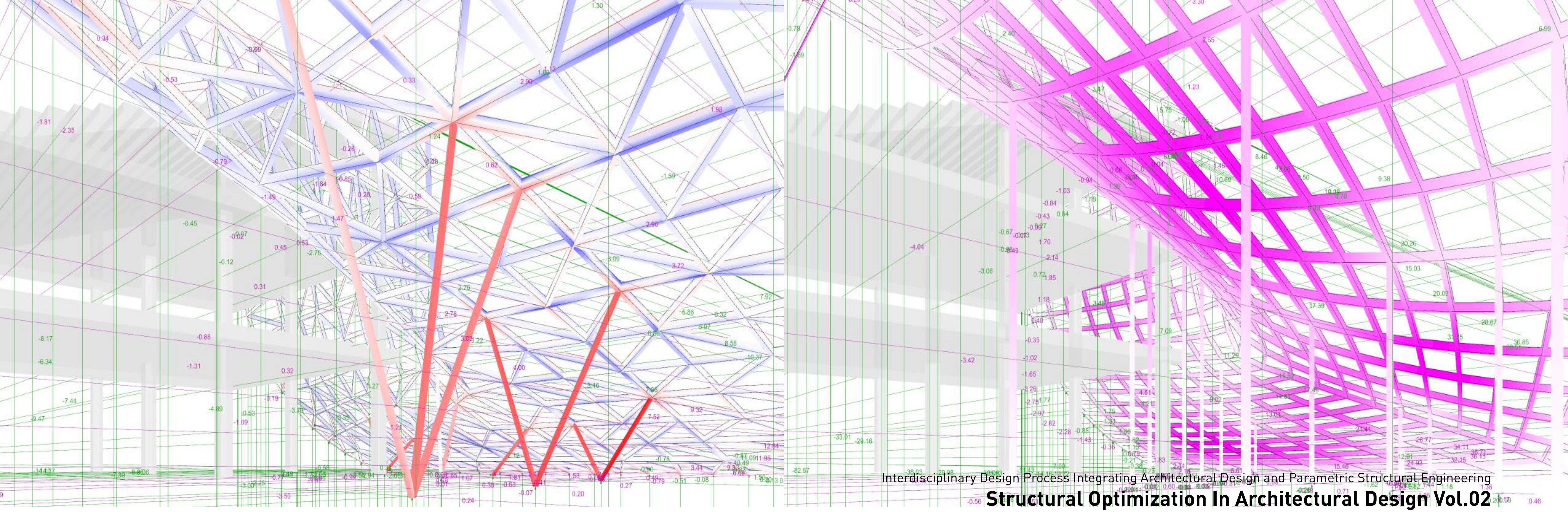

Interdisciplinary Design Process Integrating Architectural Design and Parametric Structural Engineering

Structural Optimization In Architectural Design Vol.02

STRUCTURAL OPTIMIZATION IN ARCHITECTURAL DESIGN.VOL02

Interdisciplinary Design Process integrating Architectural Design and Parametric Structural Engineering

H Architecture

This research paper was written and edited by Dongil Kim, Jaekyung Jake Han, John Hanghyun Cho, Seojoo Lee at H Architecture, 2020.

H Architecture

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Structural Optimization in Innovative Practice of Architecture

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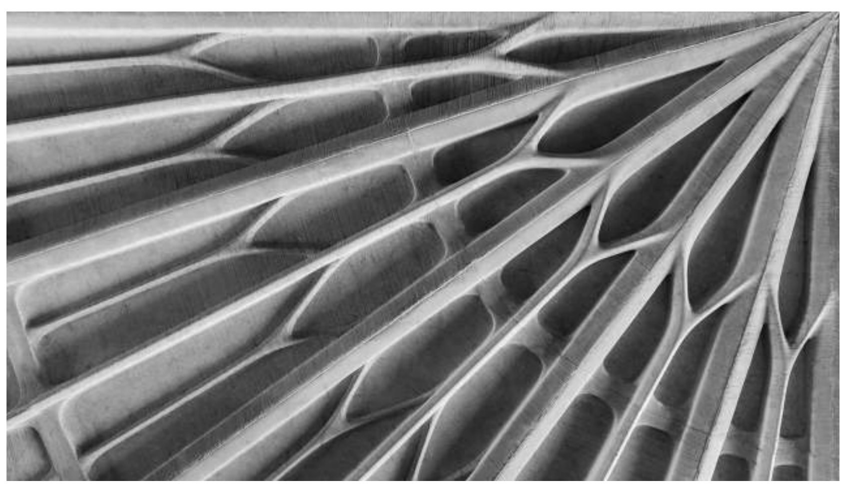
Bottom: The ribbed concrete structure Model of Functional Formwork for A Funicular Floor Research by Digital Building Technologies at ETH Zurich



Structural Optimization in Innovative Practice of Architecture

Structural Data as a design driver

The aim of this research is to investigate the dynamic relationships between innovative disciplines of architecture, computational design, and structural data. As done in the first volume, the second volume also contains both theoretical and practical approaches to structural optimization in design processes which traditional design methods struggle to account for. The interventions are apprehended through a technical and intellectual venturing of structural analysis and creative use of the data and are mediated by algorithms. In this volume, there will be a series of applications to demonstrate how to integrate structural data in contemporary architectural practice.

REVIEW OF LITERATURE

Structure as Essence in Architectural Practice

Bottom: School Building in Leutschenbach, Zürich, Switzerland by Cristian Kerez

Structure as Essence in Architectural Practice

Structural Exploration for Design Innovation in Architecture

There have been rigorous design investigations to design and discover novel shape formation strategies, involving synthetic design process in regards to optimizing material and structural redundancy. The key elements of the Gothic architecture such as vault, buttress and arch are the most seminal examples for the methodological integration of force and matter into formal and structural expression.

Under the spirit of the Gothic Architecture, Antonio Gaudi had explored advanced design methodologies of physical visualization of force by using scale models made of chains and weighted strings for his major projects, such as the unfinished Church of Colonia Guell and Sagrada familia. The hanging chain model and real construction are great to show how he used the forces and material behaviors as drivers for design and methodology of making.

The challenge of the development of synthetic formation was carried over to the next generation of architects such as Frei Otto, Felix Candela and Eladio Dieste. Even though they have distinctive material usage and geometries, their works have commonalities in more advanced design method of force being the driver in design process within the material logic. Despite the Gothic architecture's innovation in synthesizing material, structure and geometry in design, the process required a significant amount of time and labor, and complex constructibility took several decades and even more than hundreds of years to build.

Top left: Physical model of Swiss Re next Headquarter Proposal by Christian Kerez
Top Right: Physical model of the Holcim Competence Center, Holderbank, Switzerland by Christian Kerez

More recently, Architect Christian Kerez's '*House with one wall*' well demonstrates a structural solution that reinforces the architectural expression through meticulous communication between the architects' intuition and the engineers' analysis. Especially, his '*Swiss Re next Headquarter proposal*' and '*Holcim competence center proposal*' show how the structure can become the essence of architectural design. Those projects represent spatial design and structural system as an integration of the circulation, space and structure. Although Kerez's projects are rarely associated with the parametric structural design, the essence of his design very well represents the structural optimization in contemporary practice of architecture.

As mentioned before, the integration of structure and architectural expression requires extended amount of time and labor. However, modern computational technology has equipped the architects with the ability to simulate the force flow of complex geometries with less effort and time. In addition, digital fabrication technology allows for better precision and faster production.

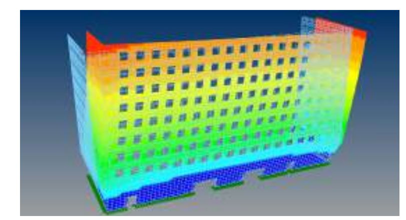
Top: Interior View of Campus Restaurant and Eventspace in Ditzingen by and Werner Sobek

The roof structure of '*the Campus Restaurant and Eventspace in Ditzingen*' by the architect Barkowleibinger and Werner Sobek, director of ILEK(Institute of lgith weight design and construction)is a long-span polygonal leaf-like canopy over groups of columns. The structure combines a steel frame and a group of columns with a glulaminated wood-cell infill. This wood cell is functionally coded and constructed either as a skylight with solar-glass, a perforated wood acoustic planking or an artificial light modified by an aluminum-honeycombed deflector. The close collaboration with structure research group brought about very crucial early reference in parametric structural optimization in contemporary practice.

More recently, a parametric structure software such as Karamba 3D has been emerged, design professionals and academic research groups have devoted themselves into the parametric structural optimization.

'*The Shogakukan Building*' by Nikken Sekkei is a seminal project to explain the creative and innovative use of parametric structural optimization. The intent of the project is to optimize varying aperture sizes without sacrificing the structural performance of the shear wall. Several configurations were tested to compare how the differences in aperture sizes

Top left: Shogakukan Building Front Facade in Tokyo, Japan by Nikken sekkei
Top Right: Early Structure optimization Study (Karamba3d) of Shogakukan Building by Nikken Sekkei



affected to surface structural performance against lateral forces. To simulate this, studies were undertaken with the height and number of apertures as a fixed variable, and the widths as an active variable.

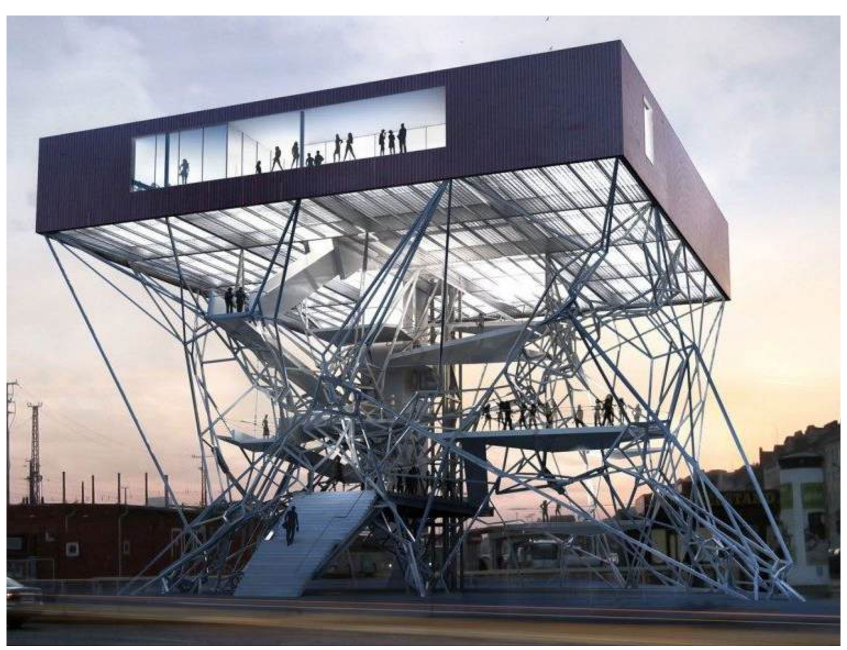
'*Infobox design proposal*' by Michael Wallraff, with engineering support from Bollinger + Grohmann, is to raise a structure on twenty-two meters above ground level. The design exercise for load transferring to the ground is limited by underground sewers, a parking lot and a bus terminal. Although the steel structure of the box was planned as a regular steel grid, the limited surfaces suitable for laying the foundations made it impossible to set the supports at regular intervals. Furthermore, the several planned levels linked by staircases were not to be pierced by structural members. Against these limitations, a generative process was used to develop a complex three-dimensional structure that would not only be structurally sufficient, but also a distinctive design feature.

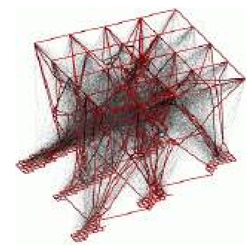
Besides the forementioned projects, there are several contemporary designers and studios which have already practiced scientific and technological improvements in built projects. One recent example is done by a research team led by Arup which has applied the 3D printing technique to the production of steel

Top Right: Structural Optimization of InfoBox in Vienna Central Station, Austria by Michael Wallraff
Bottom: Rendering of InfoBox in Vienna Central Station by Michael Wallraff

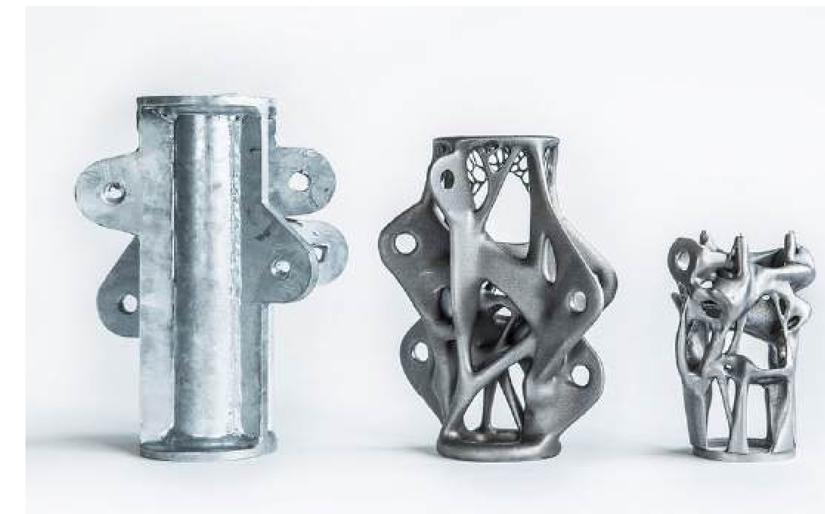
joints to produce a lightweight tensile structure joints characterized by a complex shape and customizable design. The process is developed based on addictive laser sintering principle and employing steel derivatives as printing materials. A series of prototypical models show the evolution of a steel node from the initial design to the final one. Three structural elements (nodes) are all designed to carry the same structural loads and forces. The third item is designed to adopt the latest optimization methods. As commented by Salom Galjaard, the team leader, "By using additive manufacturing we can create lots of complex individually designed pieces far more efficiently. This has tremendous implications for reducing costs and cutting waste. But most importantly, this approach potentially enables a very sophisticated design, without the need to simplify it in a later stage to lower costs."

As academic institutes and professional research groups have devoted themselves to the optimization and the production of structural members, it has become apparent that new research methodology is necessary. Increasingly, the method of design with parametric engineering from academic and industry leaders in this field has been developed and disseminated through theories, experimental design researches, and innovative professional practices.





Top: 3D Printing steel joints designed by the Arup's team: the three structural elements (nodes) are all designed to carry the same structural loads and forces (reproduced from ARUP [2014]).



The research "STRUCTURAL OPTIMIZATION IN ARCHITECTURAL DESIGN VOL.02" focuses on design exercises and application from early design stage to design development.

APPLICATION

1. Application on Partly Occupiable Roof Structure Ver.01 & Ver.02
2. Application on Partly Occupiable Roof Structure Ver.01 & Ver.02
3. Application on Partly Occupiable Roof Structure Ver.01 & Ver.02

Top: South entrance under the cloister of the new Chungju city hall project
Bottom: East Main entrance view of the new Chungju city hall project

Parametric Structural Optimization on Chungju City Hall

The research has been conducted on a series of area on Chungju New City Hall project. Following case studies have been focused on how to apply parametric structure optimization as design driver on early design phase. This research focuses on three specific parts of design process in the aforementioned project.

First case study explains "Multi-criteria optimization of slanted roof with structural pattern and column shape and location". This study allows dynamic changes in structural pattern and density, and load distribution of columns.

Second, "Material and Displacement Optimization on Column Positions" chapter aims to explore how to optimize the column positions and shapes on the cloister of the project. This is to accommodate contextual conditions of the projects and ever-changing programs under the Plat roof structure.

Last chapter of this research, "Material Distribution on Structural Optimization", is to find the ideal structural member distributions in terms of material and load. The study result represented in this chapter is the ideal condition of structural optimization in terms of material efficiency, even though it might be less cost effective within design system and work.

These sets of studies is to discover on potential application of parametric engineering optimization in early stage of design phase and expects to serve as a prototype for future projects at H Architecture.

METHODOLOGY

01. Application on Partly Occupiable Roof Structure
02. Application on Flat Roof with Context
03. Application on Facade Module Assembly

METHODOLOGY.01

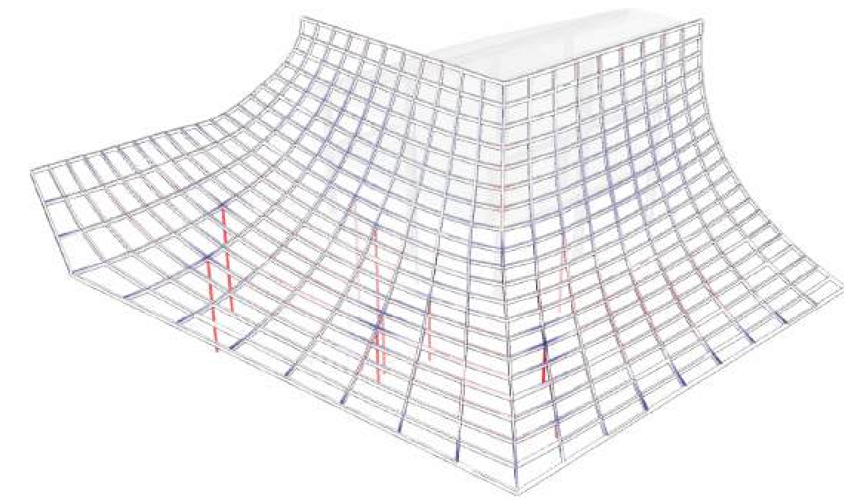
Application on Partly Occupiable Roof Structure Ver.01 & Ver.02

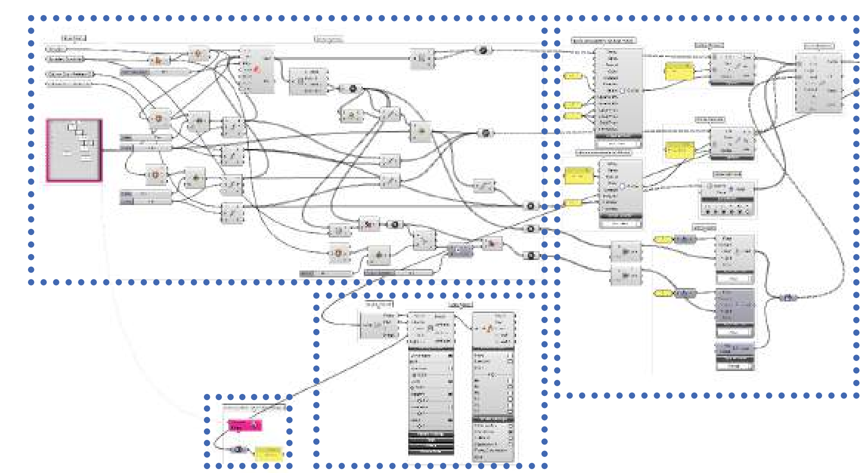
Application on Partly Occupiable Roof Structure Ver.01

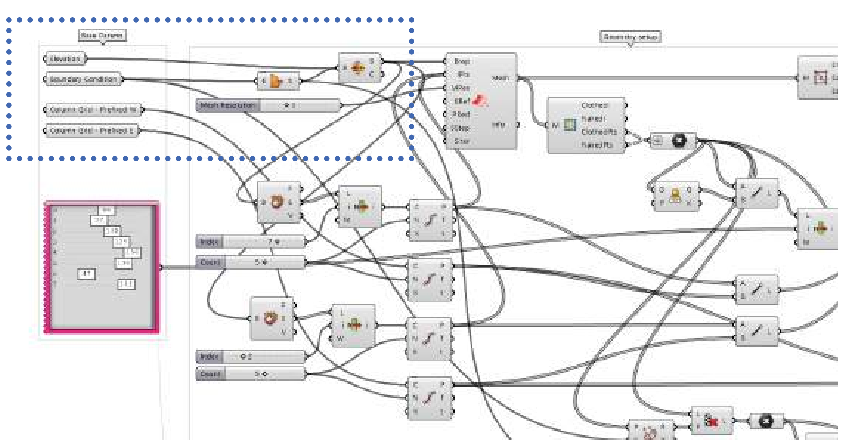
This chapter introduces structural analysis and application of the calculation to sub-structure of the slanted roof and stair aligned in single surface. Two means of application will be illustrated in this case study. One is to relocate the vertical column on entrance area for supporting irregular patterned type roof sub-structure, another is to branching the column aligned to single column line for supporting the regularly distributed grid type roof sub-structure.

The work flow of this section is following order and objective.

- How to set up the sub-structure geometry in Parametric way
- How to prepare the calculation in accordance with practical requirements
- How to connect it to Karamba3d software for calculation
- How to get the best location for column by using evolutionary computing





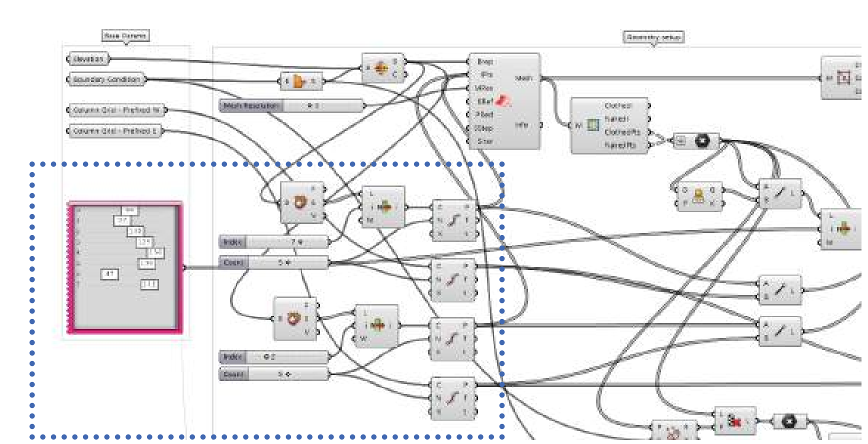


Import Roof Surface

1) Bring designated surface into Grasshopper environment

2) Convert it as a boundary representation

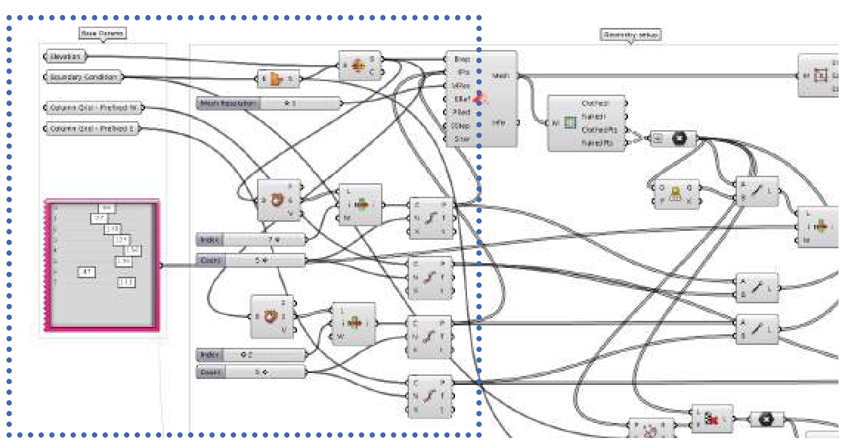
3) Join the breps to convert it into single mesh surface



Setting up Fixed Column location

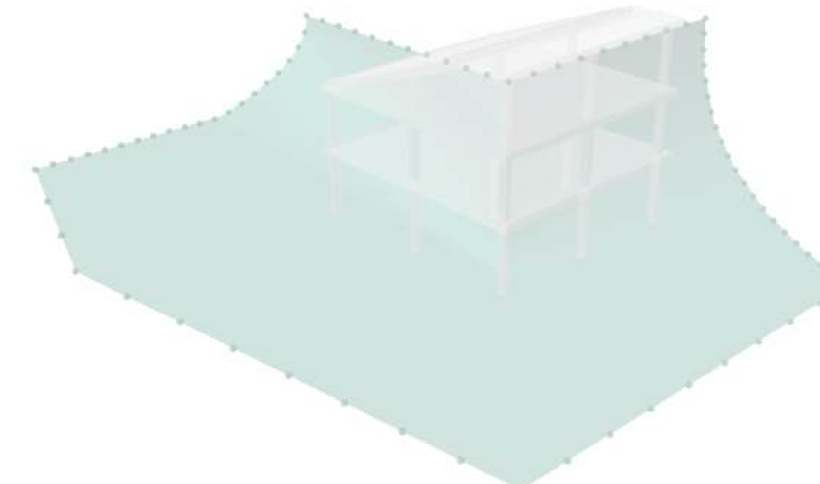
1) Bring fixed column line as a curve

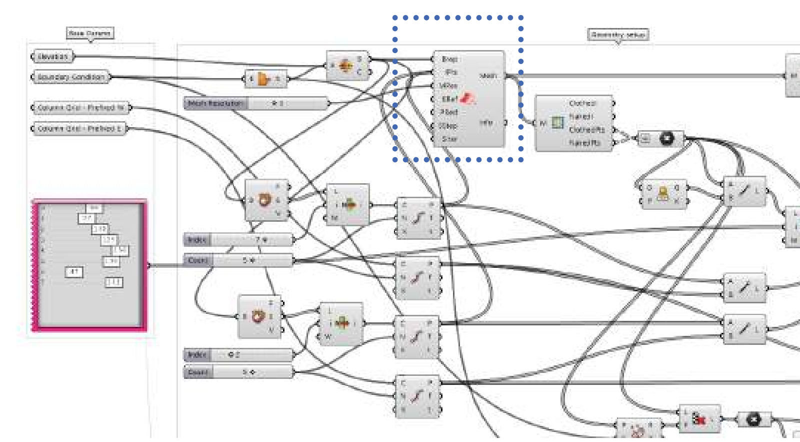
2) Divide the curve in accordance with the design



1) Sorting out the edges corresponding with the fixed column line

3) Divide the sorted out edges into the number of fixed columns



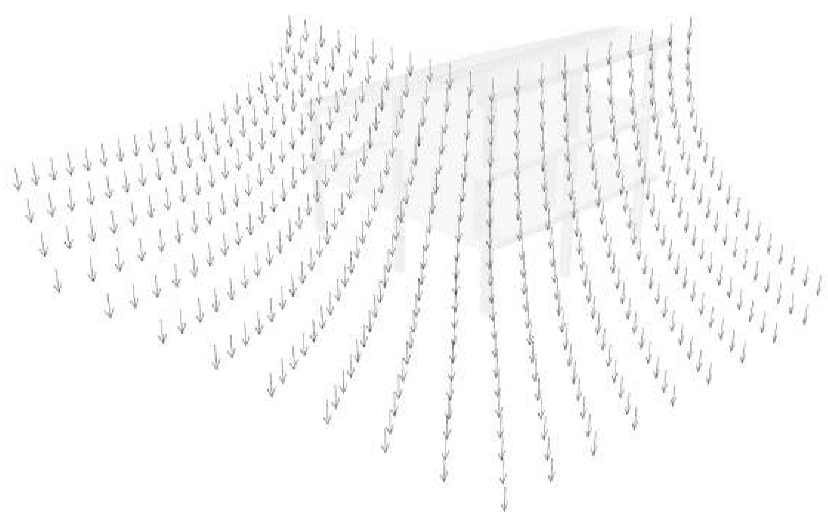


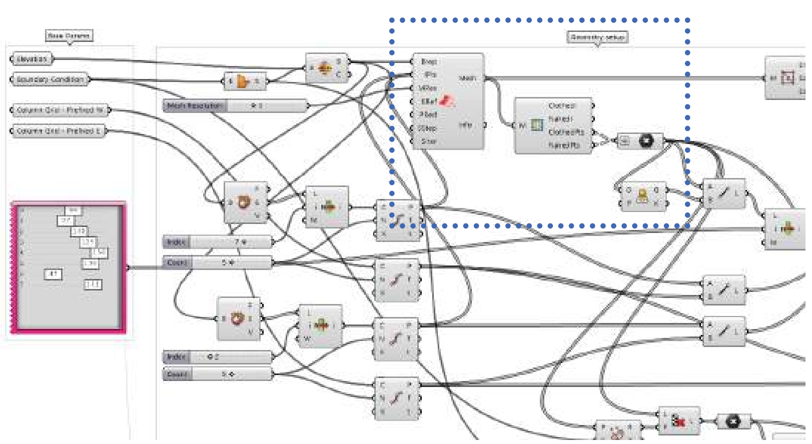
Create Mesh from Surface and Fixed Column location

1) Convert joined breps to mesh

2) Input the mesh resolution

3) Connect divided points from selected roof surface edges

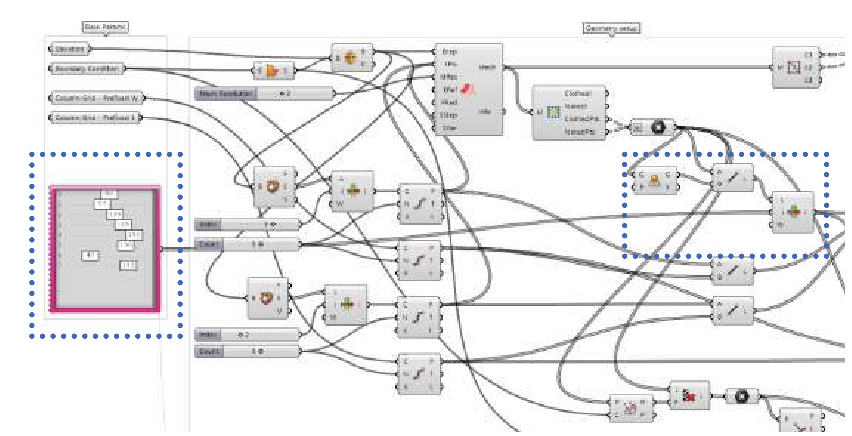




Create Possible Column Locations

1) Sorting out the points from mesh

2) Project the points to the default plane

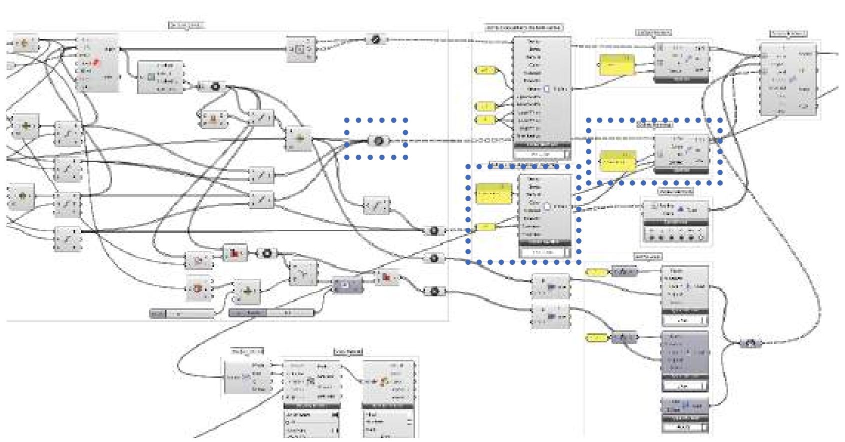


Set up Number and Location of the Column

1) Create Genepool with a specified number of the column

2) Set each genes to have maximum number as a list length of the projected points

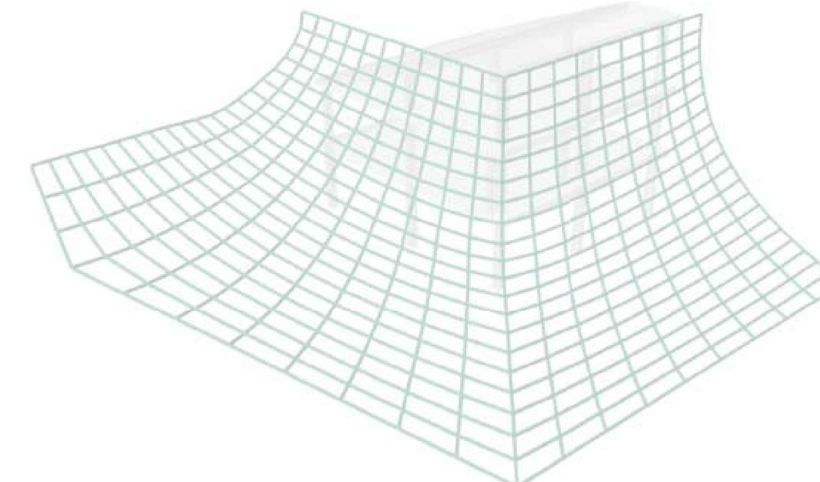
3) Connect the original and projected points and sorting out by connecting genepool

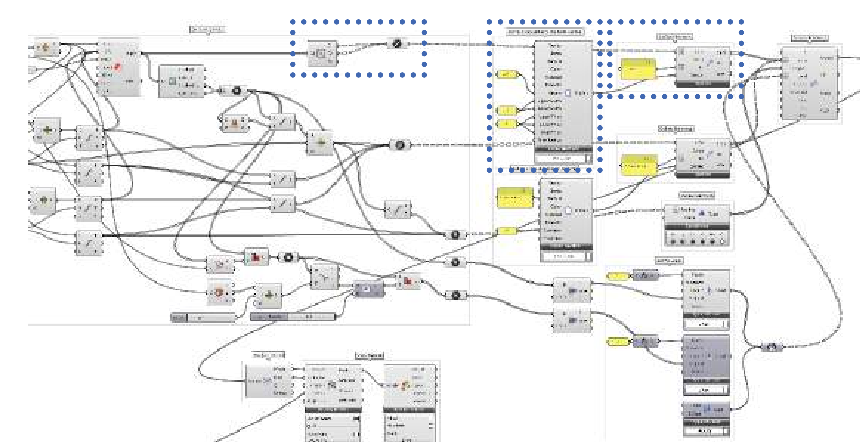


Set up Structural Element

1) Sorting out the column elements from former process

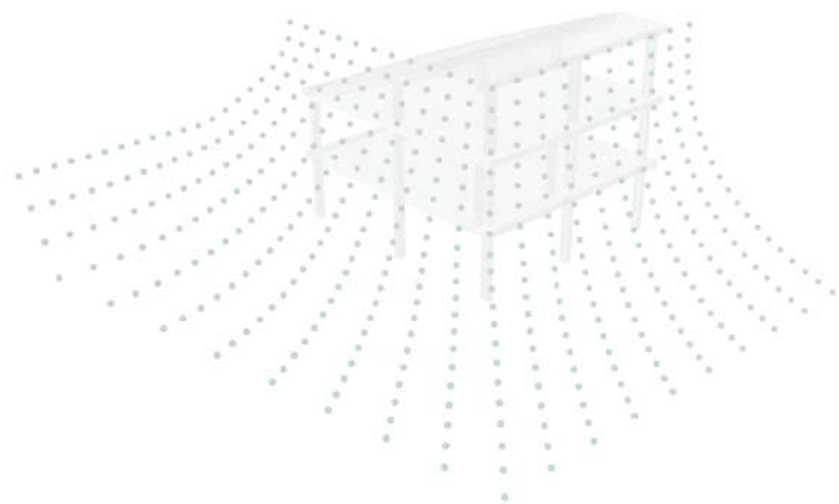
2) Create structural column with designated cross section

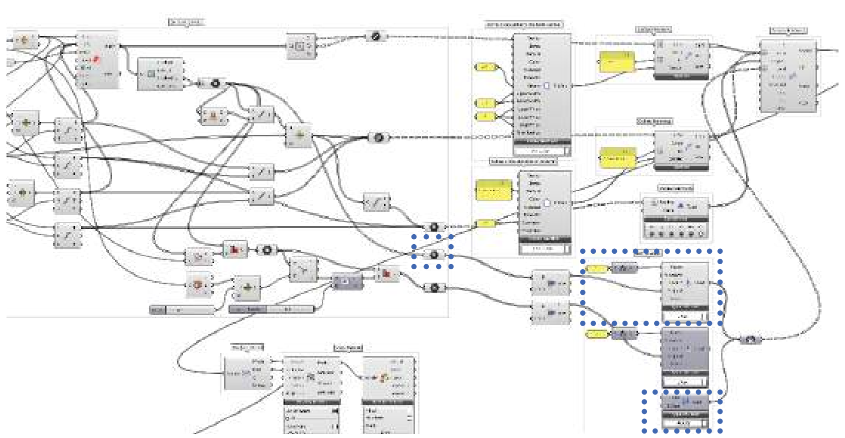




1) Sorting out the beam elements from former process

2) Create sub-structure of roof with designated cross section

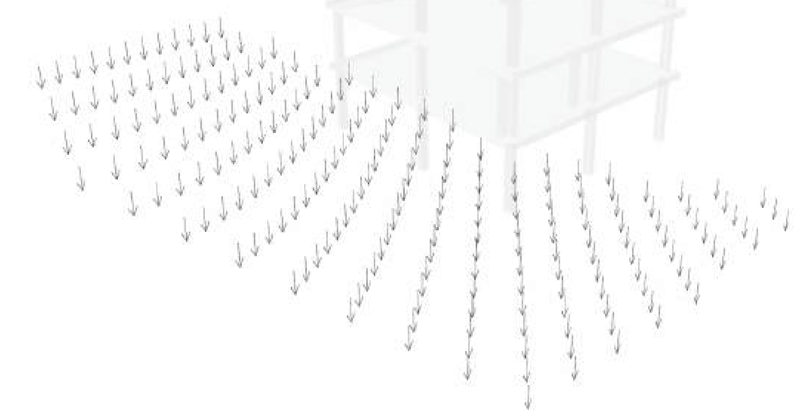


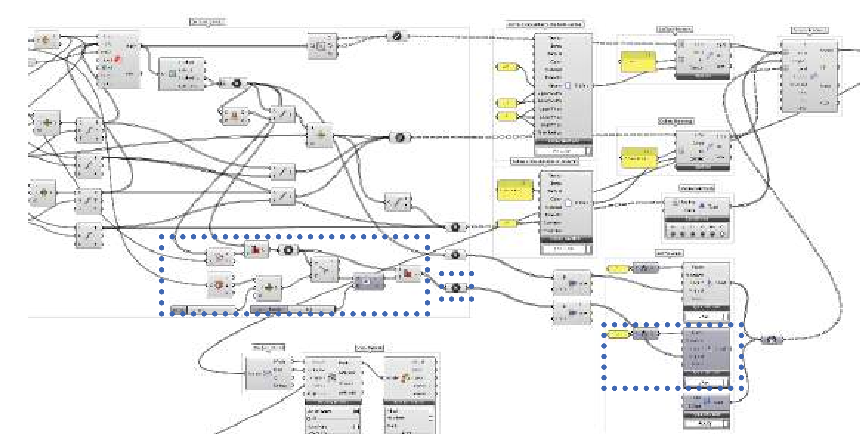


Set up Load

1) Sorting out the points for gravity and point load (dead load)

2) Connect it to designated load setting component



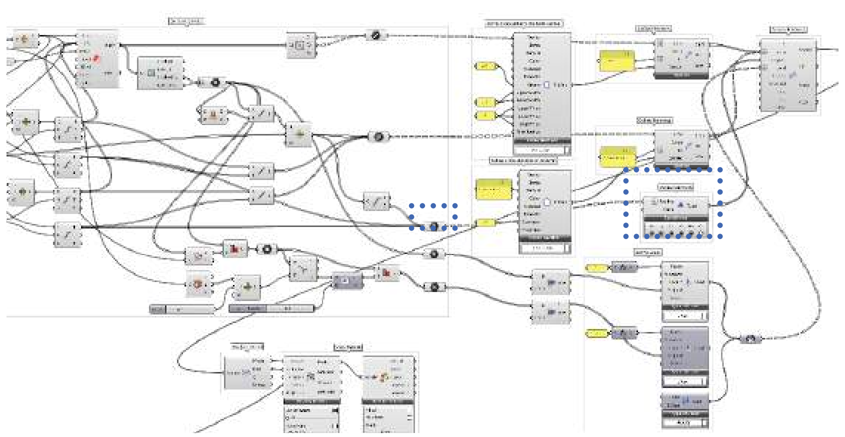


Set up Load for Staircase part

1) Sorting out the points located within stair of the roof

2) Connect it to designated load setting component

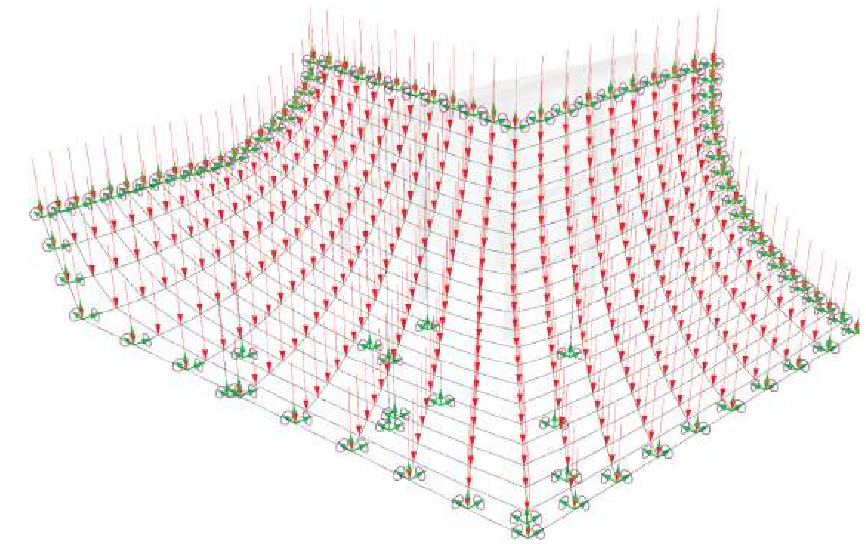
3) Apply live load for the points (1000 lbs for stair)

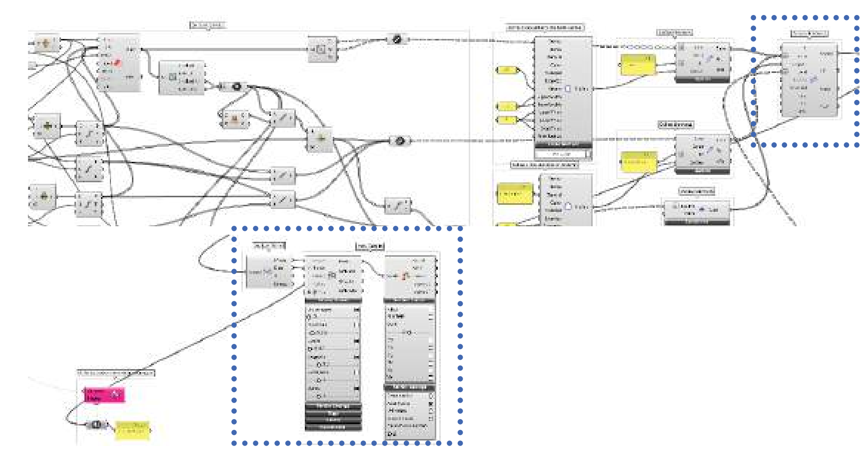


Set up support

1) sorting out the lowest points for Grasshopper support

2) set up the support condition

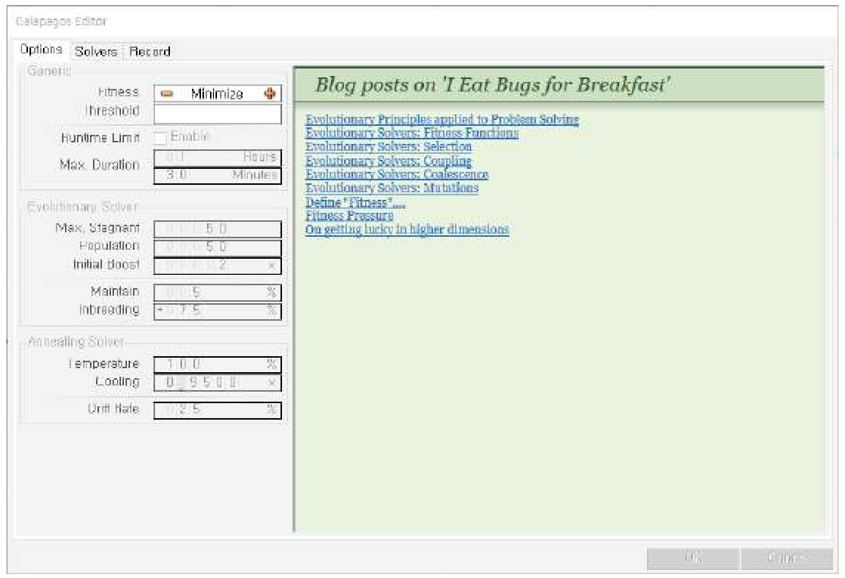


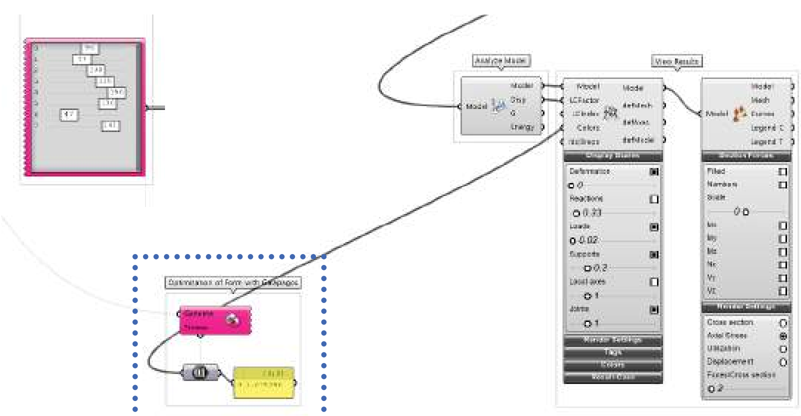


Assemble Model

1) Connect all items for the structural calculation

2) Connect it to model view for display



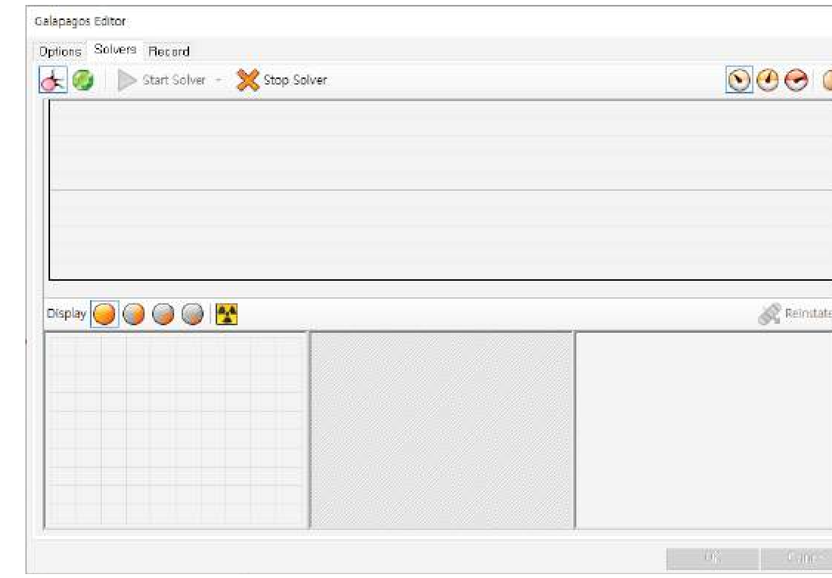


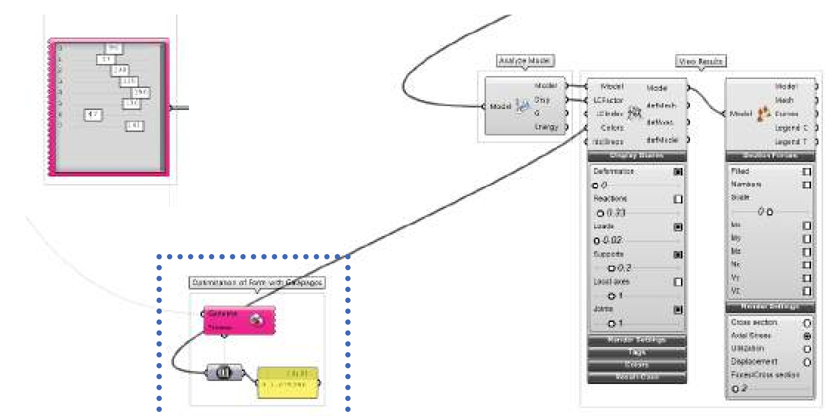
Organize Galapagos

1) Connect genepool numbers for genome

2) Connect displacement to fitness

3) Open Galapagos and set the setting as minimize for less displacement



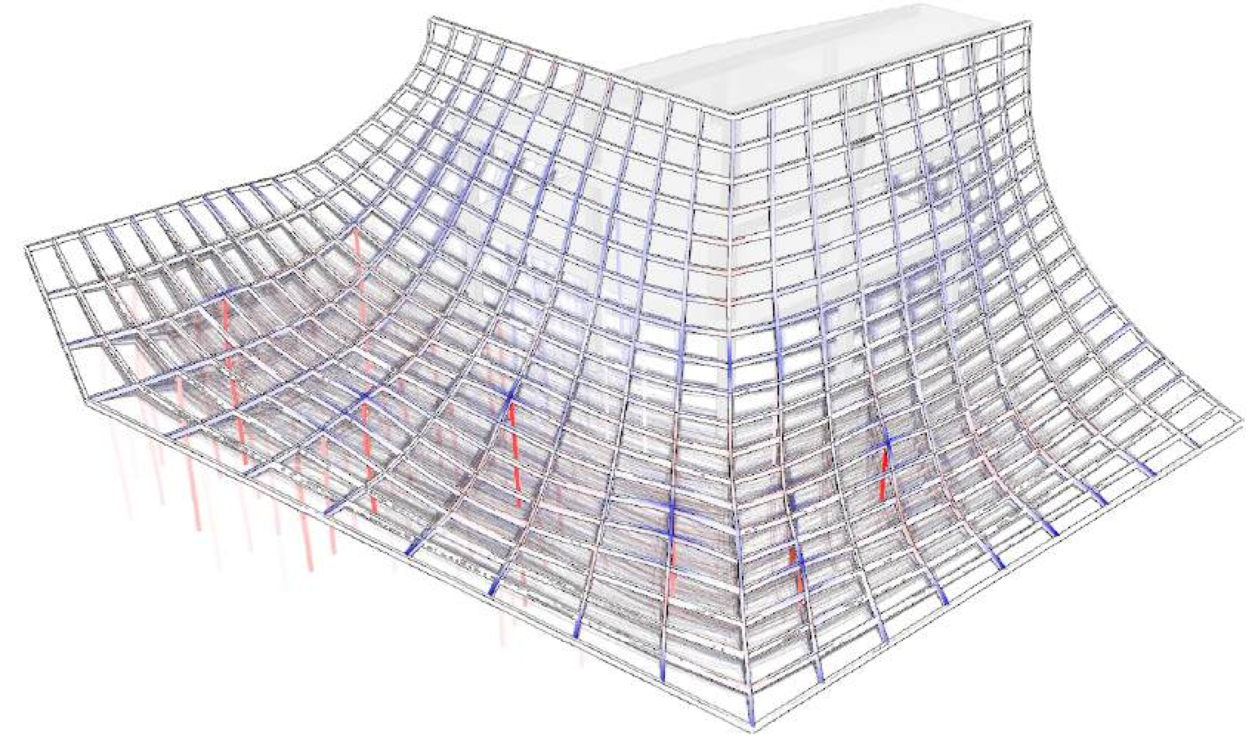


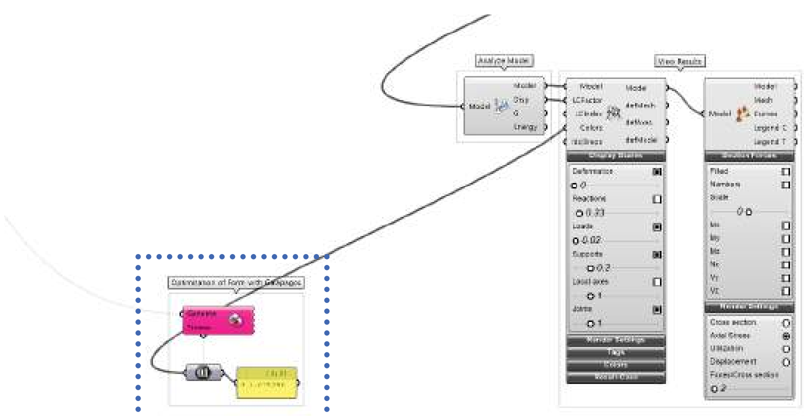
Run Solver

1) Move to solver tab and start evolutionary solver for the optimization

Displacements in different column locations

Displacements in different column locations

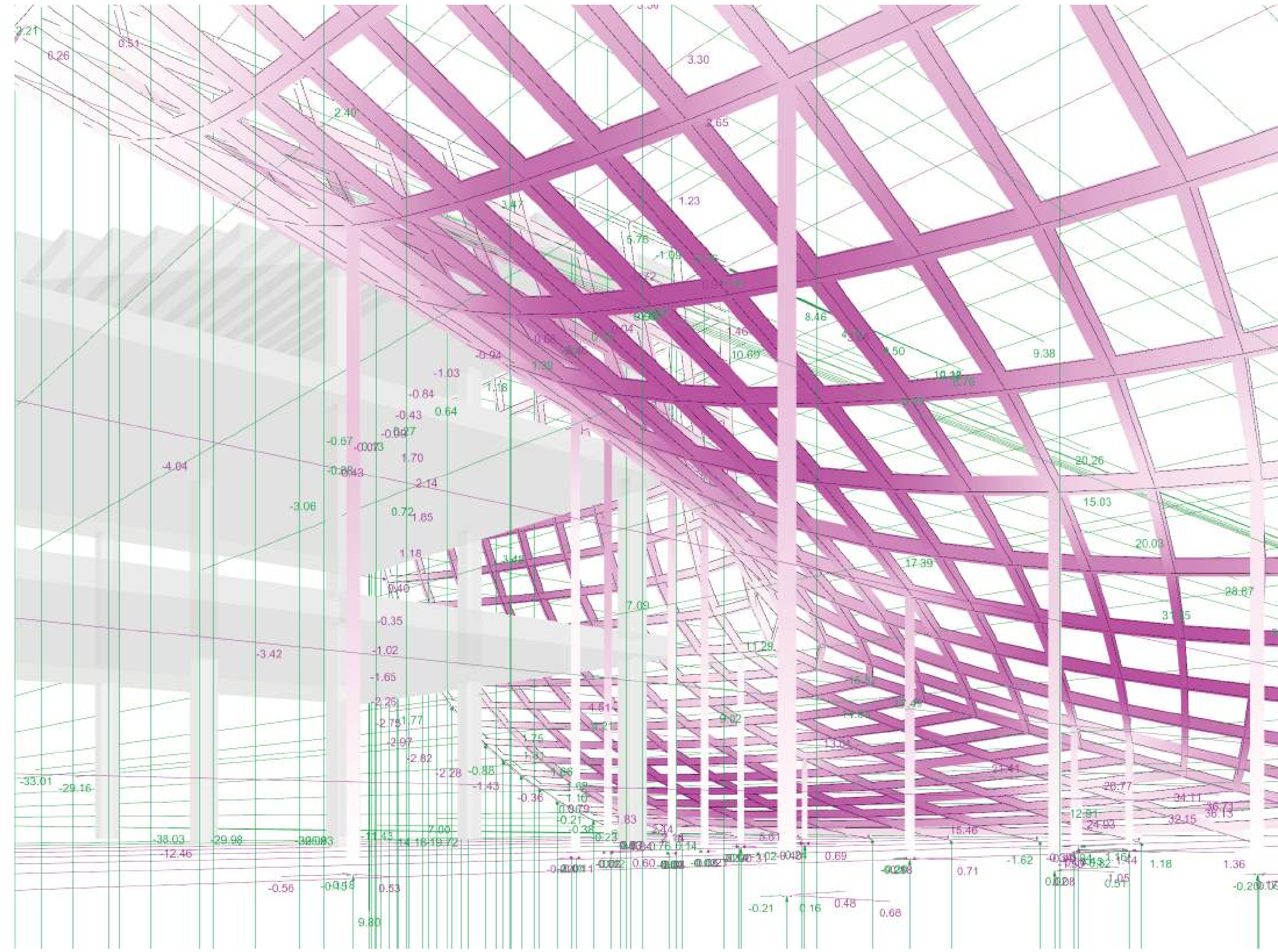




Reinstate the Optimized Option

1) Reinstate the top tier of the option

2) Check rhino viewport for the result



Application on Partly Occupiable Roof Structure Ver.02

This chapter introduces structural analysis and application of the calculation to sub-structure of the slanted roof and stair aligned in single surface. In this second chapter, the case study will branching the column aligned to single column line for supporting the regularly distributed grid type roof sub-structure.

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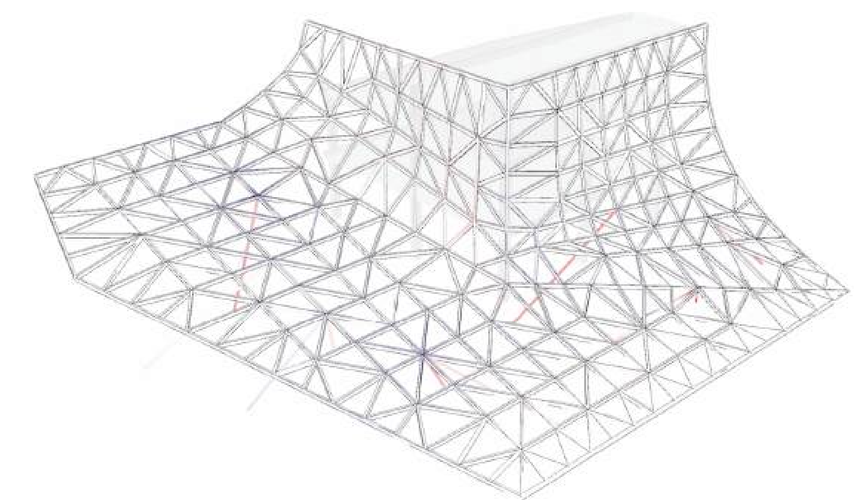
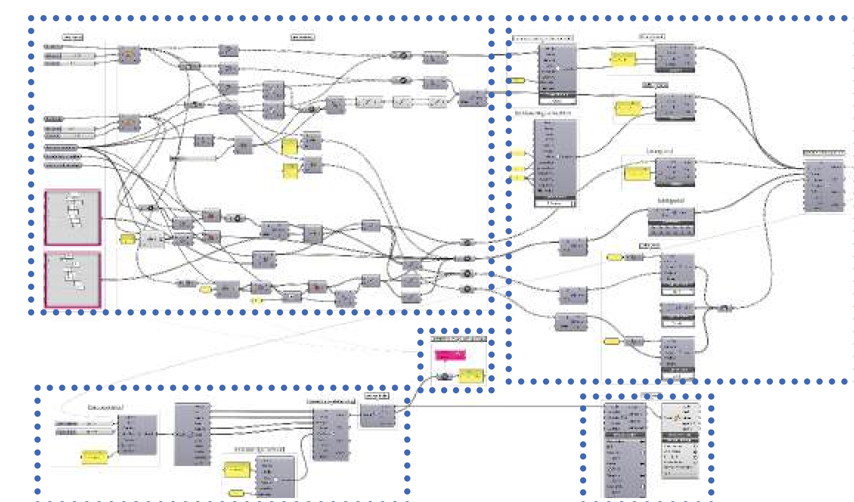
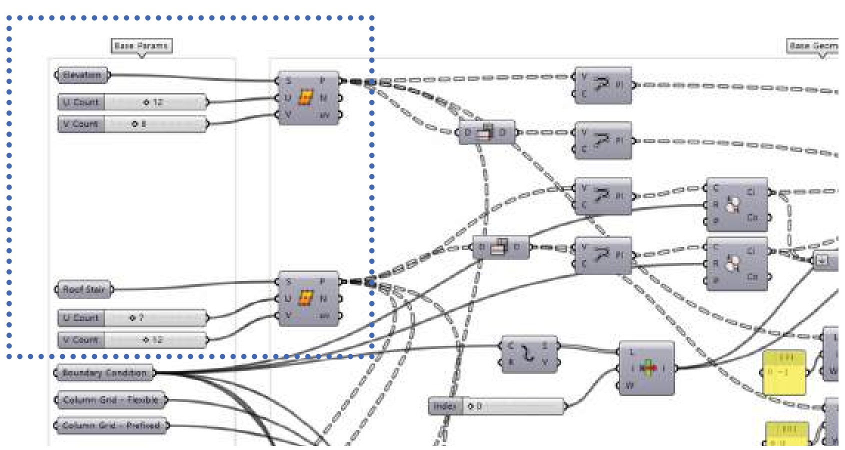


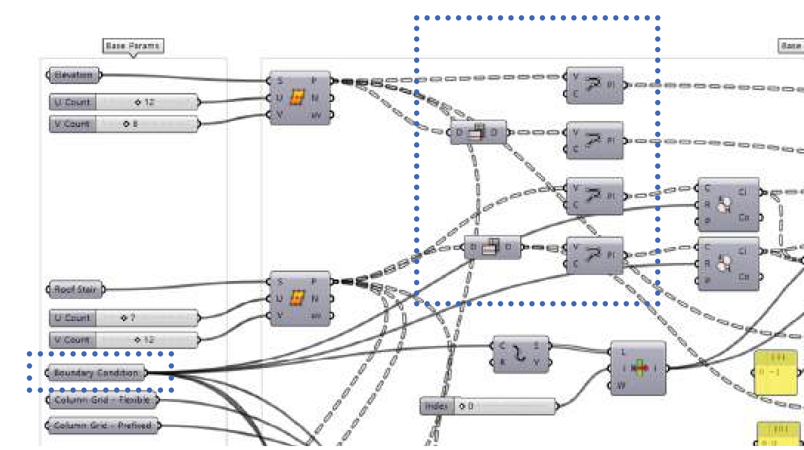




Import Roof Surface

1) Bring designated surface into Grasshopper environment

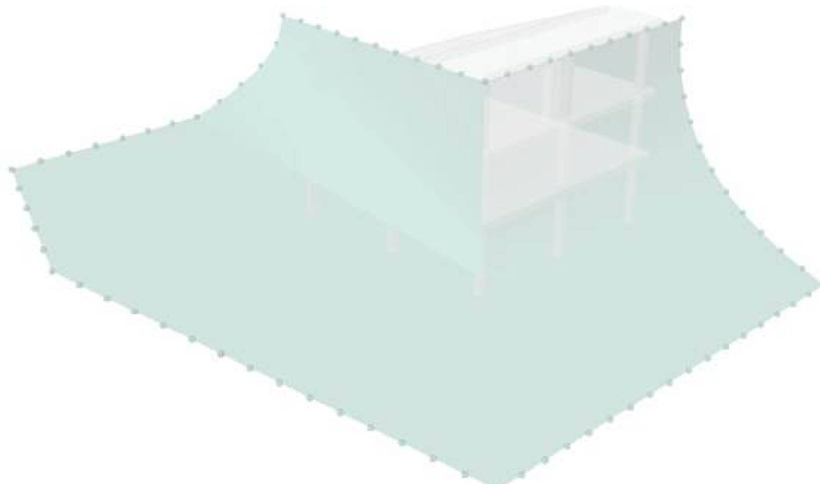
2) Sub-divide the surface with proper numbers in U,V direction

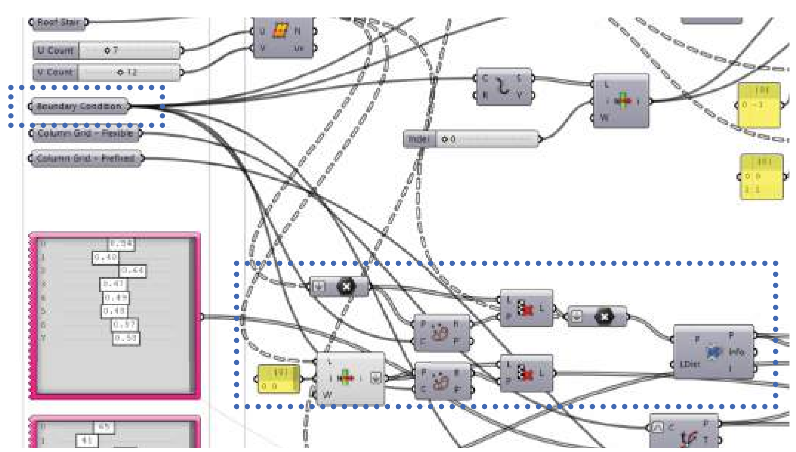


Setting up Fixed Column location

1) Sorting out the points not belongs to the designated roof shape and cull the item

2) Generate set of polylines with list management

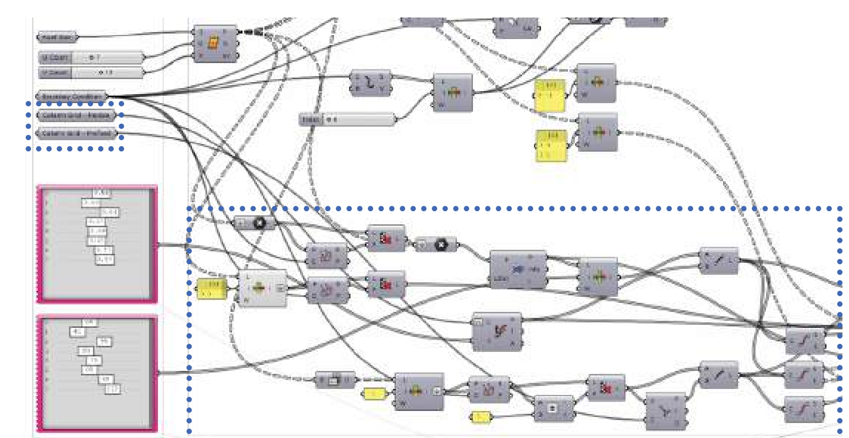




Import Roof Surface

1) Sorting out set of points not belongs to the roof surface boundary and cull the item

2) Eliminate duplicated items in the list



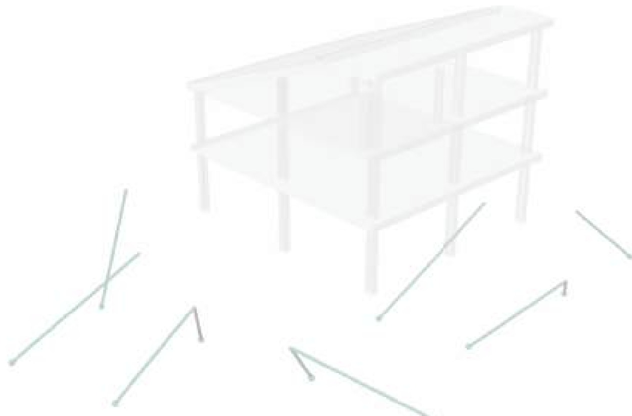
Set up Column location

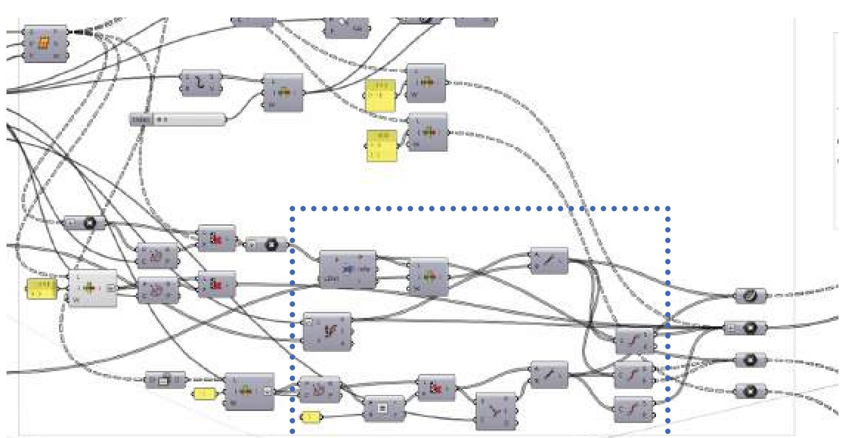
1) Reparameterize the column line and set points for column with genepool

2) Assign designate number in genepool for location and number of the column

3) Sorting out closest points from previously subdivided surface edge

4) Cull the points not belongs to the surface and define closest points in edge

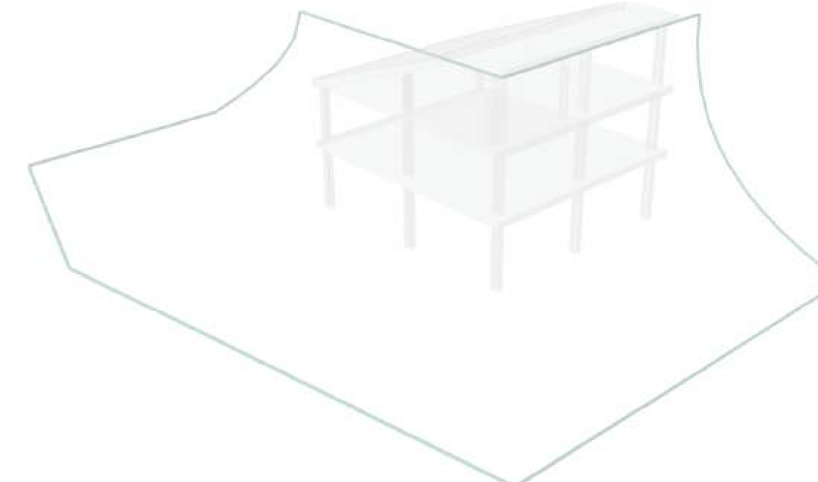


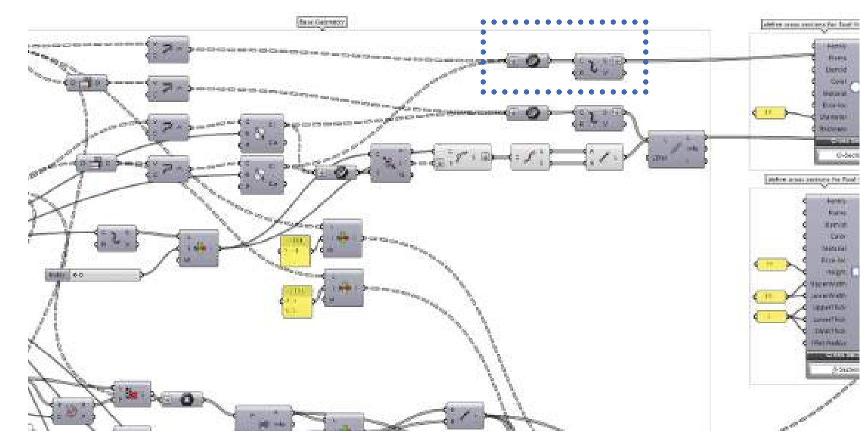


Create Column Elements

1) Sorting out specific points from subdivided surface points list

2) Create column with sorted out points from former process

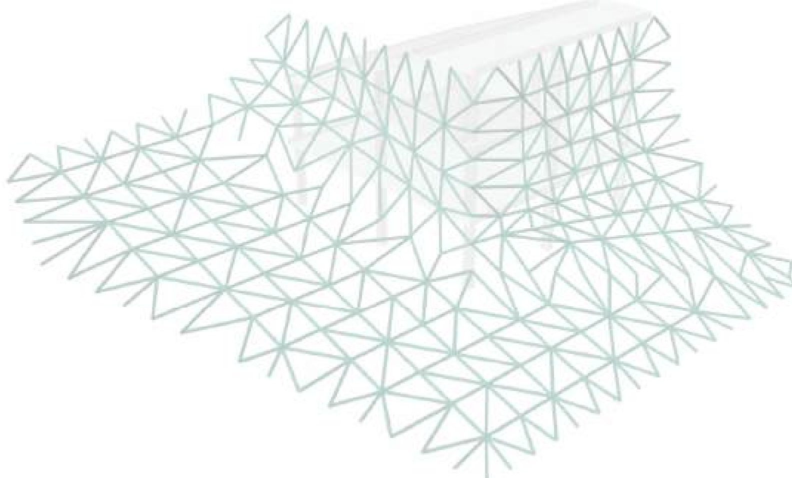


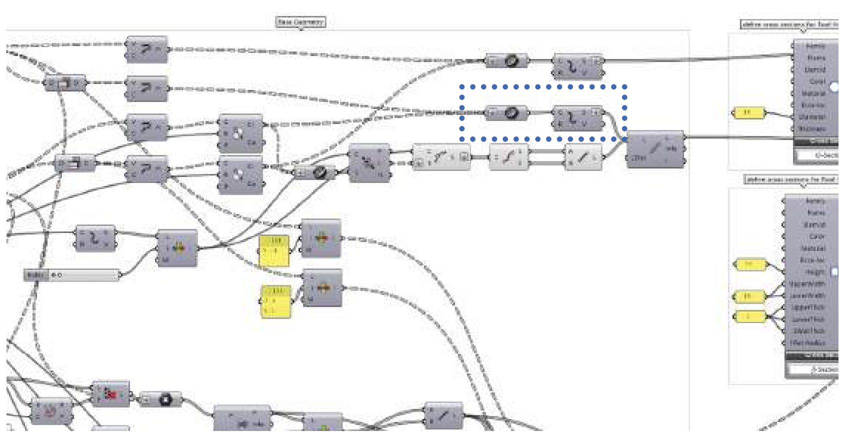


Set up Major Beam Element

1) Sorting out the horizontal beam element

2) Explode the polylines into segments

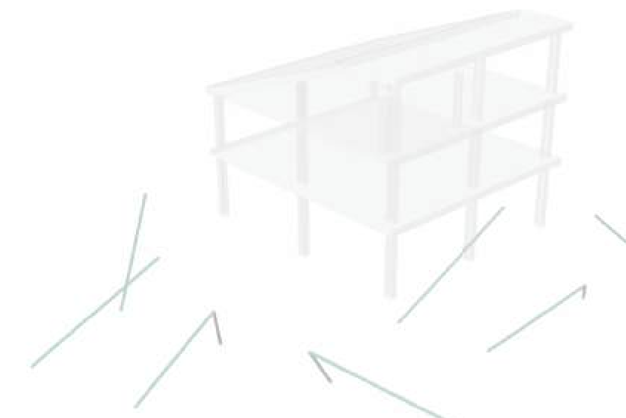


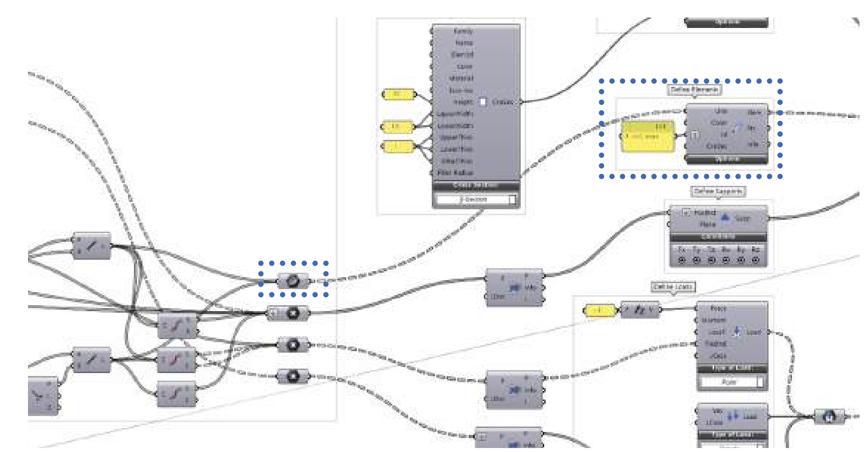


Set up Cross Beam Element

1) Sorting out the vertical beam element

2) Explode the polylines into segments

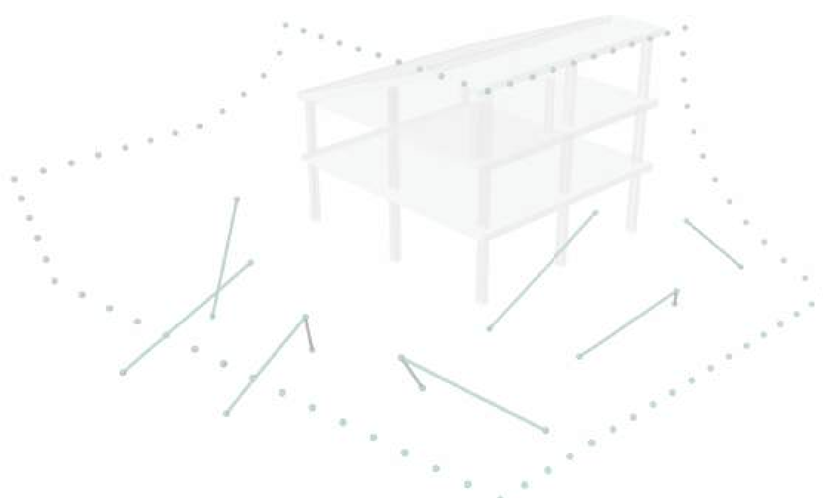


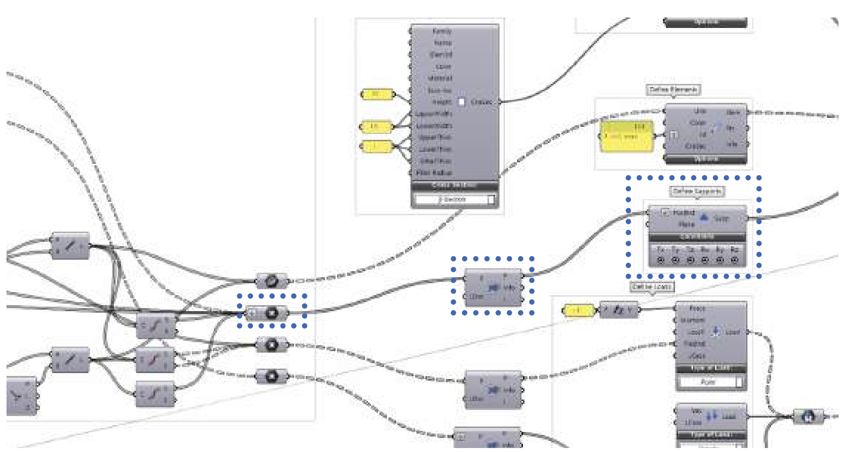


Set up Column location

1) Convert column lines to the structural element

2) Connect proper cross section for the columns



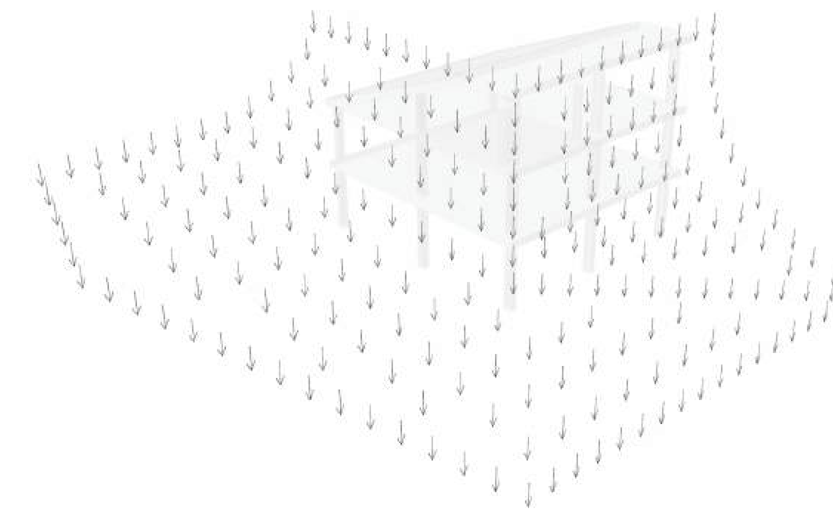


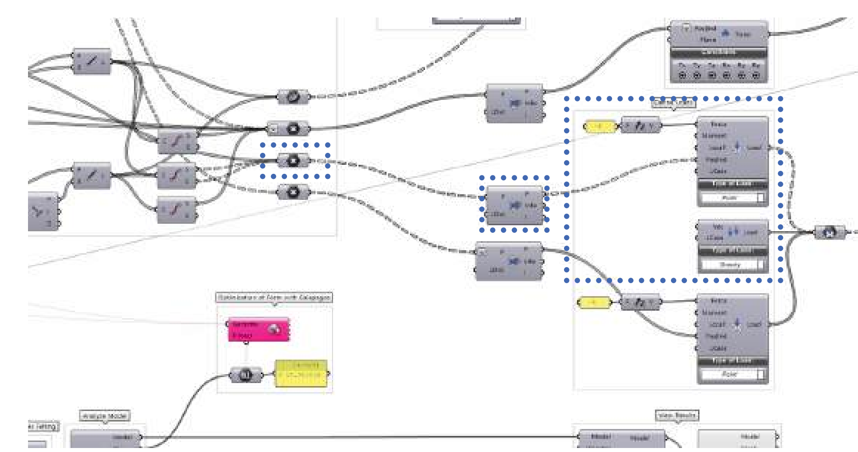
Set up Supports

1) Sorting out points for roof support

2) Eliminate possible duplicated points and convert it as a support

3) Apply proper setting for the support

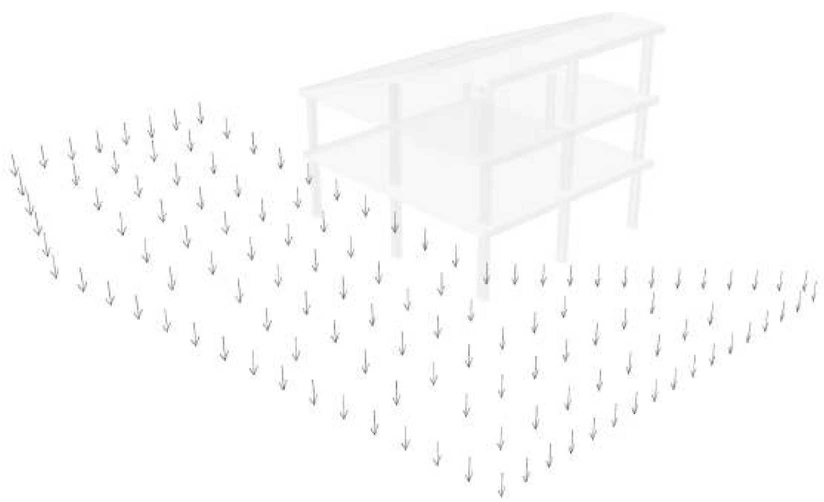


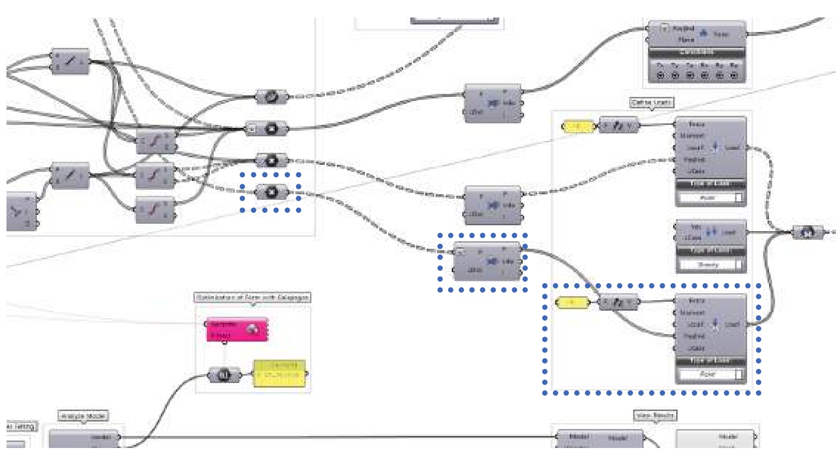


Set up Load

1) Sorting out the points for gravity and point load (dead load)

2) Connect it to designated load setting component



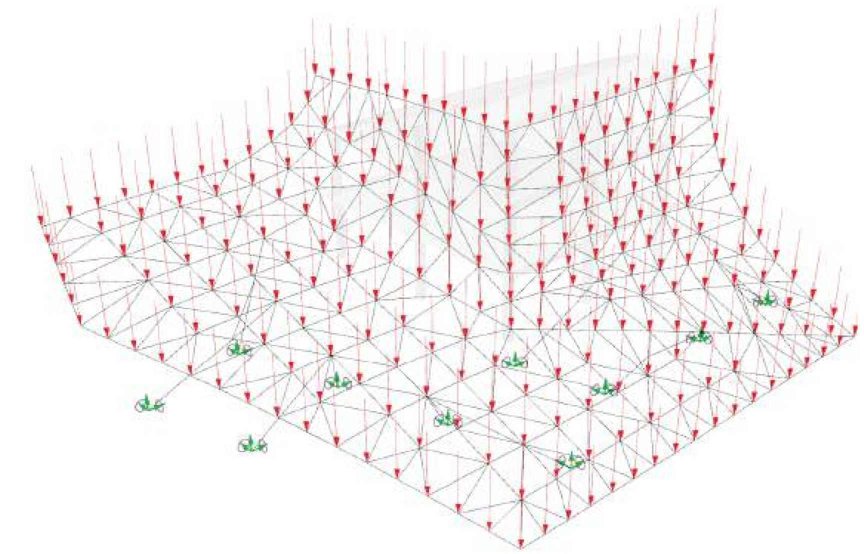


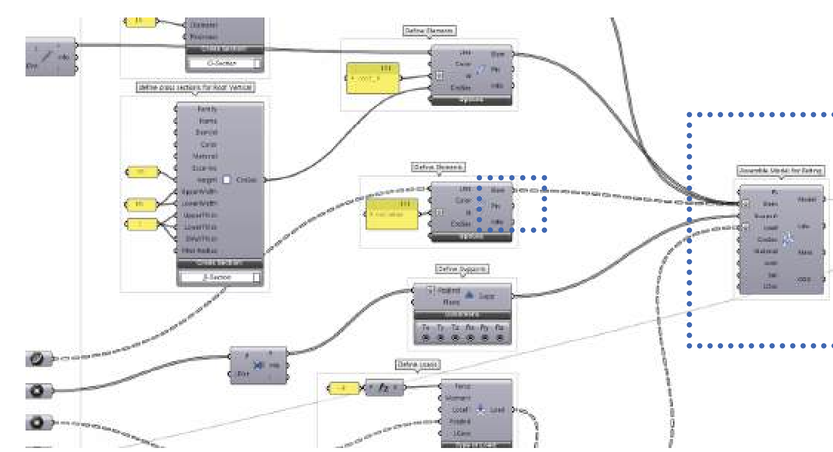
Set up Load for Staircase part

1) Sorting out the points located within stair of the roof

2) Connect it to designated load setting component

3) Apply live load for the points (1000 lbs for stair)

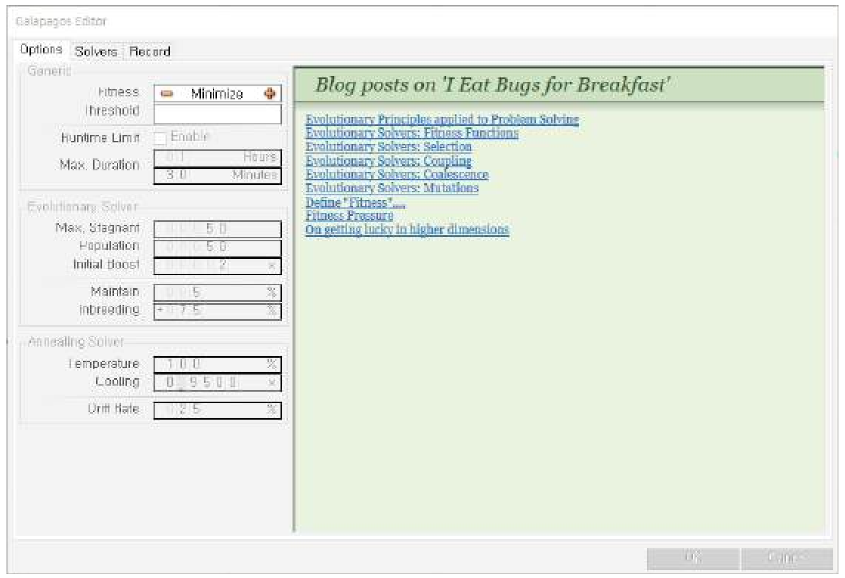


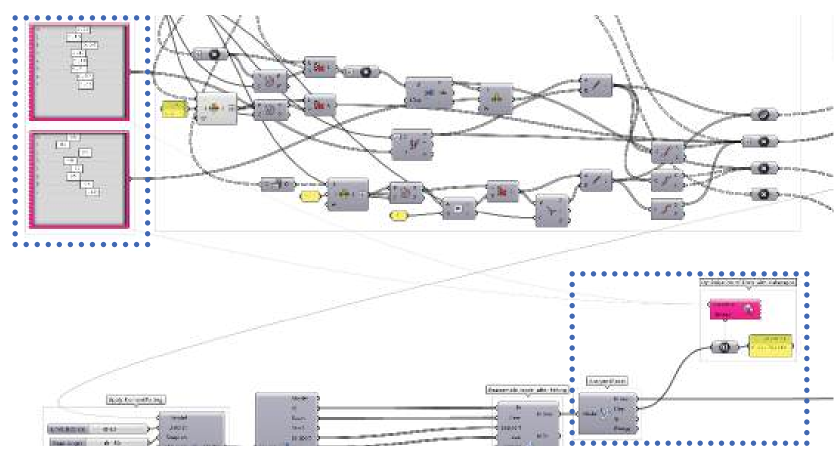


Assemble Model

1) Connect all items for the structural calculation

2) Connect it to model view for display



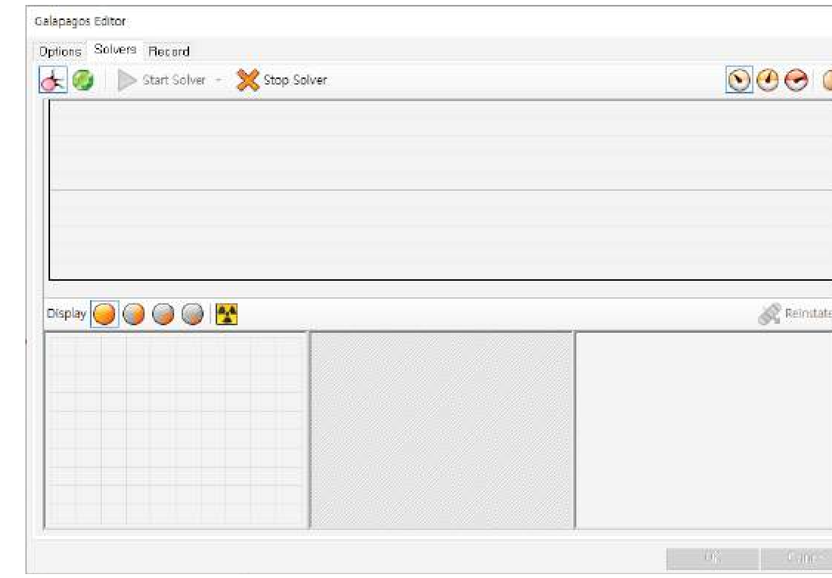


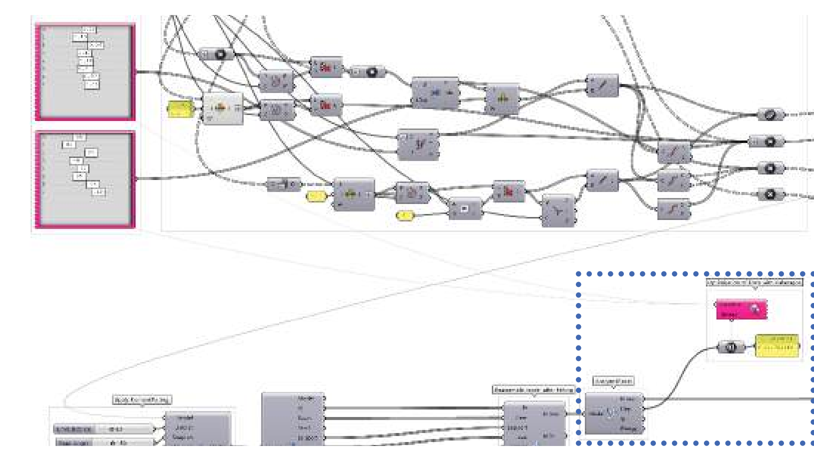
Organize Galapagos

1) Connect genepool numbers for genome

2) Connect displacement to fitness

3) Open Galapagos and set the setting as minimize for less displacement



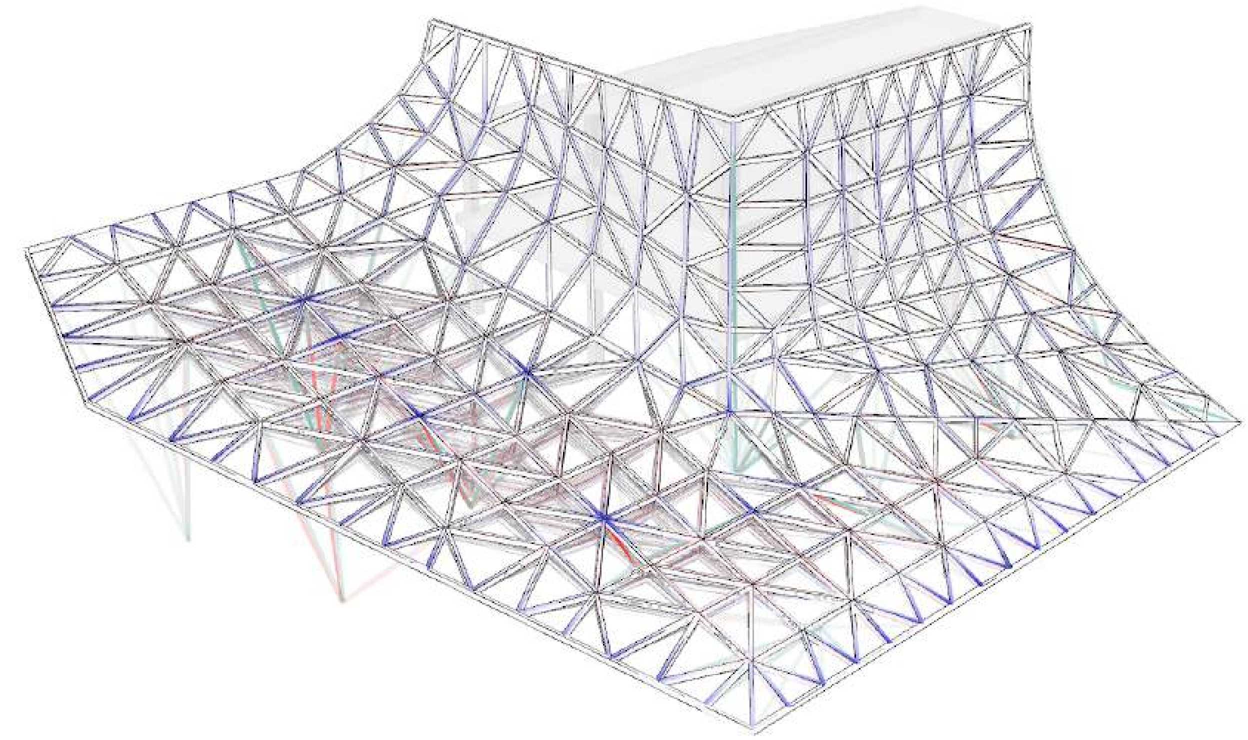


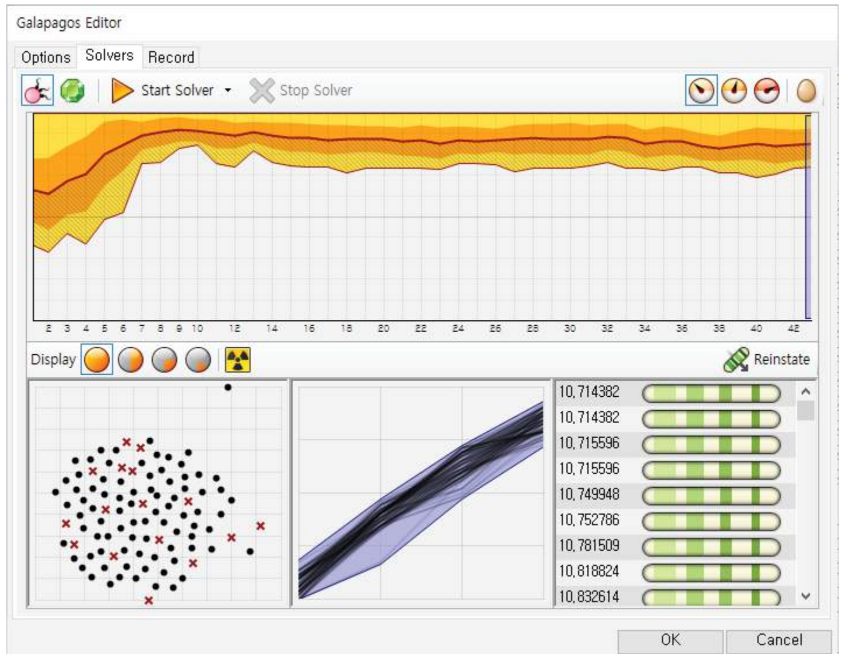
Run Solver

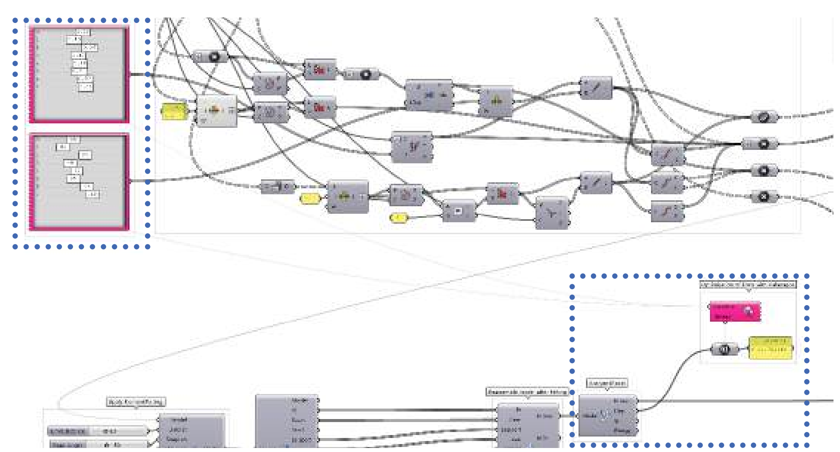
1) Move to solver tab and start evolutionary solver for the optimization

Displacements in different column locations

Displacements in different column locations





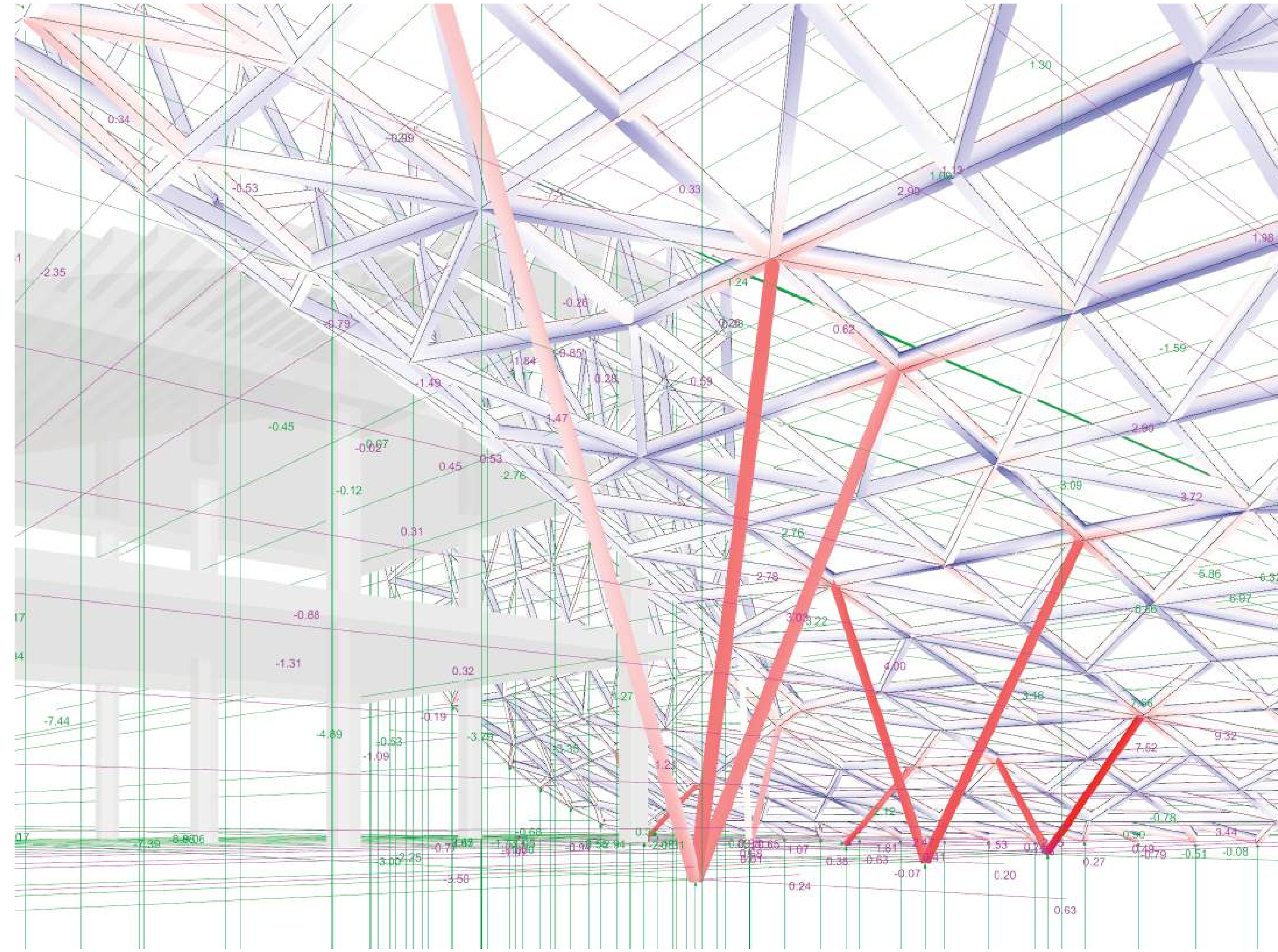


Reinstate the Optimized Option

1) Reinstate the top tier of the option

2) Check rhino viewport for the result

Optimized Column location



METHODOLOGY.02

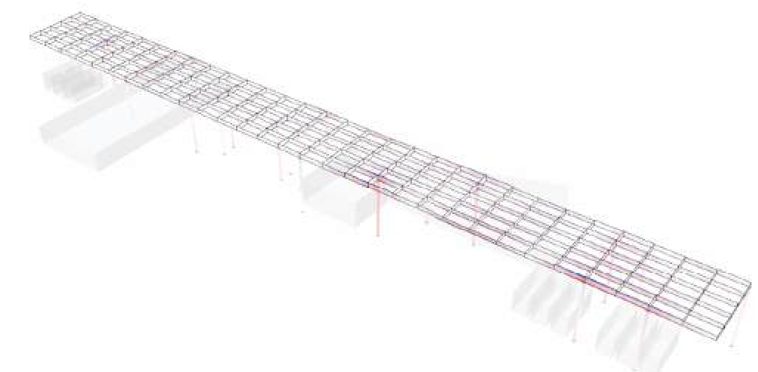
Application on Flat Roof with Context Ver.01 & Ver.02

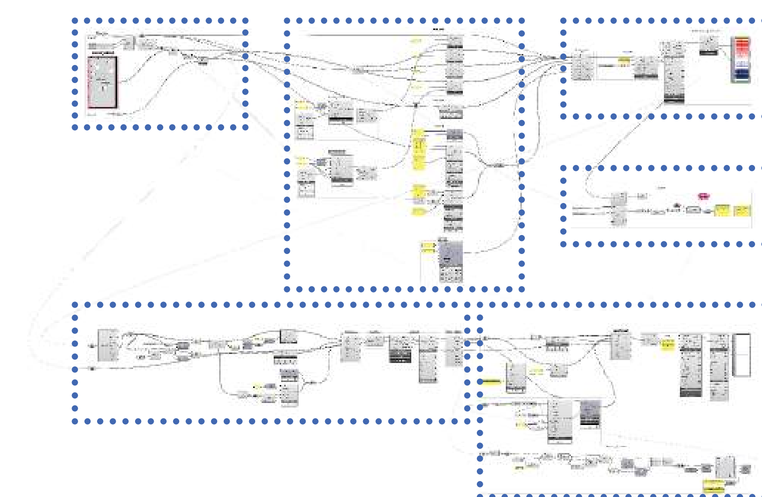
Application on Flat Roof with Context Ver.01

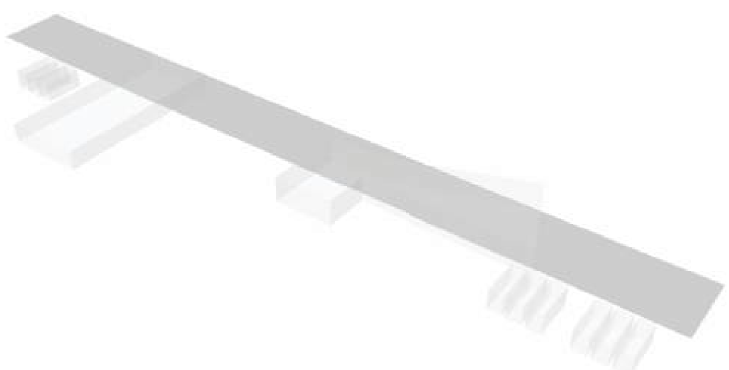
This chapter introduces structural analysis and application of the calculation to sub-structure of the flat roof with context under it which cannot be overlapped with structural members. Two case studies will be introduced in this chapter with a slight variation of design and application methodology.

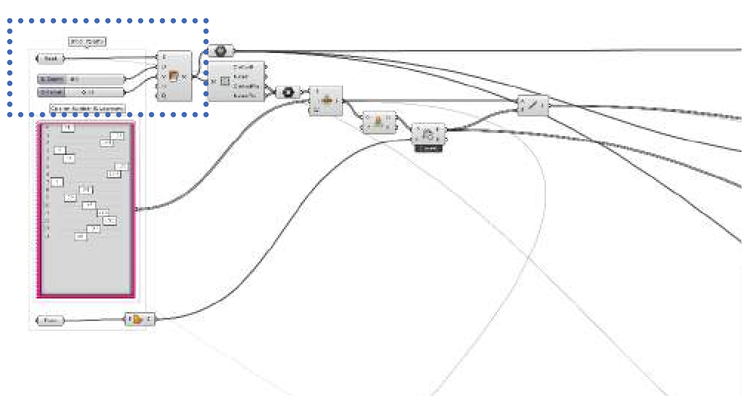
The work flow of this section is following order and objective.

- How to set up the sub-structure geometry in Parametric way
- How to incorporate the practical requirements in grasshopper environment
- How to connect it to Karamba3d software for calculation
- How to get the best location for column by using evolutionary computing





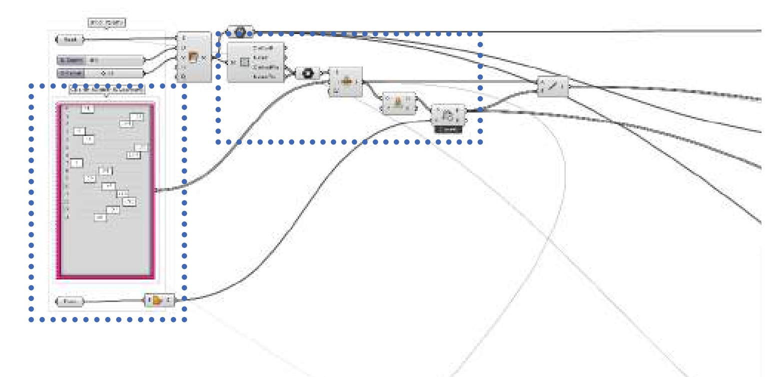




Import Roof Surface

1) Bring surface as a boundary representation

2) Convert it into mesh and subdivide it properly



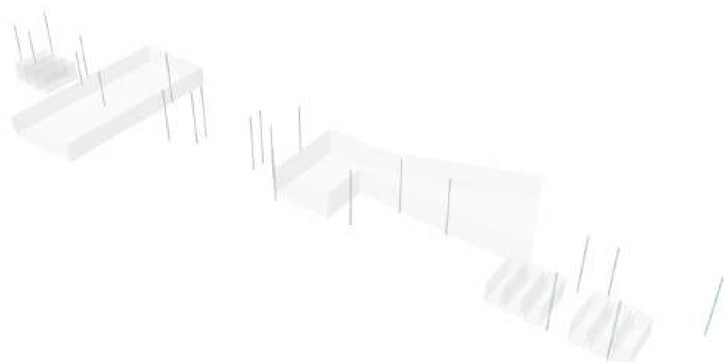
Sort out Supporting Points

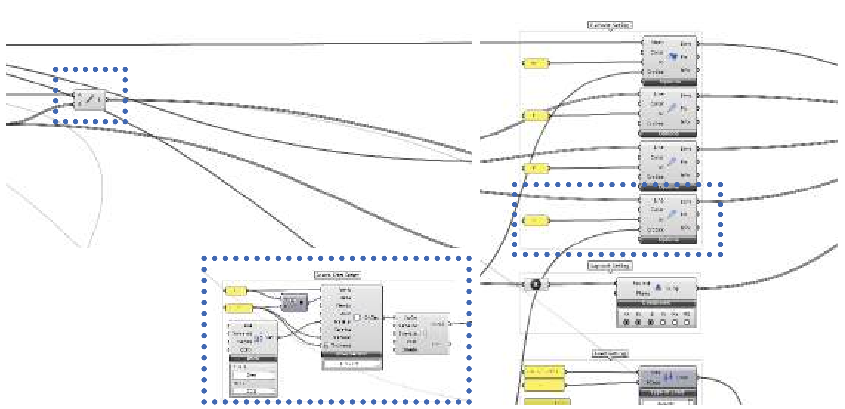
1) Create list of the mesh vertices

2) Create genepool in accordance with column number and list length

3) Sort out specified number of the items

4) Project it to the designated surface

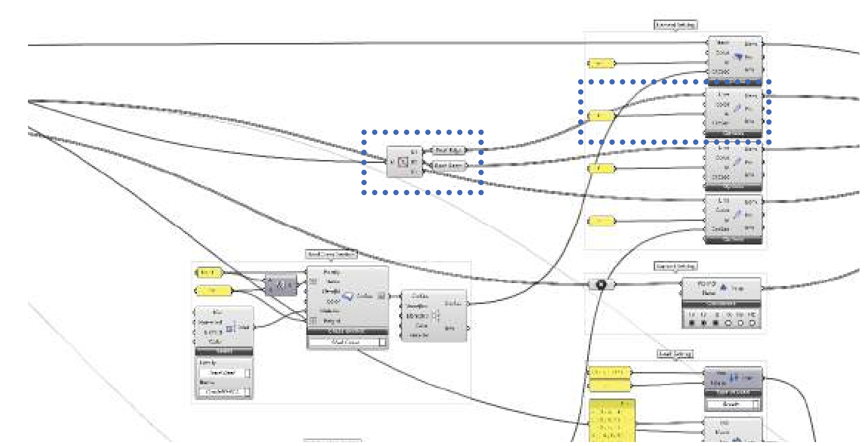




Set up Column Element

1) Connect sorted out points and projected points

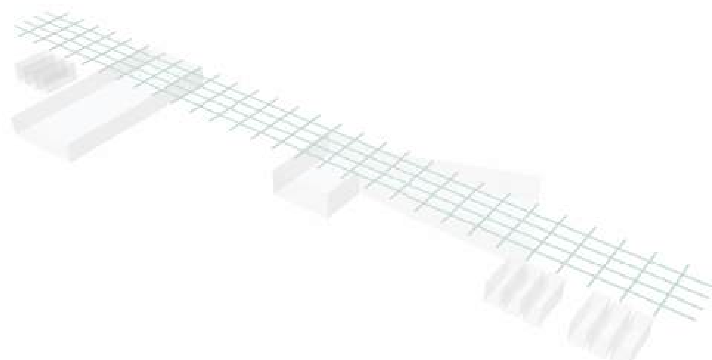
2) Assign material and cross section for the column

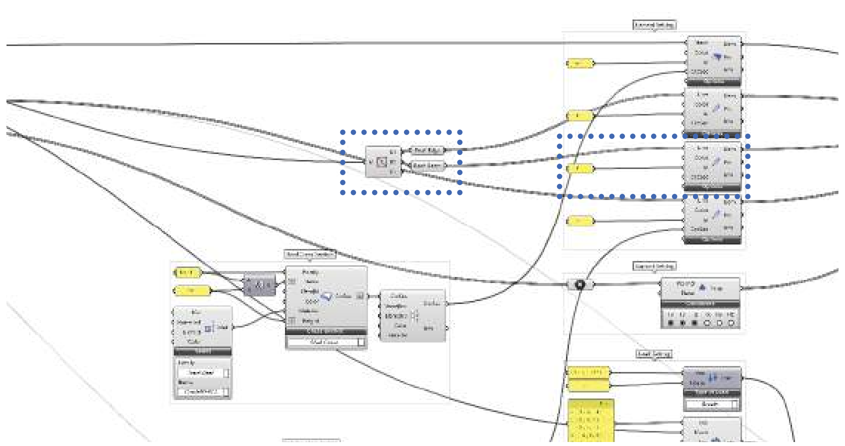


Set up Boundary Beam

1) Sorting out boundary beams from mesh edges

2) Convert it into structural beam element

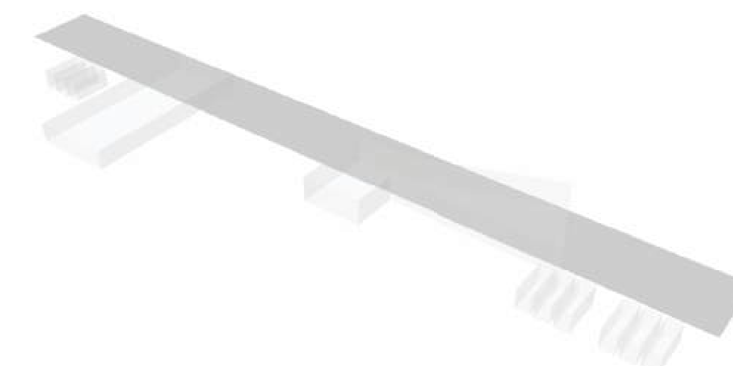


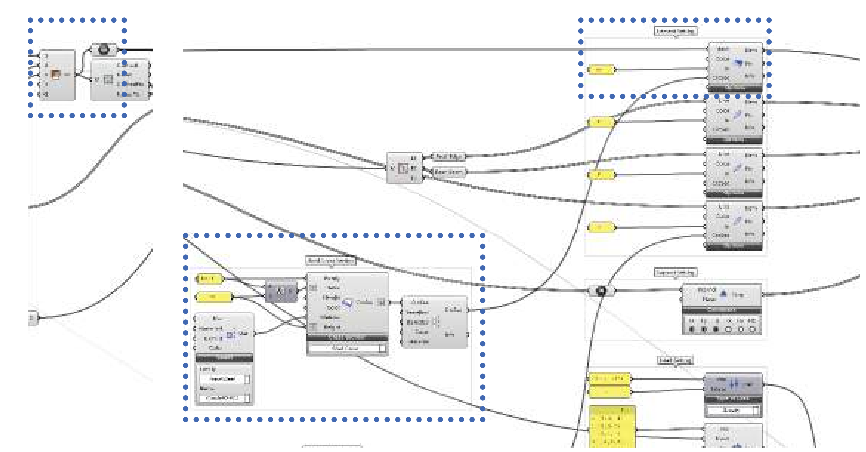


Set up Interior Beam

1) Sorting out interior beams from mesh edges

2) Convert it into structural beam element

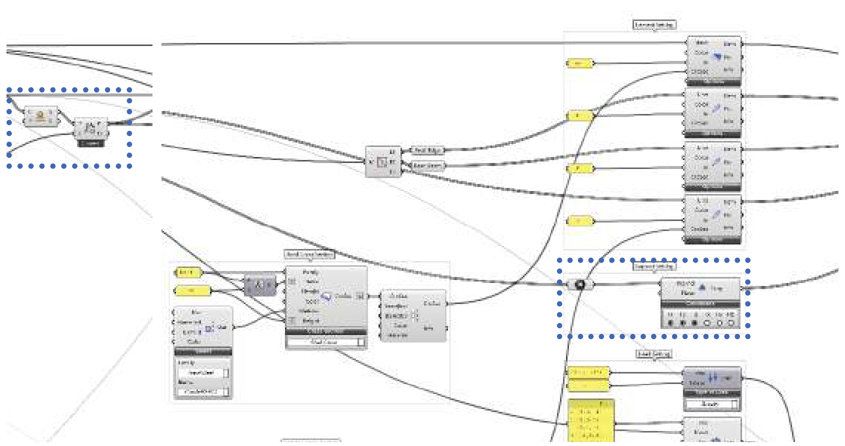




Setting up Shell

1) Convert mesh to shell structural element

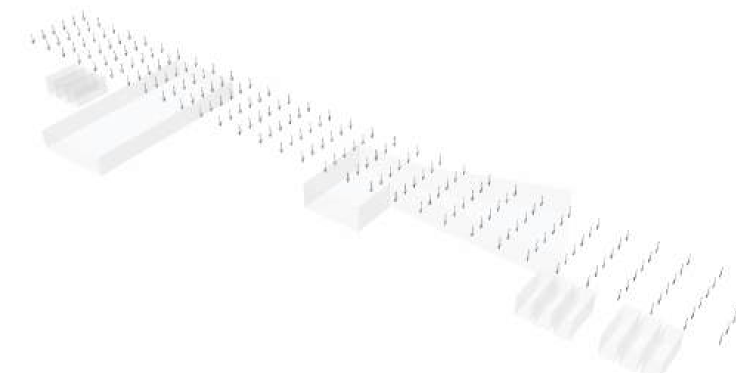
2) Set up cross section setting for the shell

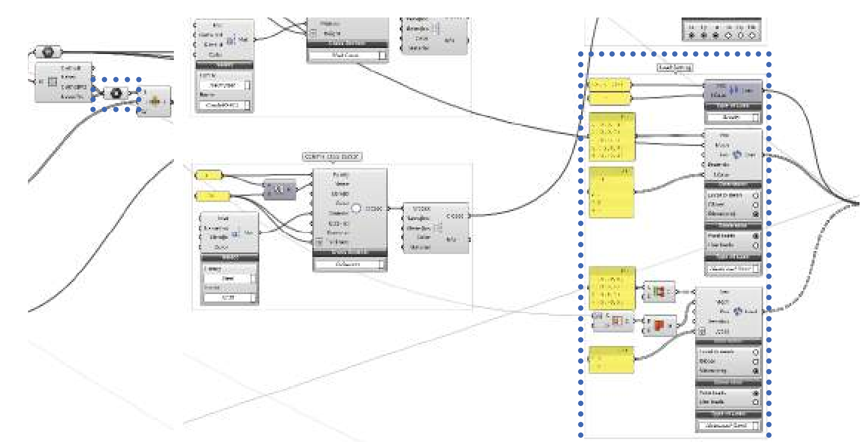


Set up Support

1) Sorting out projected points

2) Convert it into support with proper setting



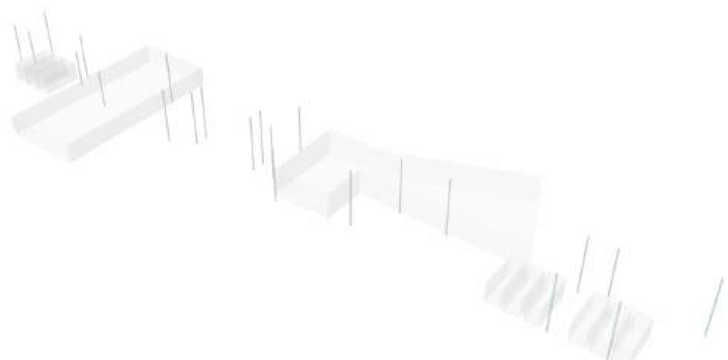


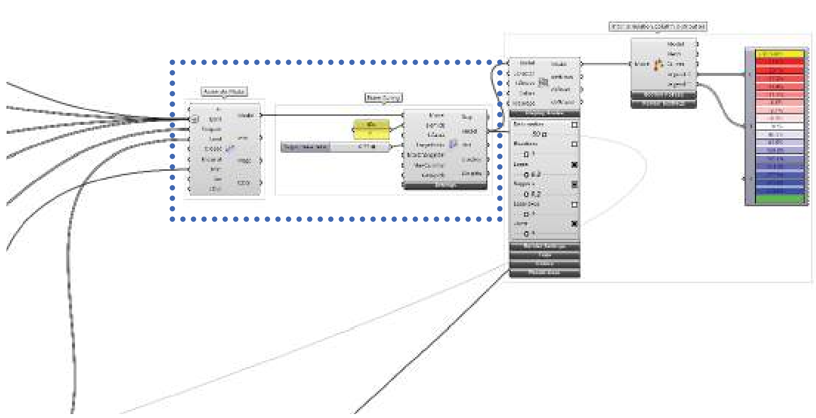
Set up Load

1) Sorting out points from roof and column

2) Convert it into structural load bearing points

3) Assign gravity load, dead load, and point load

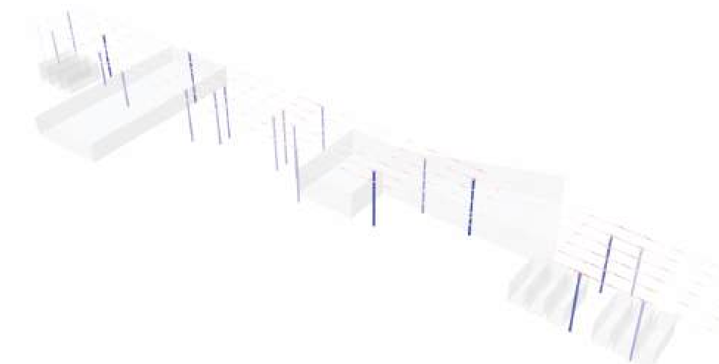


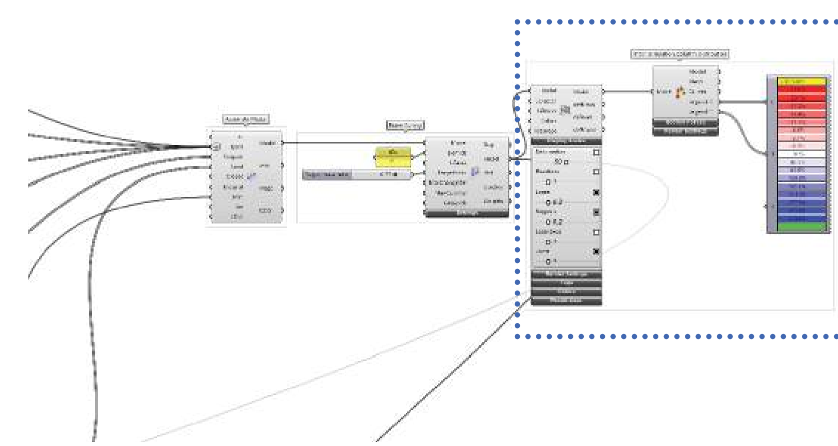


Cull out less loading elements

1) Assemble the model

2) Connect to Besobeam for the ratio driven optimization

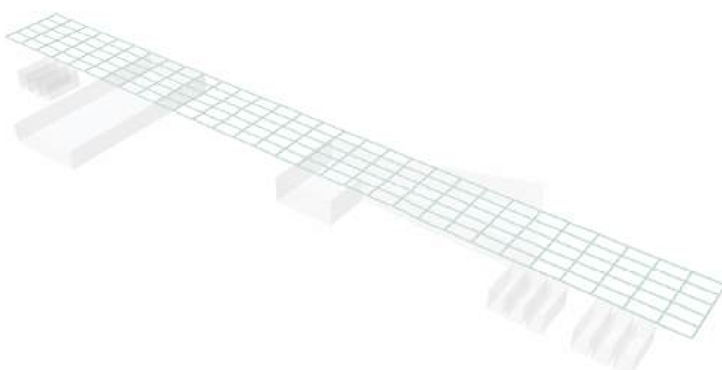


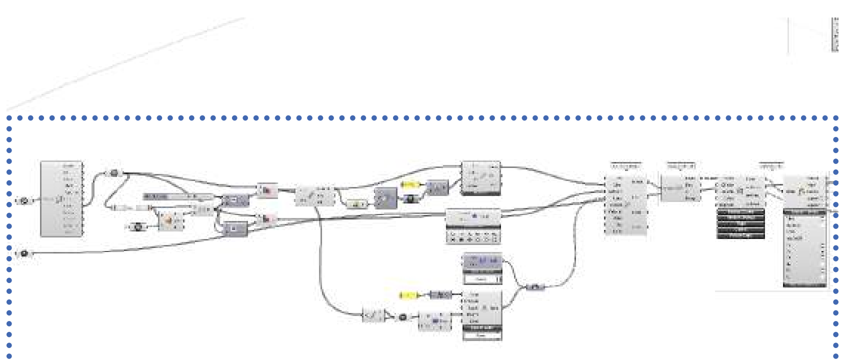


Visualize Preliminary Result

1) Connect the structural model to model view for the visualization

2) Check deformation and moment for each element

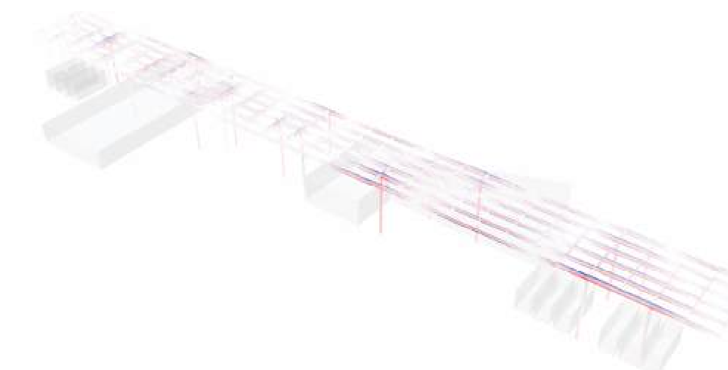


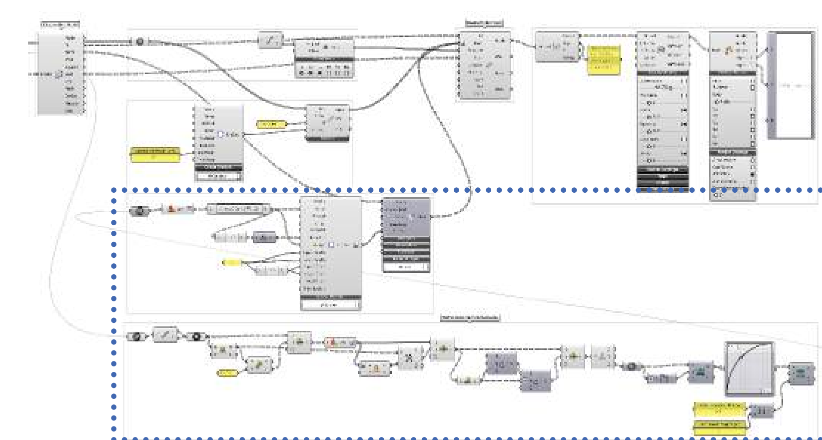


Run second analysis

1) Disassemble the model

2) Set the roof elements only for the further recalculation



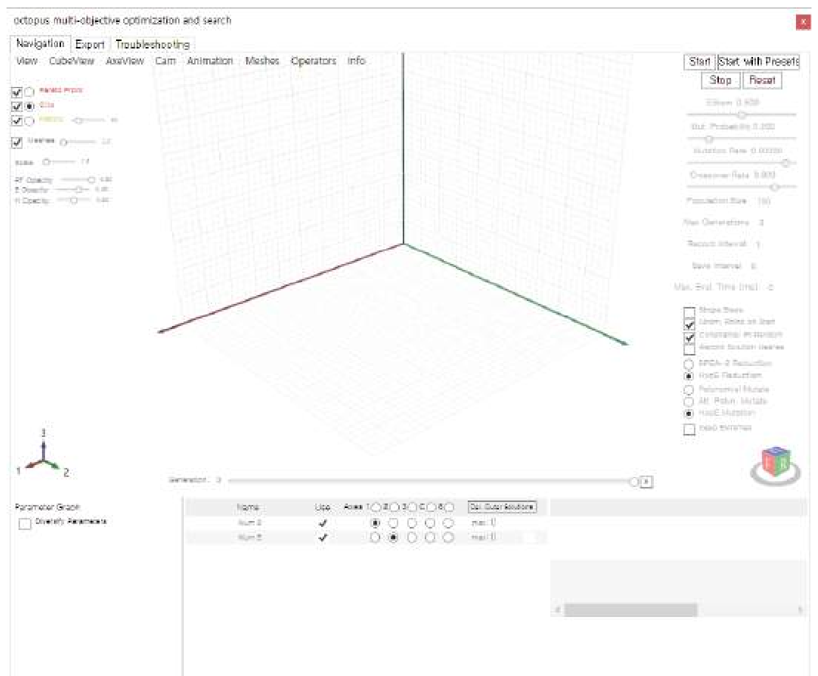


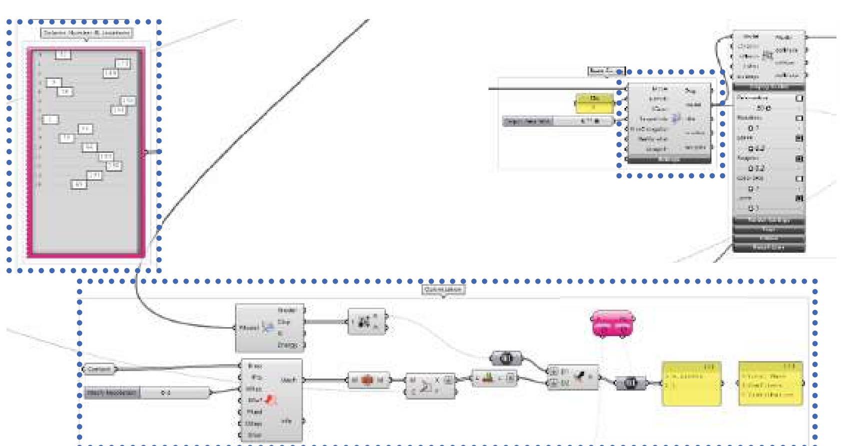
Apply Moment based Variable Cross Section

1) Sorting out moment value from roof structure

2) Create series of moment based cross section shape

3) Apply the section to the roof elements





Organize Octopus

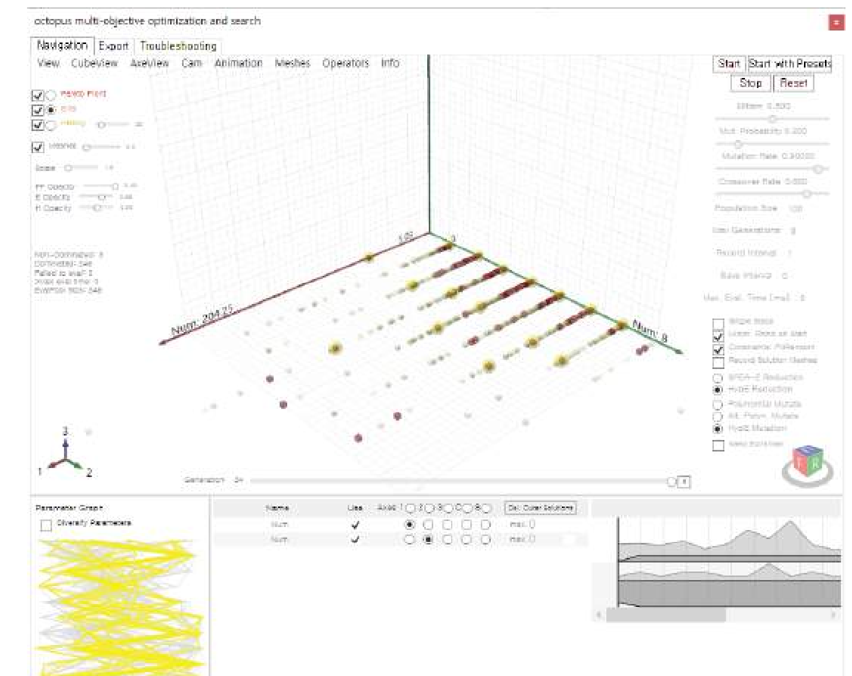
1) Connect genepool numbers to Octopus

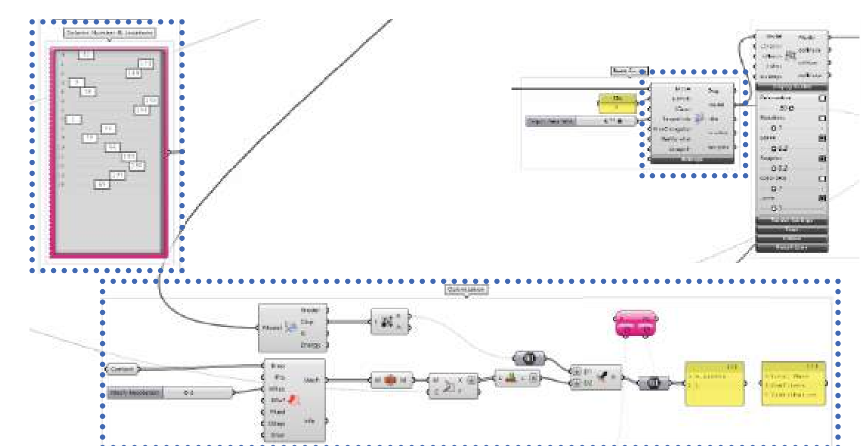
2) Import contexts as boundary representation

3) Create number as conflicts between structural members and contexts

4) Set a list of numbers and connect it into Octopus

5) Open up the Octopus interface



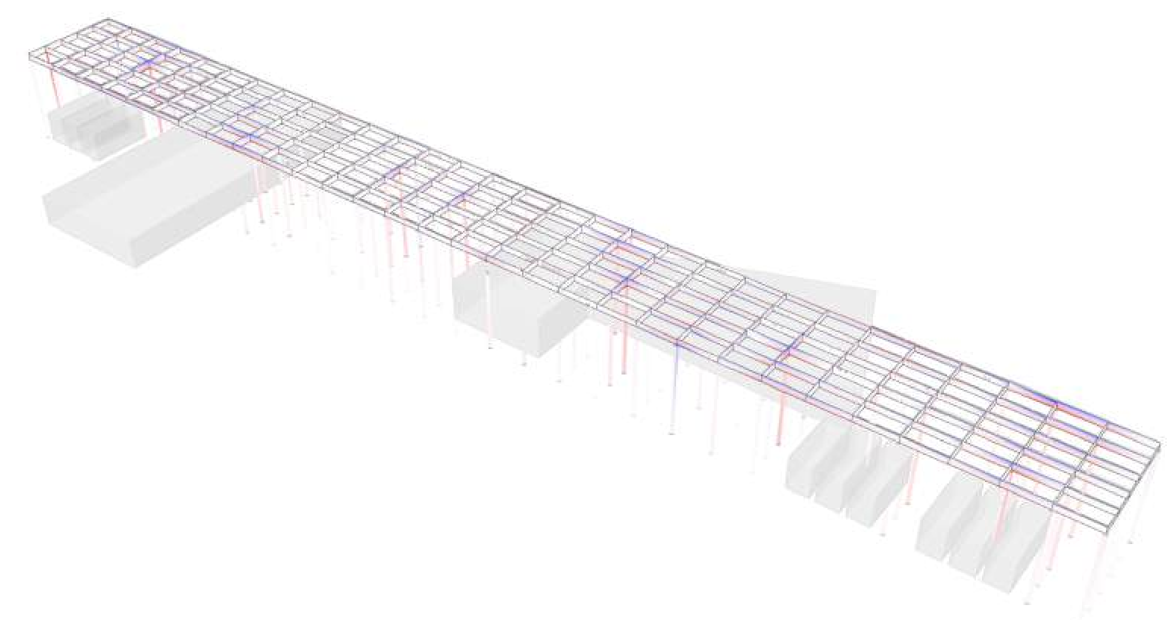


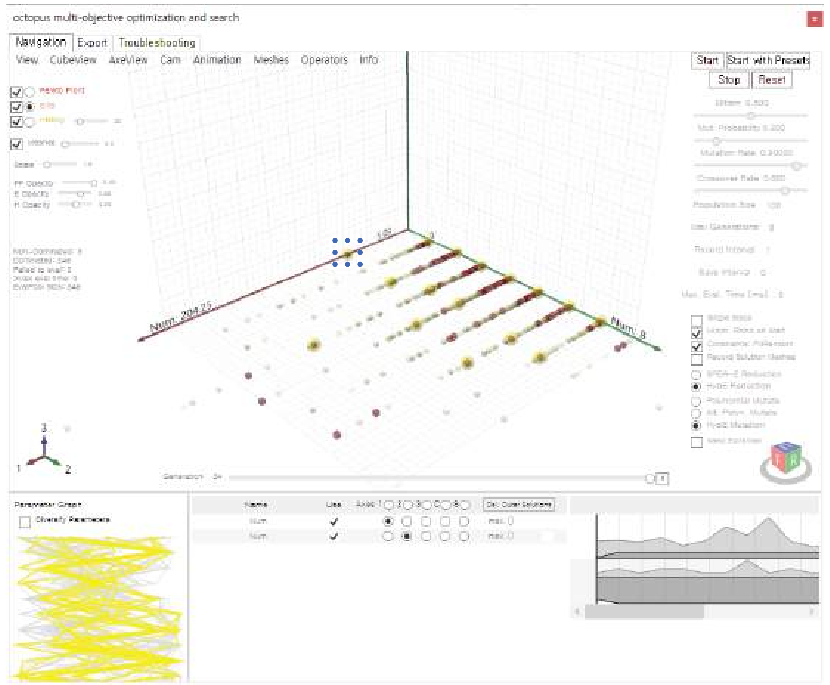
Run Solver

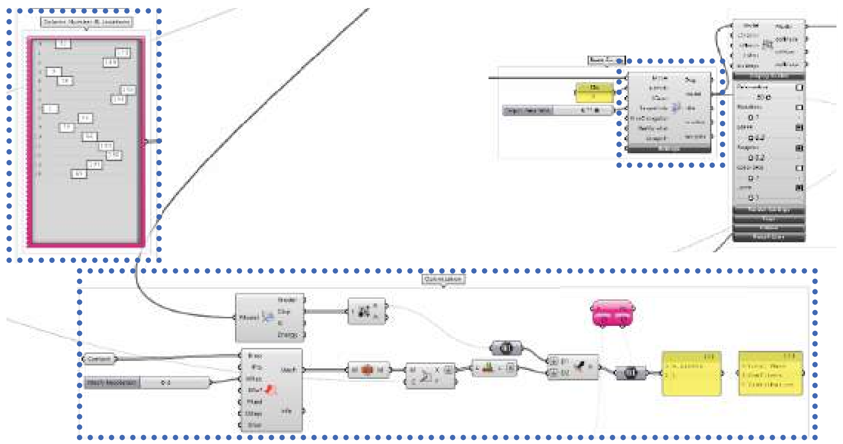
1) Run solver with a proper setting of generation

Roof substructure and its cross section in different column locations

Roof substructure and its cross section in different column locations



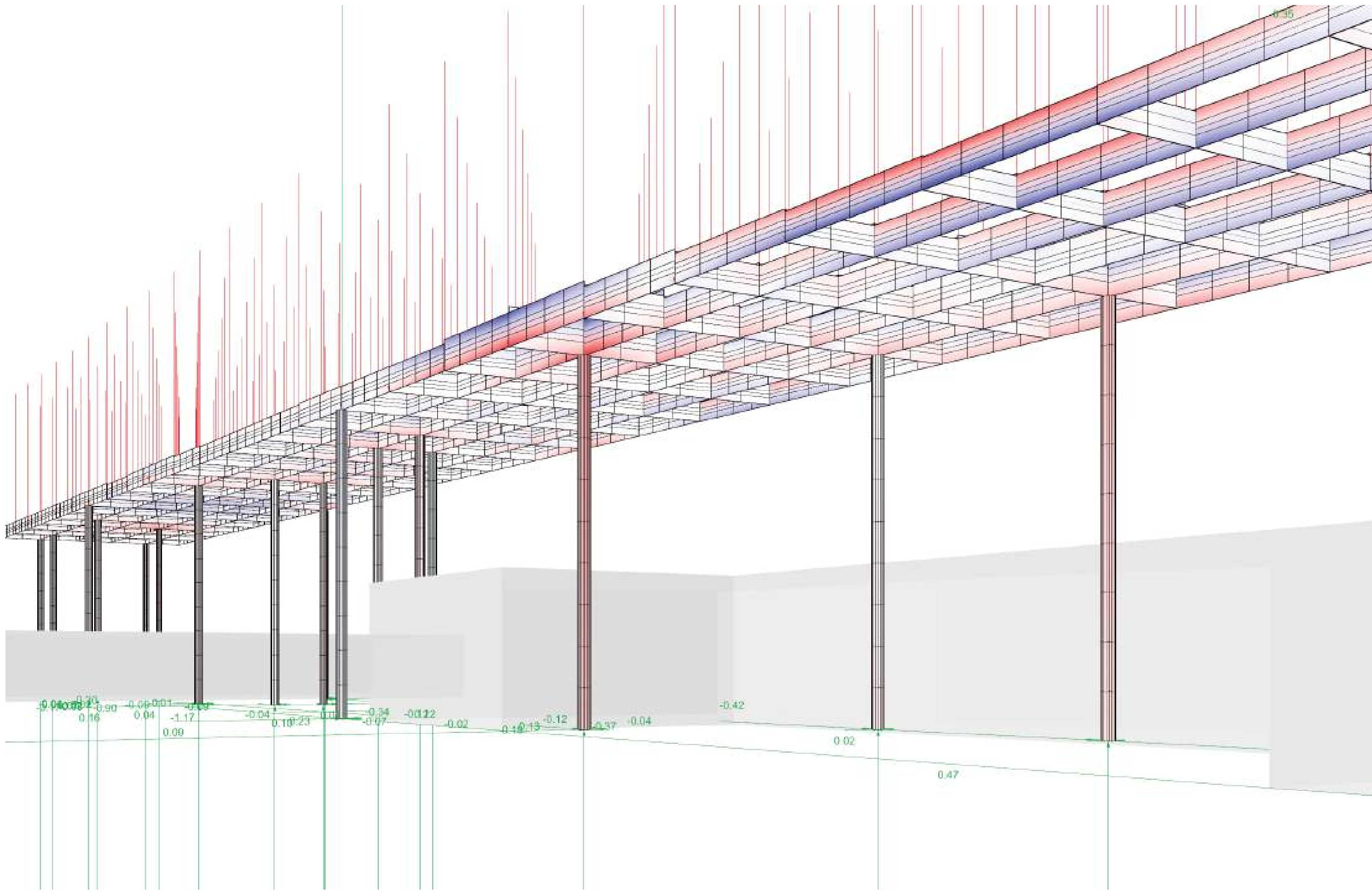




Reinstate the Optimized Option

1) Reinstate the top tier of the option

2) Check rhino viewport for the result

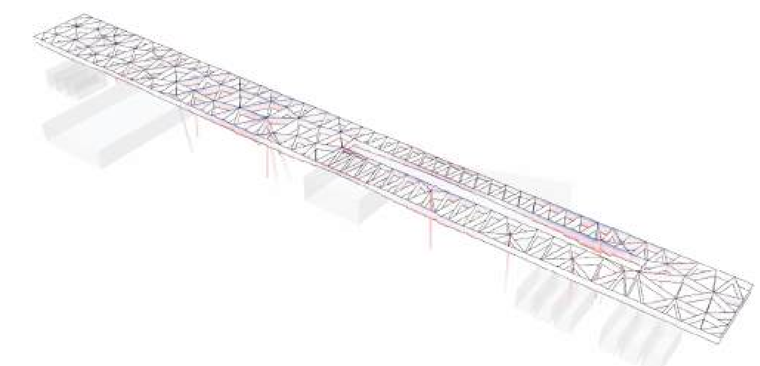


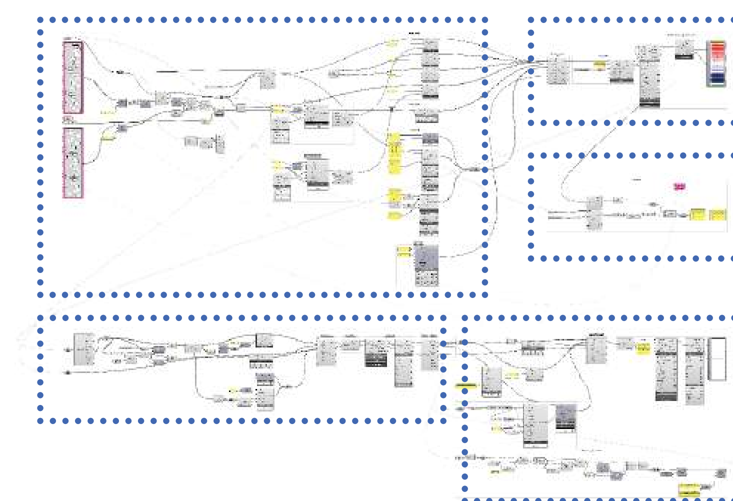
Application on Flat Roof with Context Ver.02

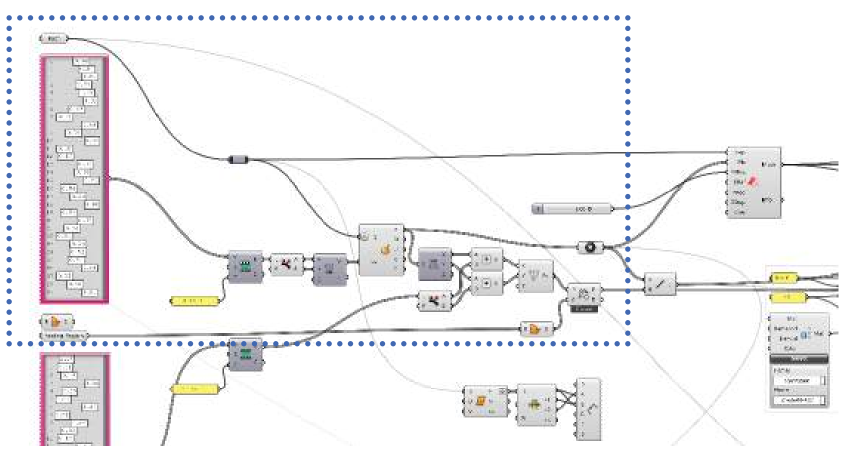
This chapter introduces structural analysis and application of the calculation to sub-structure of the flat roof with context under it which cannot be overlapped with structural members. Two case studies will be introduced in this chapter with a slight variation of design and application methodology.

The work flow of this section is following order and objective.

- How to set up the sub-structure geometry in Parametric way
- How to incorporate the practical requirements in grasshopper environment
- How to connect it to Karamba3d software for calculation
- How to get the best location for column by using evolutionary computing





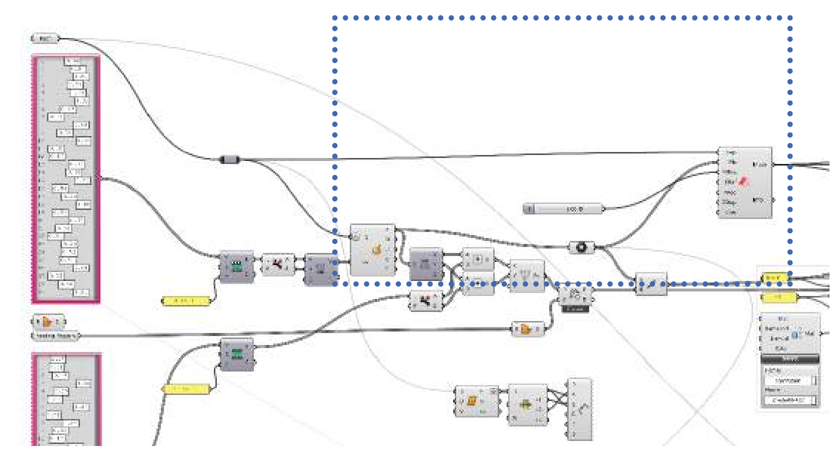


Import Roof Surface and Ground Surface

1) Bring roof and ground surfaces as a boundary representations

2) Create Genepool with number of columns

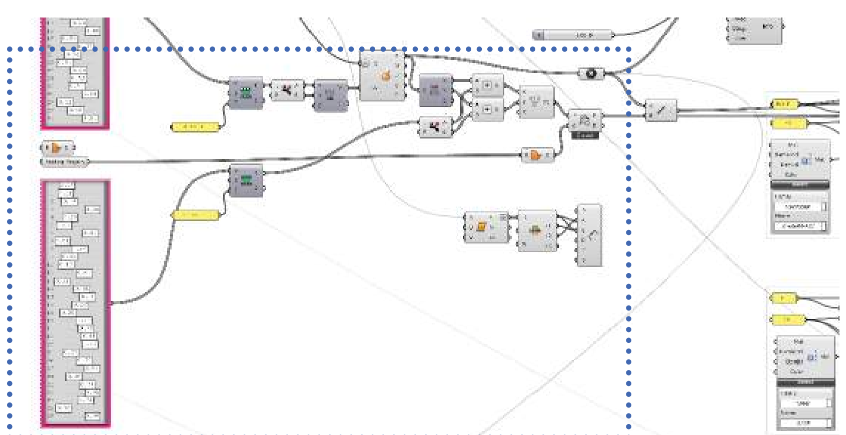
3) Sorting out points from roof surface by reparameterizing and connecting genepool



Create Roof Substructure

1) Create mesh with boundary representation of roof surface

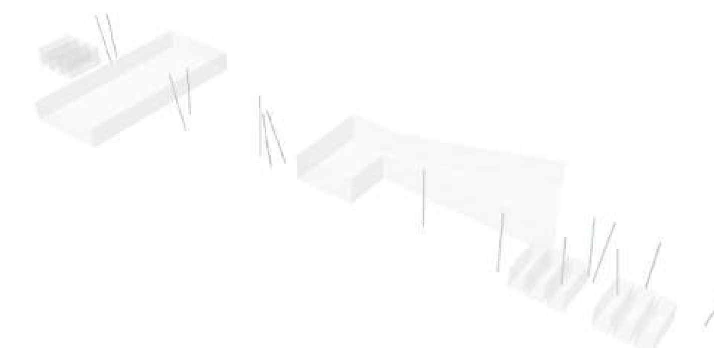
2) Connect points from genepool for the mesh creation

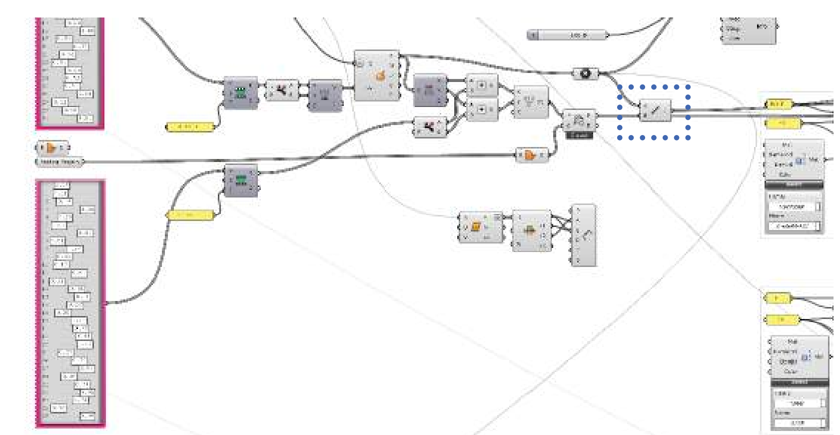


Create Column Footing from Ground Surface

1) Pull the points from roof surface to the ground surface

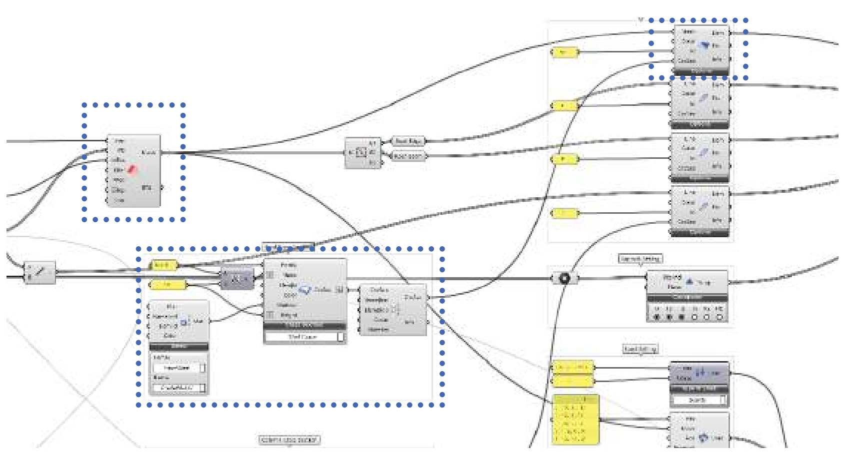
2) dispatch the genepool lists for the displaced column layout





Create Column

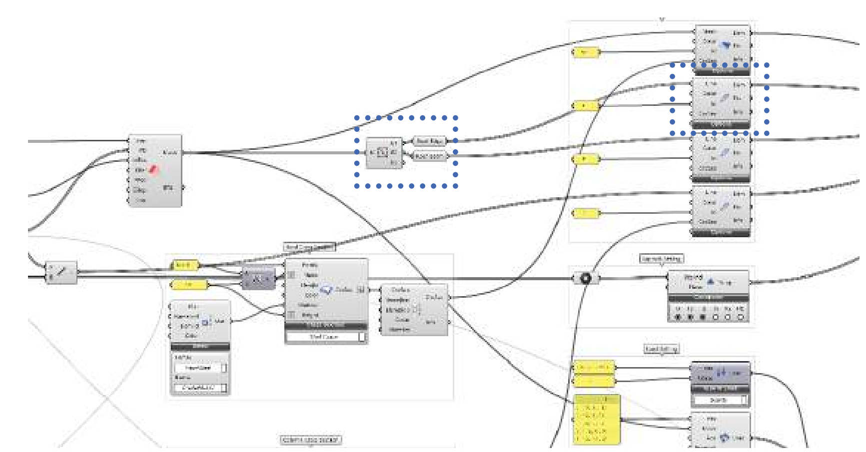
1) Connect points on roof and ground



Set up Shell

1) Convert mesh into shell

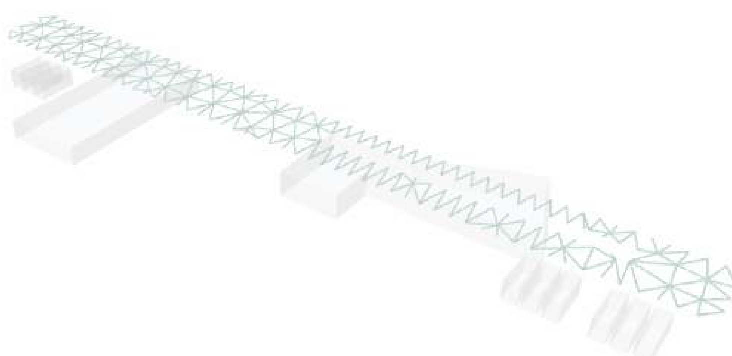
2) Assign proper material and cross section

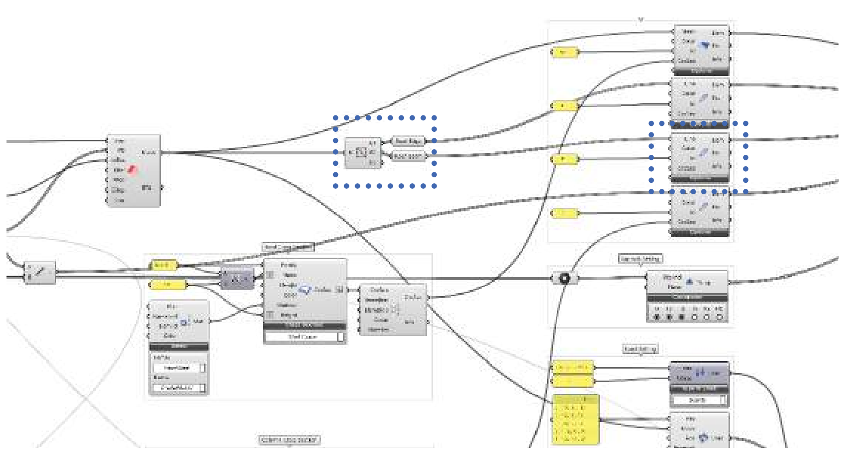


Set up Boundary Beam

1) Sorting out boundary beams from mesh edges

2) Convert it into structural beam element

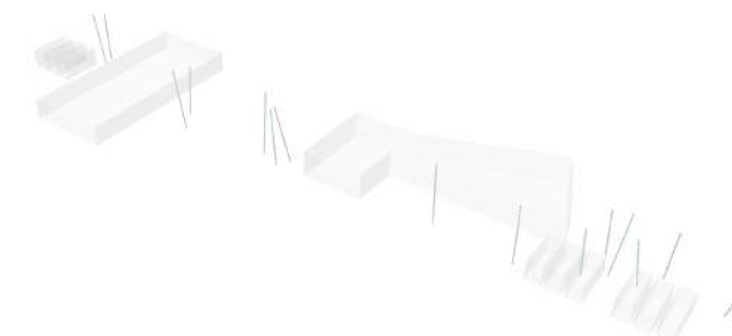


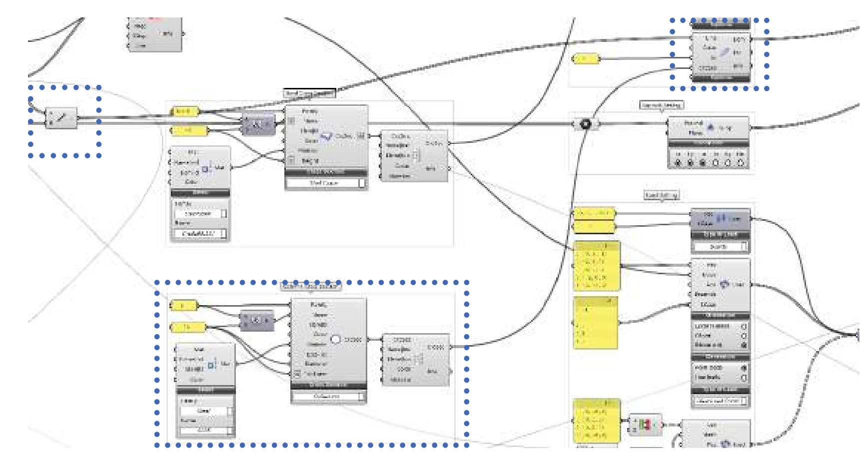


Set up Interior Beam

1) Sorting out interior beams from mesh edges

2) Convert it into structural beam element

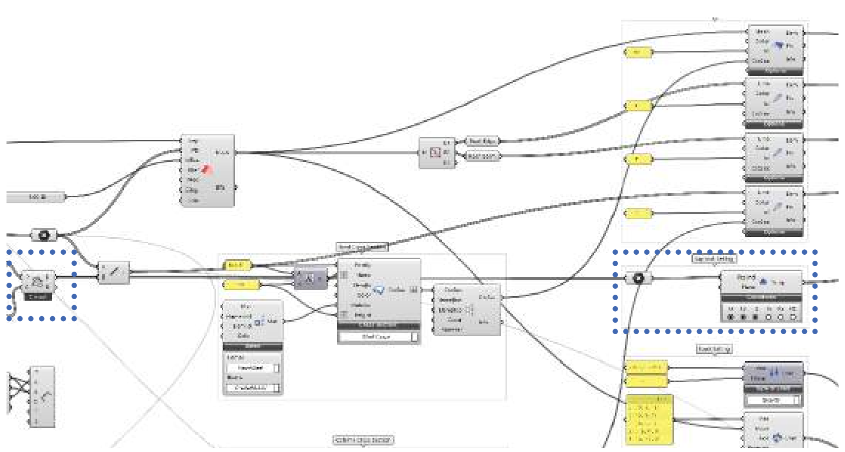




Set up Column Element

1) Connect sorted out points and projected points

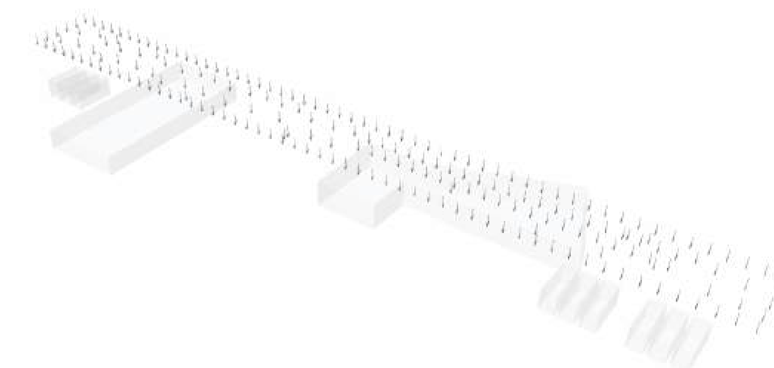
2) Assign material and cross section for the column

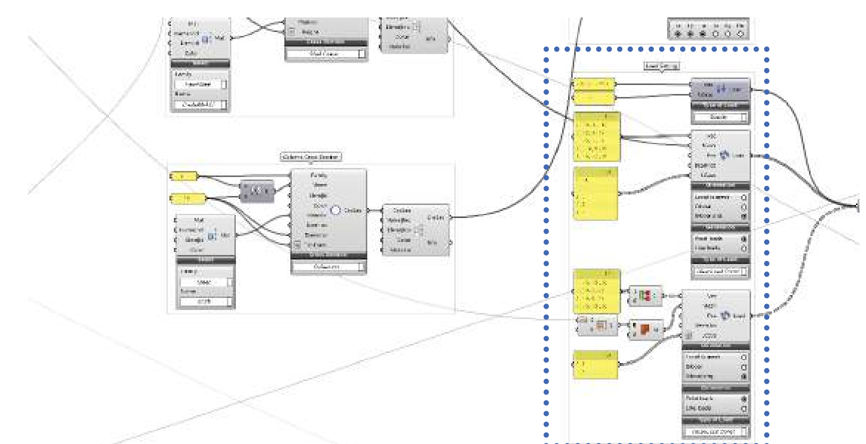


Set up Support

1) Sorting out points in ground surface

2) Convert it into support with proper setting



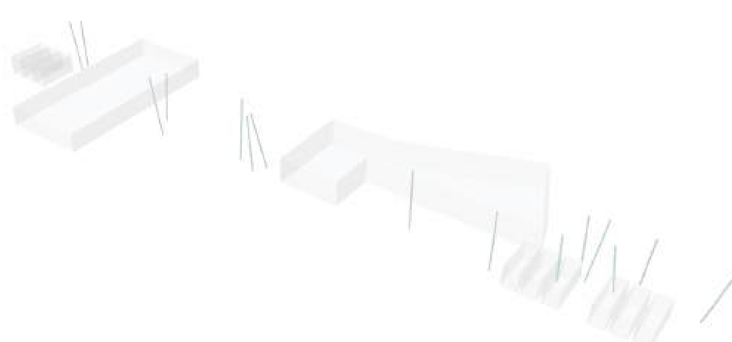


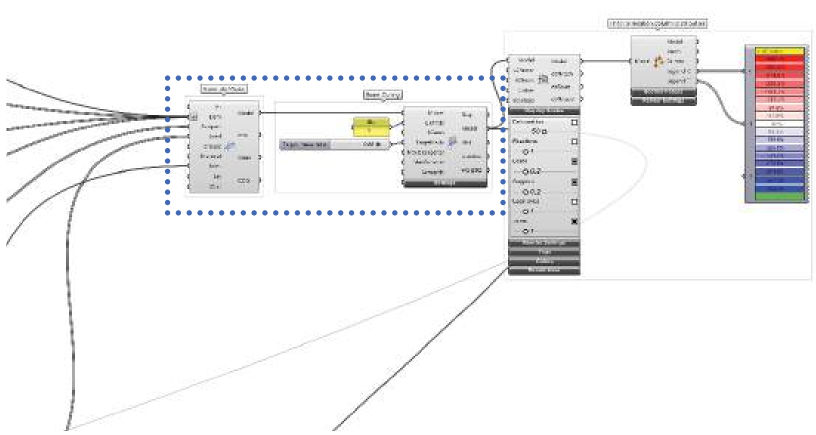
Set up Load

1) Sorting out points from roof and column

2) Convert it into structural load bearing points

3) Assign gravity load, dead load, and point load

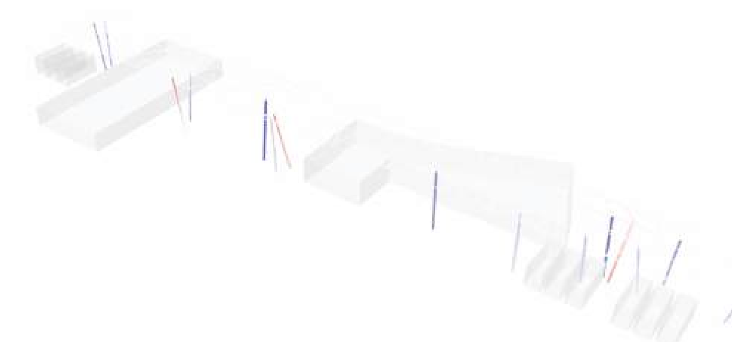


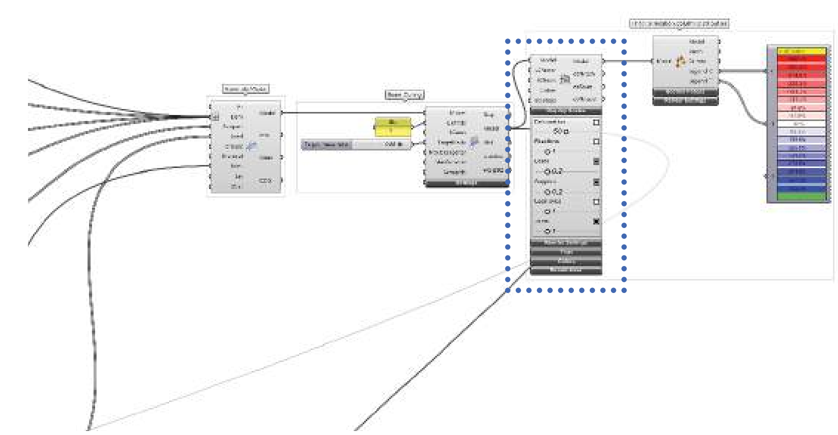


Cull out less loading elements

1) Assemble the model

2) Connect to Besobeam for the ratio driven optimization

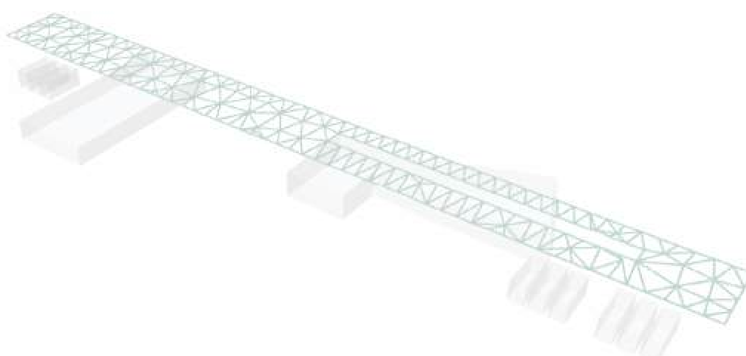


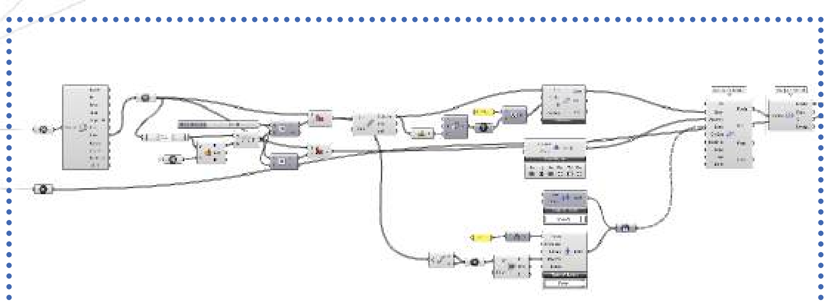


Visualize Preliminary Result

1) Connect the structural model to model view for the visualization

2) Check deformation and moment for each element

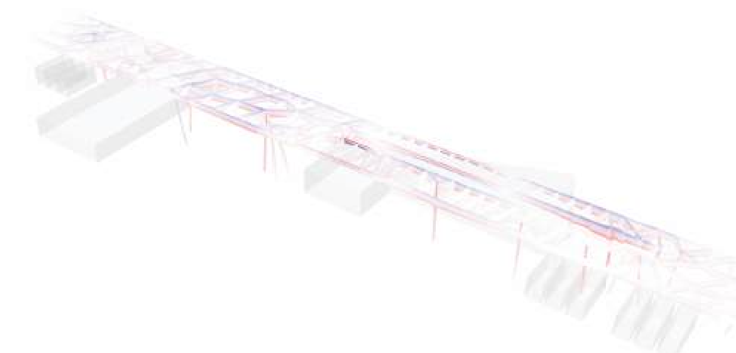


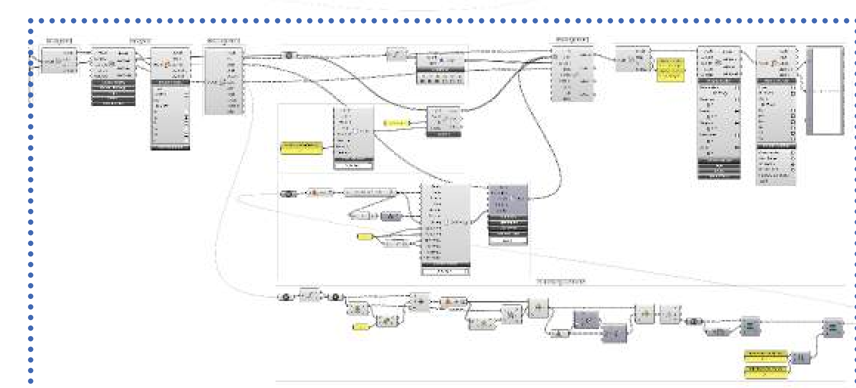


Run second analysis

1) Disassemble the model

2) Set the roof elements only for the further recalculation



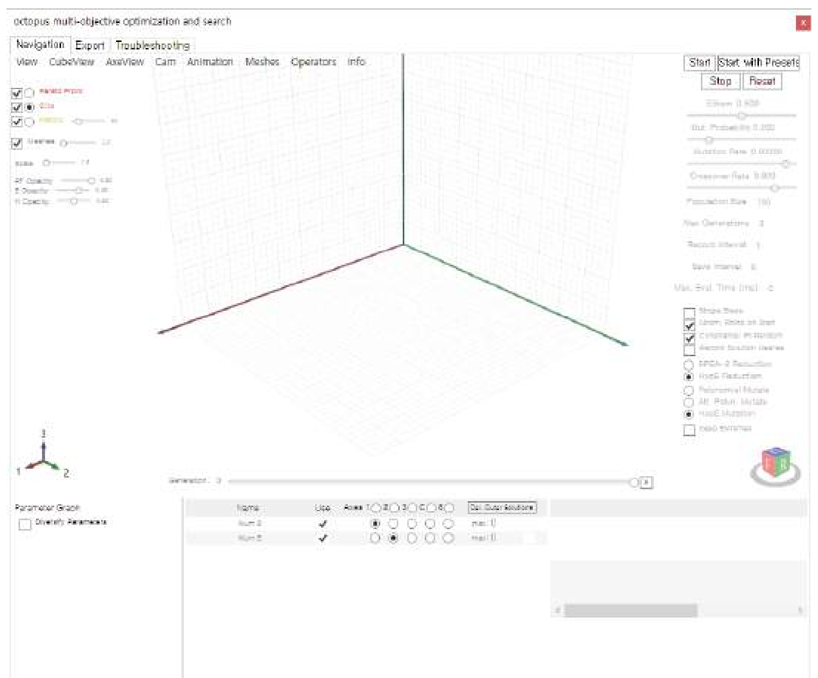


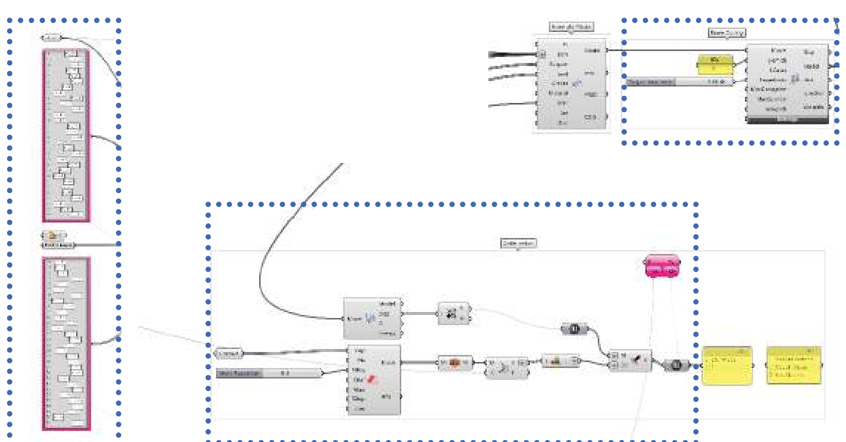
Apply Moment based Variable Cross Section

1) Sorting out moment value from roof structure

2) Create series of moment based cross section shape

3) Apply the section to the roof elements





Organize Octopus

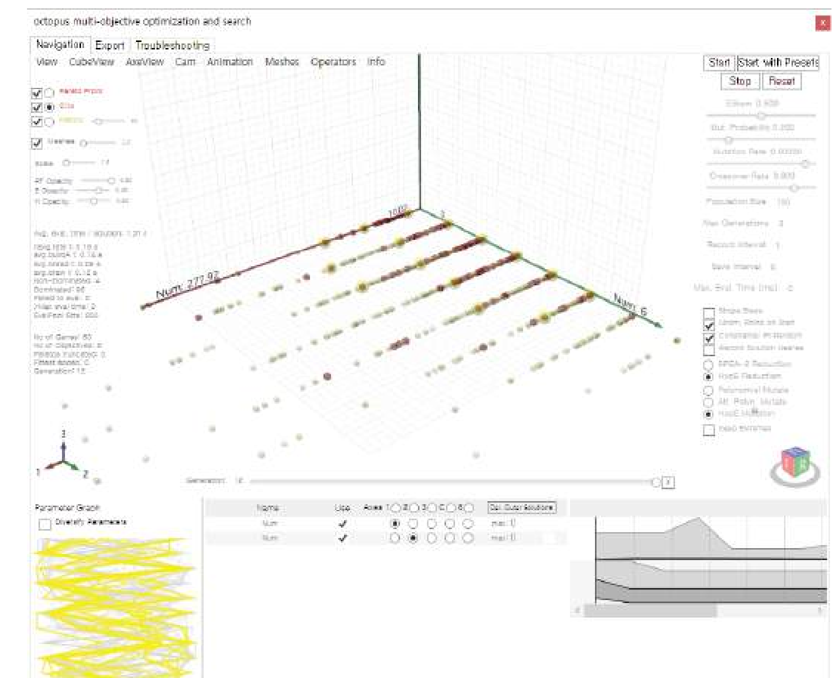
1) Connect genepool numbers to Octopus

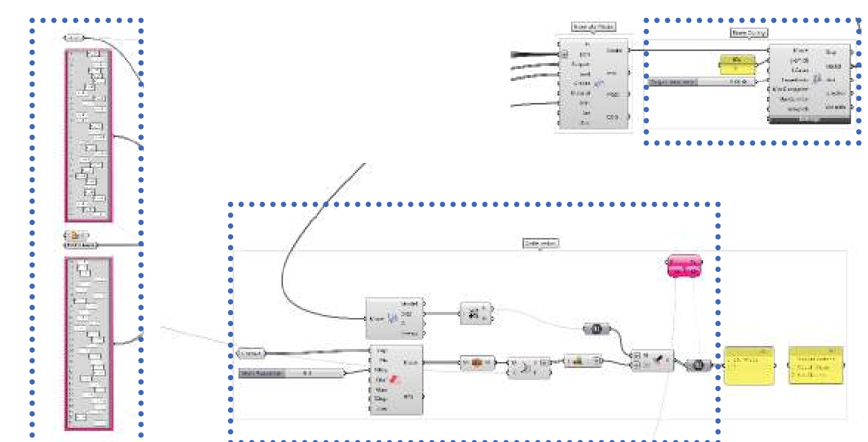
2) Import contexts as boundary representation

3) Create number as conflicts between structural members and contexts

4) Set a list of numbers and connect it into Octopus

5) Open up the Octopus interface

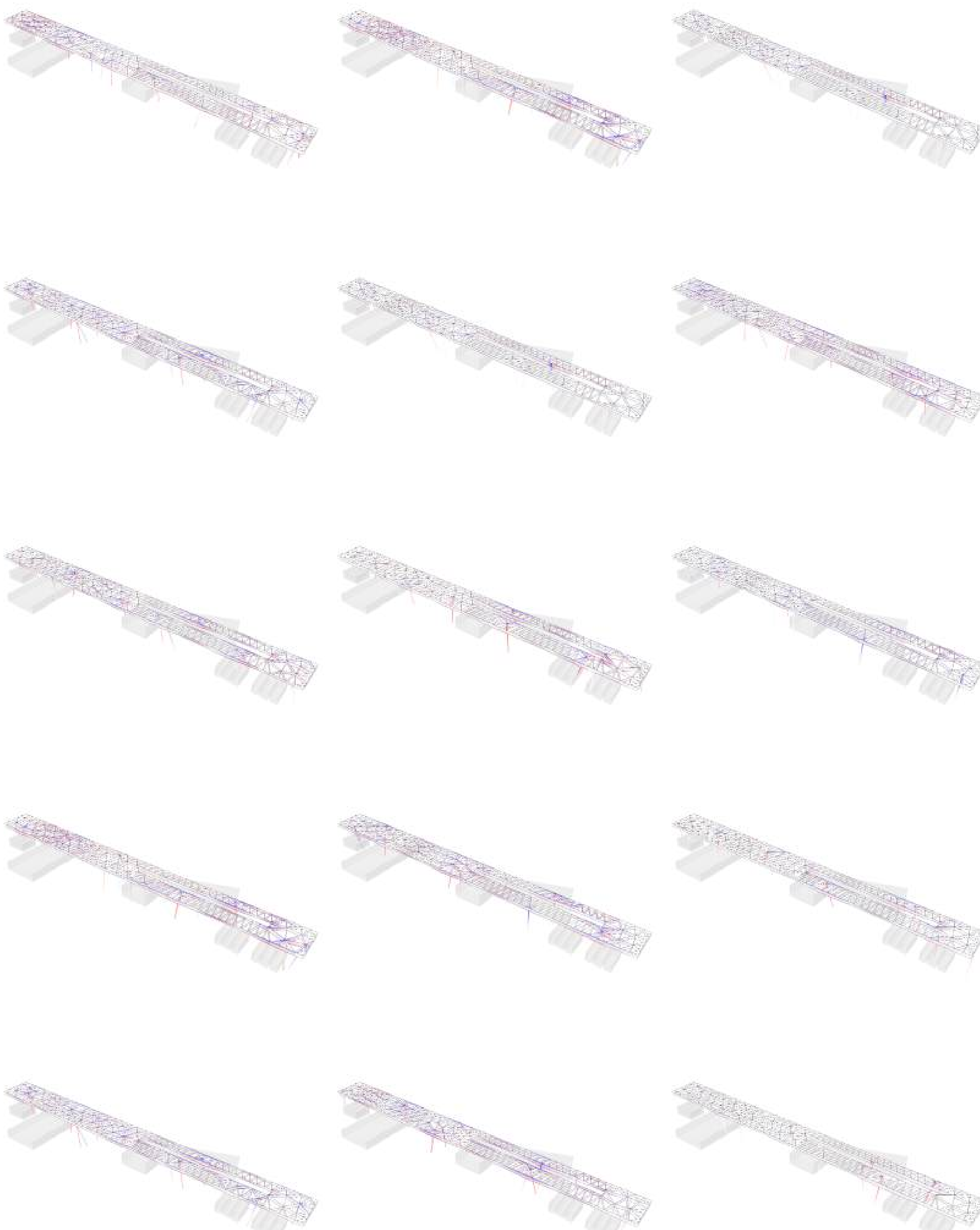




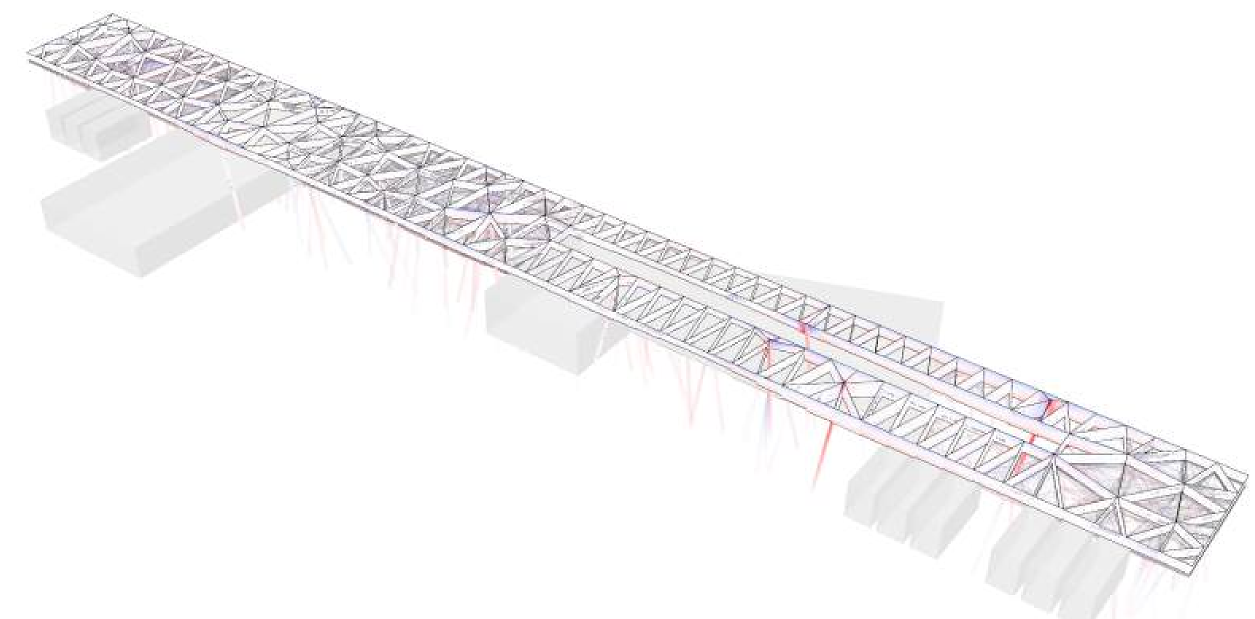
Run Solver

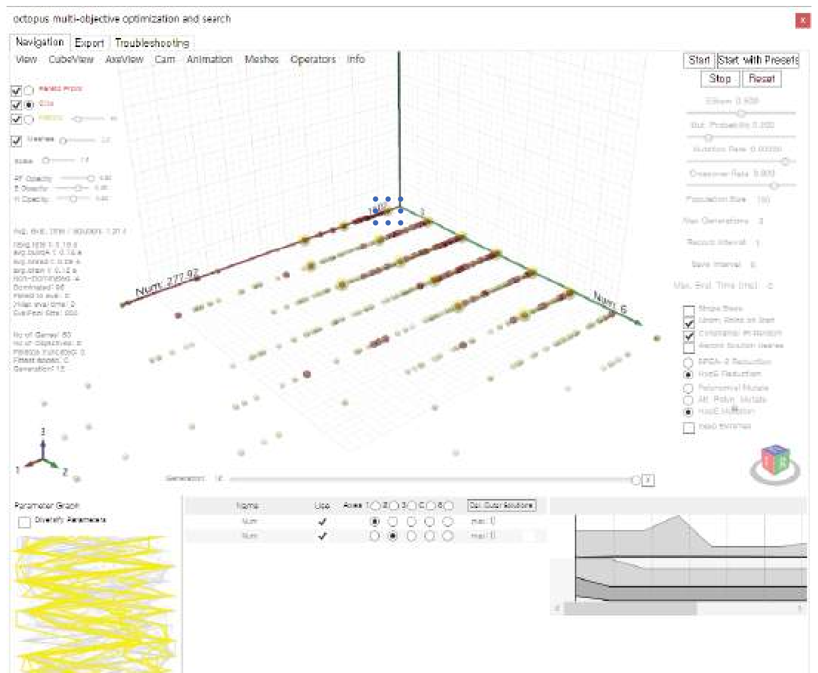
1) Run solver with a proper setting of generation

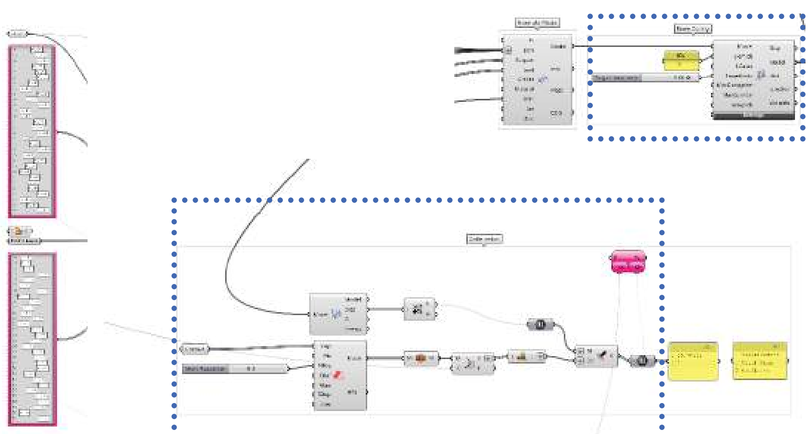
Roof substructure and its cross section in different column locations



Roof substructure and its cross section in different column locations



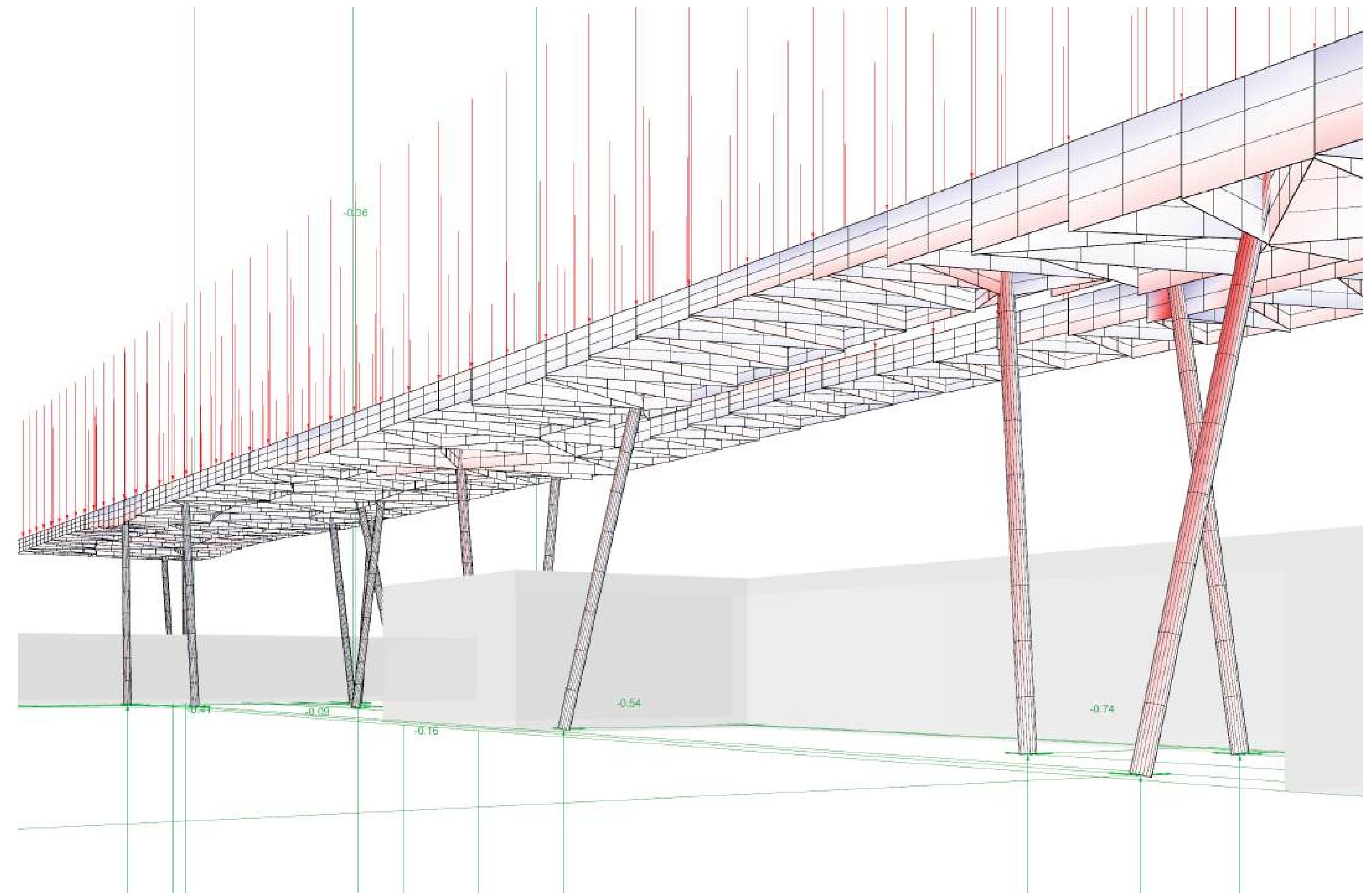




Reinstate the Optimized Option

1) Reinstate the top tier of the option

2) Check rhino view port for the result



This chapter introduces structural analysis and application of the calculation to sub-structure of the flat roof with context under it which cannot be overlapped with structural members. Two case studies will be introduced in this chapter with a slight variation of design and application methodology.

The work flow of this section is following order and objective.

- How to set up the sub-structure geometry in Parametric way
- How to incorporate the practical requirements in grasshopper environment
- How to connect it to Karamba3d software for calculation
- How to get the best location for column by using evolutionary computing

METHODOLOGY.03

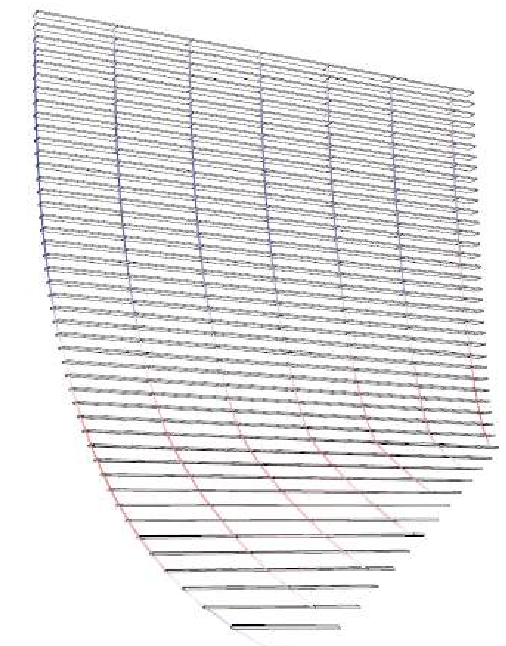
Application on Facade Module Assembly

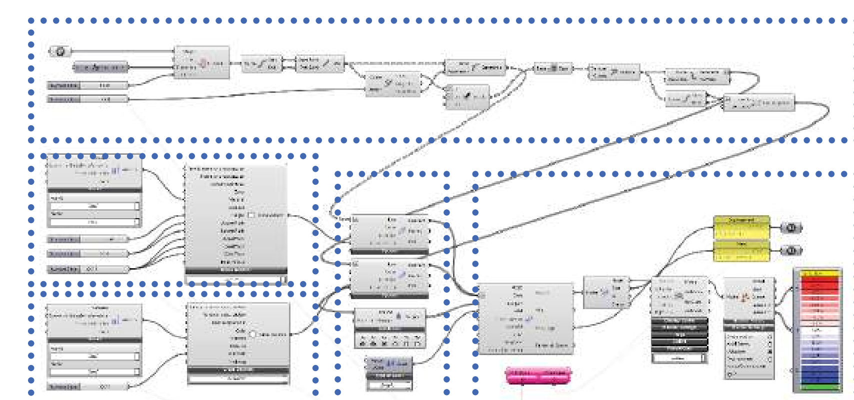
Application on Facade Assembly Ver.01

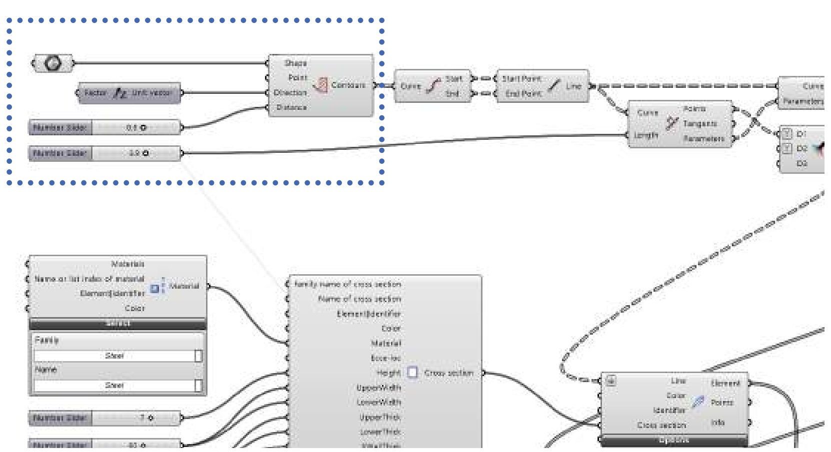
This chapter introduces structural analysis and application of the calculation to facade module without sub-structure. The case study will illustrate the translating methodology of applying calculated data into design options.

The work flow of this section is following order and objective.

- How to set up the subdivision of the facade module geometry in Parametric way
- How to prepare the calculation in accordance with practical requirements
- How to connect it to Karamba3d software for calculation
- How to translate the data from calculation to the appropriate section of the module



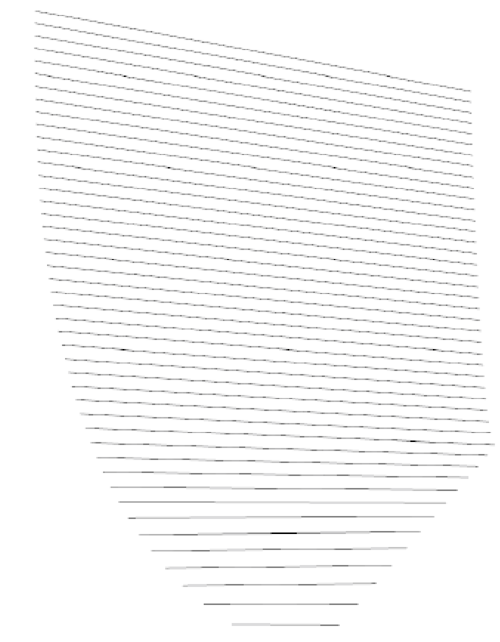


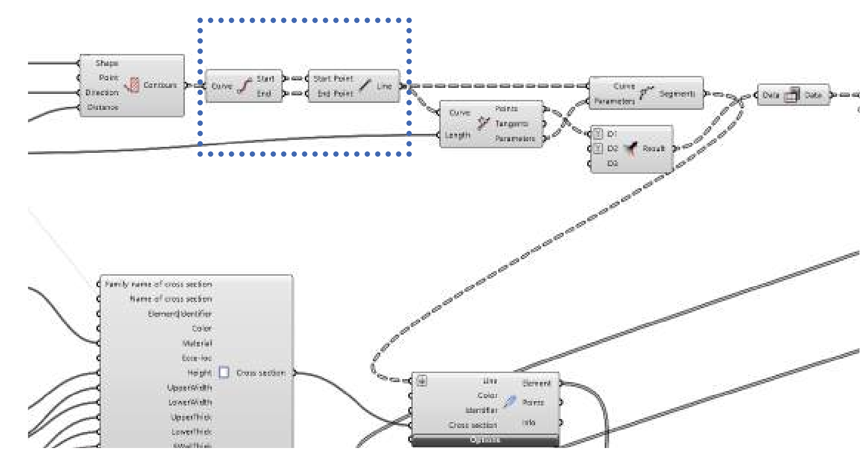


Import Facade Surface

1) Import surface into Grasshopper environment

2) Create coutour lines on the surface along Z-axis at desired distance

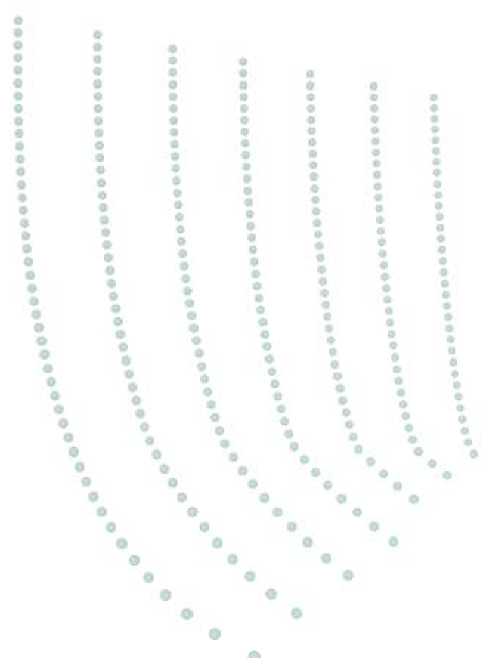


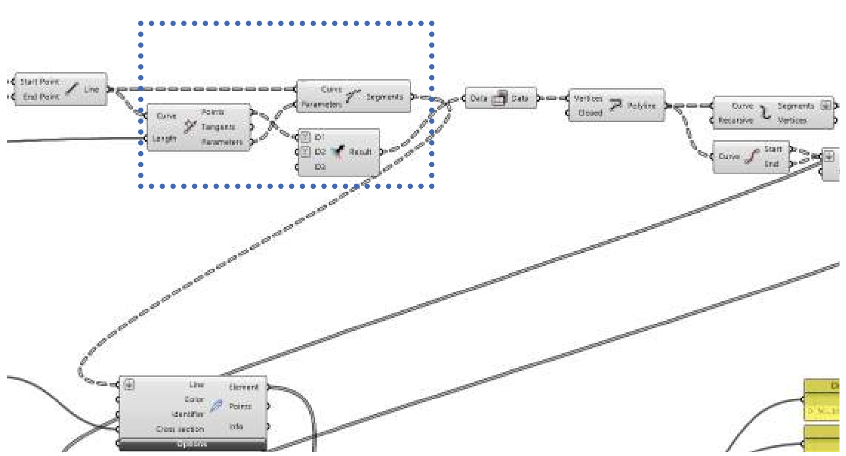


Set up Horizontal Modules

1) Extract start and end points of the contour curves

2) Draw straight lines between the extracted start and end points

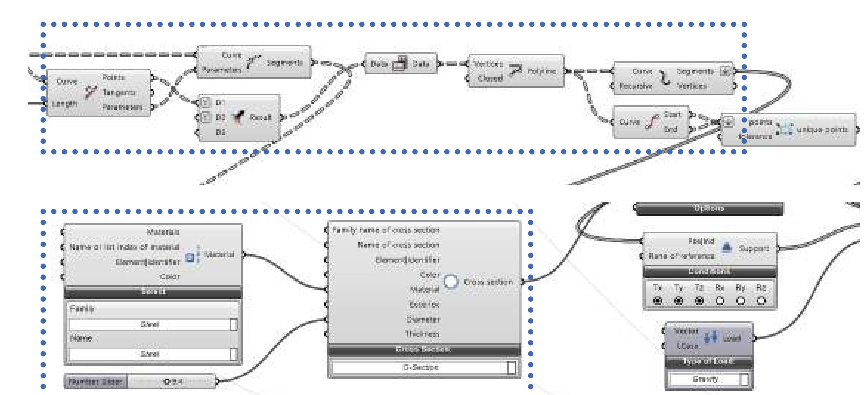




Set up Vertical Modules

1) Divide previously created lines by desired lengths

2) Subdivide the lines into segments



Create Cable

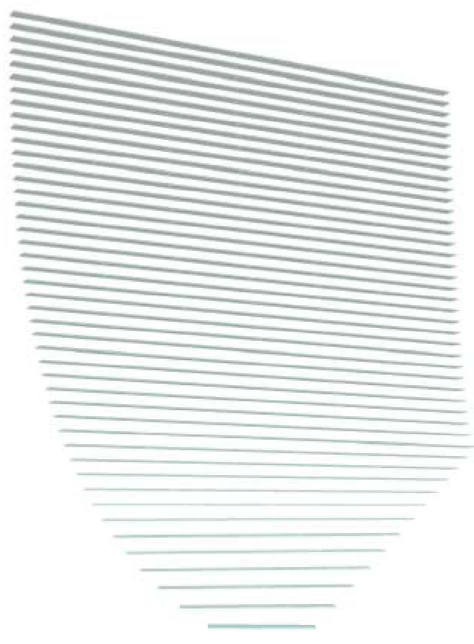
1) Extract the subdivision points and flip matrix

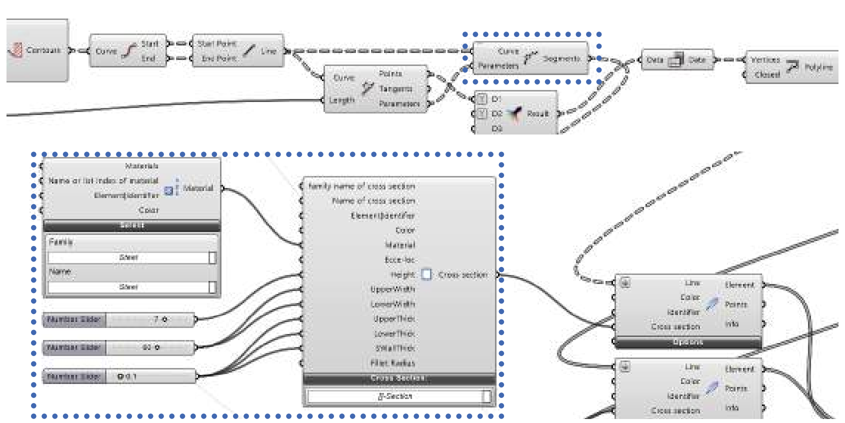
2) Create polylines along the points

3) Divide the polylines into segments

4) Convert the lines into structural elements

5) Assign desired properties (material, cross section, size, thickness, etc)



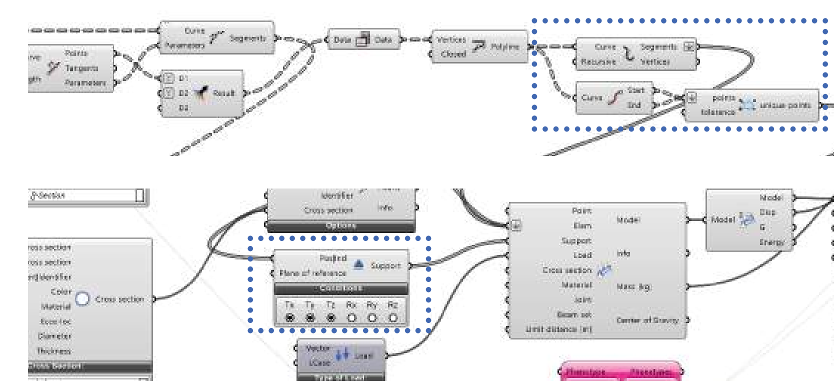


Create Louvers

1) Extract the line segments previously created

2) Convert the lines into structural elements

3) Assign desired properties (material, cross section, size, thickness, etc)



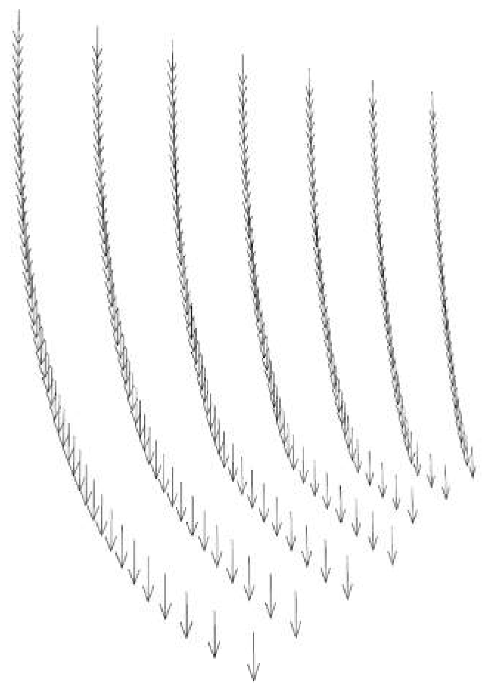
Set up Supports

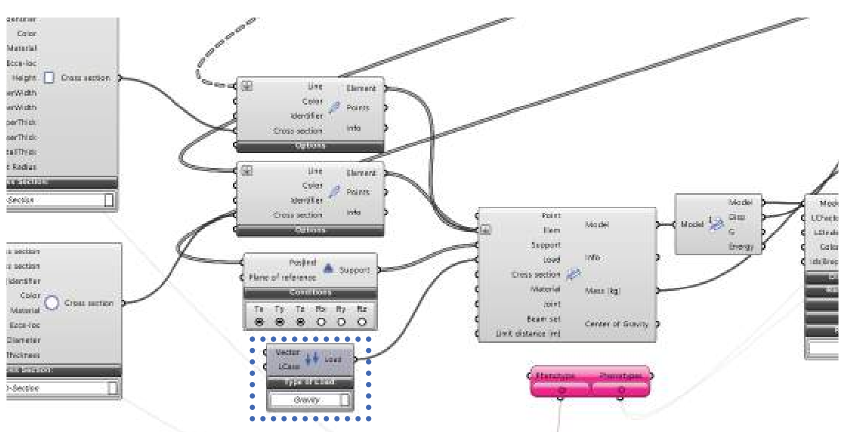
1) Extract terminal points of the cable

2) Remove duplicate points

3) Convert points into supports

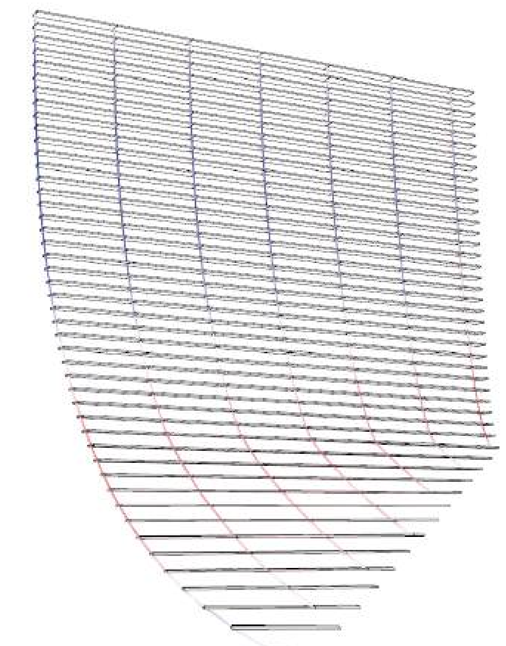
4) Assign appropriate support conditions

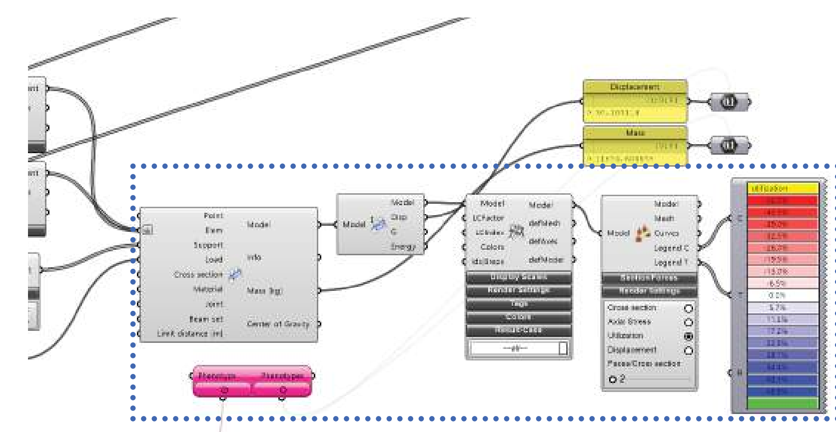




Set up Load

1) Assign gravity load



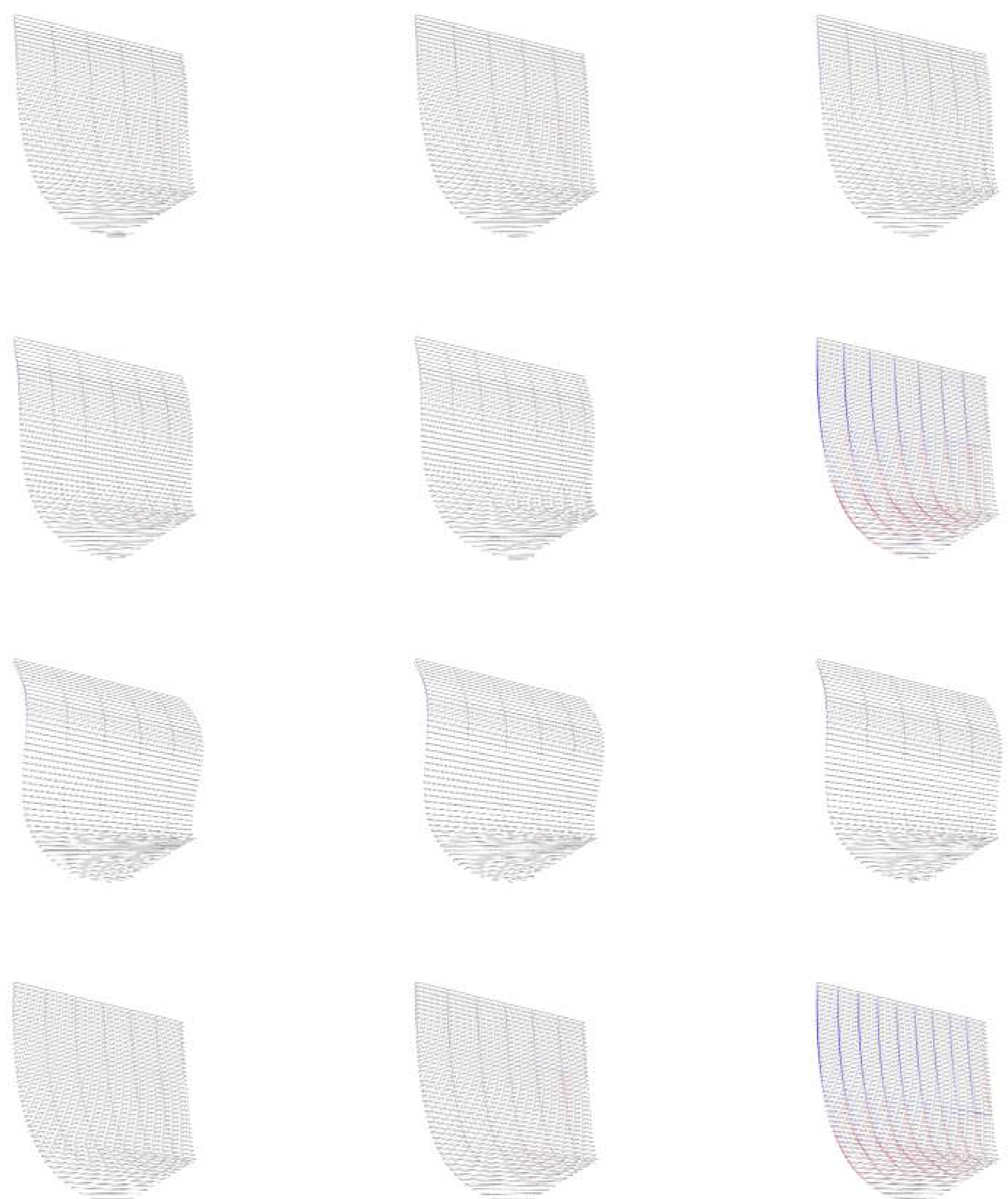


Assemble and Visualize Preliminary Result

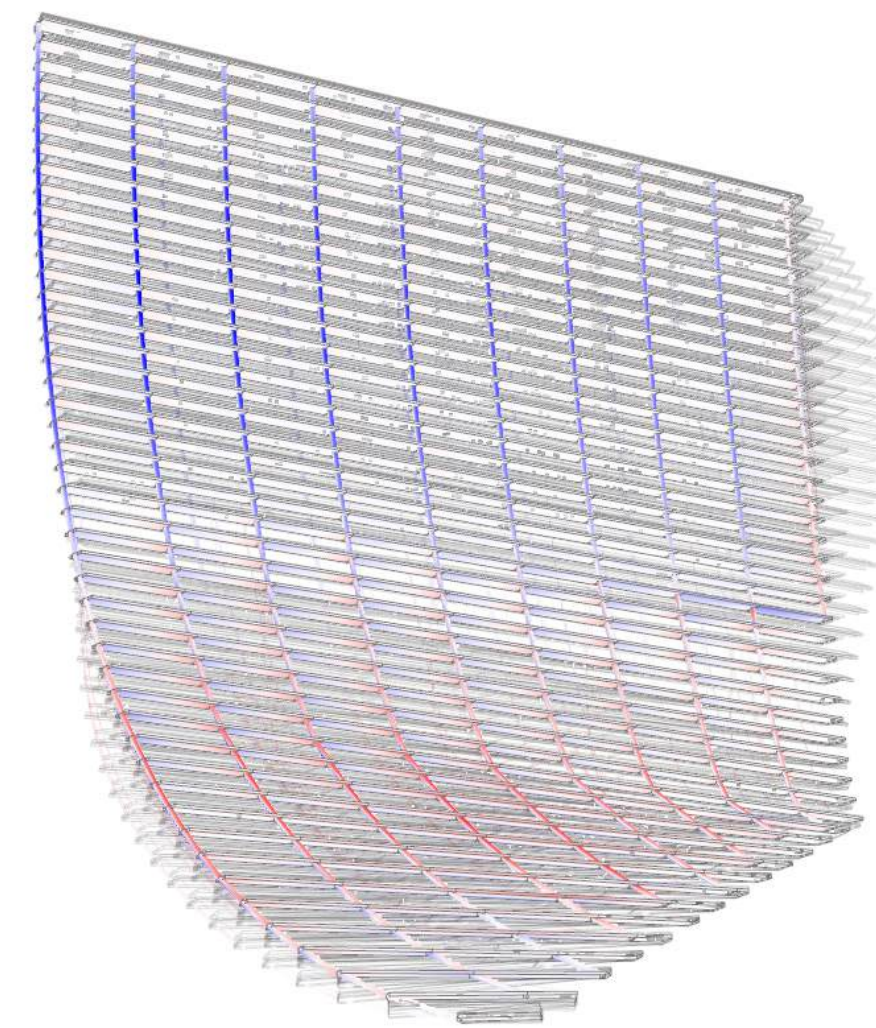
1) Assemble the elements for structural calculation

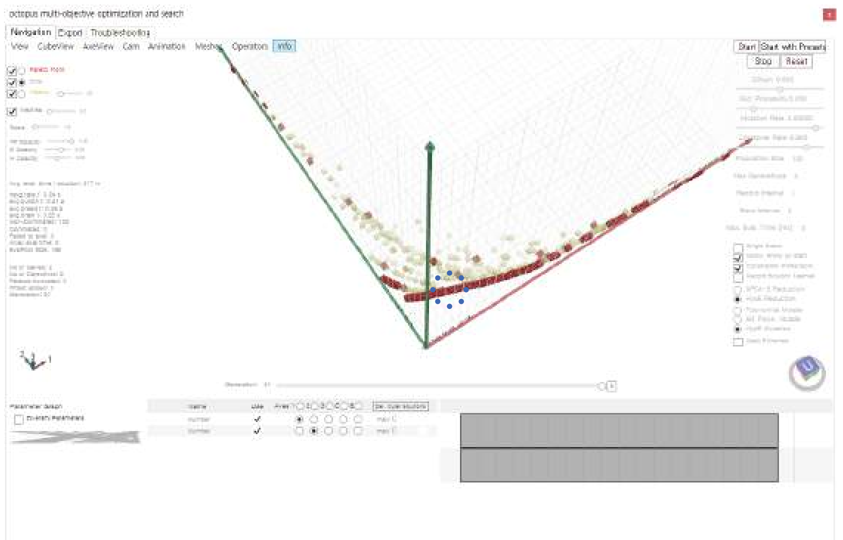
2) Connect the structural model to model view for visualization

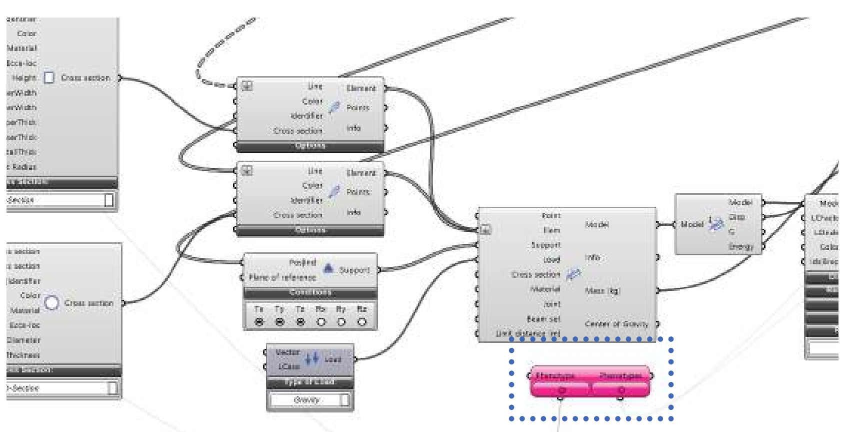
Facade structure in different cross section size and module distance



Optimized cross section size and module distance



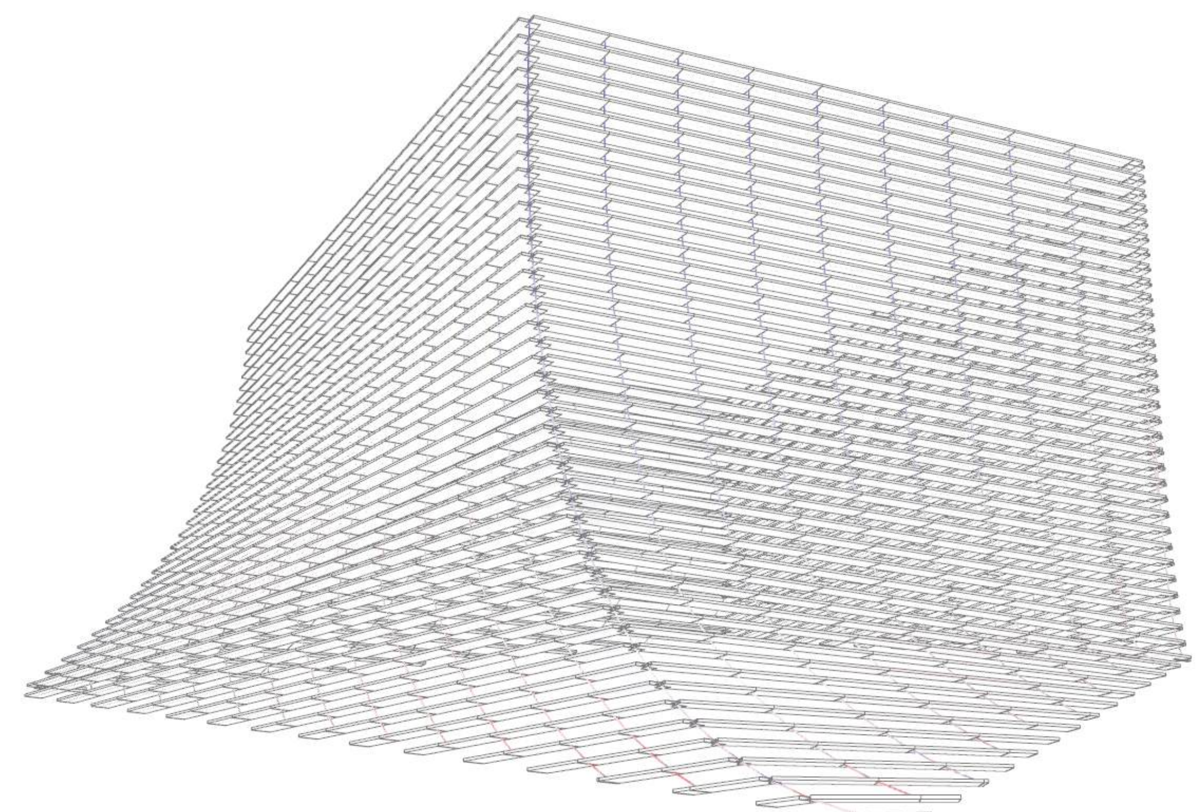




Reinstate the Optimized Option

1) Reinstate the top tier of the option

2) Check rhino view port for the result

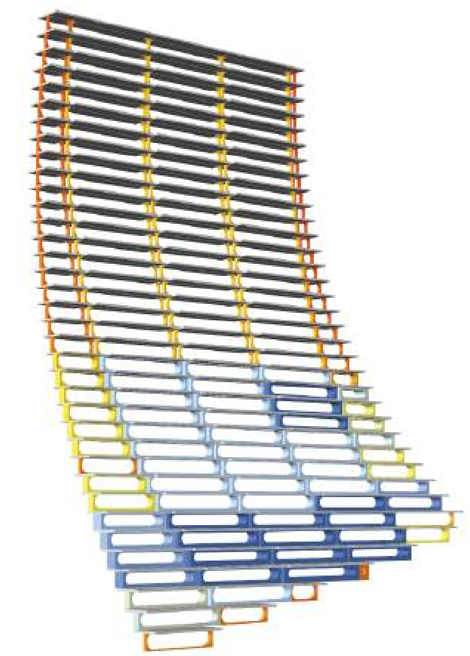


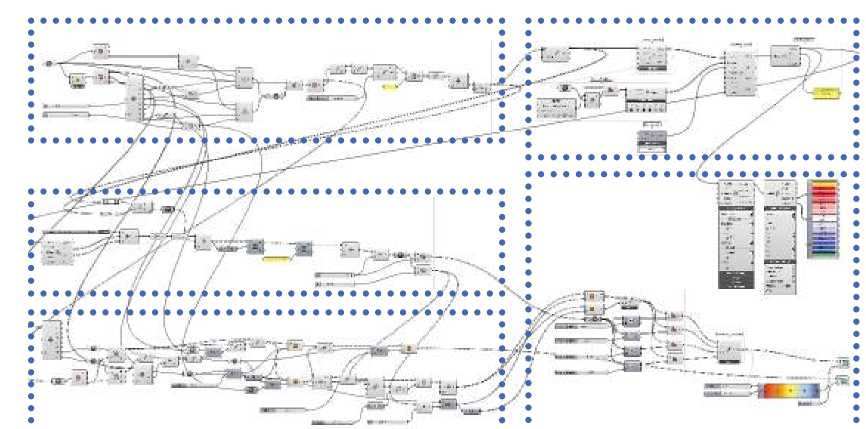
Application on Facade Assembly Ver.02

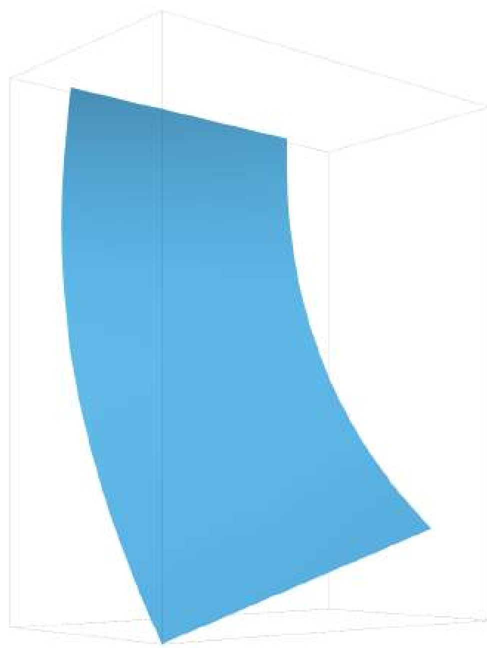
This chapter introduces structural analysis and application of the calculation to facade module without sub-structure. The case study will illustrate the translating methodology of applying calculated data into design options.

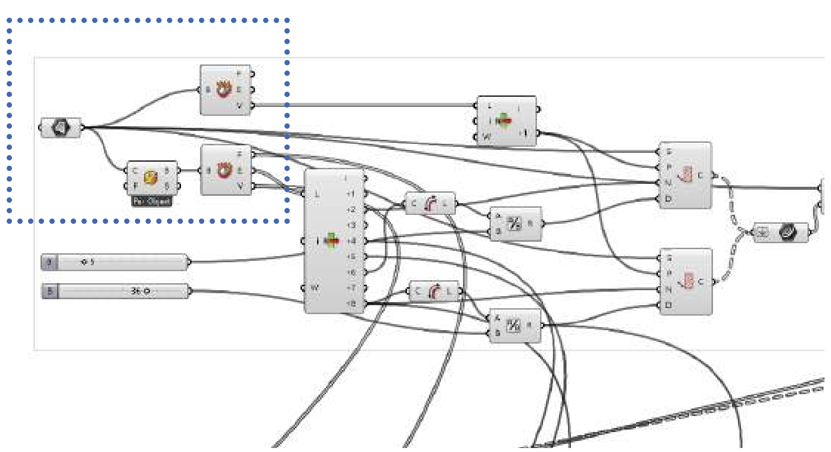
The work flow of this section is following order and objective.

- How to set up the subdivision of the facade module geometry in Parametric way
- How to prepare the calculation in accordance with practical requirements
- How to connect it to Karamba3d software for calculation
- How to translate the data from calculation to the appropriate section of the module





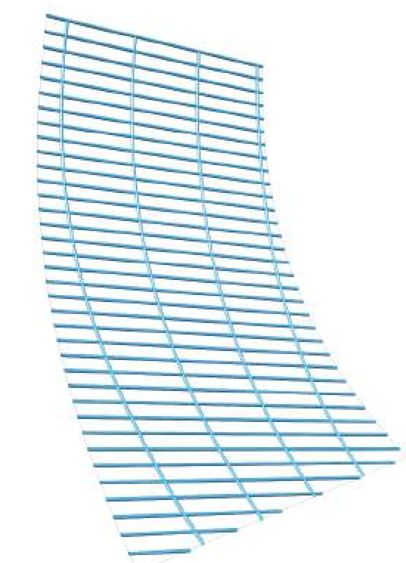


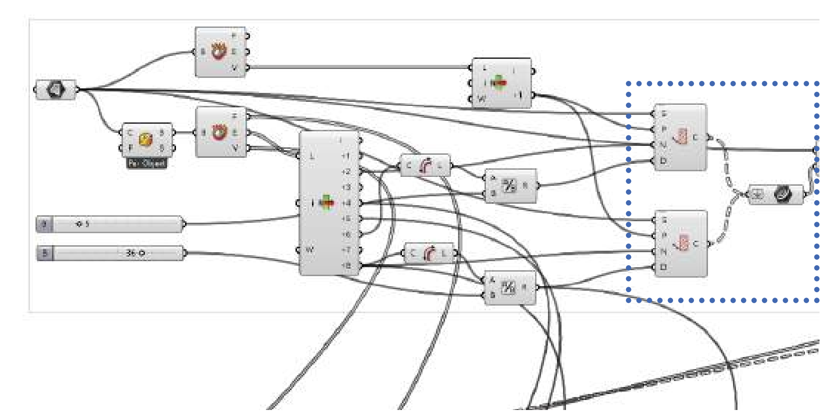


Import Facade Surface

1) Import facade surface

2) Create bounding box covering the overall surface

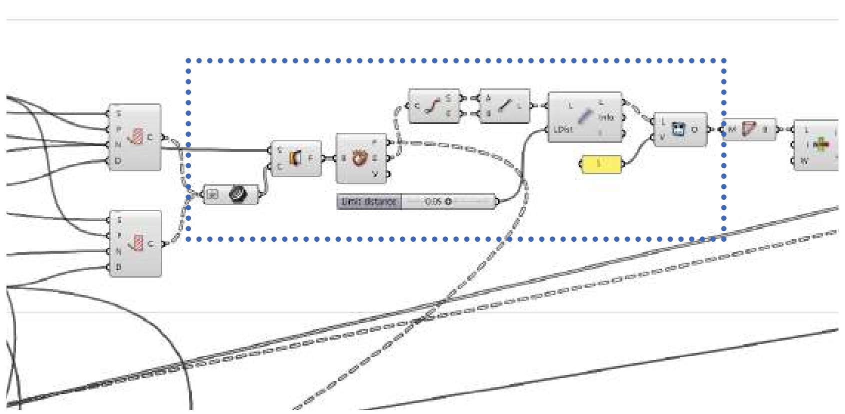




Subdivide the surface for modules

1) Create curves by contouring the surface

2) Subdivide the surface for module application

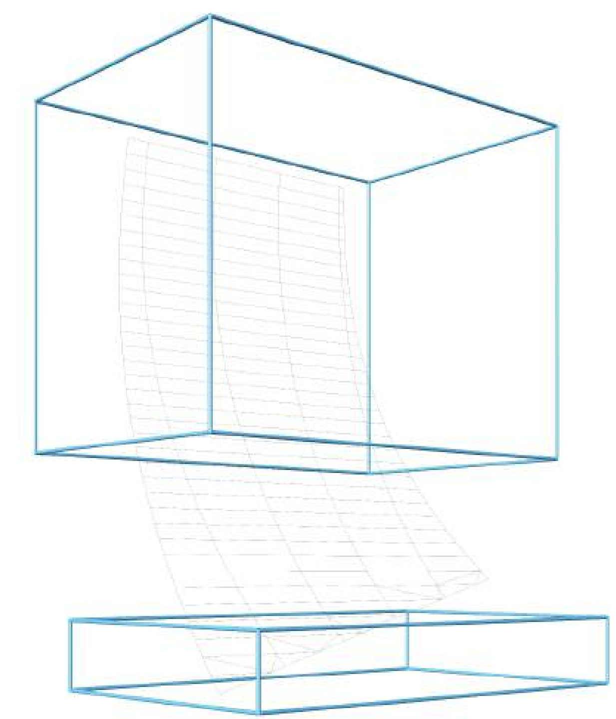


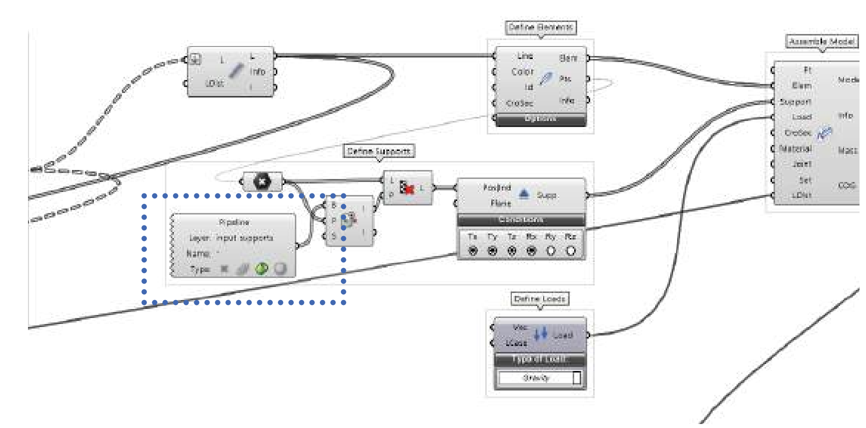
Create Mesh for the Calculation

1) Subdivide the facade surface

2) deconstruct each face and sort out edges as a curve

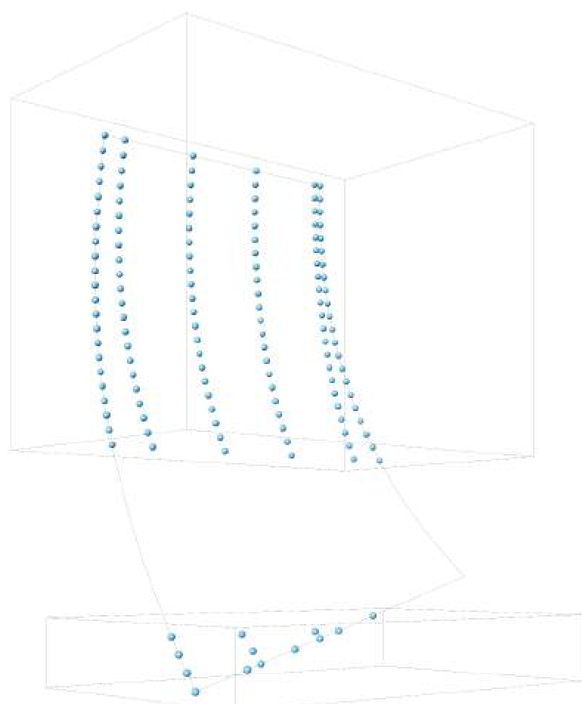
3) eleminate duplicated lines and create mesh from lines

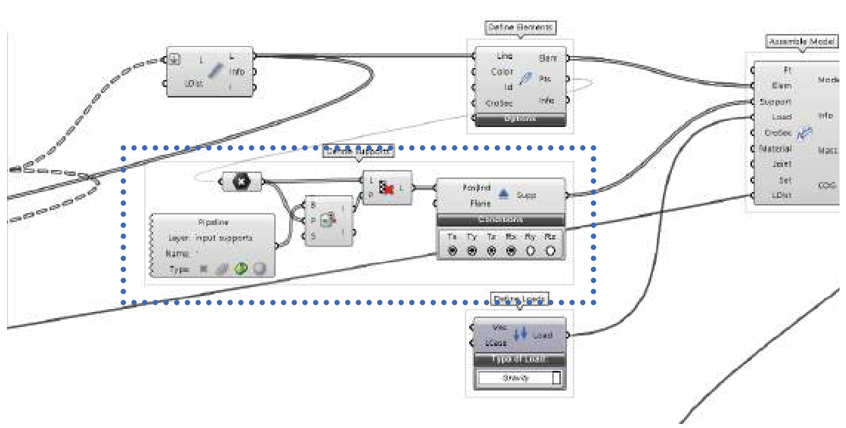




Create Boundary for Support

1) Import Boundary for the Support in accordance with project's condition

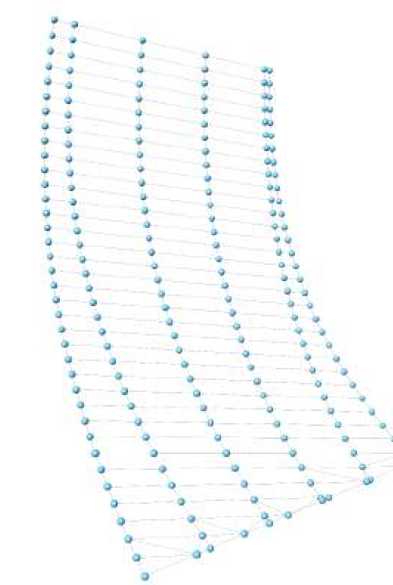


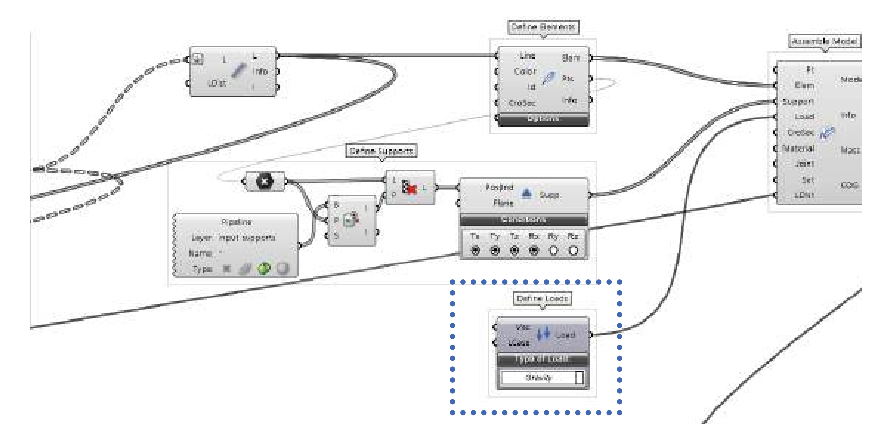


Set up supports

1) Cull out the points from mesh not belongs to the boundary

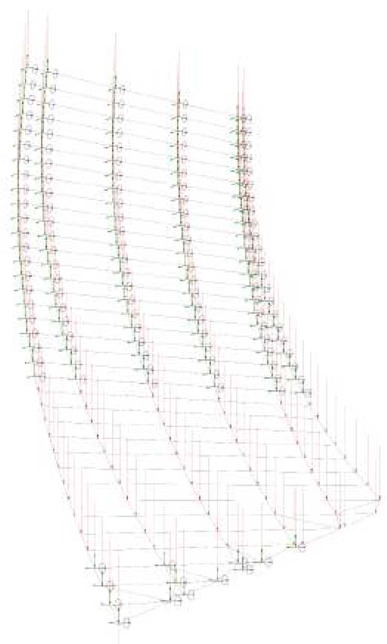
2) Convert rest of the items to supports with a proper setting

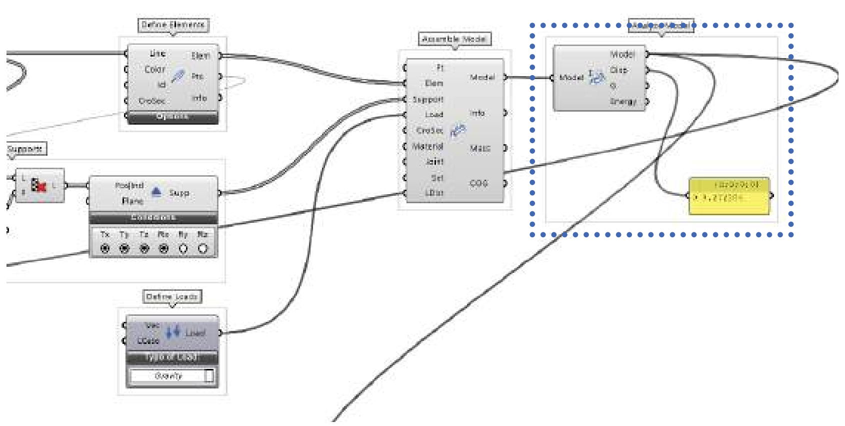




Set up Load

1) Assign gravity load

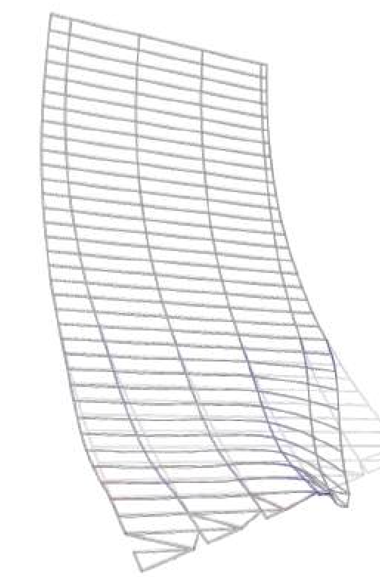


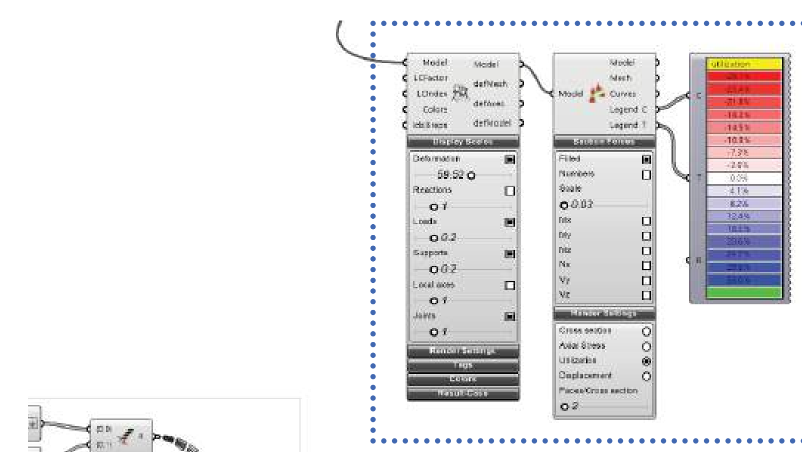


Assemble Model

1) Assemble the elements into model

2) Check the displacement as a number

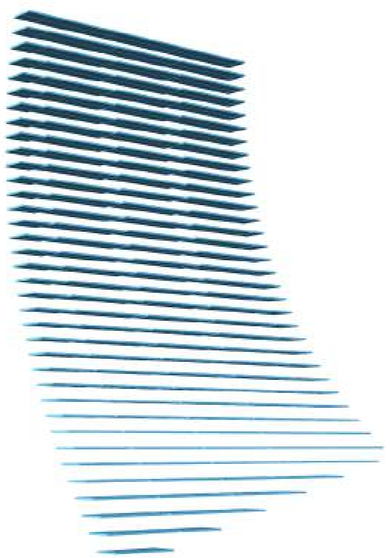


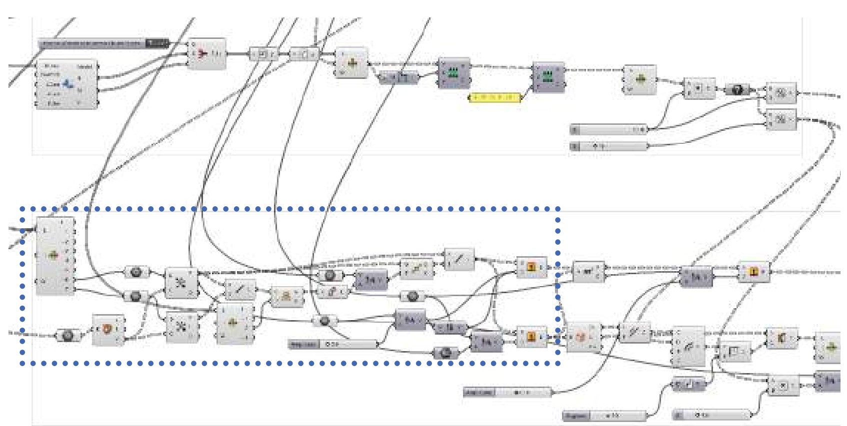


Visualize Preliminary Result

1) Connect the structural model to model view for the visualization

2) Check deformation for each element

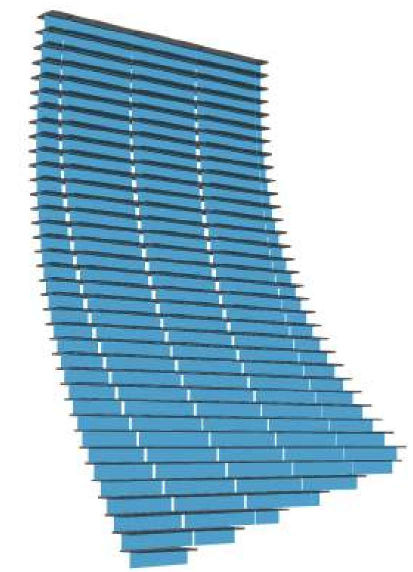


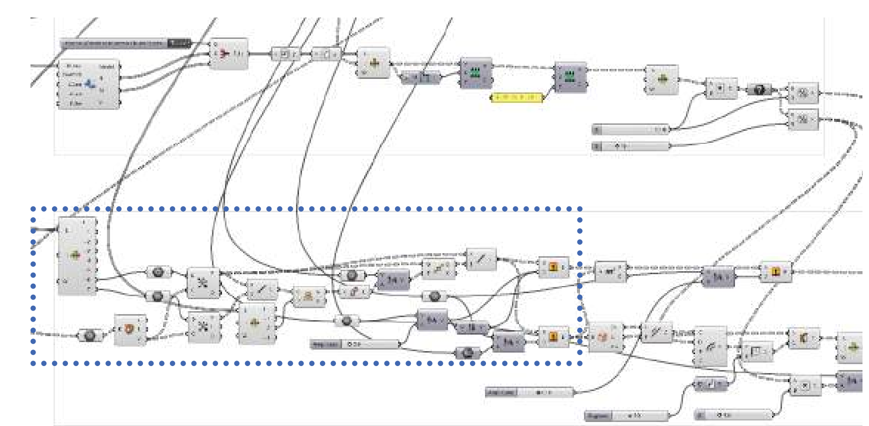


Create Louvers

1) Sorting out horizontal curves from subdivided surface

2) Extrude the curve in proper direction, depth, and width for the louver

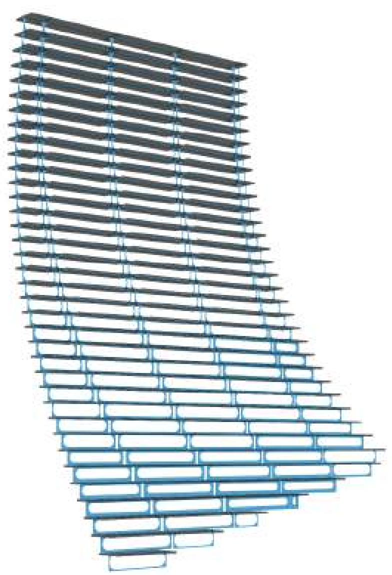


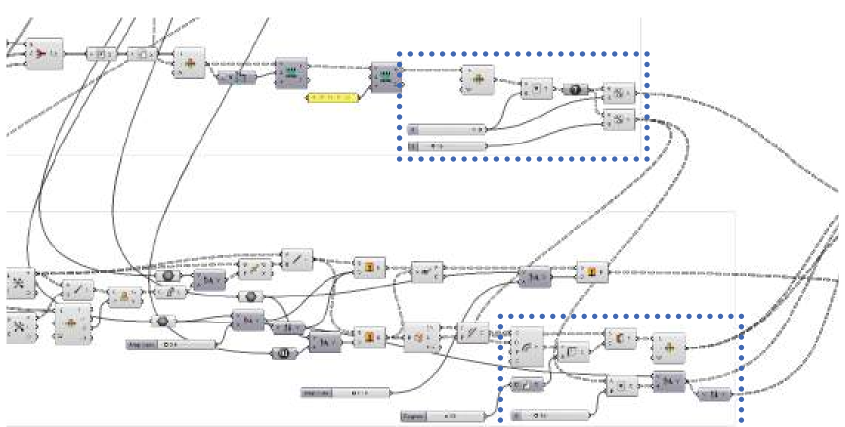


Create Web of the module

1) Sorting out horizontal curves from subdivided surface

2) Extrude the curve in proper direction and height

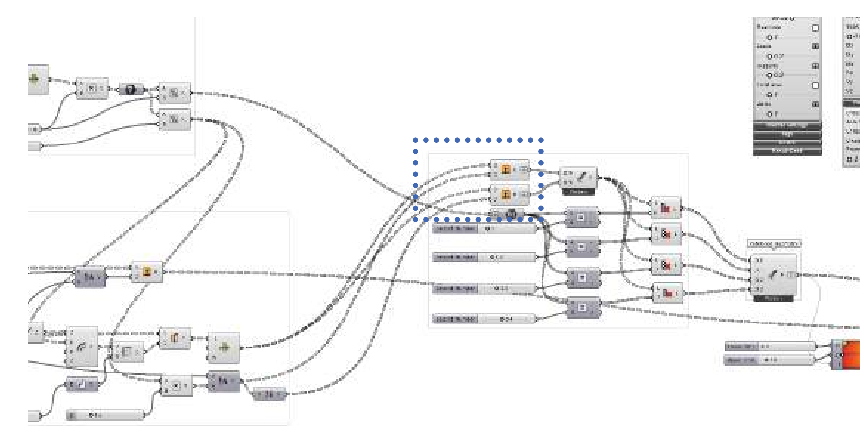




Create Shape of the Web

1) Create list of the number from former calculation reflecting moments

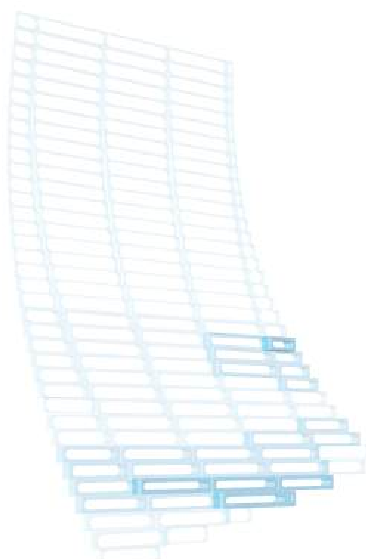
2) Cull out less loading parts of the web via offset sorted out list of numbers

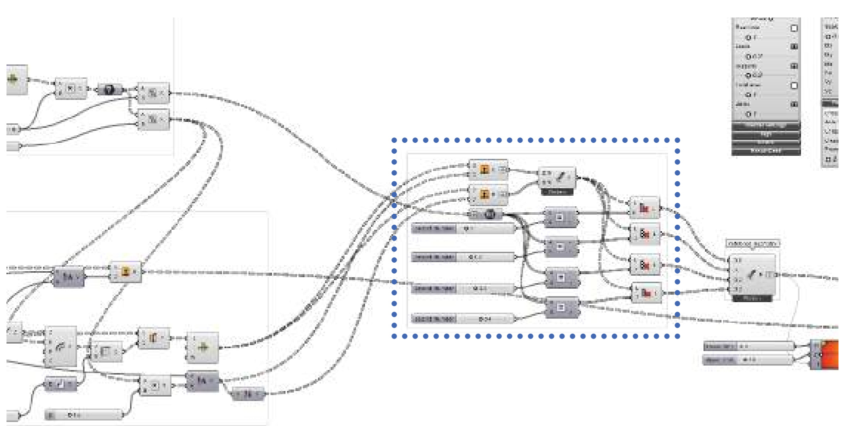


Create Depth of the Web

1) Set up shape of the web to be extruded in proper direction

2) Connect list of the number from former calculation to extrusion



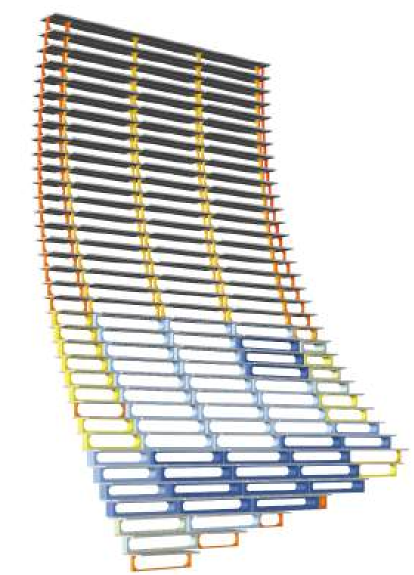


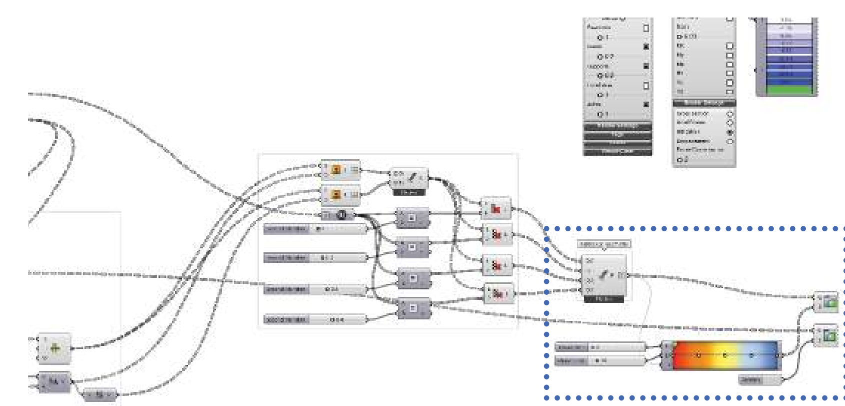
Align Modules

1) Create list of the items

2) Remaping and integering the numbers to be categorized

3) Clean up and list up the item again for the further management



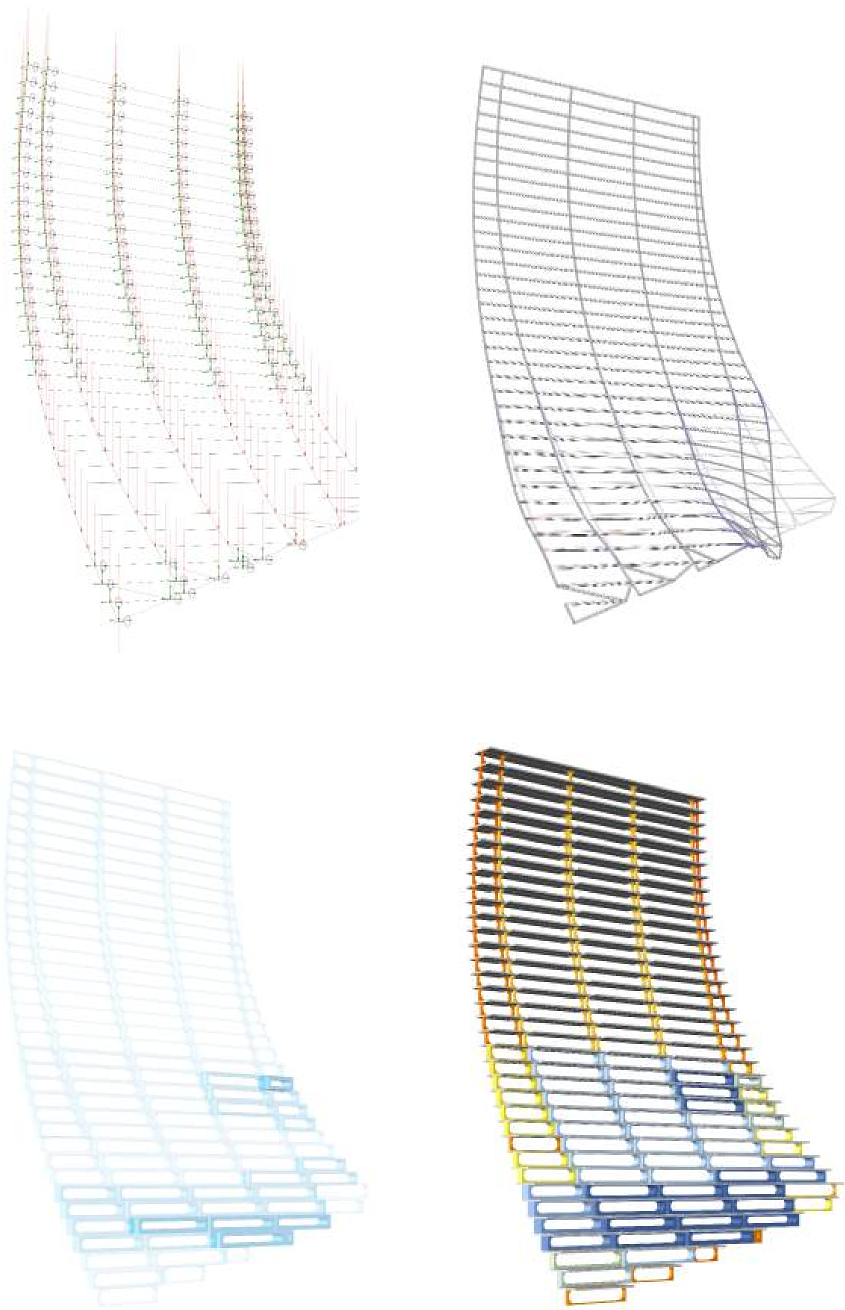


Visualize the Result

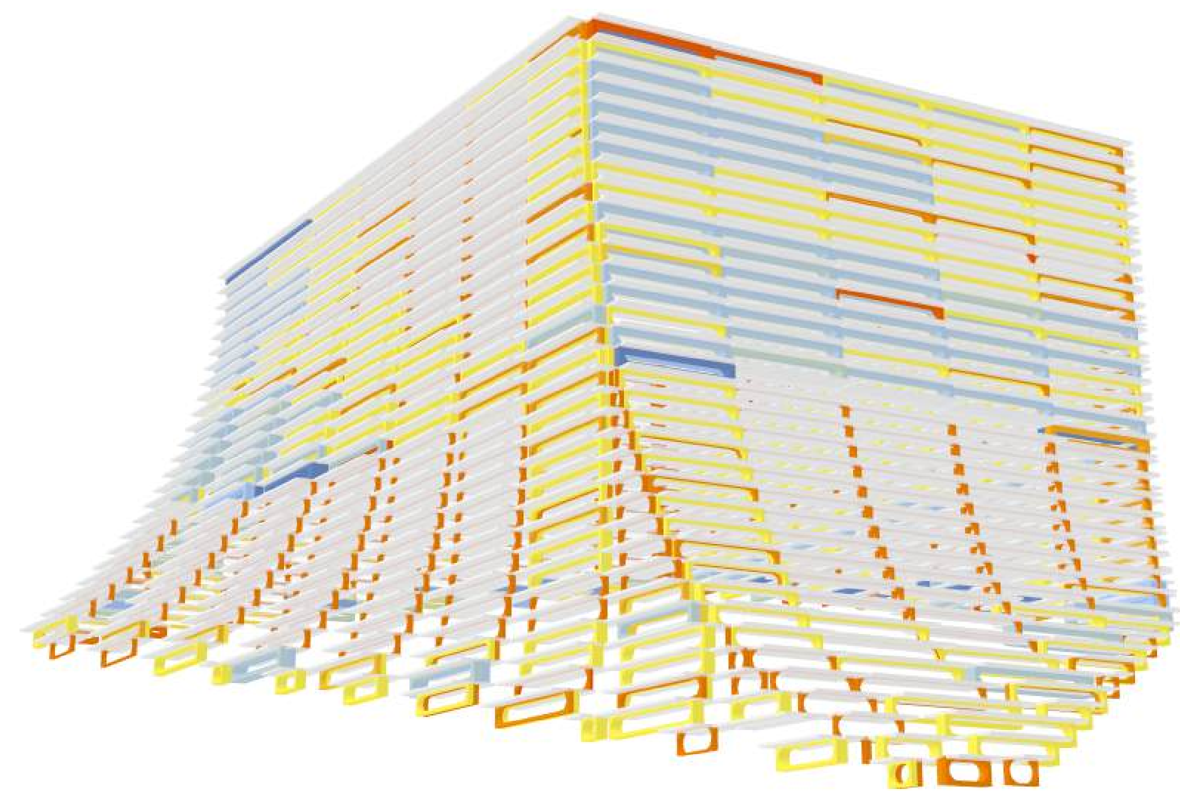
1) Connect the items to gradient for the visualization

Top left: Structure Assembly Model
Bottom left: Load Reflected Module type

Top right: Structural Displacement Model
Bottom right: Color mapped Visualized Model



Application over multiple surface



CONCLUSION & FUTURE STUDY

Conclusion & Future Study

The application of structural optimization methods with other computational design methods in architectural practice is a relatively young subject. Yet, as academic researchers and design professionals have devoted themselves into the integrative design methodologies, other disciplines such as engineering, material science and construction came to be integrated with the architectural design and other trajectories had emerged.

The First volume covered the size and shape optimization in regards with each structural members based on the direction of forces and locations of reinforcing elements. The Second volume has focused on the application of parametric structural optimization to architectural design process.

A series of studies has been developed for architects and designers to manipulate the design alternatives based on their own design process in macro scale. The computation design strategy allows design studies and analyses to occur simultaneously from the beginning of the process. The parametric structural optimization requires less labor and time to produce both the design and construction. In addition, this research has a potential to expend both in meso and micro scale to explore further details of macro level of the research. Through this research, one can expect a wide range of applications on models that operate under similar system of formation.

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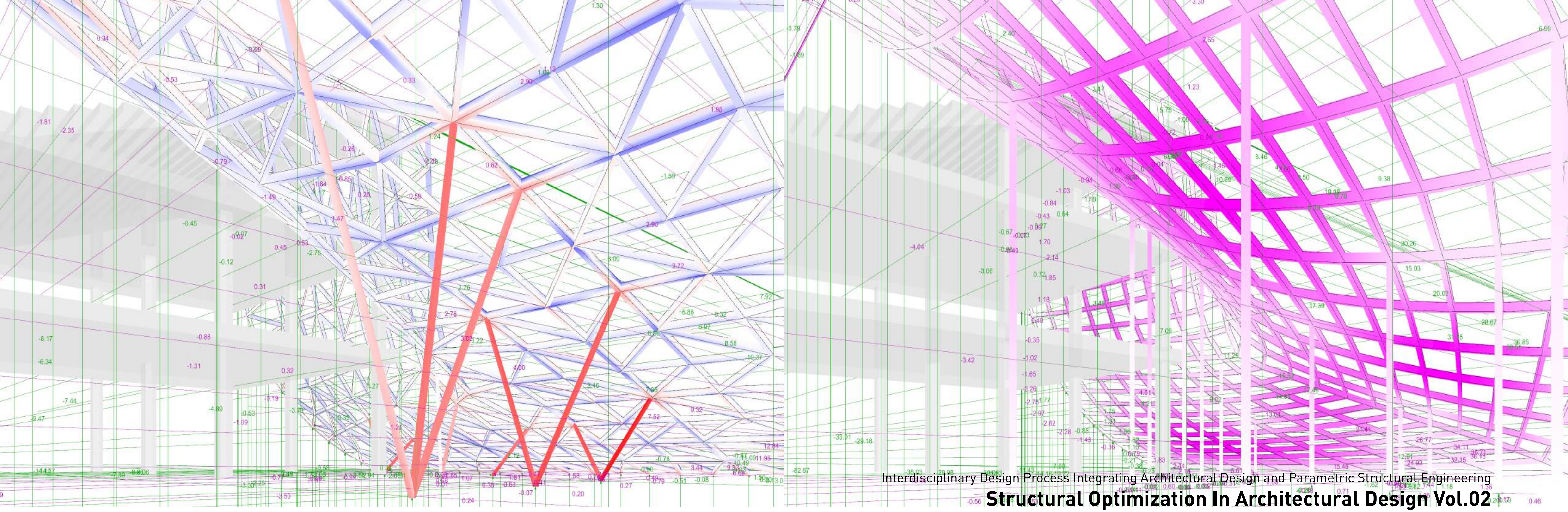

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Structural Optimization In Architectural Design Vol.02

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