

UNSW 2016
karamba

Intro – Structural design

A structure consists of different parts:

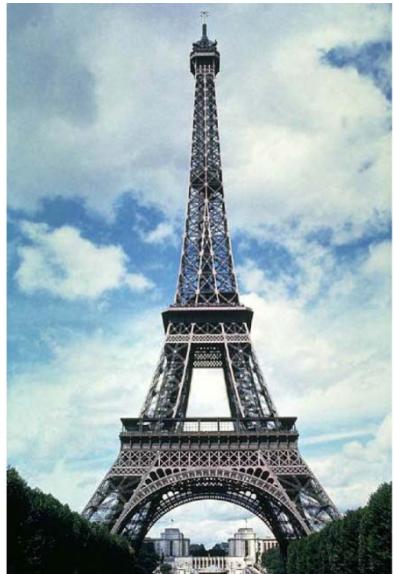
1. Beams
2. Columns
3. Trusses
4. Shear Structural Elements
5. Steel Rods
6. Connection Elements
7. Walls
8. Shells
9. Supports
10. Forces

Intro – Structural design

Types of Forces:

1. Dead loads
2. Live loads
3. Impact
4. Wind loads
5. Snow loads
6. Earthquake loads
7. Hydrostatic and soil pressure
8. Thermal and other effects

Typical Structures



Eiffel Tower, Paris – 1899
(Space Frame, Truss-System)



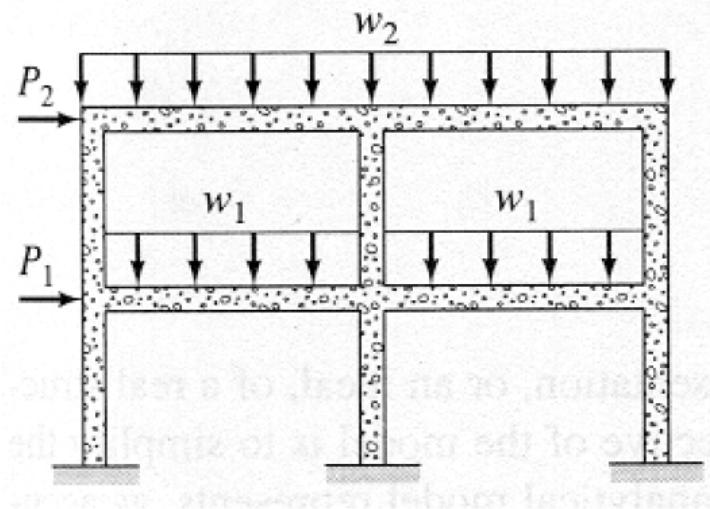
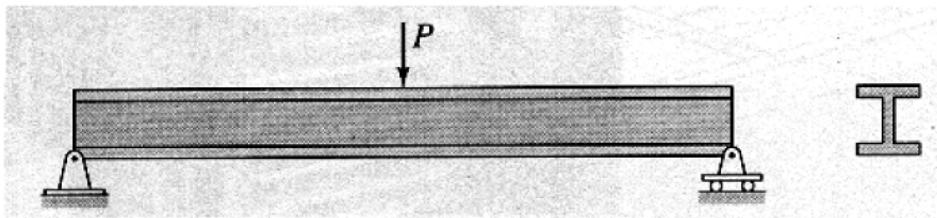
Sears Tower, Chicago – 1974
(Steelframe + Concrete Cores)



Rhine Bridge, Cologne-Germany –
1947 (Suspending Bridge)

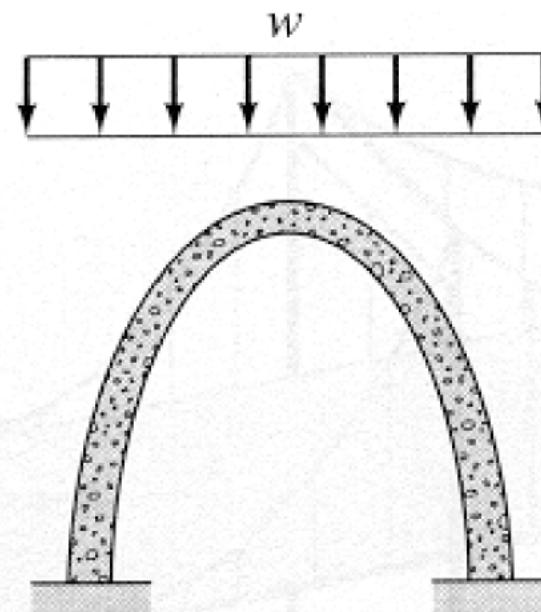
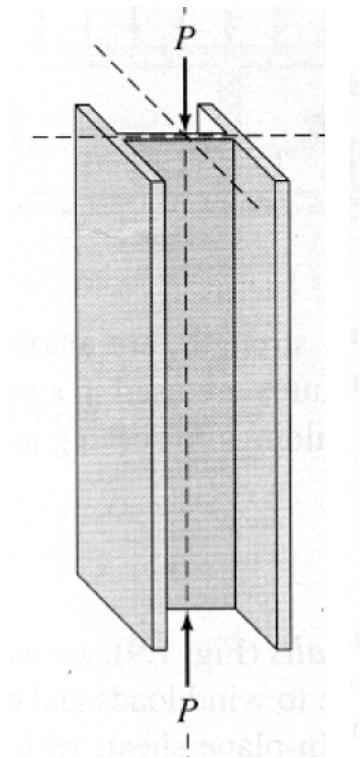
Typical Structural Elements

Bending Structures:



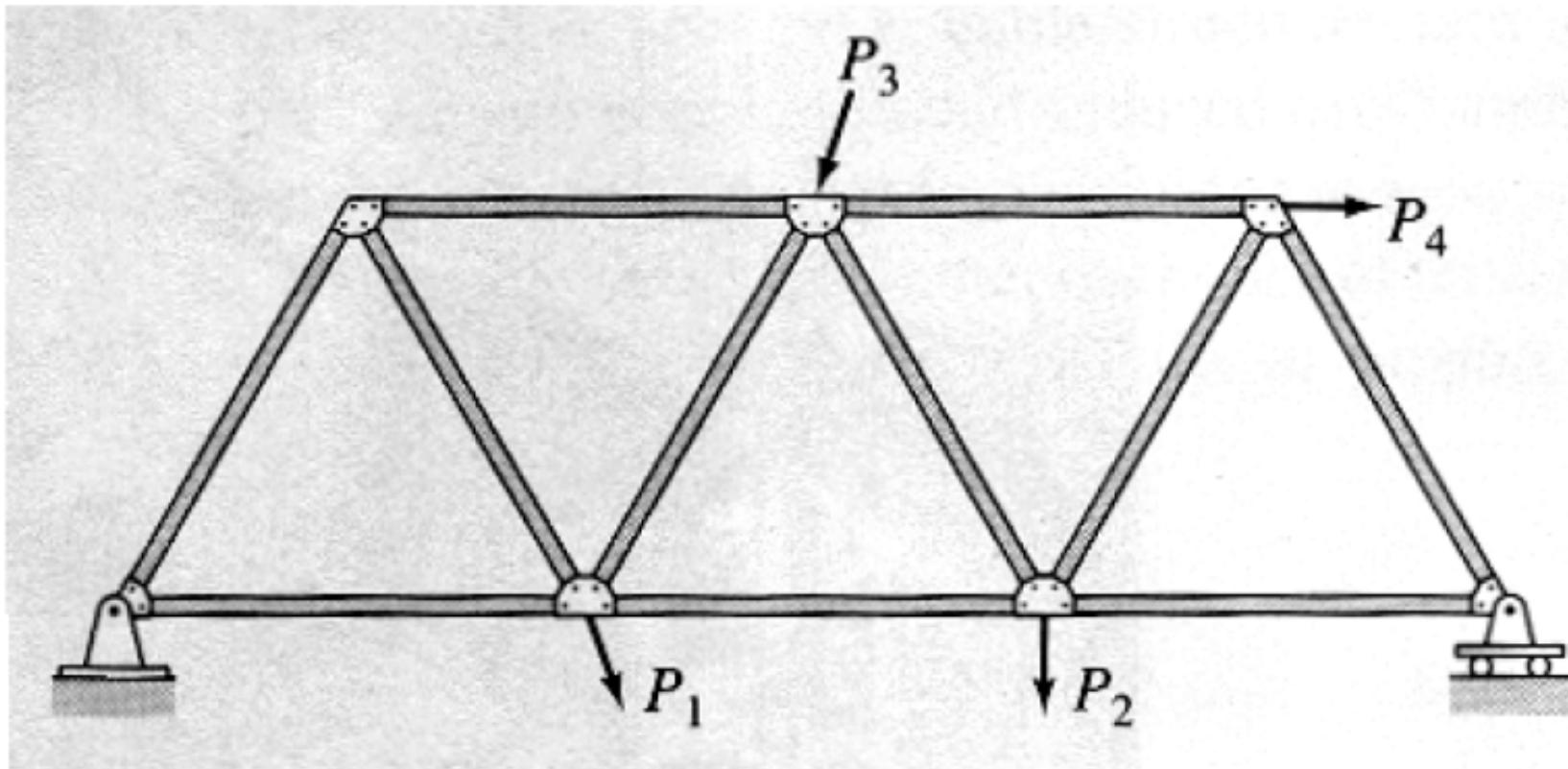
Typical Structural Elements

Compression Structures:



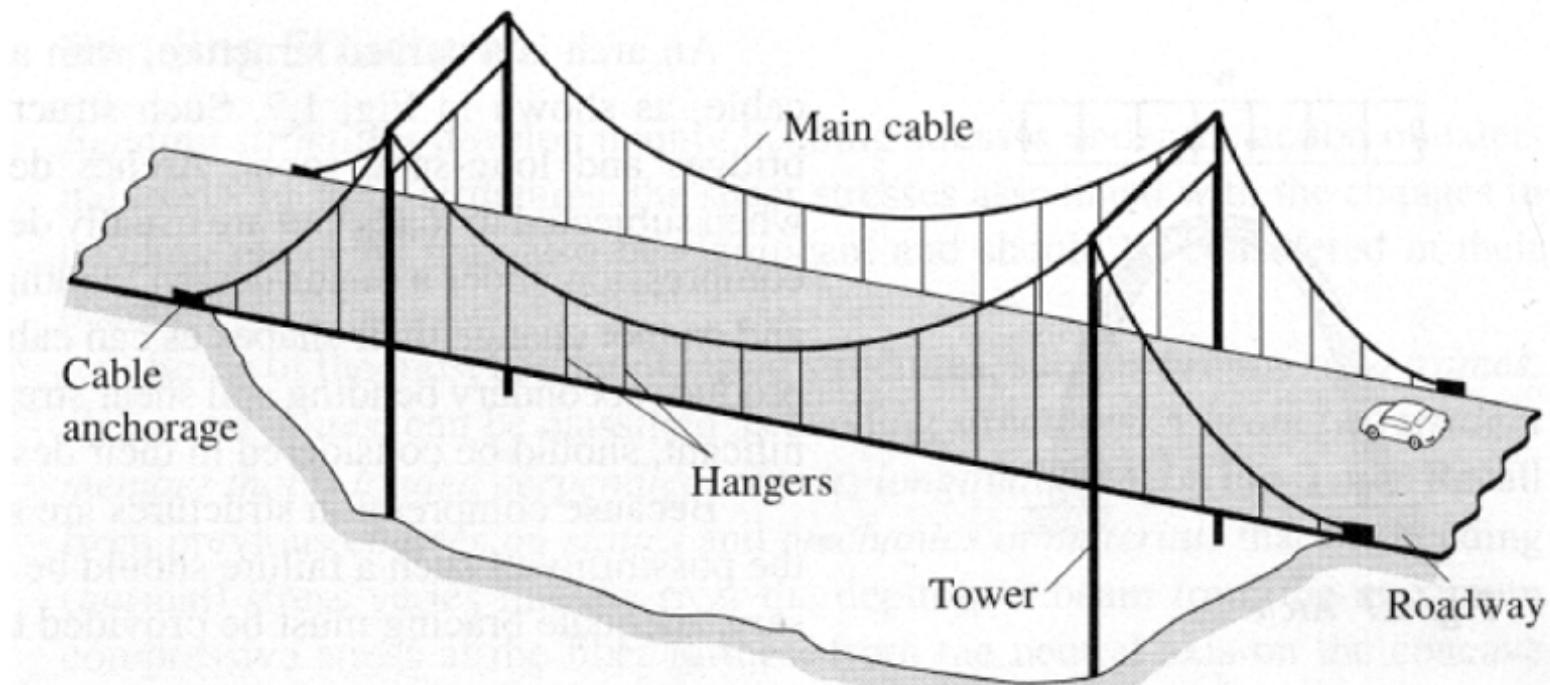
Typical Structural Elements

Truss Structures:



Typical Structural Elements

Tension Structures:



Differences between Structural Design and Structural Analysis

Structural Design:

Structural design is the methodical investigation of the stability, strength and rigidity of structures.

Structural design determines the size and arrangement of structural elements.

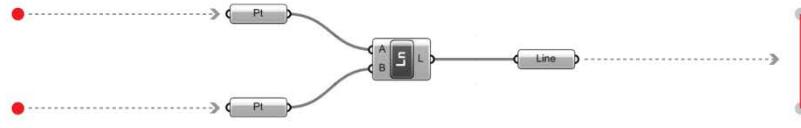
Structural Analysis:

is the prediction of the performance of a structure under prescribed loads and/or effects, such as movements, temperature and dynamic behaviour

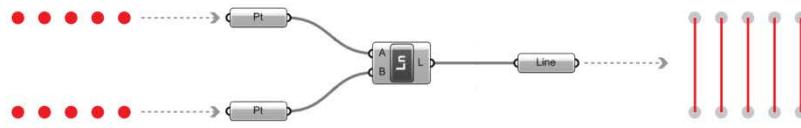
Basic Knowledge : Data Matching

Data matching is one of key concepts of most parametric tools. Since a Grasshopper object deal with multiple data from different sources, we need to have a clear logic on how to match data.

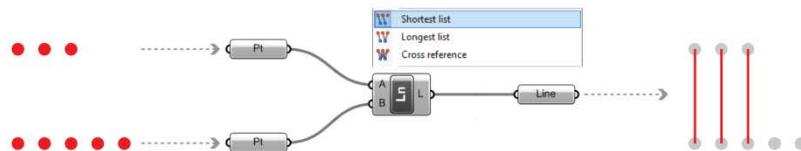
For example, let's say that we have a Grasshopper object which draws a line out of two input points like below.



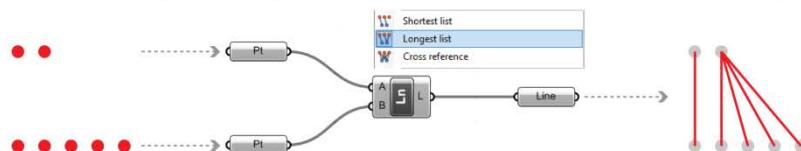
We can also supply multiple points to get multiple lines at the same time as below.



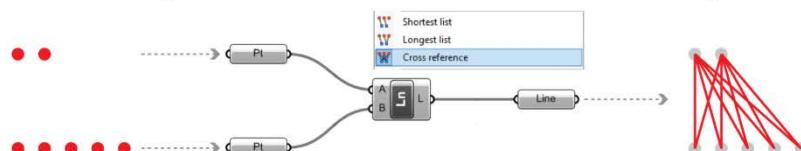
What if we have different numbers of points for each input? This may cause problem in drawing lines because the number of input points are not matching. If we set the data matching option as 'Shortest list' in option window, Grasshopper will draw lines based on short input list.



Else if we set the data matching option as 'Longest list' in option window, Grasshopper will draw lines based on longest input list.



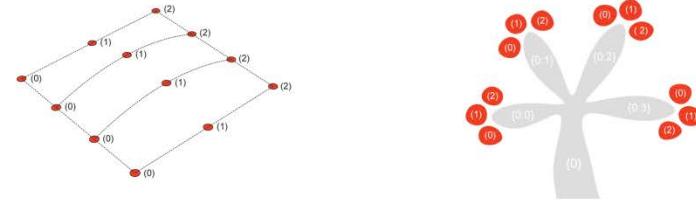
Or we can set the data matching option as 'Cross reference' in option window, in case we want to have crazy data matching.



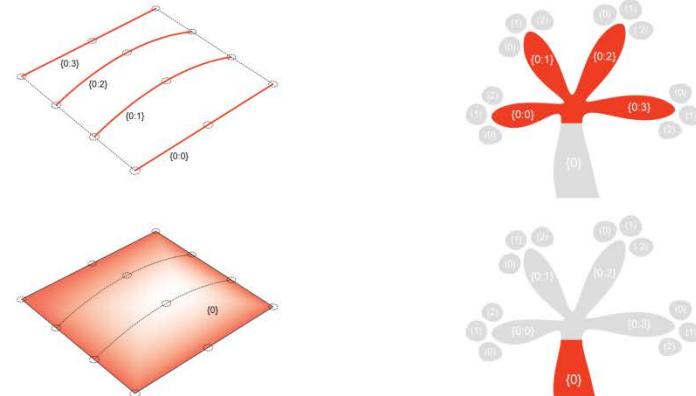
Basic Knowledge : Data Structure (Tree / Branch / List / Item)

Grasshopper provides multi-dimensional data structure, which we call 'Tree'. 'Tree' is composed of multiple 'Branches'. Branches can have sub branches. Only the branches at the lowest hierarchy can have 'List'. A list is a one-dimensional array containing items with index number.

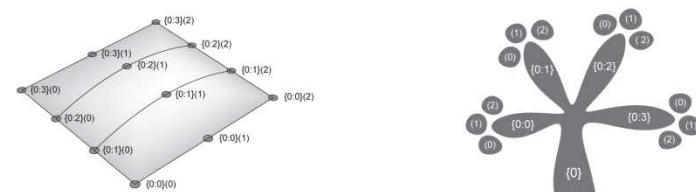
Let's say that we have 4 lists, and each of them has 3 items in it. Numbers in round bracket in the figure below is item index number.



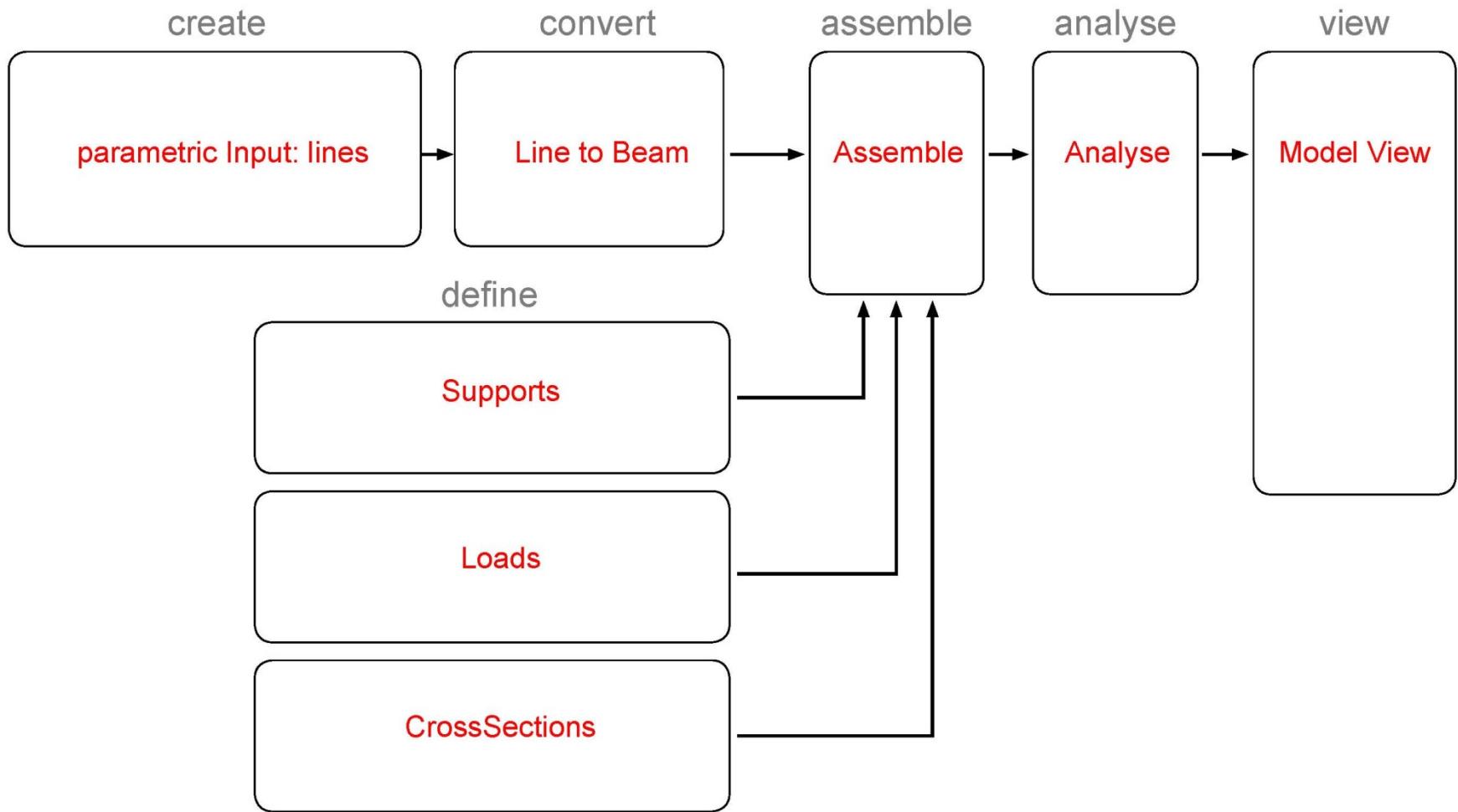
Branch is represented as form of numbers separated by semicolons in braces. Numbers in braces represent hierarchy, which means a branch can have any numbers of sub branches. The 4 lists from the diagram above can be mapped onto 4 branches as shown in the figure below like {0:0}, {0:1}, {0:2}, {0:3}. And these branches can be merged as another branch which is represented as {0}.



Below is complete map of data tree structure with one main branch, 4 sub branches, 4 lists, and 12 items.

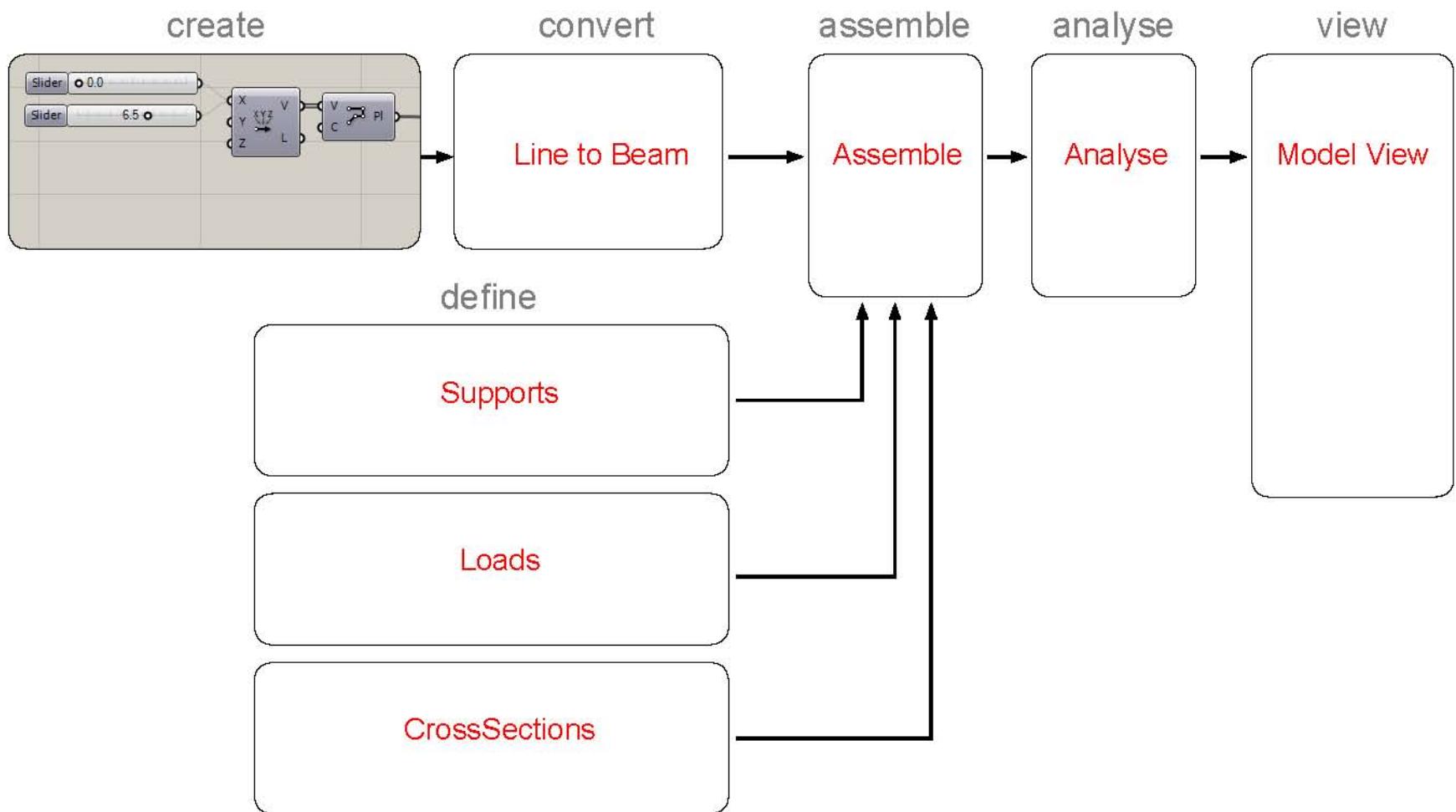


karamba setup



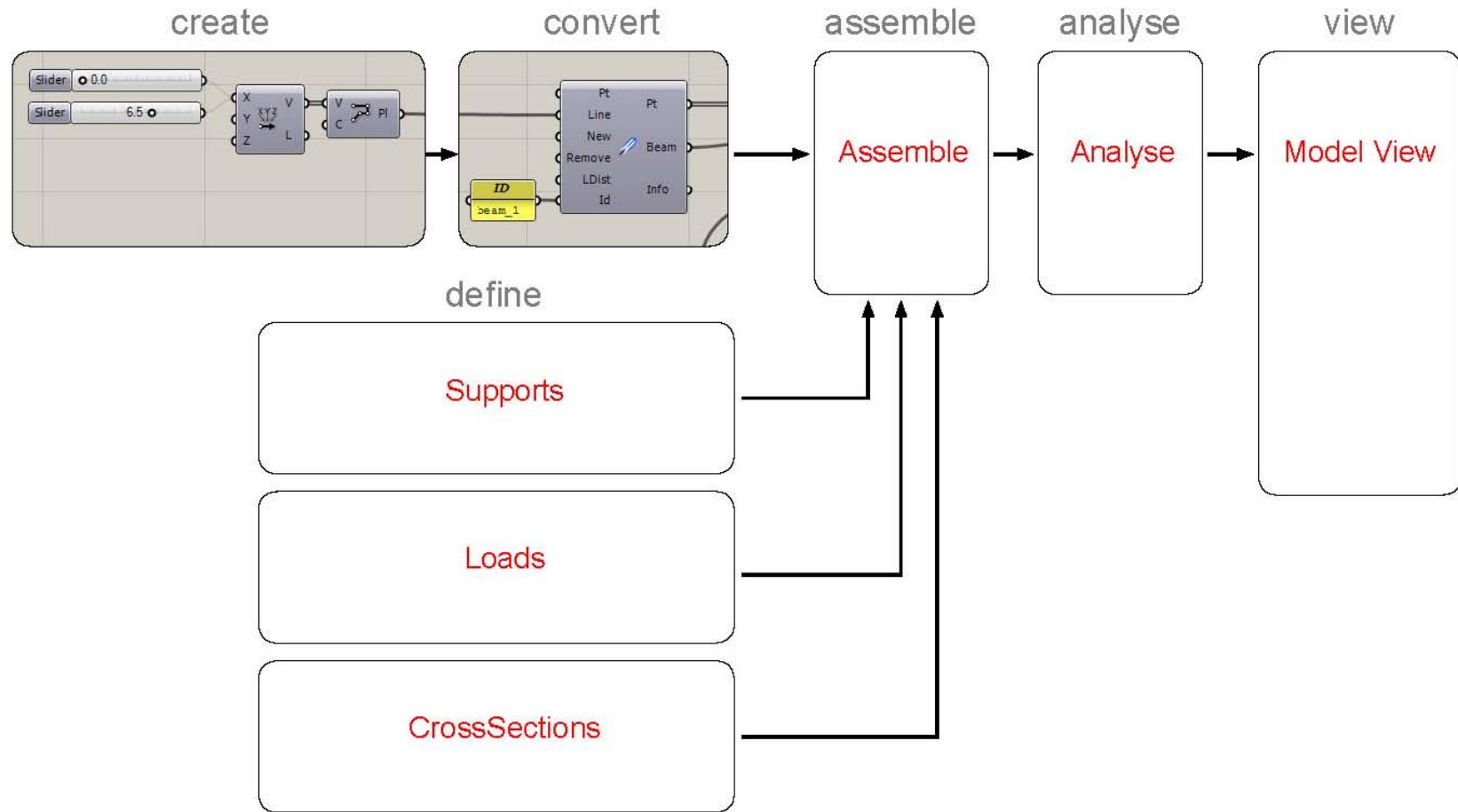
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create geometry



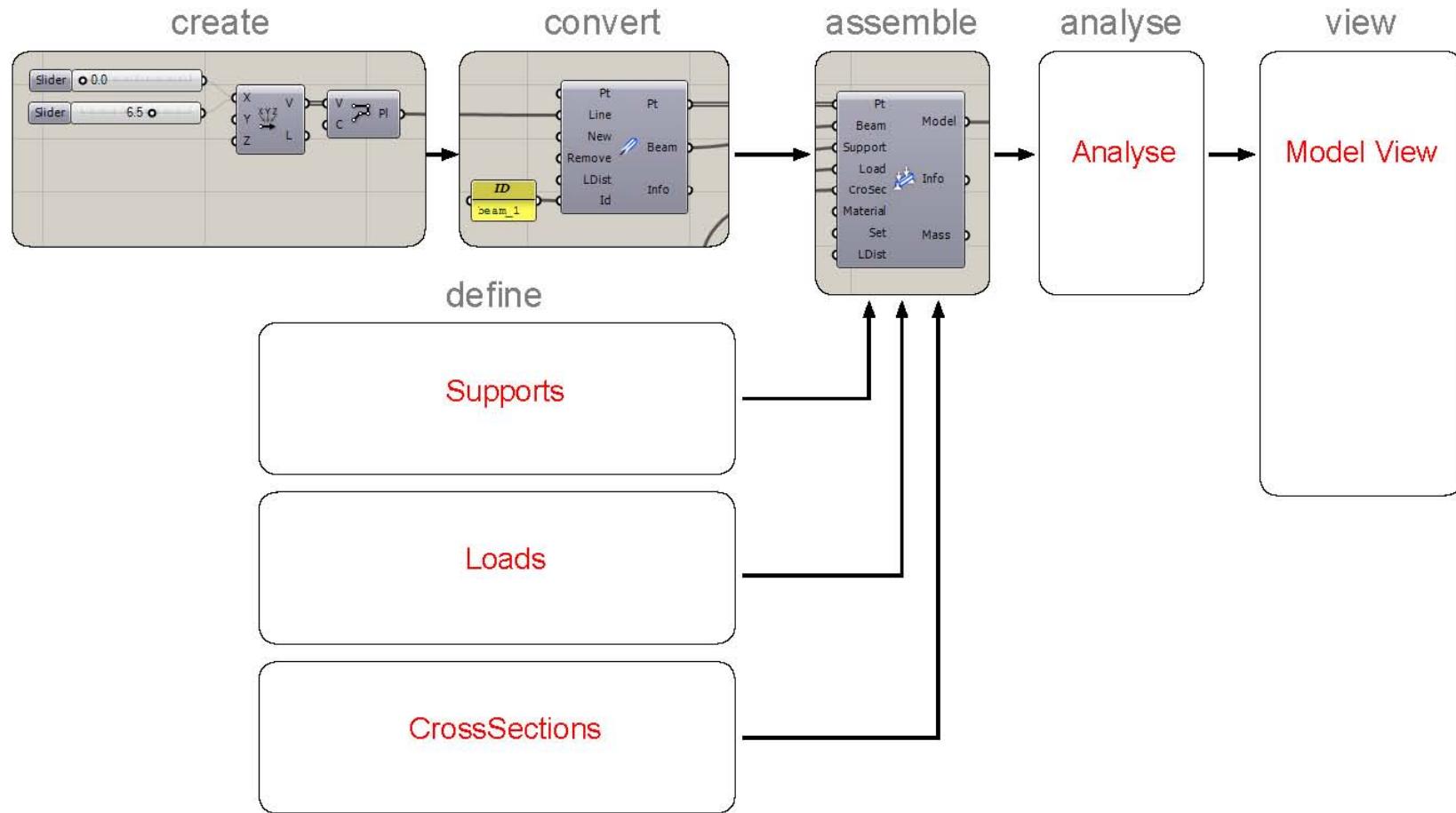
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convert geometry into structural members



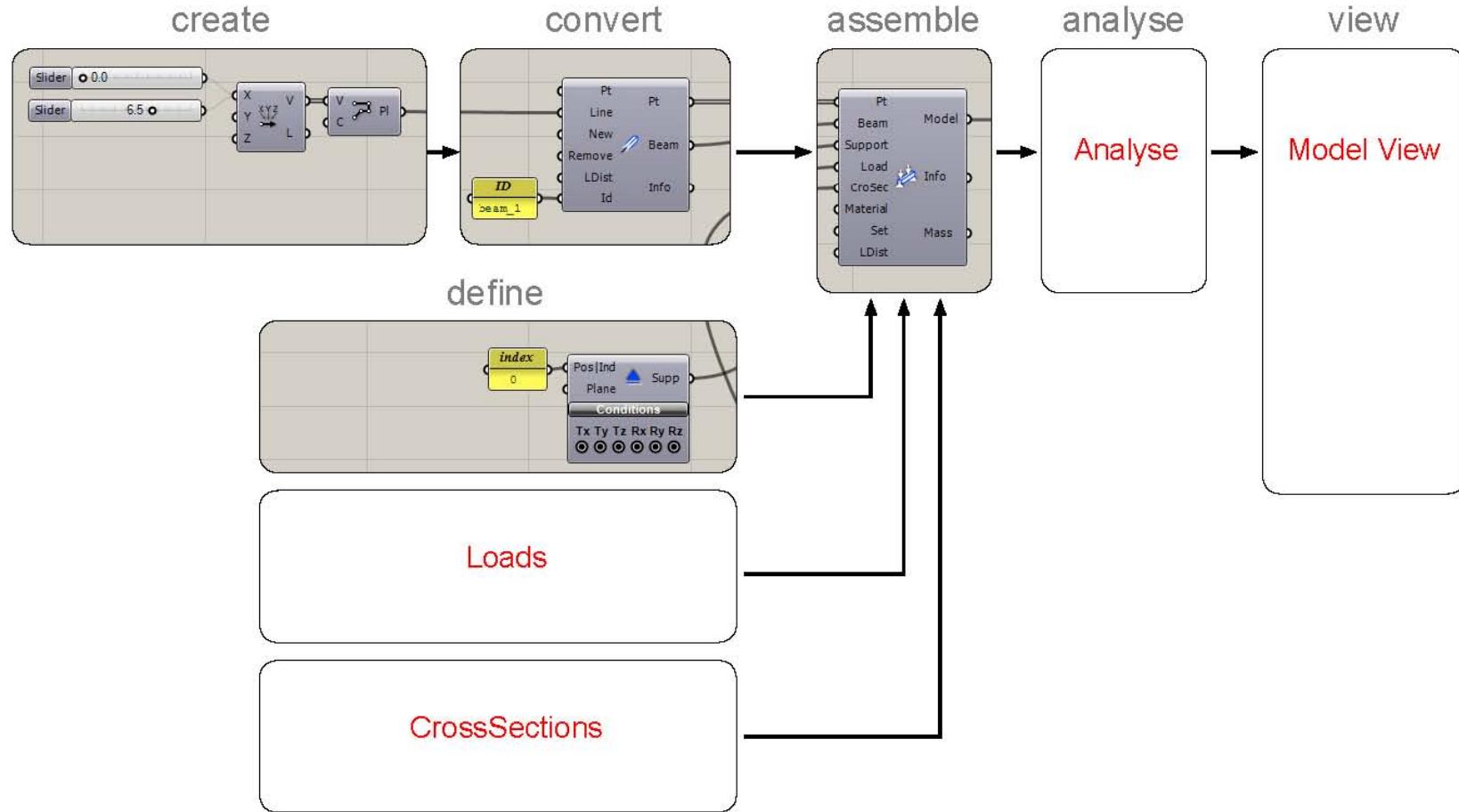
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assemble structural model



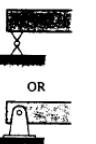
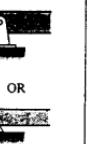
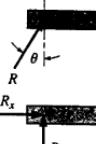
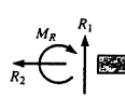
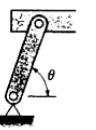
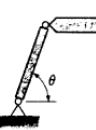
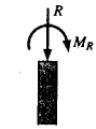
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define supports and support conditions

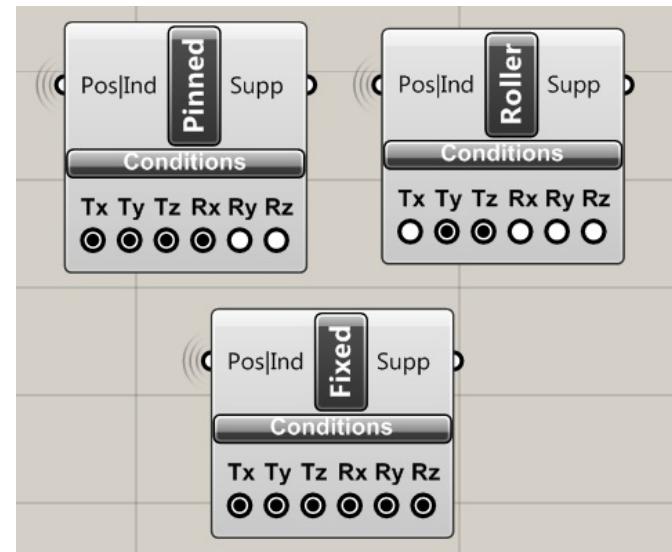


Karamba

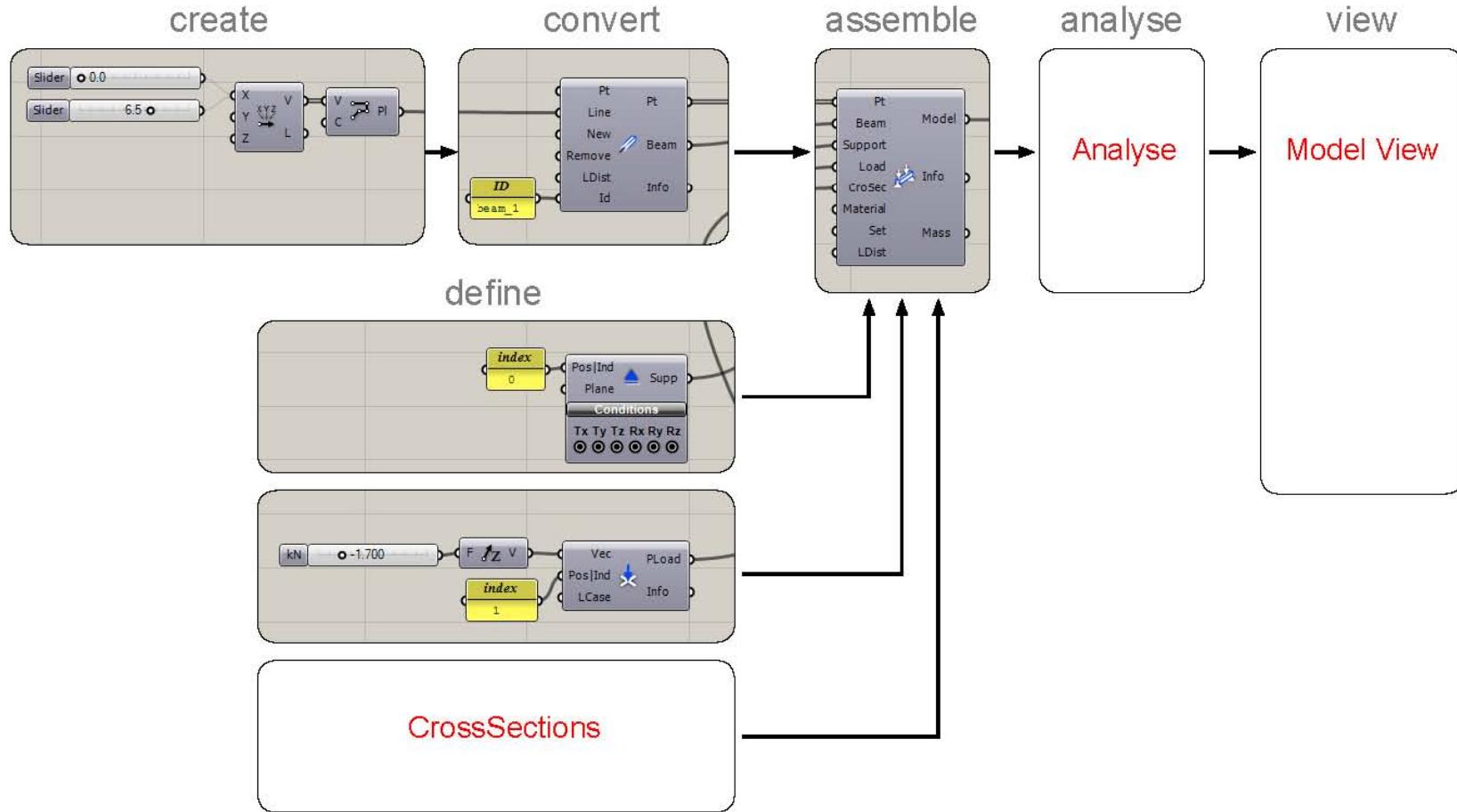
Table 1. Idealized Structural Supports

Type	Sketch	Symbol	Movements Allowed or Prevented	Reaction Forces	Unknowns Created
(a) Pin	 OR 	 OR 	<i>Prevented:</i> horizontal translation, vertical translation <i>Allowed:</i> rotation	A single linear force of unknown direction or equivalently A horizontal force and a vertical force which are the components of the single force of unknown direction	
(b) Hinge			<i>Prevented:</i> relative displacement of member ends <i>Allowed:</i> both rotation and horizontal and vertical displacement	Equal and oppositely directed horizontal and vertical forces	
(c) Roller			<i>Prevented:</i> vertical translation <i>Allowed:</i> horizontal translation, rotation	A single linear force (either upward or downward*)	
(d) Rocker					
(e) Elastomeric pad					
(f) Fixed end	 		<i>Prevented:</i> horizontal translation, vertical translation, rotation <i>Allowed:</i> none	Horizontal and vertical components of a linear resultant; moment	
(g) Link	 		<i>Prevented:</i> translation in the direction of link <i>Allowed:</i> translation perpendicular to link, rotation	A single linear force in the direction of the link	
(h) Guide			<i>Prevented:</i> vertical translation, rotation <i>Allowed:</i> horizontal translation	A single vertical linear force; moment	

Typical Structural Support Conditions

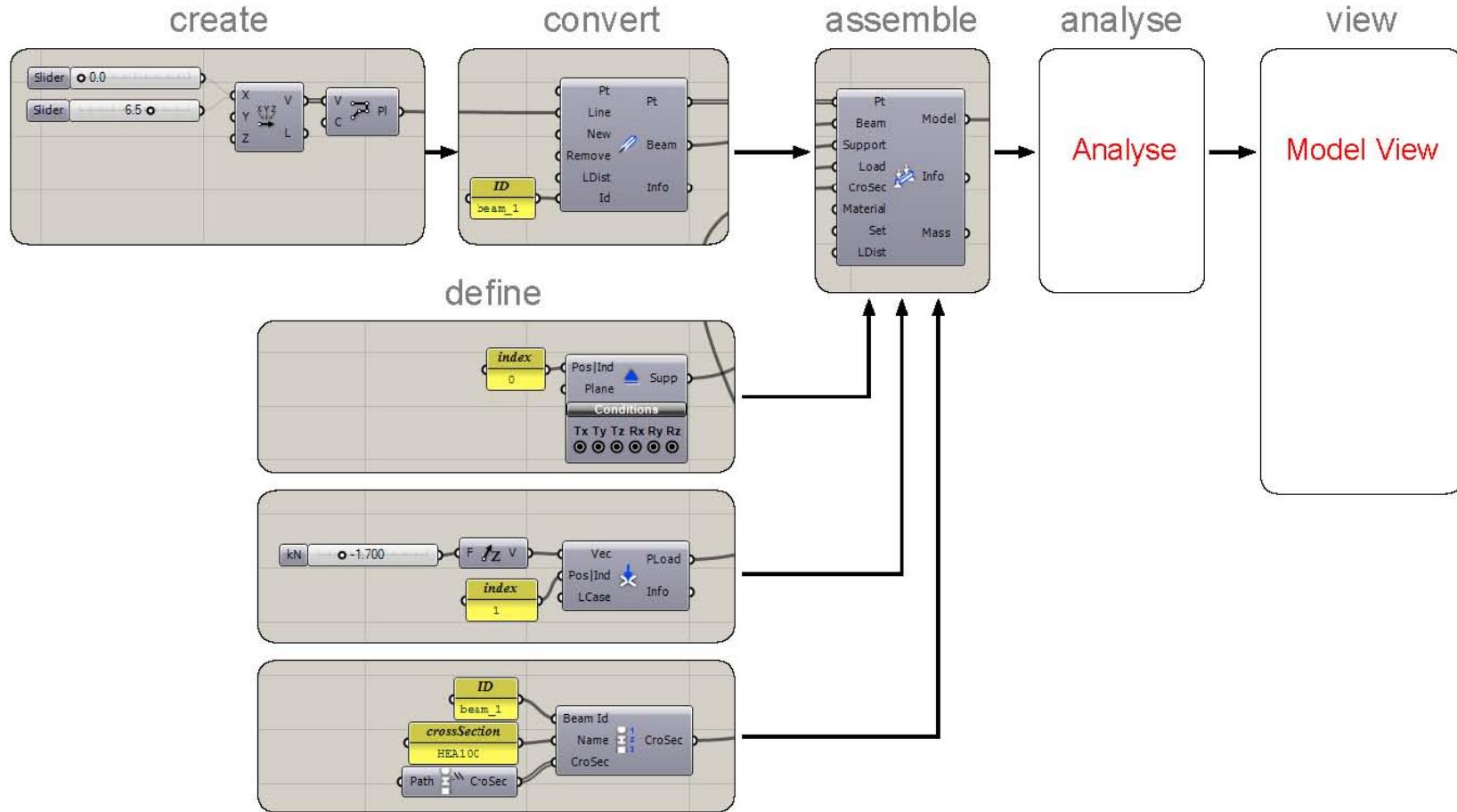


define loads



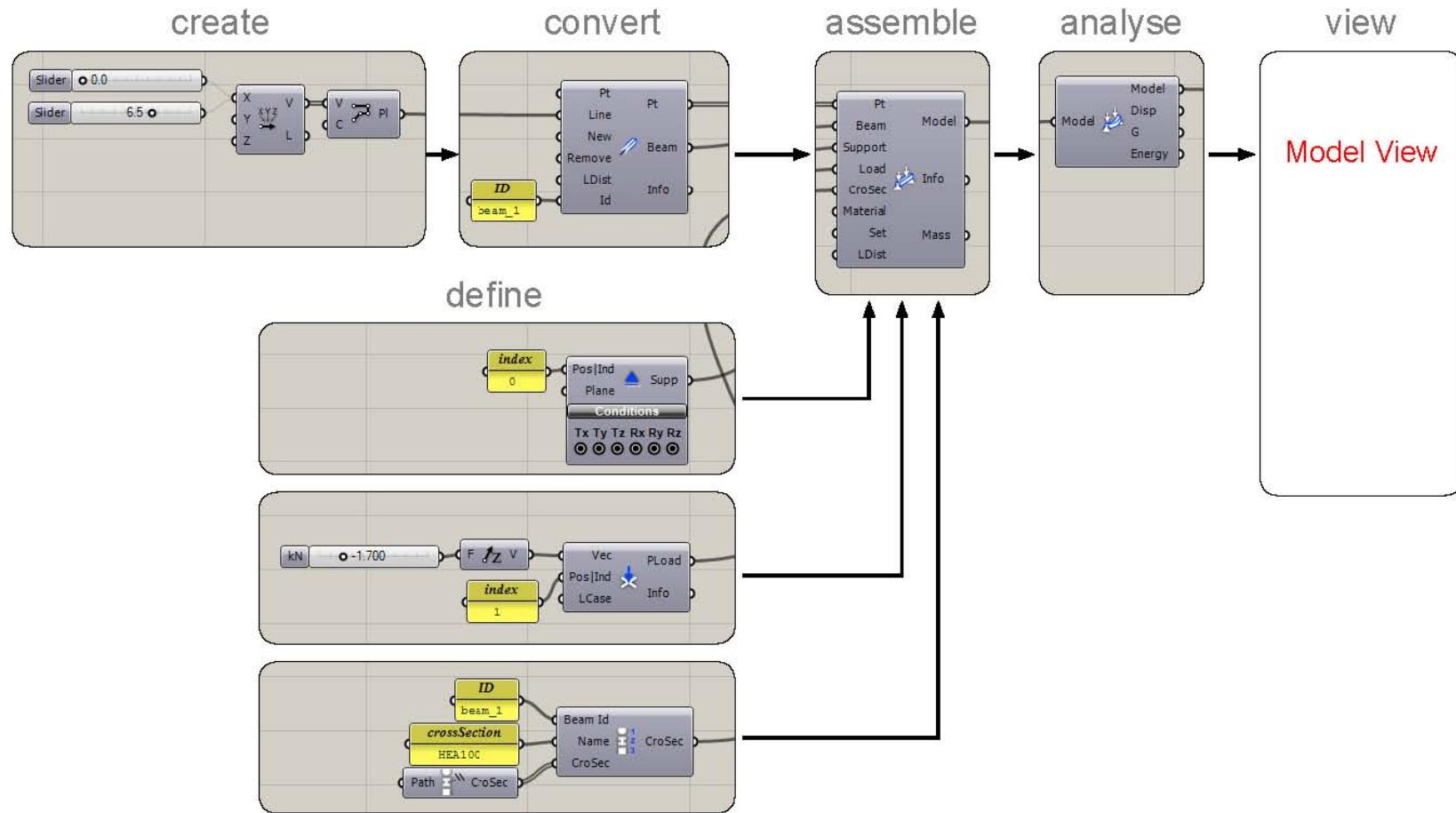
Karamba
3D

define crossSections



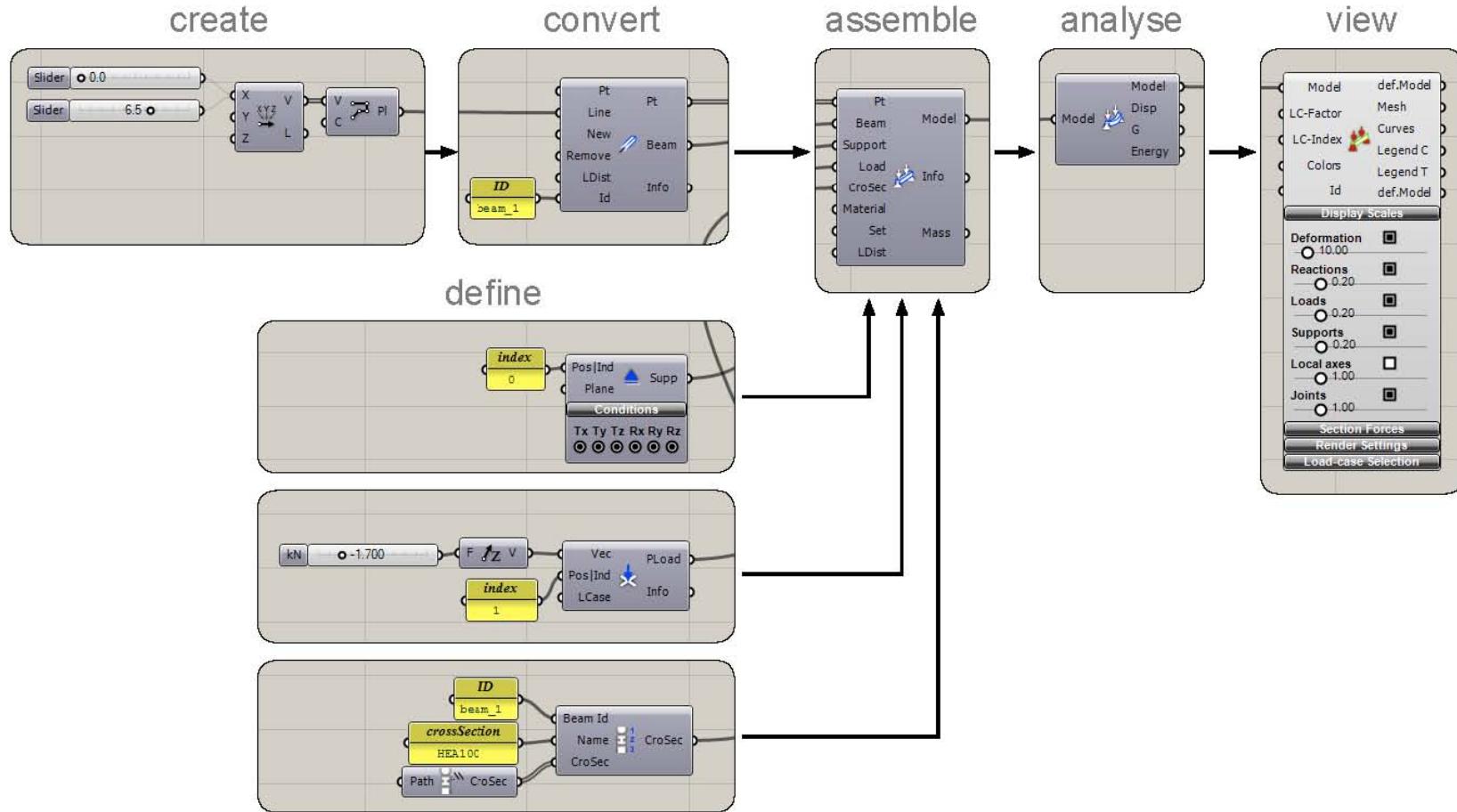
Karamba

analyse structural model



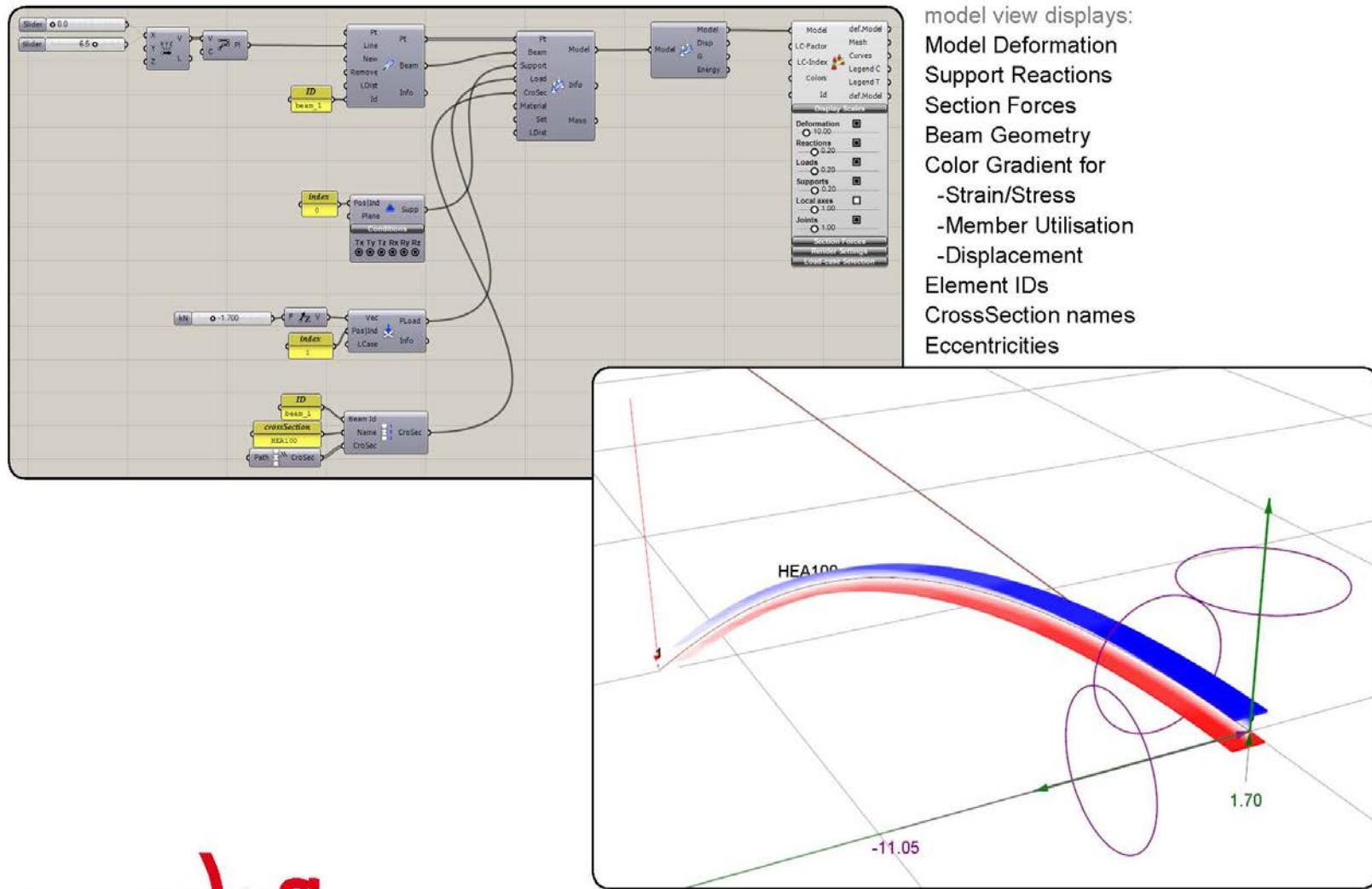
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view result



Karamba

visual output in realtime



Karamba

How to judge a structure:

How to set up and judge a structure:

Dead Load:

The value of gamma is expected to be in **kilo Newton per cubic meter [kN=m³]**. This is a force per unit of volume. Due to Earth's gravitational acceleration (**a = g = 9.81 [kg m=s²]**) and according to Newton's law ($f = ma$) a mass m of one kilogram acts downwards with a force of $f = 9.81\text{N}$. For calculating deflections of structures the assumption of $f = 10\text{N}$ is accurate enough.

Karamba expects all force-definitions to be in kilo Newton (kN). On earth the mass of 100kg corresponds to a weight force of roughly 1kN. The exact number would be 0.981kN but 1kN is normally accurate enough.

1KN = 100 Kg

How to judge a structure:

How to set up and judge a structure:

Rules of Thumb:

Loads:

Loads acting along lines or on a specified area can be approximated by point-loads. All you need to do is estimate the area or length of influence for each node and multiply it with the given load value. The Mesh-Load- component automates this task for surface loads.

When using the Analysis-component for assessing the structural behaviour be aware of two preconditions: First deflections are small as compared to the size of the structure. Second materials do behave in a linear elastic manner i.e a certain increase of deformation is always coupled to the same increase of load.

Real materials behave differently: they weaken at some point and break eventually. If you want to calculate structures with large deflections you have to increase the load in several steps and update the deflected geometry. This can be done with the Large Deformation Analysis-component.

How to judge a structure:

How to set up and judge a structure:

Cross-section optimisation:

In order to get meaningful cross section dimensions the deflection of the structure has to be minimized.

Deflection:

The **maximum deflection** of a building should be such that people using it do not start to feel uneasy. As a rough rule of thumb try to limit it to **L=300**. If your structure is more like a cantilever **L=150** will do.

This can always be achieved by increasing the size of the cross-section. If deflection is dominated by bending it is much **more efficient to increase the height of the cross-section than its area**.

How to judge a structure:

How to set up and judge a structure:

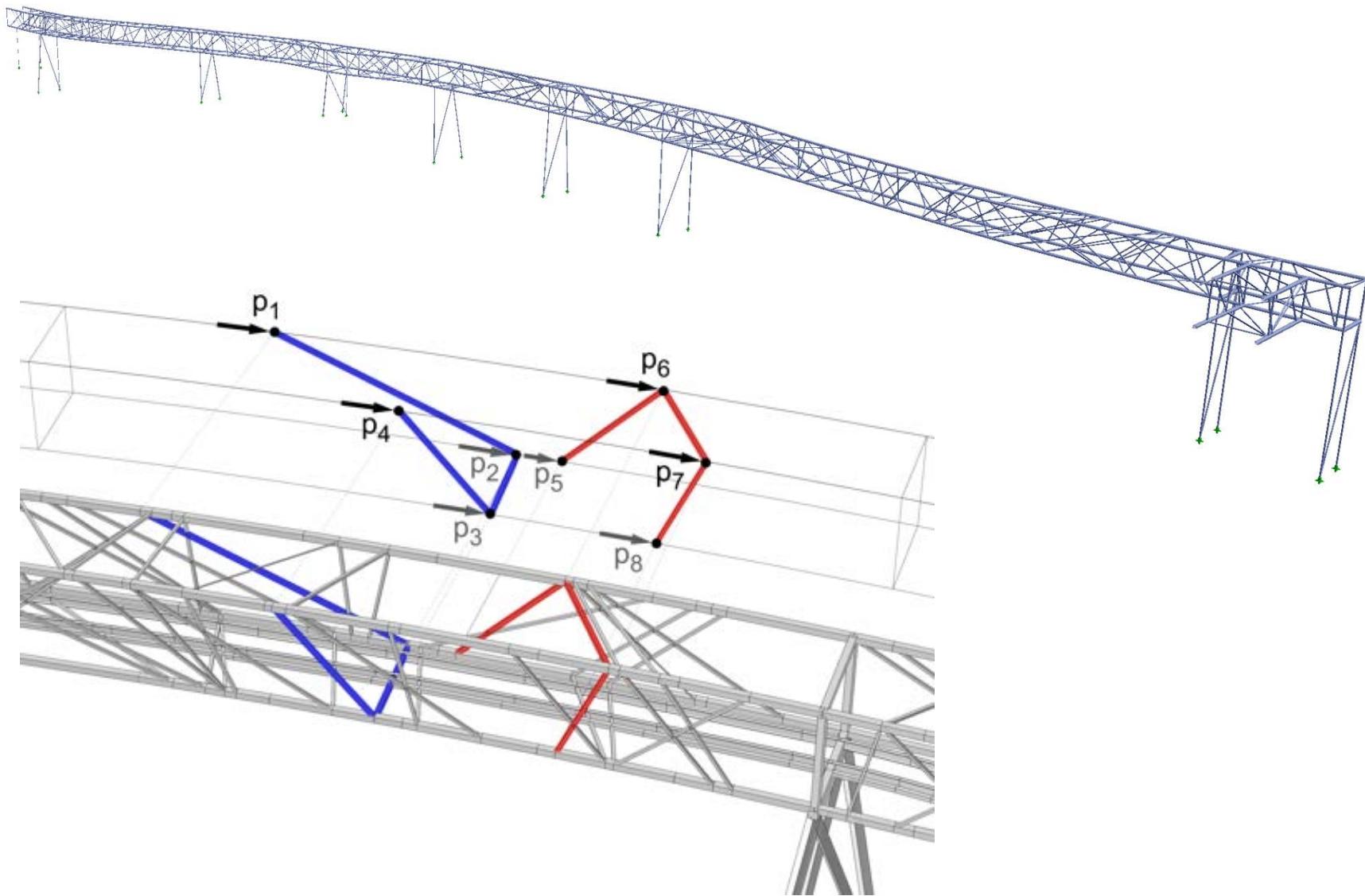
Make sure to include all significant loads (dead weight, live load, wind...) when checking the allowable maximum deflection.

For a first design however it will be sufficient to take a multiple of the **dead weight (e.g. with a factor of 1:5)**. This can be done in Karamba by giving the vector of gravity a length of 1:5.

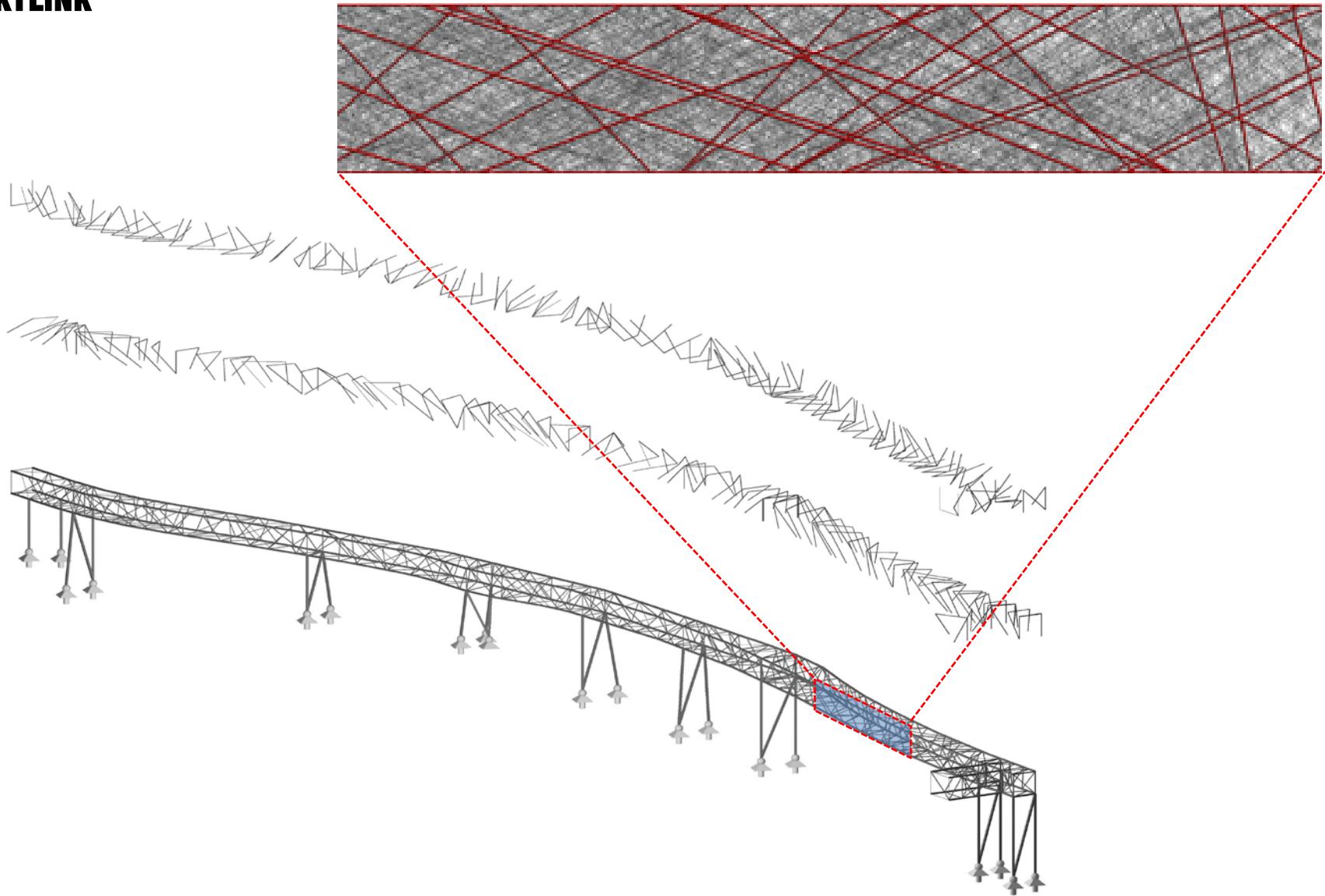
So limiting deflection automatically leads to a safe design.

As a rule of thumb limit the **slenderness** which is approximately the ratio of free span to diameter of compressed elements to **1=100!**.

SKYLINK - Example



SKYLINK



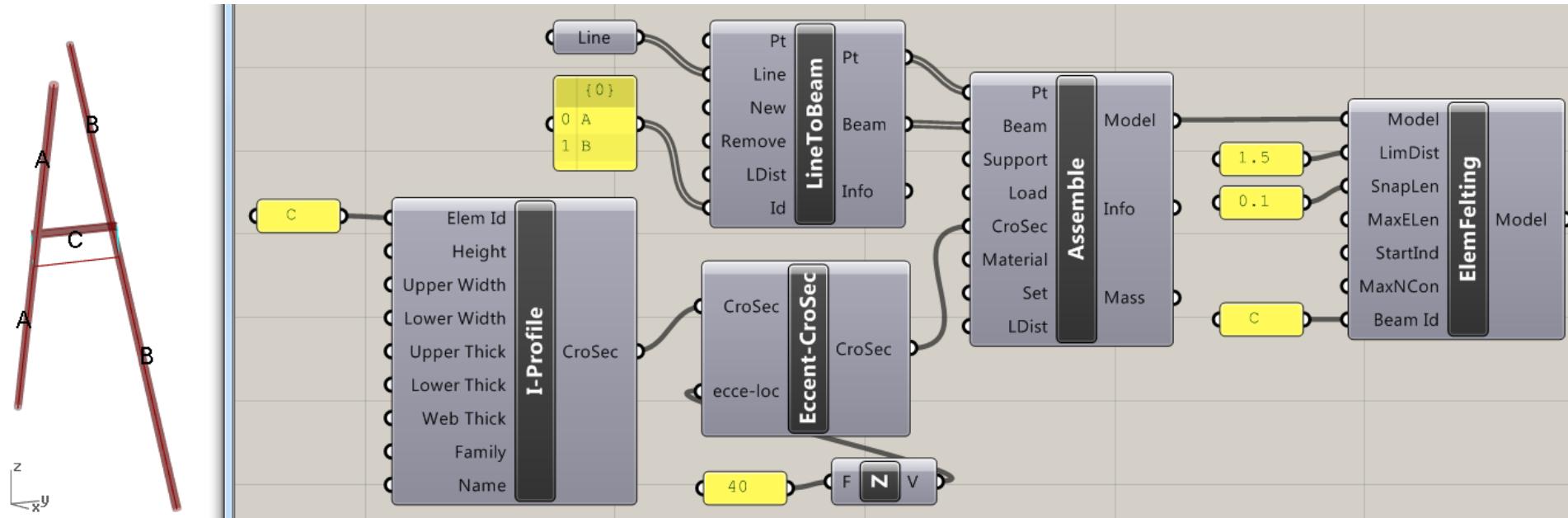


SKYLINK / FRANKFURT AIRPORT



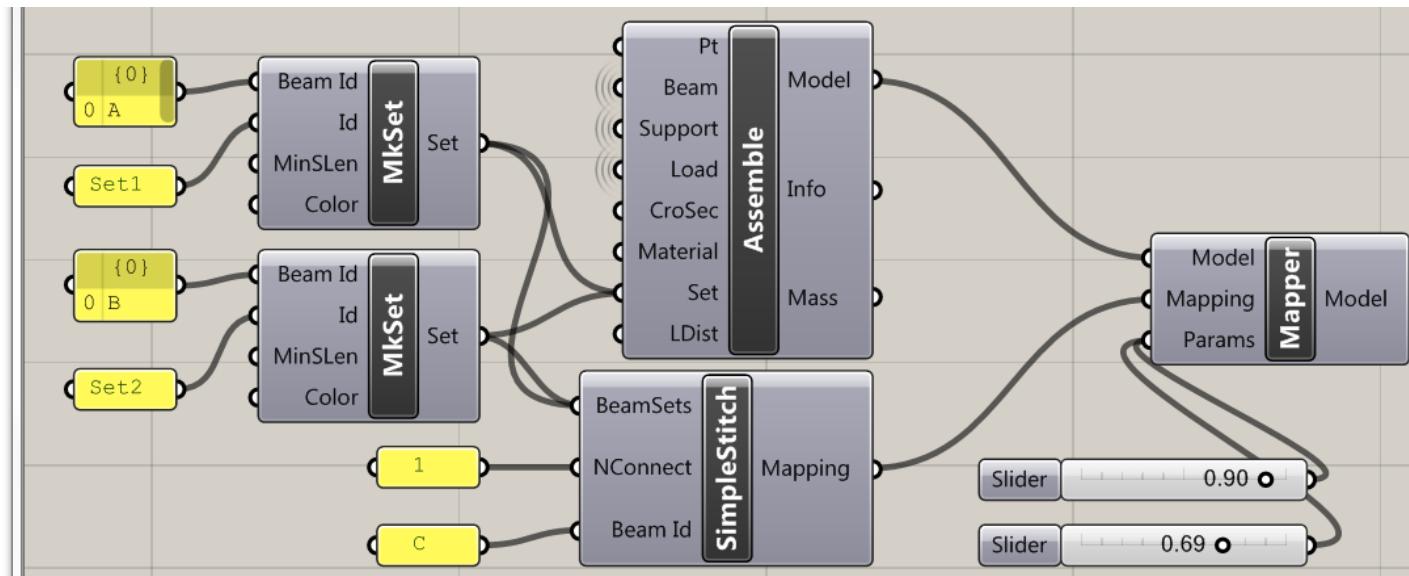
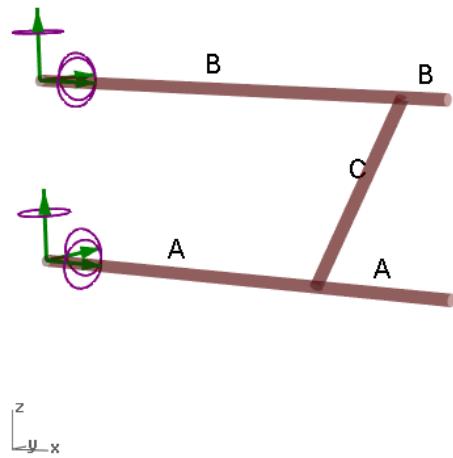
SKYLINK / FRANKFURT AIRPORT

Element Felting



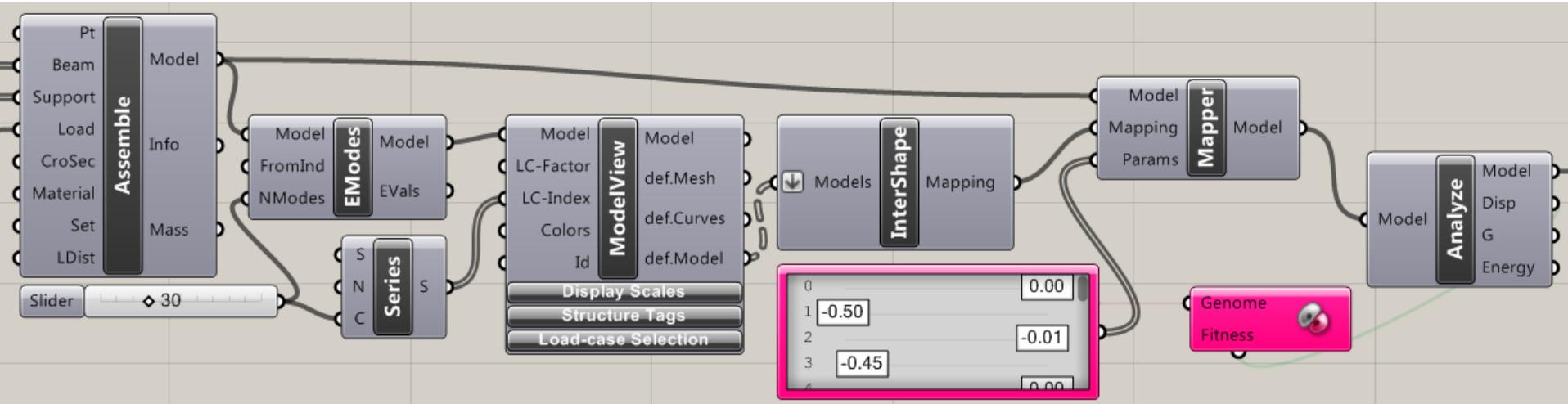
The elements "A" and "B" of the original model are connected resulting in the additional element "C".

Mapper



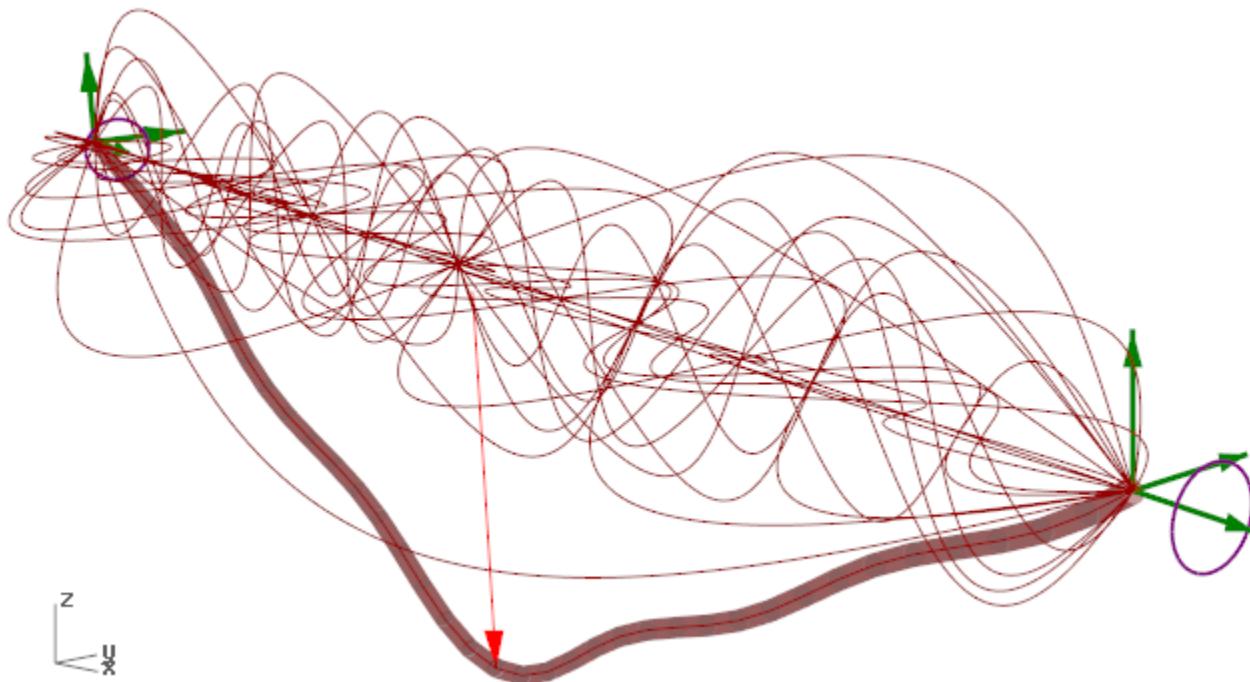
The "Mapper"-component applies mappings to a given model. In this case there is one mapping that connects two beam-sets with elements whose position is controlled by the parameters given to the mapper.

Interpolate Shape



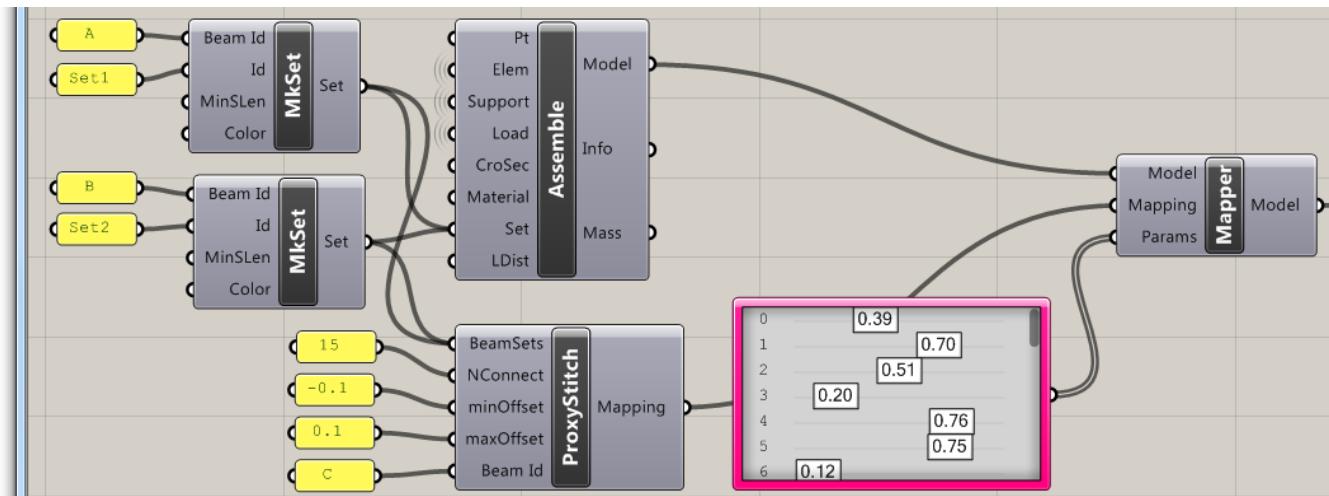
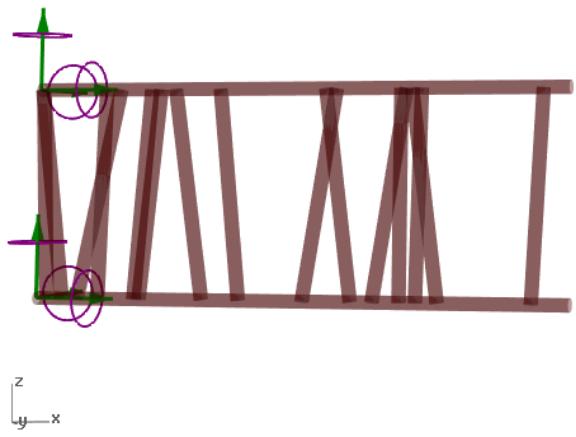
Definition for optimizing the shape of a simply supported beam under mid-span single load.

Interpolate Shape



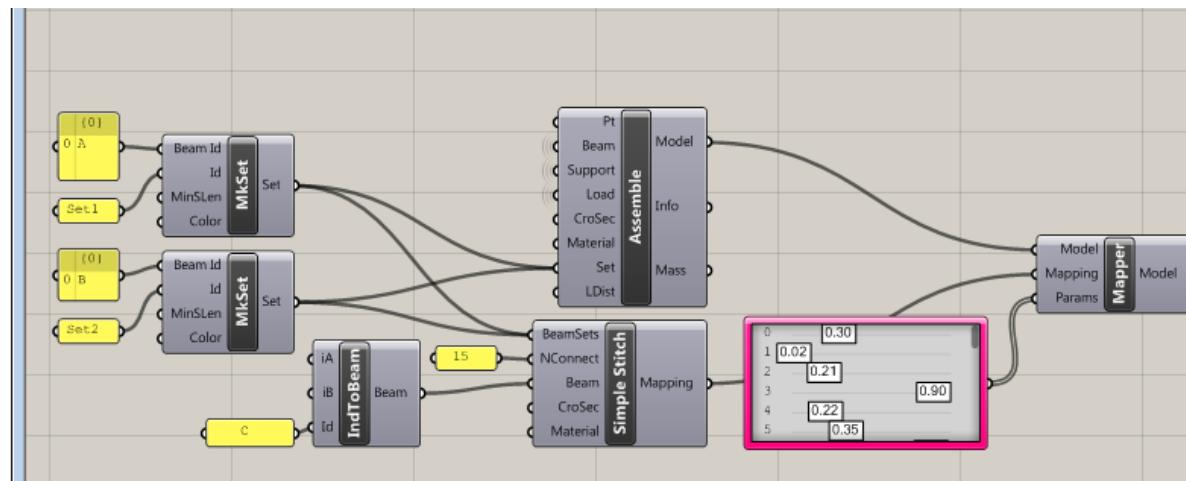
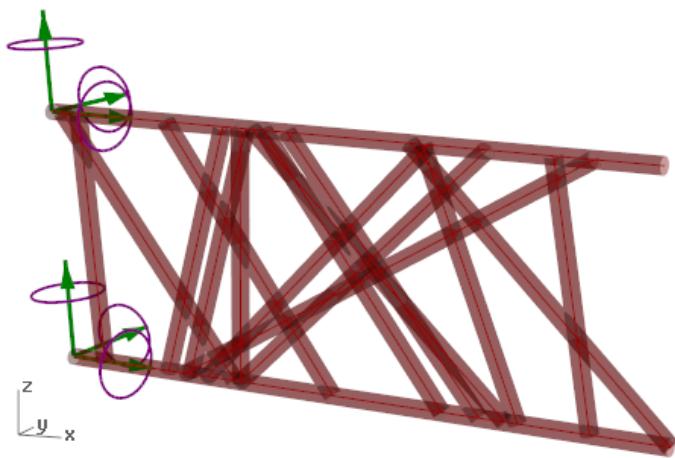
Result of shape optimization (thick red line) for a simply supported beam under mid-span single load using the first 30 Eigen-forms – the thin red lines – as axes of the design space..

Proximity Stitch



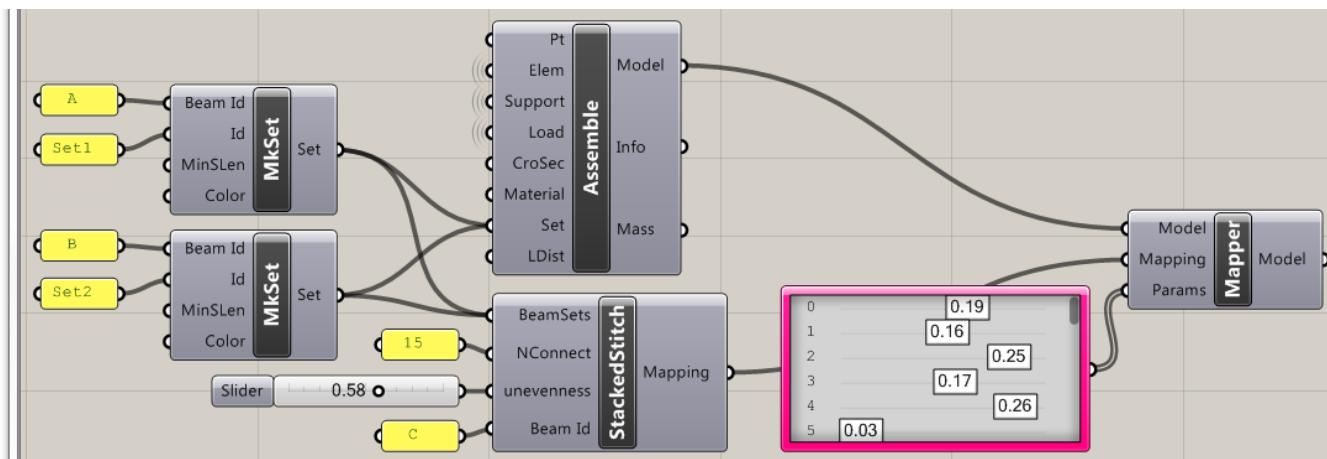
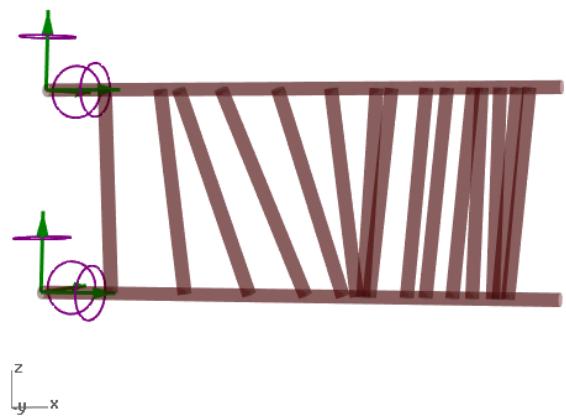
"Proximity Stitch"-mapping with the same set-up as in the Mapper function but fifteen random connections instead of two.

Simple Stitch



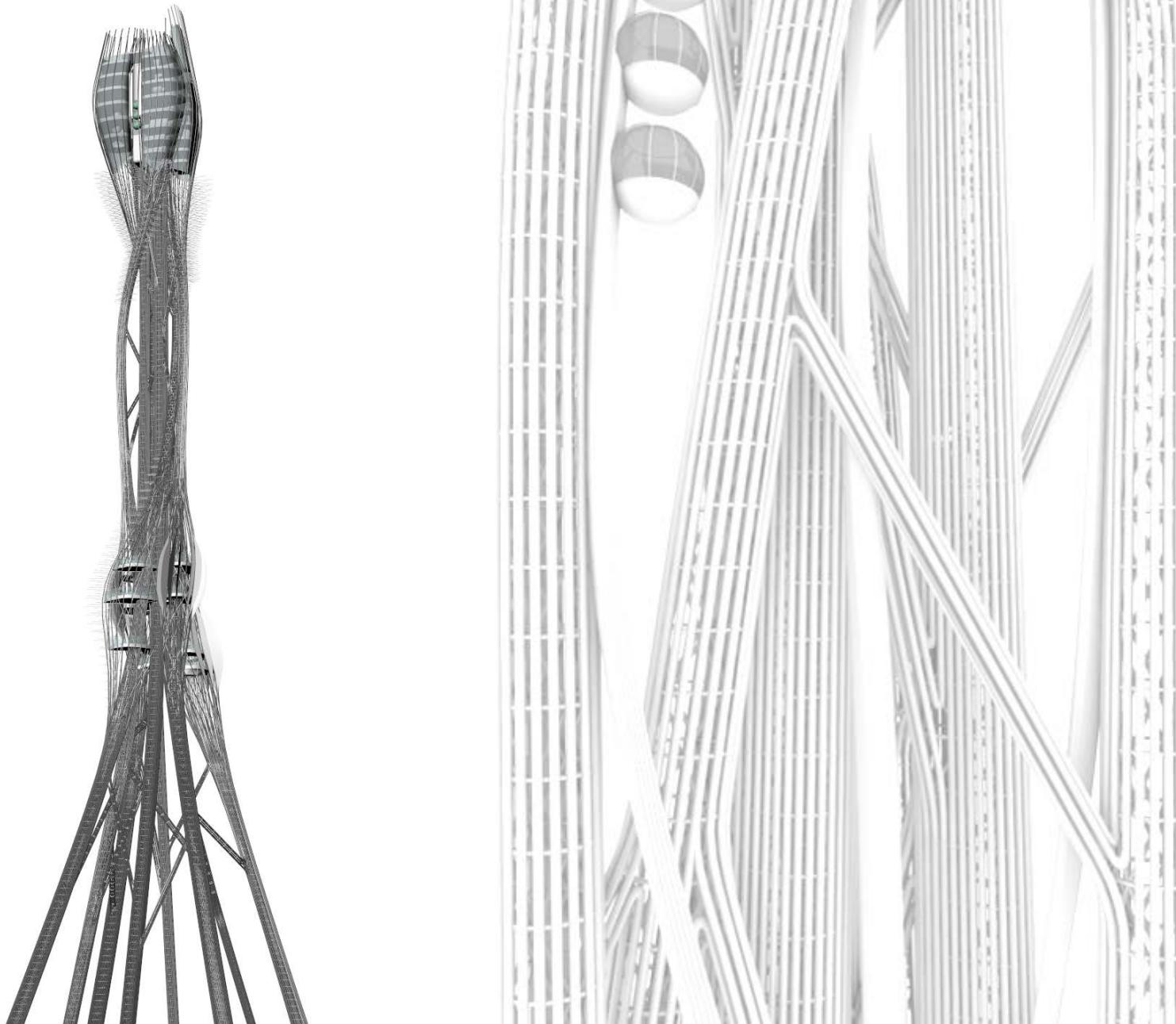
"Simple Stitch"-mapping with the same set-up as in the Mapper function but fifteen random connections instead of two.

Stacked Stitch



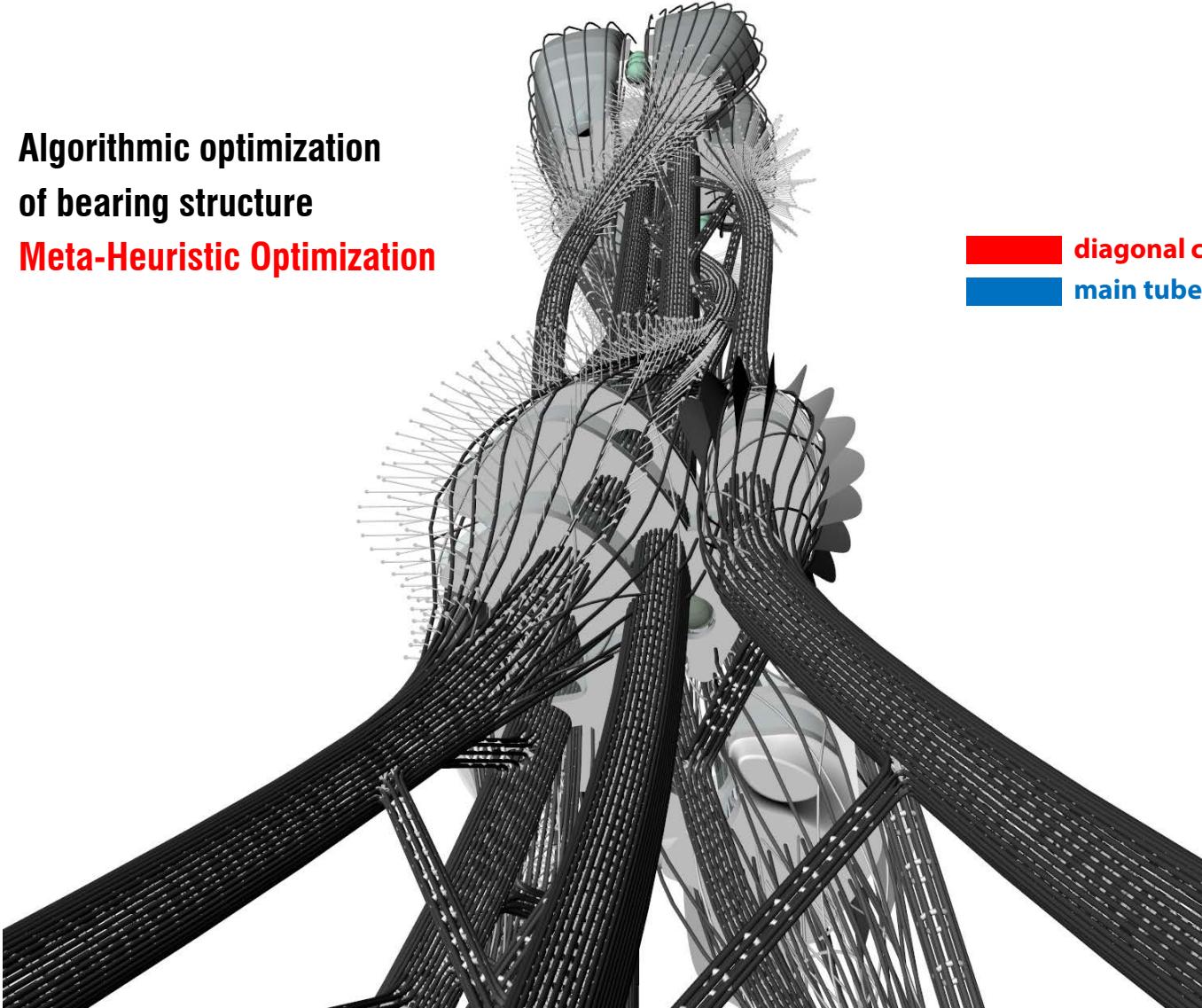
"Stacked Stitch"-mapping with the same as in the Mapper function but fifteen random connections instead of two.

Taichun Tower Taiwan

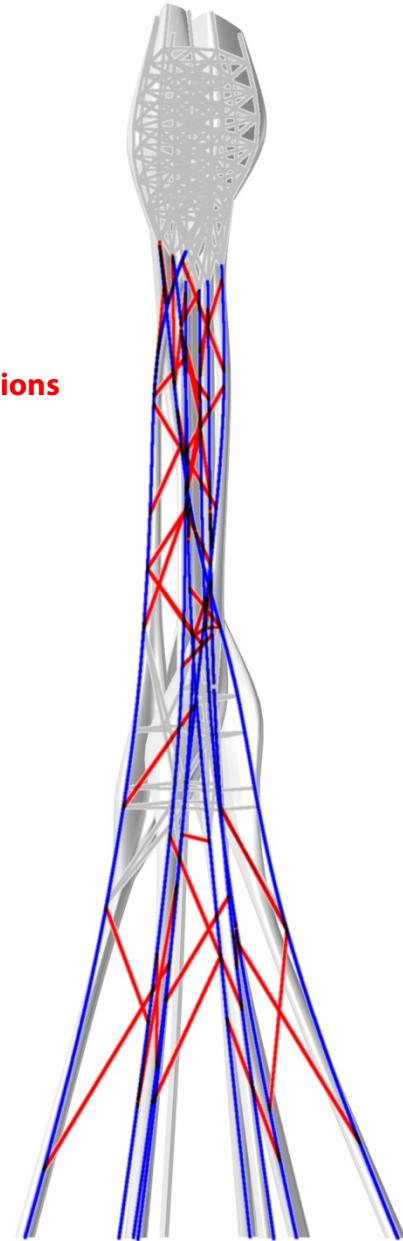


Taichun Tower Taiwan

Algorithmic optimization
of bearing structure
Meta-Heuristic Optimization

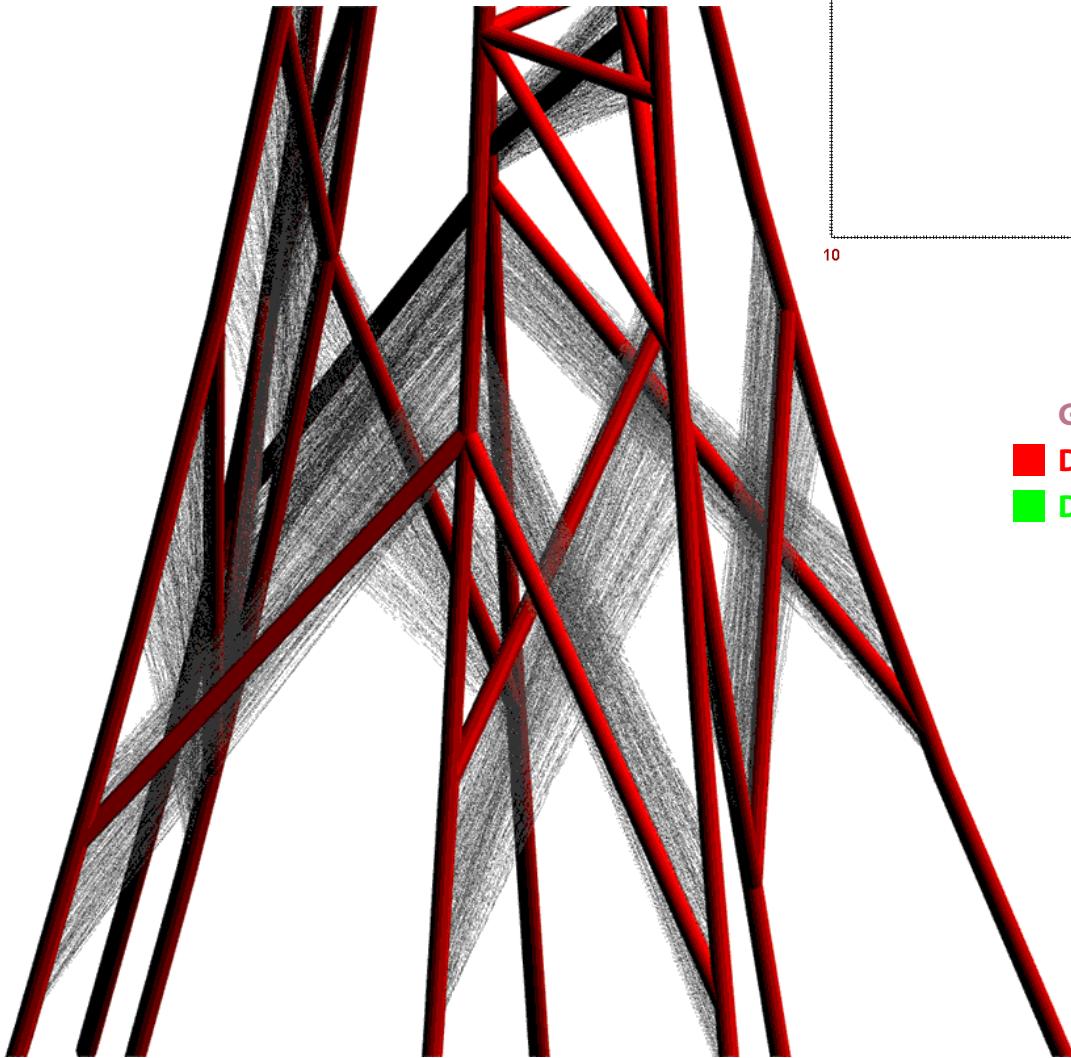


diagonal connections
main tubes



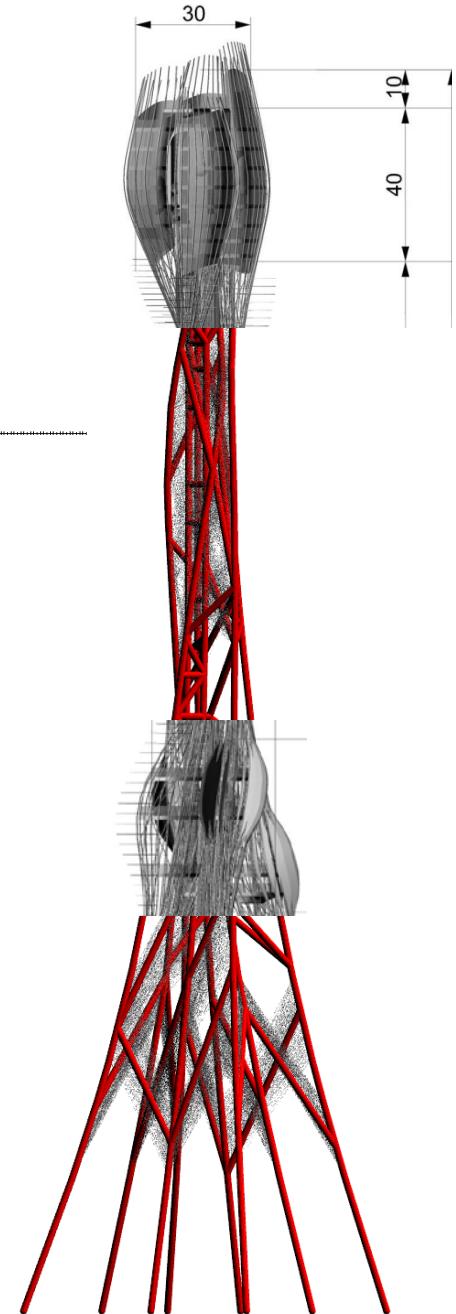
Taichun Tower Taiwan

Meta-Heuristic Optimization
Genetic Algorithm



Generation Process:

- Dead Weight
- Deflection



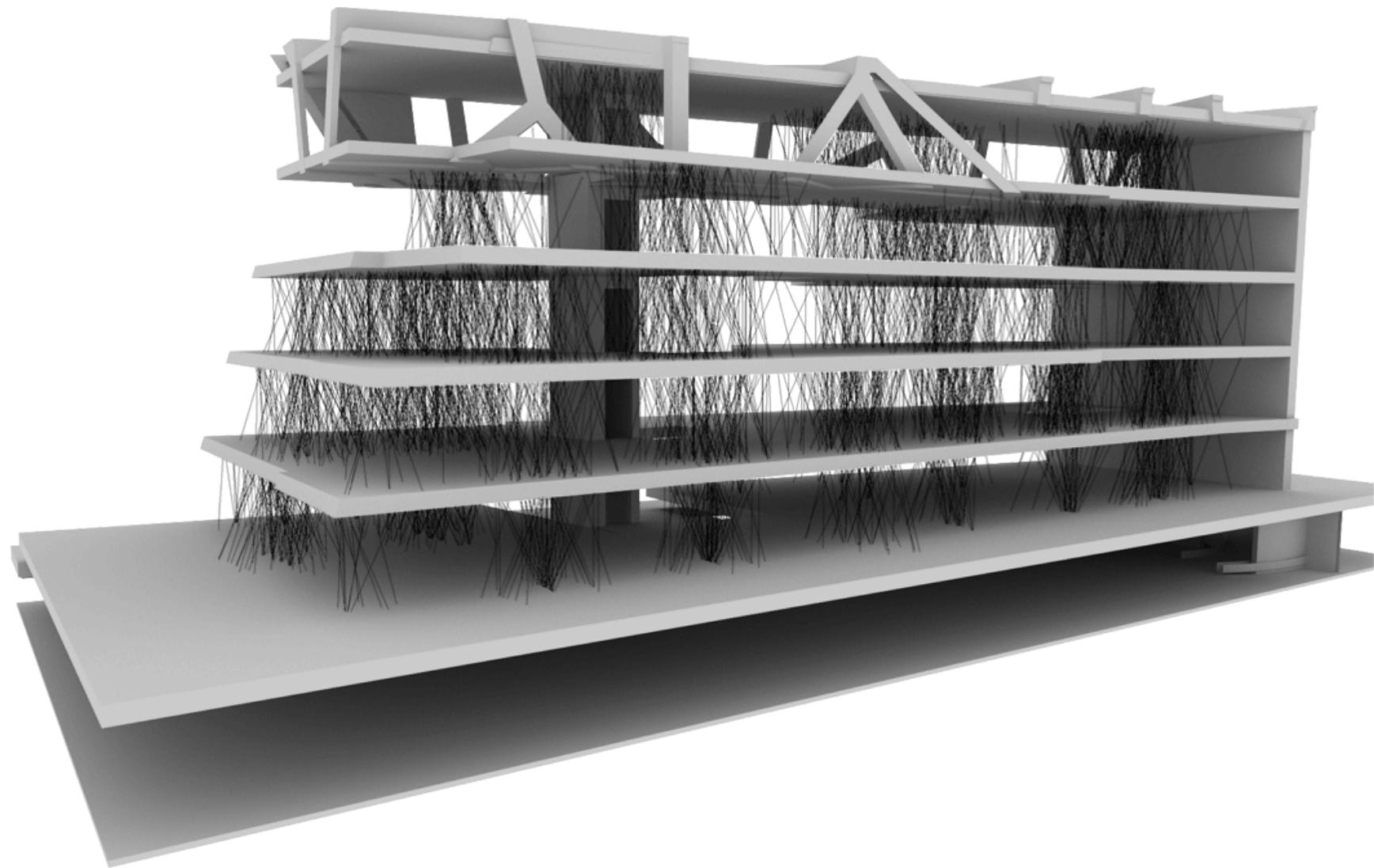
Marxer Active Energy Building - Vaduz, Liechtenstein

Dissolved organic bearing structure: Column Trees



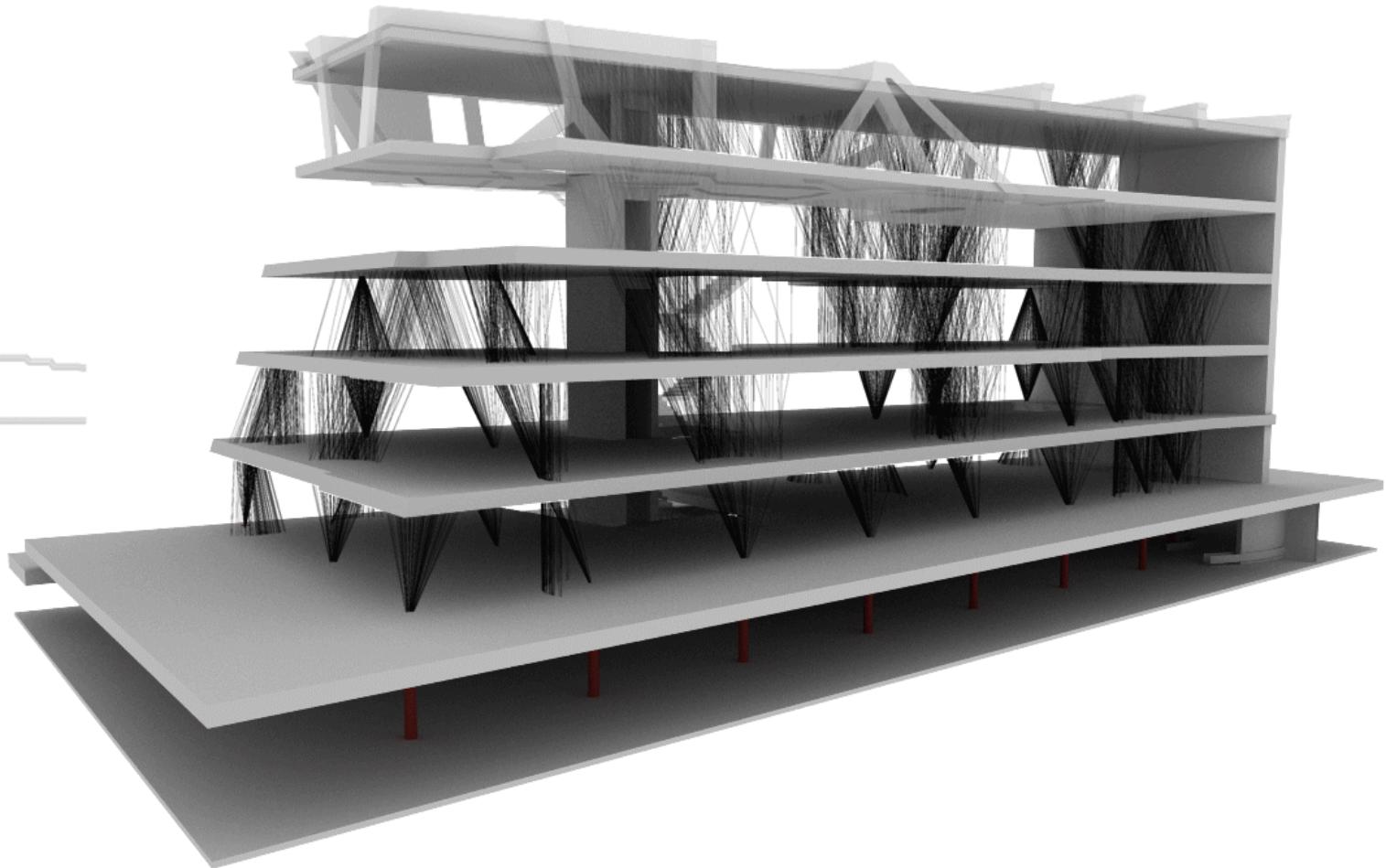
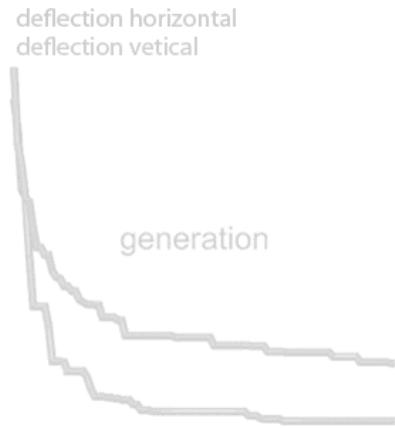
Marxer Active Energy Building - Vaduz, Liechtenstein

Step 1 column arrangement by **Force Flow Finder**

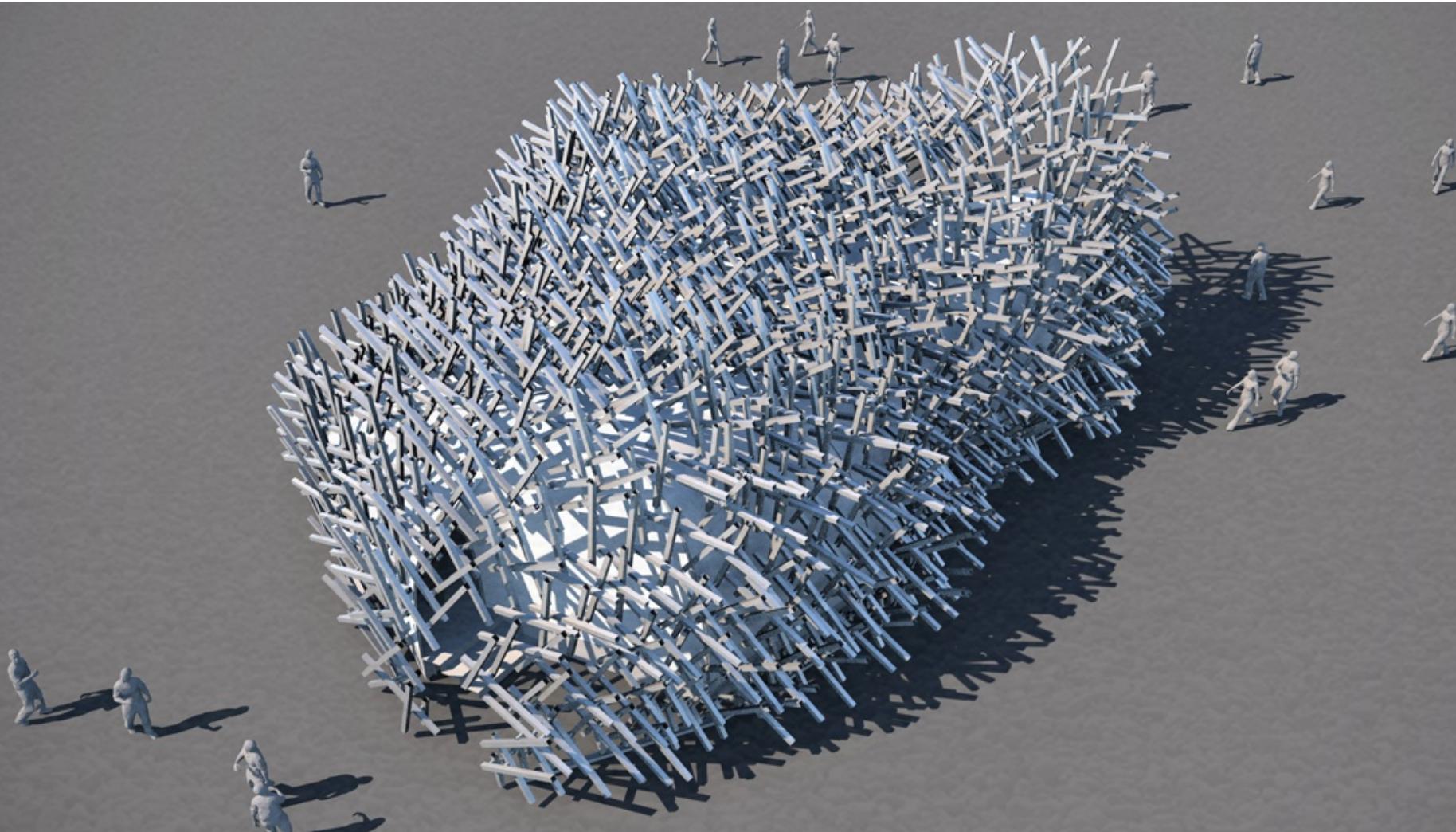


Marxer Active Energy Building - Vaduz, Liechtenstein

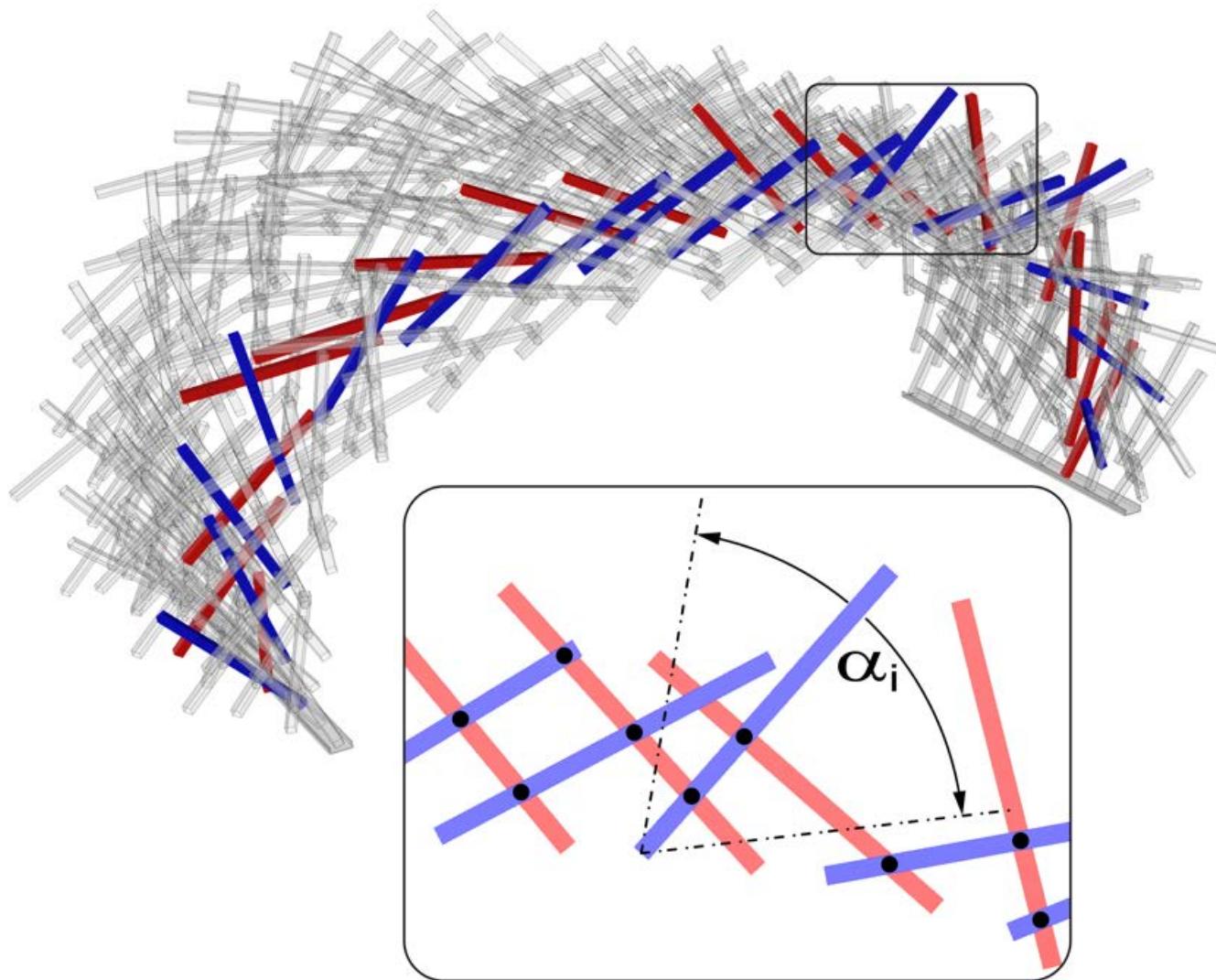
Step 2 optimization of column positions by **Meta-Heuristic Genetic Algorithm**

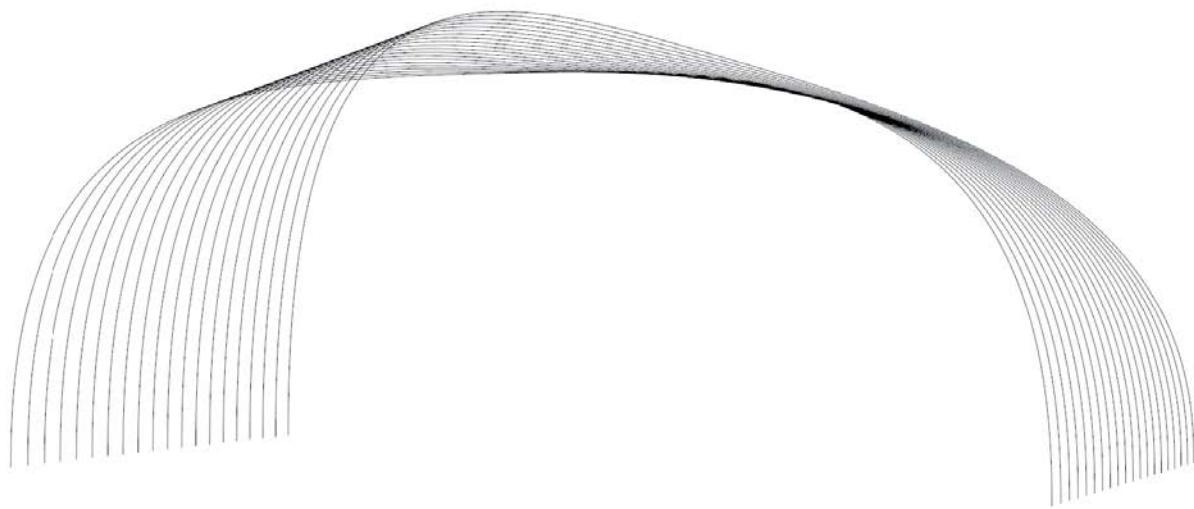


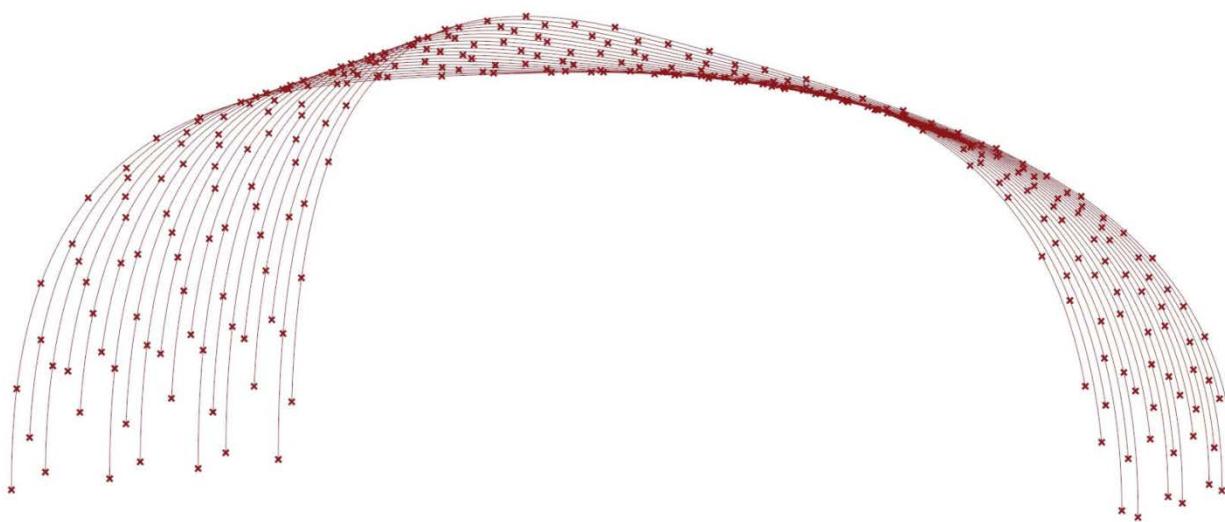
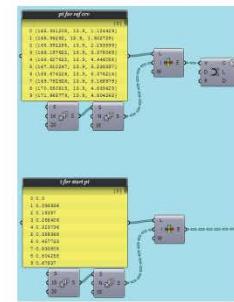
WHITE NOISE – SOMA

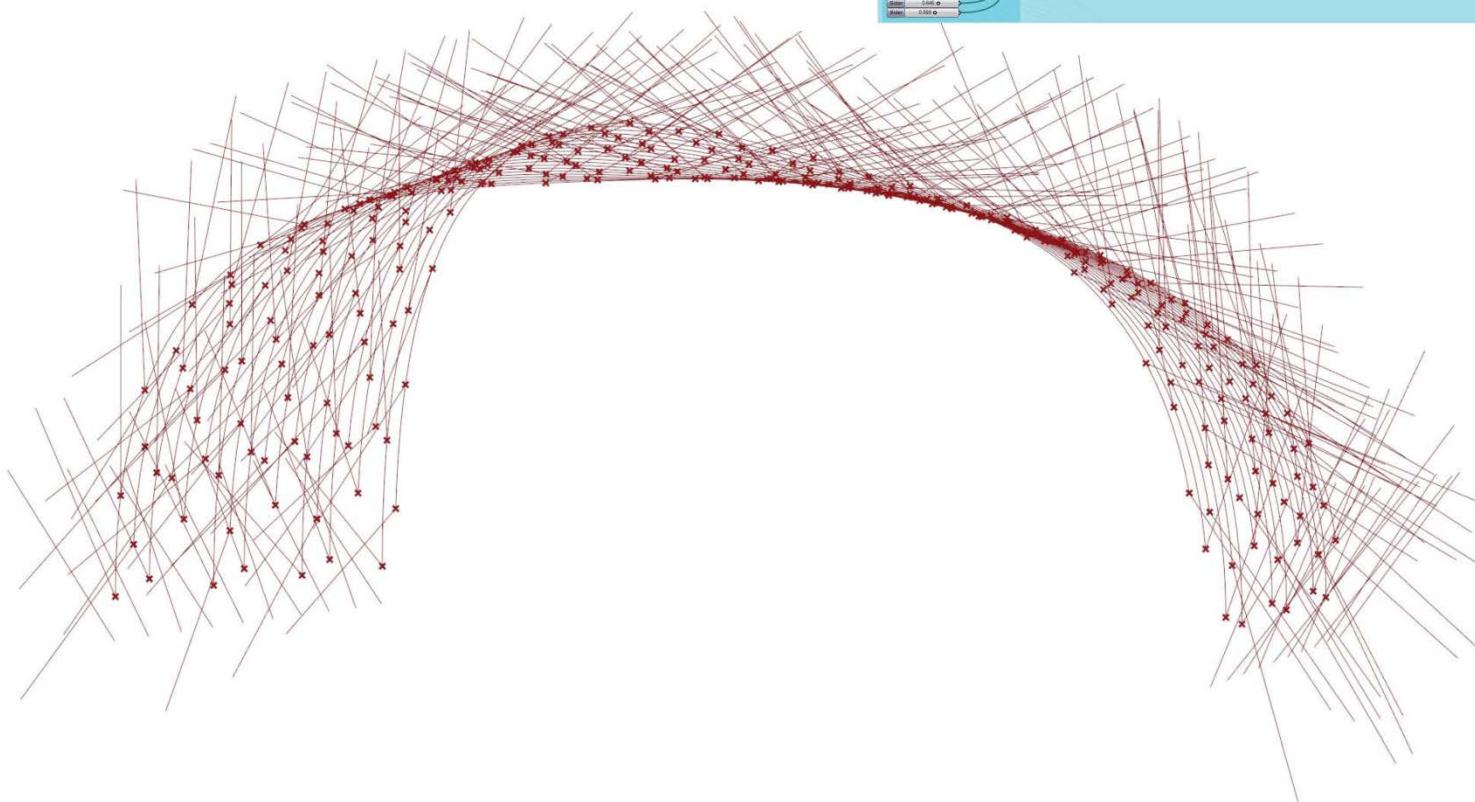
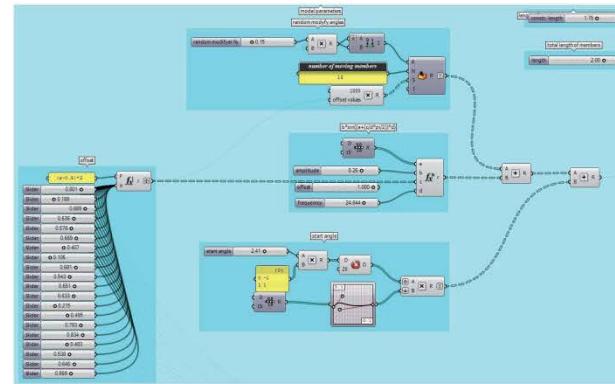


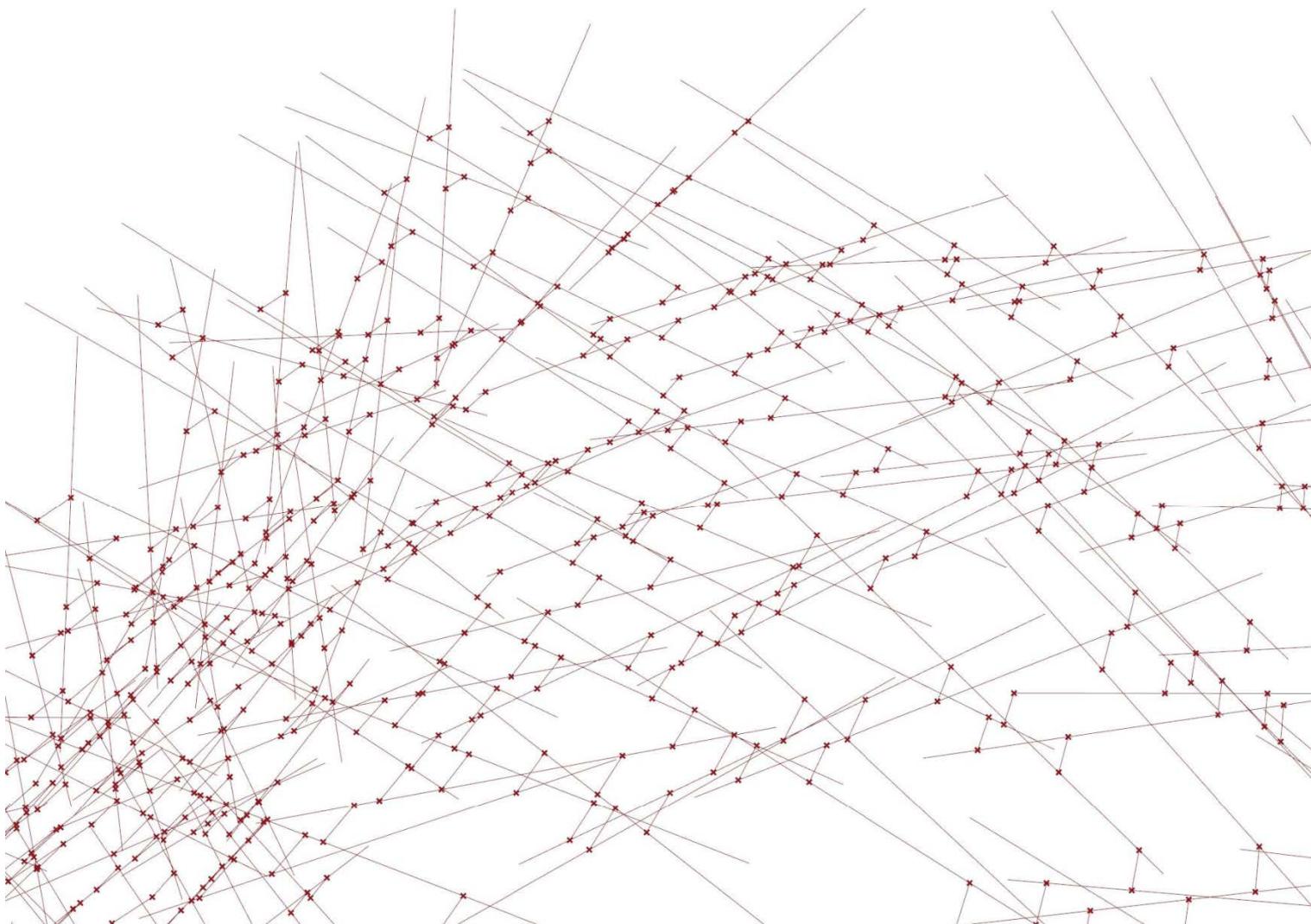
WHITE NOISE – SOMA

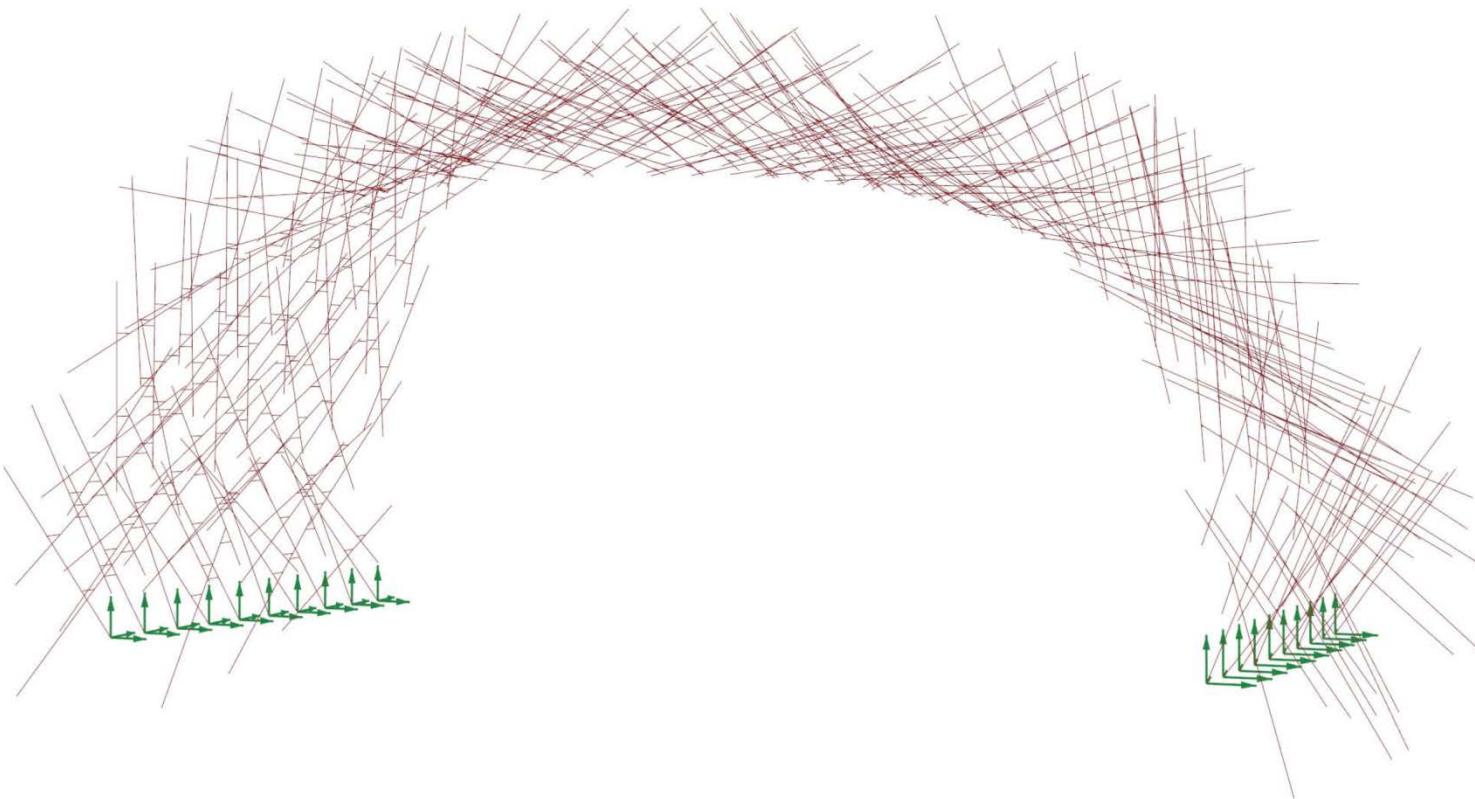
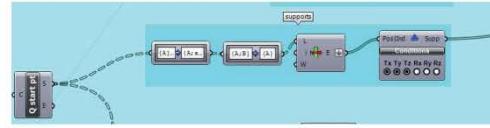


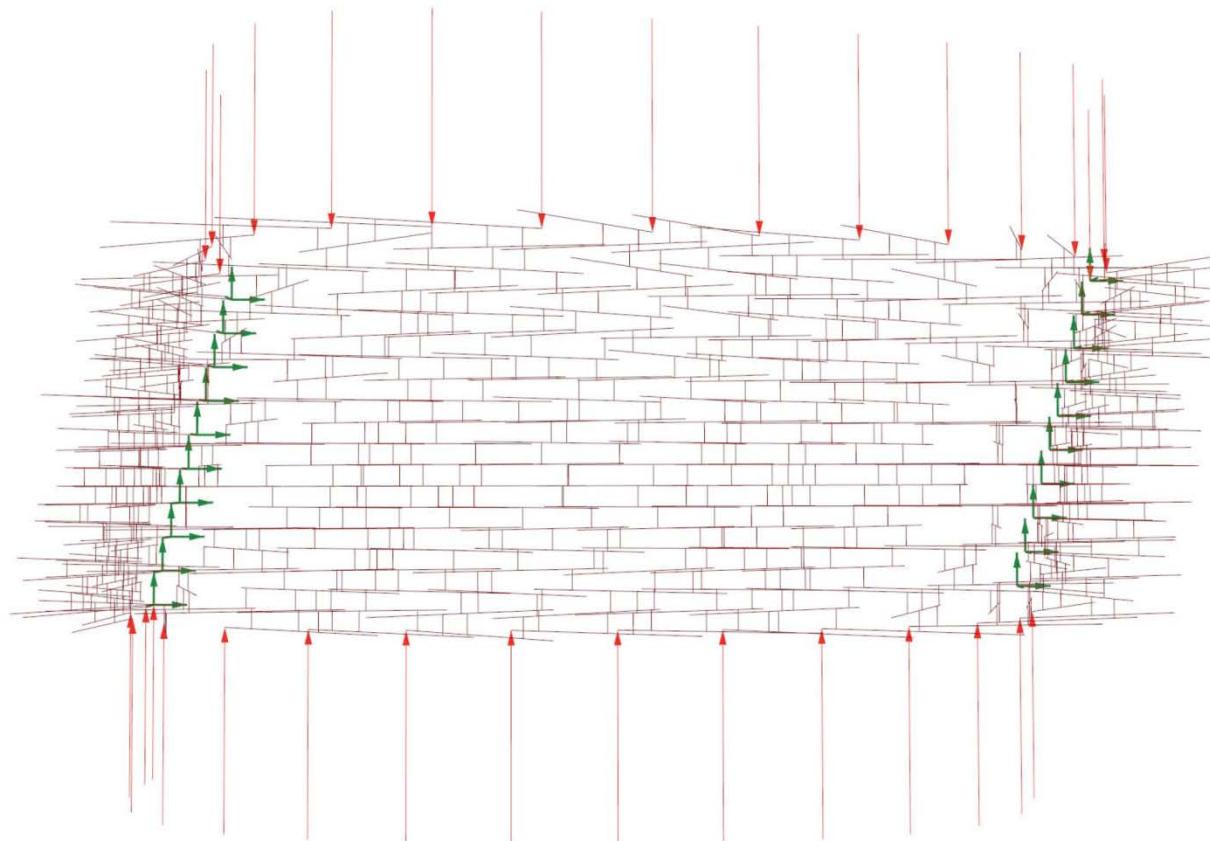
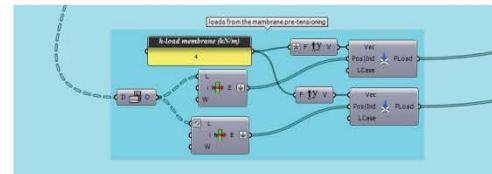


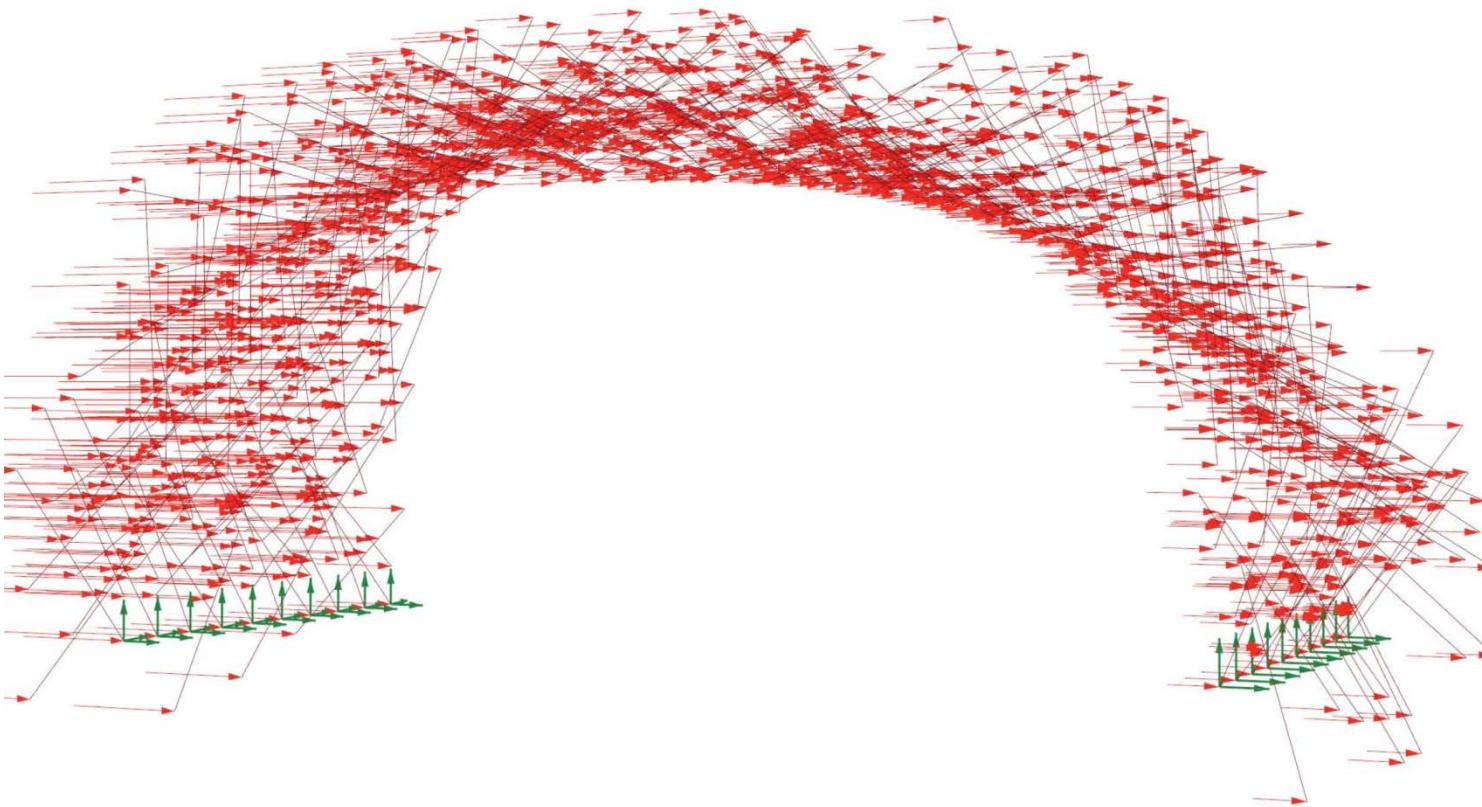
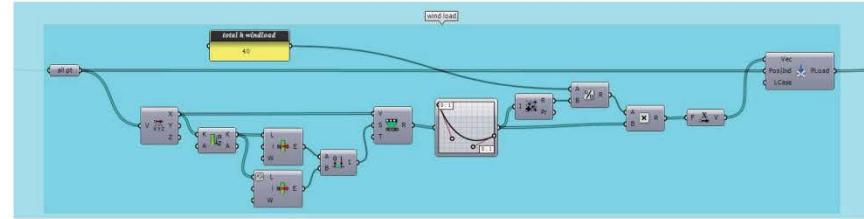






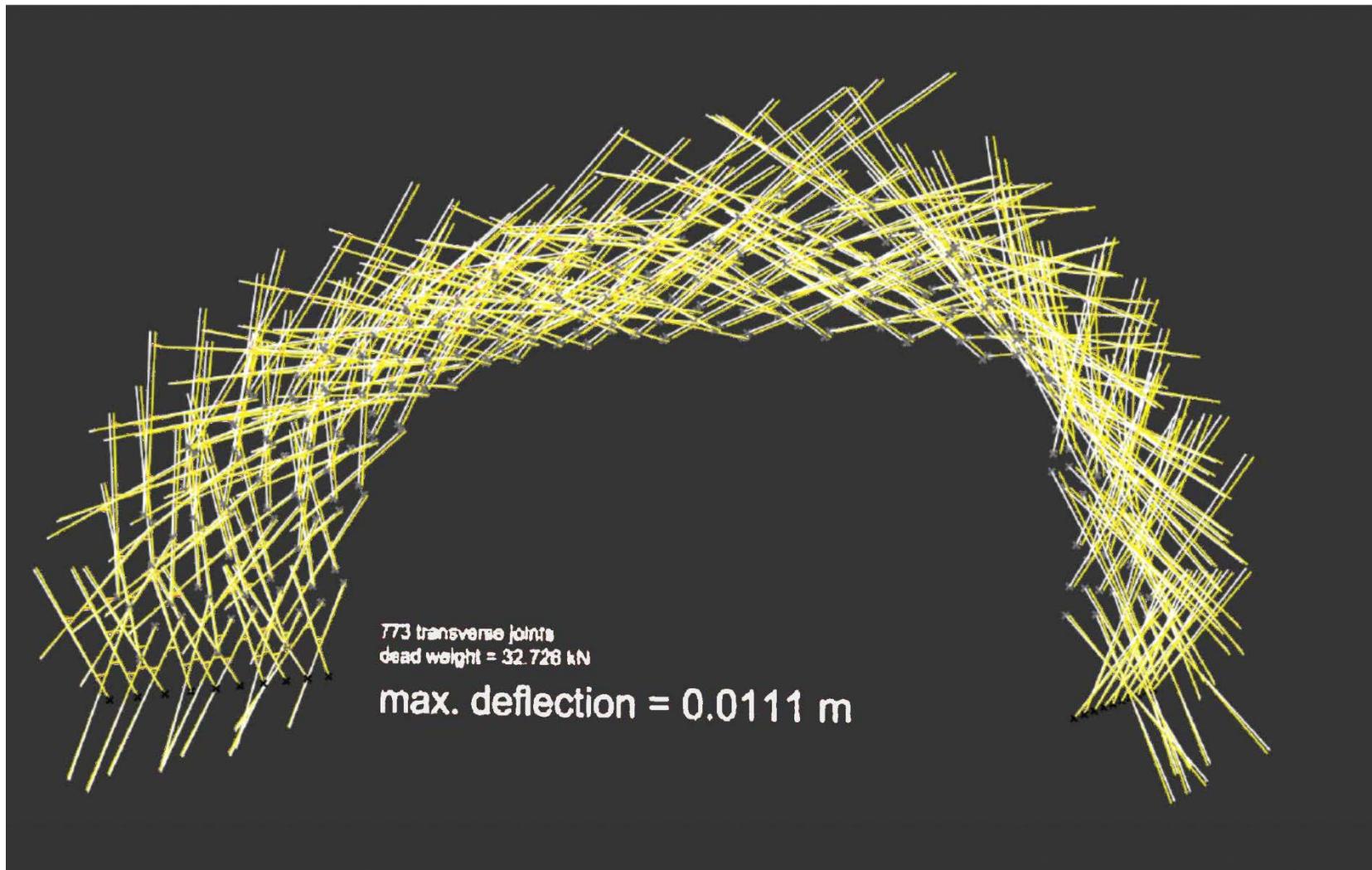


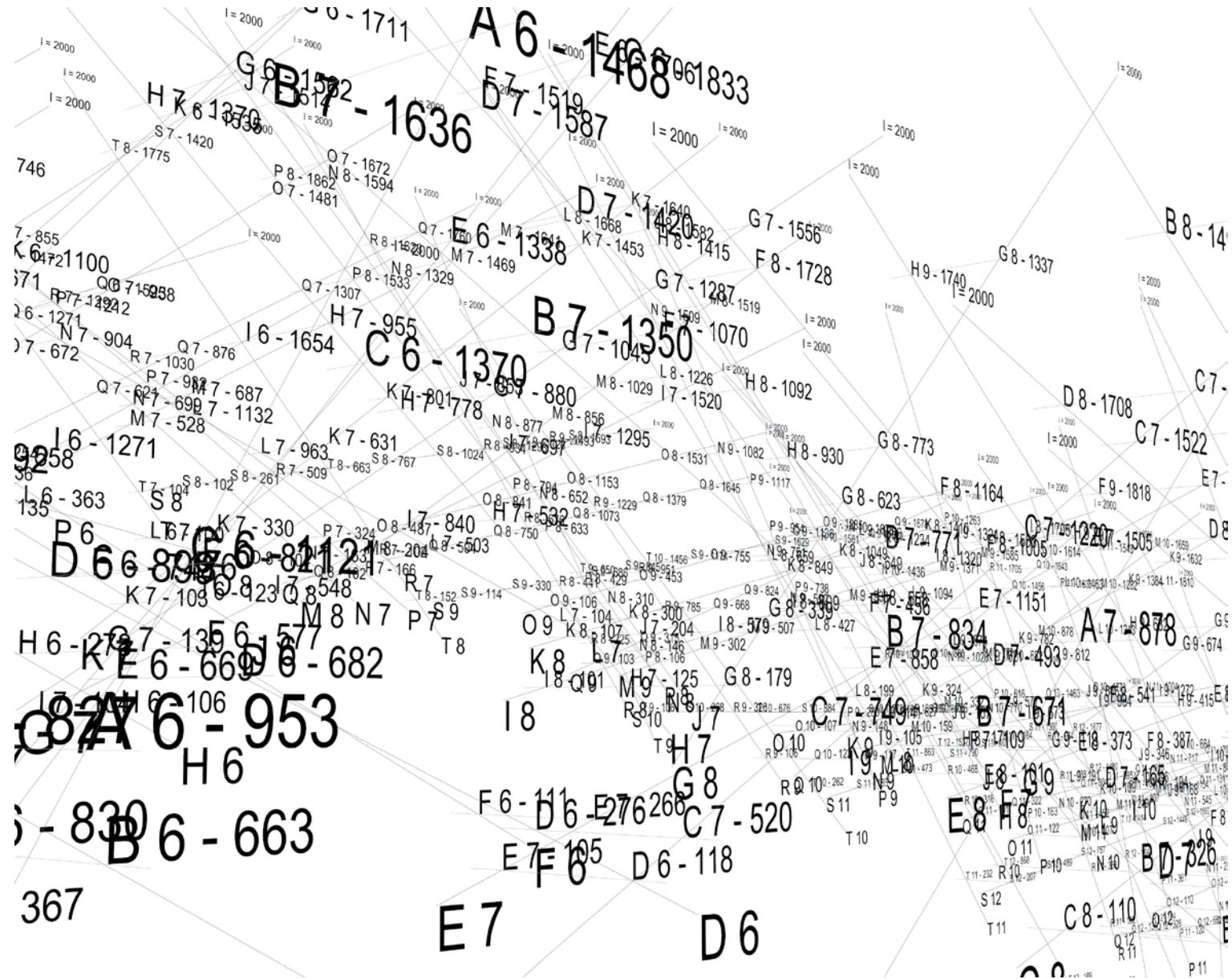


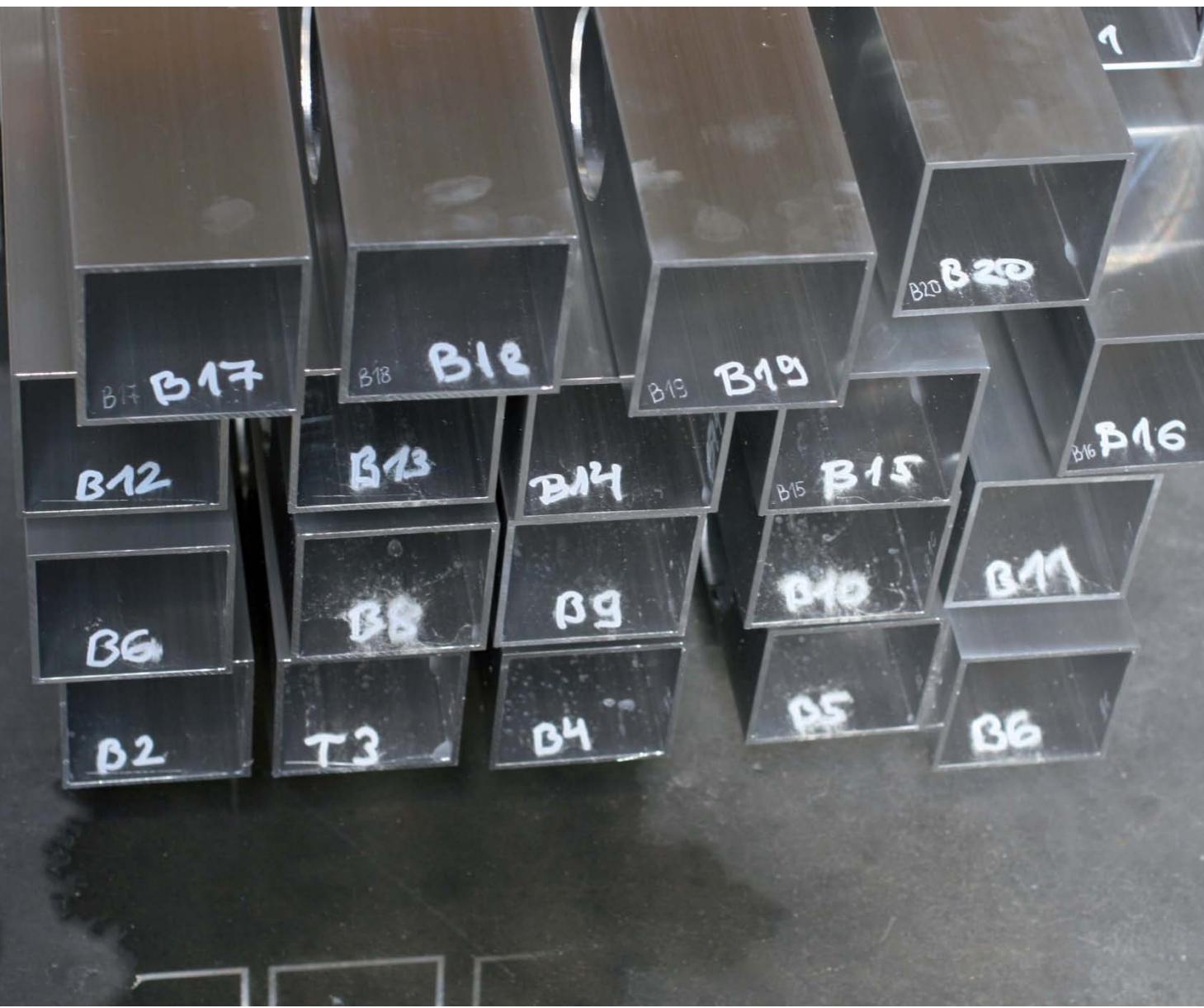


Video ,MAP_opti.mov'

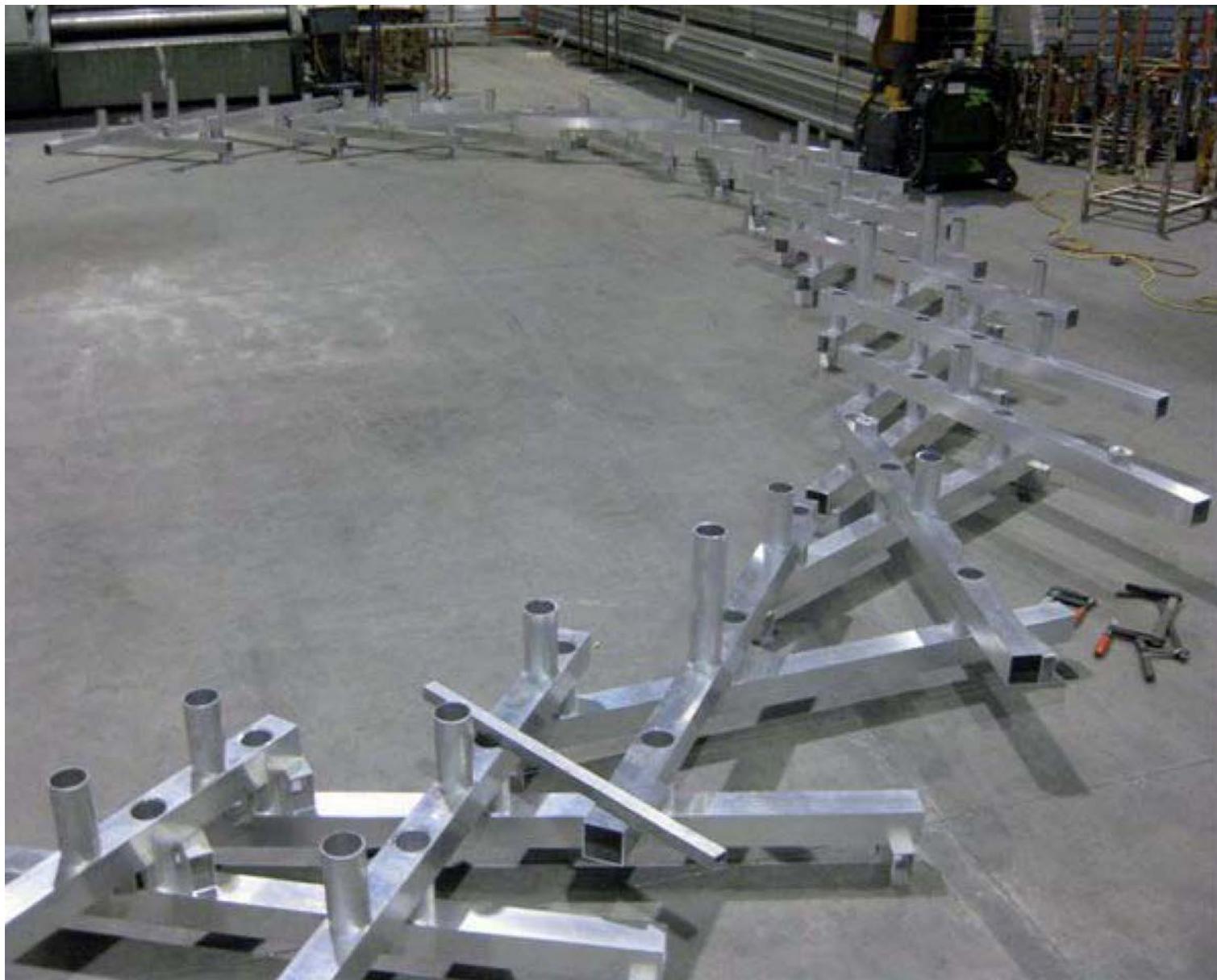
Project: Salzburg Biennale Pavillon - soma



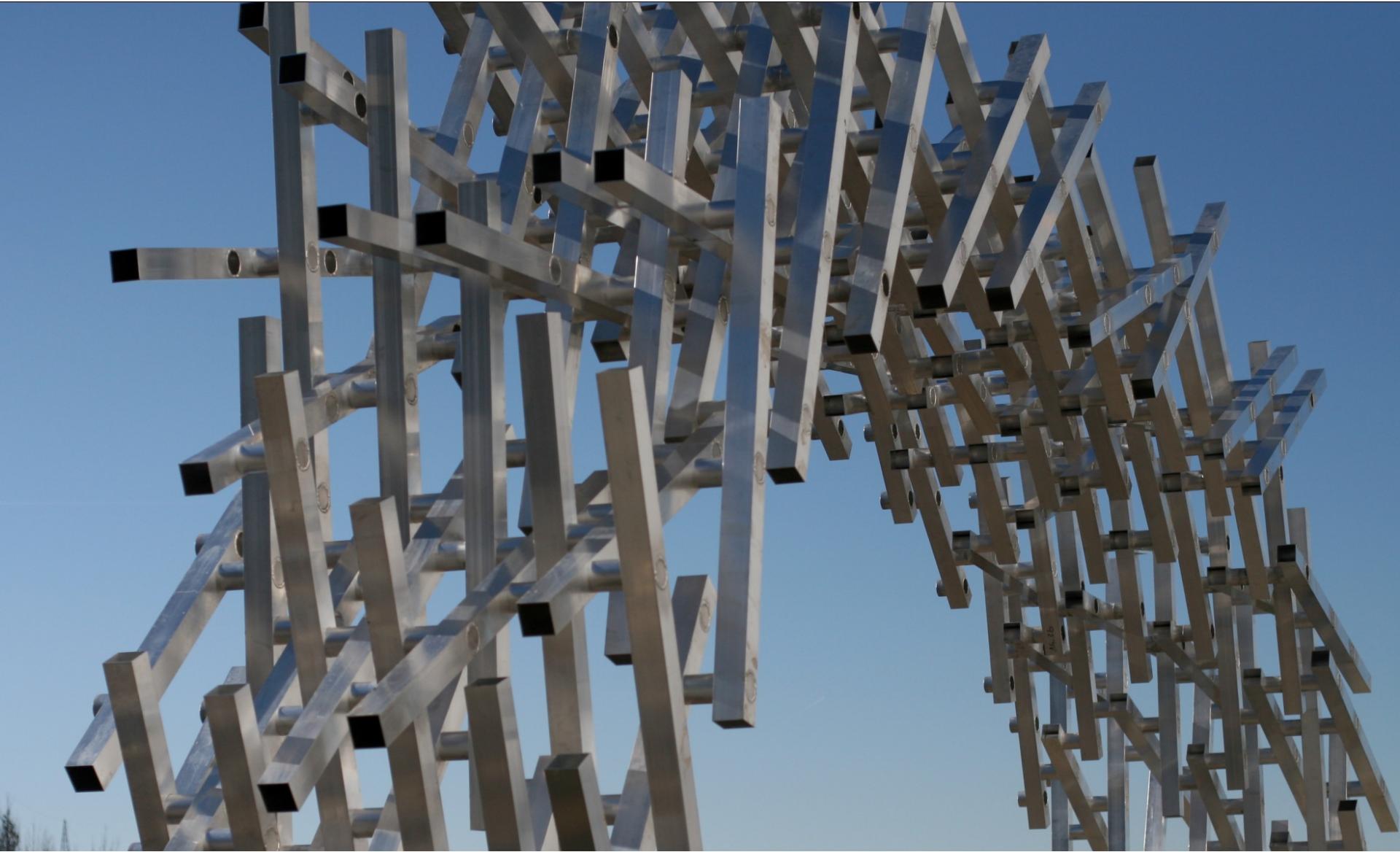












PROJECT: SALZBURG BIENNALE PAVILLON - SOMA



PROJECT: SALZBURG BIENNALE PAVILLON - SOMA



PROJECT: SALZBURG BIENNALE PAVILLON - SOMA



VOxEL

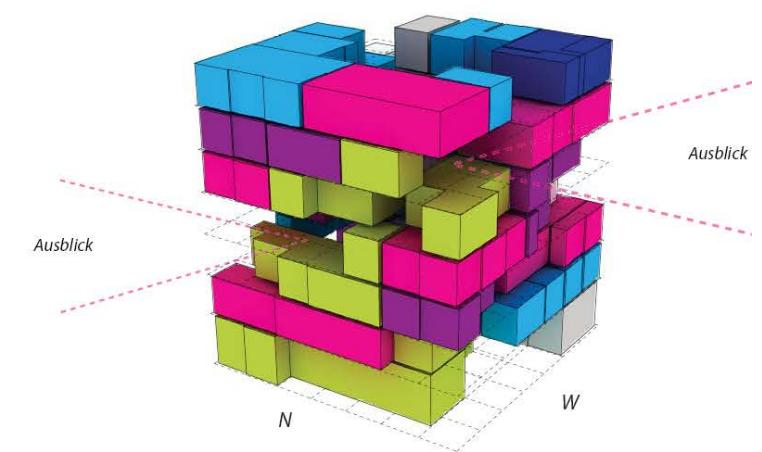
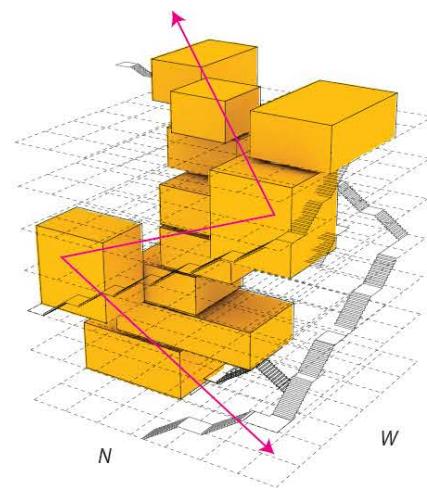
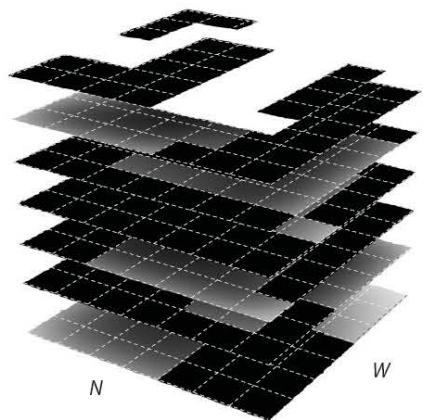


VOxEL, Hochschule für Technik, Stuttgart/LAVA

BOLLINGER + GROHMAN
Ingenieure

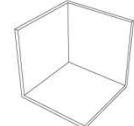
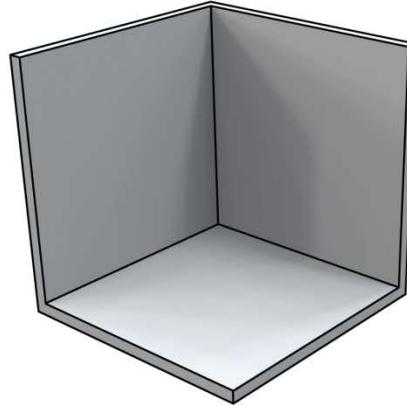
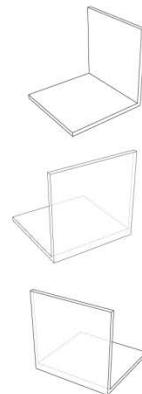
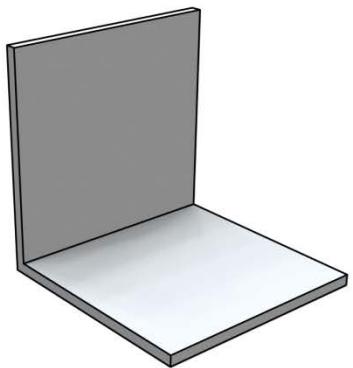
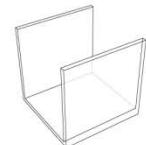
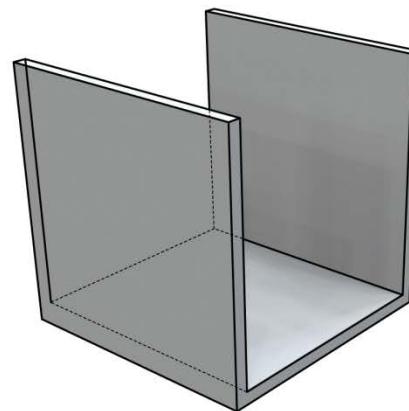
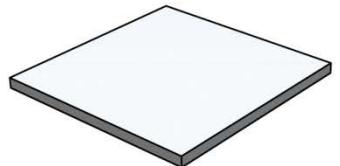


Architectural concept

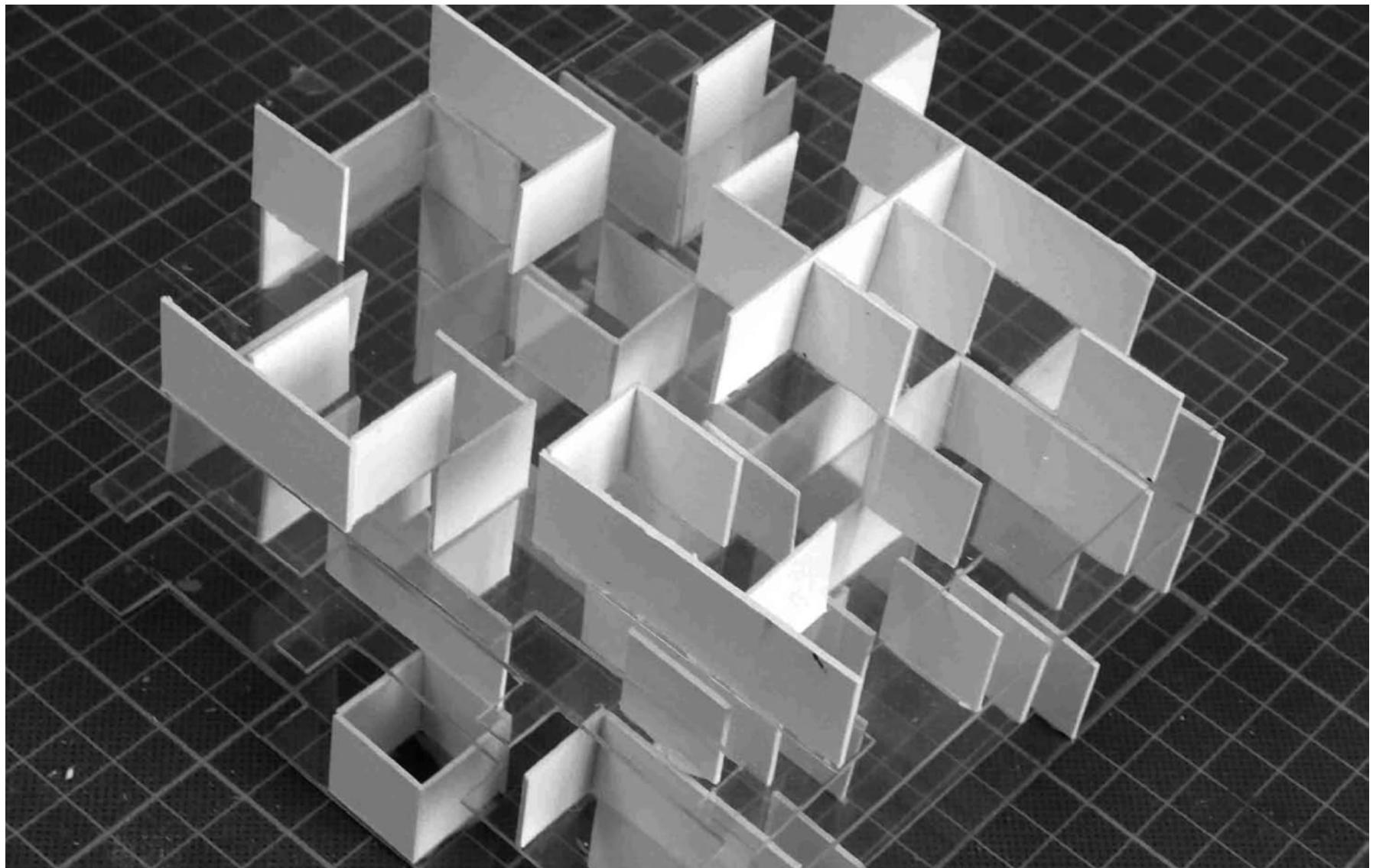




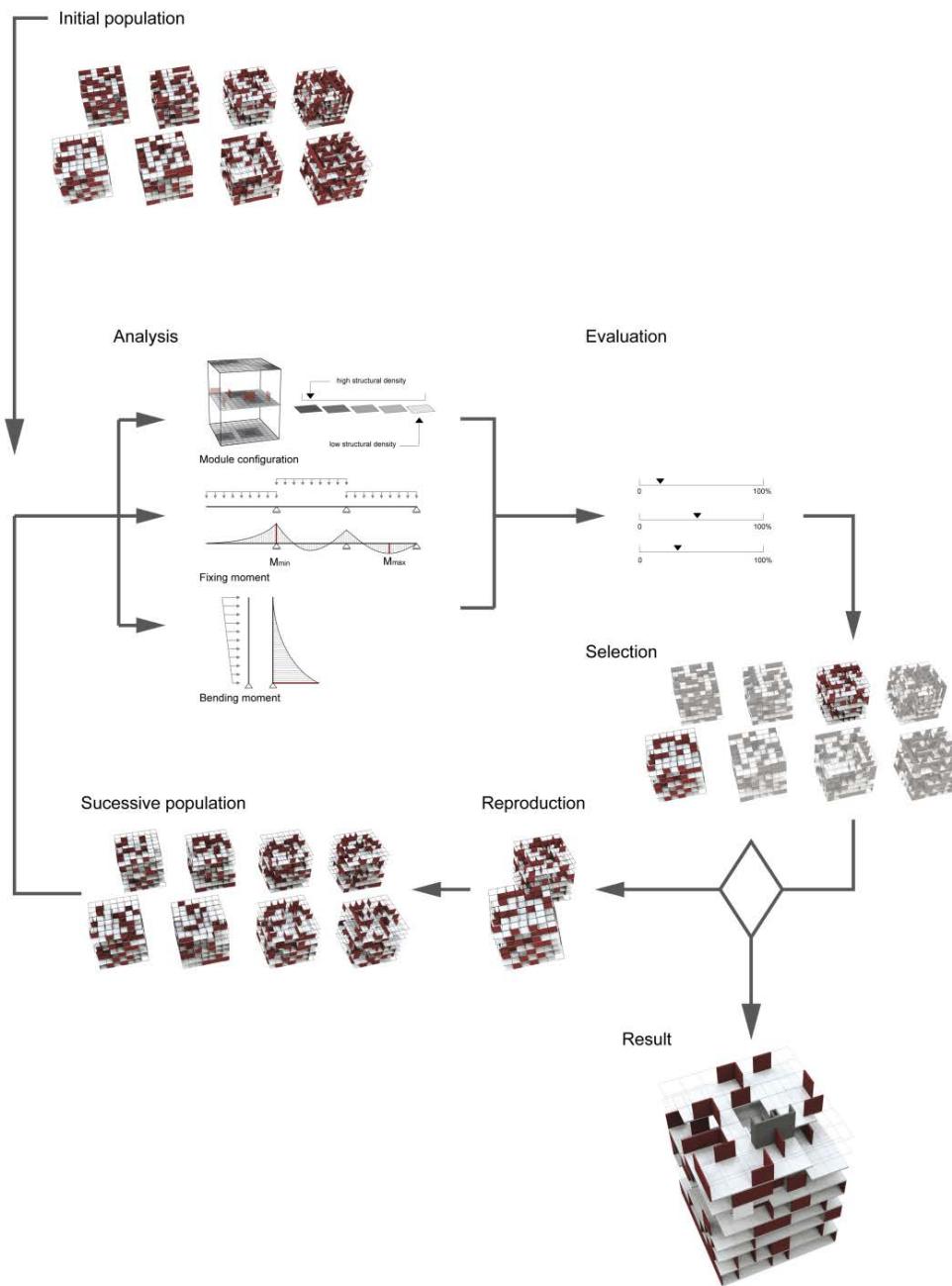
Basic Moduls



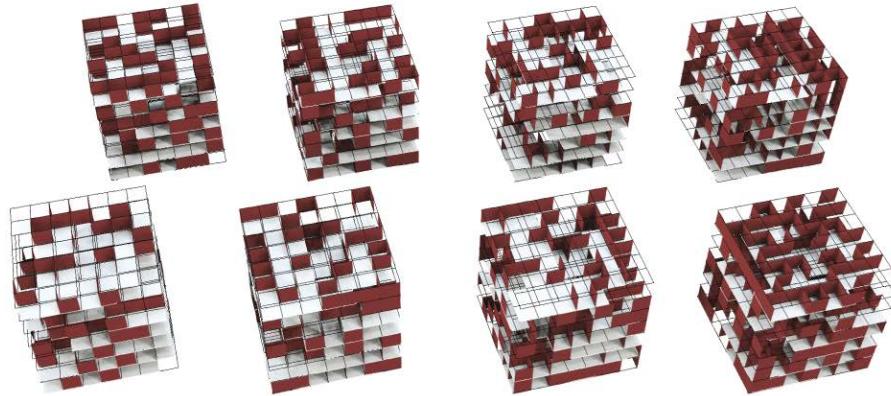
Conceptual Idea



Evolutionary Process



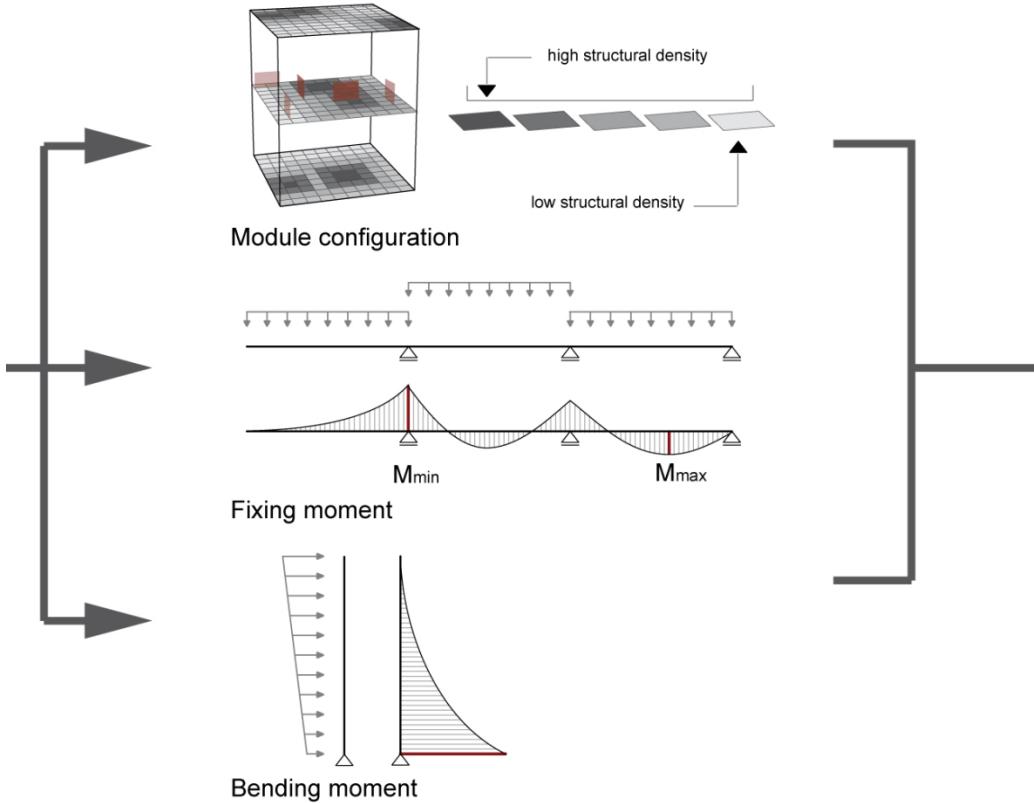
Initial population of random solutions



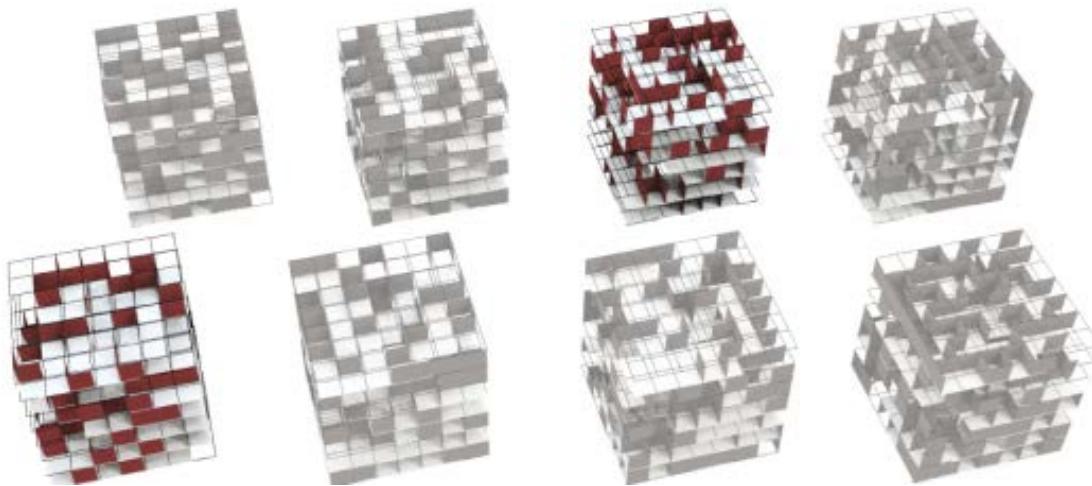


Fitness criteria

Analysis

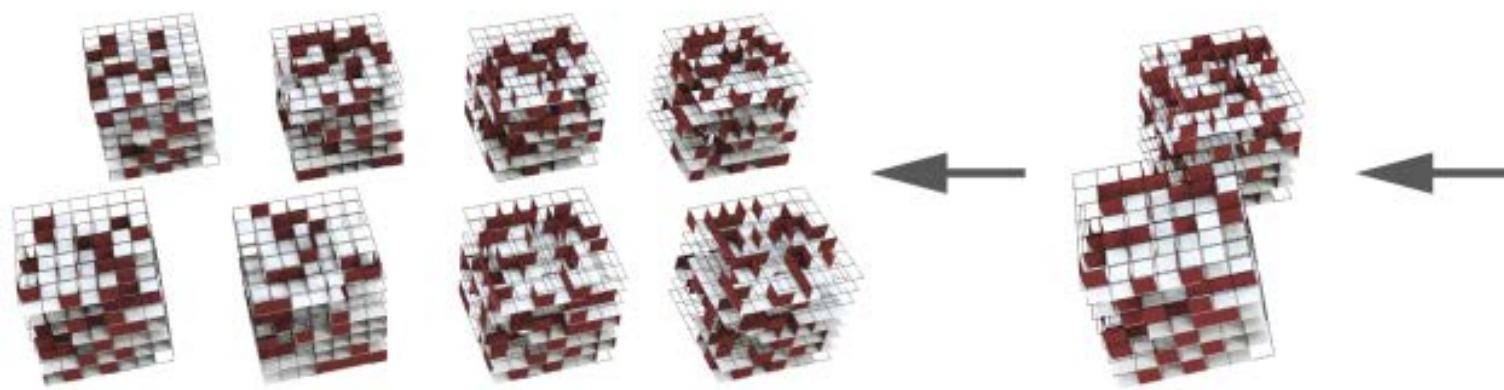


Selection process





Reproduction

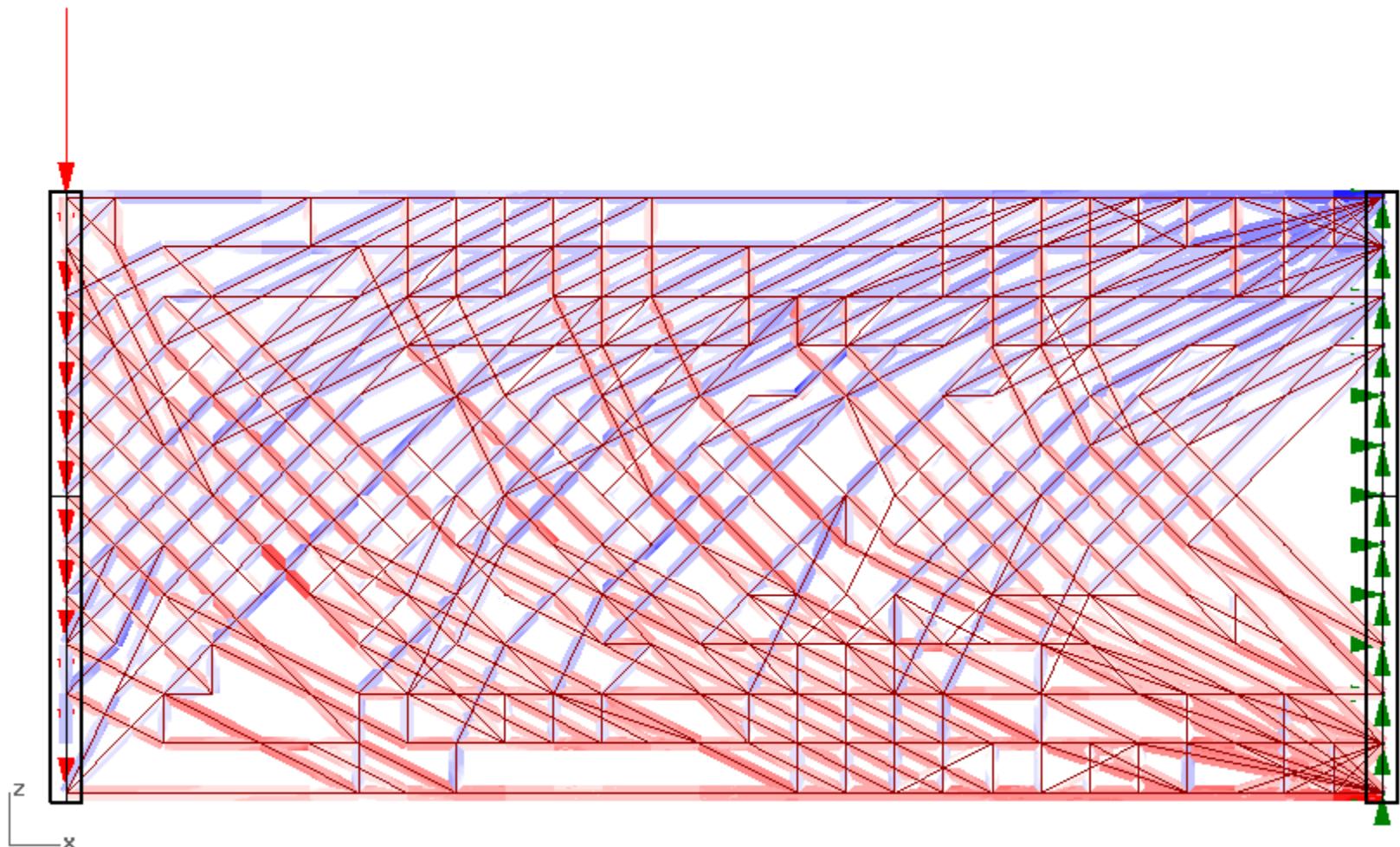




Section through central void

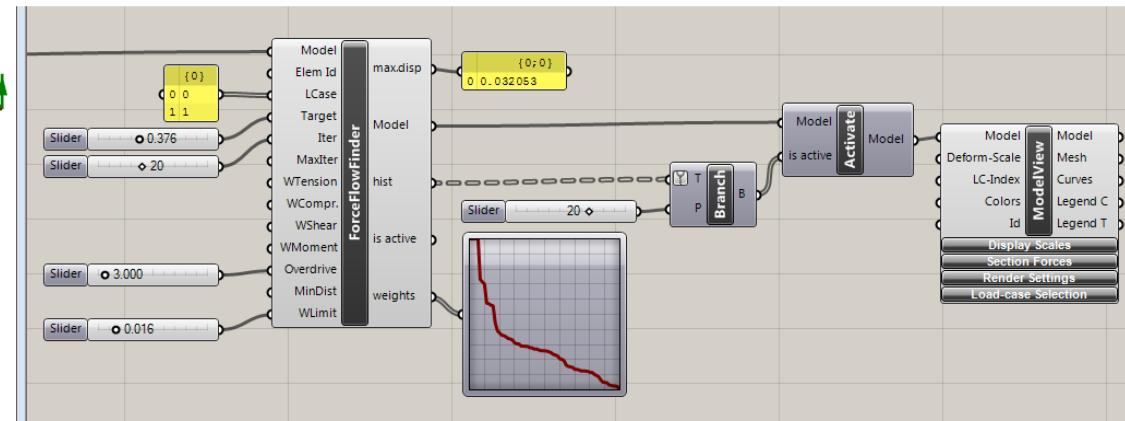
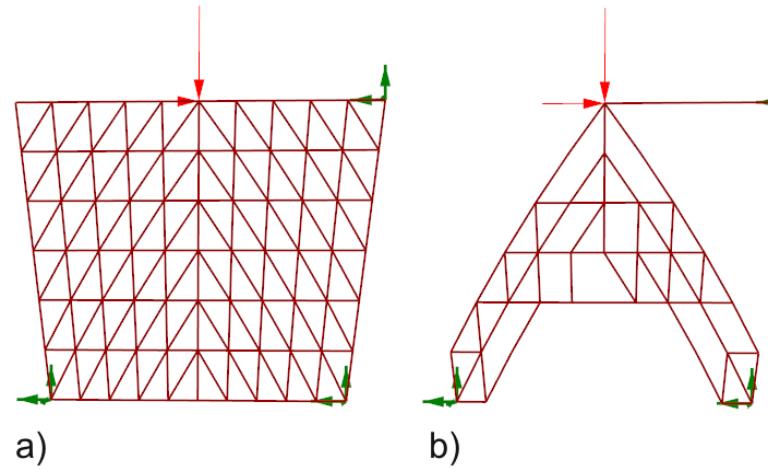


BESO – Bi-directional evolutionary structural optimisation: Force Flow



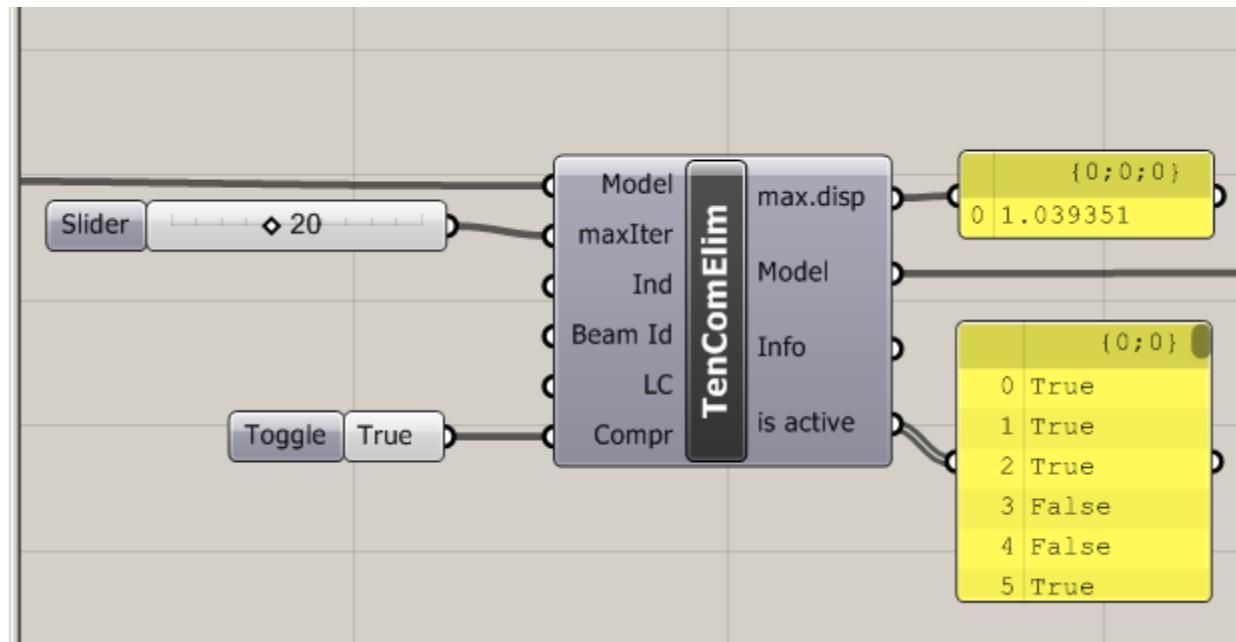
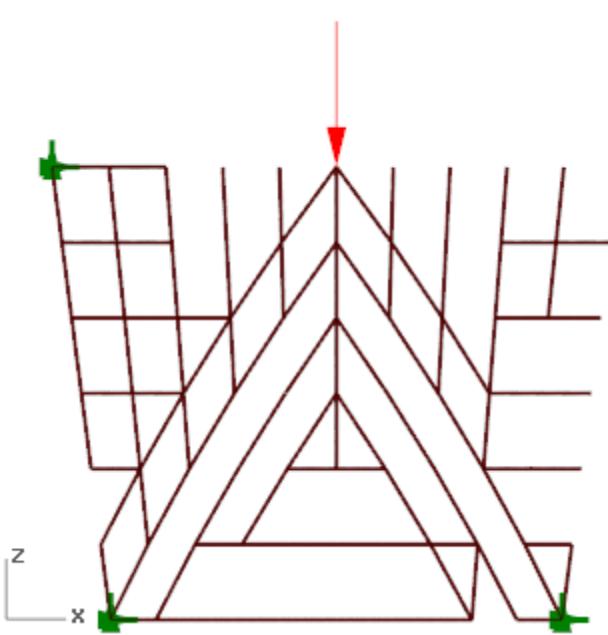
Cantilever with initially regular mesh after application of the "ForceFlowFinder"-component.

BESO – Bi-directional evolutionary structural optimisation: Force Flow



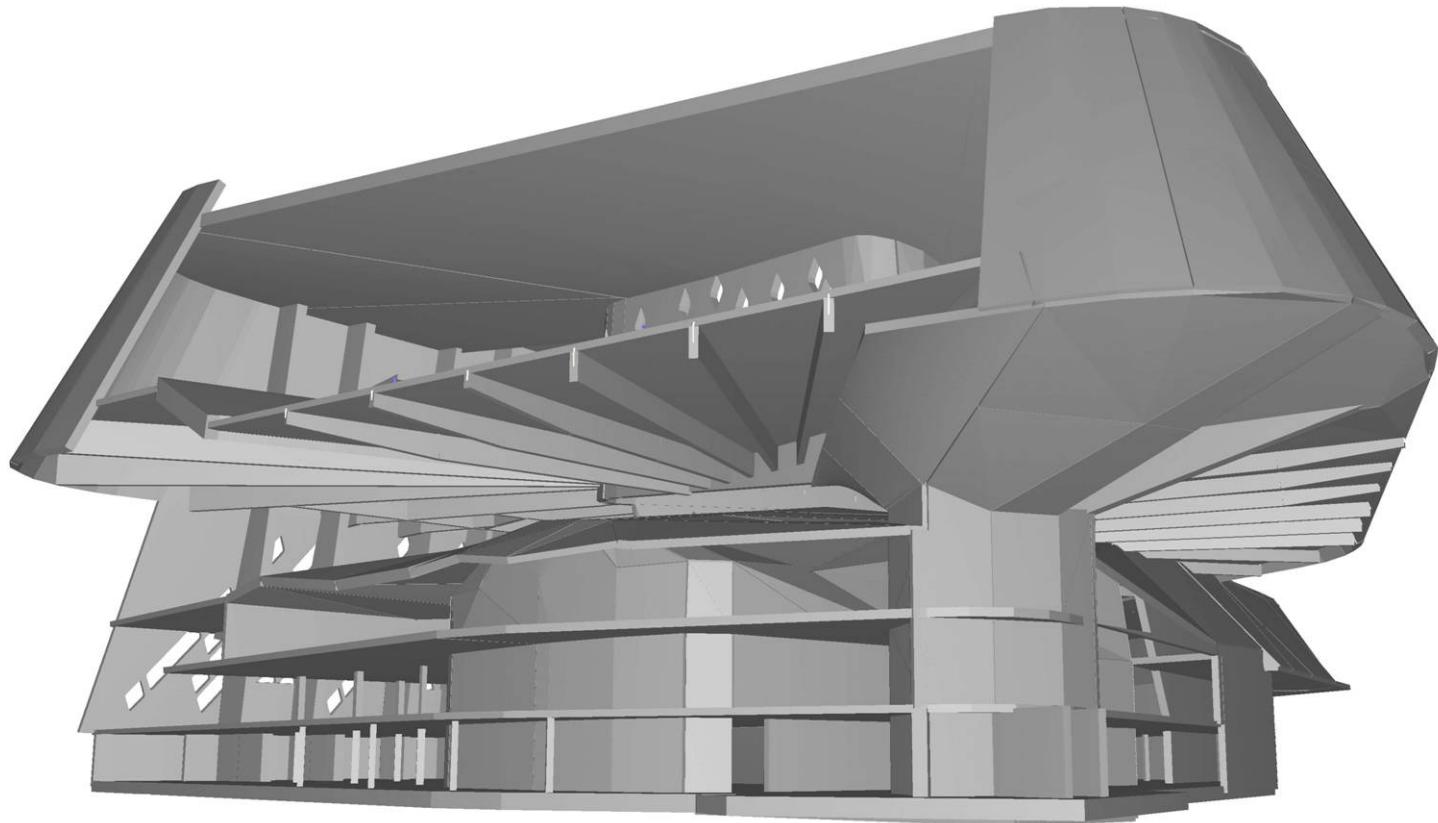
Triangular mesh of beams before (a) and after (b) applying the "FindForcePath"-component.

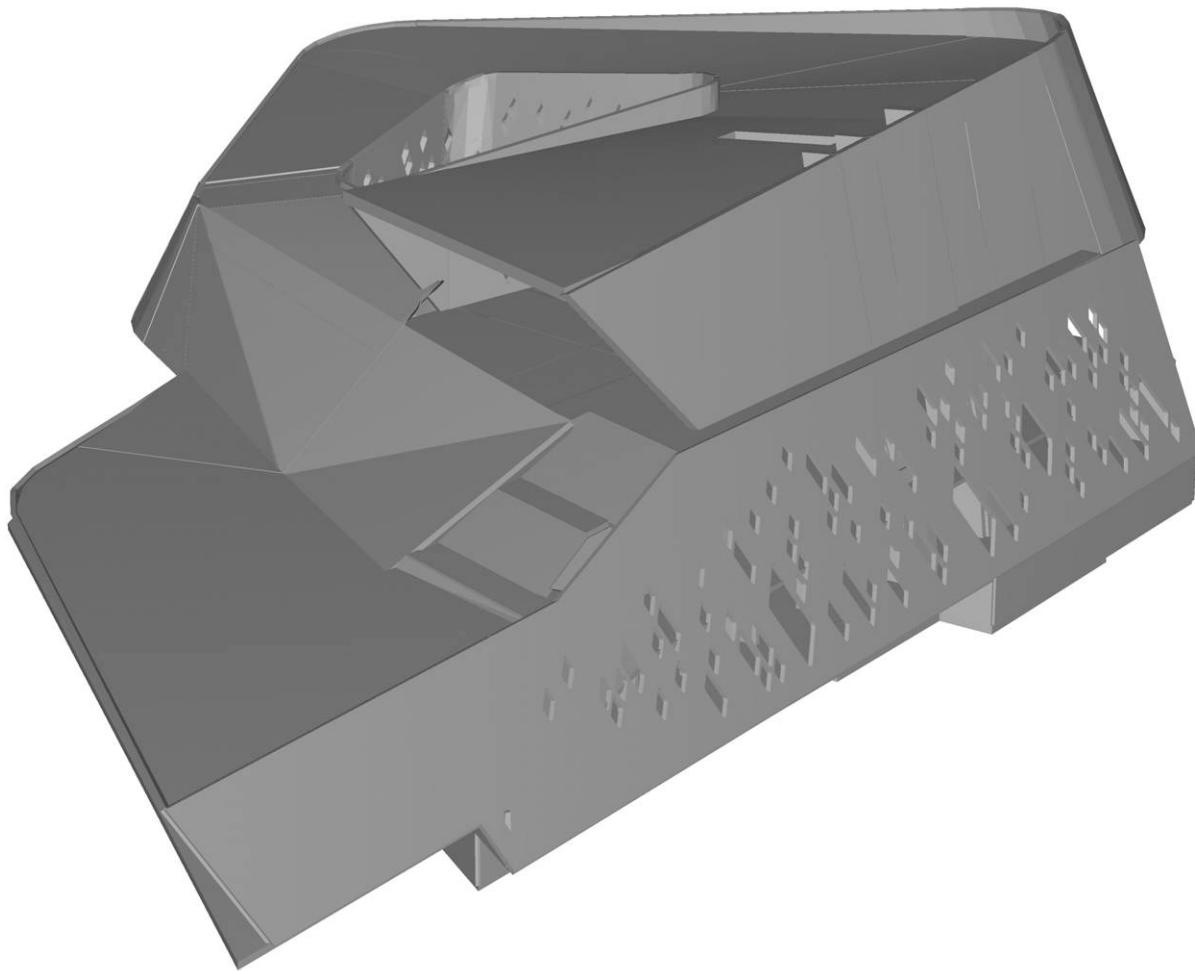
BESO – Bi-directional evolutionary structural optimisation: Force Flow



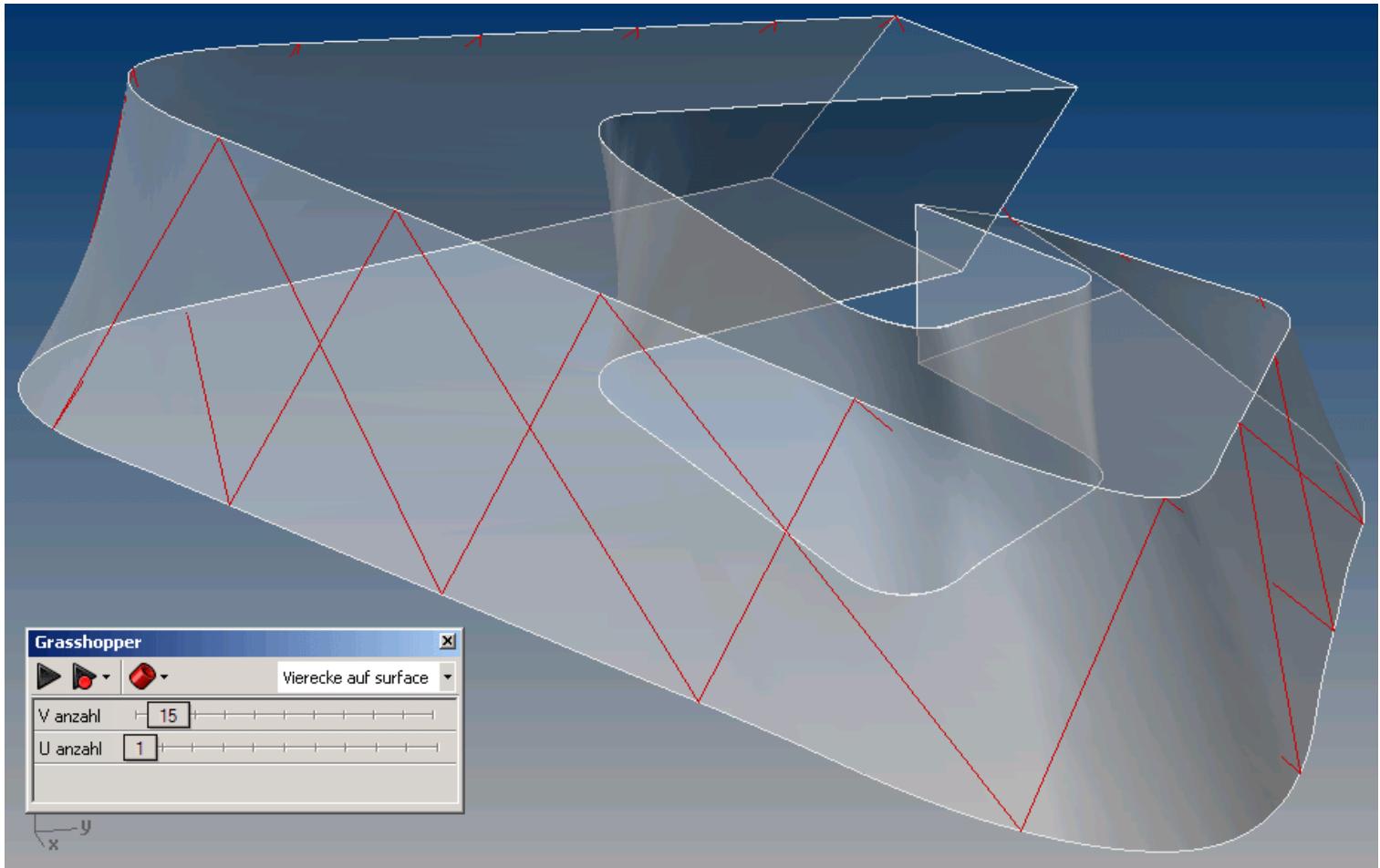
The "Tension/Compression Eliminator"-component.

Sheikh Zayed Desert Learning Centre

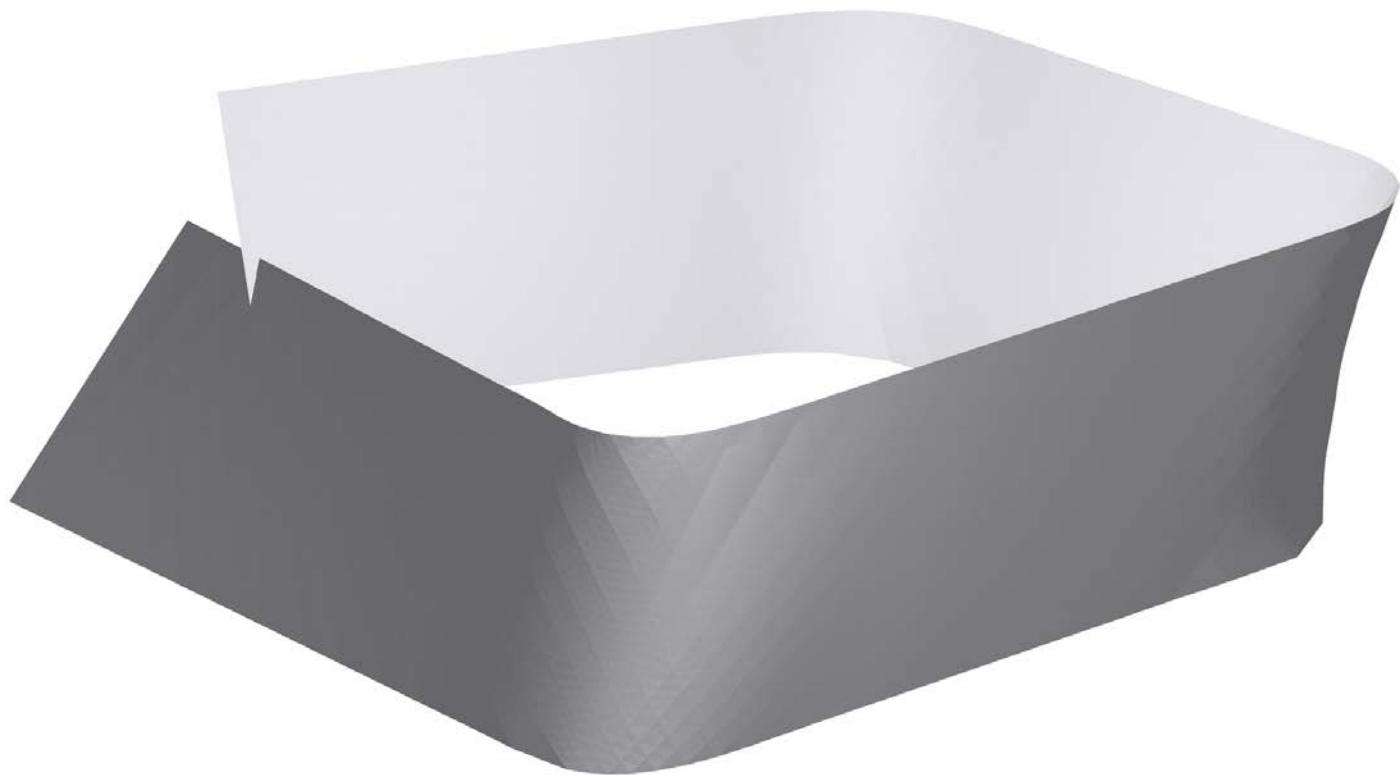




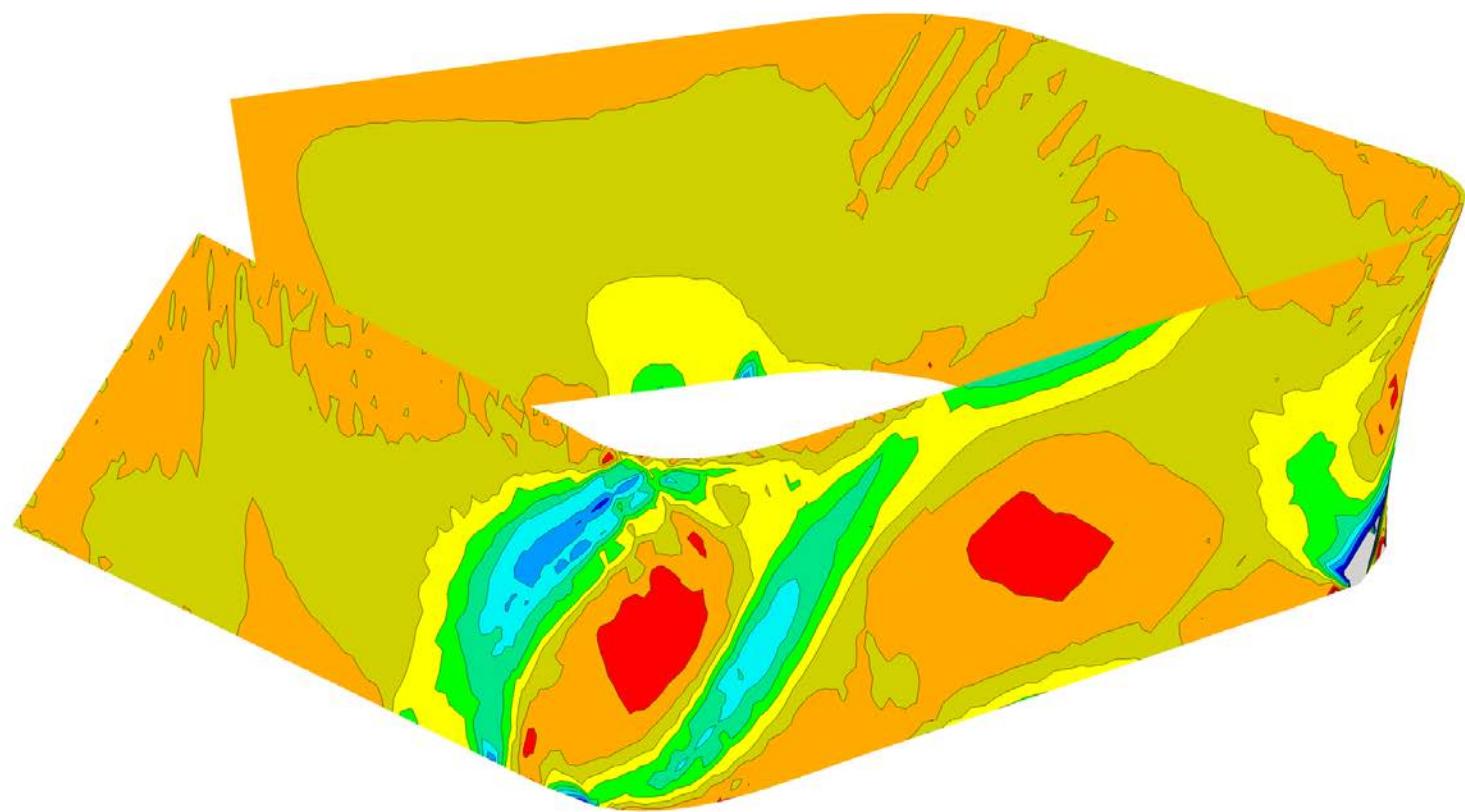
Generating the basic grid structure



Generating openings based on the basic grid structure

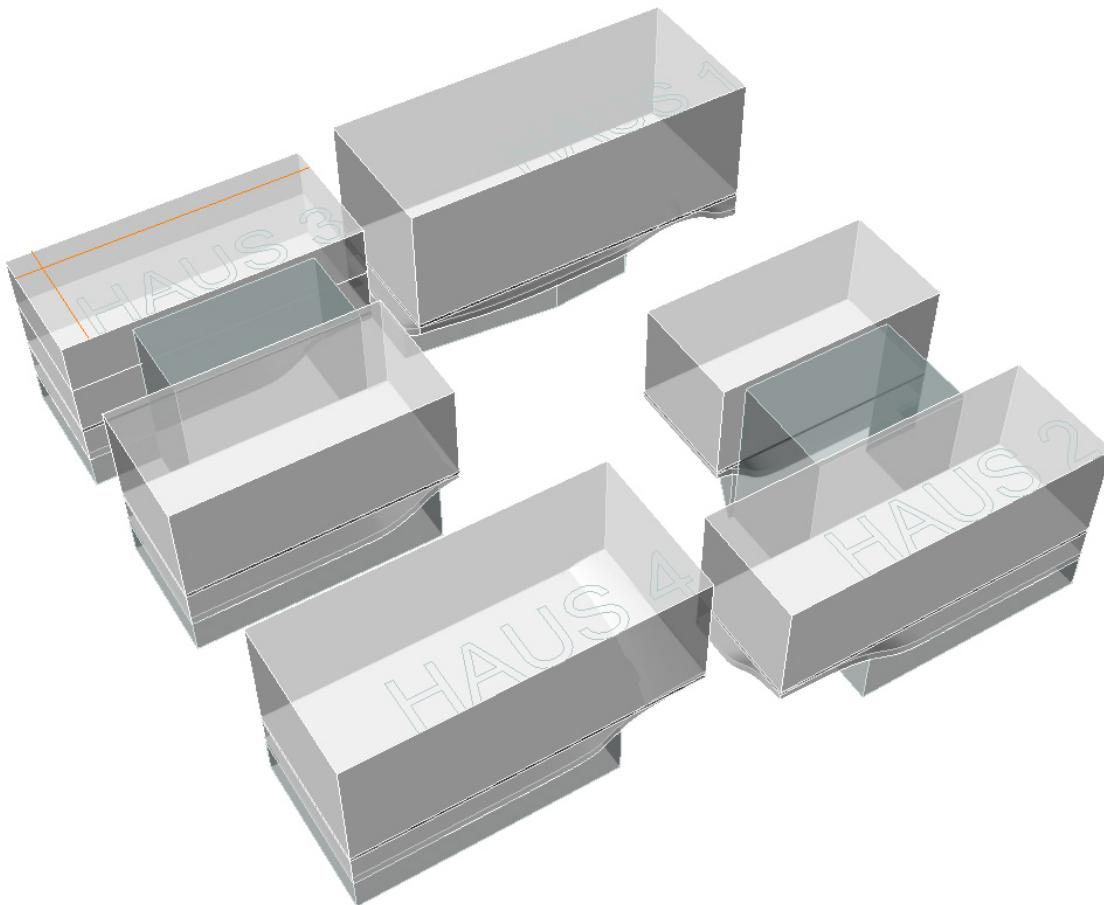


Visualisation of main forces

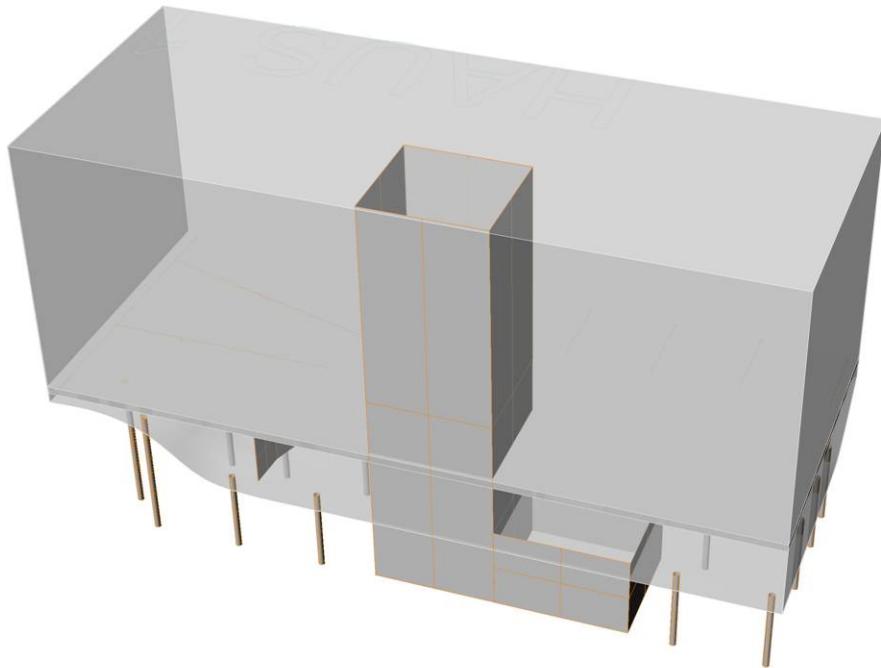


Competence Centre Salzburg

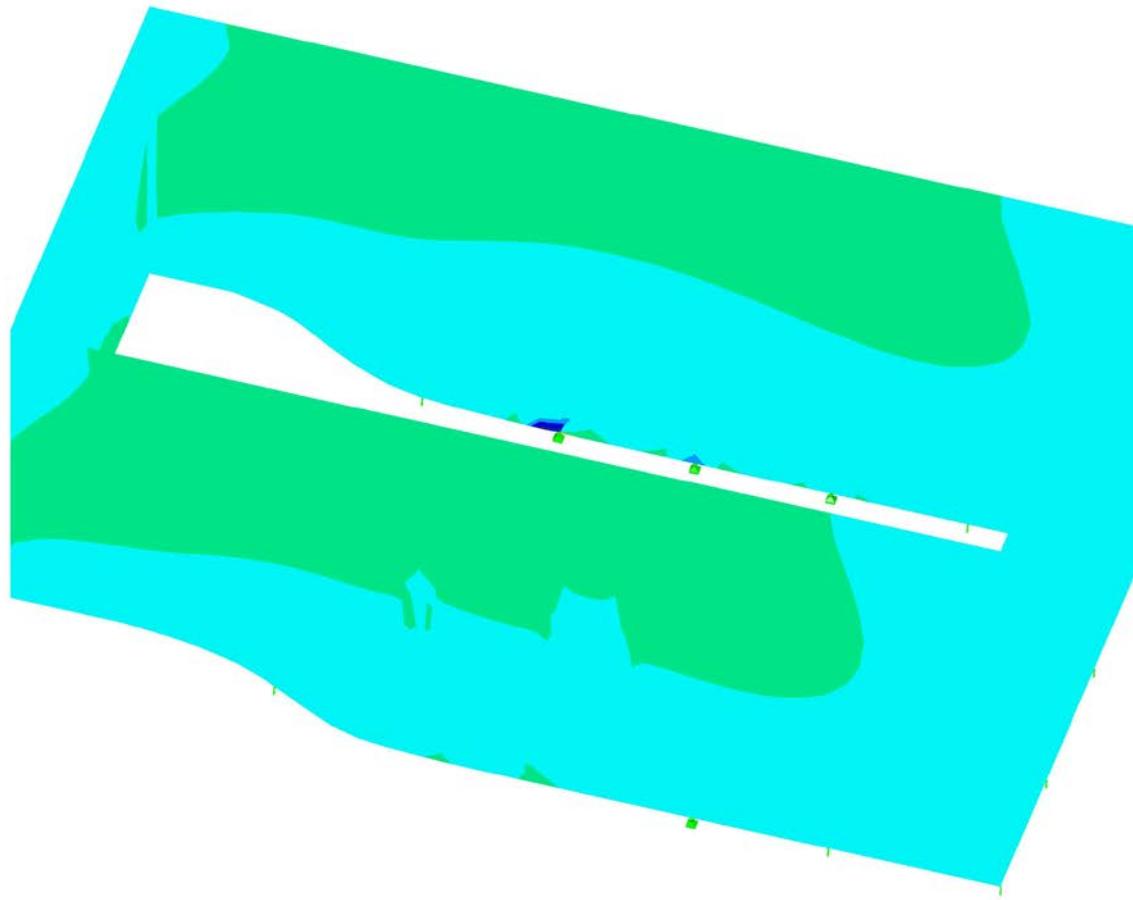
Overview



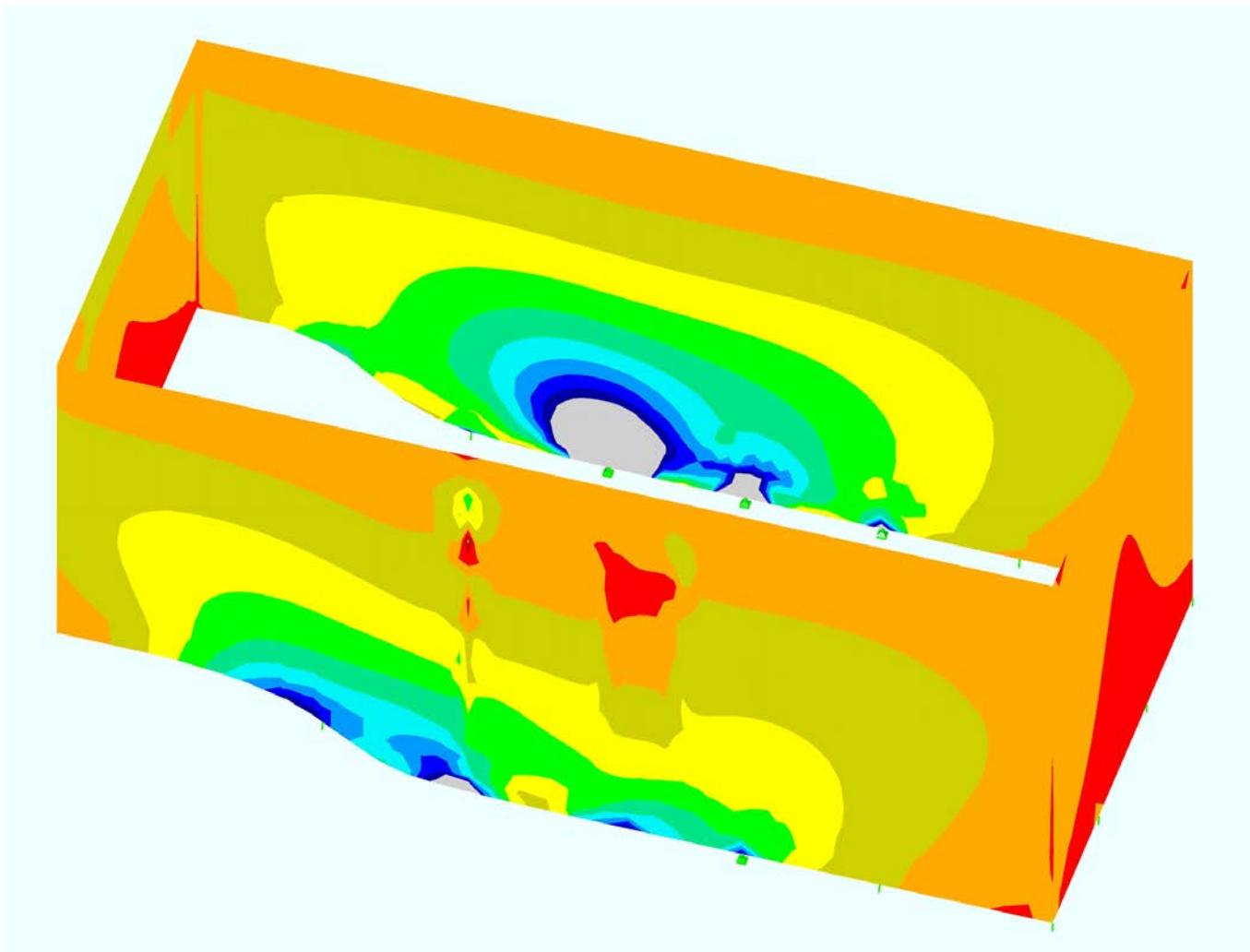
Zoom in of single unit



Openings: Visualisation of main forces 1.direction

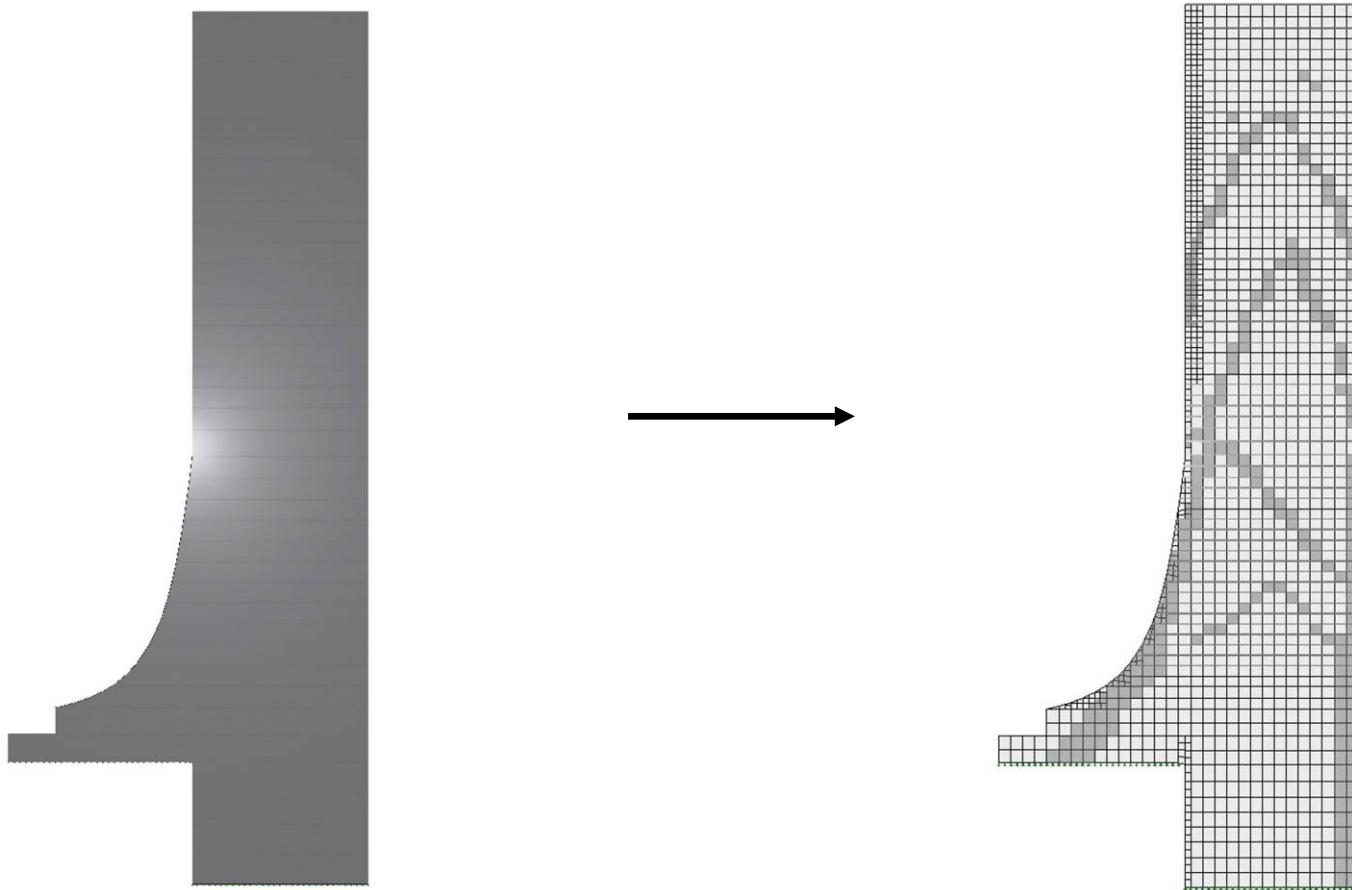


Openings: Visualisation of main forces 2.direction



Mixed Use Baku

Defining bracing elements via BESO-method

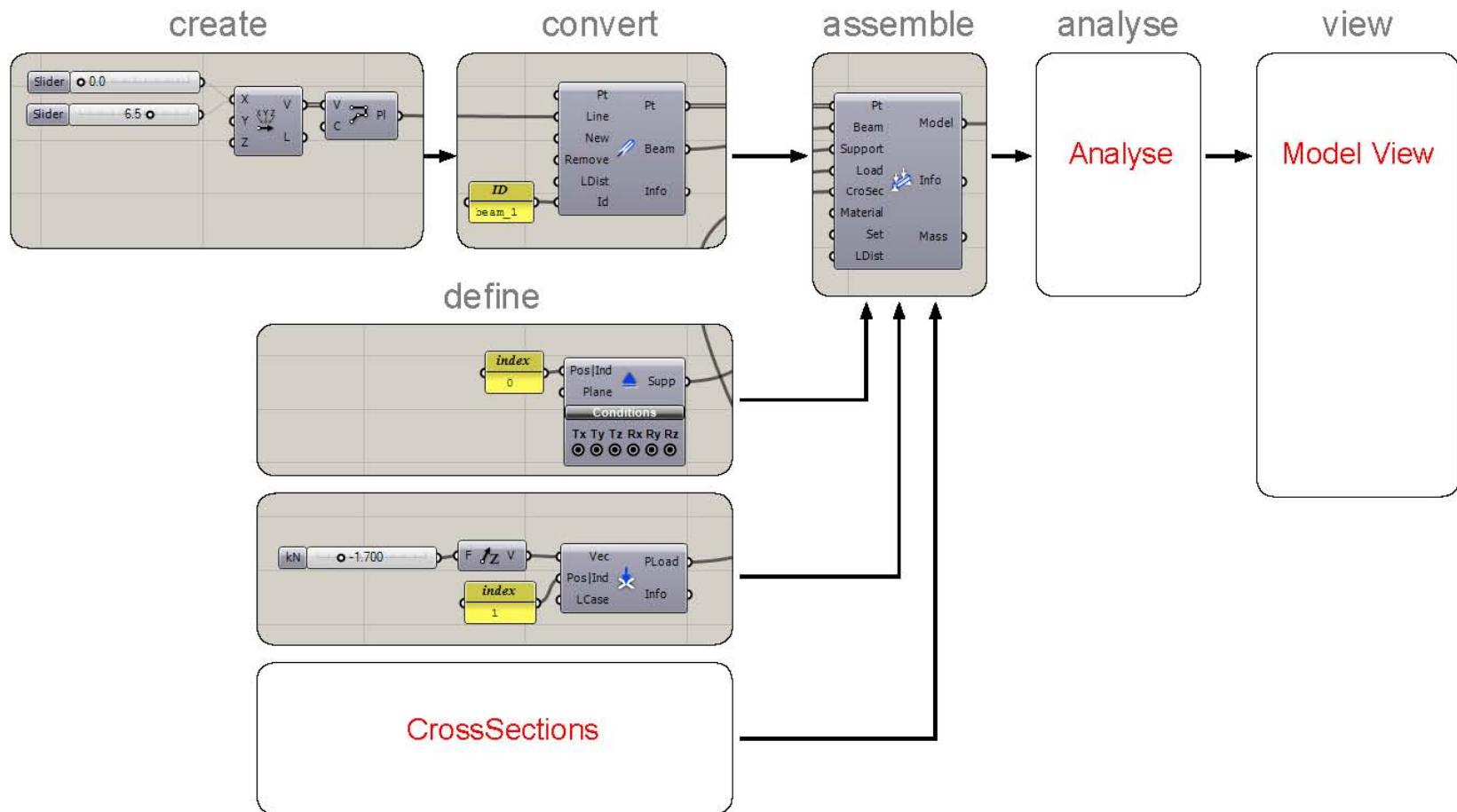


Final Design



define loads

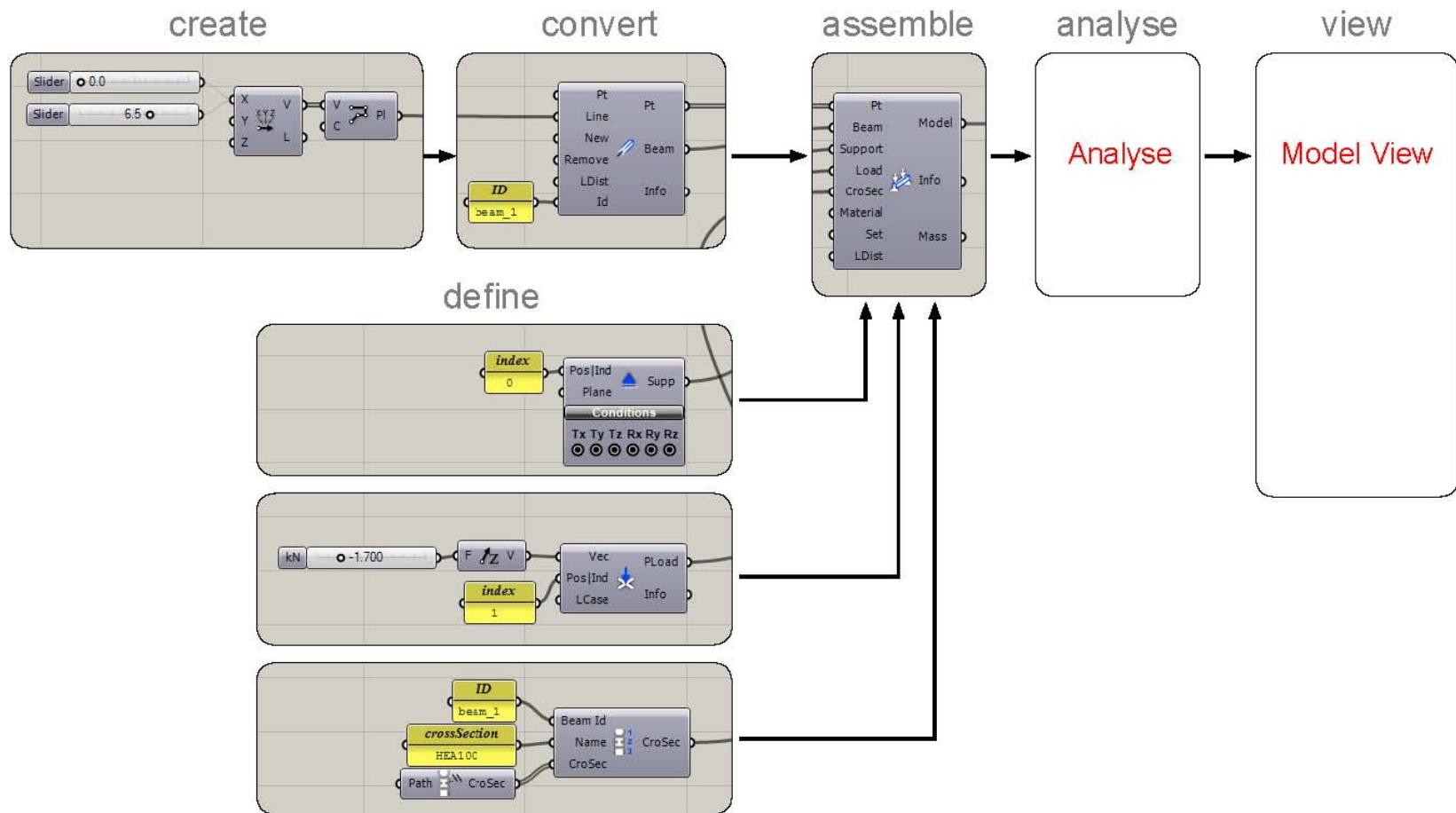
Tutorial 1:



Karamba

define crossSections

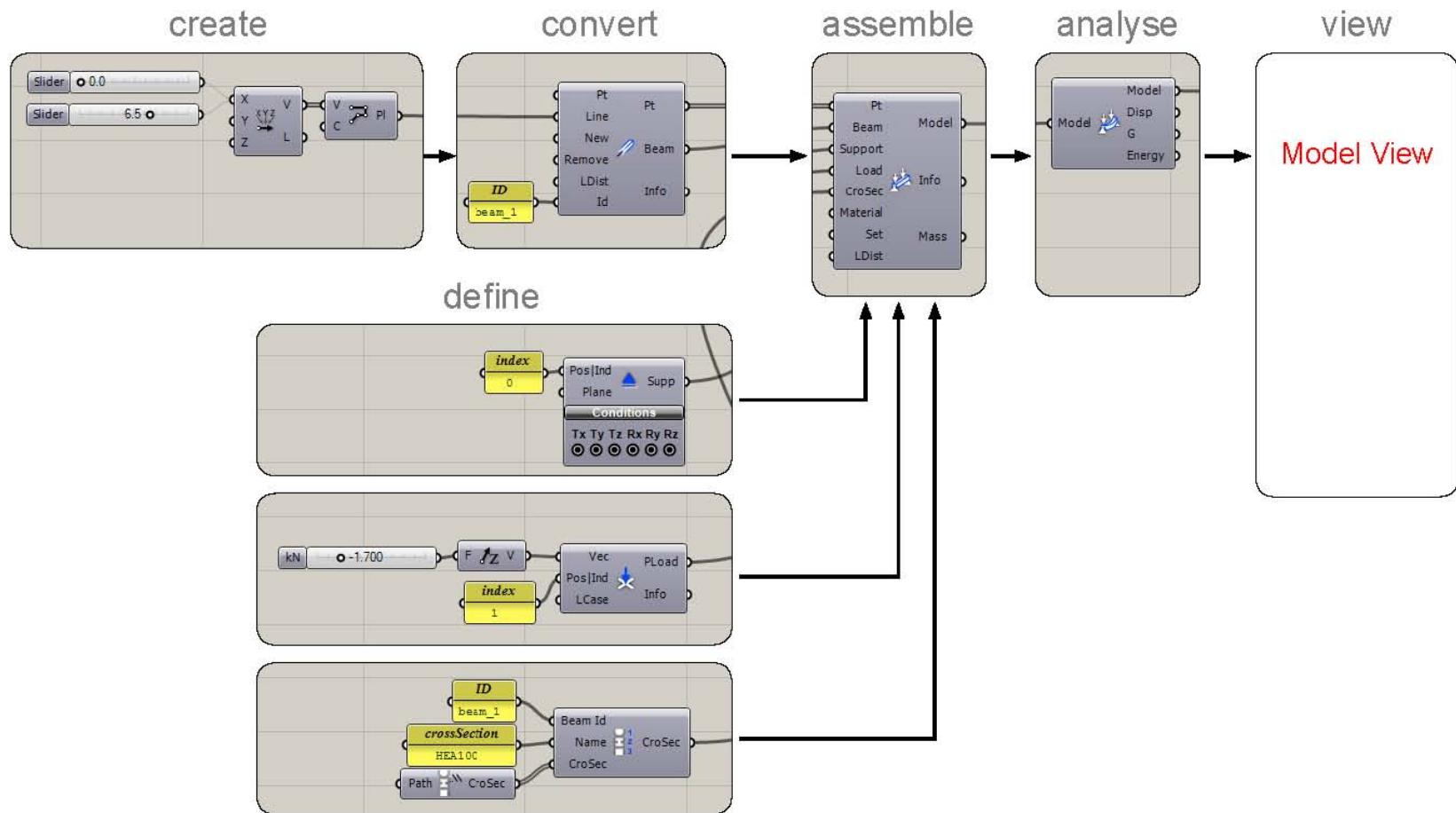
Tutorial 1:



Karamba

analyse structural model

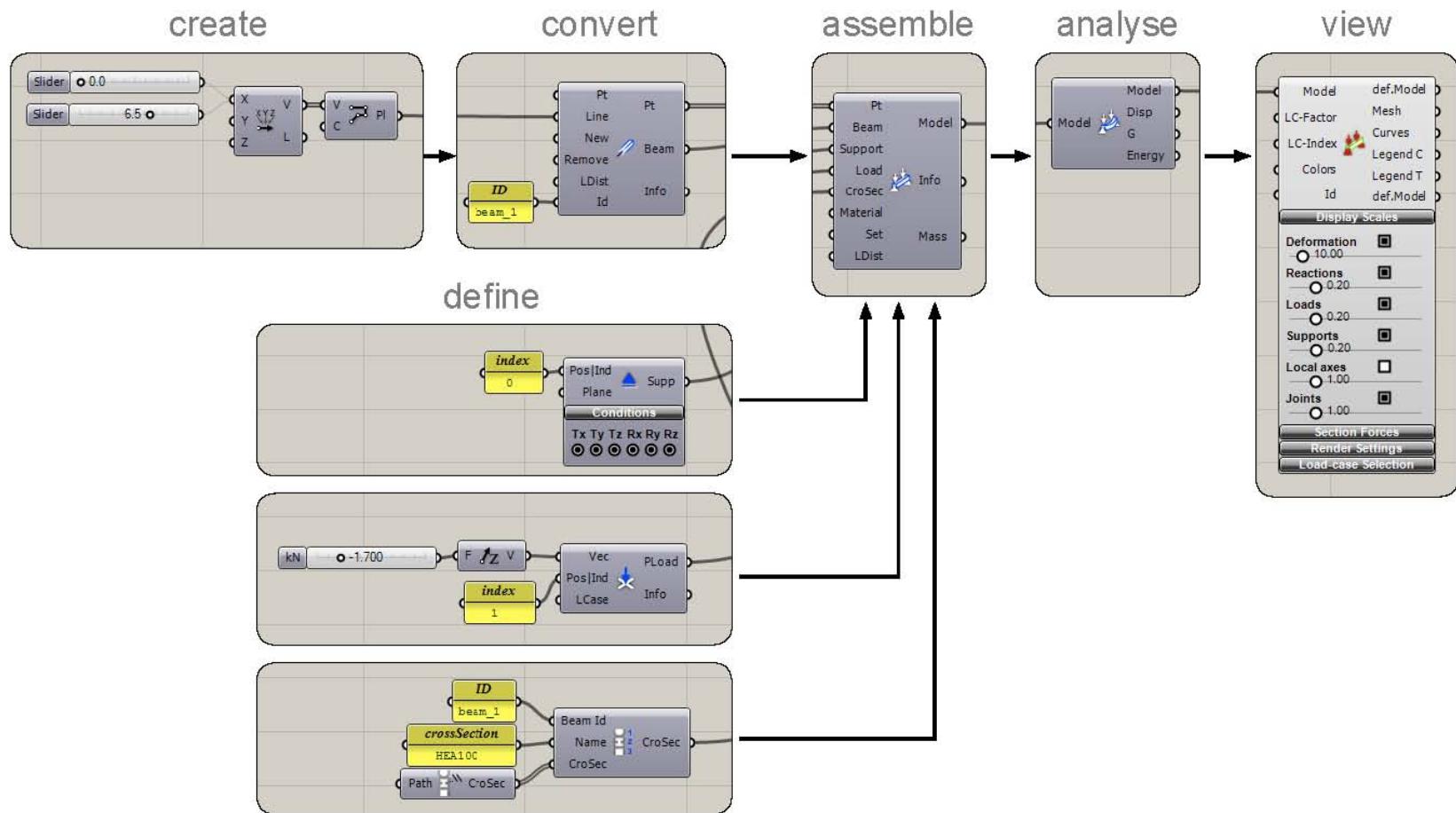
Tutorial 1:



Karamba

view result

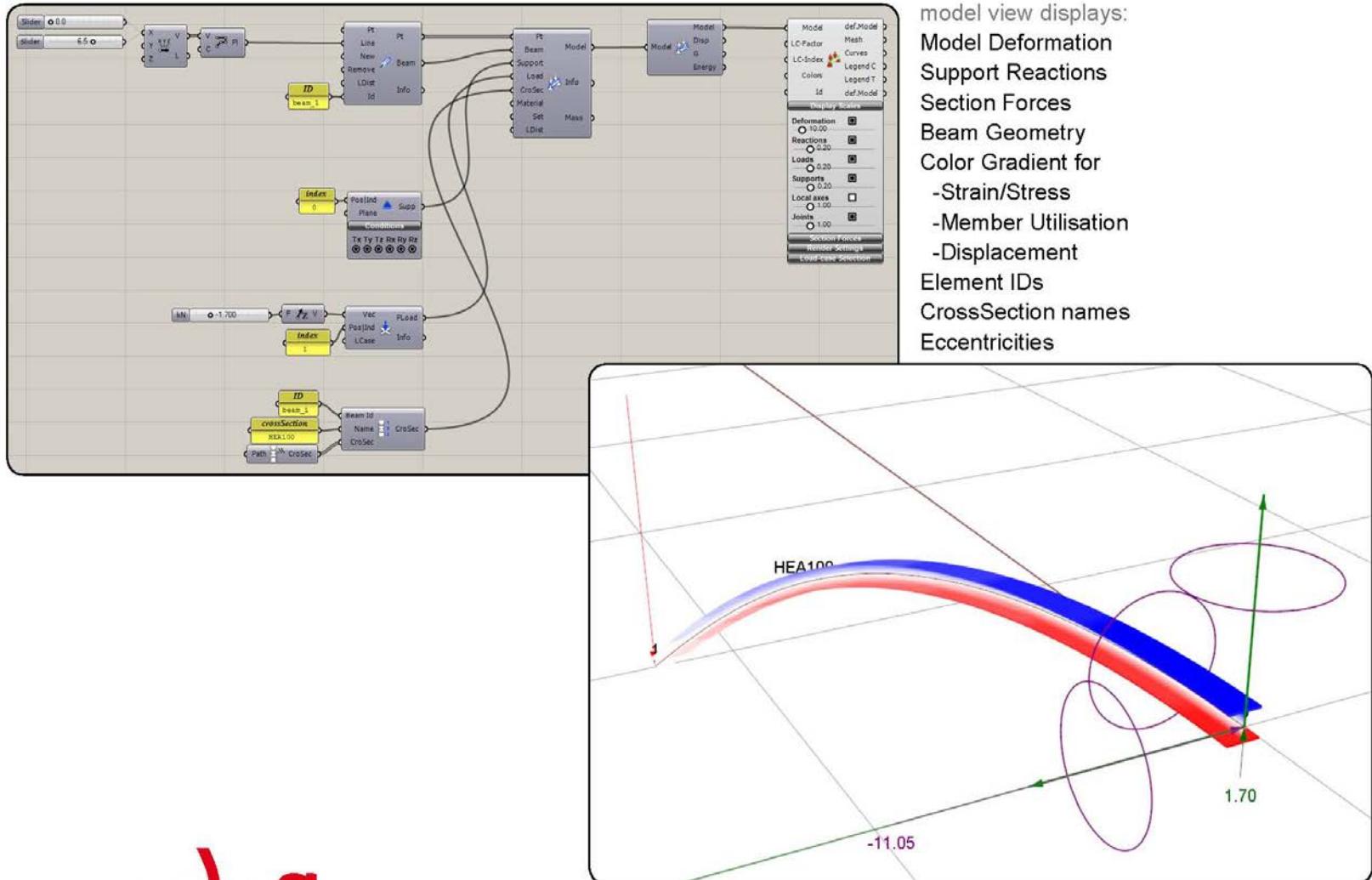
Tutorial 1:



Karamba

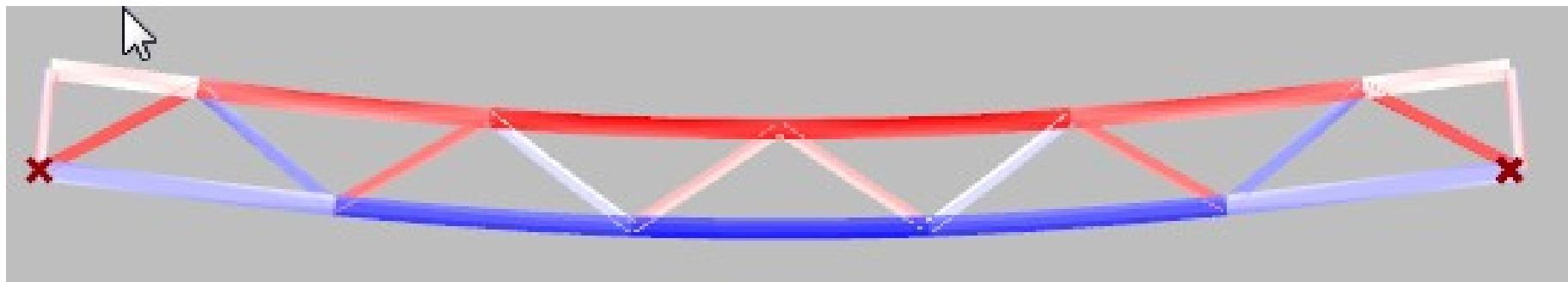
visual output in realtime

Tutorial 1:

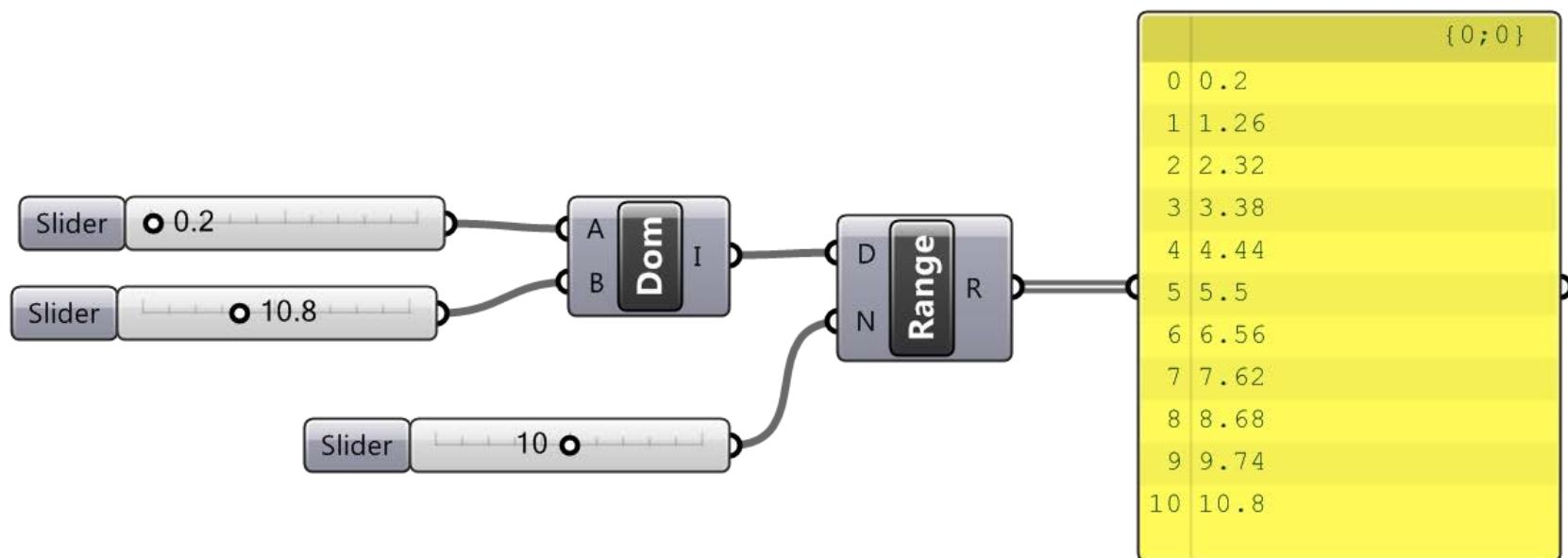


Karamba

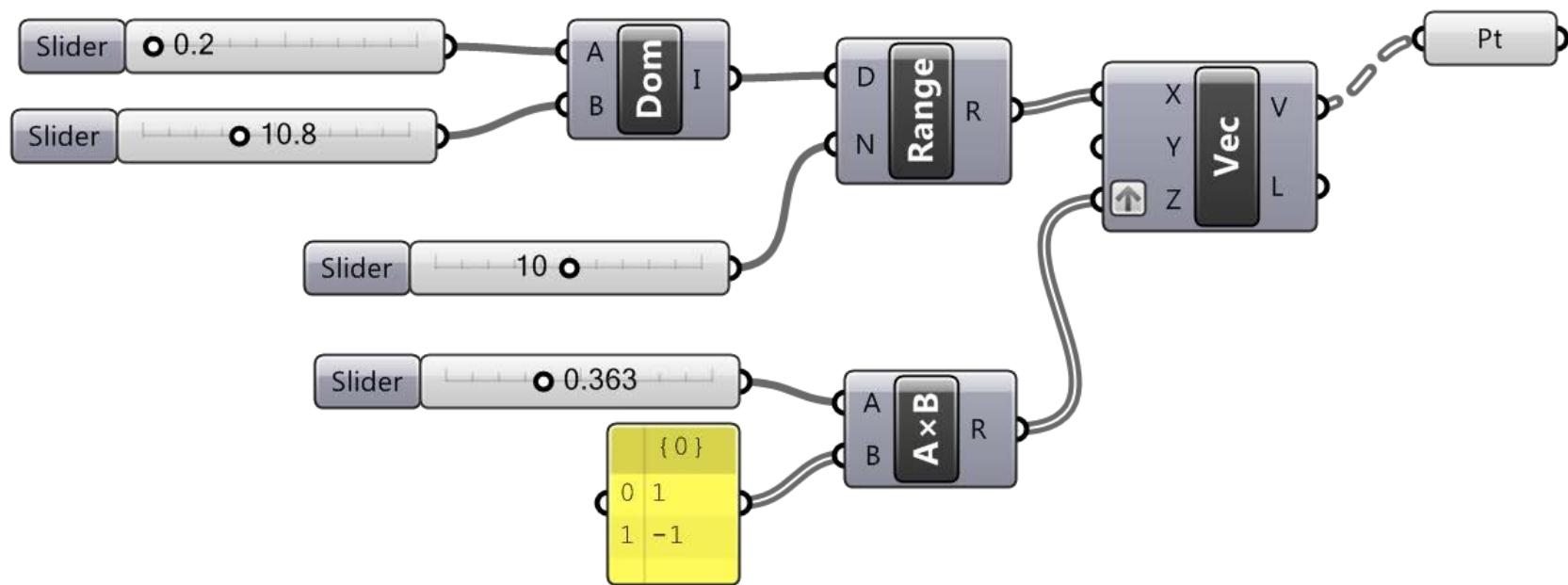
Tutorial 2:



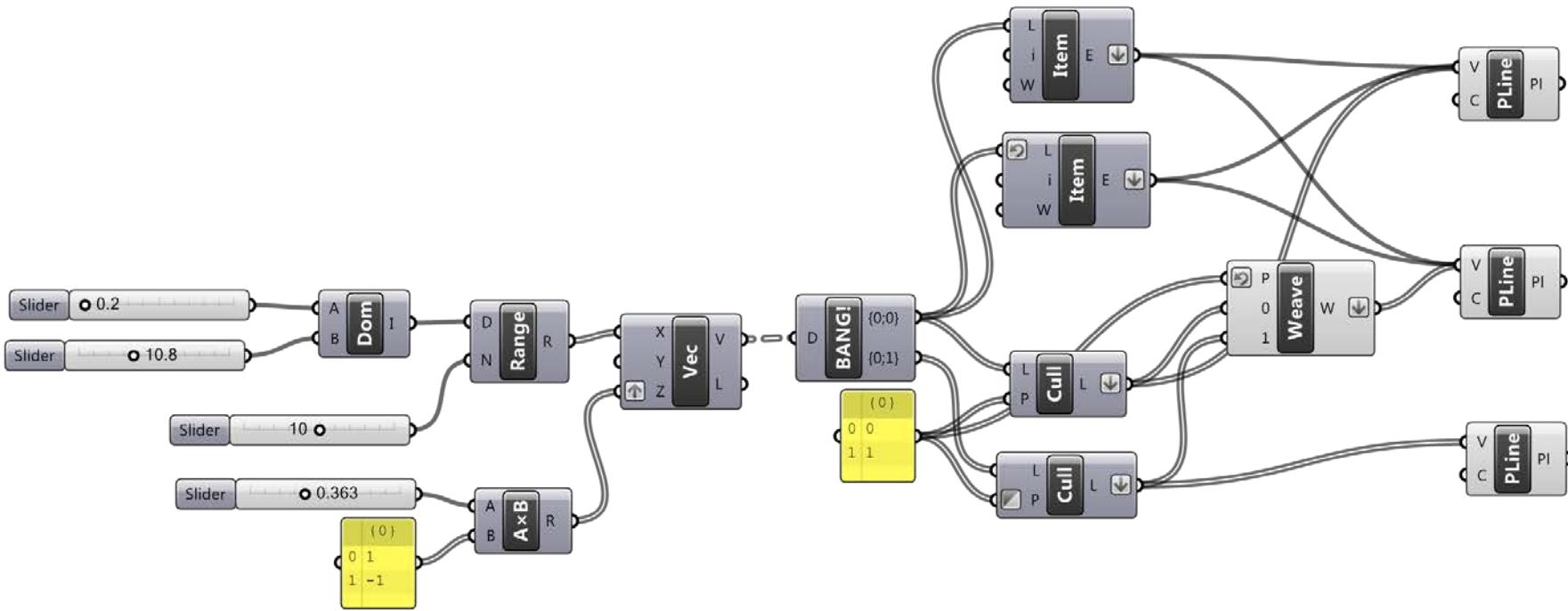
Tutorial 2:



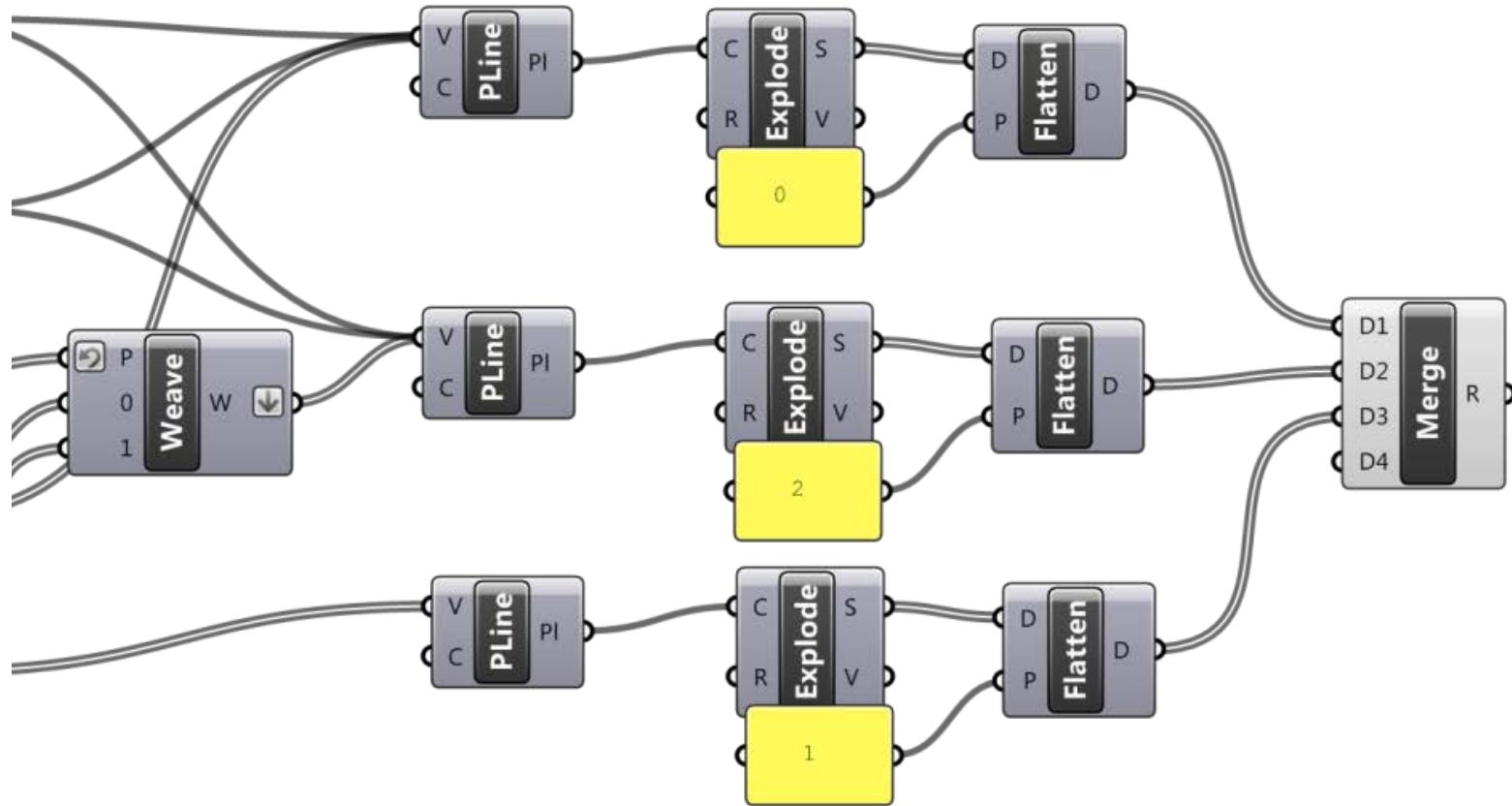
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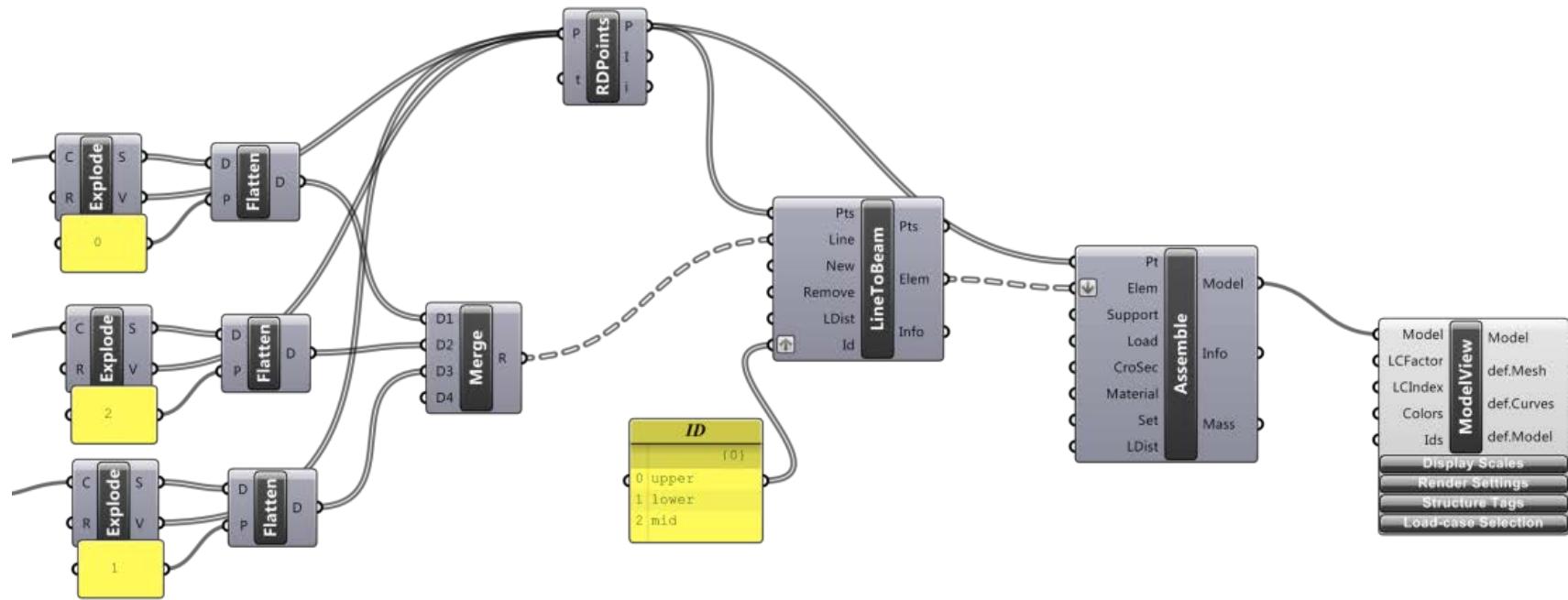
Tutorial 2:



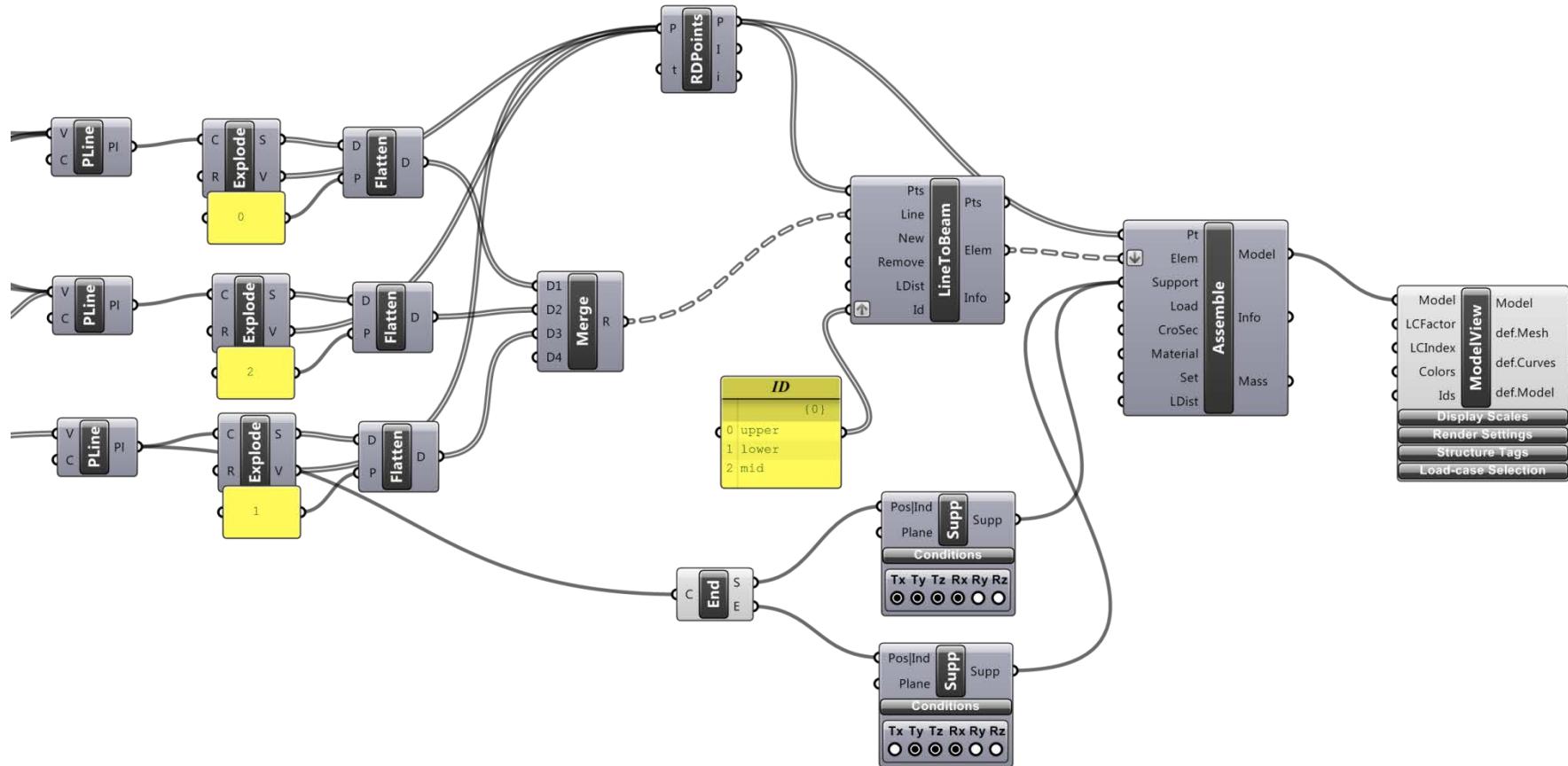
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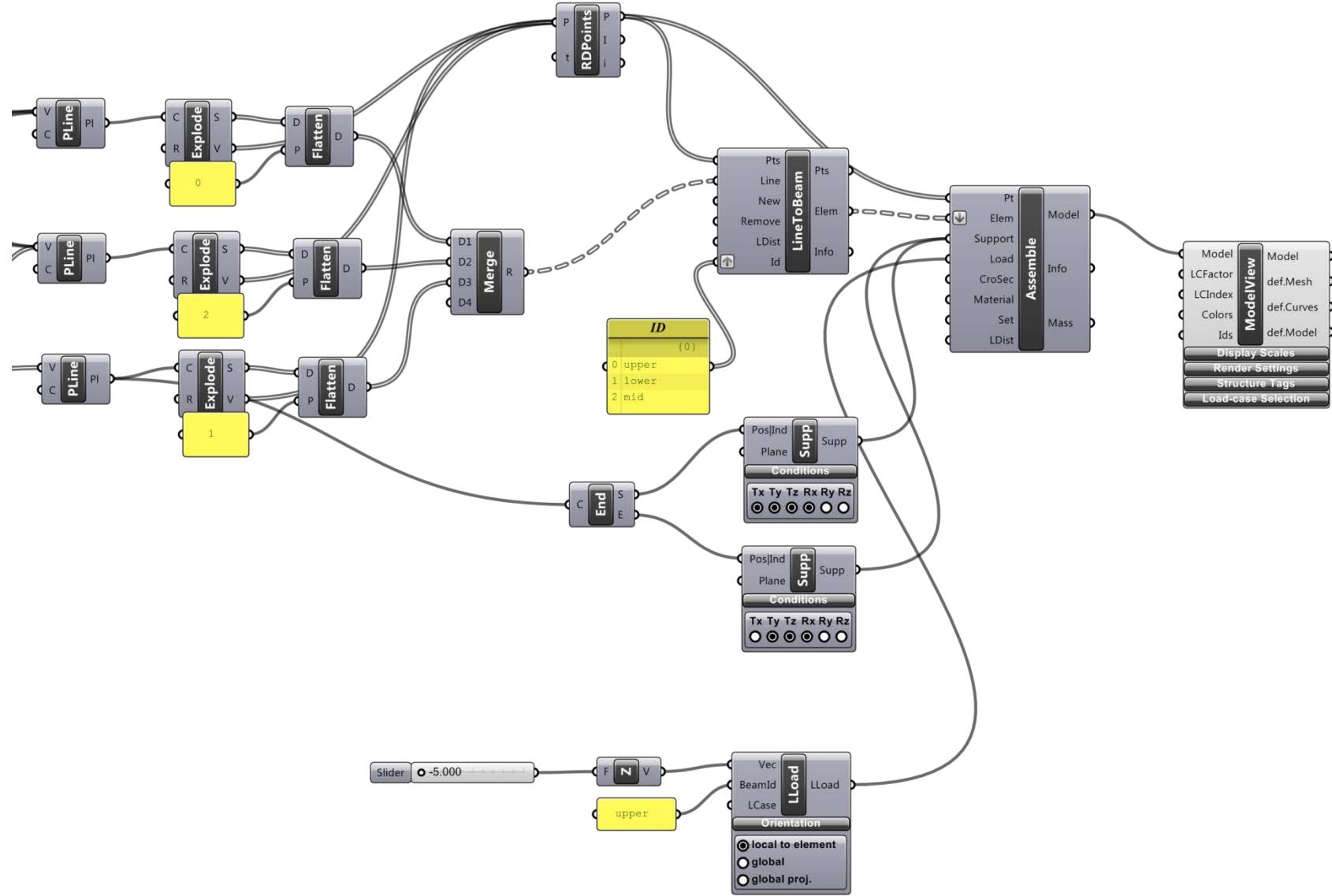
Tutorial 2:



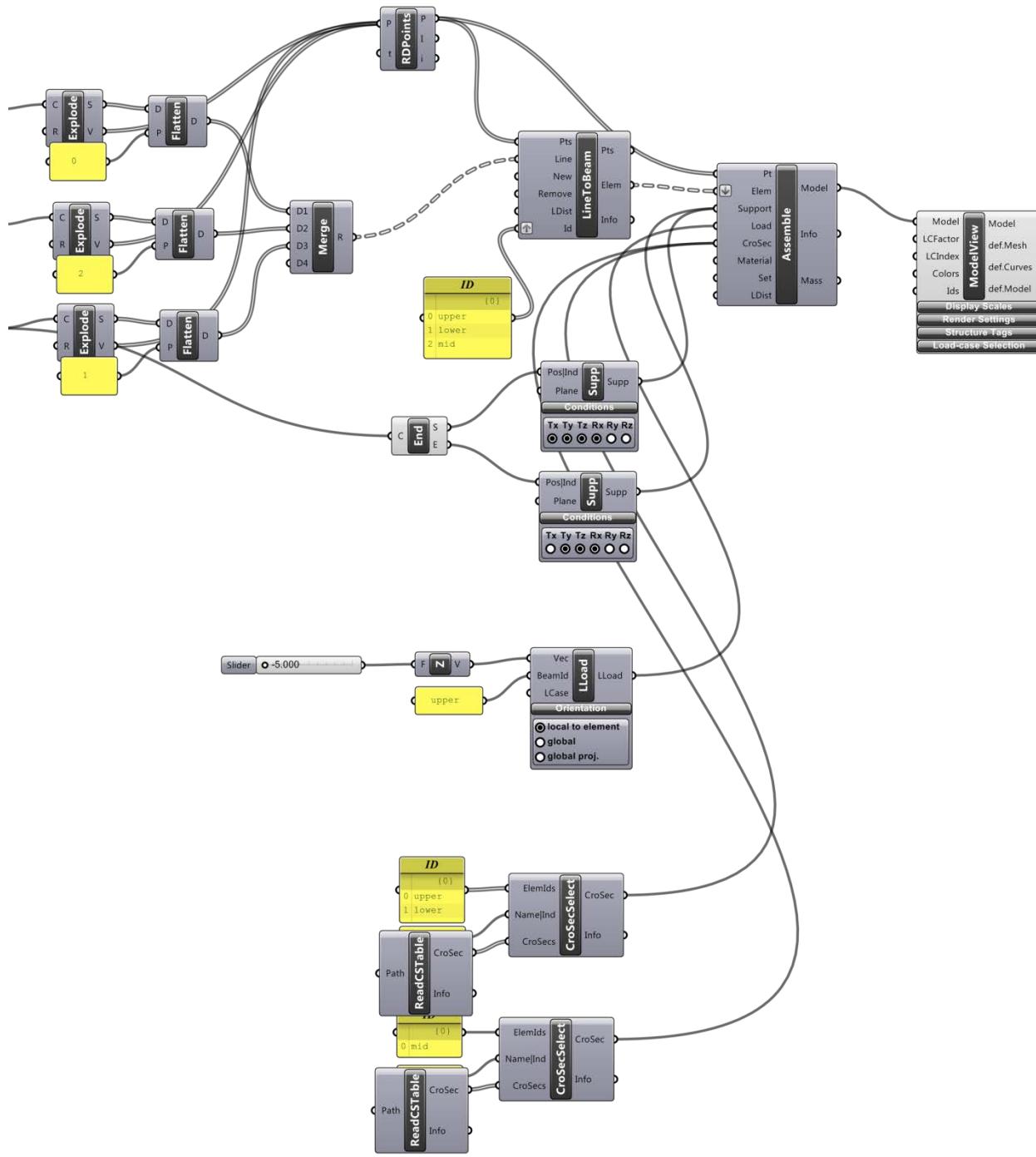
Tutorial 2:



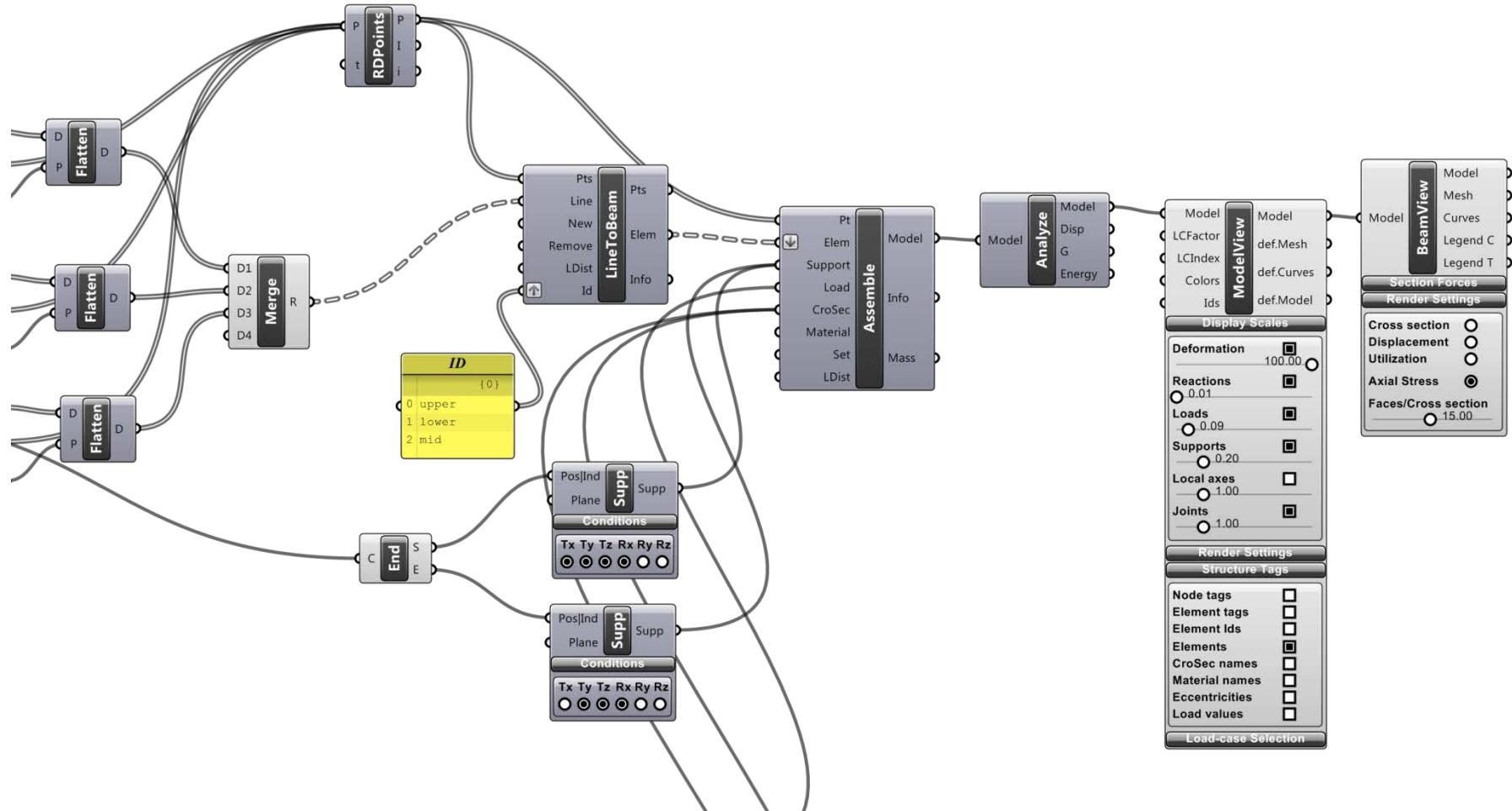
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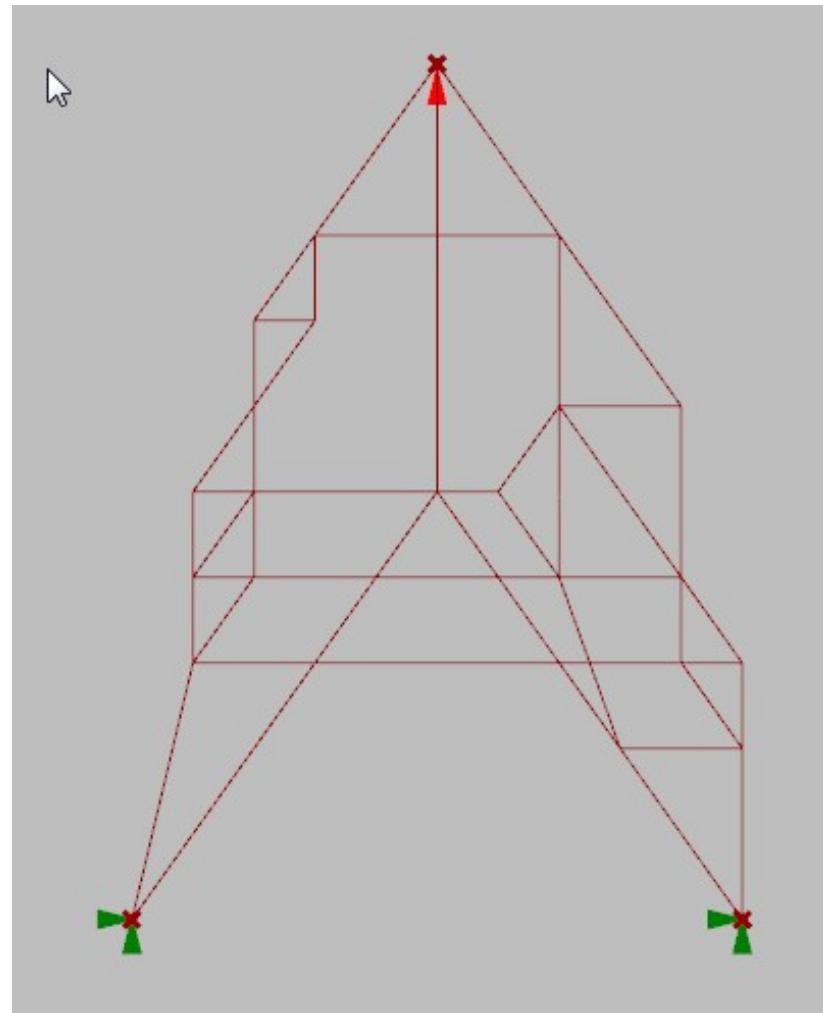
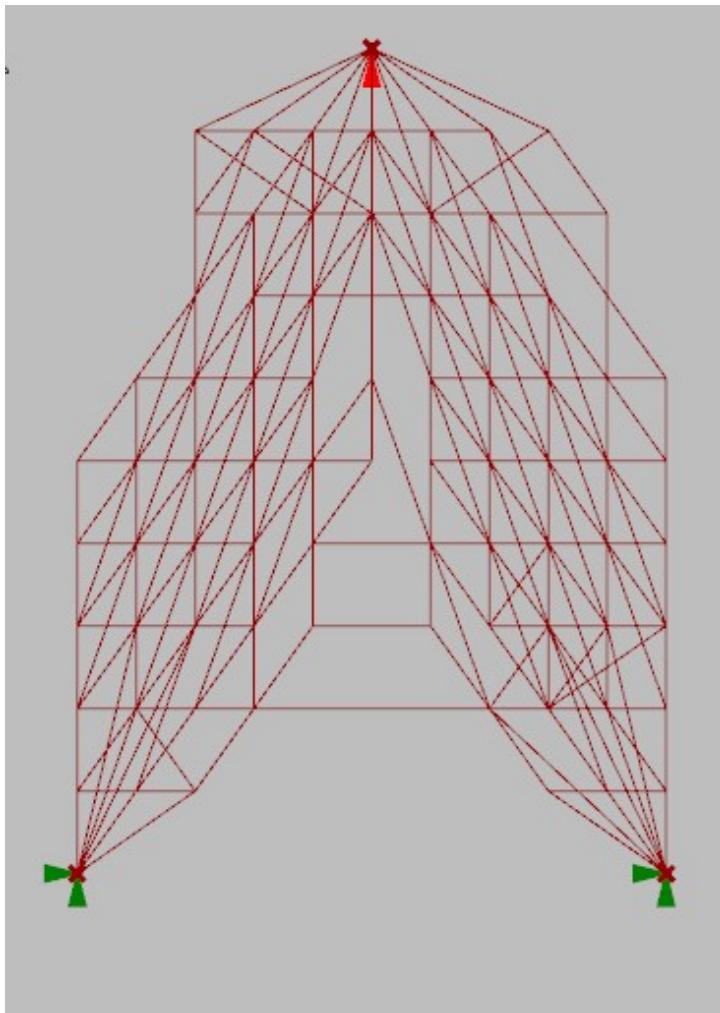
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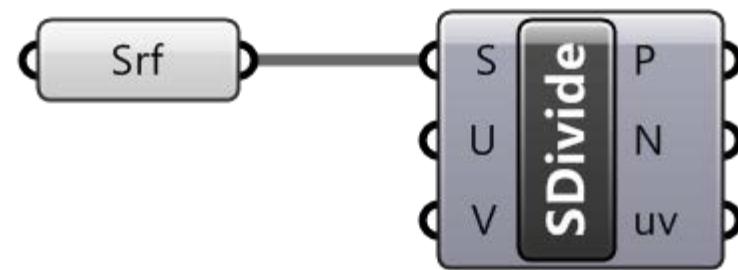
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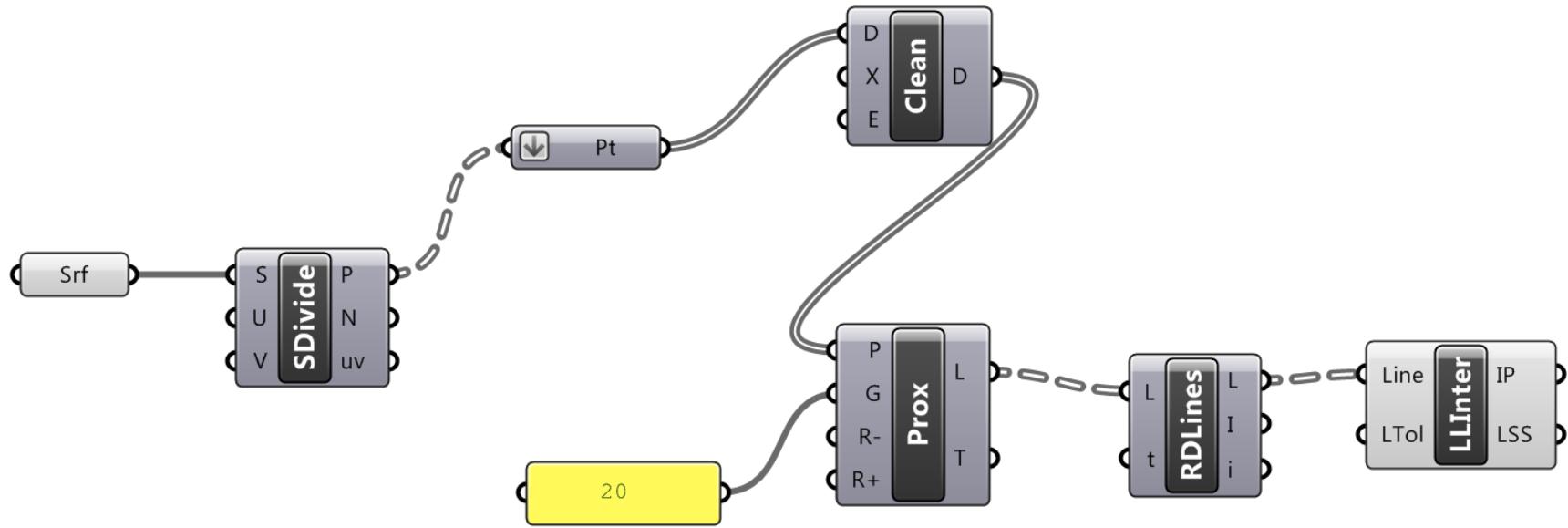
Tutorial 3:



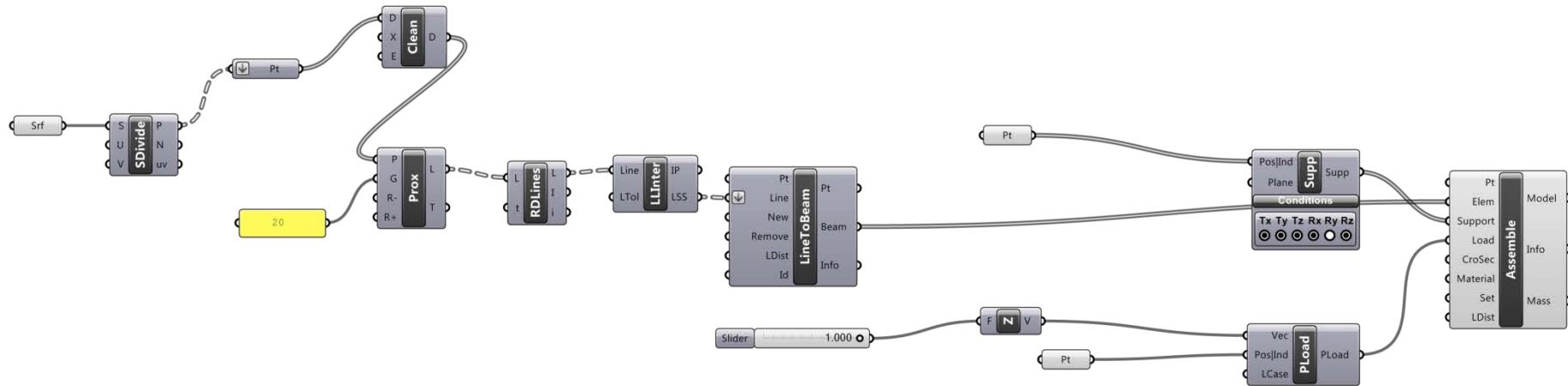
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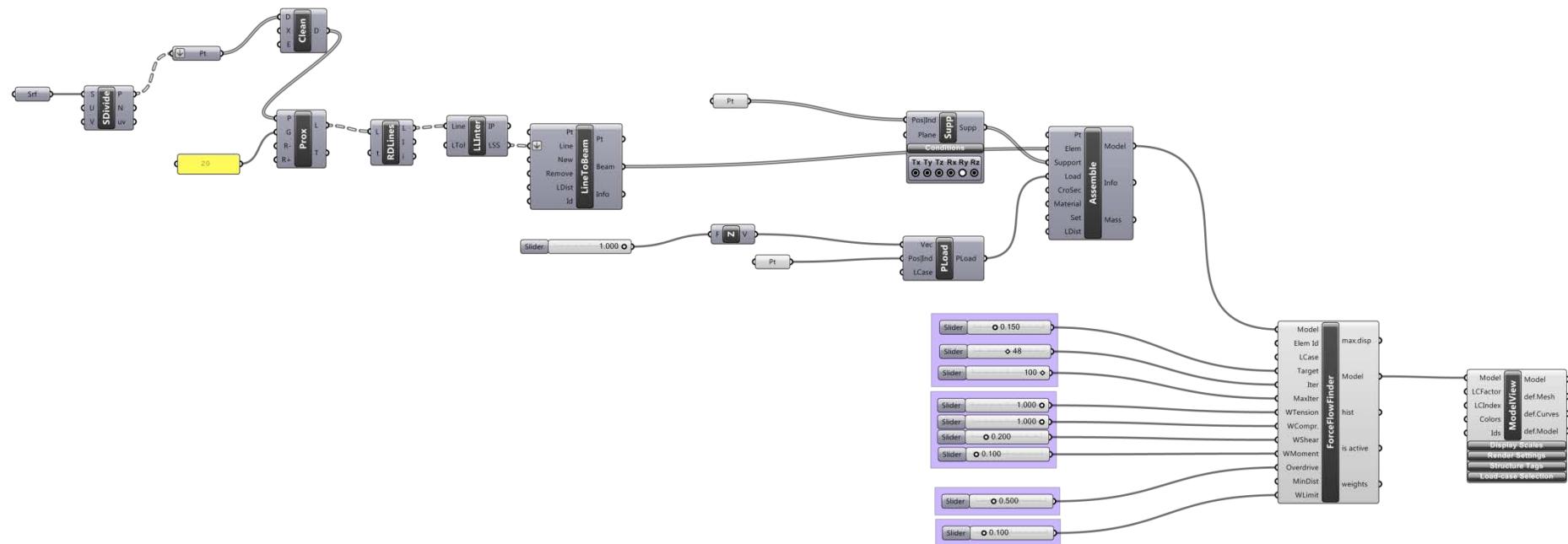
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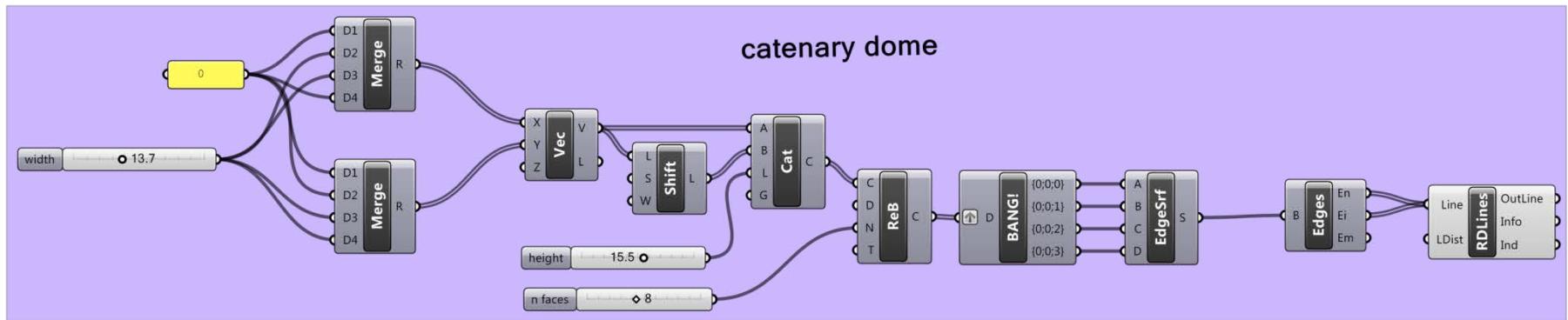
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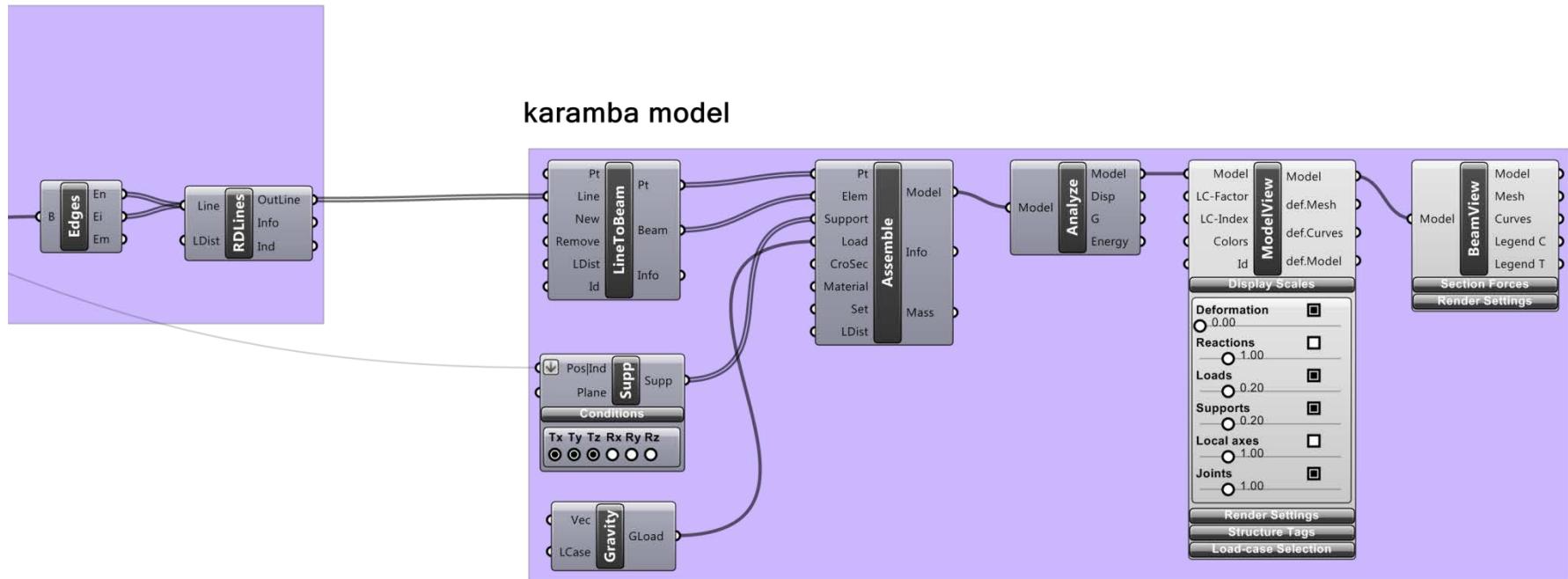
Tutorial 3:



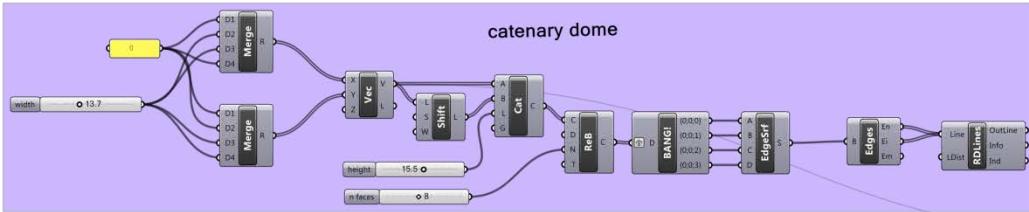
Tutorial 4:



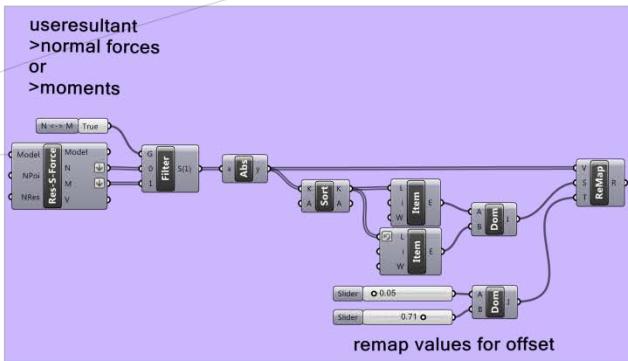
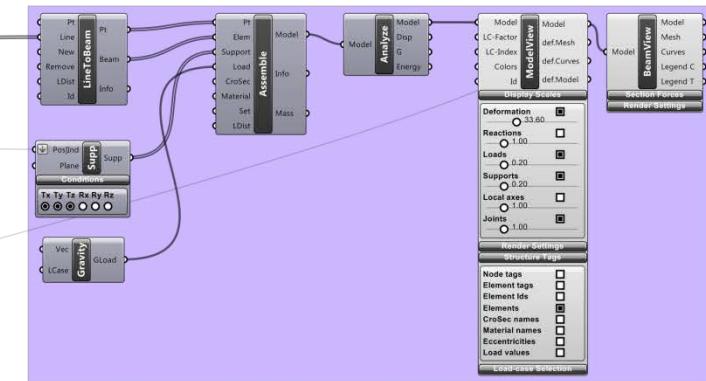
Tutorial 4:



Tutorial 4:

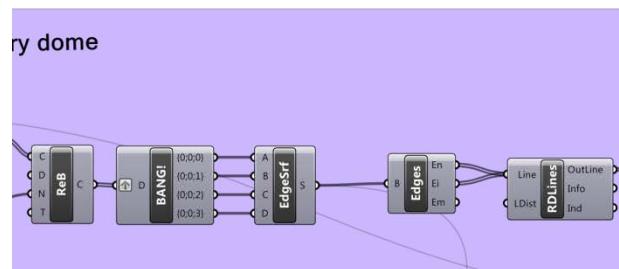


karamba model

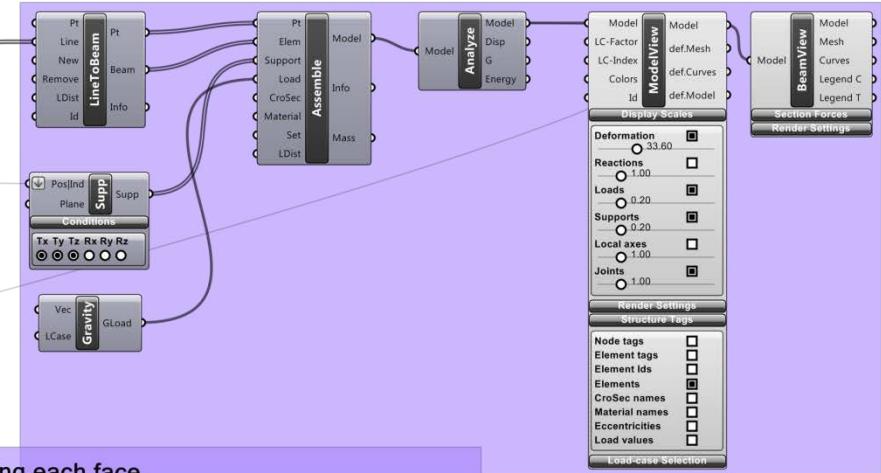


Tutorial 4:

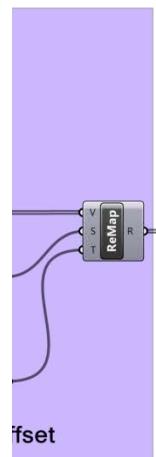
try dome



karamba model



select values neighbouring each face



offset

Tutorial 4:

