0.9	0.0	OK	OK
		◢3.0◣	119	LE1	2.2	0.0	-0.5	1.0	-0.7	0.5	0.0	OK	OK
EP1b	RM1-w 1	◢3.0◣	238	LE1	1.4	0.0	0.7	0.5	-0.5	0.3	0.0	OK	OK
		◢3.0◣	238	LE1	1.4	0.0	-0.3	0.3	-0.7	0.3	0.0	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490.0	0.90	435.6	352.8

Symbol explanation

T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
ε_{Pl}	Strain
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
Safety factor γ_{M0}	1.00	-	EN 1993-1-1: 6.1
Safety factor γ_{M1}	1.00	-	EN 1993-1-1: 6.1
Safety factor γ_{M2}	1.25	-	EN 1993-1-1: 6.1
Safety factor γ_{M3}	1.25	-	EN 1993-1-8: 2.2
Safety factor γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
Safety factor γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	Yes		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	Yes		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Material

Steel	S 355
Concrete	C25/30

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

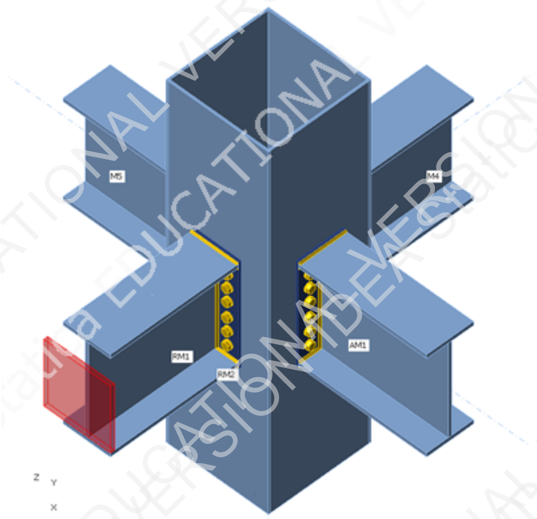
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
AM1	3 - Iw260x119	0.0	0.0	0.0	0	0	0
RM1	3 - Iw260x119	90.0	0.0	0.0	0	0	0
RM2	2 - BoxWeb260x(260/260)	0.0	90.0	0.0	0	0	0
M4	3 - Iw260x119	90.0	0.0	0.0	130	0	0
M5	3 - Iw260x119	-180.0	0.0	0.0	130	0	0

Supports and forces

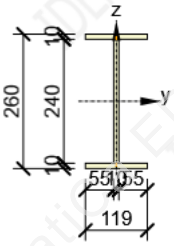
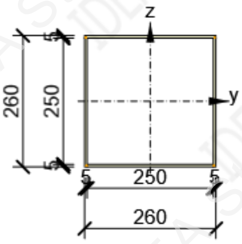
Name	Support	Forces in	X [mm]
AM1 / end		Position	0
RM1 / begin	N-Vy-Vz-Mx-My-Mz	Position	0
RM2 / begin		Position	0
RM2 / end		Position	0
M4 / end		Position	0
M5 / end		Position	0



Cross-sections

Name	Material
3 - Iw260x119	S 355
2 - BoxWeb260x(260/260)	S 355

Cross-sections

Name	Material	Drawing
3 - Iw260x119	S 355	
2 - BoxWeb260x(260/260)	S 355	

Bolts

Name	Bolt assembly	Diameter [mm]	f_u [MPa]	Gross area [mm^2]
M12 4.6	M12 4.6	12	400.0	113

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	AM1 / End	-0.2	0.0	0.0	0.0	0.0	0.0
	RM1 / Begin	0.2	0.0	0.0	0.0	0.0	0.0
	RM2 / Begin	0.0	0.0	0.0	0.0	0.0	0.0
	RM2 / End	0.0	0.0	0.0	0.0	0.0	0.0
	M4 / End	-0.2	0.0	0.0	0.0	0.0	0.0
	M5 / End	-0.2	0.0	0.0	0.0	0.0	0.0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	0.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	0.2 < 100%	OK
Welds	0.4 < 100%	OK
Buckling	Not calculated	

Plates

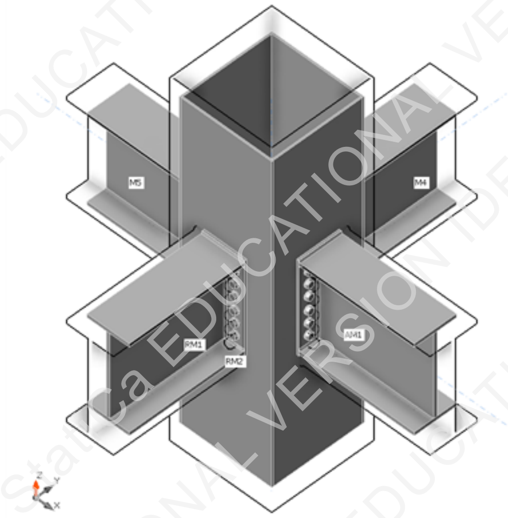
Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
AM1-tfl 1	10.0	LE1	0.5	0.0	0.0	OK
AM1-bfl 1	10.0	LE1	0.5	0.0	0.0	OK
AM1-w 1	10.0	LE1	0.1	0.0	0.0	OK
RM1-tfl 1	10.0	LE1	0.5	0.0	0.0	OK
RM1-bfl 1	10.0	LE1	0.5	0.0	0.0	OK
RM1-w 1	10.0	LE1	0.1	0.0	0.0	OK
RM2-tfl 1	5.0	LE1	2.0	0.0	0.2	OK
RM2-bfl 1	5.0	LE1	2.1	0.0	0.2	OK
RM2-w 1	5.0	LE1	2.1	0.0	0.2	OK
RM2-w 2	5.0	LE1	2.1	0.0	0.2	OK
M4-tfl 1	10.0	LE1	0.5	0.0	0.0	OK
M4-bfl 1	10.0	LE1	0.5	0.0	0.0	OK
M4-w 1	10.0	LE1	0.1	0.0	0.0	OK
M5-tfl 1	10.0	LE1	0.5	0.0	0.0	OK
M5-bfl 1	10.0	LE1	0.5	0.0	0.0	OK
M5-w 1	10.0	LE1	0.1	0.0	0.0	OK
EP1a	6.0	LE1	1.4	0.0	0.5	OK
EP1b	6.0	LE1	1.4	0.0	0.5	OK
EP2a	6.0	LE1	1.4	0.0	0.5	OK
EP2b	6.0	LE1	1.5	0.0	0.5	OK

Design data

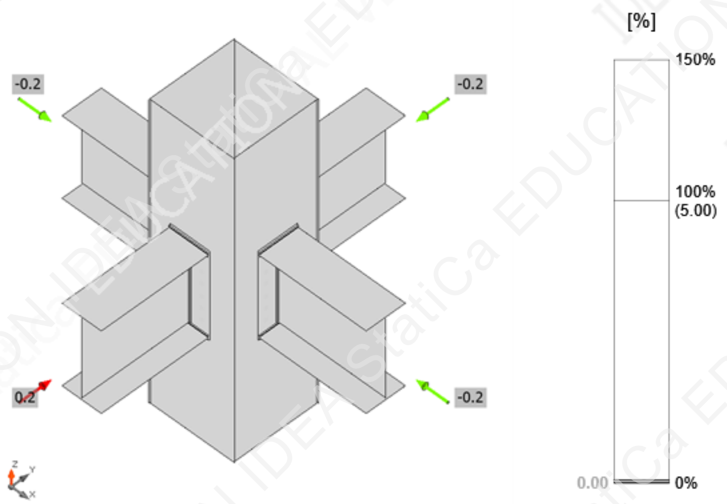
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

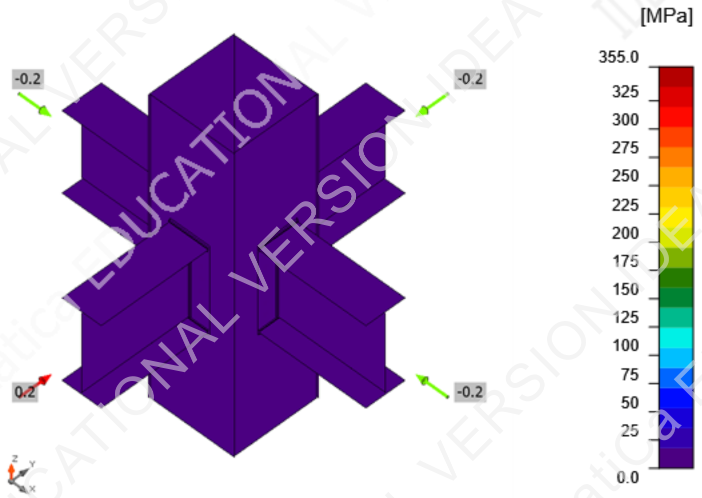
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

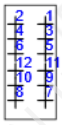
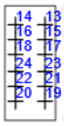
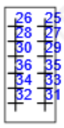
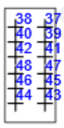


Strain check, LE1



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B2	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B3	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B4	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B5	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B6	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B7	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B8	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B9	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B10	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B11	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B12	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B13	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B14	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B15	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B16	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B17	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B18	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B19	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B20	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B21	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B22	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B23	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B24	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B25	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B26	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B27	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B28	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B29	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B30	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B31	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B32	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B33	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B34	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B35	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B36	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B37	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B38	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B39	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B40	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B41	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B42	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B43	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B44	M12 4.6 - 1	LE1	0.0	0.0	48.0	0.2	0.0	0.1	OK	OK
	B45	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B46	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B47	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK
	B48	M12 4.6 - 1	LE1	0.0	0.0	39.7	0.0	0.0	0.0	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 4.6 - 1	24.3	70.3	16.2

Symbol explanation

$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_\perp$ [MPa]	$\tau_\perp$ [MPa]	$\tau_{\|\|}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
EP1a	AM1-tfl 1	◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	-0.5	-0.4	0.3	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	0.6	-0.7	0.4	0.0	OK	OK
EP1a	AM1-bfl 1	◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	-0.6	0.7	0.4	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	0.5	0.4	0.3	0.0	OK	OK
EP1a	AM1-w 1	◢ 3.0 ◣	238	LE1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	OK	OK
		◢ 3.0 ◣	238	LE1	0.2	0.0	-0.1	0.1	0.0	0.0	0.0	OK	OK
EP1b	RM1-tfl 1	◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	-0.5	0.4	0.3	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	0.6	0.7	0.4	0.0	OK	OK
EP1b	RM1-bfl 1	◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	-0.6	-0.7	0.4	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	0.5	-0.4	0.3	0.0	OK	OK
EP1b	RM1-w 1	◢ 3.0 ◣	238	LE1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	OK	OK
		◢ 3.0 ◣	238	LE1	0.2	0.0	0.1	-0.1	0.0	0.0	0.0	OK	OK
EP2a	M4-tfl 1	◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	-0.5	0.4	0.3	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.6	0.0	-0.7	0.6	-0.6	0.4	0.0	OK	OK
EP2a	M4-bfl 1	◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	-0.6	0.7	0.4	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	0.5	0.4	0.3	0.0	OK	OK
EP2a	M4-w 1	◢ 3.0 ◣	238	LE1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	OK	OK
		◢ 3.0 ◣	238	LE1	0.2	0.0	-0.1	0.1	0.0	0.0	0.0	OK	OK
EP2b	M5-tfl 1	◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	-0.5	0.4	0.3	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	0.6	-0.7	0.4	0.0	OK	OK
EP2b	M5-bfl 1	◢ 3.0 ◣	119	LE1	1.7	0.0	-0.7	-0.6	-0.7	0.4	0.0	OK	OK
		◢ 3.0 ◣	119	LE1	1.3	0.0	-0.4	0.5	-0.4	0.3	0.0	OK	OK
EP2b	M5-w 1	◢ 3.0 ◣	238	LE1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	OK	OK
		◢ 3.0 ◣	238	LE1	0.2	0.0	-0.1	0.1	0.1	0.0	0.0	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490.0	0.90	435.6	352.8

Symbol explanation

T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
ε_{Pl}	Strain
$\sigma_\perp$	Perpendicular stress
$\tau_\perp$	Shear stress perpendicular to weld axis
$\tau_{\|\|}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

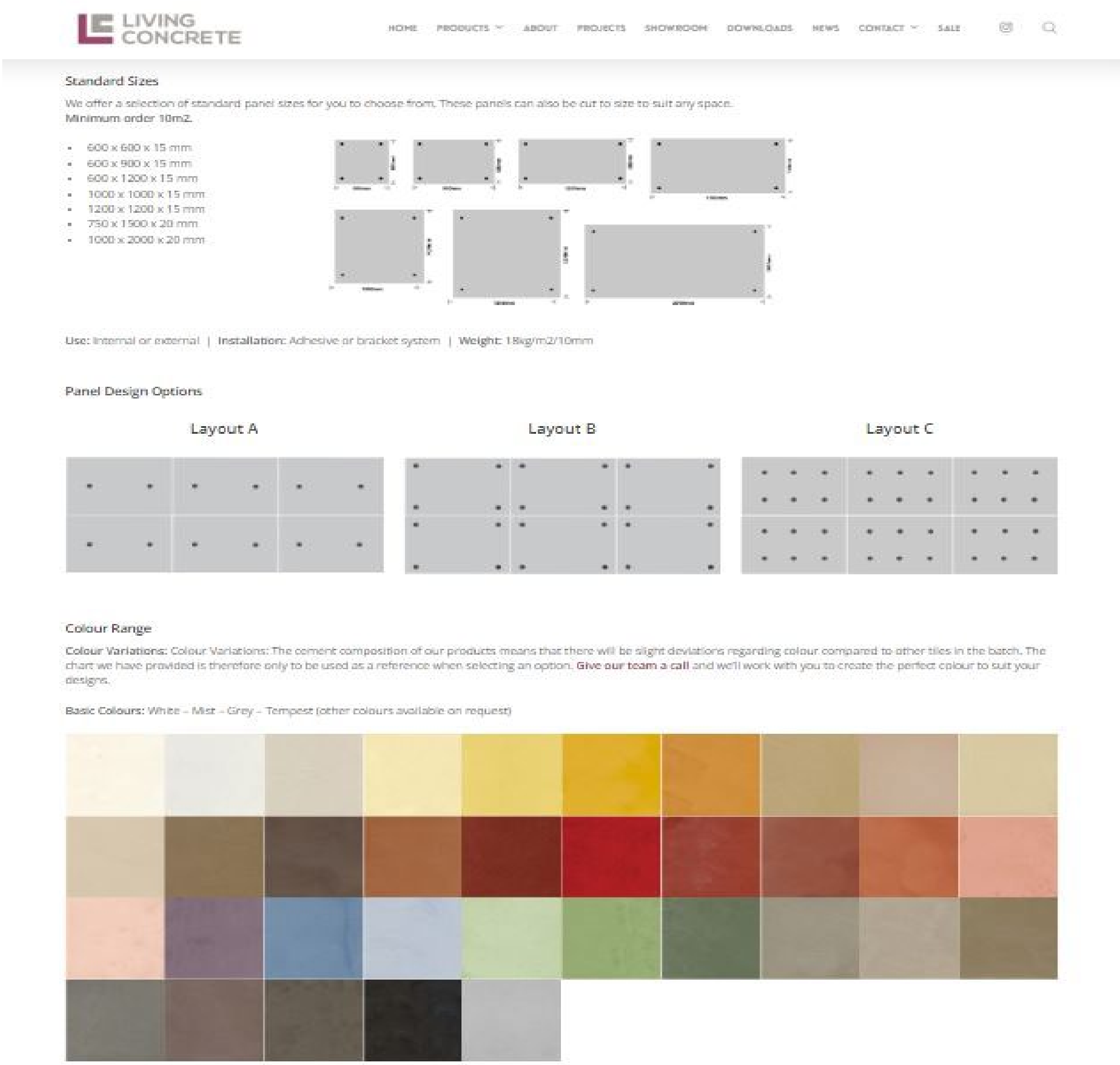
Buckling

Buckling analysis was not calculated.

Facade Design

In the design process of faced we try to consider the whole volume and each cube as a modular faced. Therefore, each cube has maximum four faced and minimum one faced, facing toward the light and the outer space the module is three in five and four height. So, the user can choose the bigger side five in four or the little one, three in four, for allocating the windows. In this way at least one side of each room can have an opening toward the outer space and other sides can be solid which can cover with panels.

We have two kind of faced the curtain wall and panels. The panels are proposed concrete one (GFRC) prefabricated the dimension of each of them 1*1 or 1*2.



The panels have different colors. The colors are chosen in a way that influenced by the other building of Detmold campus, tunes of red, pink, white and gray.

TECHNISCHE HOCHSCHULE OSTWESTFALEN-LIPPE
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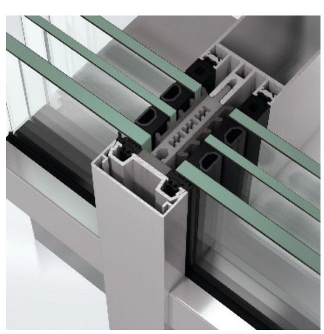
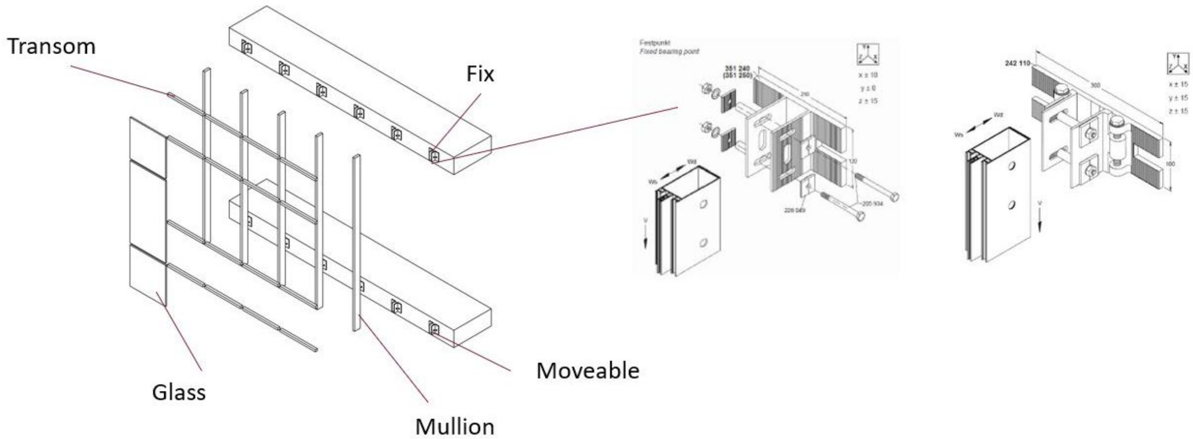
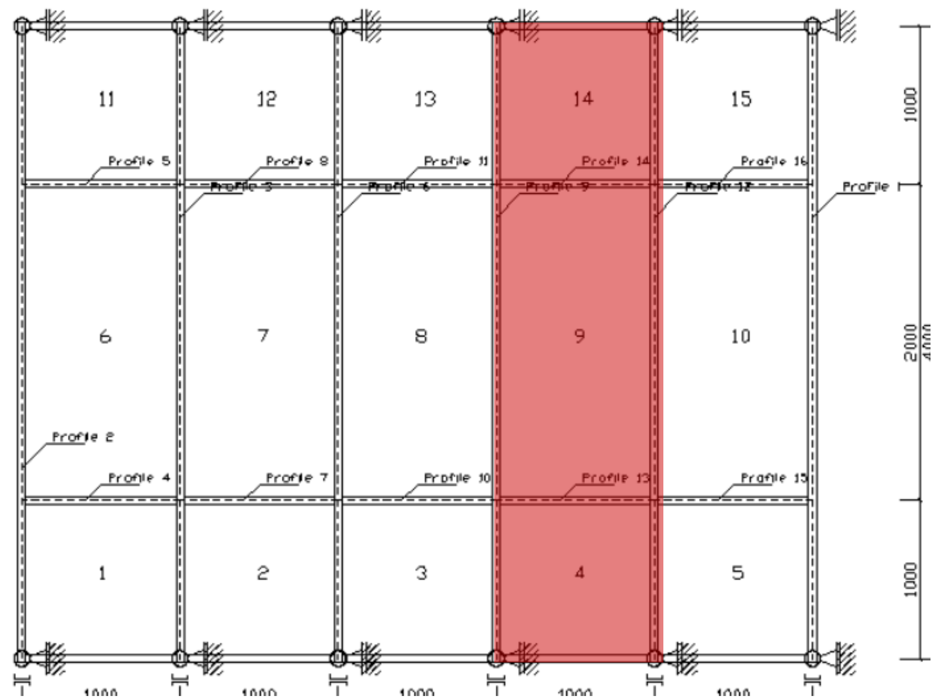
The system for other part of faced is curtains wall. At least one of the faces of each cube has windows aluminum mullion/transom façade system with Schüco products. The system is Schüco FWS 50.SI, highly thermally insulated self-supporting aluminum façade system. As a mullion/transom construction for multi-storey façades with an internal and external face width of 50 mm.



The system and order of fabrication is the upper supports are fixed the lower part are moveable which installed in front of slabs. The mullion will install next then the transom, glasses and the outer cup.



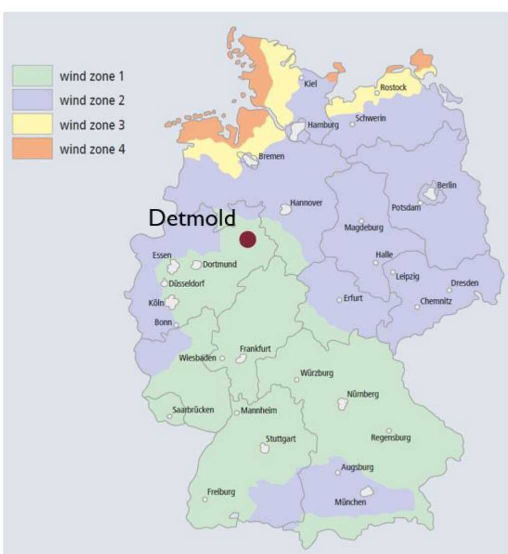
The curtain wall is divided in three parts. Upper and the lower part have the dimension of 1*1. We decide to use the wider part in middle to provide better view and light. It is 1*2 meter. So, each of module is 3*1. The details for bigger part 5*4 are like the picture and it can be changed and reduce to 3*4.



The upper support is fixed, and the lower part is moveable and free

Facade system: Schüco FWS 50.SI
Entire façade: façade, Modular façade, Modular façade
Width: 5050.0 mm
Height: 4050.0 mm
Unit areas:
10 x Glass 28 mm (6-16-6), Ug=1.1 W/m²K, Stainless steel, from standard, 950.0 mm x 950.0 mm
5 x Glass 28 mm (6-16-6), Ug=1.1 W/m²K, Stainless steel, from standard, 950.0 mm x 1950.0 mm
Profiles:
Transom 55 mm - 322390
Mullion 150 mm - 322300
Edge seals:
Glass 28 mm (6-16-6), Ug=1.1 W/m²K, Stainless steel, from standard - Transom 55 mm - 322390
Glass 28 mm (6-16-6), Ug=1.1 W/m²K, Stainless steel, from standard - Mullion 150 mm - 322300

Then we calculated the wind load on the faced. Trying to choose the first data of the faced.

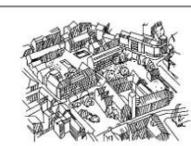


WindZone	V_b, 0 (m/s)	q_b, 0 (kN/m²)
WZ 1	22,5	0,32
WZ 2	25,0	0,39
WZ 3	27,5	0,47
WZ 4	30,0	0,56

Terrain Category 4

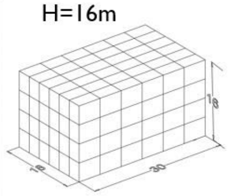
Urban areas where at least 15% of the area is covered by buildings with a mean height exceeding 15m

Roughness length z_0 =1,05m
profile exponent α = 0,30



WindZone		Velocity pressure q_p in kN/m² at a building height h within the limits of		
		h <= 10m	10m < h <= 18m	18m < h <= 25m
1	Interior	0,50	0,65	0,75
2	Interior	0,65	0,80	0,90
	Coast and islands of the Baltic Sea	0,85	1,00	1,10
3	Interior	0,80	0,95	1,10
	Coast and islands of the Baltic Sea	1,05	1,20	1,30
4	Interior	0,95	1,15	1,30
	Coast North and Baltic Sea and Islands of the Baltic Sea	1,25	1,40	1,55
	North Sea Islands	1,40	-	-

H=16m



The most critical part of the faced is selected. The part A , because it has the biggest number in the table in comparison with other parts.

qp=0.65 KN/m2

H=16m, b=18m, d=30m

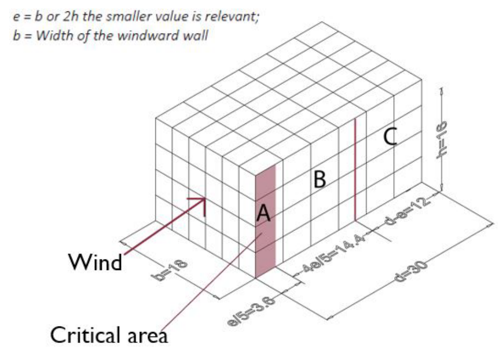
2h=32 , b=18 So b<2h So b=e=18

Cpe=-1.2

e/5=3.6
4e/5= 14.4
d-e=12
h/d=16/30= 0.533 so 0.533<1

External pressure coefficients for vertical walls of rectangular buildings

Facade Zone	A		B		C		D		E	
h/d	c_{pe},10	c_{pe},1	c_{pe},10	c_{pe},1	c_{pe},10	c_{pe},1	c_{pe},10	c_{pe},1	c_{pe},10	c_{pe},1
<= 5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
<= 1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
<= 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	



Wind pressure acting on the external surfaces, W_e :

$$W_e = q_{p\ (ze)} * c_{pe}$$

We= 0.65* -1.2= -0.78

The maximum deflection for the mullion and transom is calculated.

Maximum deflection for mullion:

- If L is equal/ less than 3 m, the maximum deflection is L/200 or 15mm (whichever is smaller)
- If 3 ≤ L ≤ 7.5 m, the maximum deflection is L/300 + 5mm

L=4000
L/300+5=4000/300+5=18.3 so **15mm**

Maximum deflection for transom:

Maximum deflection for Transom due to dead load: L/500 or 3mm

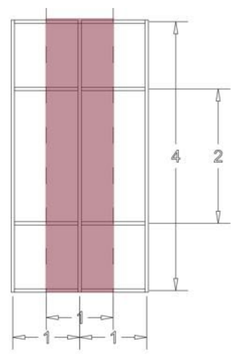
L=1000
L/500=1000/500= **2 mm**

Maximum deflection for Transom due to wind load: L/200 OR 15mm

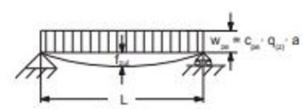
E = 7000KN.CM2

L=1000
L/200=1000/200= **5 mm**

Mullion moment of inertia and deflection of it calculated and compared with maximum one and also it compared with the mullion part which we choose for our faced system, mullion 150 mm.



E-Modul Aluminium Modulus of elasticity for aluminium	$E = 7000\ kN/cm^2$
E-Modul Stahl Modulus of elasticity for steel	$21000\ kN/cm^2$
Windlast Wind load	$w_{ze}\ [kN/cm^2]$
Rastermaß Module size	a [cm]
Zulässige Durchbiegung Permissible deflection	f_{zul} [cm]
Lagerabstand Distance between bearings	L [cm]
Böengeschwindigkeitsdruck Velocity pressure of gusts	$q_{(z)}\ [kN/m^2]$
Außendruckbeiwert External pressure coefficient	c_{pe}



Mullion moment of inertia:

- moment of inertia: (cm^4)

- $I_x = \frac{5*q*l^4}{384*E*\sigma_{max}}$

$Ix = \frac{5*-0.0075*(400)^4}{384*7000*1.5} = 238.09\ cm4$

velocity pressure of gust on the edge:

q=we * a
We=-0.78
a= 1
q = -0.78 * 1= -0.78 KN/M (or -0.0075 KN/cm)

Deflection calculation due to wind load

$\sigma_{max} = \frac{5*q*l^4}{384*E*I_x}$

$6 = \frac{5*0.0075*(400)^4}{384*7000*238.09} = 1.5\ cm$

Description	Basic depth in mm	Face width in mm	Art. No.	$I_x$ava	$I_y$ava
Mullion 150 mm	150	50	322300	423,85	44,37

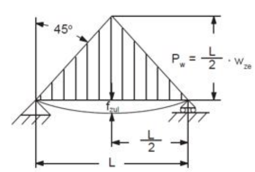
Then transom moment of inertia and dead load and glass load of transom is calculated and compared with the maximum one and the ones chosen for the transom, transom 55 mm.

Transom moment of inertia:

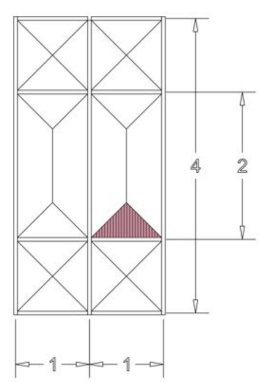
$$I_x = \frac{1}{120} \cdot \frac{L/2 \cdot w_{ze} \cdot L^4}{E \cdot f_{zul}}\ [cm^4]$$

Fzul= 5mm or 0.5 cm
Wze=0.78 KN/m2 or 0.000078 KN/cm2
E=7000 KN/cm2
L=100

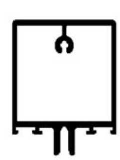
$Ix = \frac{1}{120} * \frac{100/2*0.000078*(100)^4}{7000*0.5} = 0.92857\ cm4$

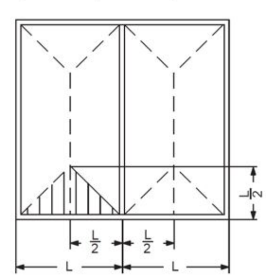


Erforderliches Trägheitsmoment (erf. I_x):
Required moment of inertia (erf. I_x):

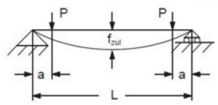


Description	Basic depth in mm	Face width in mm	Art. No.	$I_x$ava	$I_y$ava
Transom 55 mm	55	50	322390	28,08	17,16





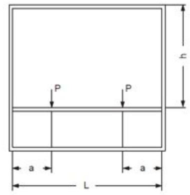
Transom dead load and glass load Calculationn



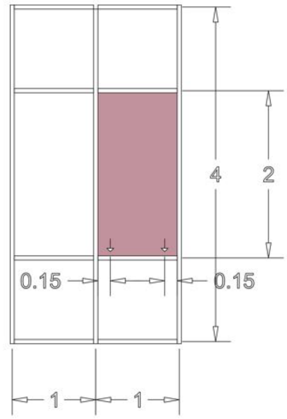
$$P = \frac{h \cdot L}{20000} q_G \text{ [kN]}$$

$$I_{y\,Alu} = \frac{(P \cdot a)}{(24 \cdot 7000 \cdot f_{zul})} \cdot (3L^2 - 4a^2)$$

$$+ \frac{(1{,}88 \cdot R_G \cdot L^4)}{f_{zul.} \cdot 10^8} \text{ [cm}^4\text{]}$$



Klotzungsabstand = a
Scheibenhöhe = h [cm]
Stützenweite = L [cm]
Distance between blocks = a
Pane height = h [cm]
Span = L [cm]



Lastannahmen Glas Design loads for glass	
$q_G = 0{,}15$ kN/m^2	(Einfachglas) bis 8 mm Glas (Single glazing) up to 8 mm of glass
$q_G = 0{,}30$ kN/m^2	(Isolierglas) bis 12 mm Glas (Insulating glazing) up to 12 mm of glass
$q_G = 0{,}45$ kN/m^2	(Dreifachglas) bis 18 mm Glas (Triple glazing) up to 18 mm of glass
Riegelgewicht Transom weight	R_G [kN/m]
Punktlast = P Concentrated load = P	½ Glaslast [kN] ½ glass load [kN]
Zulässige Durchbiegung Permissible deflection	$f_{zul.}$ [cm] ≤ 3 mm bzw. L/500 [1]
Klotzungsabstand Distance between blocks	a [cm]

[1] bei Stützweiten bis L = 1500 mm beachten
[1] Observe for spans up to L = 1500 mm

h=200 L=100

$p = \frac{200*100}{2000}*0.45 = 4.5$ KN

A=15cm

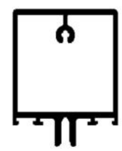
RG= Area * aluminum density * gravity (KN/m)

- area= 590 * 10-6 = 0.000590 (m2)
- aluminum densty= 2710 (kg/m3)

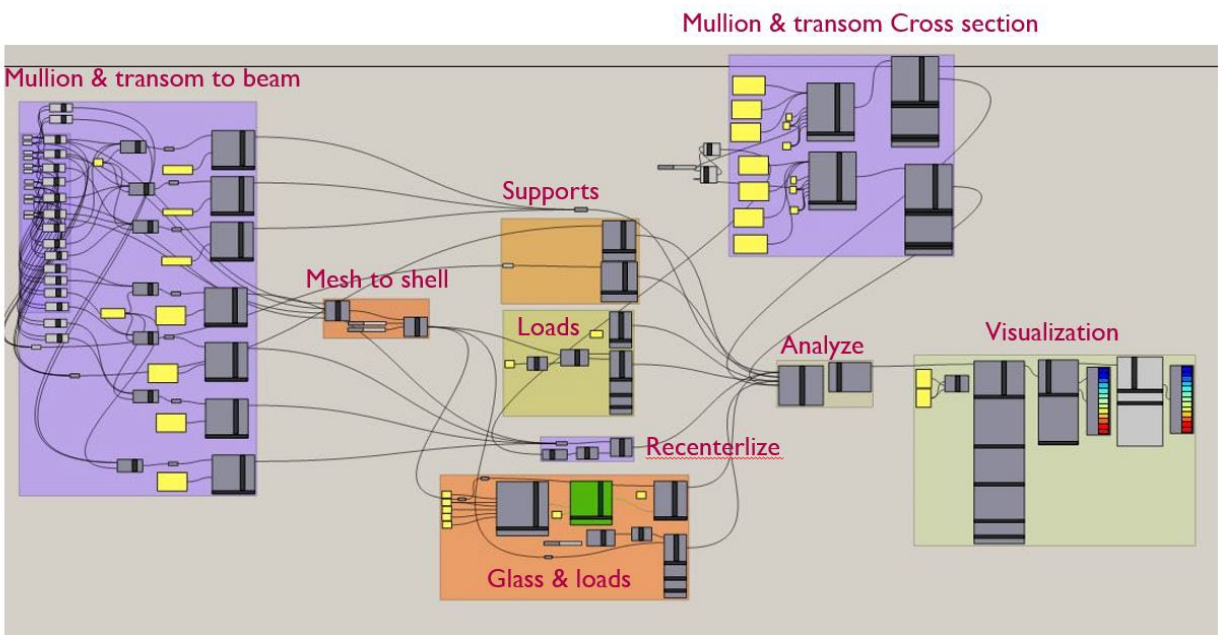
- 0.00059 * 9.81* 2710= 15.6852 Kn/m

$$\text{Iy} = \frac{4.5*15}{24*7000*5}*(3(100)^2 - 4(10)^2) + \frac{1.88*15.685*(100)^4}{5*(10)^8} = 8.27606$$

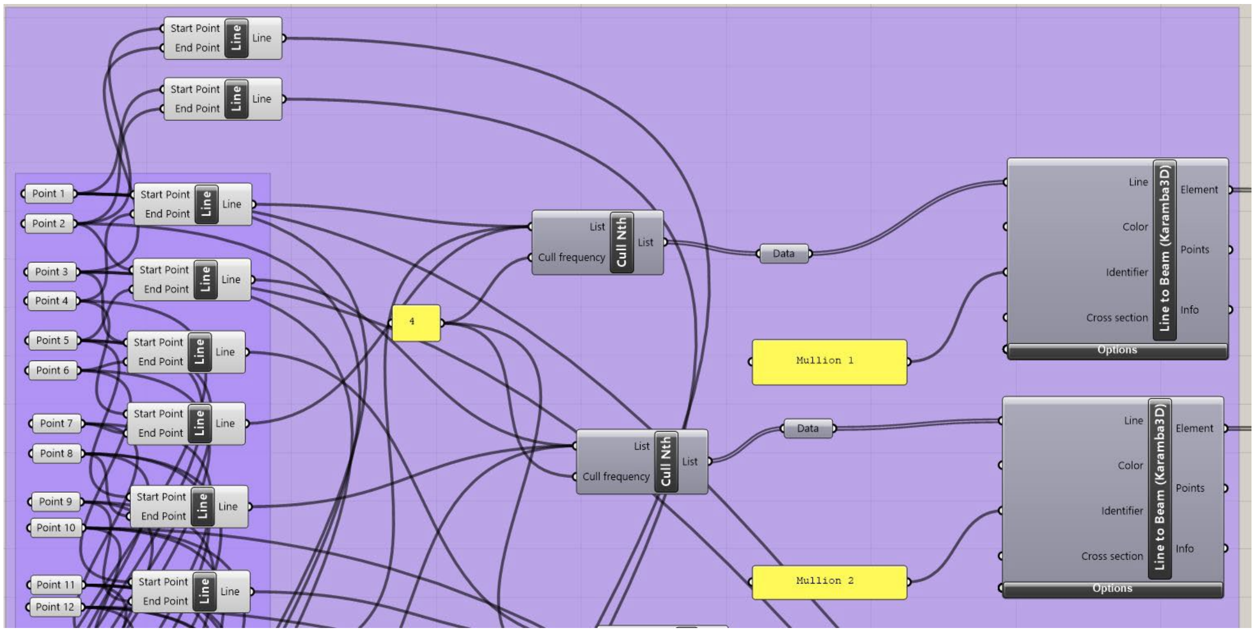
Description	Basic depth in mm	Face width in mm	Art. No.	$I_x$ava	$I_y$ava
Transom 55 mm	55	50	322390	28,08	17,16

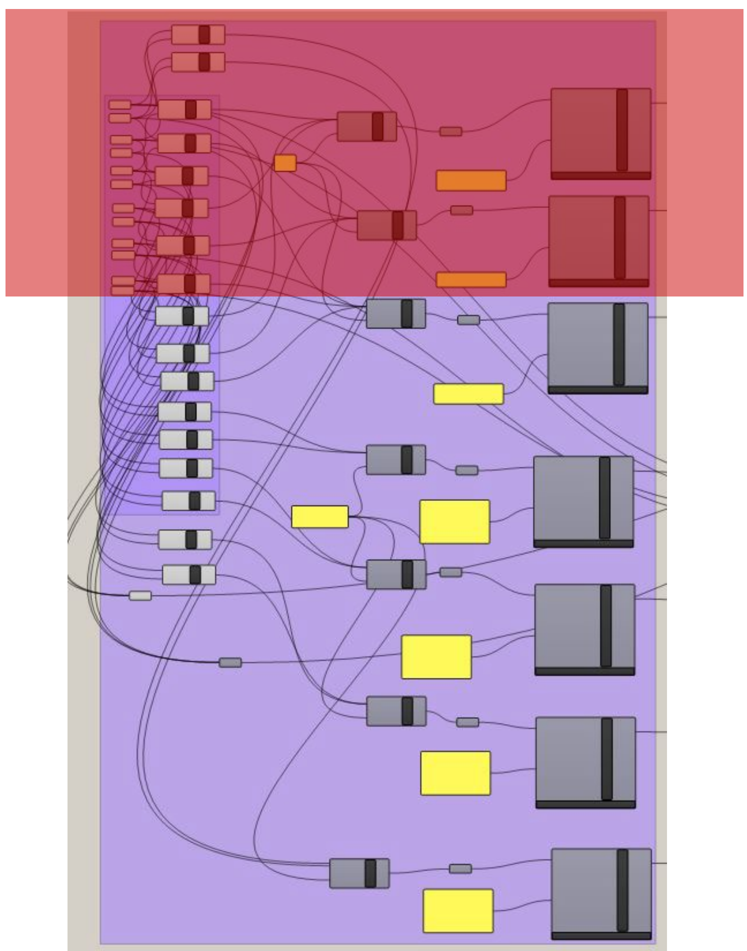


The karamba is used to model and analyze the loads. For this part we analyze two vertical modules 2*4. The process will be explaining in following.

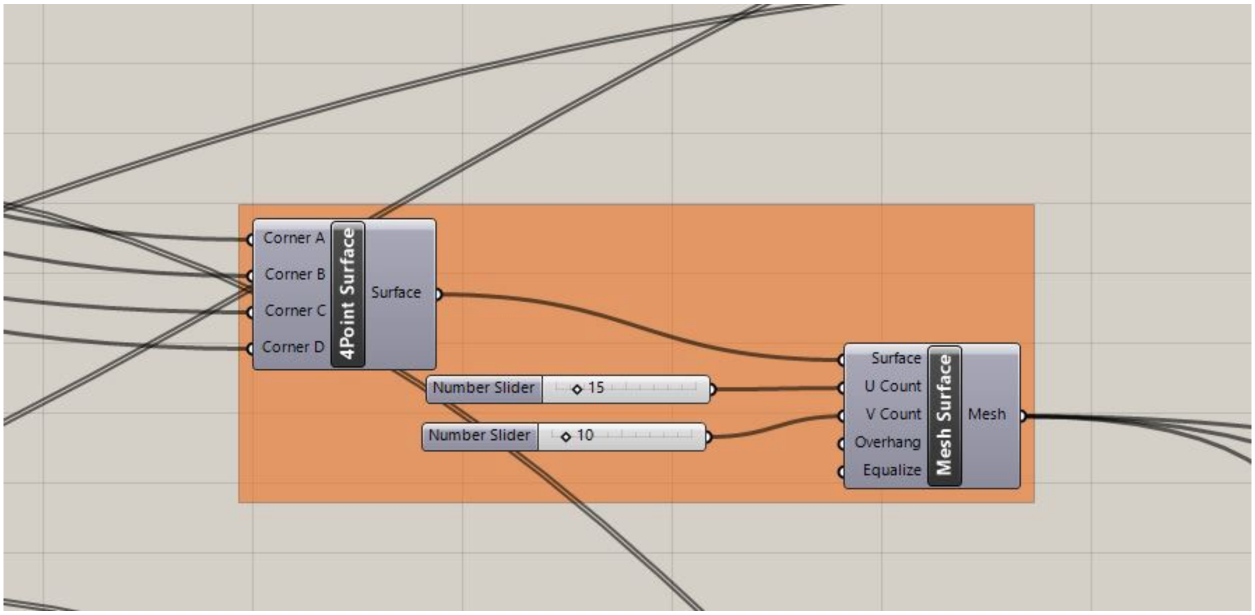


***Mullion & transom to beam:** the mullion and transom module is created and converted to elements that Karamba can read. The points make the lines and the lines express themselves as mullions and transoms. Then the lines converts to beams.

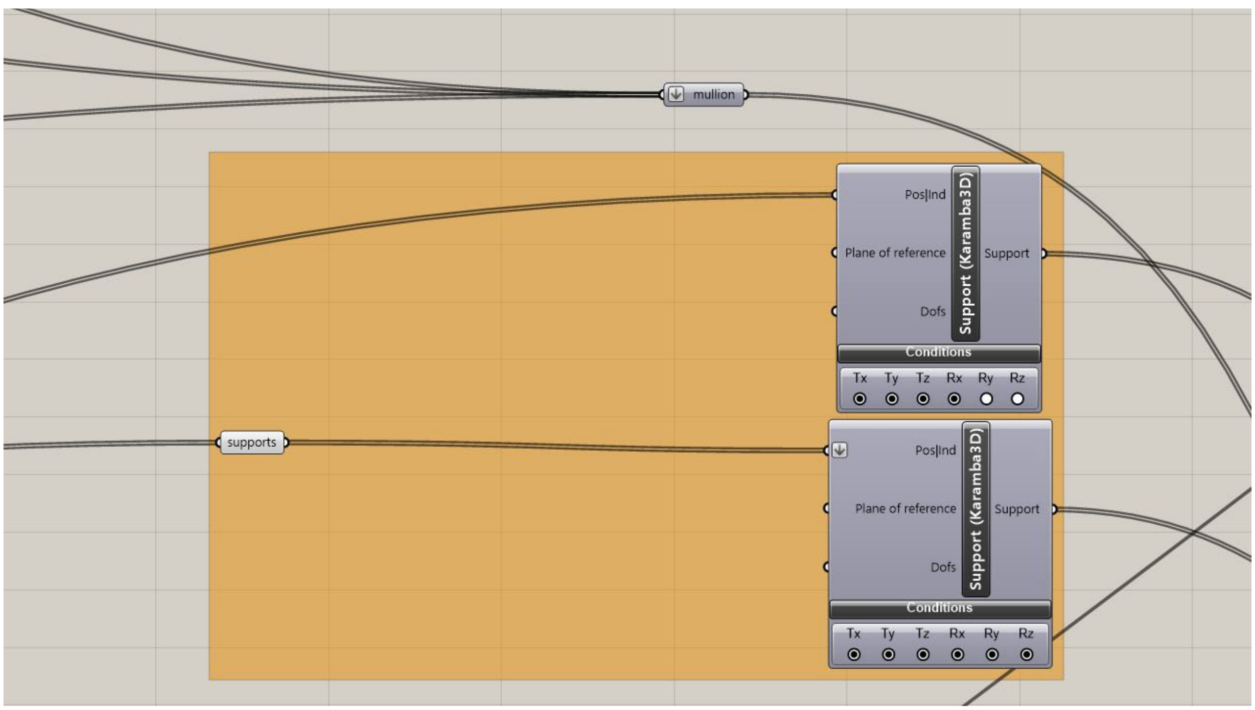

Start Point
End Point
Line
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6
Point 7
Point 8
Point 9
Point 10
Point 11
Point 12
List
Cull frequency
Cull Nth
Data
4
Mullion 1
Mullion 2
Line
Color
Identifier
Cross section
Line to Beam (Karamba3D)
Element
Points
Info
Options



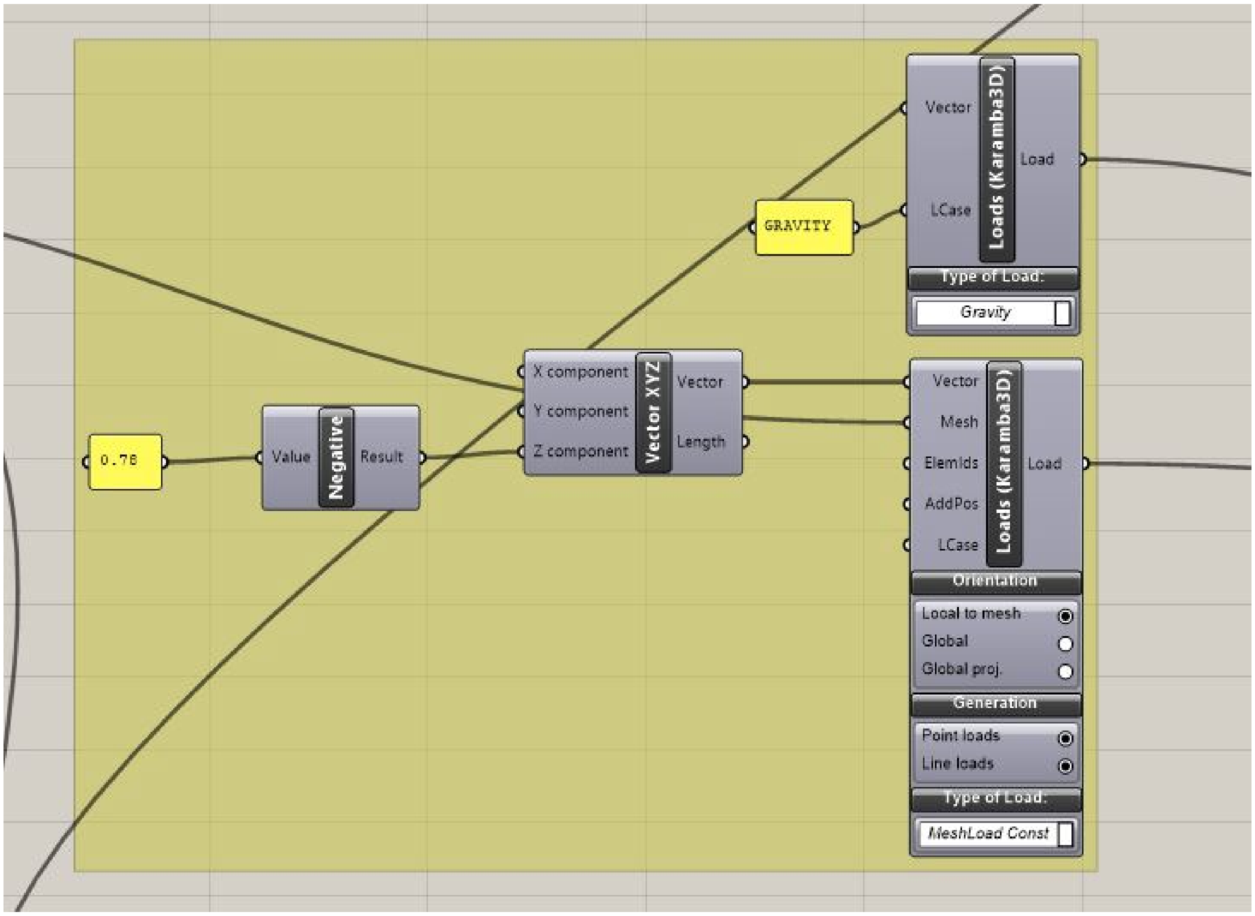
***Mesh to shell:** the glass mesh is converted to shell to be easy to read by Karamba.



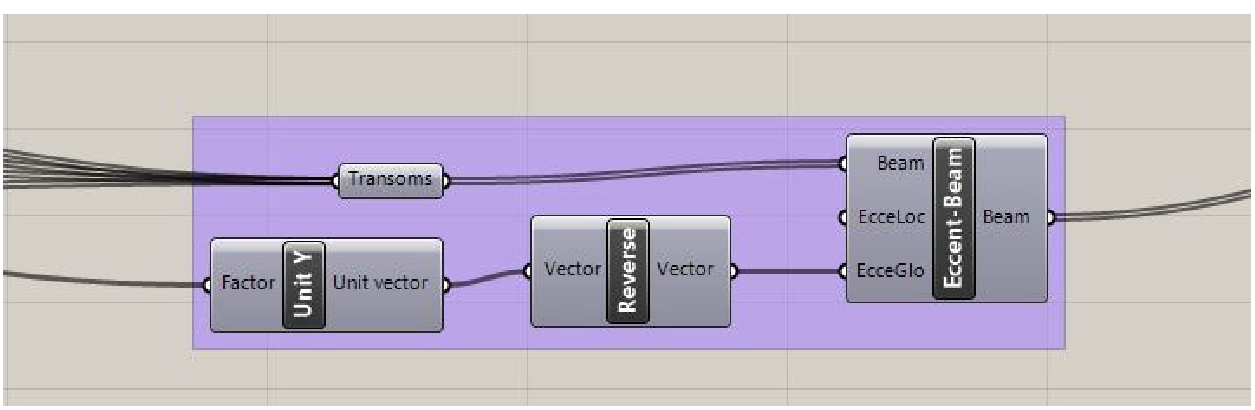
Supports: two different kind of supports allocating the upper one which are fixed and the lower part which free in some direction.



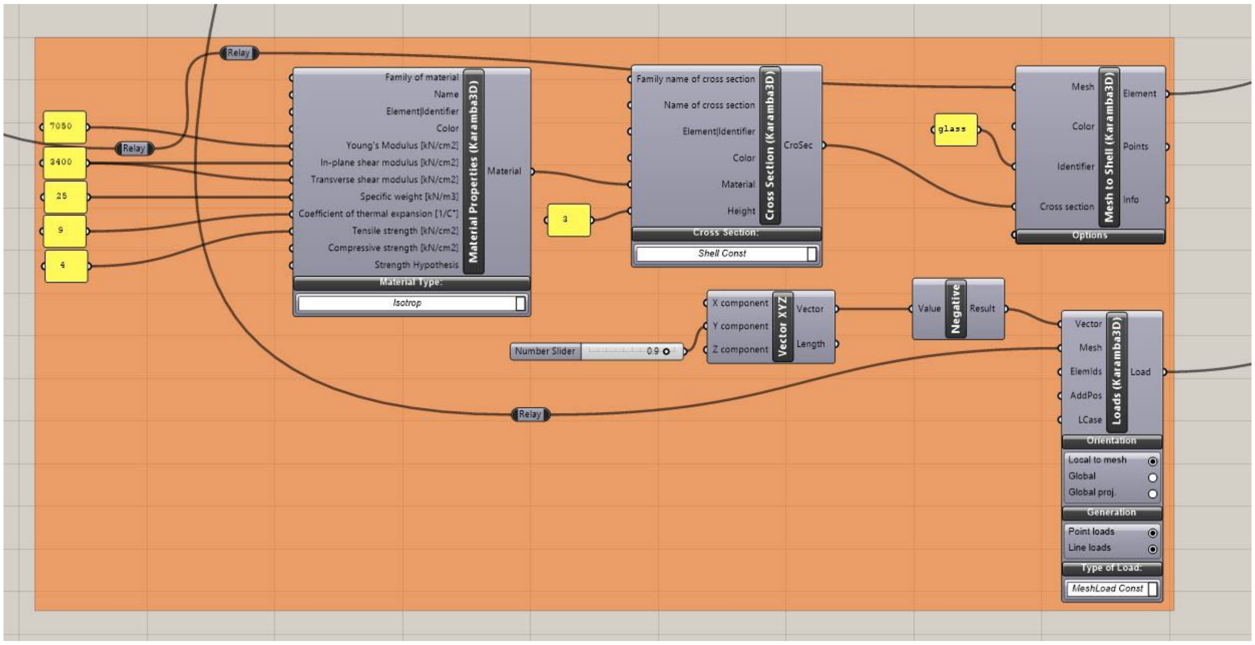
Loads: the different loads that can affect the system defined like the gravity and wind load we use some calculational number in this part like wind pressure acting in external faced.



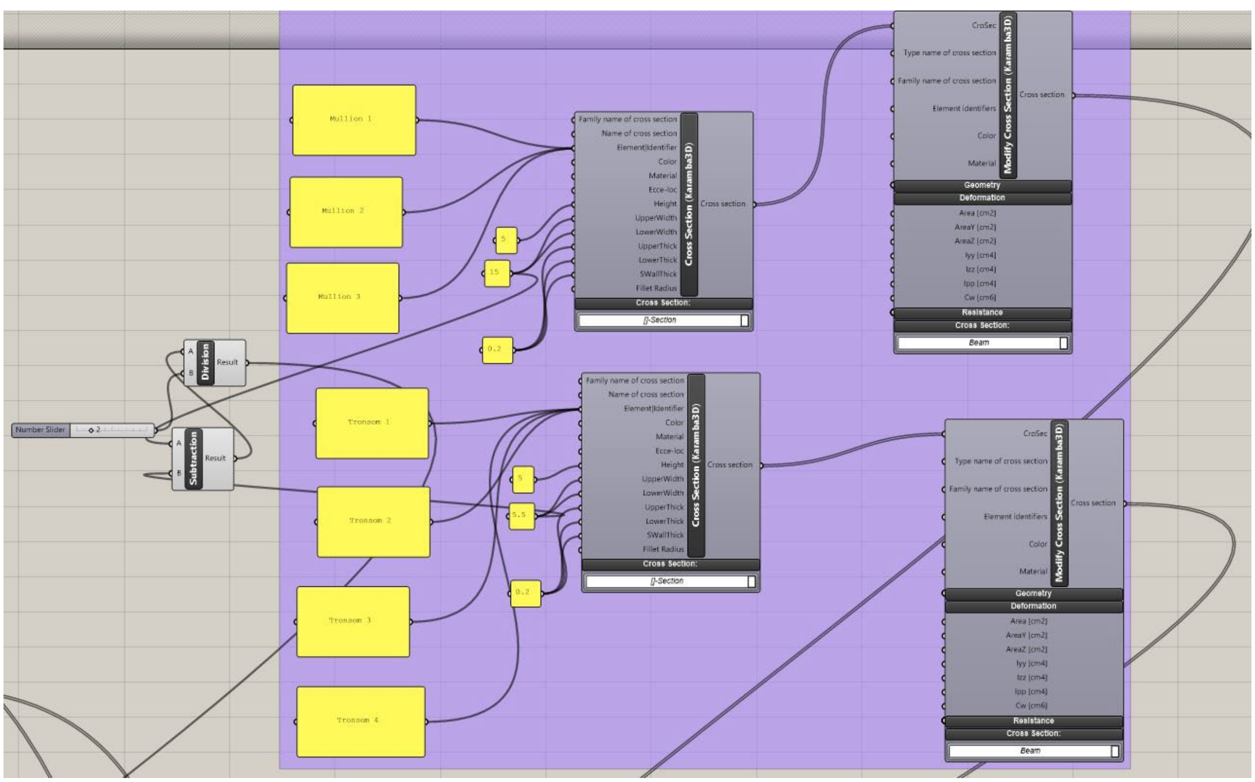
Recentralize: we keep the mullions, but we recentralize the transom to locate them in a correct position for calculating different loads.



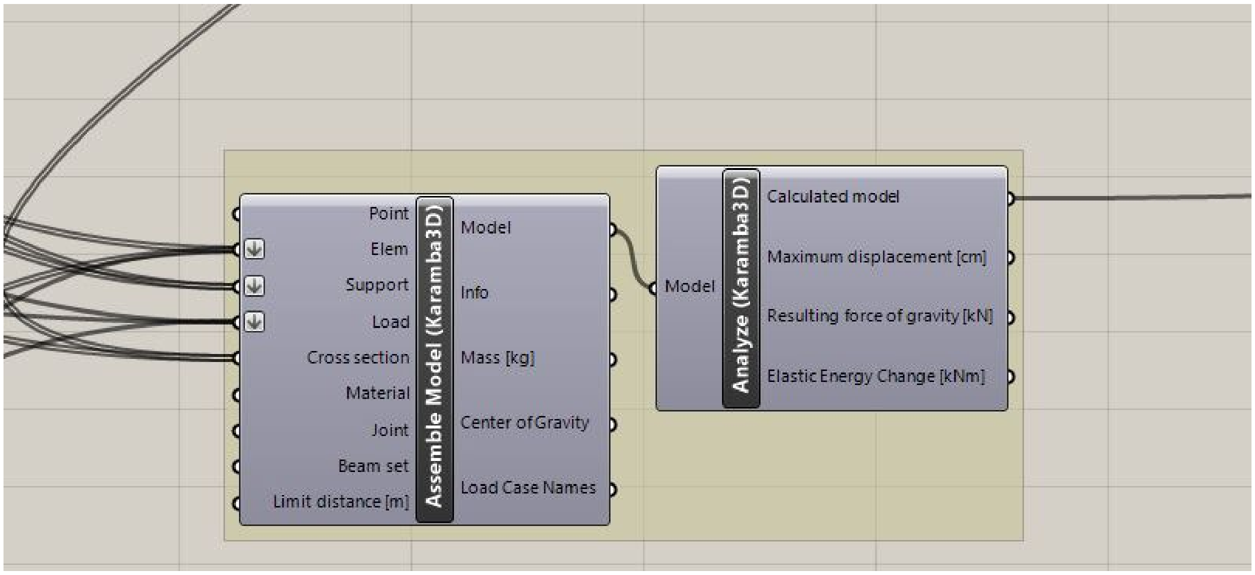
Glass and loads: the dimension and material of glass is added to detail the calculation.



Mullions and transoms cross section: based on what we choose for our faced system we define the mullions and transoms cross sections



Analyze: then assemble all the models and analyze them



Visualization: the mullions and transoms and glasses deformation and their stress visualized.