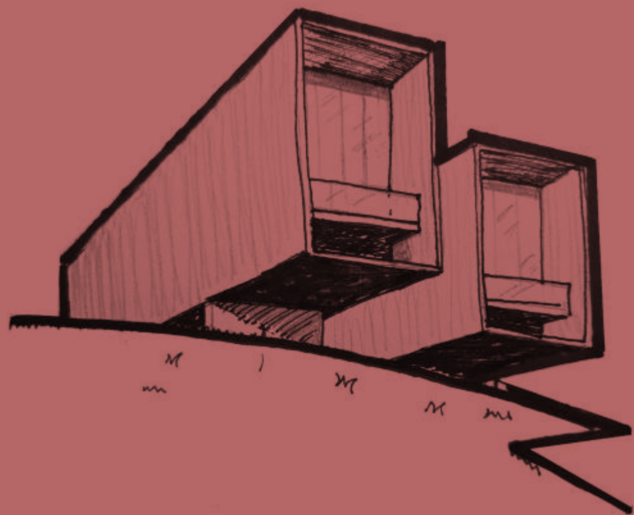


TWO HULLS HOUSE

MSc Architecture - Politecnico Di Milano (AY 2019-2020)

Project Type - Structural Analysis (Pre-existing Project)

Architects - Mackay-Lyons Sweetapple Architects

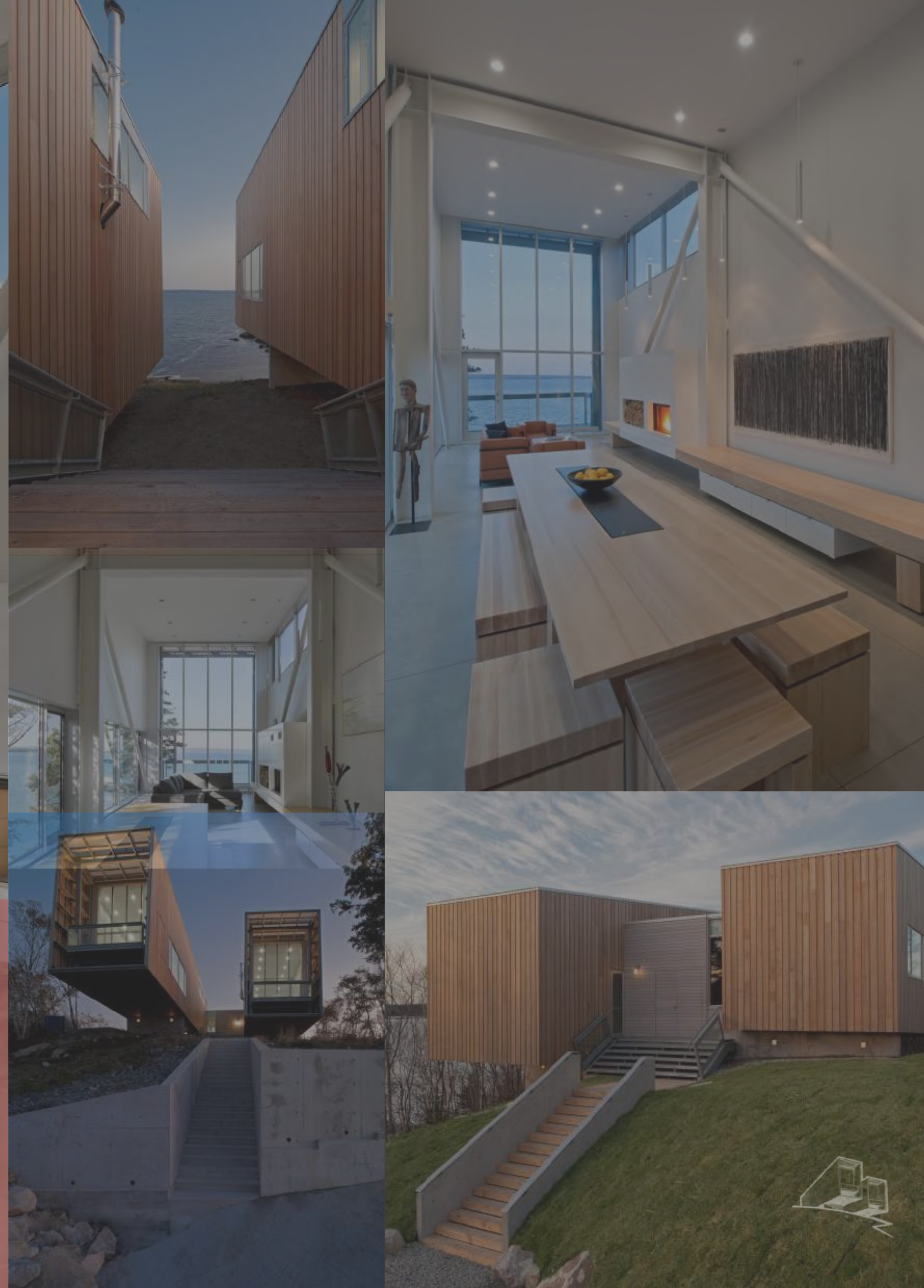
Location - Port Mouton, Nova Scotia, Canada

TWO HULLS HOUSE

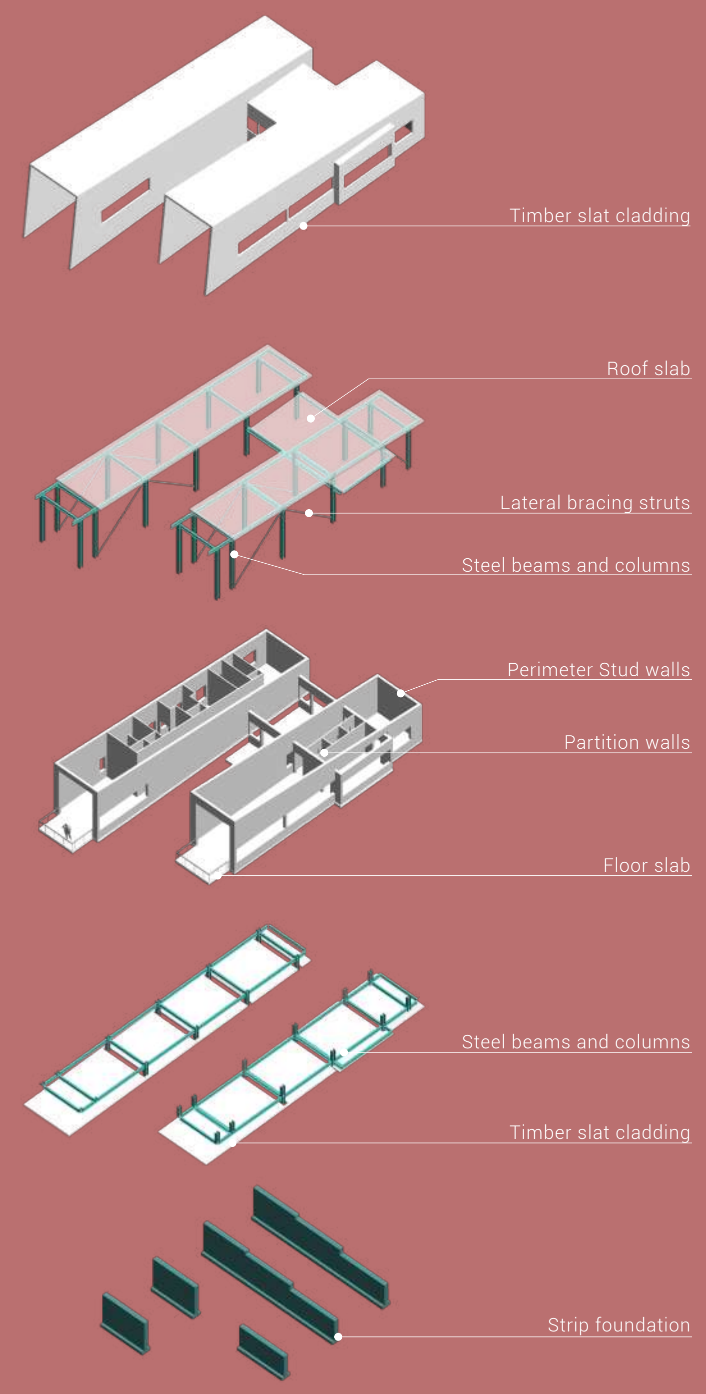
BY MACKAY-LYONS SWEETAPPLE ARCHITECTS

The aim of this project was to gain basic knowledge on structural design and analysis for steel structure, using as a case study, an existing building. I chose to study 'The Two Hulls House 'by Mackay-Lyons Sweetapple Architects as I was intrigued by its architectural composition. The application of a simple steel frame configuration in realization of what seems to be two sets of exaggerated cantilevers directly facing the North Atlantic Ocean. The two compartments comprise of 9.29m cantilevers, providing interesting contraints structurally and architecturally.

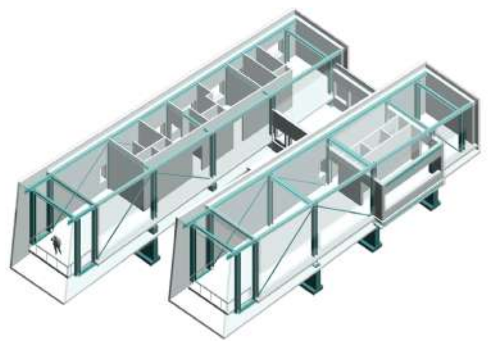
The structural analysis was carried out using finite element code software; MIDAS Gen for simulation and generation of values. Due to lack of adequate technical information from the real project, through online sources and from consultants involved, alot of information had to be estimated in-order to proceed with the structural analysis. This estimated data is then examined and then modified to more suitable values/dimensions.



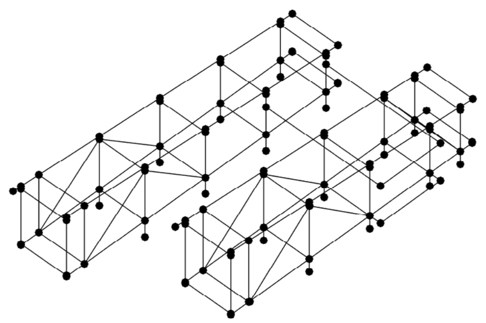
GEOMETRIC CONFIGURATION



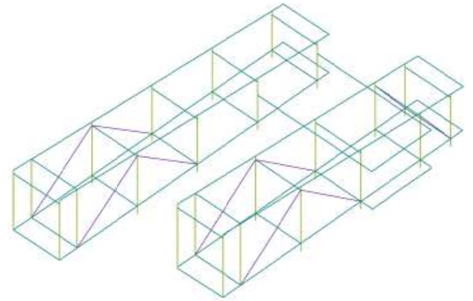
WORKFLOW



Revit Architectural Model



Revit Analytical Structural Model



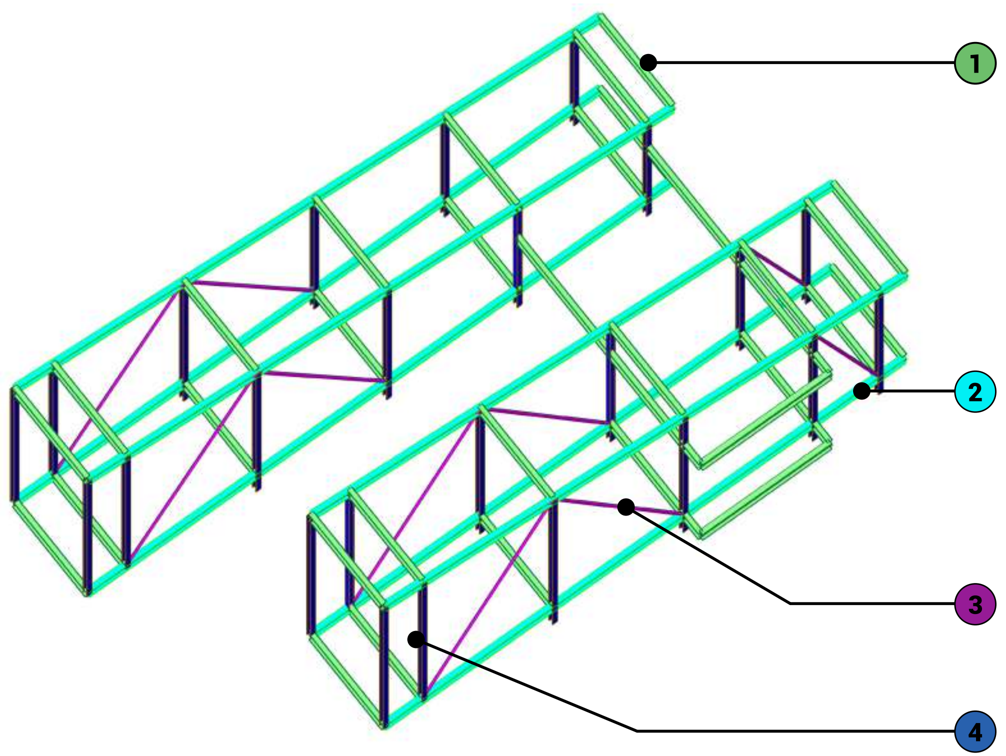
AutoCAD DXF

Using dimensions from existing plans and sections, a model of the geometrical configuration of members was made in the following order;

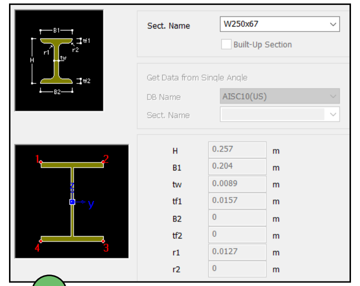
1- Geometrical configuration modelled in Revit and then reduced to analytical line models.

2- The analytical model is exported to AutoCAD, scaled, and then converted to DXF format

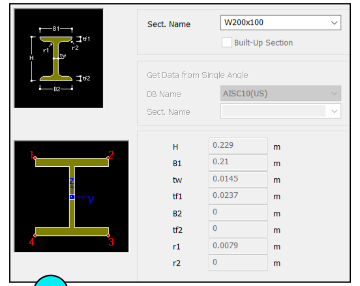
3- The DXF file is imported into MIDAS.



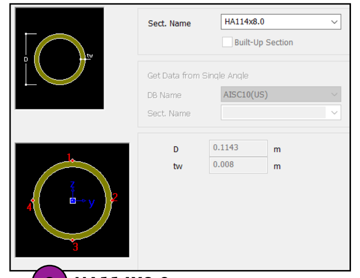
STEEL CLASSIFICATION & CROSS-SECTIONAL PROPERTIES



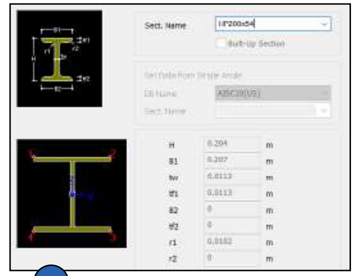
1 **W250x67**



2 **W200x100**



3 **HA114X8.0**



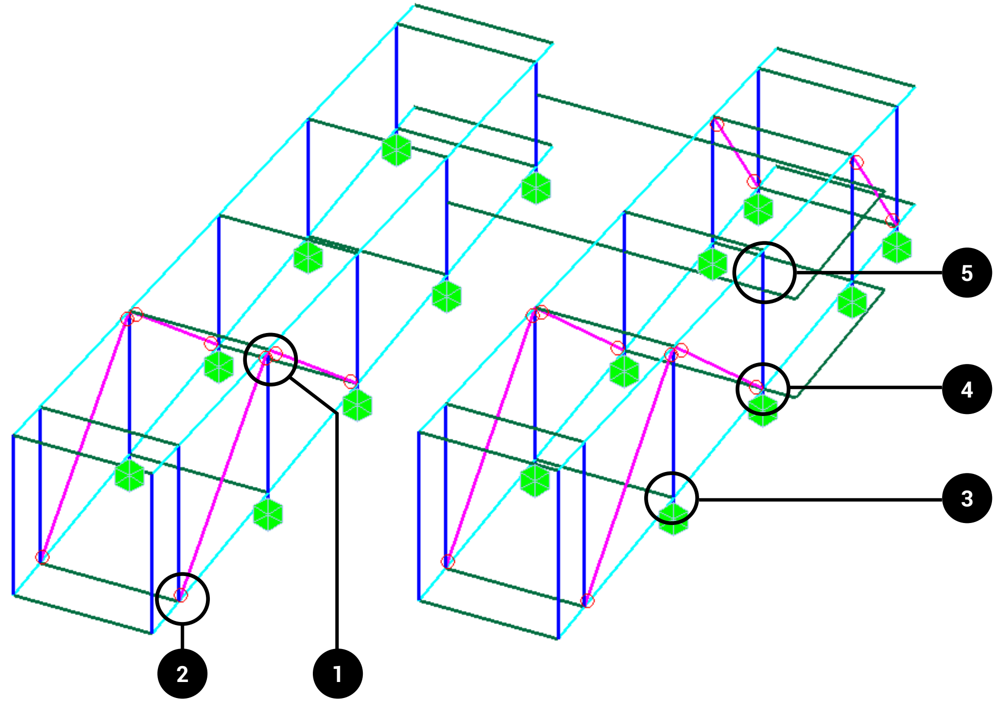
4 **HP200x54**

In approximation of the sectional profiles, I have used the Canadian Institute of Steel Construction **CISC02(SI)** as the main database.

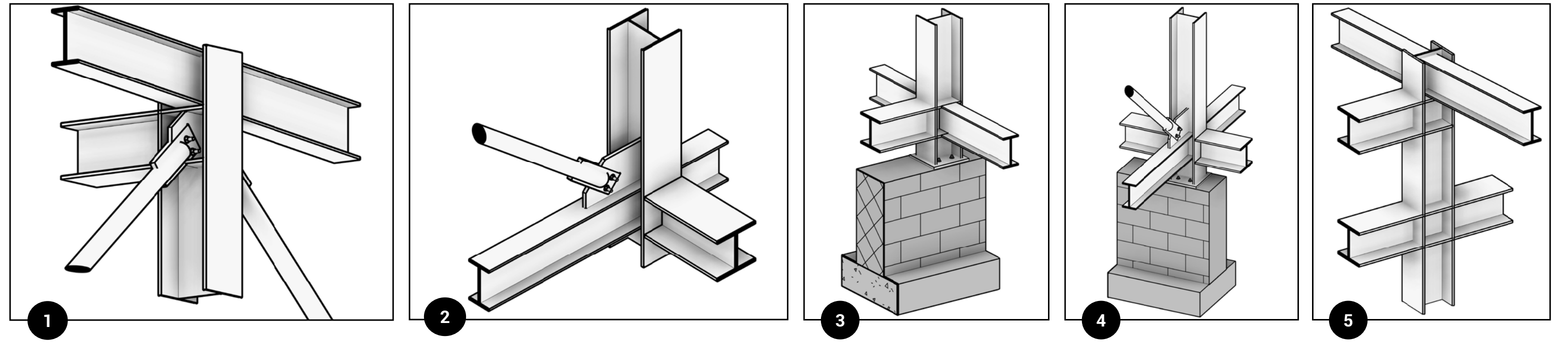
Steel classification of **S235,** based on the European Norm standards, and giving a yield total strength and Modulus of Elasticity of **235MPa** and **210GPa** respectively.

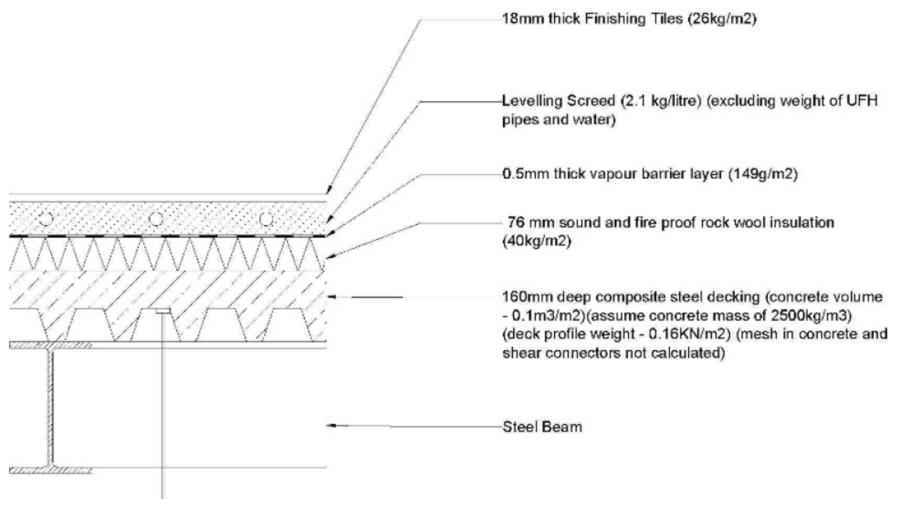
The structure comprised mostly of welded moment resisting joints at member nodes, as such they are all assumed fixed. Connections to the strip foundation substructure are fully constrained anchor bolted joints. Pinned joints are used for the bracing struts, as such the are approximated to members with beam releases.

Joints 1 & 5 have been simplified from overlapping nodes to single nodes. As the same effects are achieved from a structural stand point

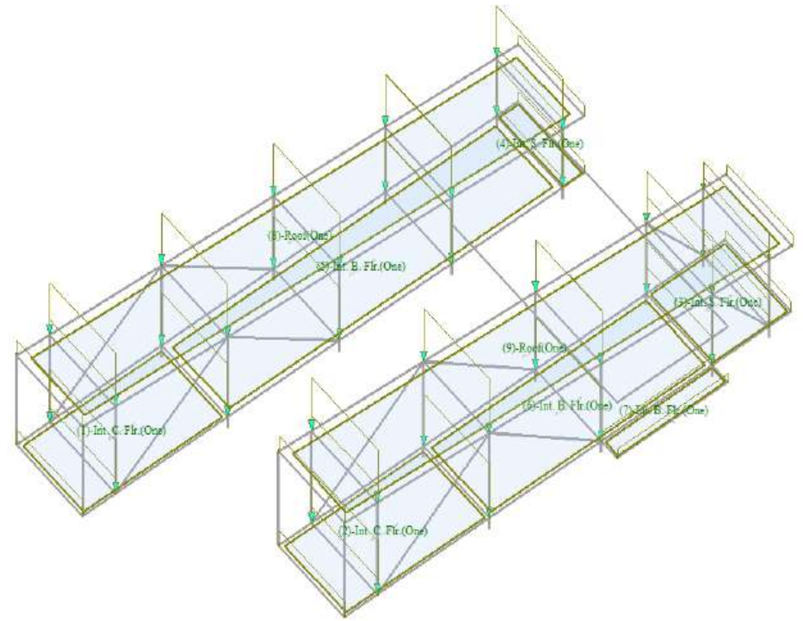


JOINTS, BEAM END RELEASE & BOUNDARY CONDITIONS





FLOOR COMPOSITION



DEAD LOADS ASSIGNED AS FLOOR LOADS

DEAD LOADS

Structural self weight (UDL) - Automatically calculated in MIDAS, using the members material volumetric density and cross-sectional areas, and then imposed across the length of each member.

Floor Compositon Loads - Evaluation of finished floor composition with 160m deep composite steel decking - 3.19 KN/m2

Roof Compositon Loads - Estimated to be the same as Floor composition loads - 1.5KN/m2

Perimeter Wall Loads - Based on weight of average weight of a curtain wall panel - 0.6 KN/m2 * 3.5m(take min and max height) (average wall height of internal walls) = 2.1 KN/m

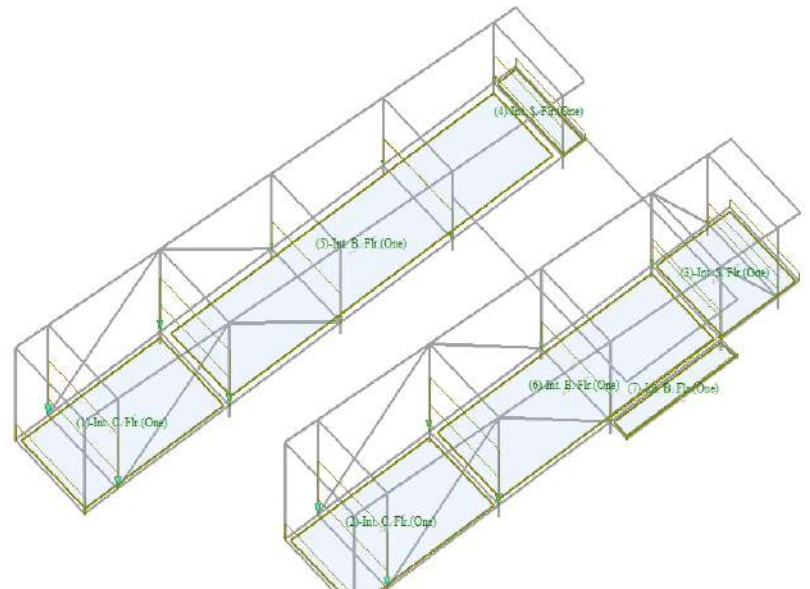
LIVE LOADS

Residential Area (Category A - Floors) - 2.0KN/m2

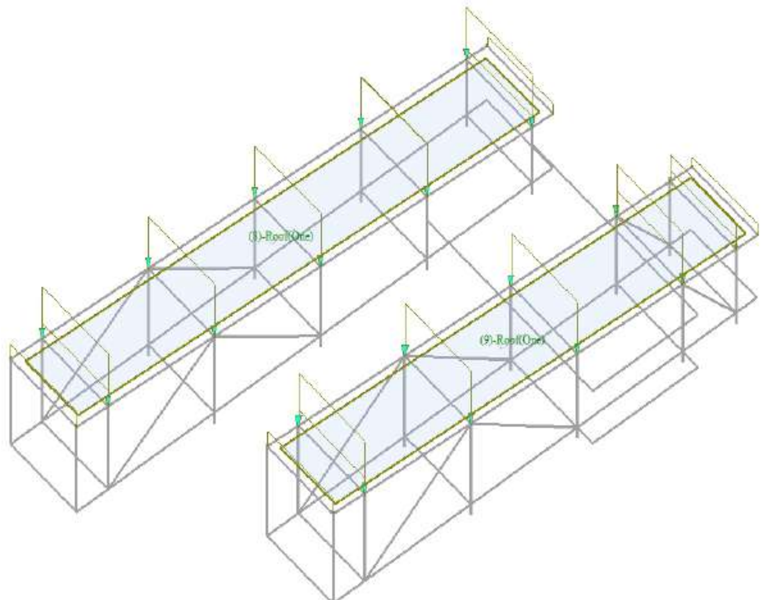
Cantilevered Residential Area (Category A - Balconies) - 4.0KN/m2

Study Rooms (Category B) - 3.0KN/m2

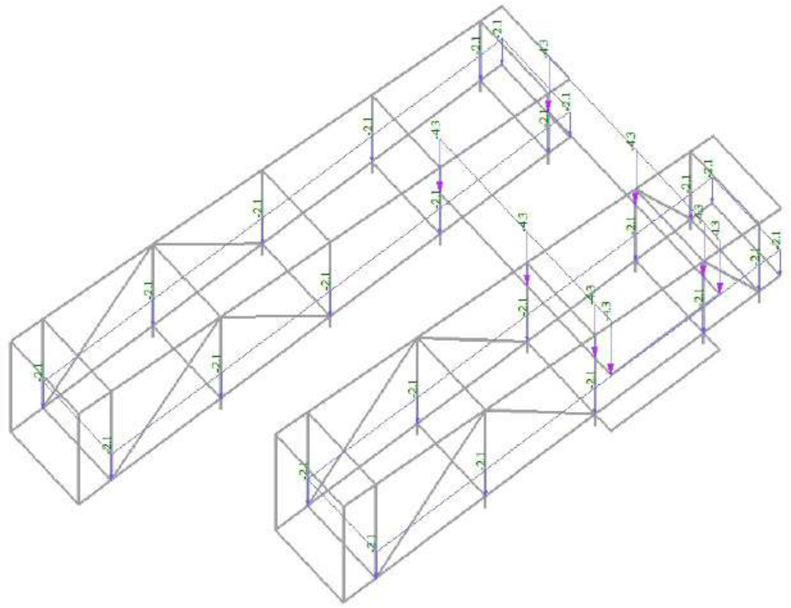
These values were derived based on EN 1991-1-1:2002 - Eurocode 1 - Actions of Structures



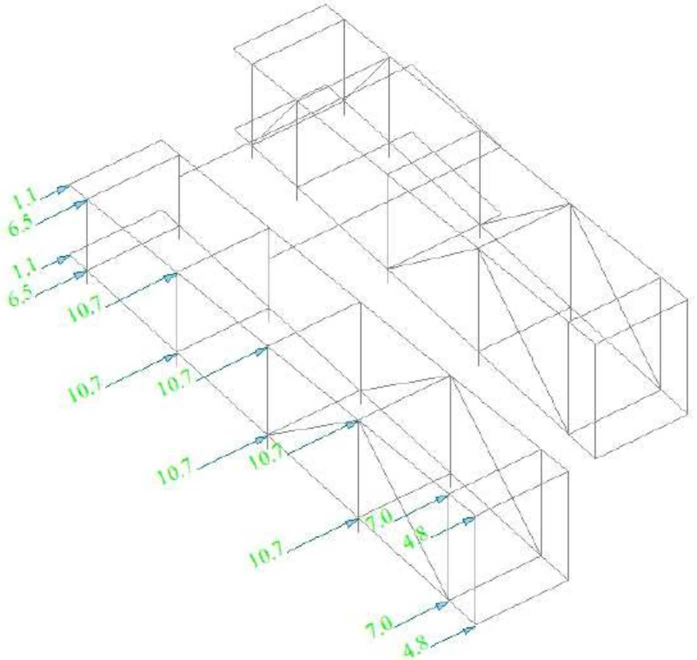
LIVE LOADS ASSIGNED AS FLOOR LOADS



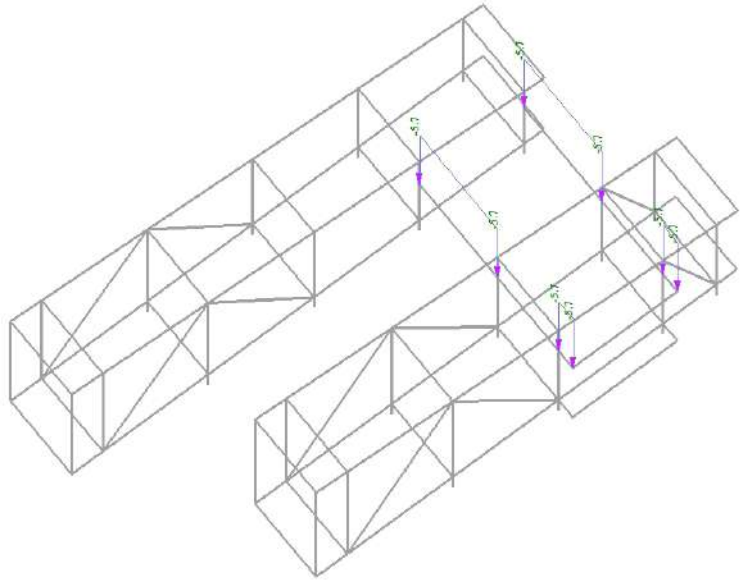
SNOW LOADS ASSIGNED AS FLOOR LOADS



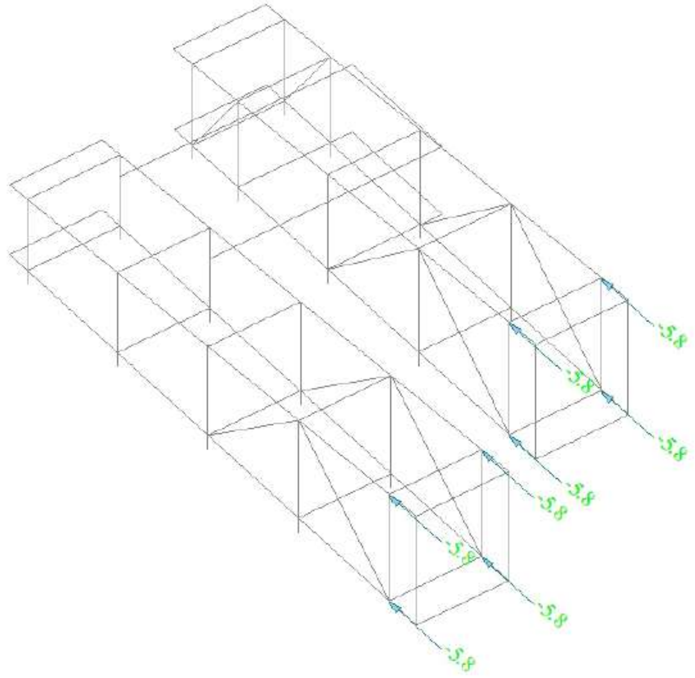
DEAD LOADS ASSIGNED AS LINEAR LOADS



NODAL WIND LOAD (WY)



SNOW LOADS ASSIGNED AS BEAM LOADS



NODAL WIND LOAD (WX)

Snowloads were applied as Uniformly Distributed Beam loads on some beams, as these were not applied on complete quadilateral bays as such cannot be inputed as floor loads in MIDAS.

Area load of 2KN/m2, multiplied by tributary length of 5.7m / 2, gives a total value of 5.7KN/m (UDL)

WY - Calculating the force exerted on each 4.7*5.7 bay result in a total of 21.4KN
Therefore applied to quadrilateral nodes as 5.35kN

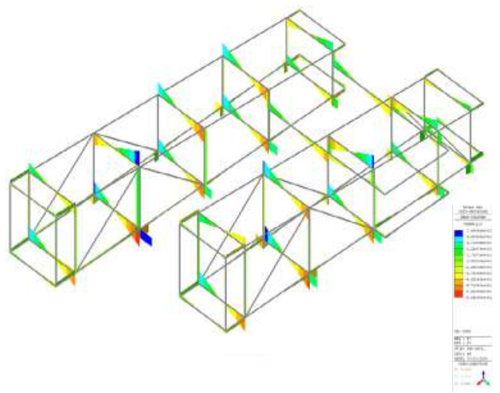
The total force exerted on each 4.7*1.2 bay is 4.5KN
Therefore applied to quadrilateral nodes as 1.13kN

The total force exerted on each 4.7*1.7 bay is 6.39KN
Therefore applied to quadrilateral nodes as 1.6kN

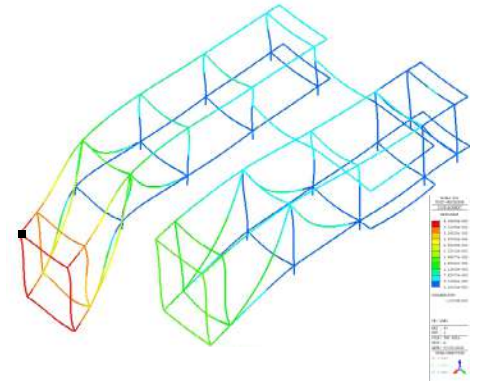
WX - Calculating the force exerted on each 5.4*4.26 bay results in a total of 23KN. Therefore applied to quadilateral nodes as 5.75KN

LOAD COMBINATION FOR ALLOWABLE STRESS DESIGN
= DeadLoads (DD) + Live Loads (LL) + WindLoads(WX) + WindLoads(WY) + SnowLoads(SL)

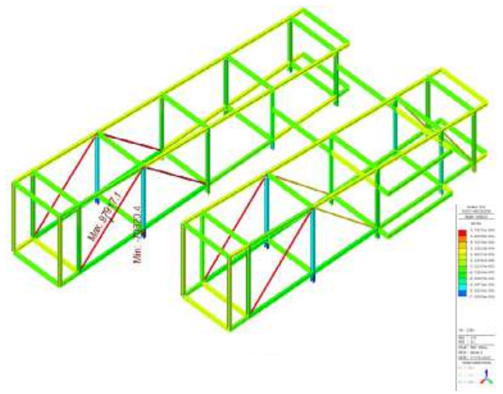
CASE 01 - OBSERVATION



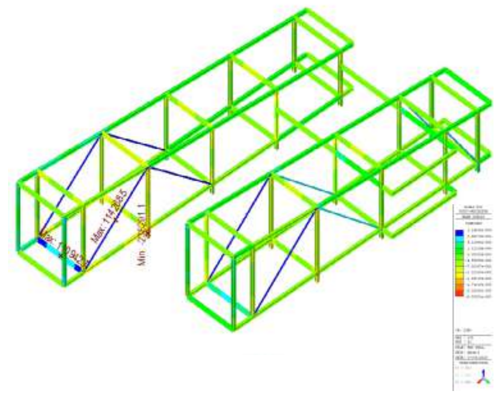
Shear Force Fyz - Apart from the vertical loads, there are significant contributions to the shear forces in the local y and z axis, due to the lateral forces are induced by high wind loads



Deformed Shape - High values of displacements are realized form the deformed shape, with the highest nodal displacement giving a value of 40mm and node No.48.

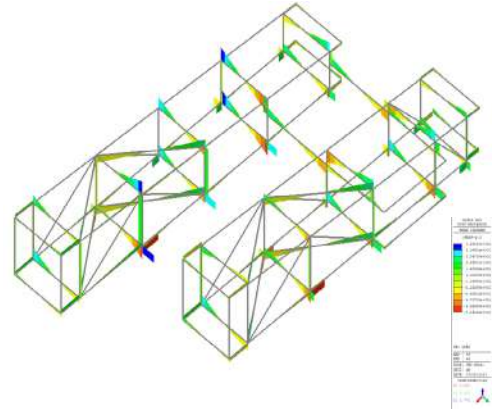


Axial Stress along the x-axis - This contour map is a clear representation of the members in tension and in compression and to what degree of magnitude

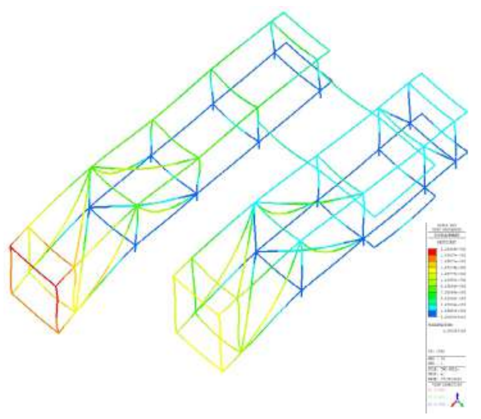


Combined Internal Beam Stress - The values identify areas susceptible to structural failure. The maximum bending stress is found on a uniformly loaded beam, the maximum compressive stress is found on a column supporting the cantilever, and the maximum tensional stress is found in the bracing member.

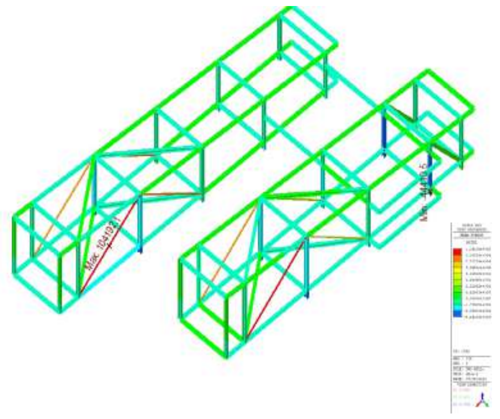
CASE 02 - HYPOTHESIS



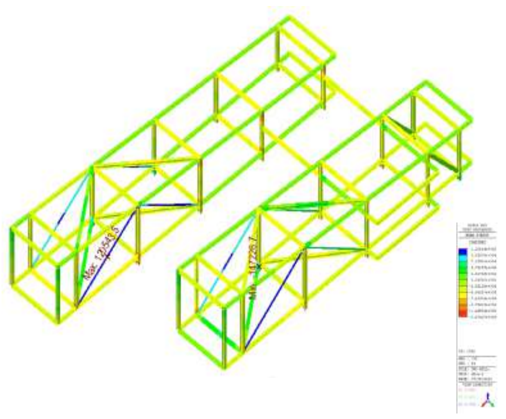
Shear Force Fyz - A considerable reduction in magnitude of shear about the local y and z axis can be observed in comparison to the previous case



Deformed Shape - The maximum displacement is now at node 36, with an approximate value of 20mm. This reduction can be attributed to the addition of bracing struts in the roof and floor area.



Axial Stress along the x-axis - Case 02 gives immense reduction in the compressive stress due to the increased cross sectional area and reduction of induced bending and stress from lateral loads



Combined Internal Beam Stress - By changing the cross-sectional thickness of the steel columns supporting the cantilever. The maximum compressive stress is reduced significantly. These stress are now well within range of the allowable stress.

VERIFICATION

The aim of this procedure is to verify that the structure is able to perform under the worst loading combination without failure, and satisfy standard requirements, by experimenting with the effects of the observed situation and then a hypothetical condition. Evaluating how it improves the performance of the system as a whole.

CASE 01

Roof Beam - The maximum displacement on the roof member is 4.08489e-002m imposed on the cantilevered section of length 7.45m. Using the general roof displacement limit δmax/L = 1/200. The displacement ratio is evaluated as 4.08489e-002m/ (7.45m * 2) = 1/365 **(VALID)**

Floor Beam - The maximum displacement in the floor area is 3.90174e-002m imposed on the cantilevered section of length 7.45m. Using the general roof displacement limit δmax/L = 1/400. The displacement ratio is evaluated as 3.90174e-002m/ (7.45m * 2) = 1/382 **(INVALID)**

Combined Internal Stress - Using characteristic yield strength of 235MPa, the allowable stress is fyd =fyk/(safety factor) ; 235/1.15 = 204.35MPa. The maximum internal stress is identified in member No.42 as 2.38291e+005KN/m2, approximately 238MPa. **(INVALID)**

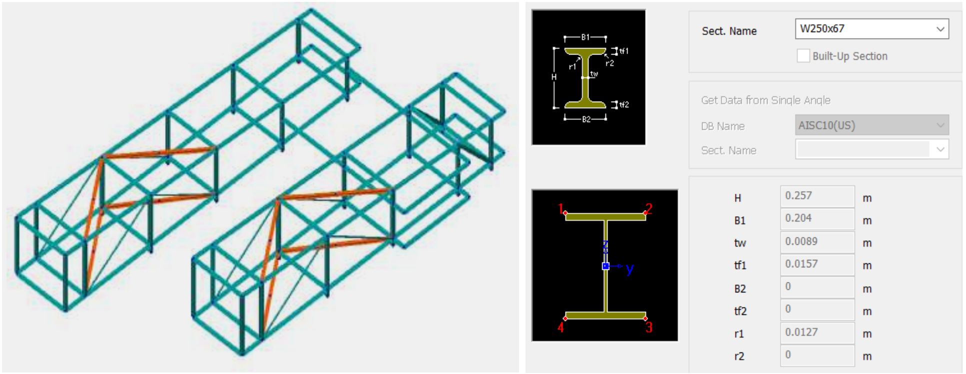
CASE 02

Roof Beam - The maximum displacement on the roof member is 2.01949e-002m imposed on the cantilevered section of length 7.45m. Using the general roof displacement limit δmax/L = 1/200. The displacement ratio is evaluated as 2.01949e-002m/ (7.45m * 2) = 1/737 **(VALID)**

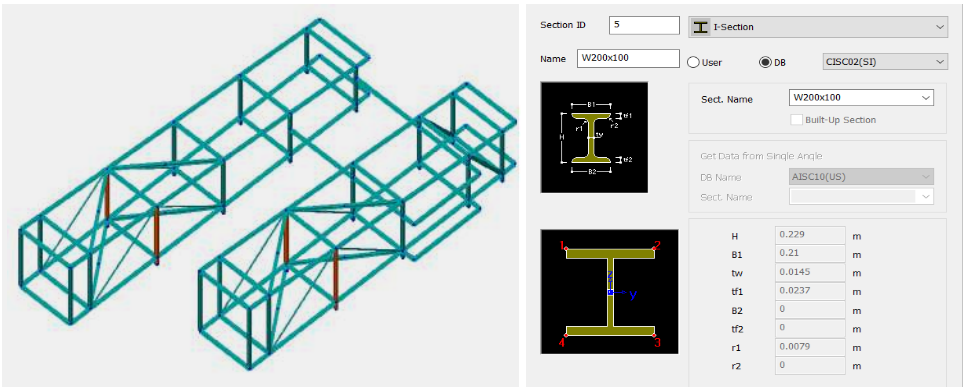
Floor Beam - The maximum displacement in the floor area is 1.80897e-002m imposed on the cantilevered section of length 7.45m. Using the general roof displacement limit δmax/L = 1/400 The displacement ratio is evaluated as 1.80897e-002m/ (7.45m * 2) = 1/824 **(VALID)**

Combined Internal Stress - Using characteristic yield strength of Steel S235 as 235MPa, the allowable stress is fyd =fyk/(safety factor) ; 235/1.15 = 204.35MPa. The maximum internal stress is identified as a compressive stress in member No. 24 as -1.47227e+005KN/m2, approximately 147MPa **(VALID)**

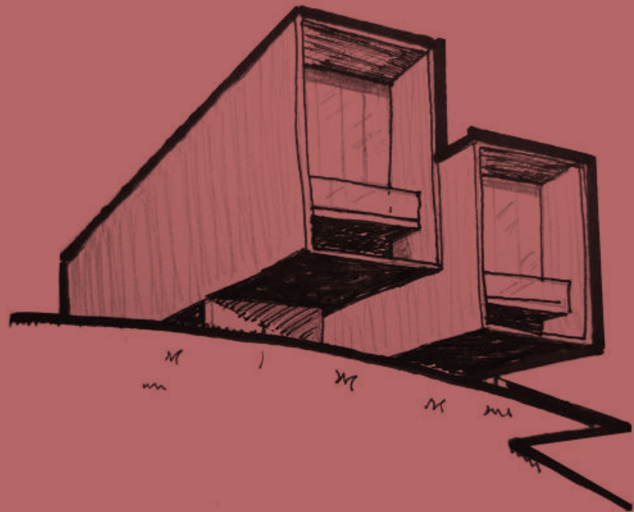
By adding lateral bracing struts of section W250*67 to the roof and floor, and changing the sections of just the columns supporting the cantilever area from HP200x54 to W200x100. I have resolved the issue of excessive deformation and the issue of high internal stress contribution due to lateral shear and bending. The major challenge was to make these improvements without influencing the aesthetical features. The structure is now able to perform better.



Added bracing to contain excessive deflection induced by lateral loads **(W250x67)**



Columns with modified cross sections from **HP200x54 to W200x100.**



TWO HULLS HOUSE