Hydropower plant 1 (200 MW)

Table of content

Appendix

1. GENERAL/MEASUREMENTS

1.1 STRCTURAL TYPE

This report describes the design of hydropower plant between baseline 1 and baseline 2. The structure is termed Part I.

The structure is exposed to the loads mentioned bellow.

- Dead load
- Water load
- Live load
- Earthquake load

1.2 PRODUCTION SCHEME

The production scheme assumes that the structure is cast-in situ.

1.3 FOUNDATION

The foundation assumes the bottom slab rests directly on solid unweathered rock.

Theoretical foundation level : +51.50 ∴ +53.00-1.50

Water level at completion : +53.63 to +62.94 (+64.50)

Level	Flow	Remark
+62.94	8110	10000 year
+61.62	5859	1000 year
+55.10	240	Design flow*
+53.63	13.4	Ecological flow
m	m^3/s	-

* = Corresponds to 100 year flow

Water level during production fase : < +51.50

Backfill : rockfill

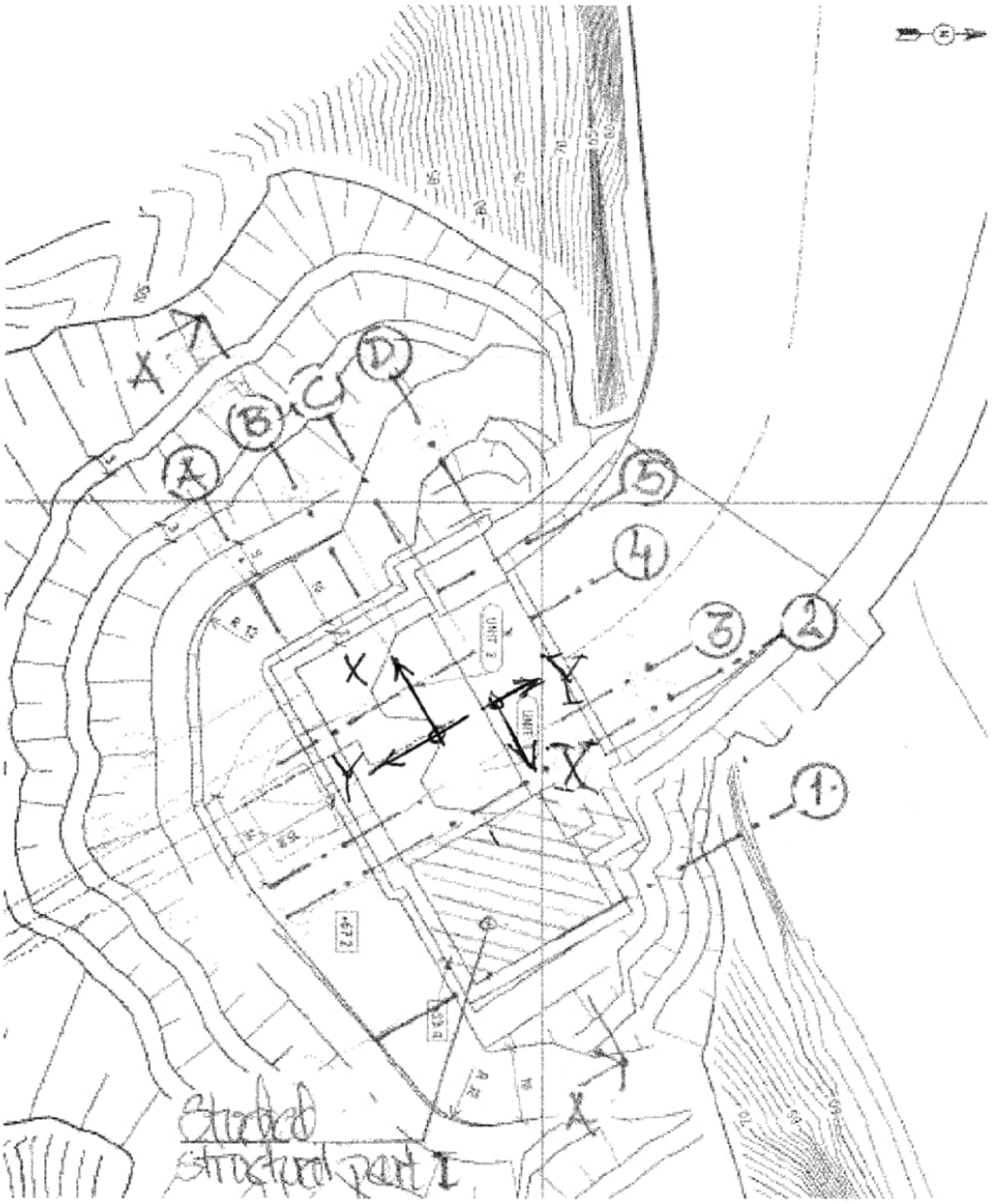
1.4 TECHNICAL SPECIFICATION AND BUILDNING CODE

Building Code Requirements for Structural Concrete (ACI 318-05).

1.5 MEASUREMENTS

1.5.1 Orientation measurements

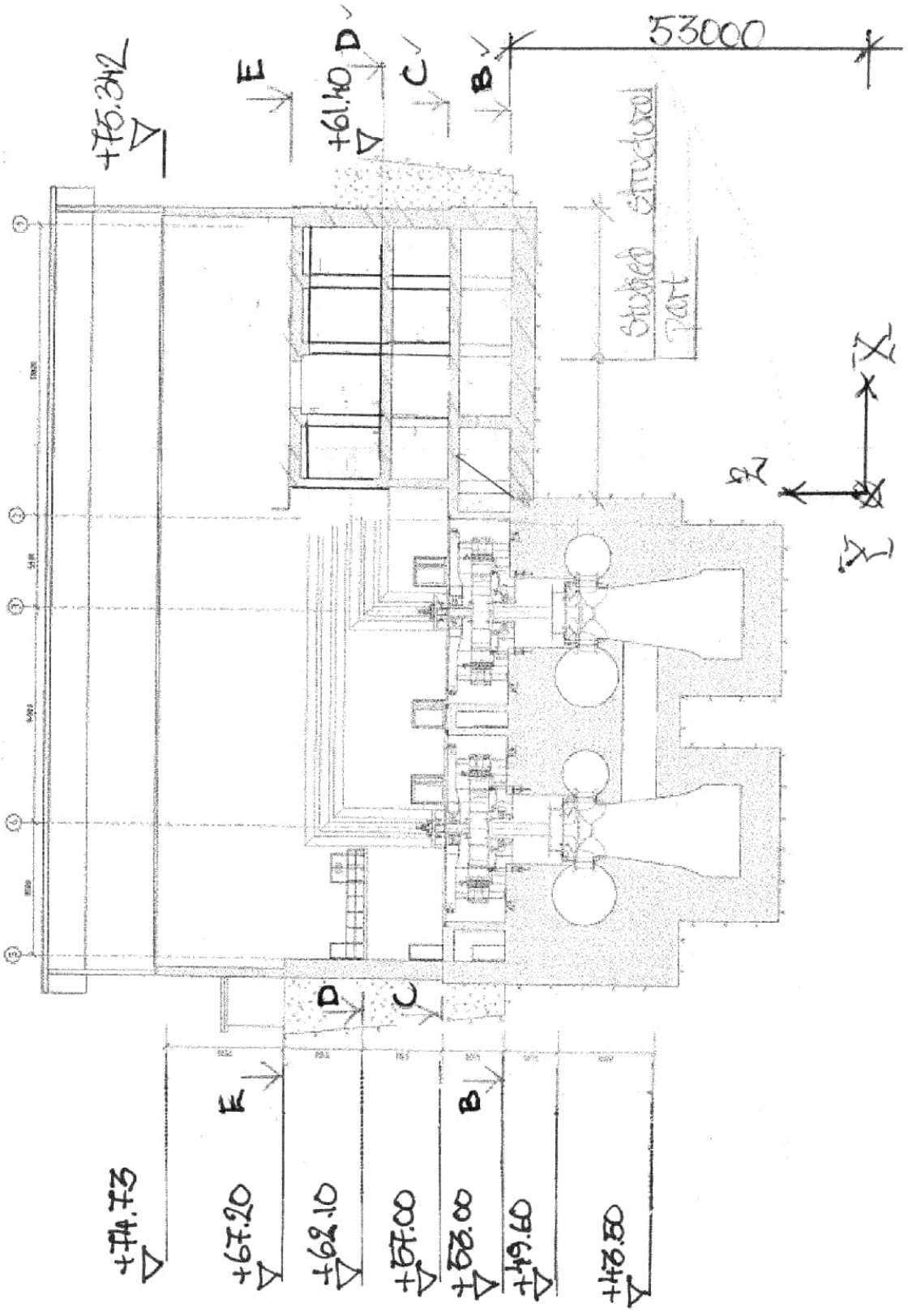
Plane :



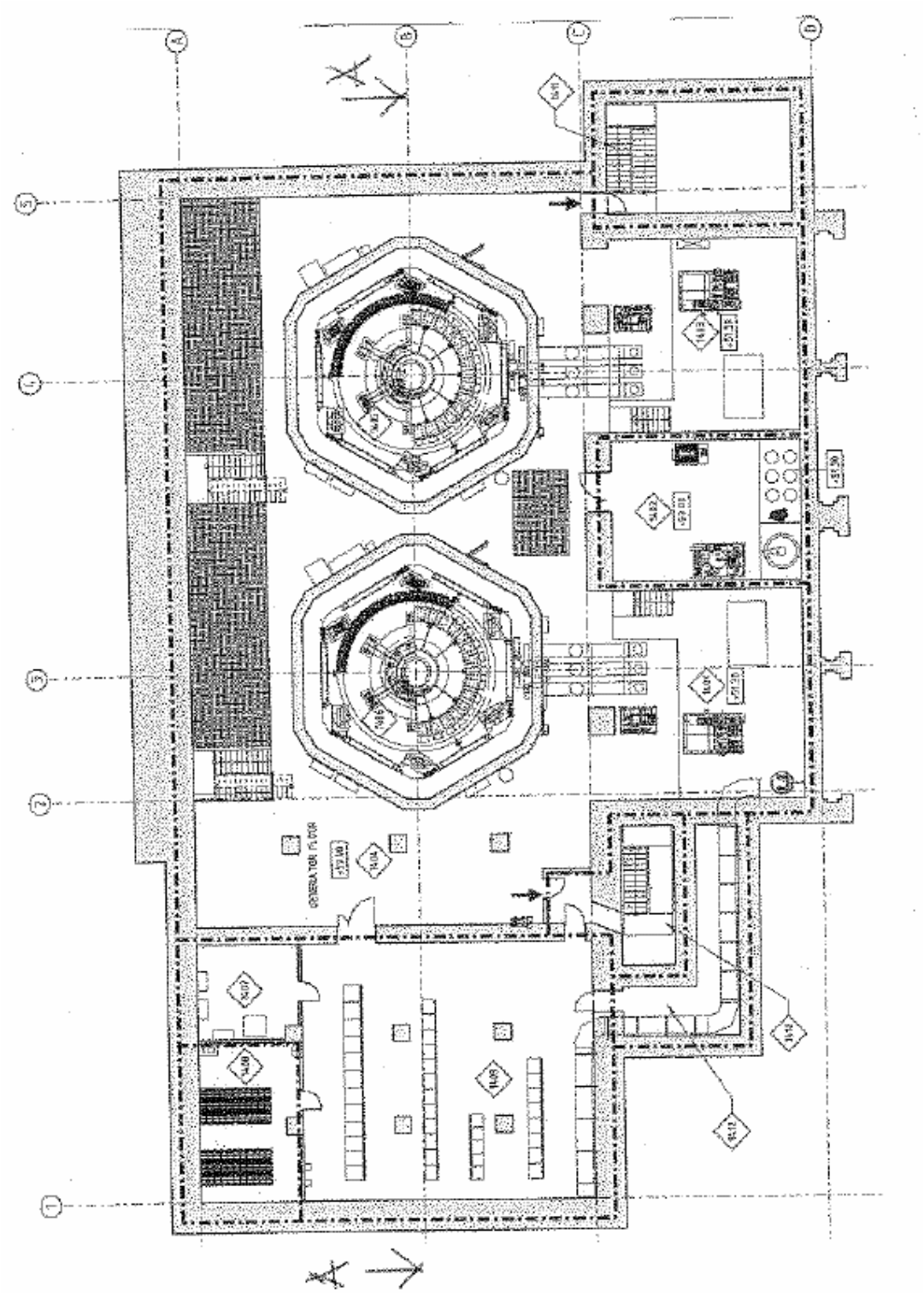
Koordinatsystem in drawing : X/Y/Z

Koordinatsystem in analysis : X/Y/Z

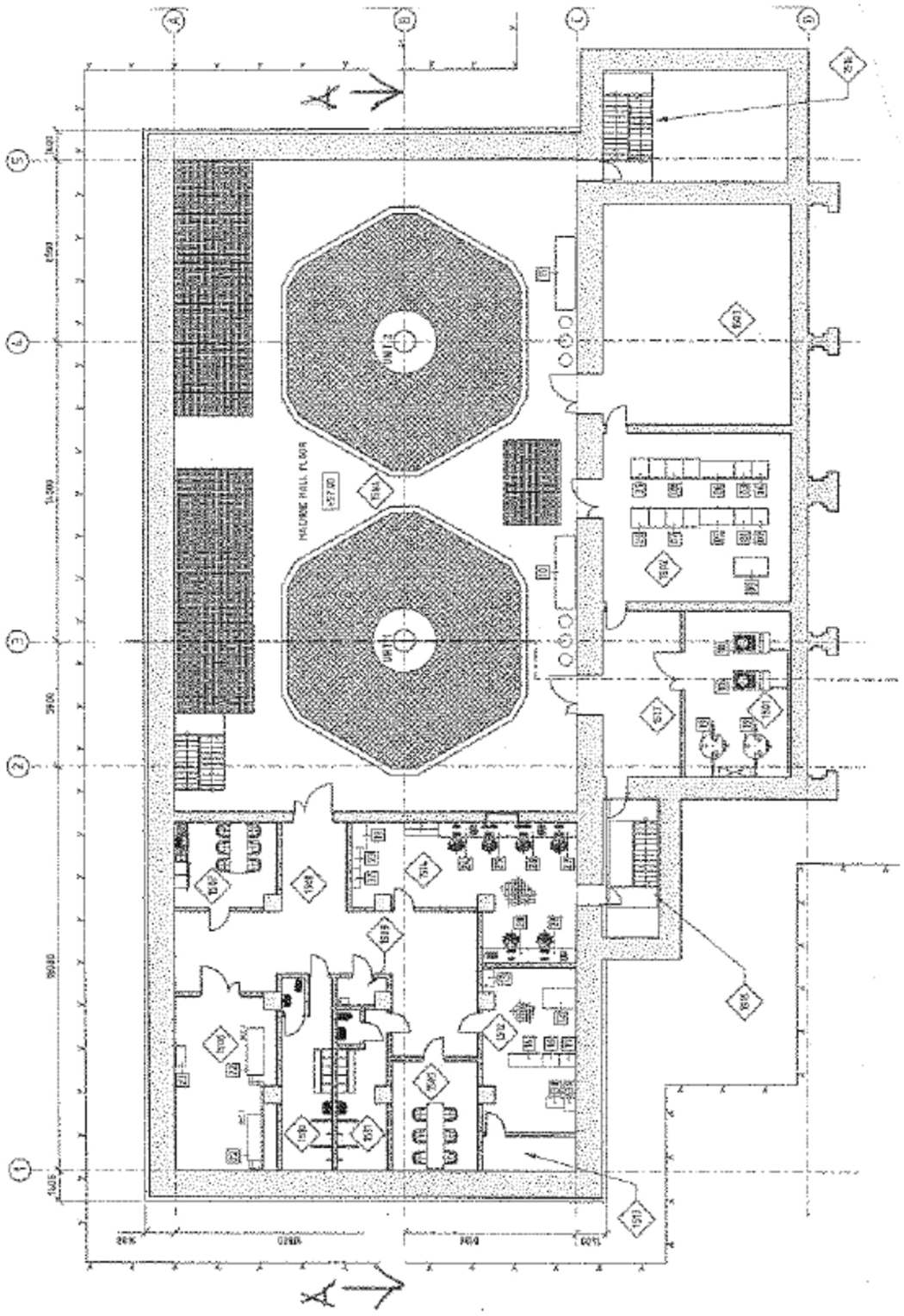
Section A-A :


53000
+75.342
+61.40
E
D
C
B
Stubbad structural part
+44.73
+67.20
+62.10
+57.00
+52.00
+49.60
+42.80

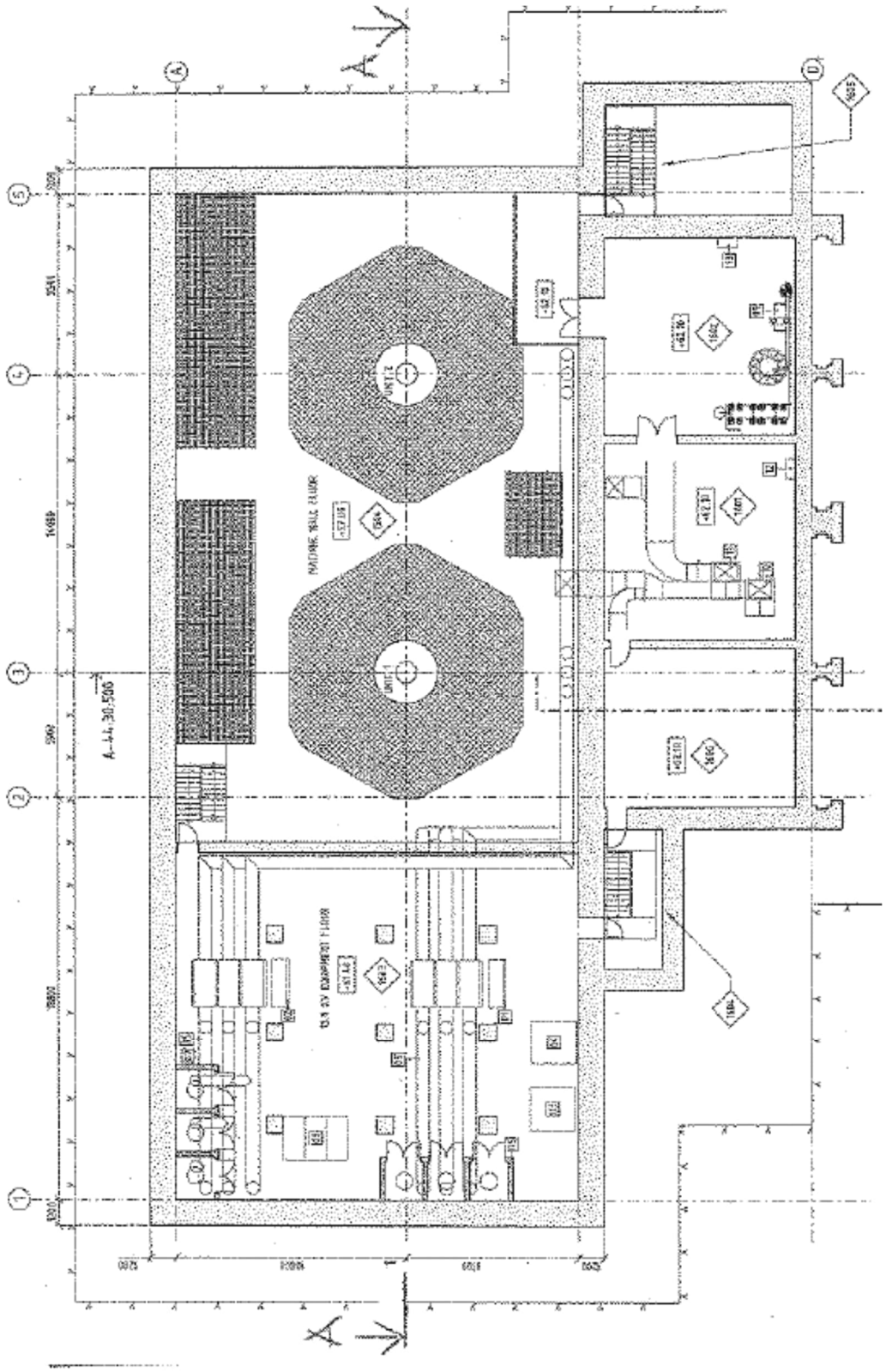
Section B-B (Generator floor +53.00):



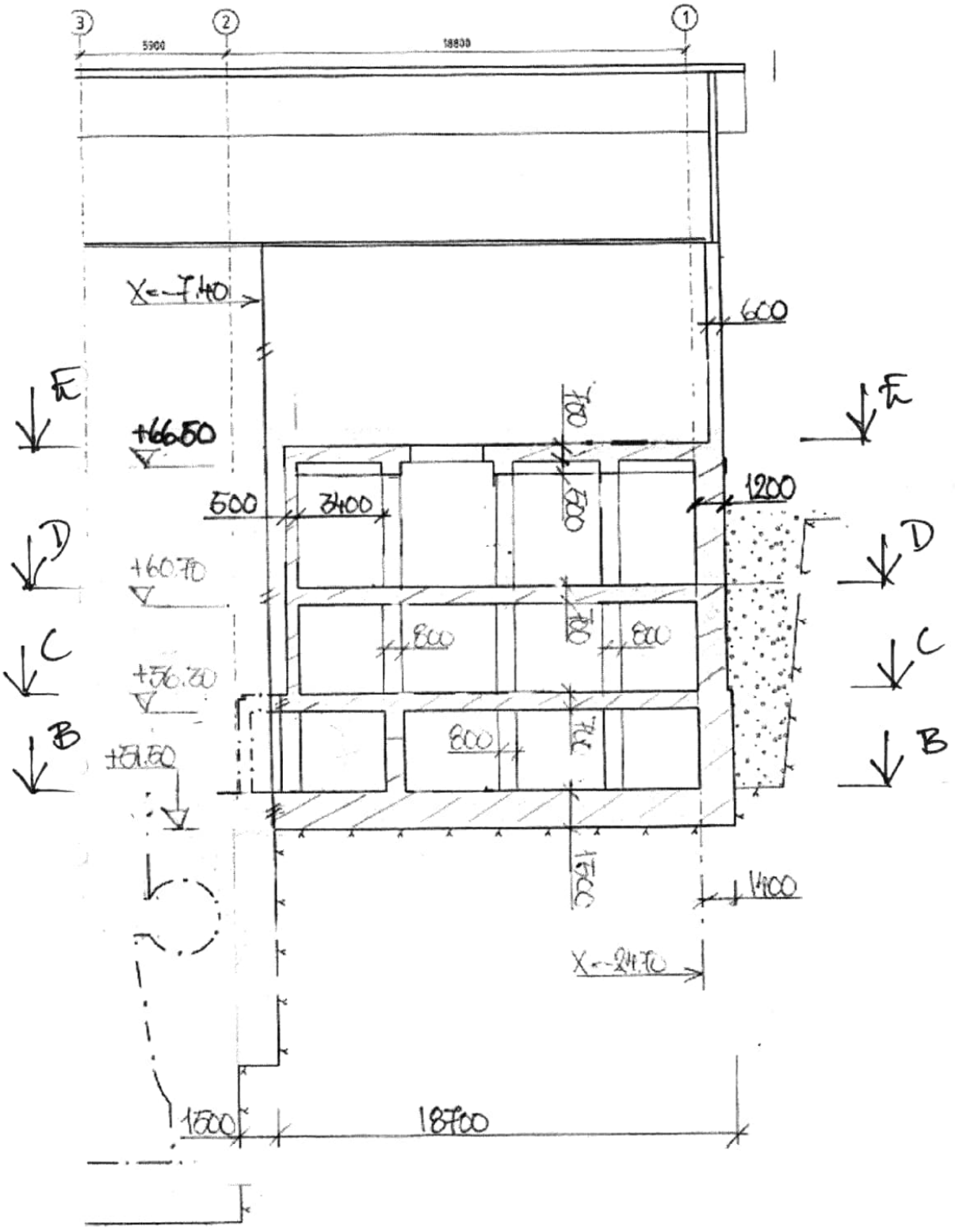
Section C-C (Mashine hall floor +57.00):



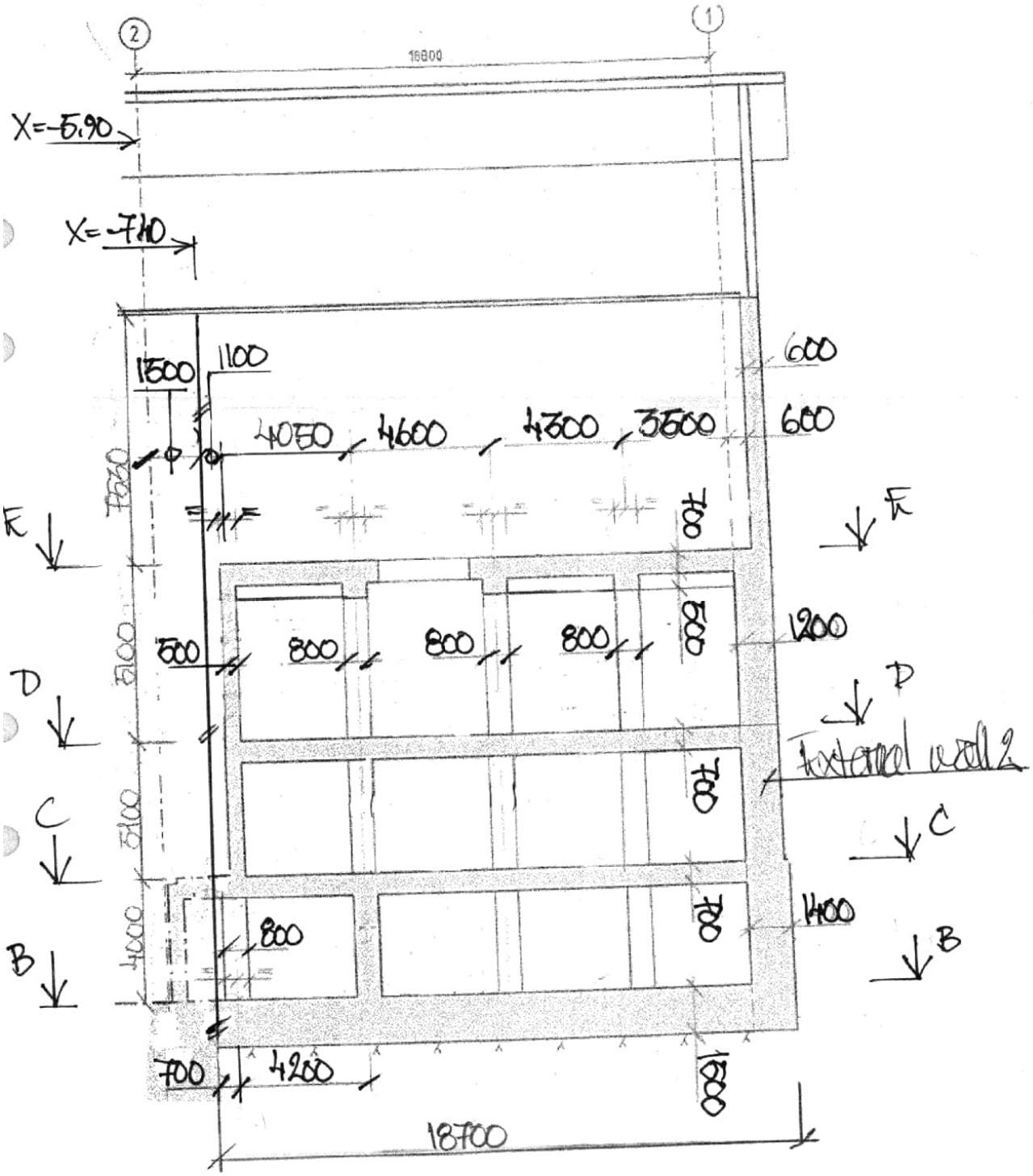
Section D-D (Mashine hall floor +57.00 & Repair bay floor +67.20):

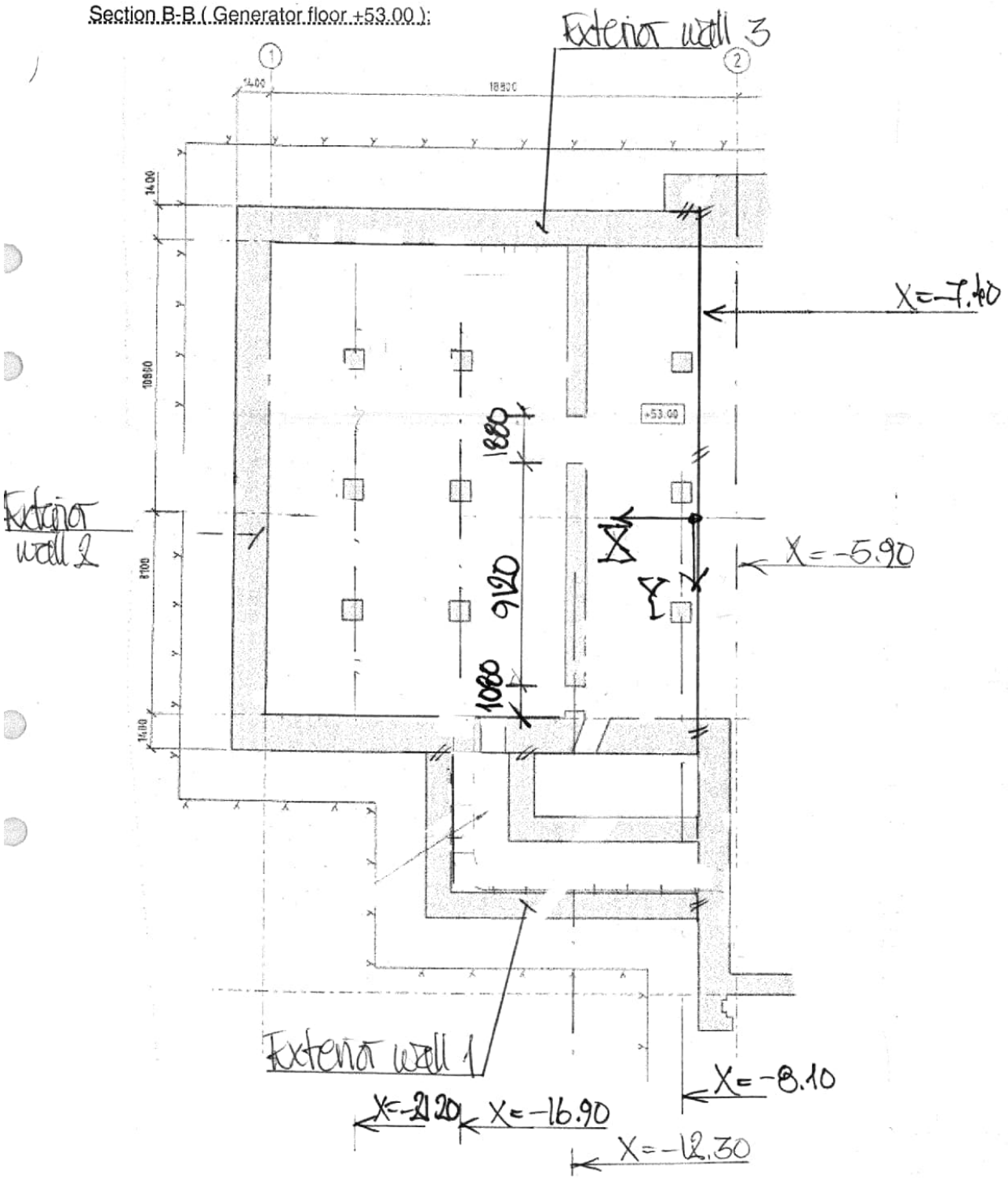


1.5.2 Design measurements

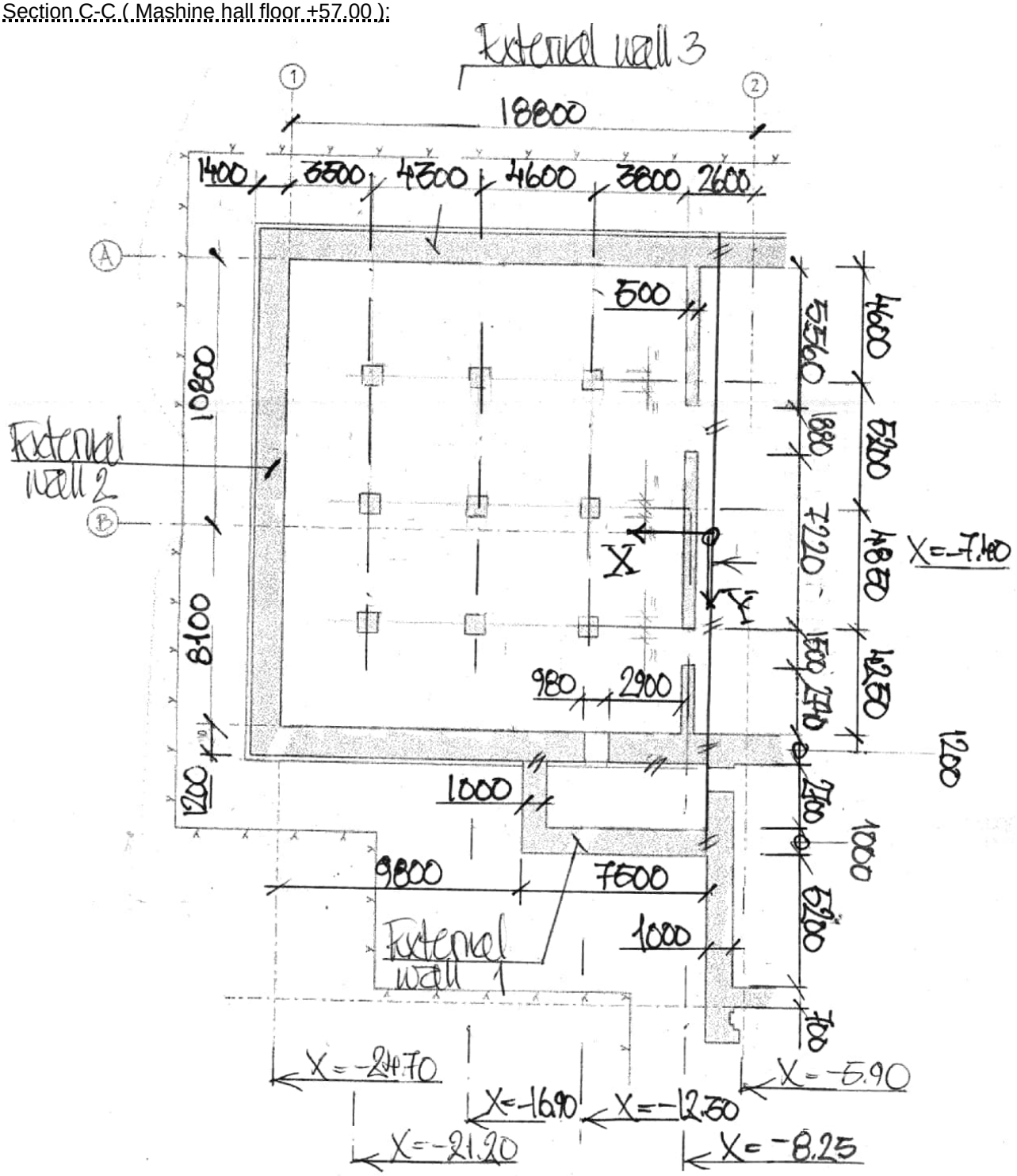


Section A-A :

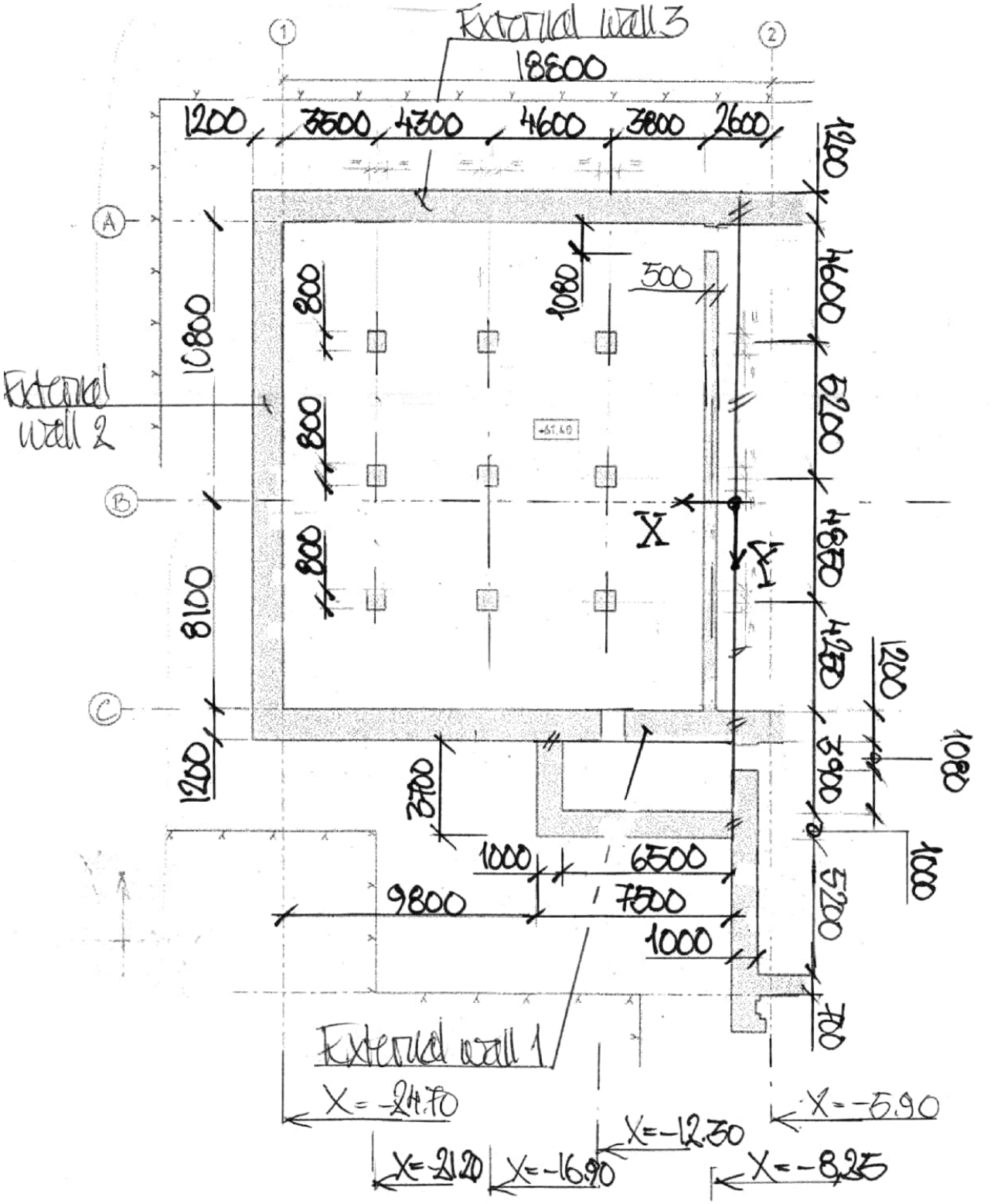

2
1
16800
X=-5.90
X=-7.10
1500
1100
600
4050
4600
4300
3500
600
700
F
F
500
800
800
800
500
1200
D
D
External wall 2
700
C
C
5100
5100
4000
800
700
1400
B
B
700
4200
1500
18700


Section B-B (Generator floor +53.00):
External wall 3
External wall 2
External wall 1
X=-7.40
X=-5.90
X=-8.10
X=-12.30
X=-16.90
+53.00

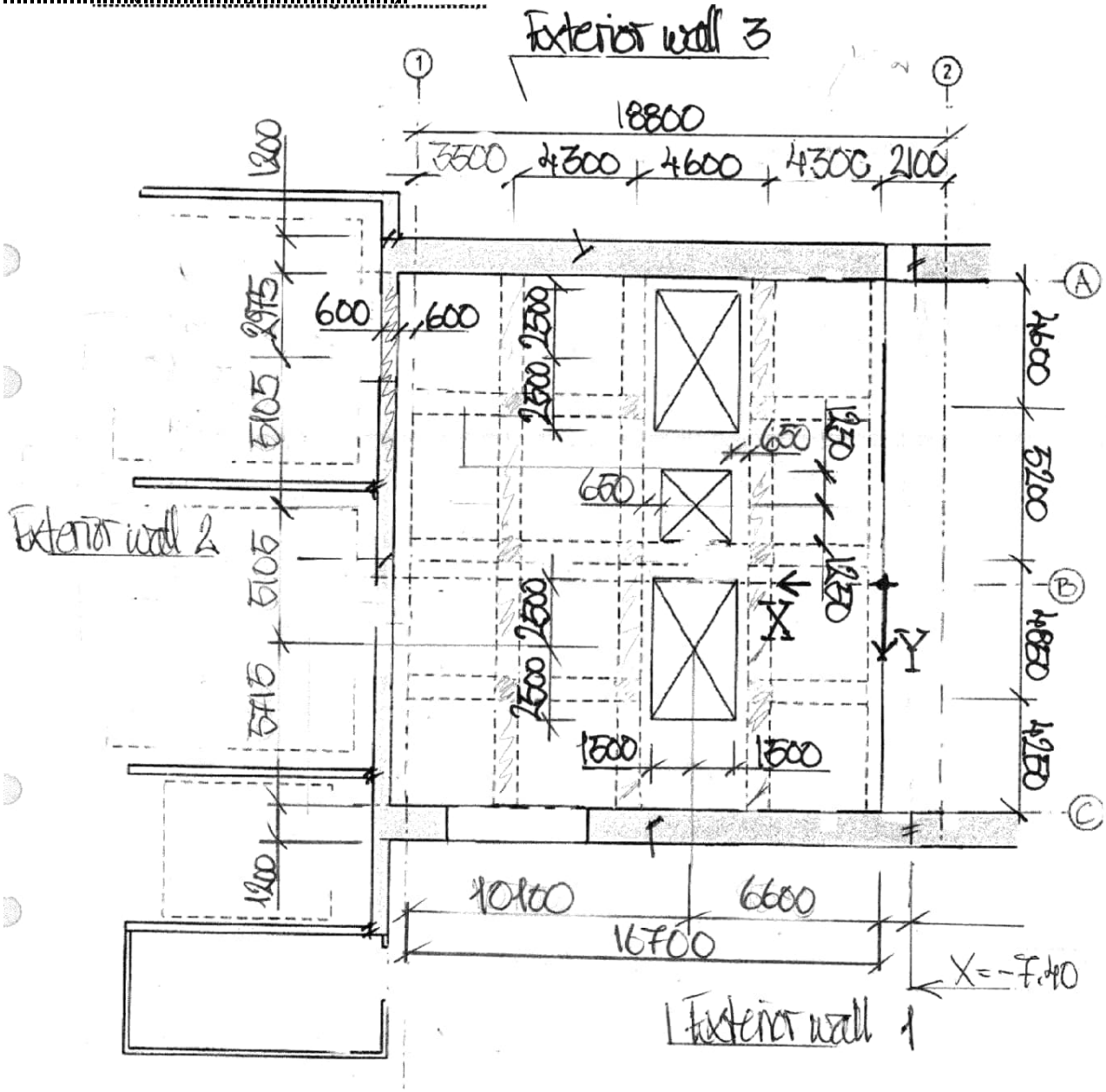
Section C-C (Mashine hall floor +57.00):



Section D-D (13.8 kV Equipment floor +61.40):



Section E-E (Repair bay floor +67.20):



2. STATICAL SYSTEM

2.1 GENERAL

The structure is designed as a reinforced concrete-structure resting on unweathered rock.

The structure is modelled using rigid vertical springs underneath each column/wall connected to the bottom slab at level +53.00.

The structure termed Part I is connected to the rest of Powerhouse basline 2 offset by 1.5 m.

For this reason a rigid horizontal spring is in X-direction along Exterior wall 1 and Exterior wall 2.

2.2 STATICAL MODELL

2.2.1 Geometry

In order to describe the structures geometry first *POINTS* have to be defined. From these *LINES* and *SURFACES* are generated.

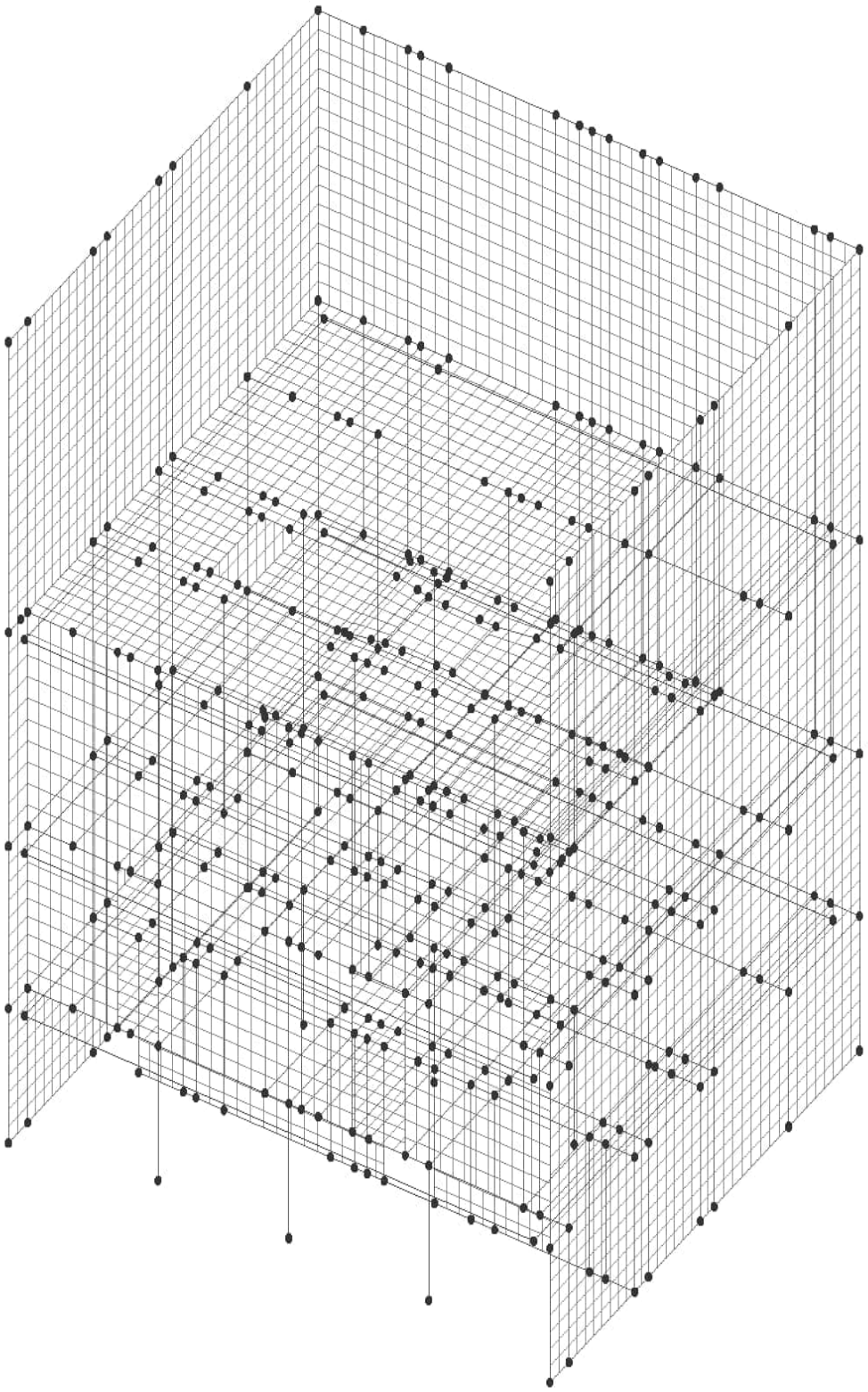
Shell elements are applied to *SURFACES*.

Beam elements are applied to *LINES.*

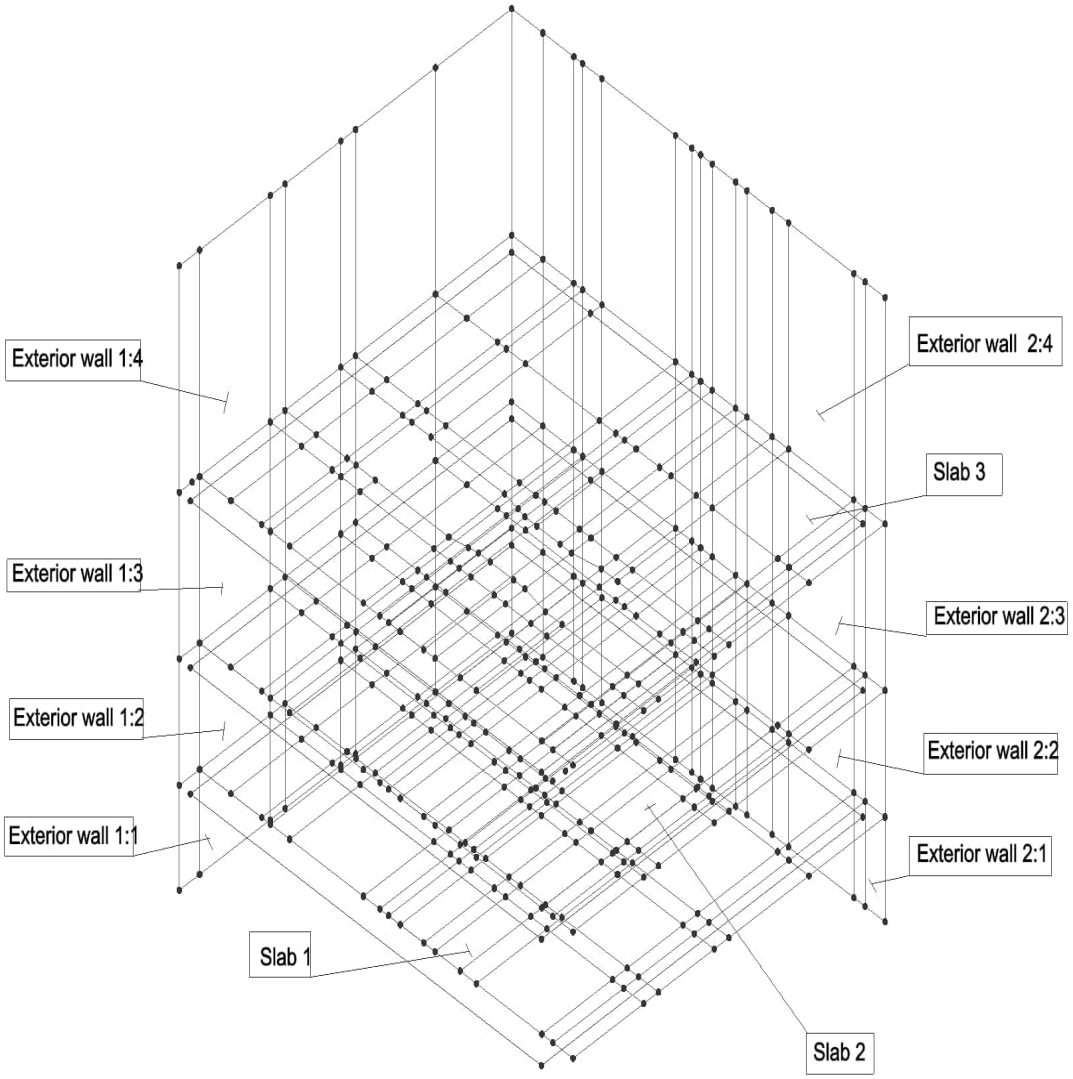
All coordinates defining *POINTS* are presented in appendix 1.

All *LINES* used to define *SURFACES* are presented in appendix 1.

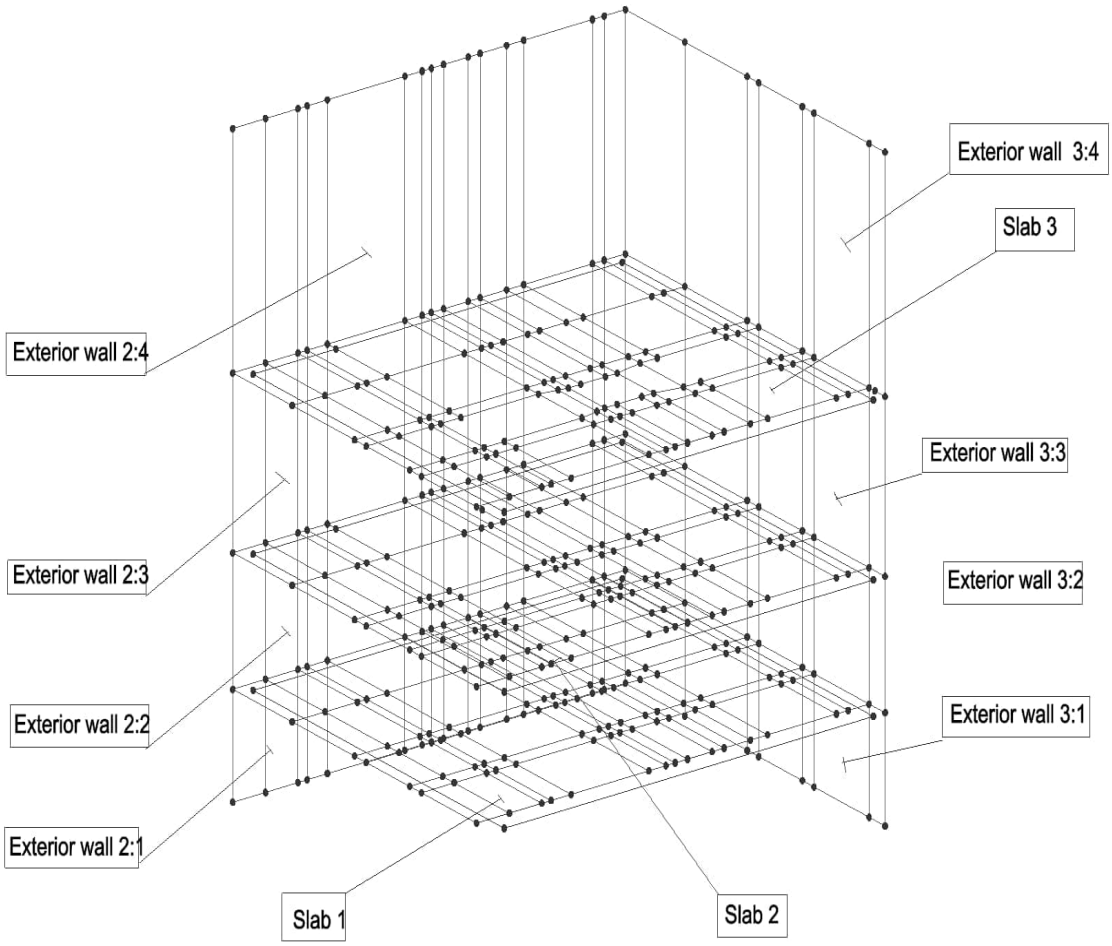
Overview :



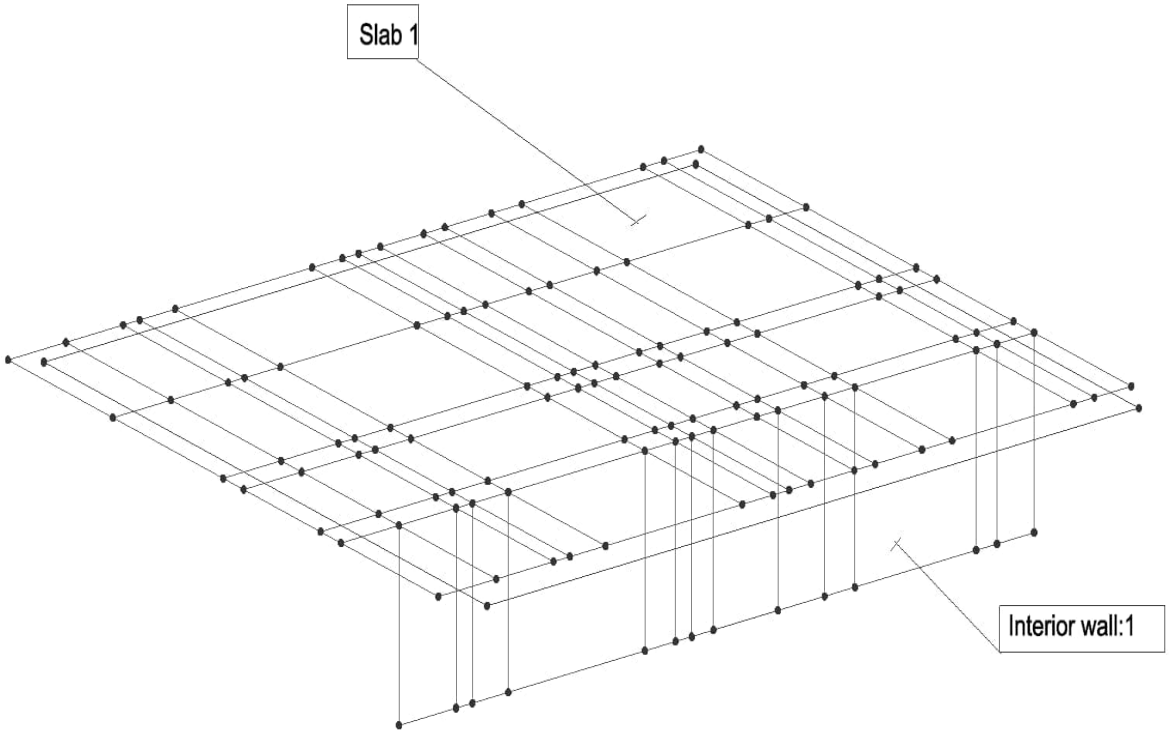
View - Exterior wall 1/ Exterior wall 2 / Slab 1 / Slab 2 / Slab 3 :



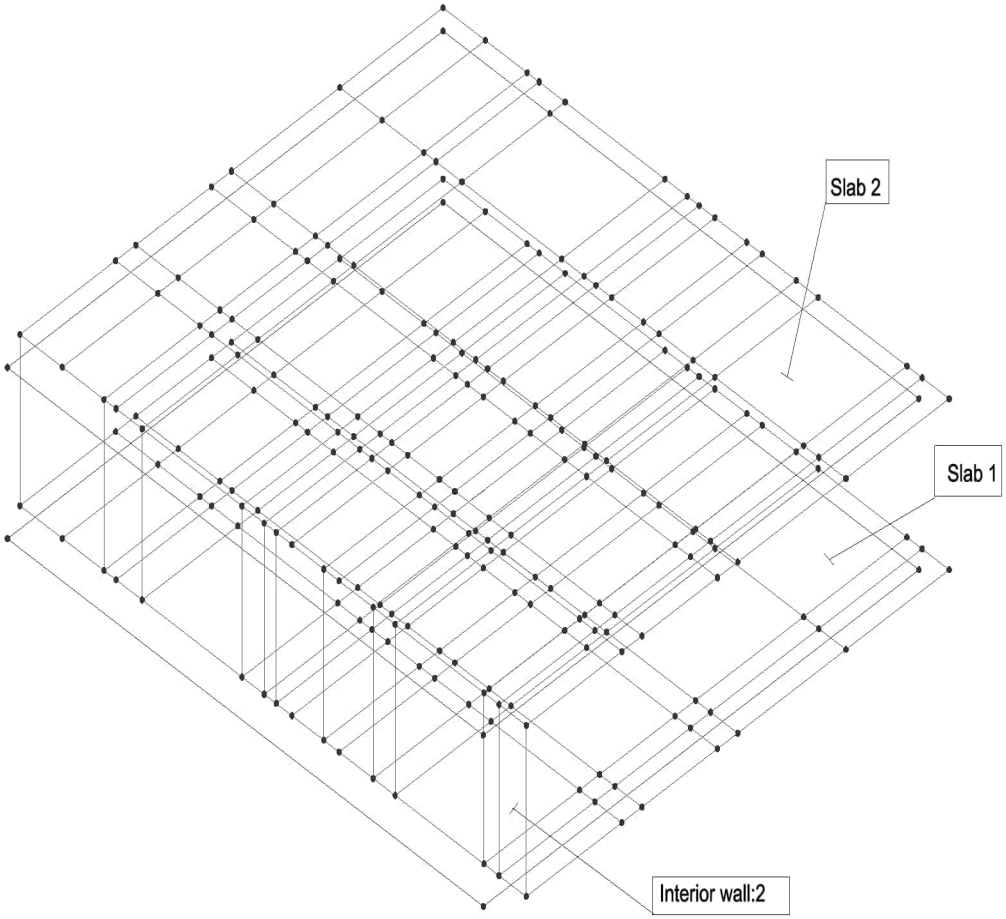
View - Exterior wall 2/ Exterior wall 2 / Slab 1 / Slab 2 / Slab 3 :



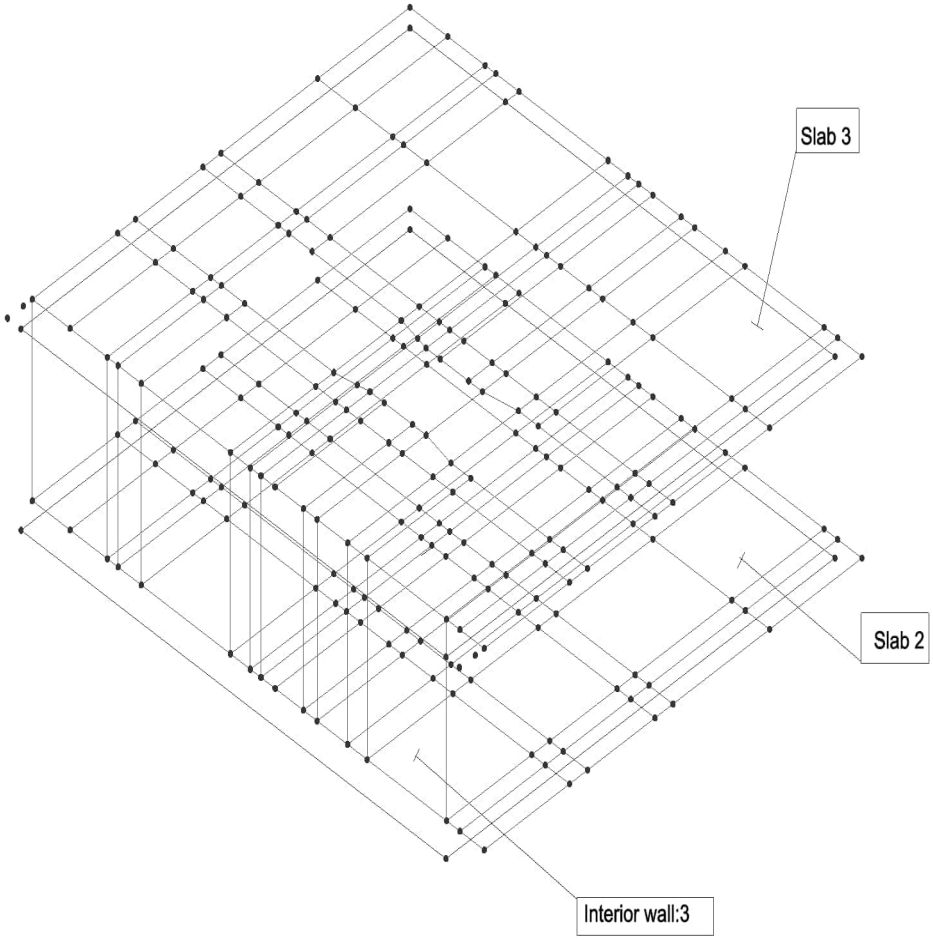
View – Interior wall 1/ Slab 1 :



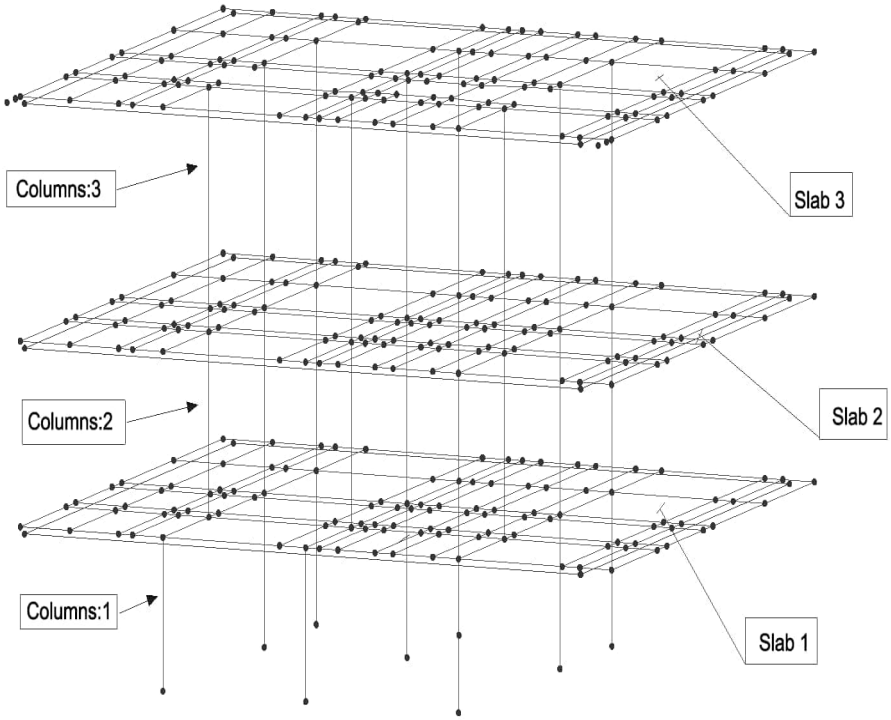
View – Interior wall 2/ Slab 1 / Slab 2 :



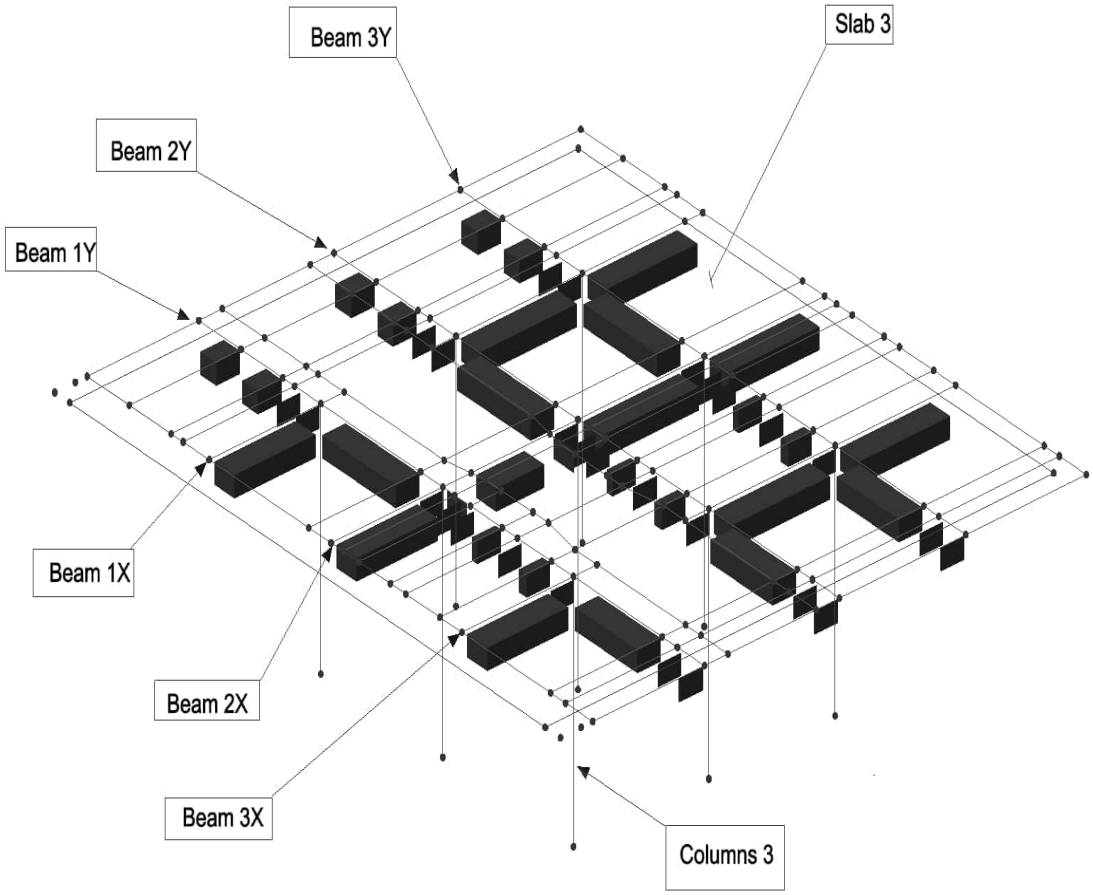
View – Interior wall 3/ Slab 2 / Slab 3 :



View – Columns 1 / Columns 2 / Columns 3 / Slab 1 / Slab 2 / Slab 3 :

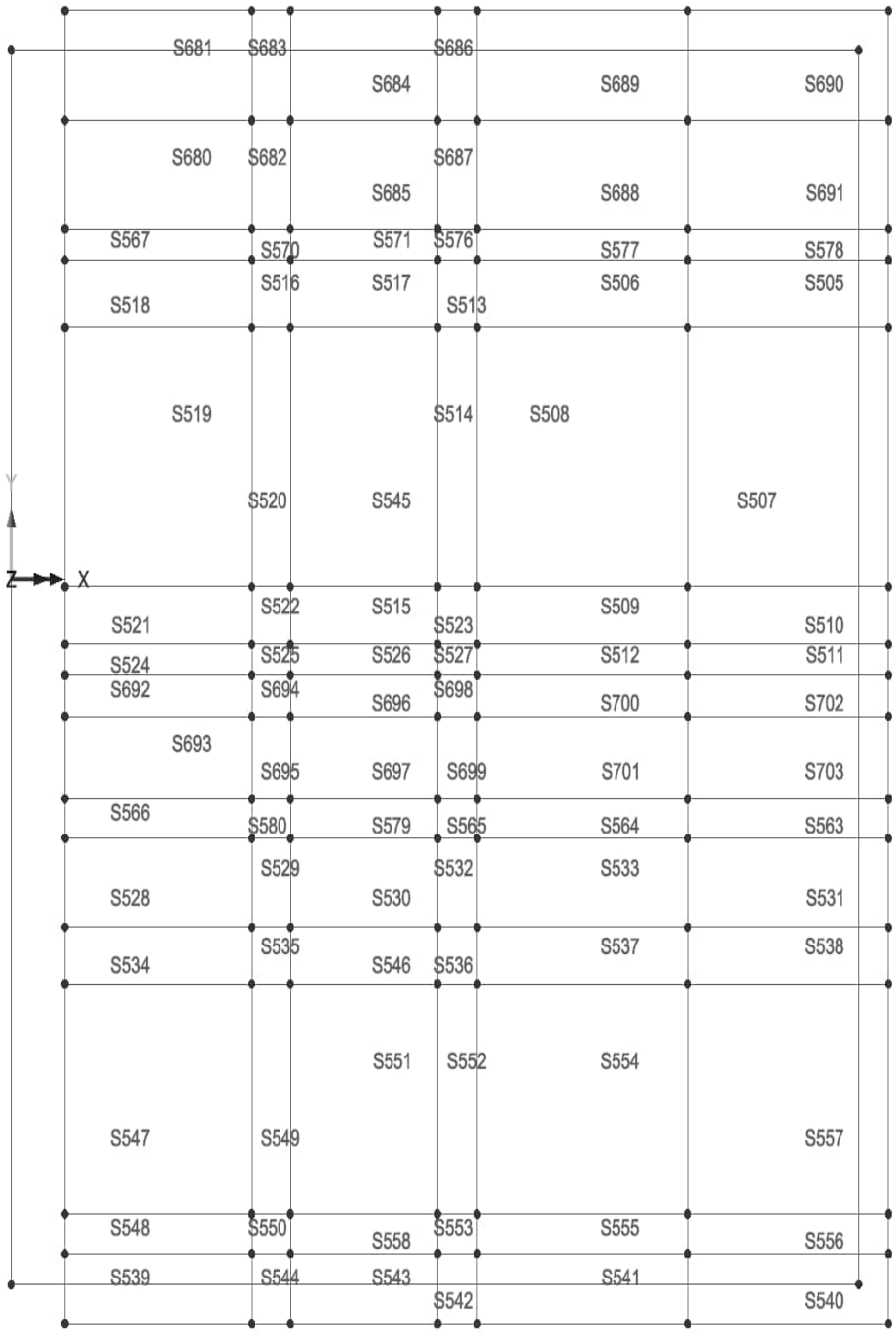


View – Beams 1X..3X / Beams 1Y..3Y / Columns 3 / Slab 3 :

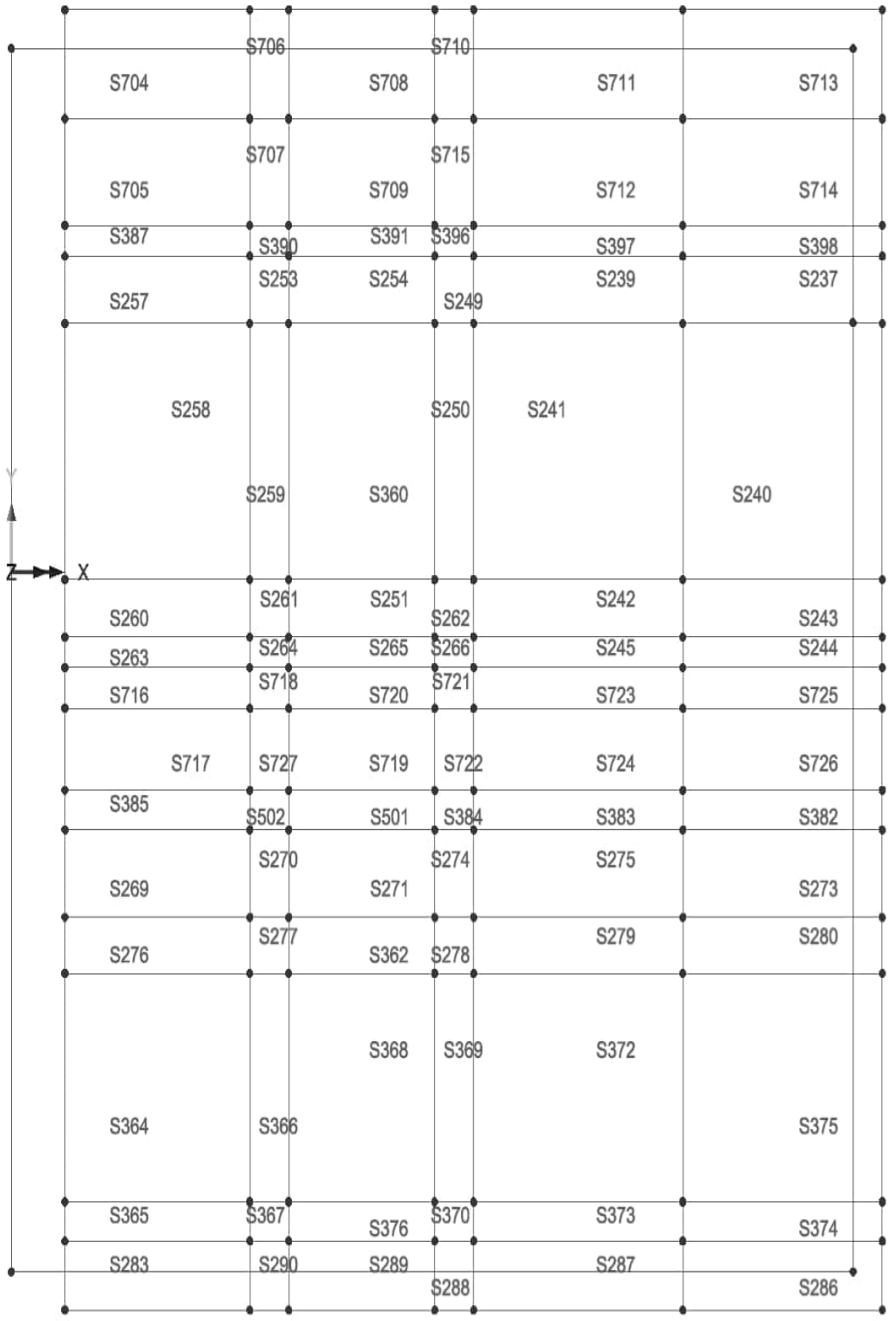


2.2.1.1 Geometry : SURFACES

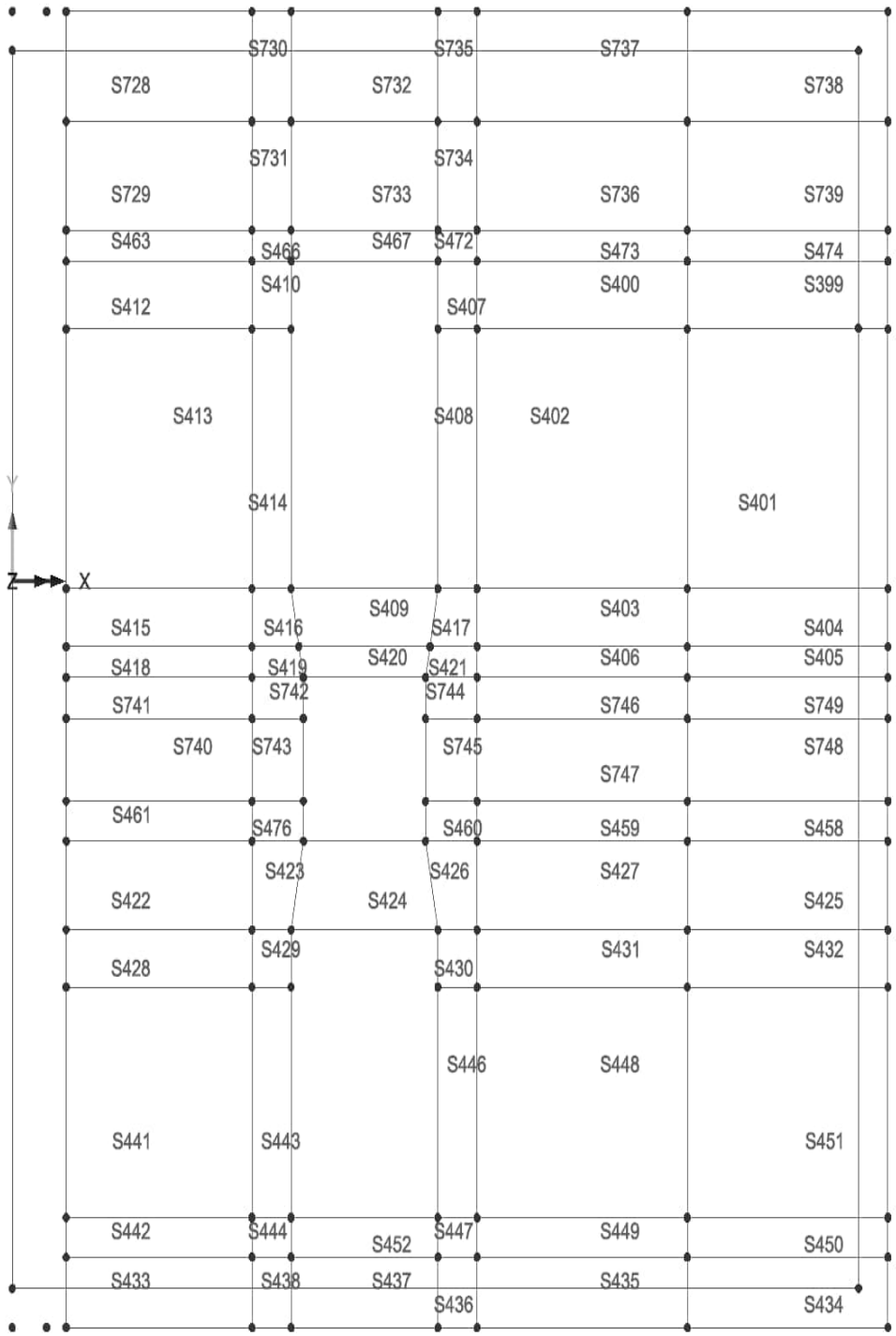
Slab 1 – level +56.65 :



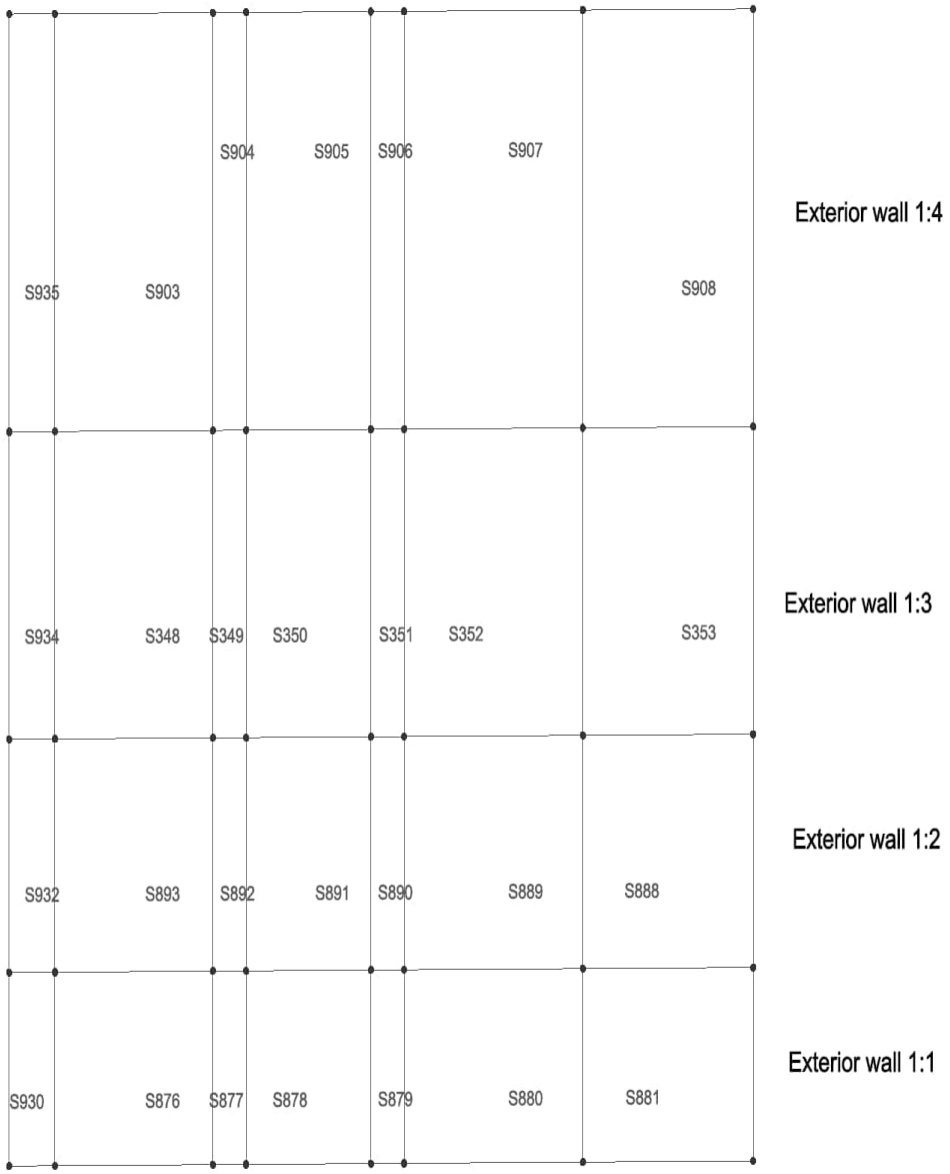
Slab 2- level +61.05 :



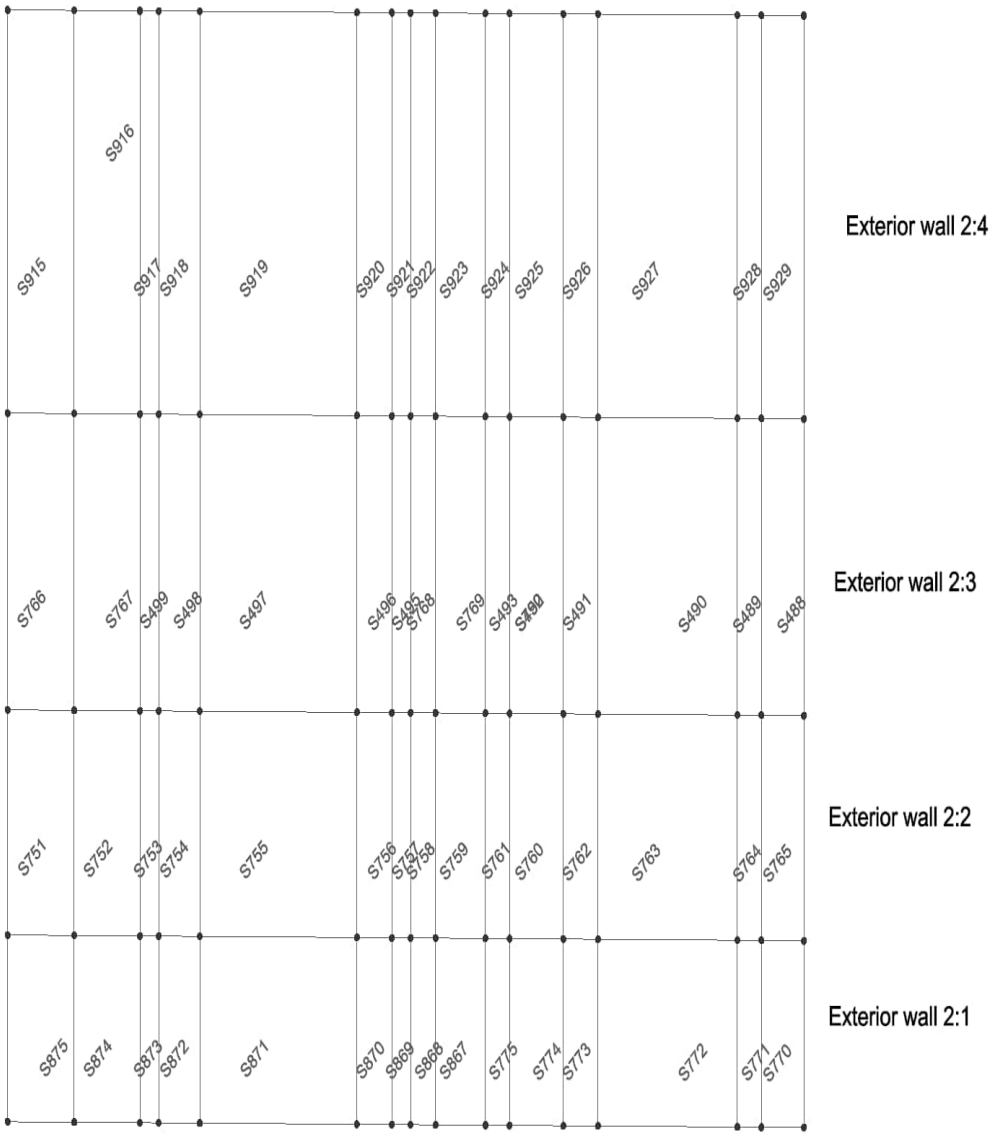
Slab 3 – level +66.85 :



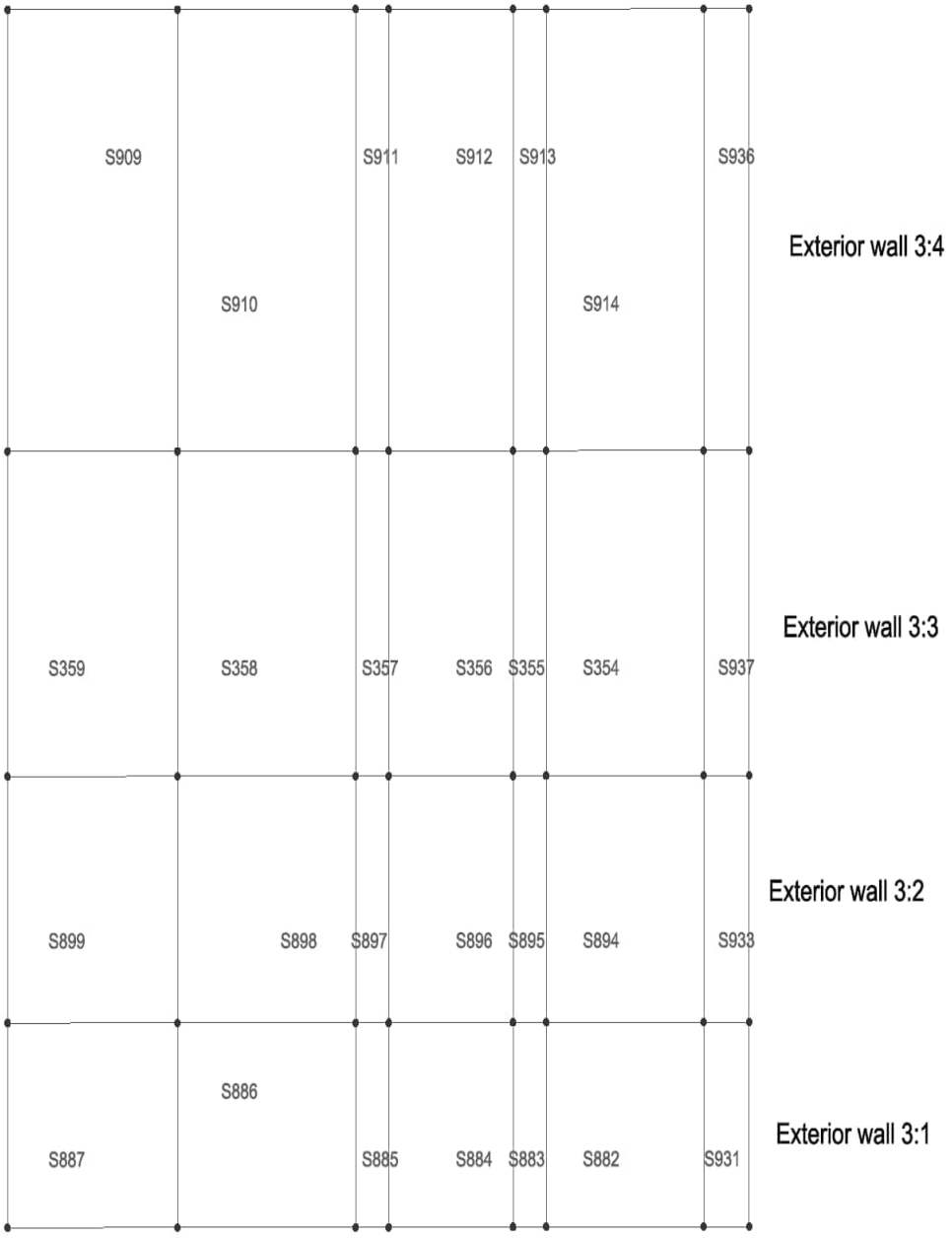
Exterior wall 1 - northern wall :



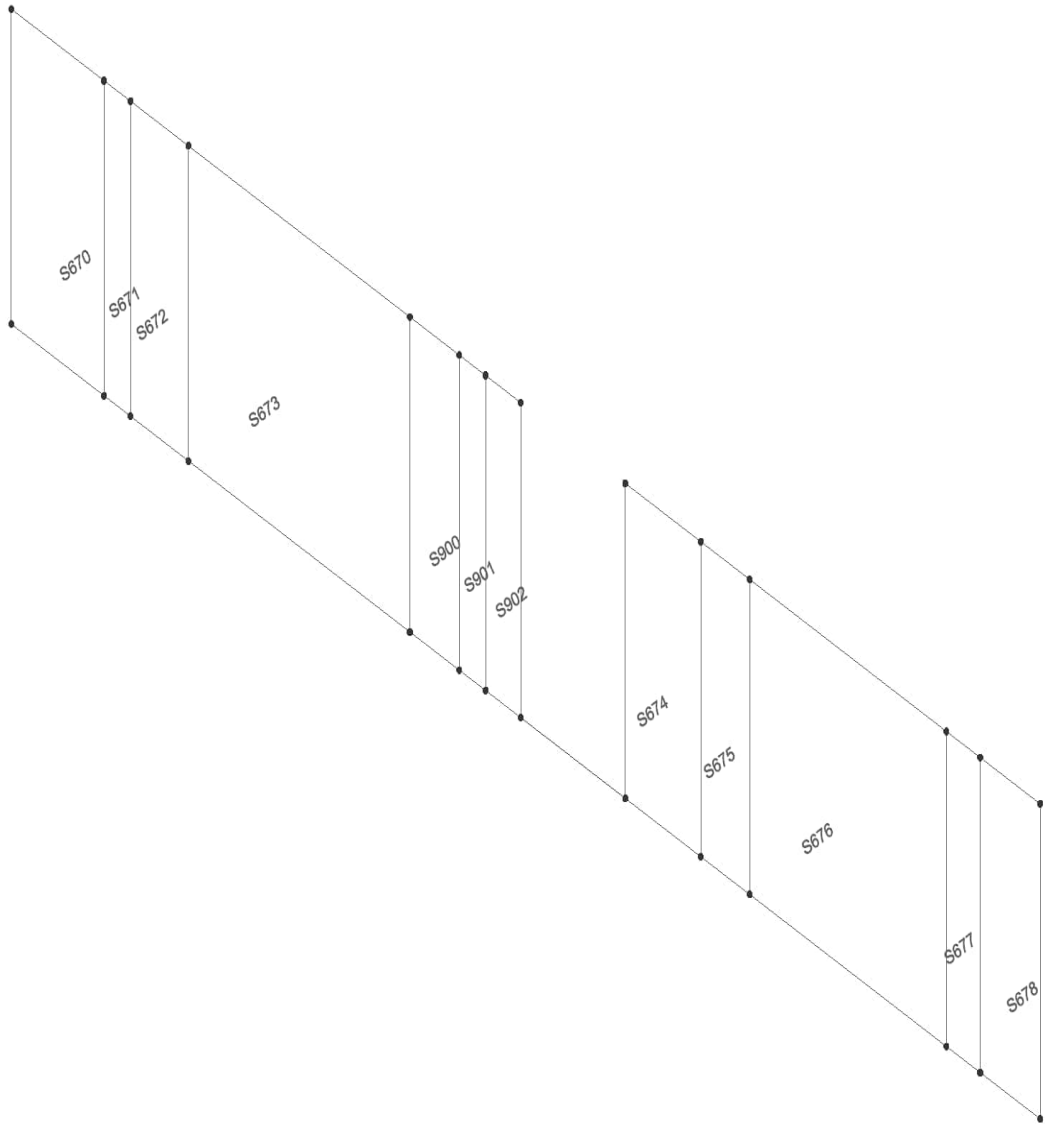
Exterior wall 2 - eastern wall :



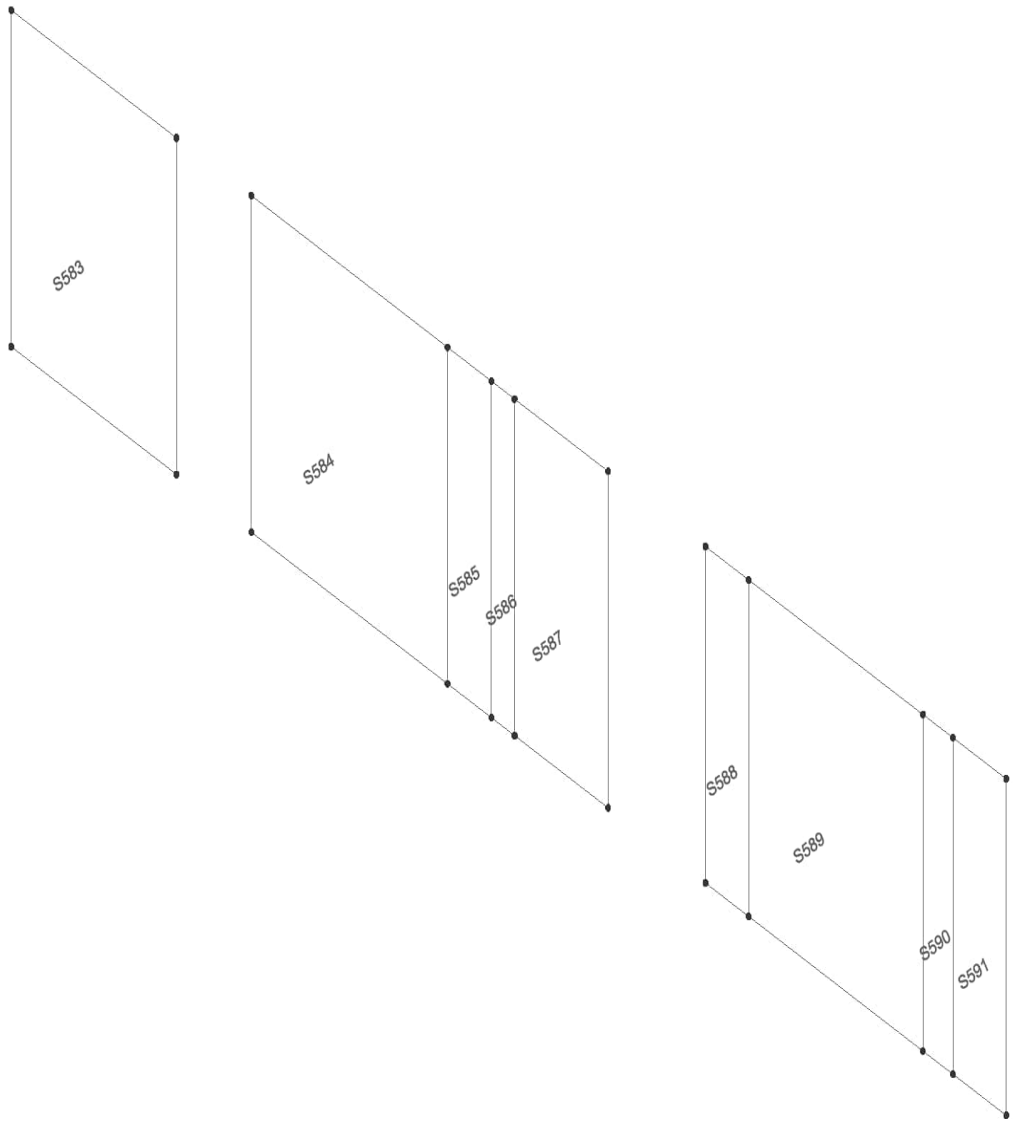
Exterior wall 3 - southern wall :



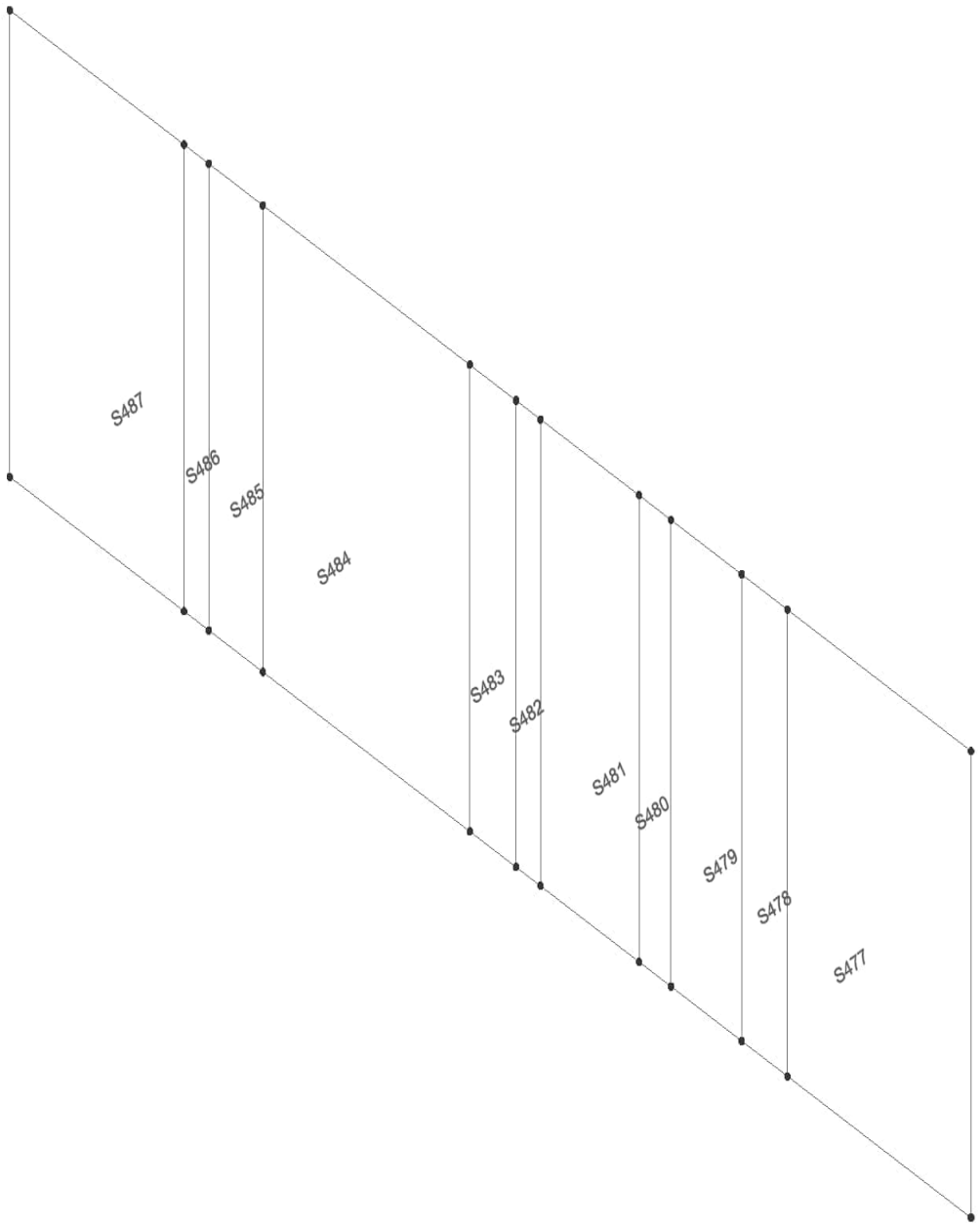
Interior wall 1 :



Interior wall 2 :

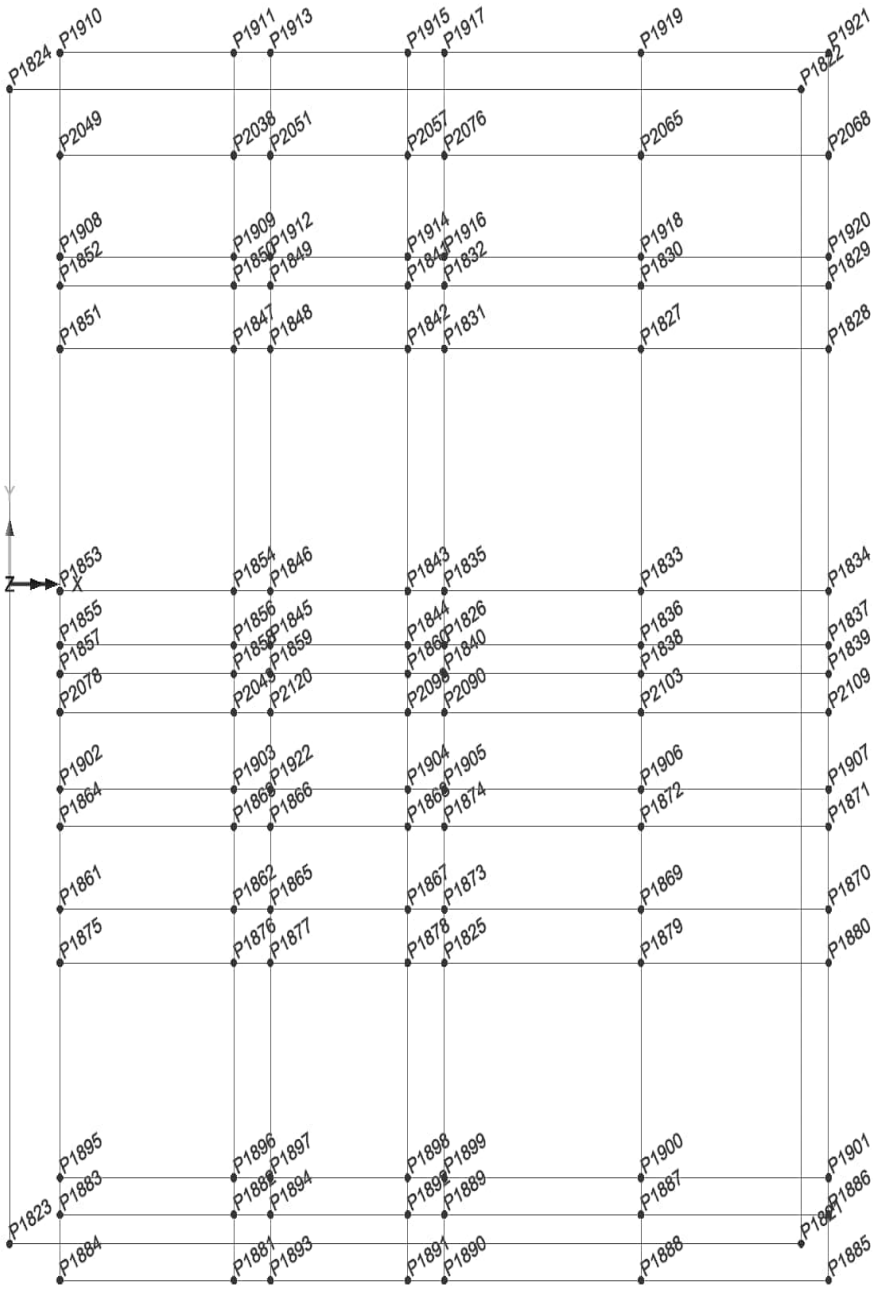


Interior wall 3 :

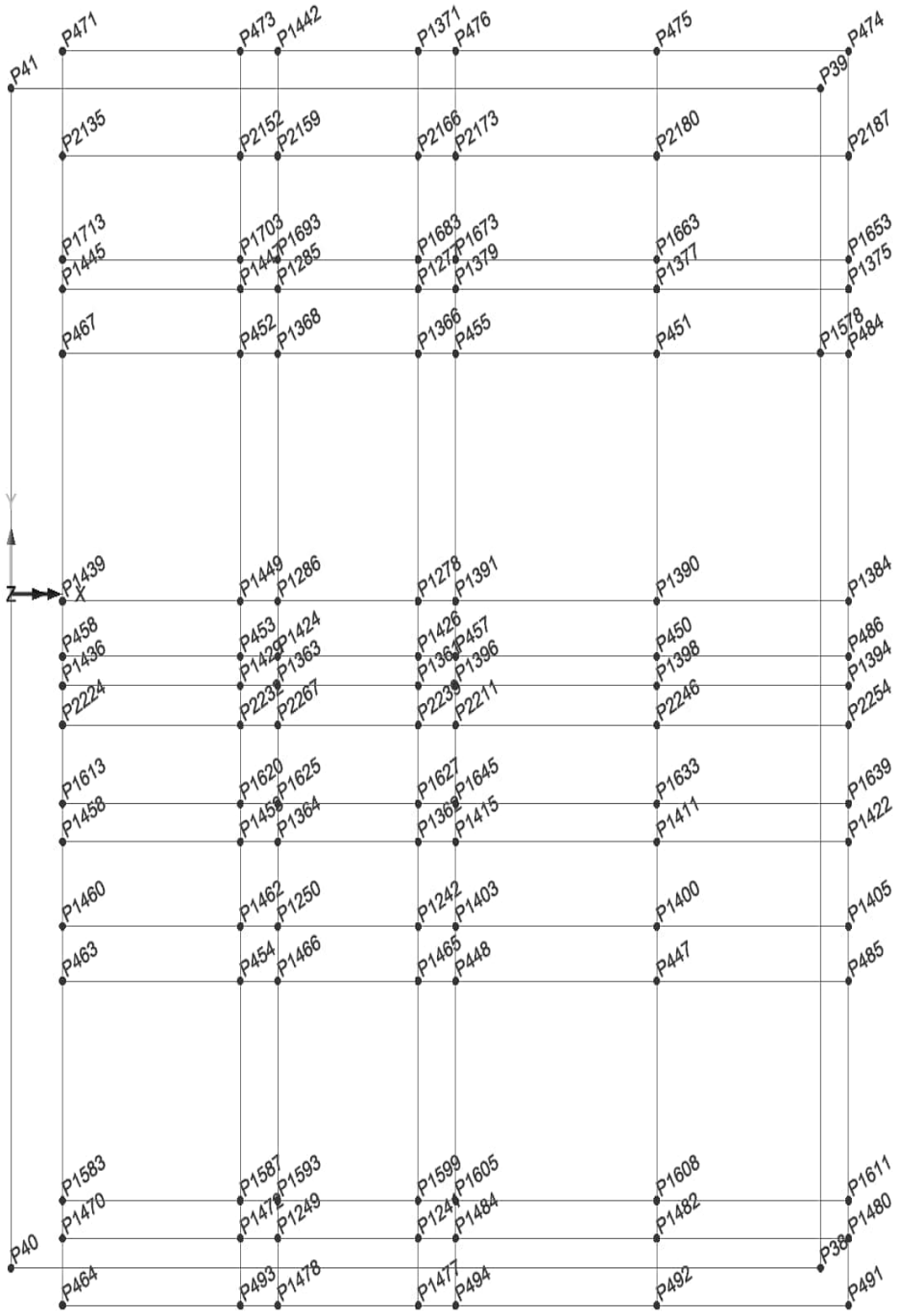


2.2.1.2 Geometry : POINTS

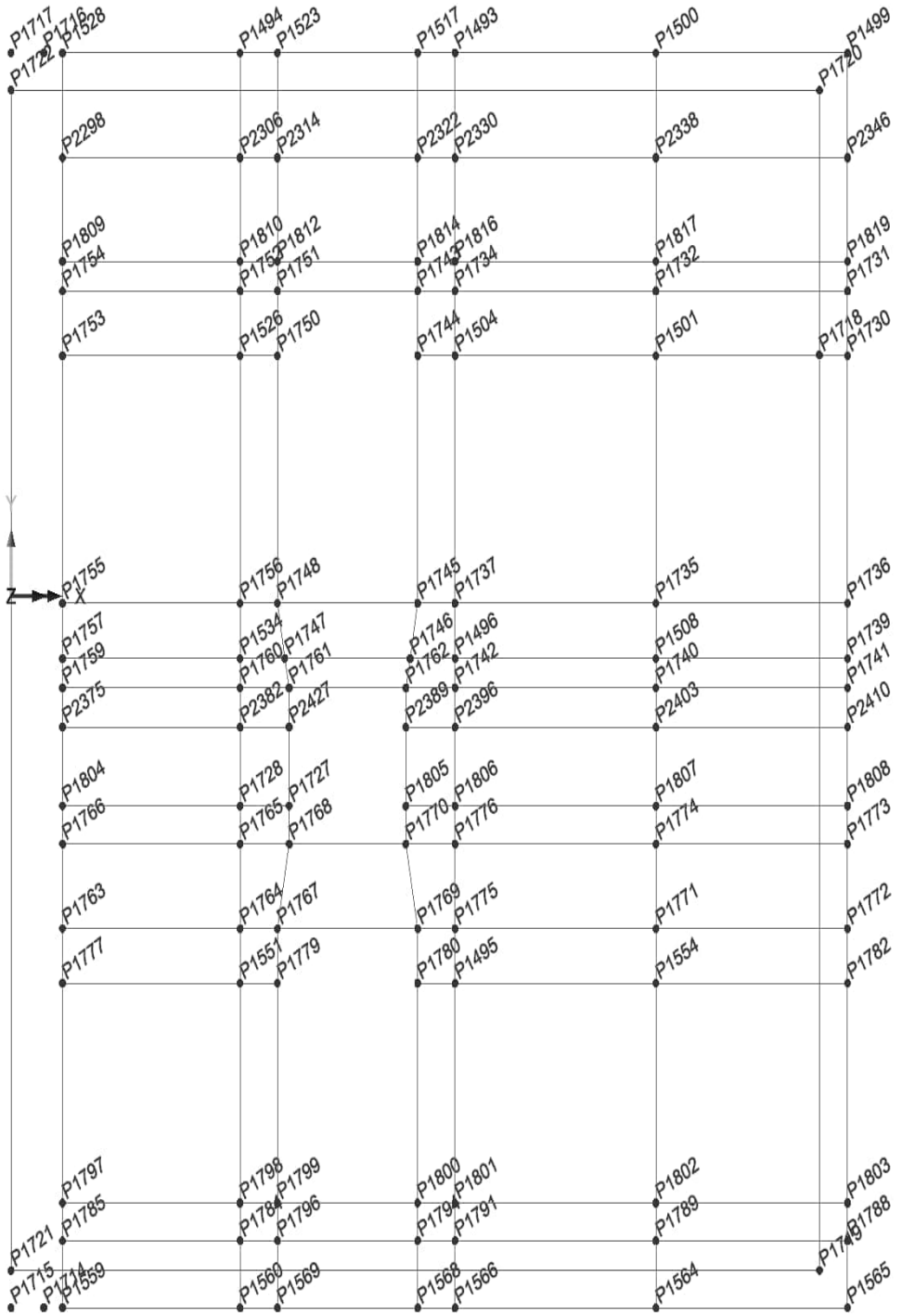
Slab 1 – level +56.65 :



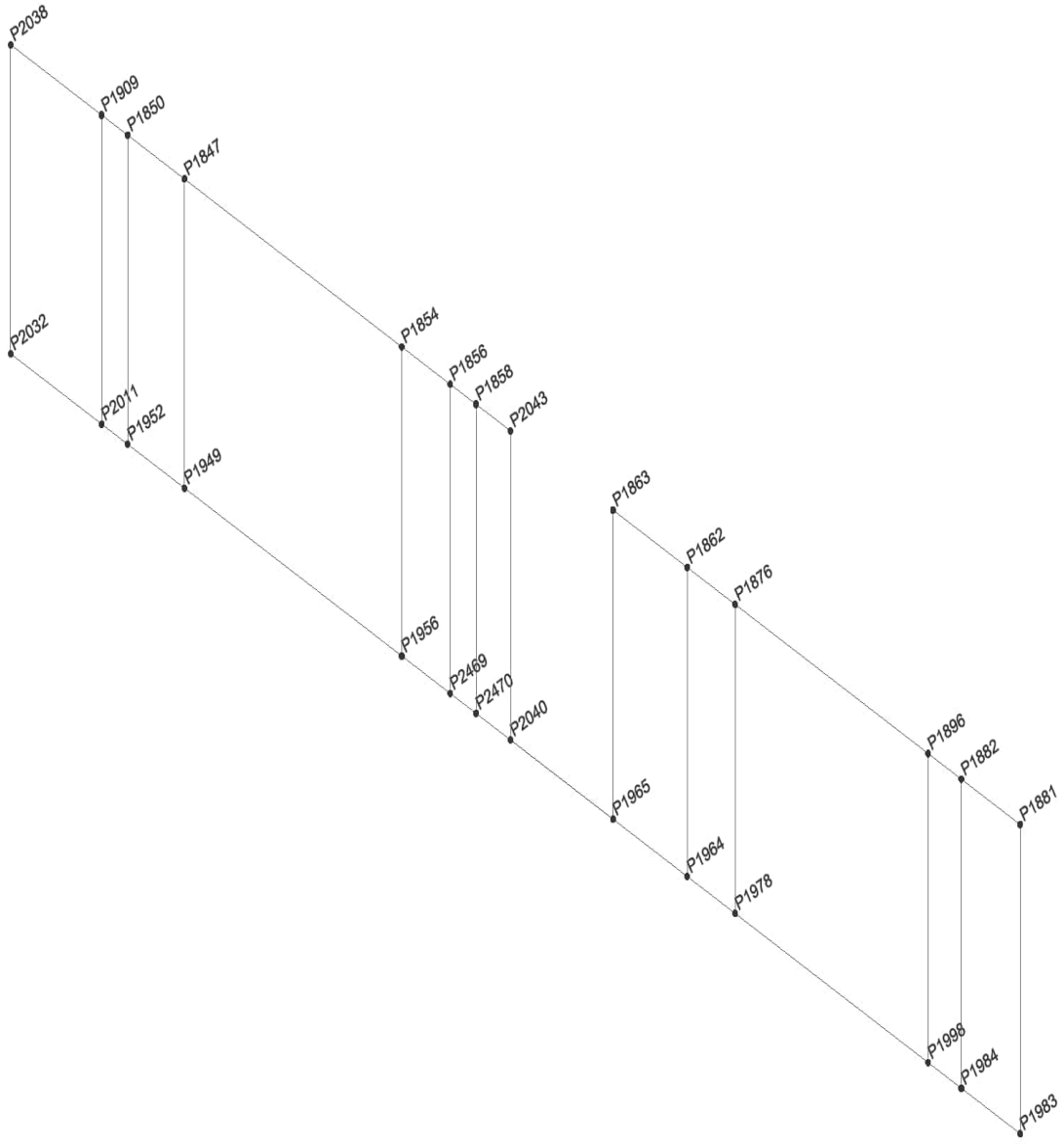
Slab 2- level +61.05 :



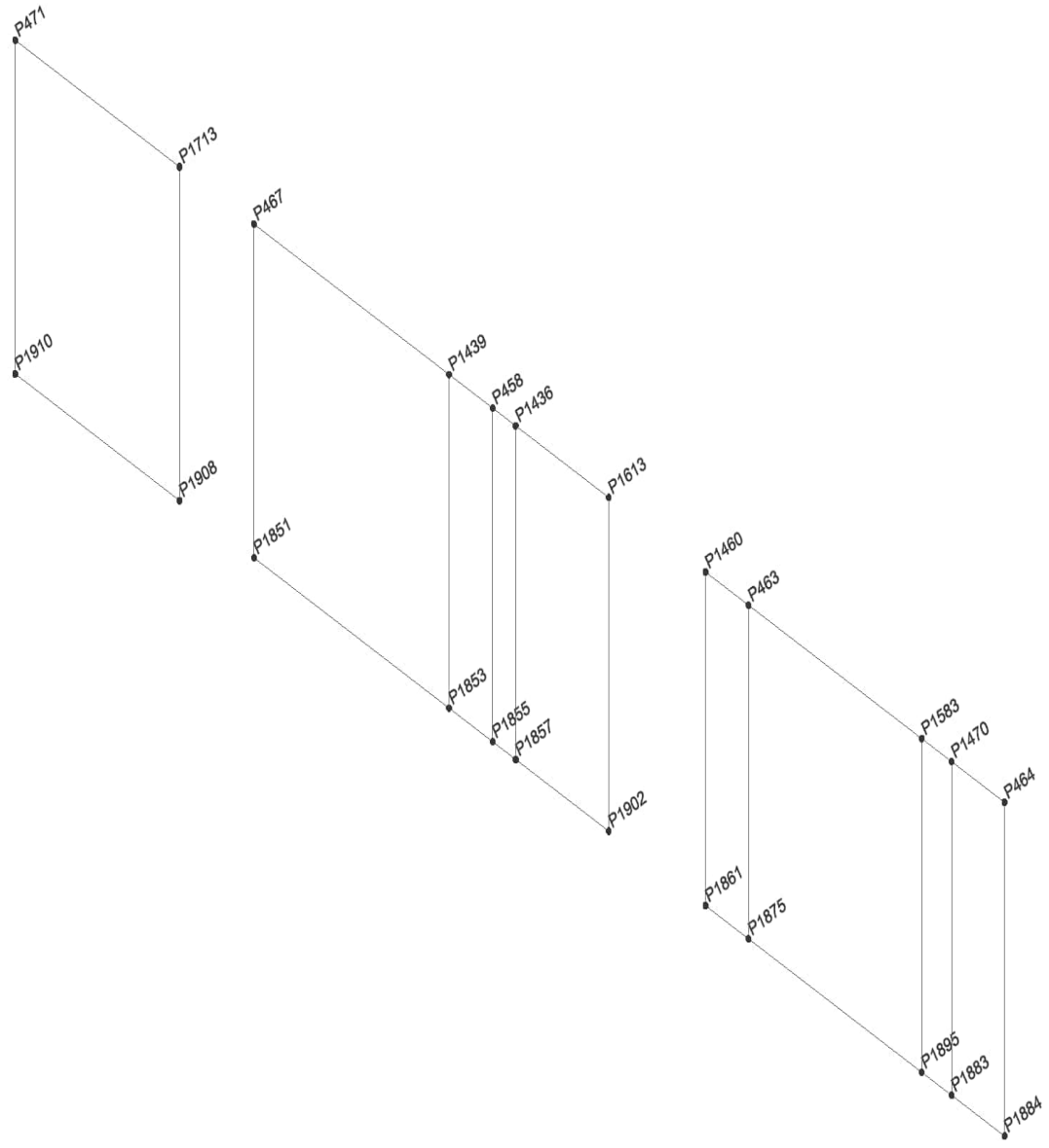
Slab 3 – level +66.85 :



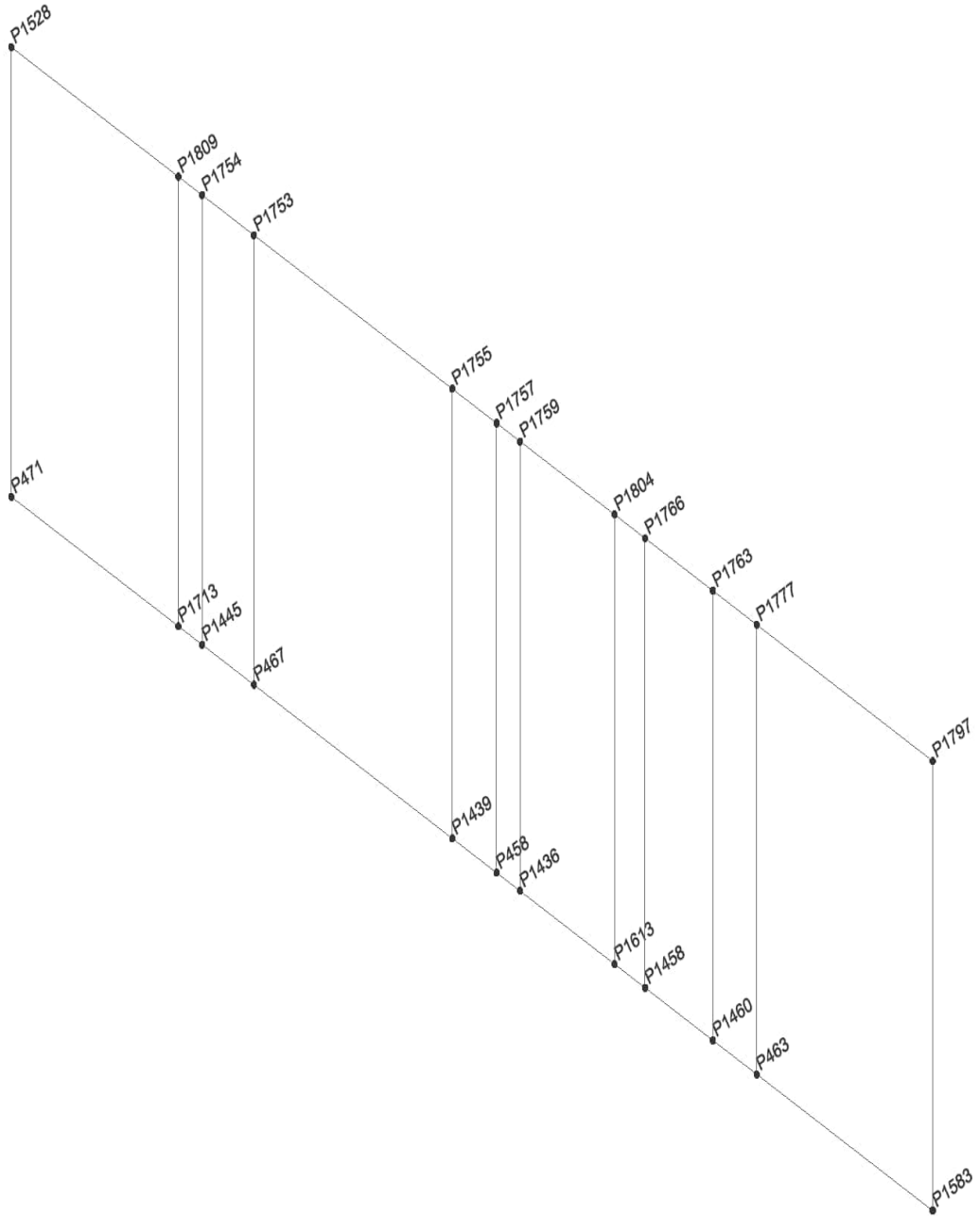
Interior wall 1 :



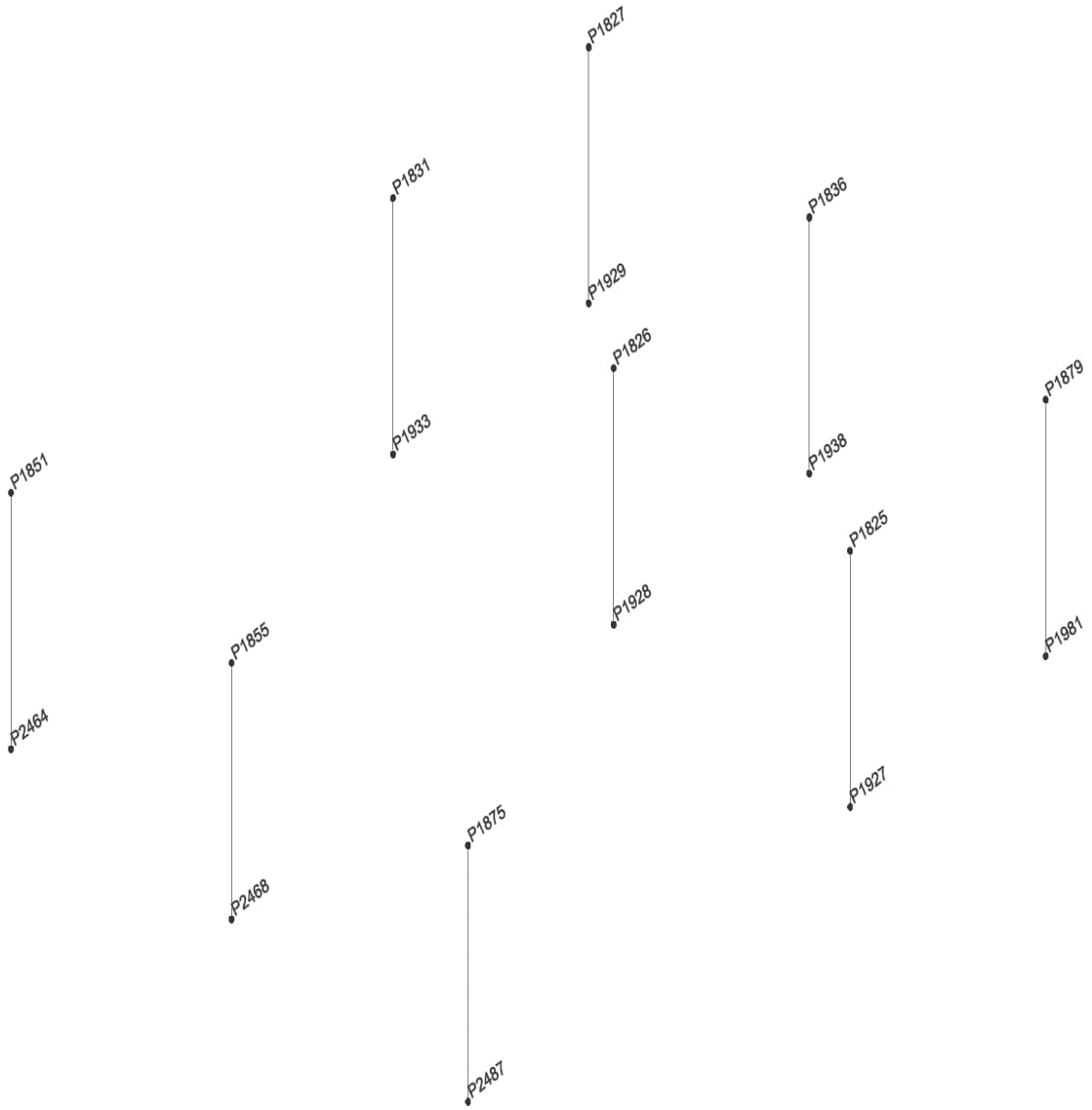
Interior wall 2 :



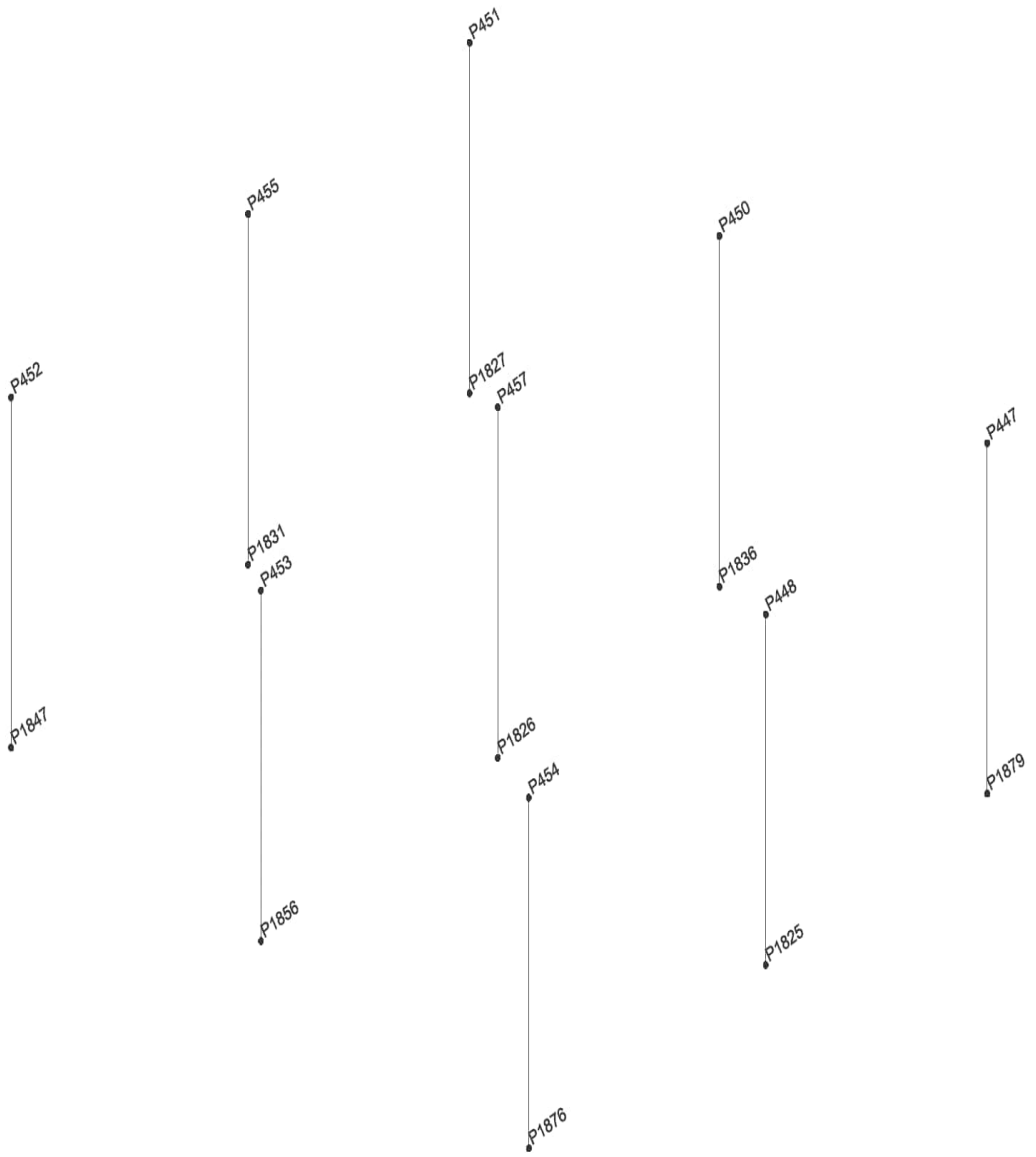
Interior wall 3 :



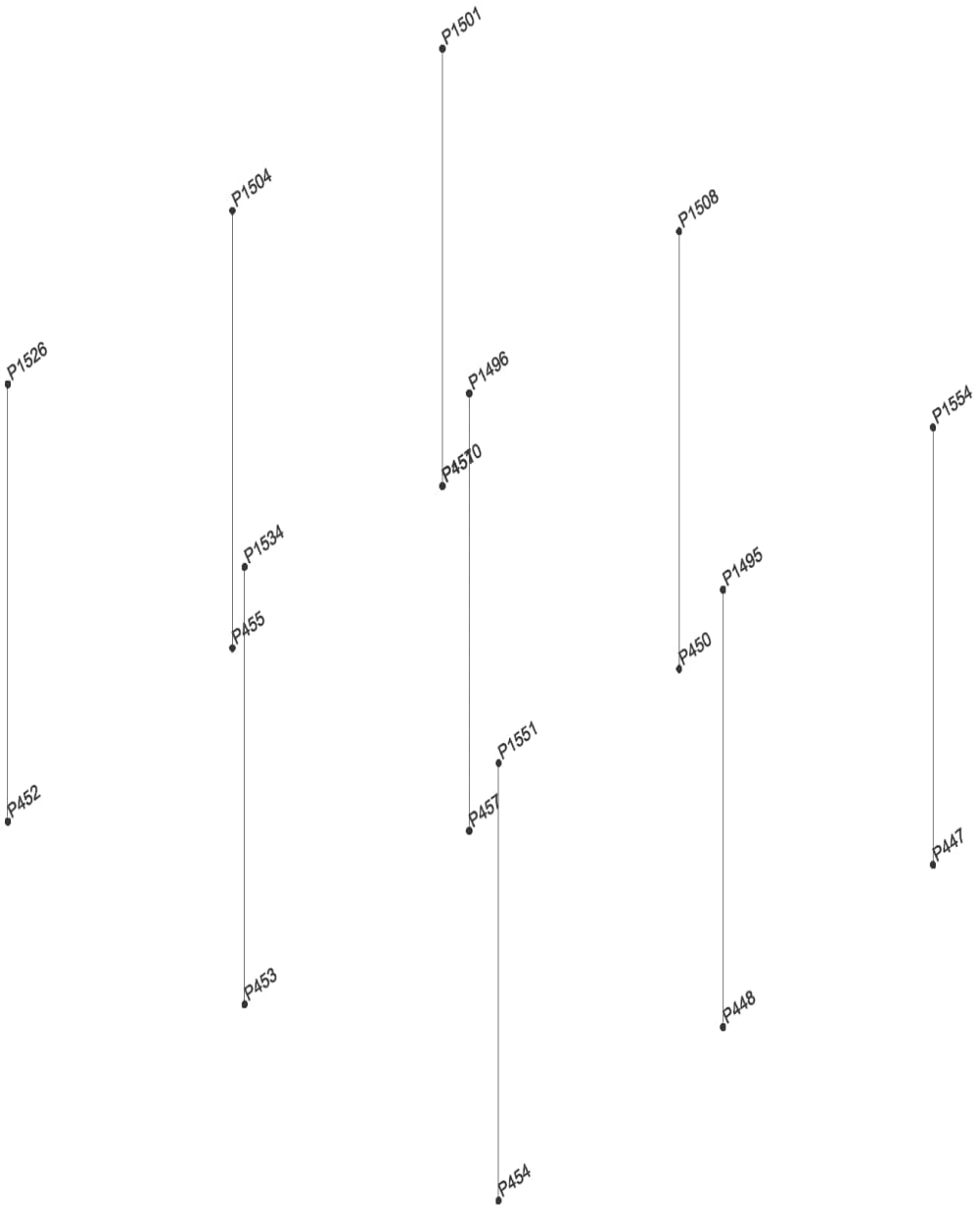
Columns 1 :


P1827
P1831
P1836
P1929
P1826
P1879
P1851
P1933
P1938
P1825
P1928
P1855
P1981
P2464
P1927
P1875
P2468
P2487

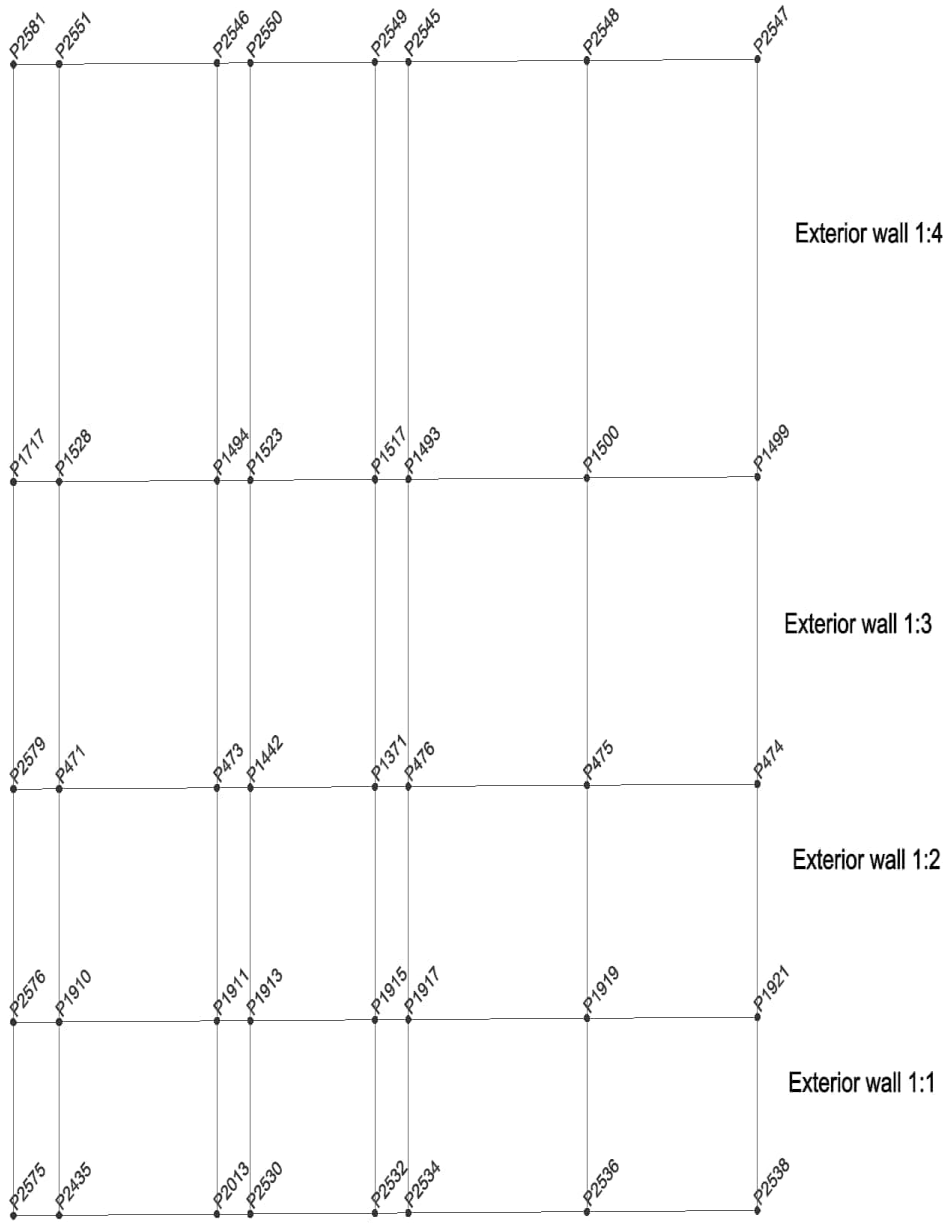
Columns 2 :


P451
P455
P450
P452
P1827
P457
P447
P1831
P453
P1836
P448
P1847
P1826
P454
P1879
P1856
P1825
P1876

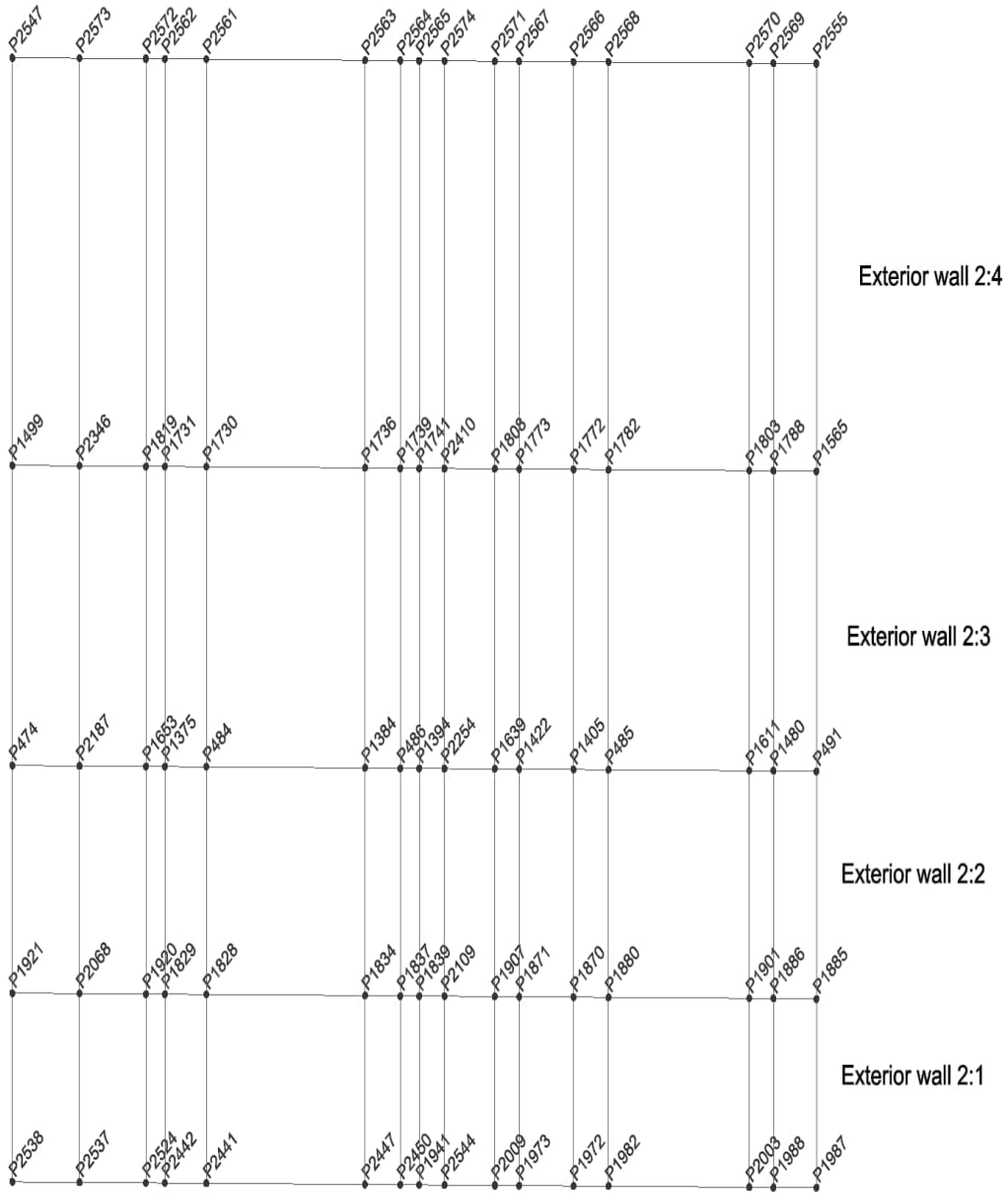
Columns 3 :


P1501
P1504
P1508
P1526
P1496
P1554
P4570
P1534
P1495
P455
P450
P1551
P452
P457
P447
P453
P448
P454

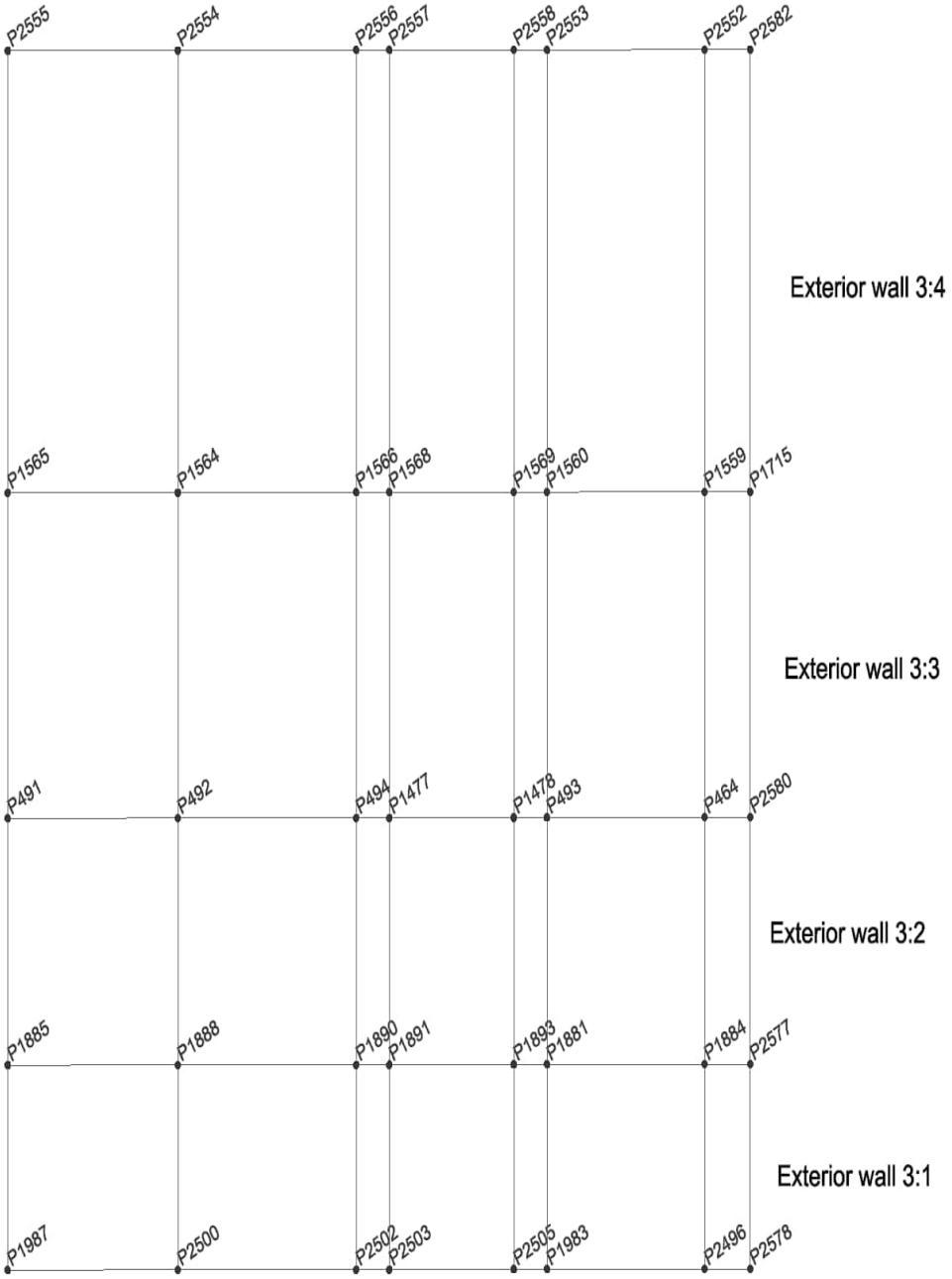
Exterior wall 1 - northern wall :



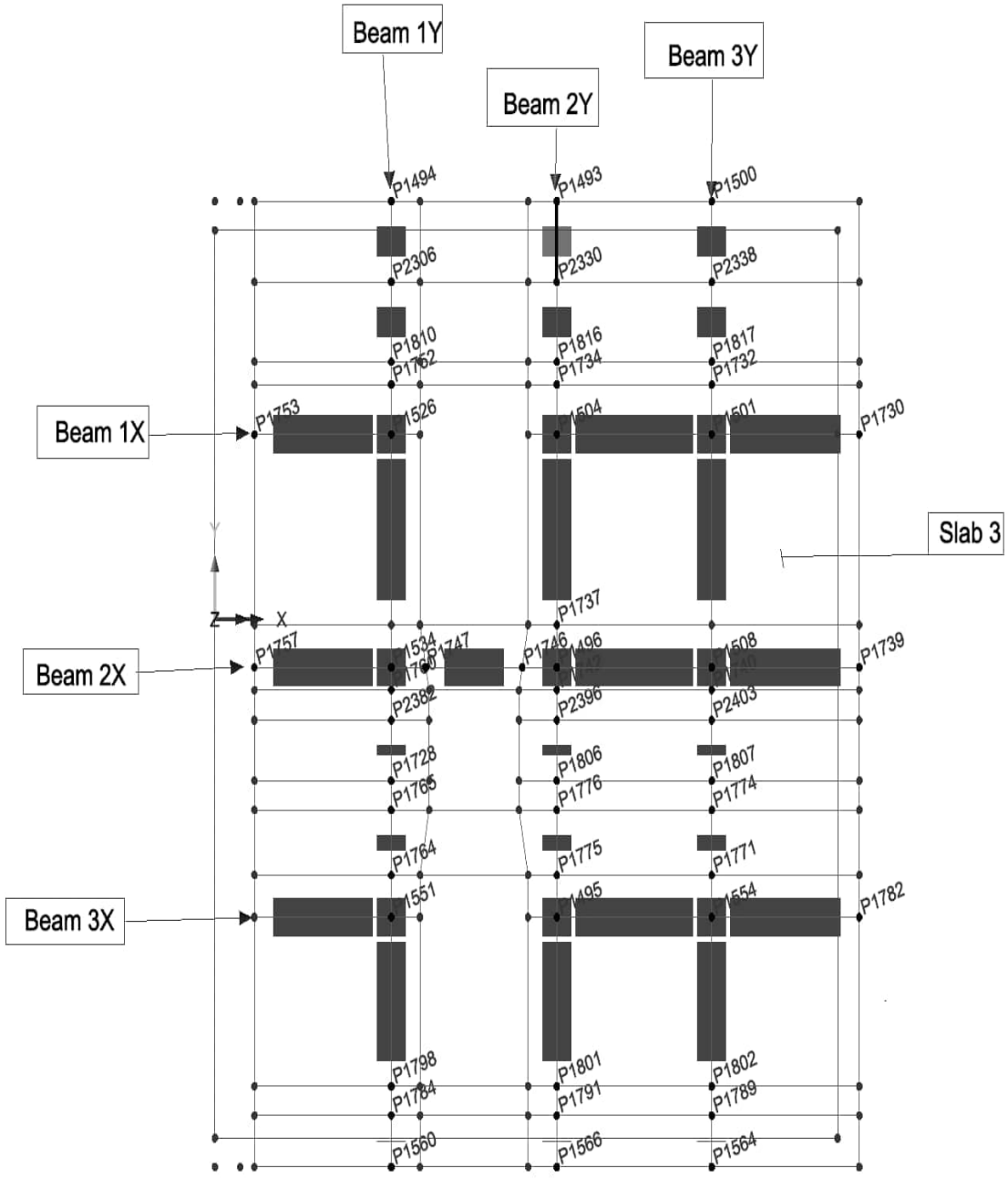
Exterior wall 2 - eastern wall :



Exterior wall 3 - southern wall :

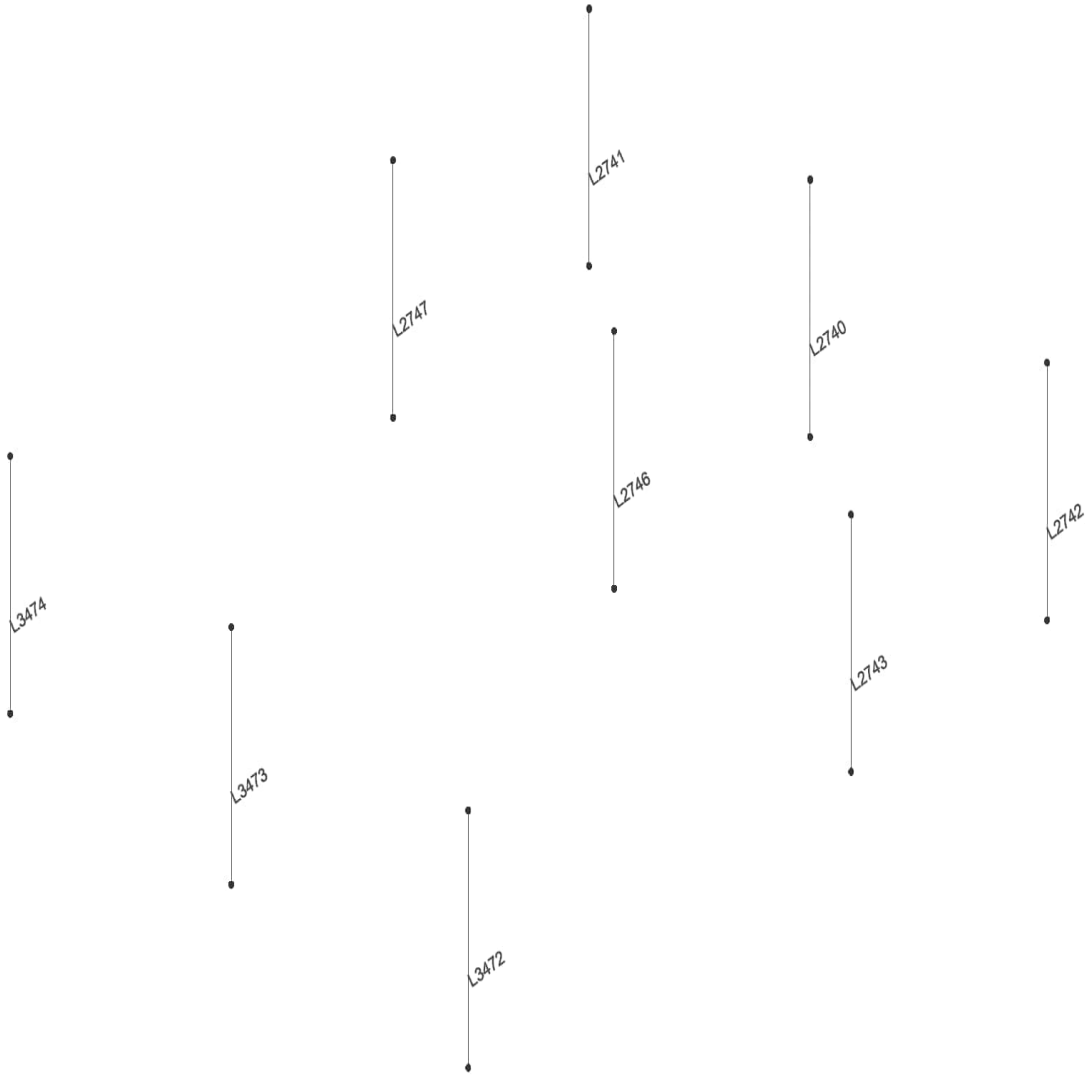


Beams 1X..3X / Beams 1Y..3Y :

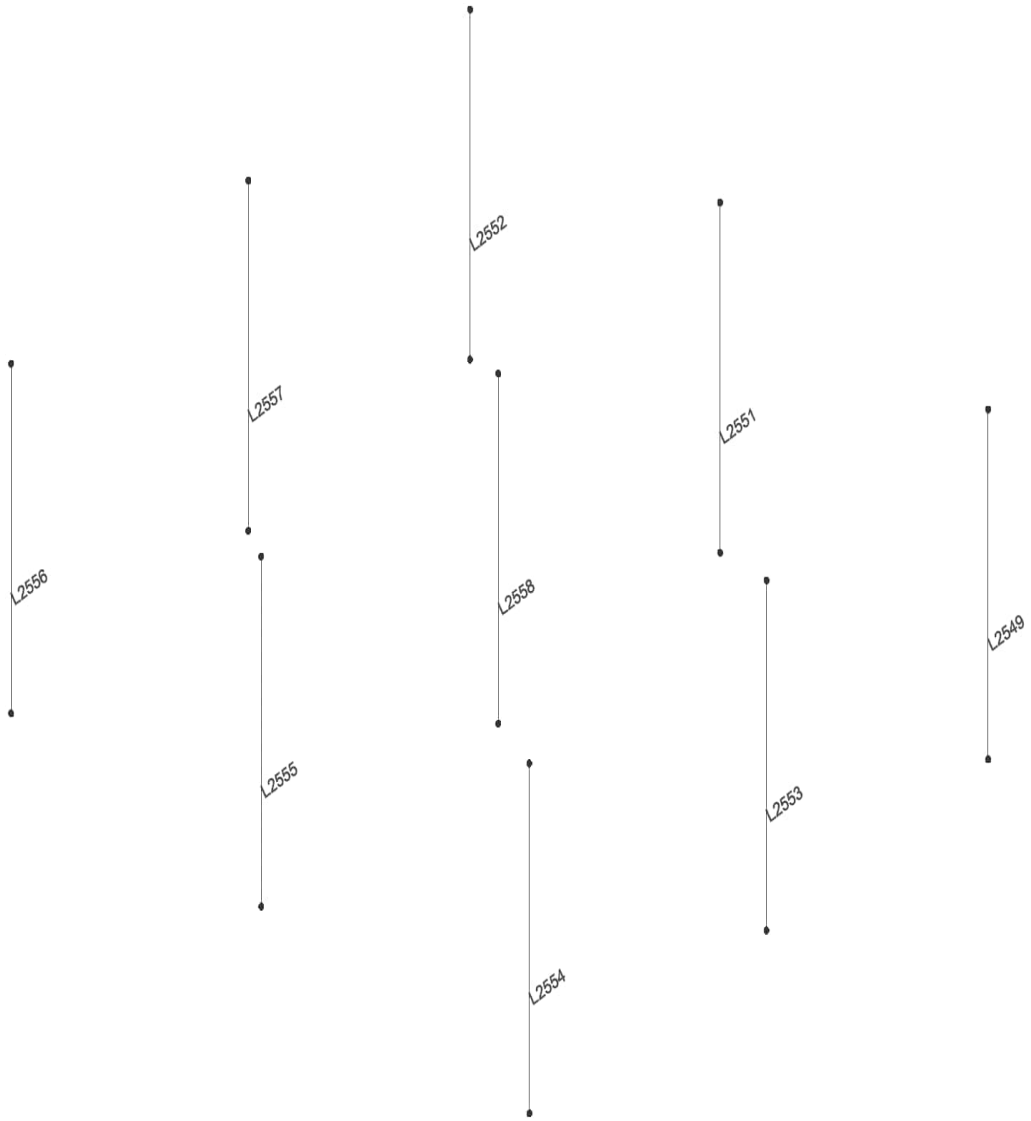


2.2.1.3 Geometry : LINES

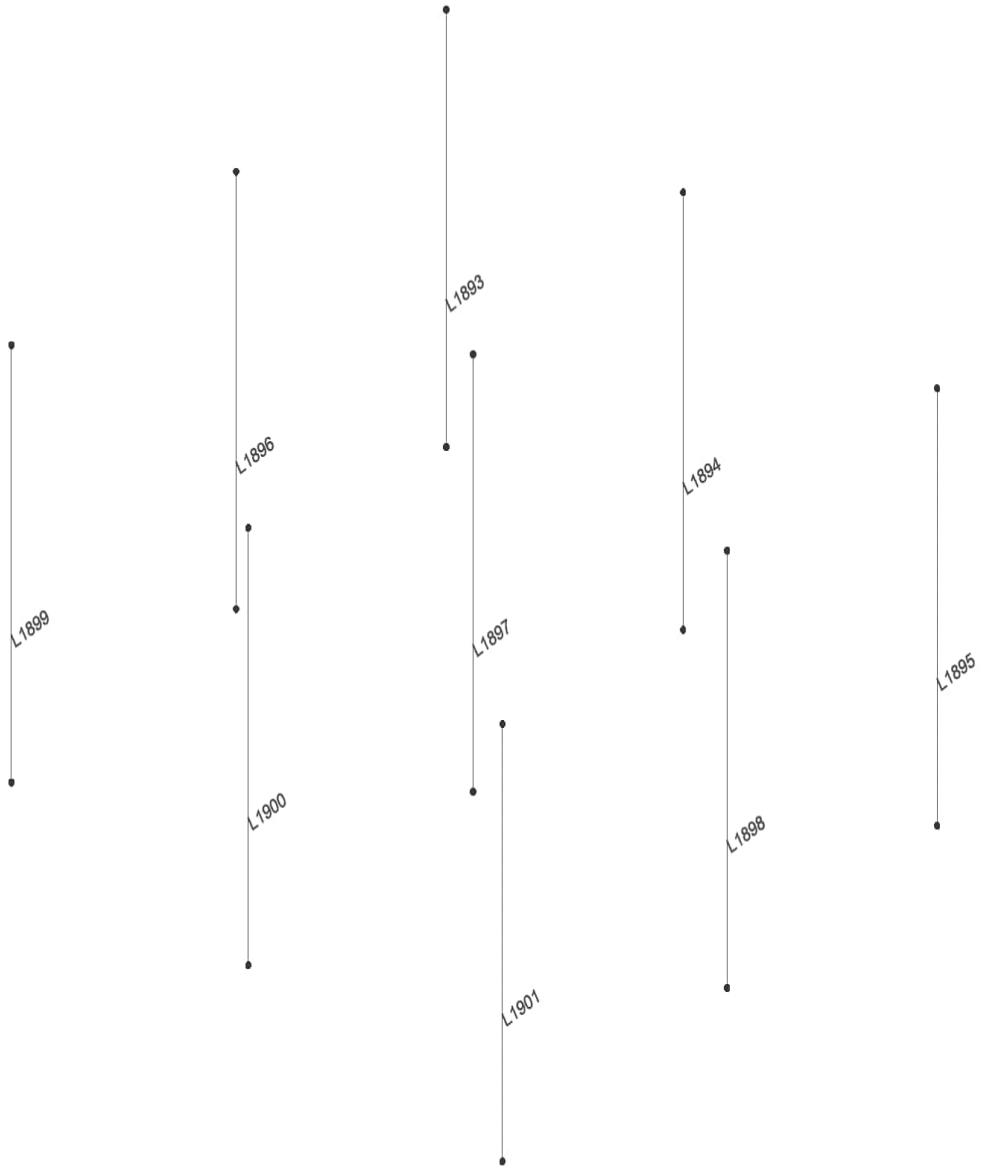
Columns 1 :



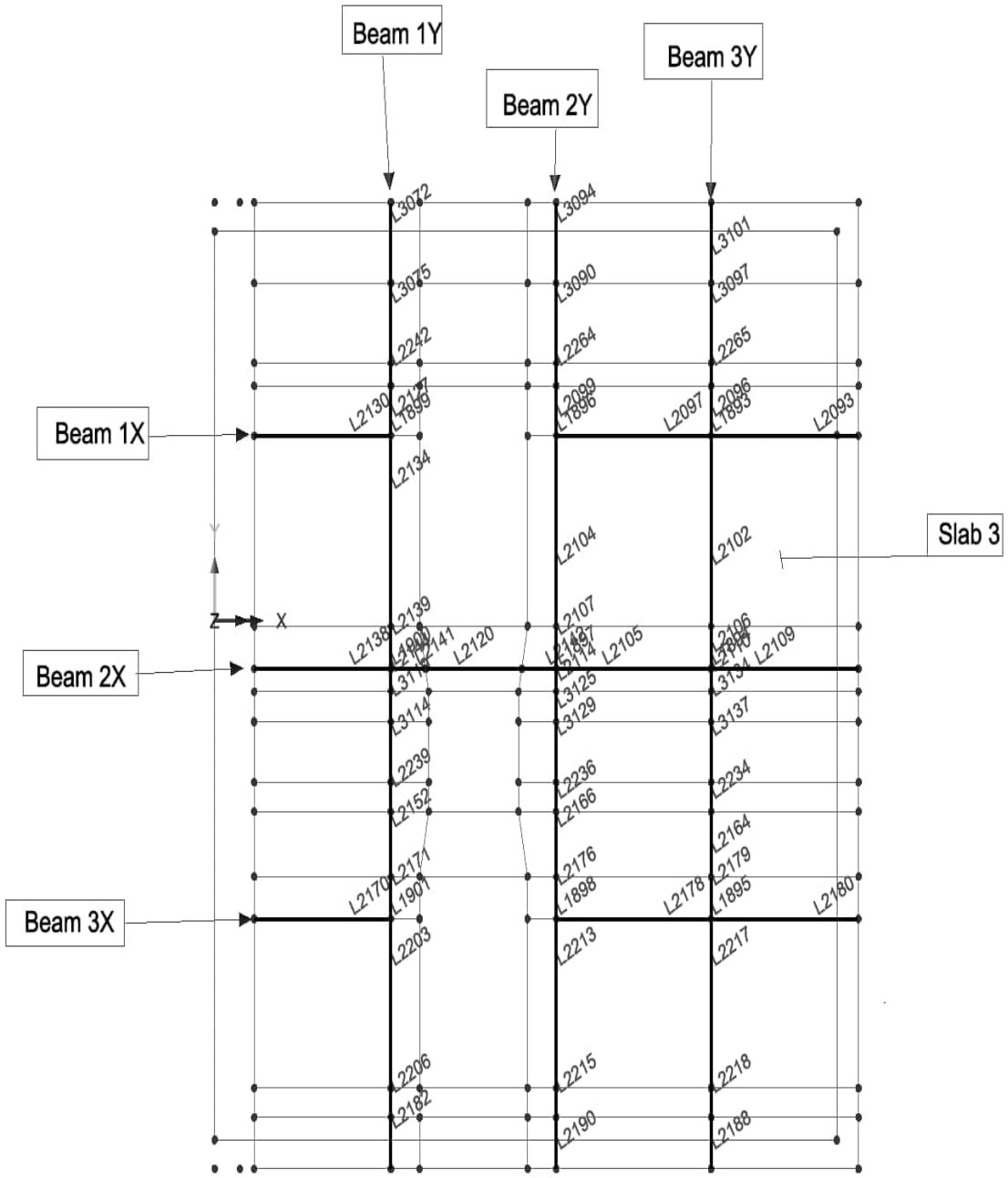
Columns 2 :



Columns 3 :



Beams 1X..3X / Beams 1Y..3Y :

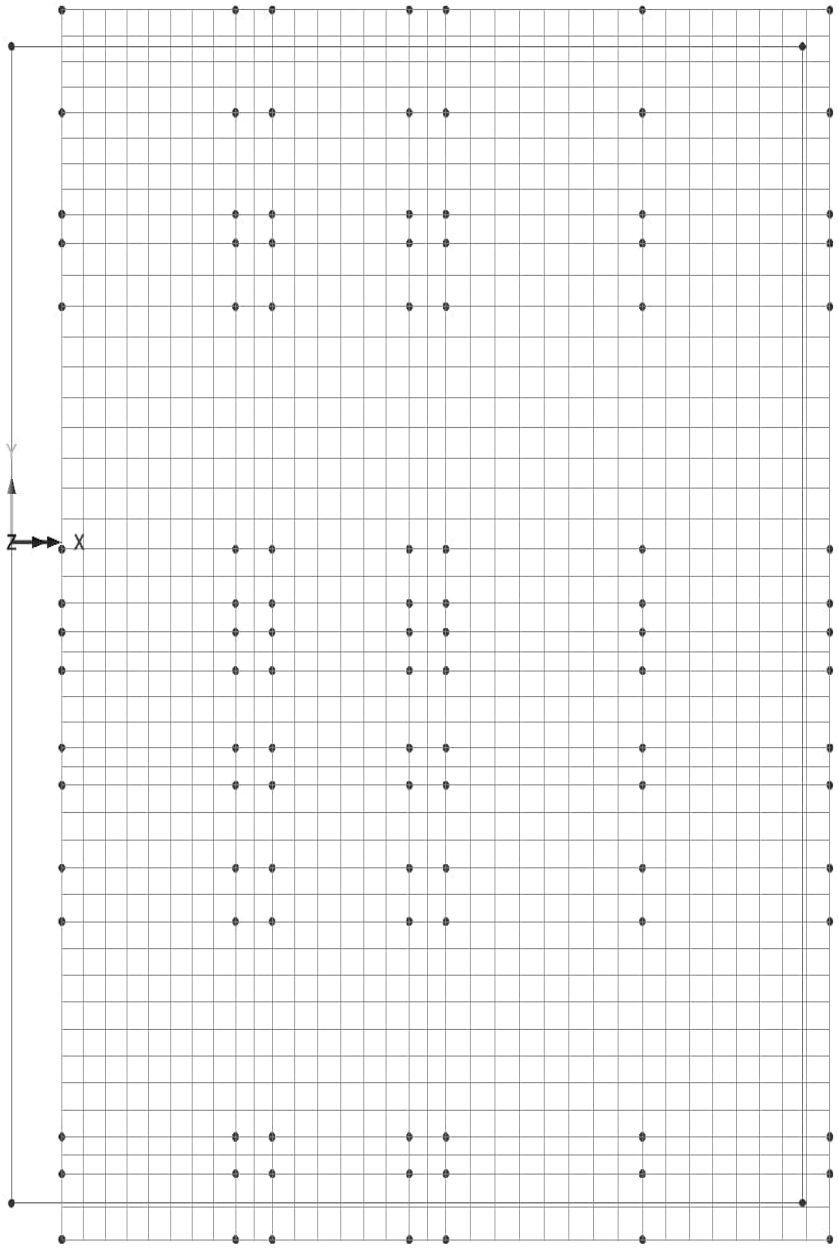


2.2.2 MESH

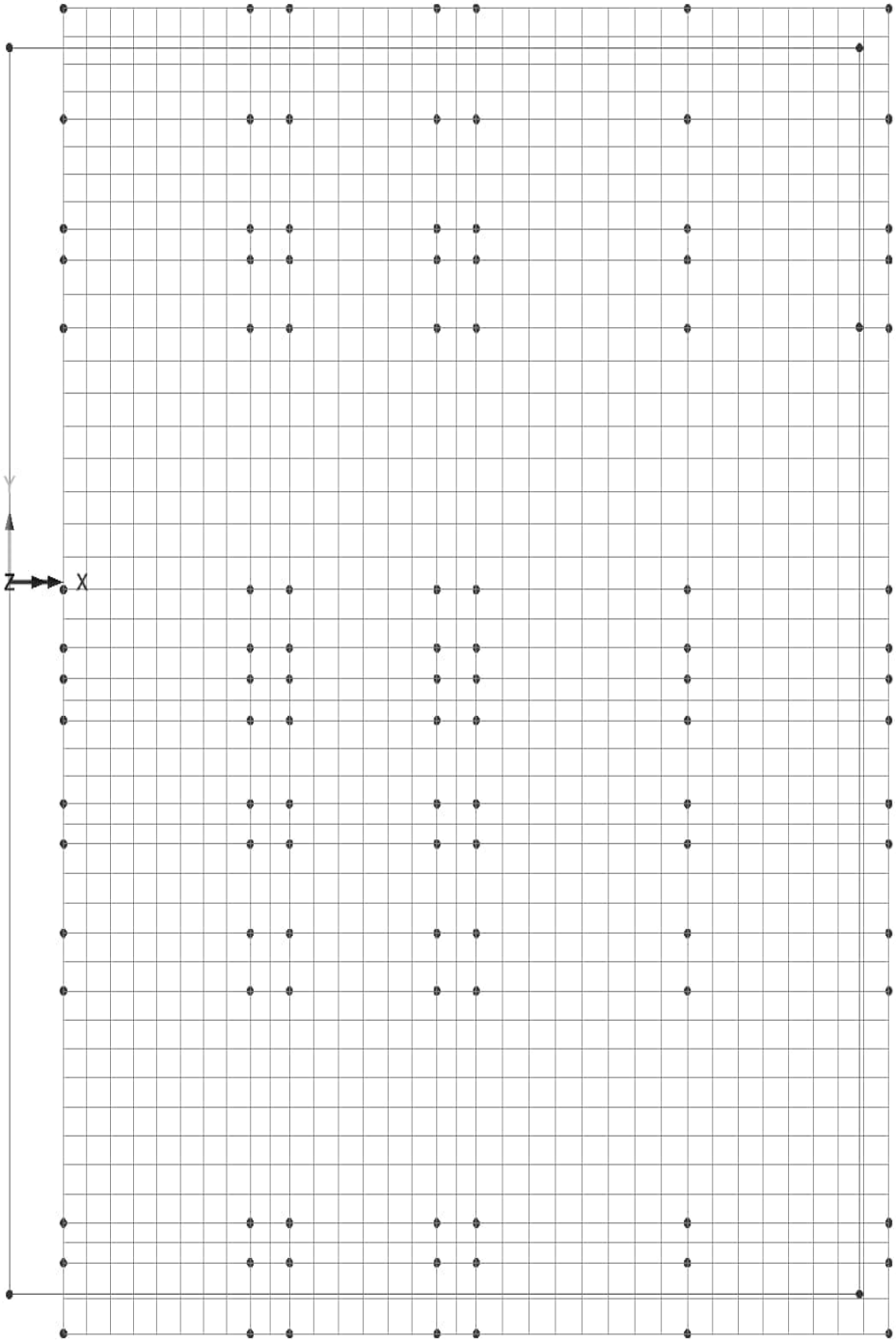
The proviously defined *LINES/SURFACES* are given attributes for generation of *MESH*.

During the generation of *MESH* the underlying *ELEMENTS* and *NODES* are created. They are found in appendix 1.

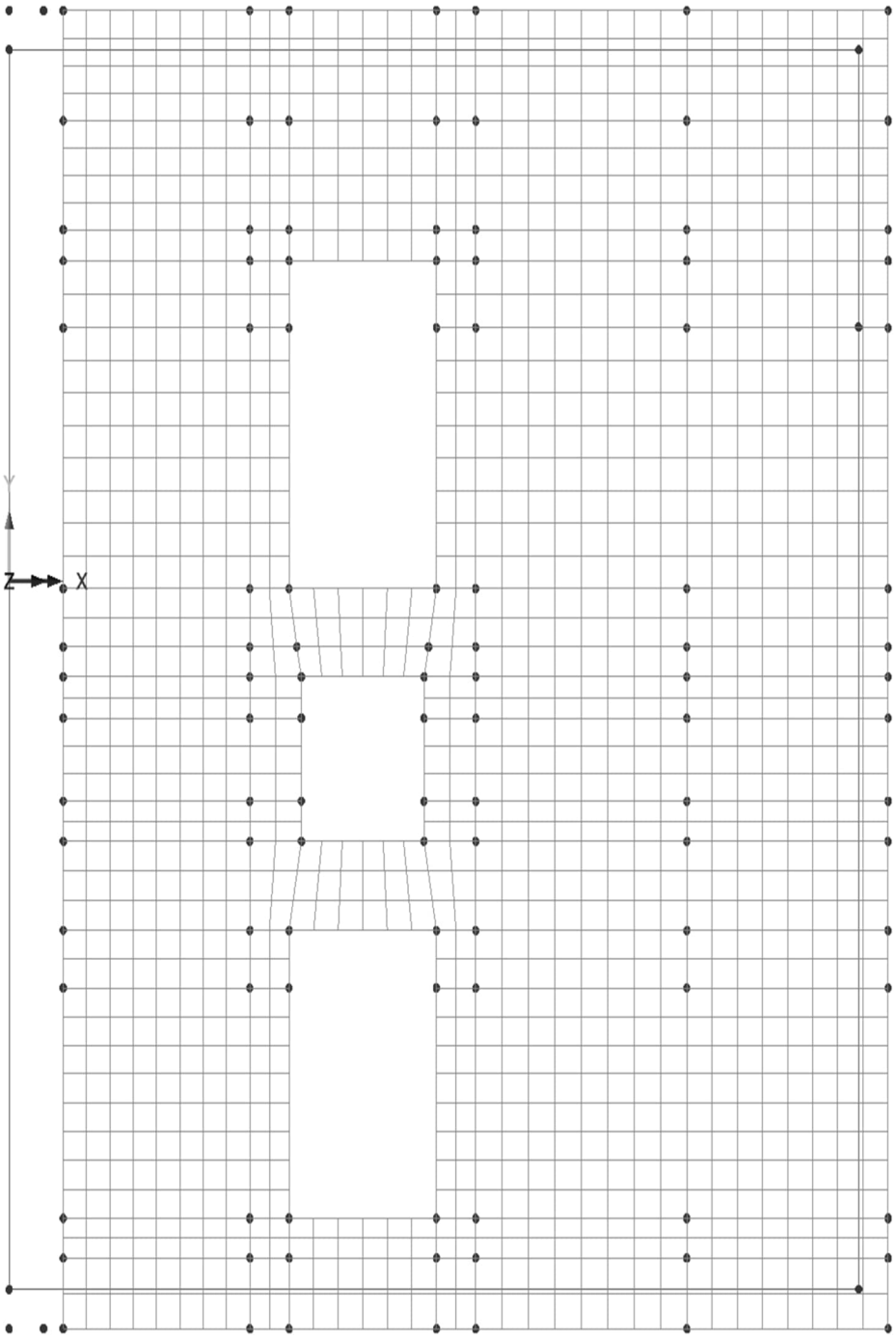
Slab 1 – level +56.65 :



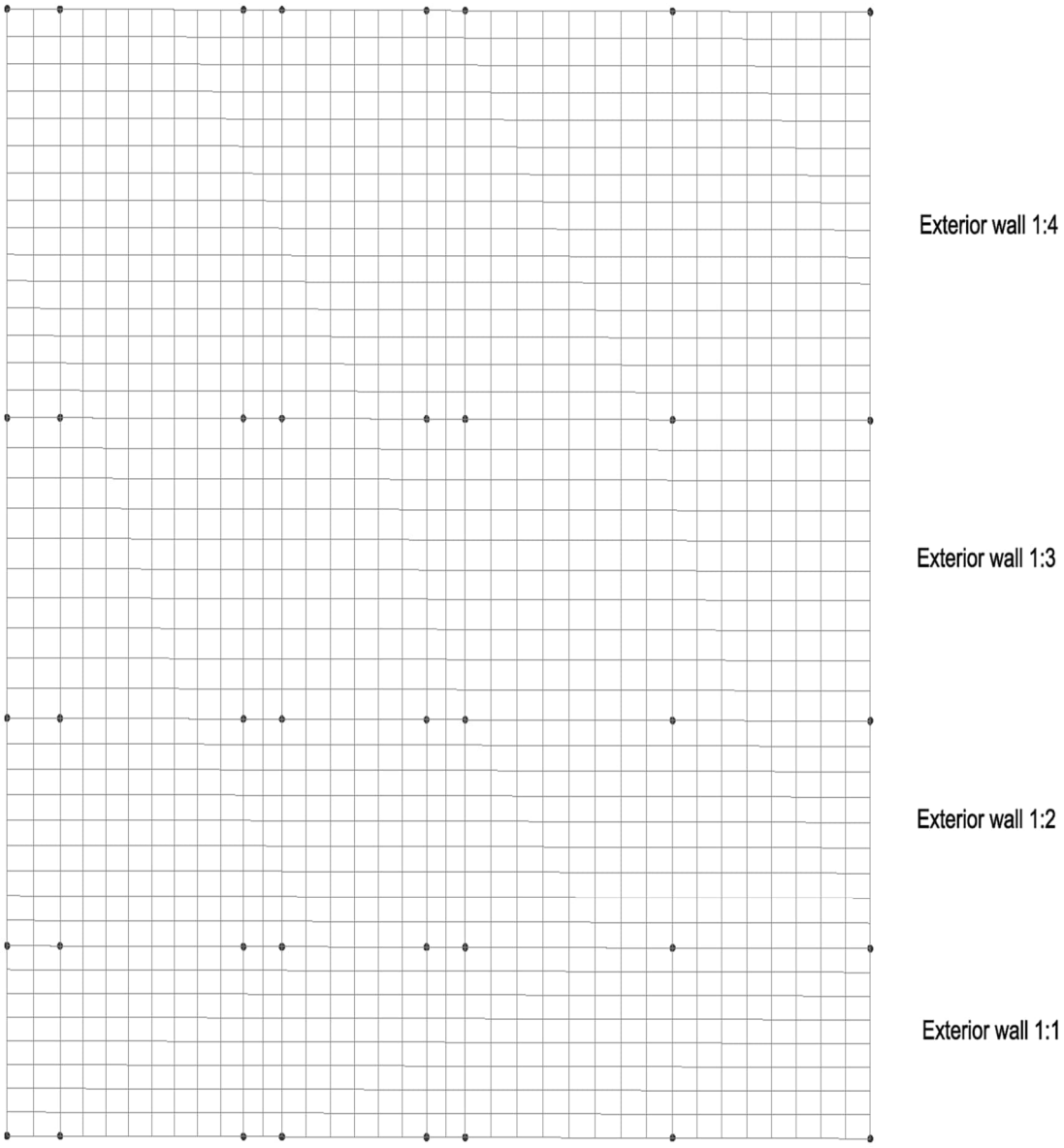
Slab 2- level +61.05 :



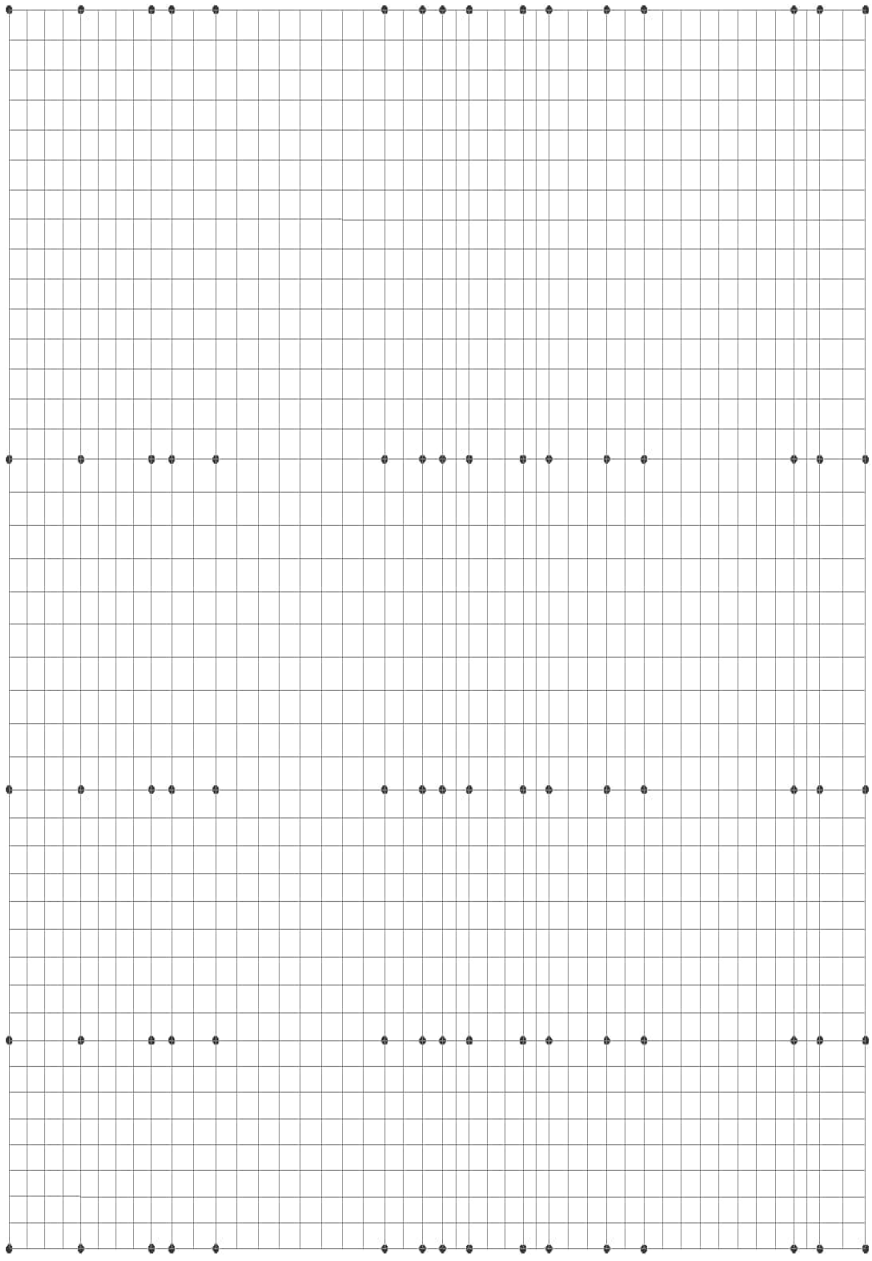
Slab 3 – level +66.85 :



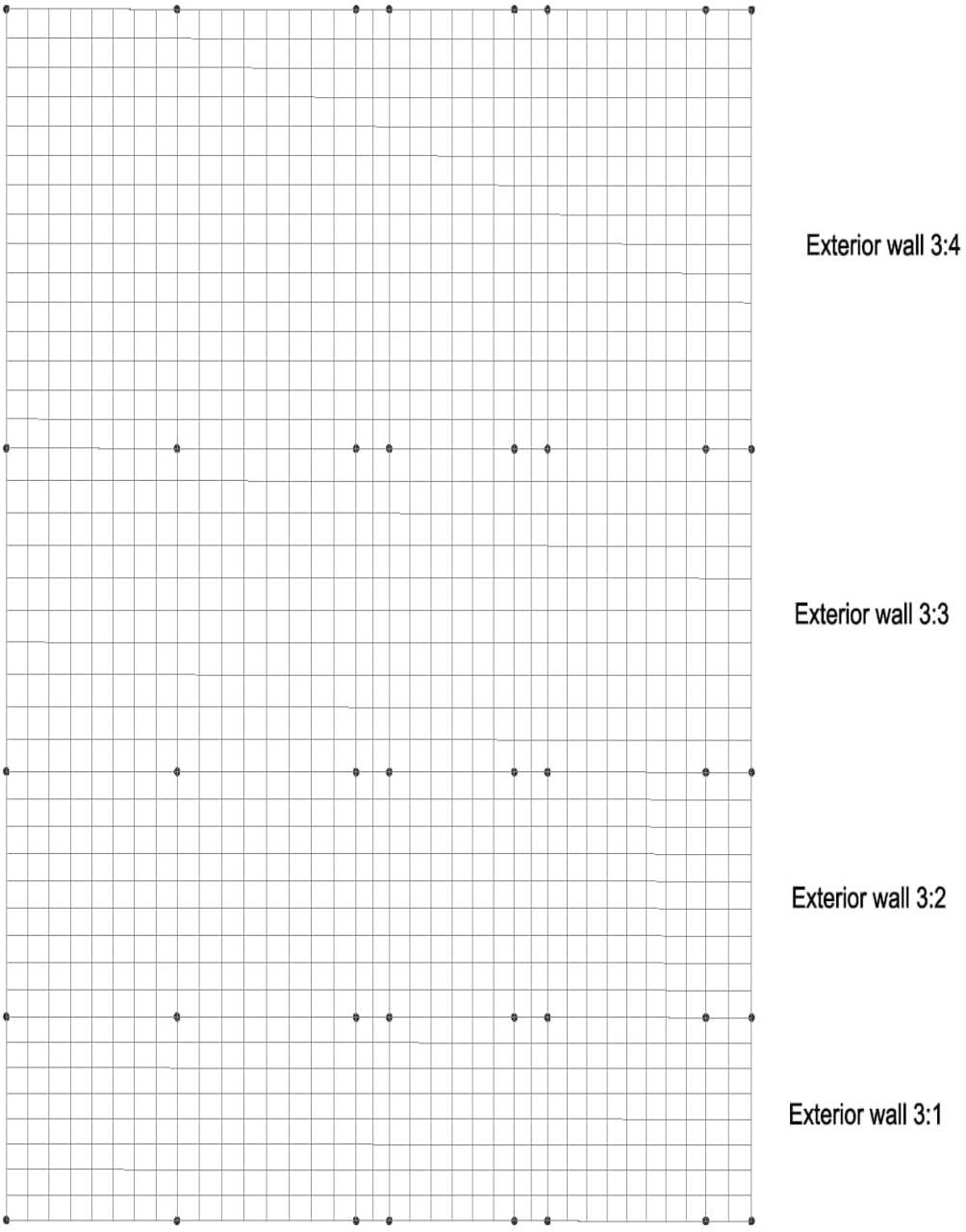
Exterior wall 1 - northern wall :



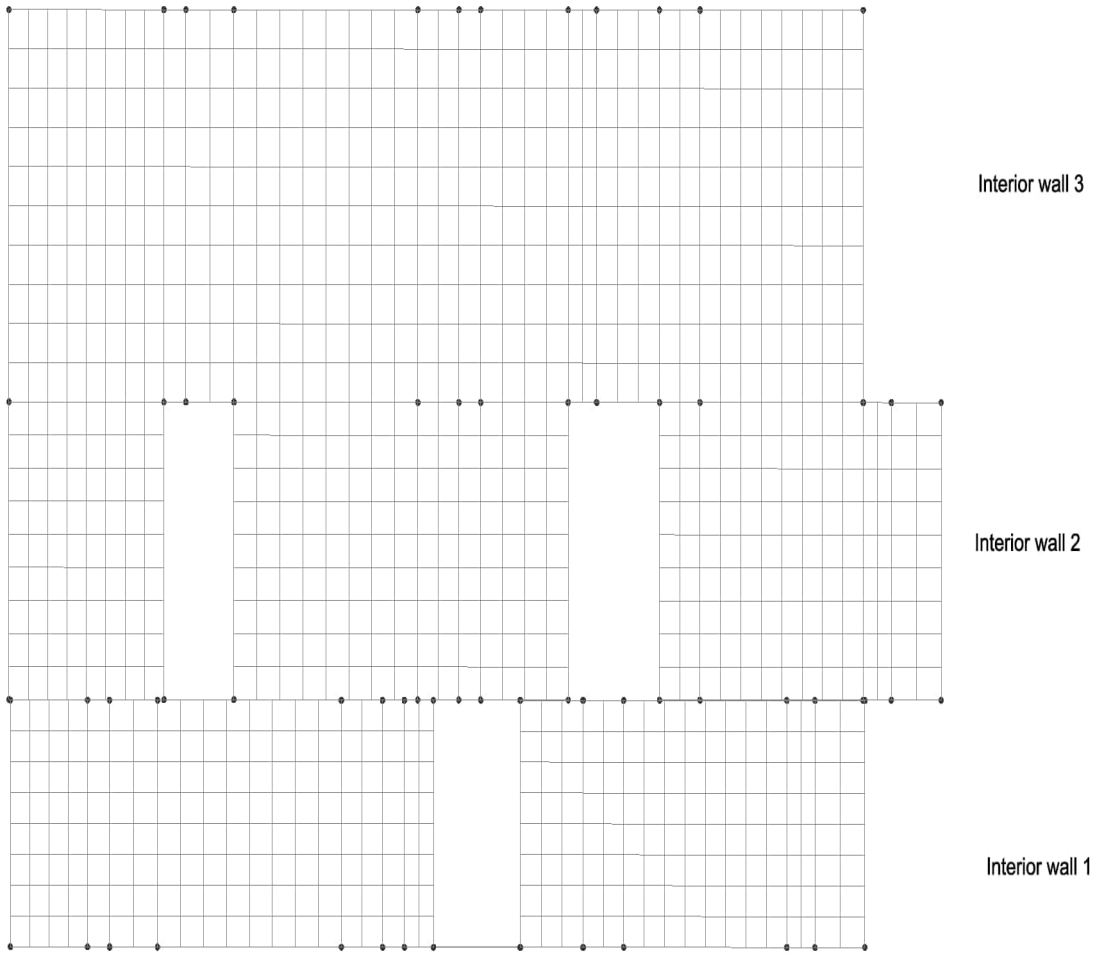
Exterior wall 2 - eastern wall :



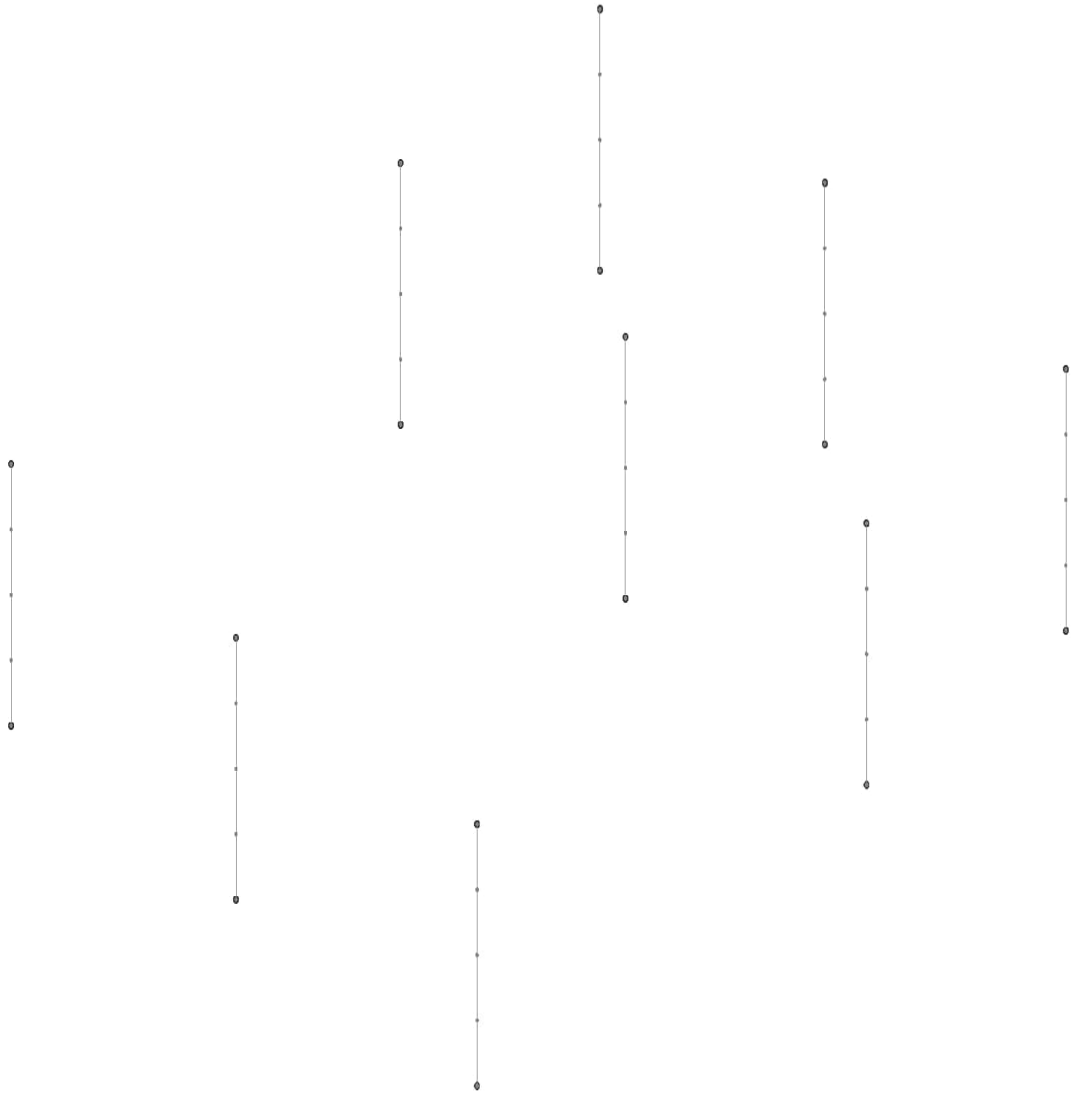
Exterior wall 3 - southern wall :



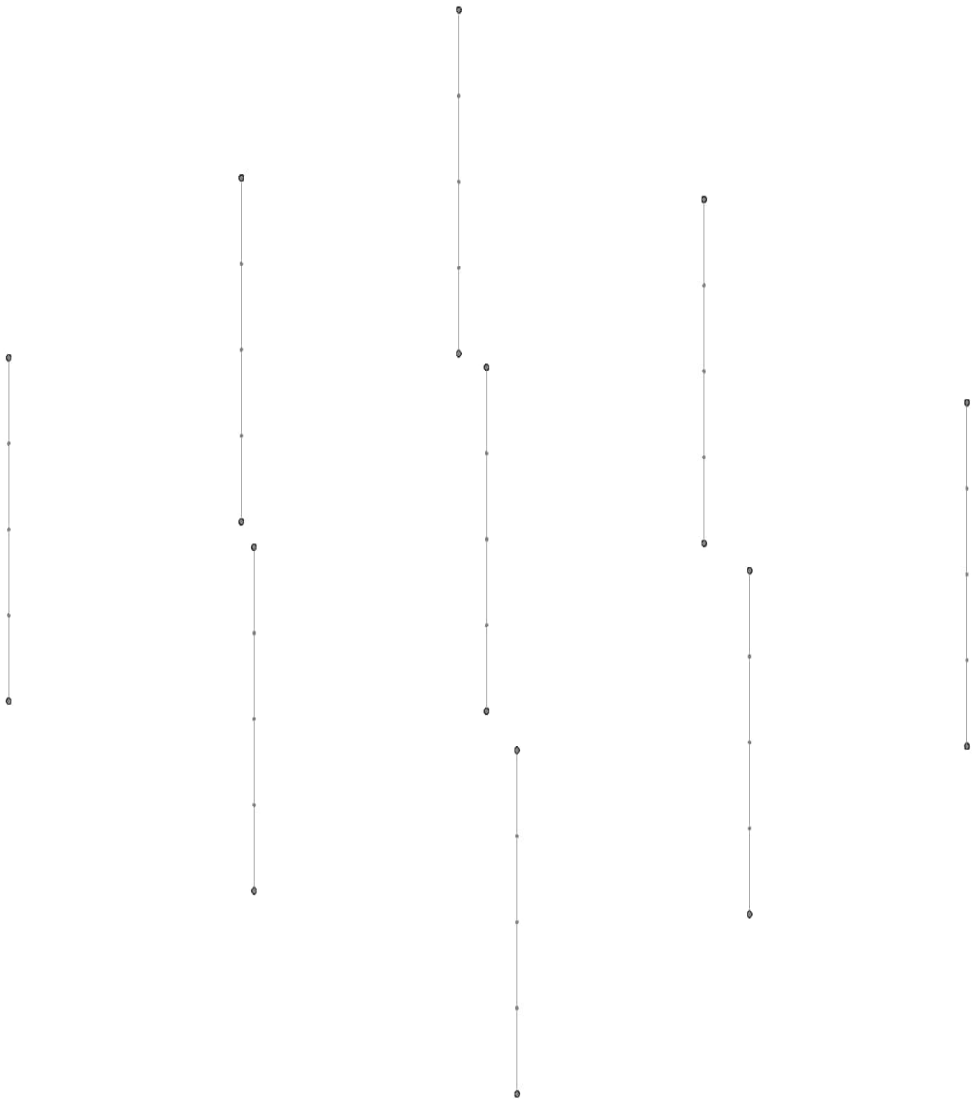
Interior wall 1..3 :



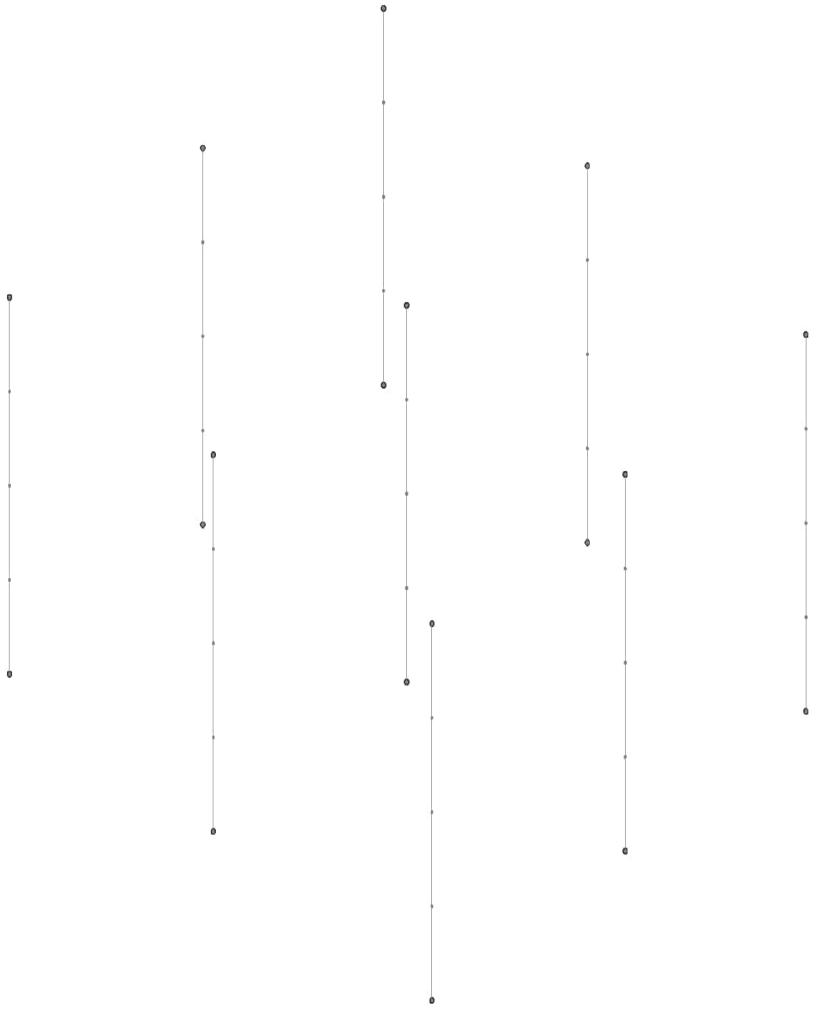
Columns 1 :



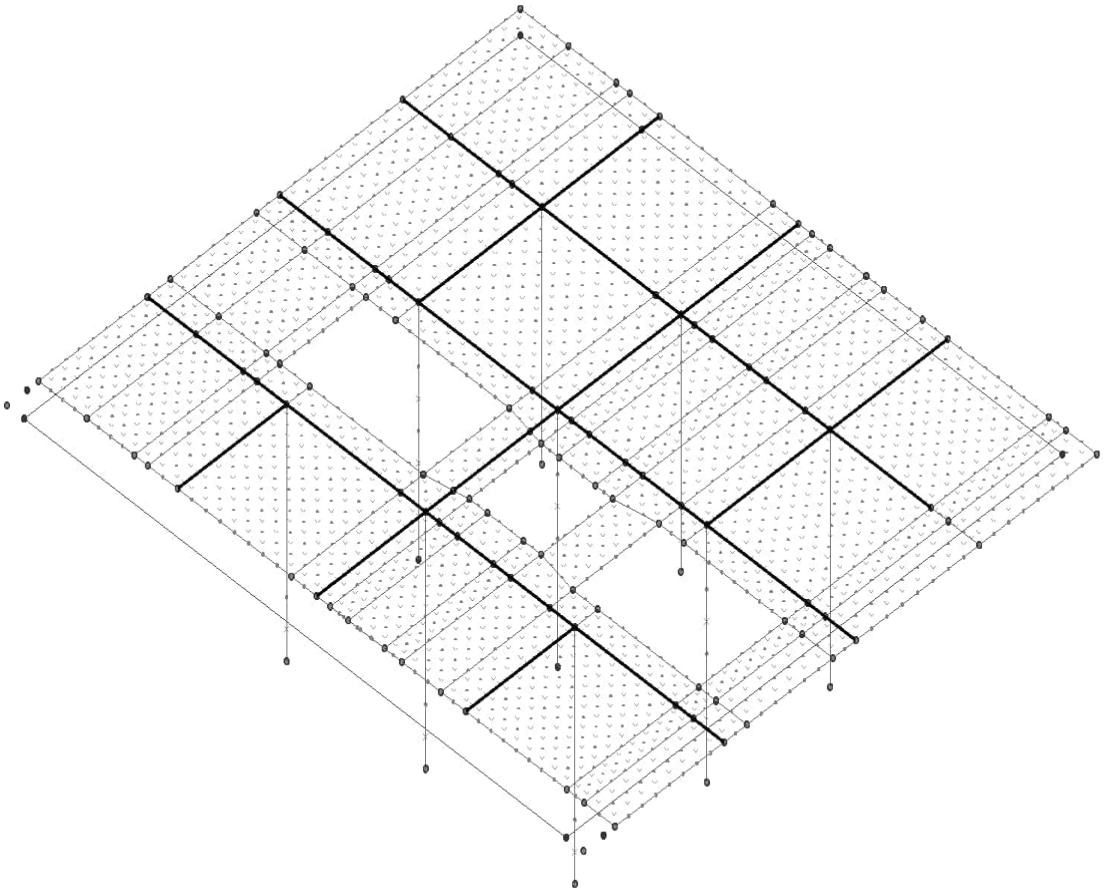
Columns 2 :



Columns 3 :



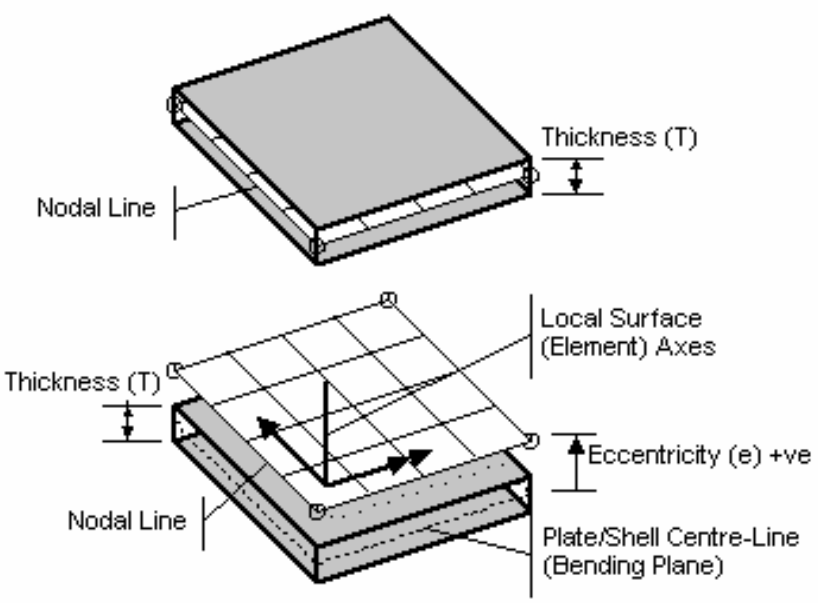
Beams 1X..3X / Beams 1Y..3Y :



2.3 CROSSECTION PROPORTIES

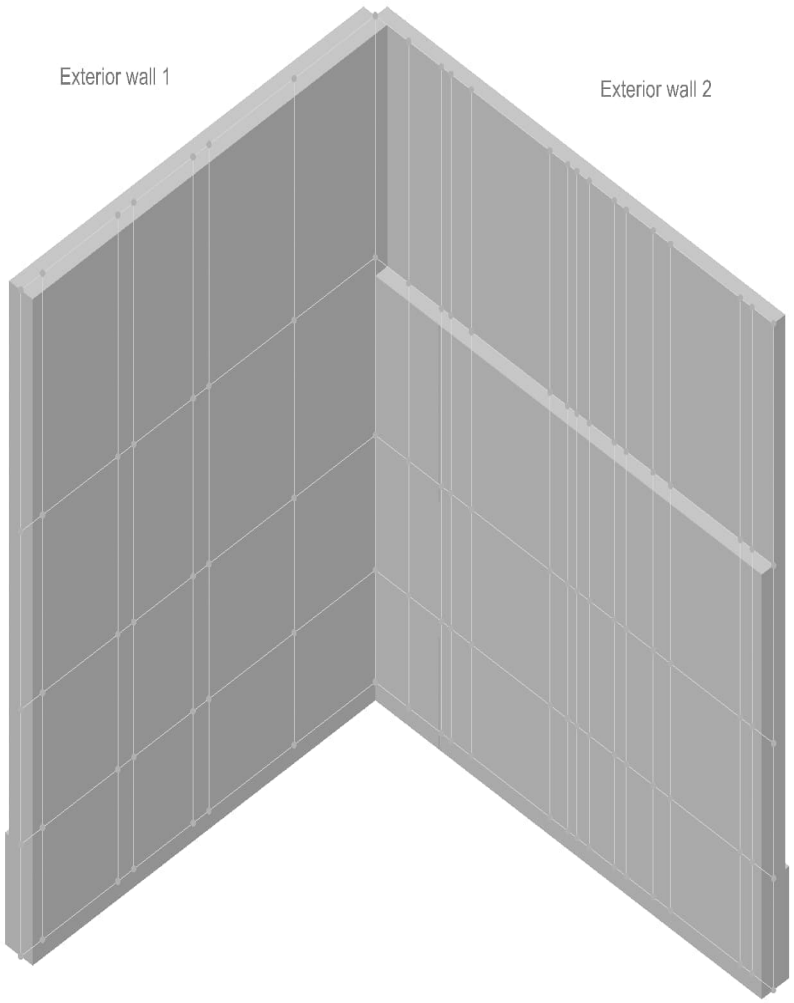
The structure is modelled with Shell elements (”Thick shell” / QTS4) or as 3D thick beam elements (”Thick beam” / BMS3) .

2.3.1 Shell elements (”Thick shell” / QTS4)

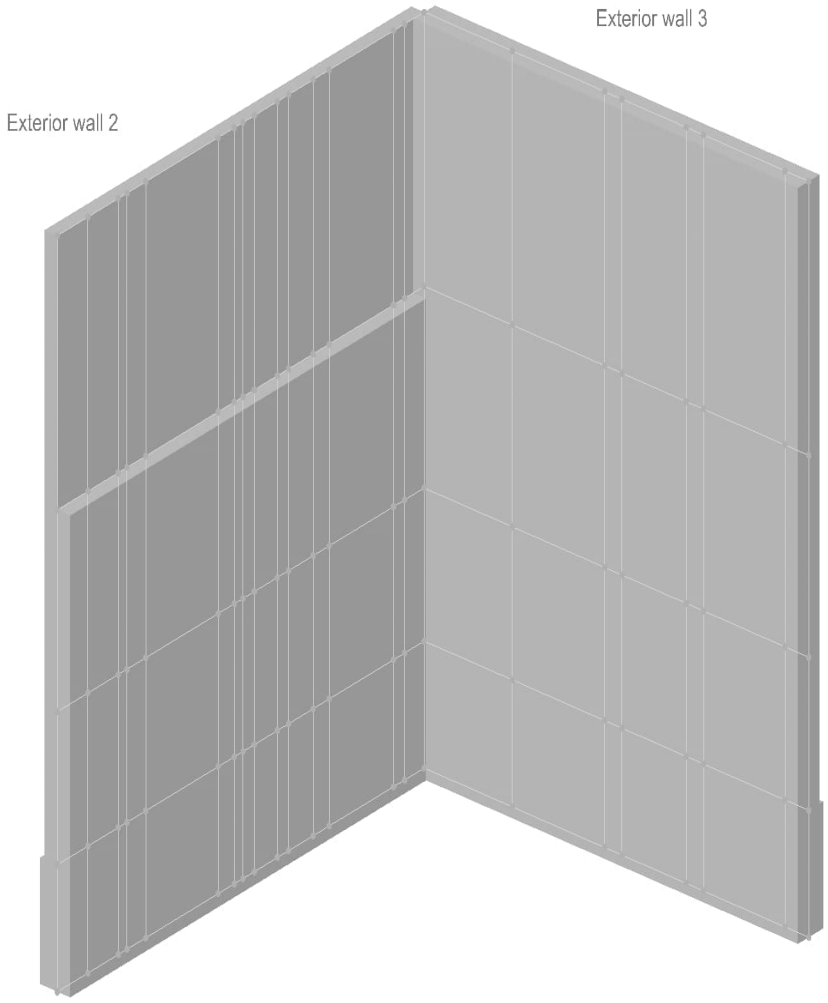


Geometry	t	e_z	Remark
Skiva t=1.4m	1.40	-0.10	Exterior wall 1:1..1:3
Skiva t =0.8 m	0.80	0	Exterior wall 4:3
Skiva t = 0.7 m	0.70	0	Slab 1..3
Skiva t = 1.2 m	1.20	0	Exterior wall 2:1..2:3, 3:1..3:3, 4:2, 4:3
Skiva t = 0.5 m	0.50	0	Interior wall 2..3
Skiva t = 0.6 m	0.60	-0.30	Exterior wall 4:3
-	m	m	-

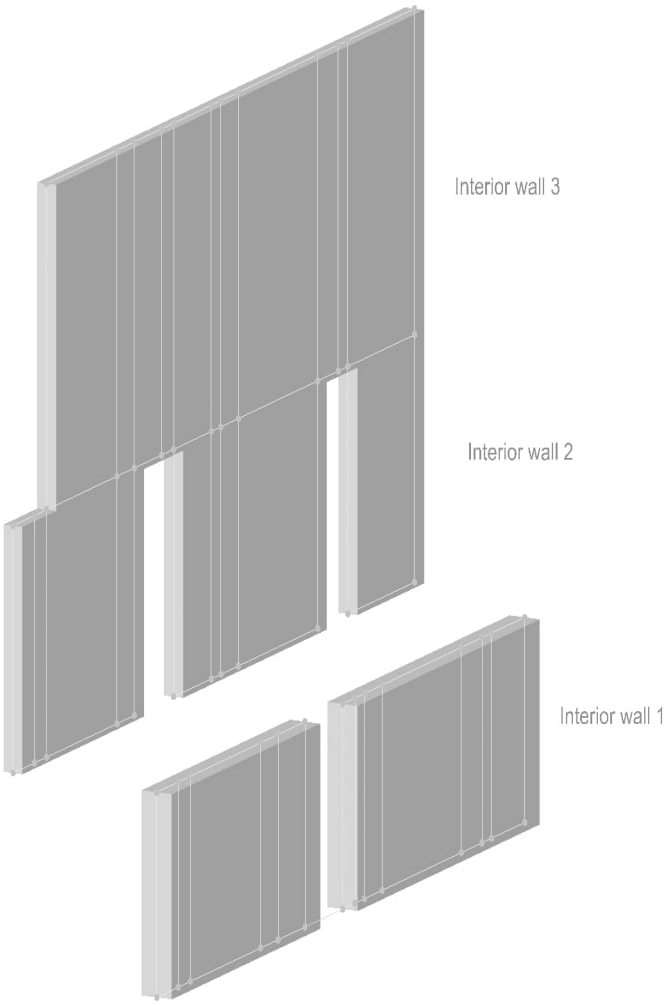
View – Exterior wall 1 / Exterior wall 2 :



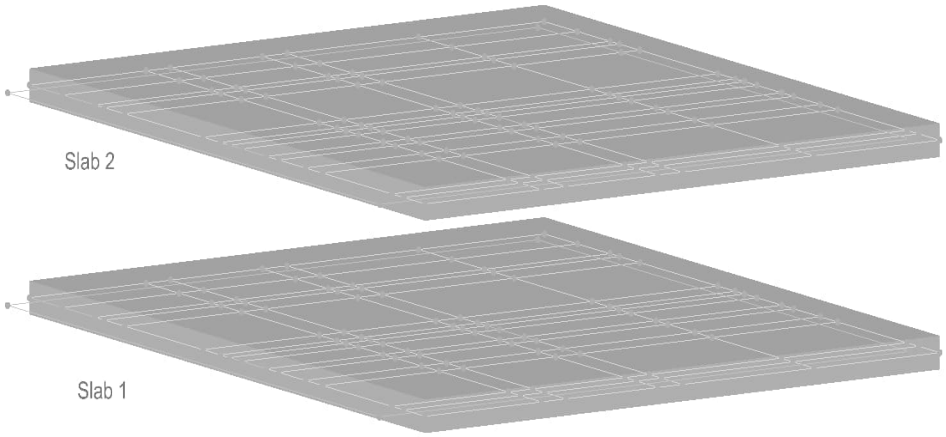
View – Exterior wall 2 / Exterior wall 3 :



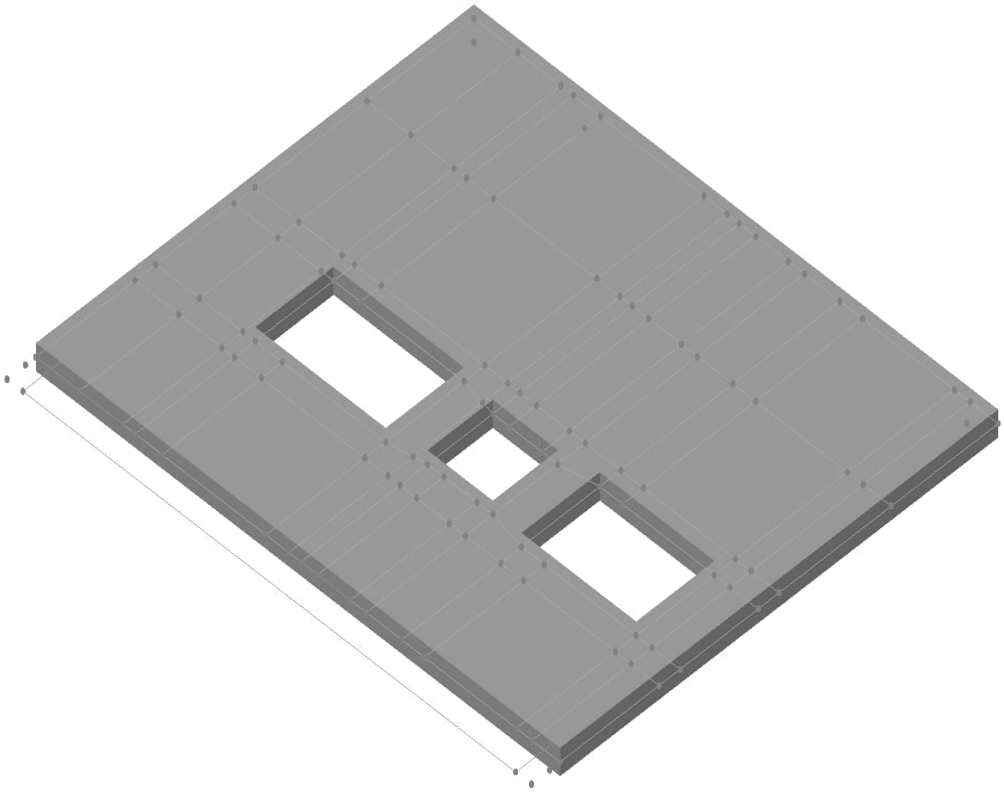
View – Interior wall 1..3 :



View – Slab 1/ Slab 2 :



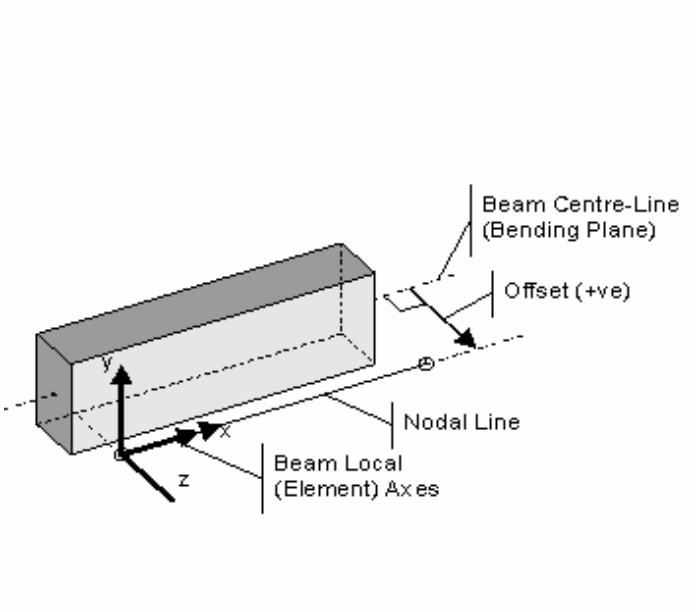
View – Slab 3 :



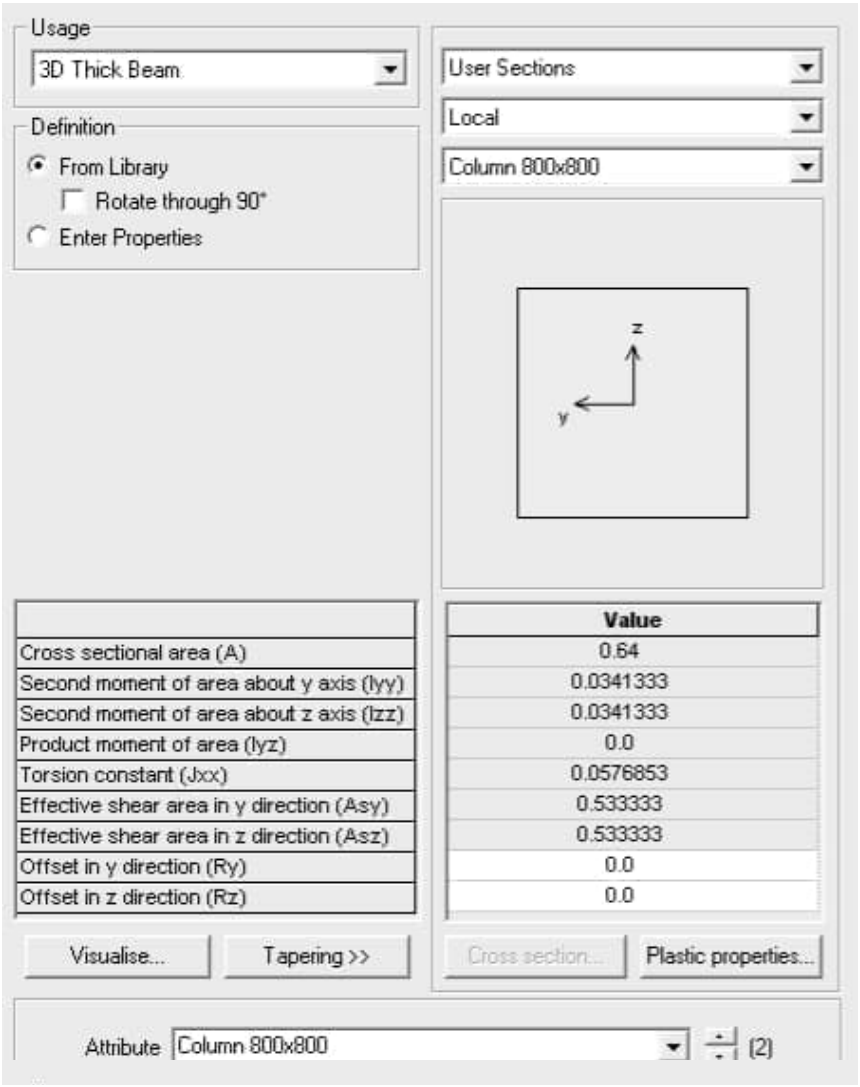
2.3.2 3D- beam element (”Thick beam” / BMS3)

Cross section properties are calculated with *Section Property Calculator*.

When introducing beam elements into structure an Offset as seen below can be used.



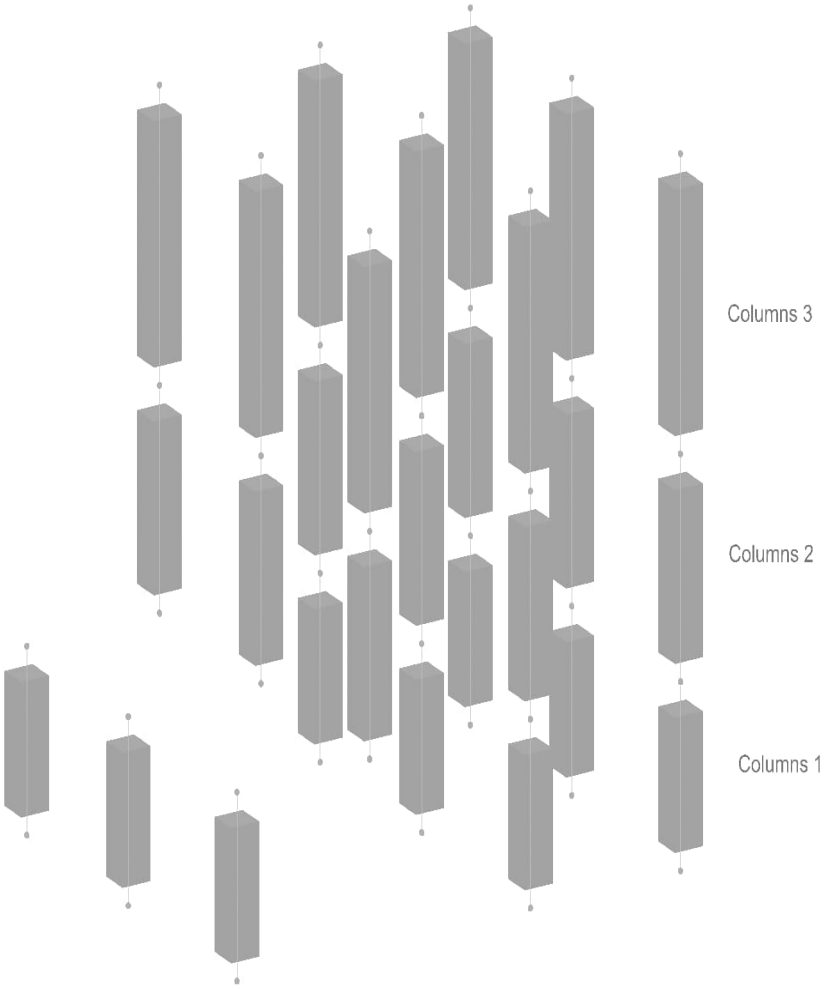
2.3.2.1 Columns



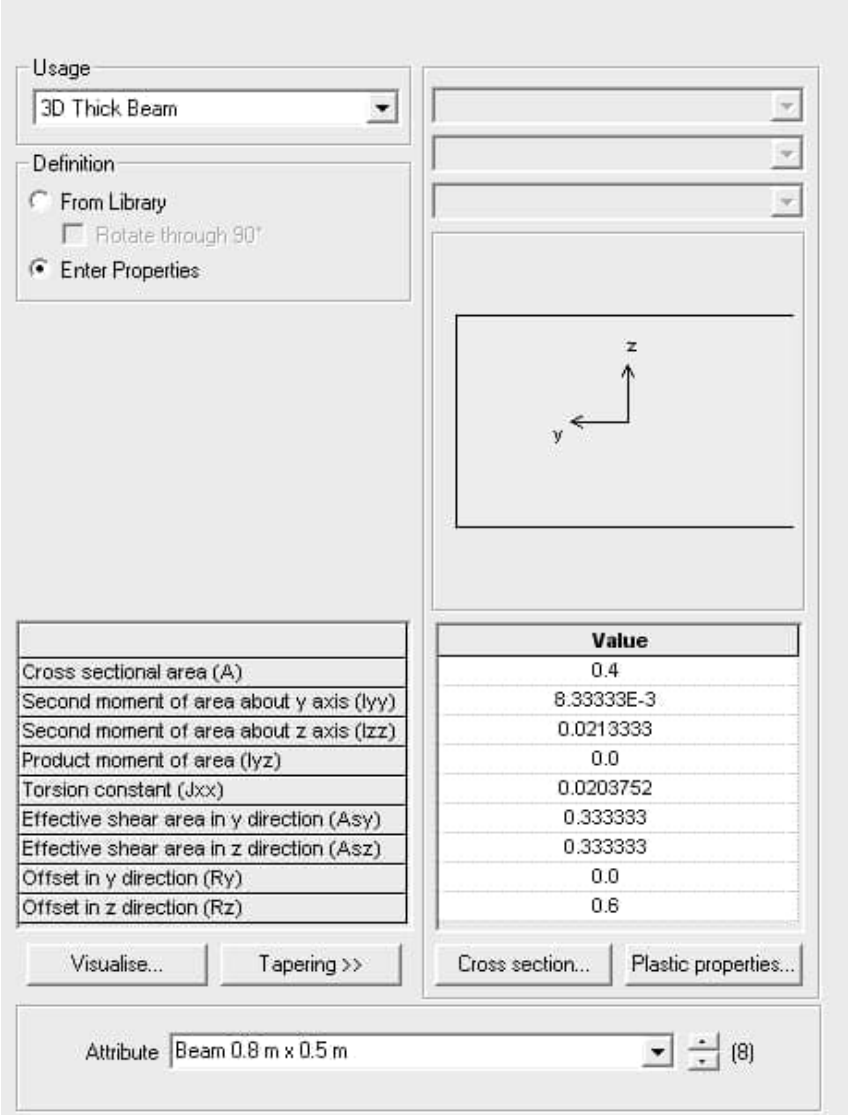
Offset vertical direction : 0

Offset horizontal direction : 0

View – Columns 1..3 :



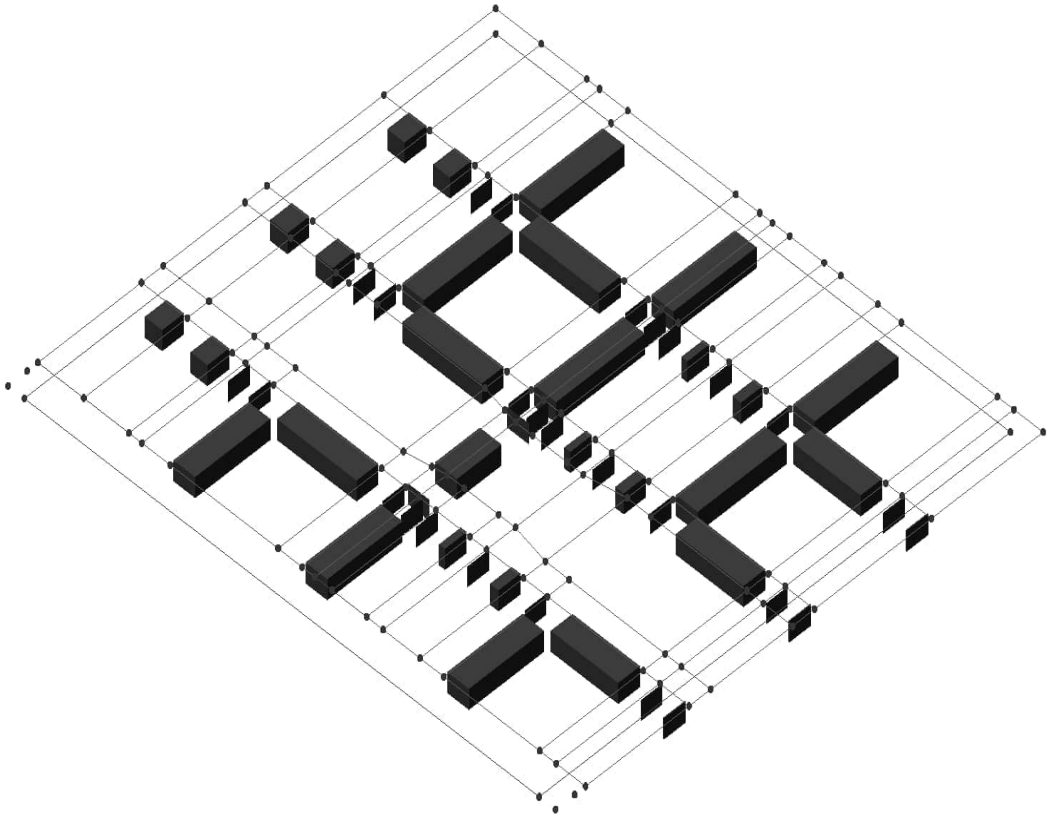
2.3.2.2 Beams 1X..3X / 1Y..3Y (∴ level of slab 3)



Offset vertical direction : 0.6 m

Offset horizontal direction : 0

View – Beams 1X..3X / 1Y..3Y :



2.4 MATERIAL

Concrete : E_{ck} = 30 GPa

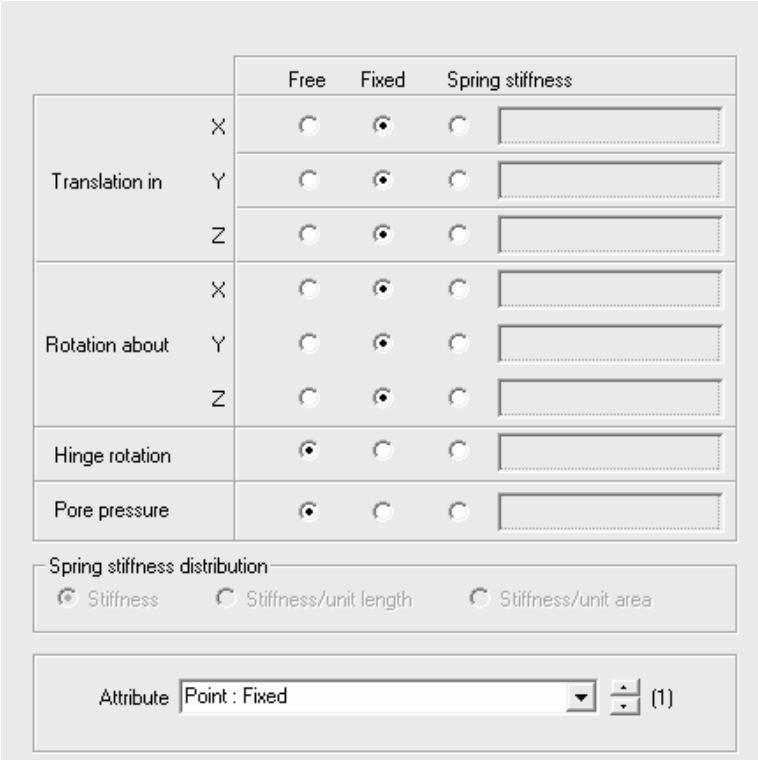
Material	Värde
E	$30 \cdot 10^6$ kPa
ν	0.2 *
ρ	2400 kg/m^3

* = According to general engineering recommendation $\nu = 0$ can be applied. However in the analysis $\nu = 0.002$ is inserted.

2.5 BOUNDARY CONDITIONS

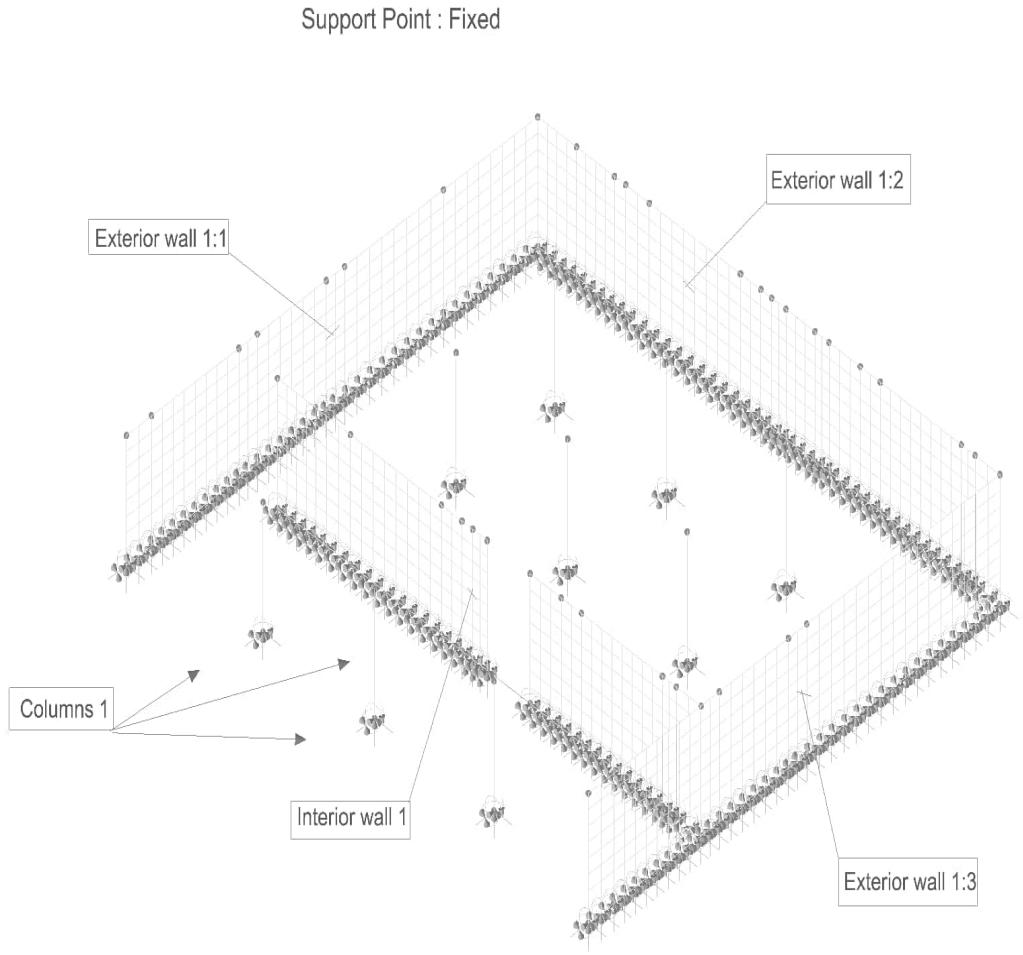
The structure is modeled with two different boundry conditions used to describe either the foundation or the connection to the powerstation at basline 2 .

2.5.1 Boundry at foundation : “Fixed”



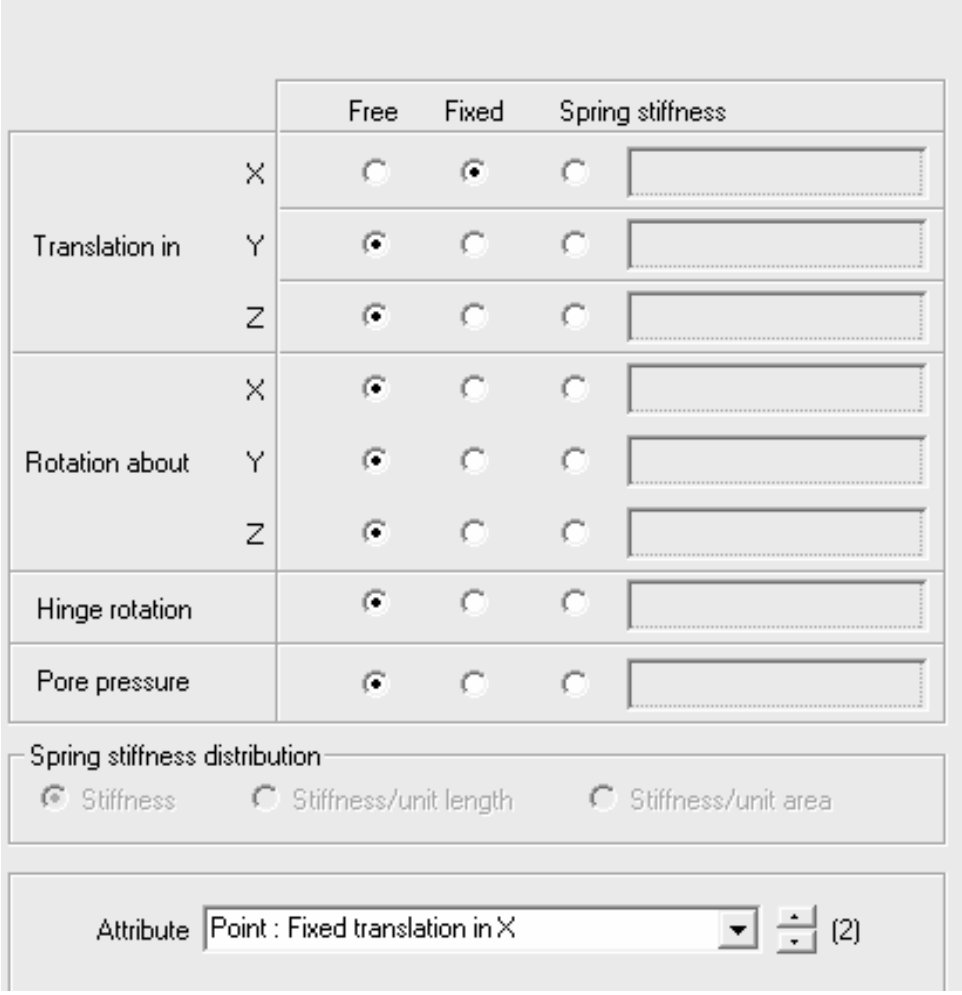
-

View – "Point: fixed"

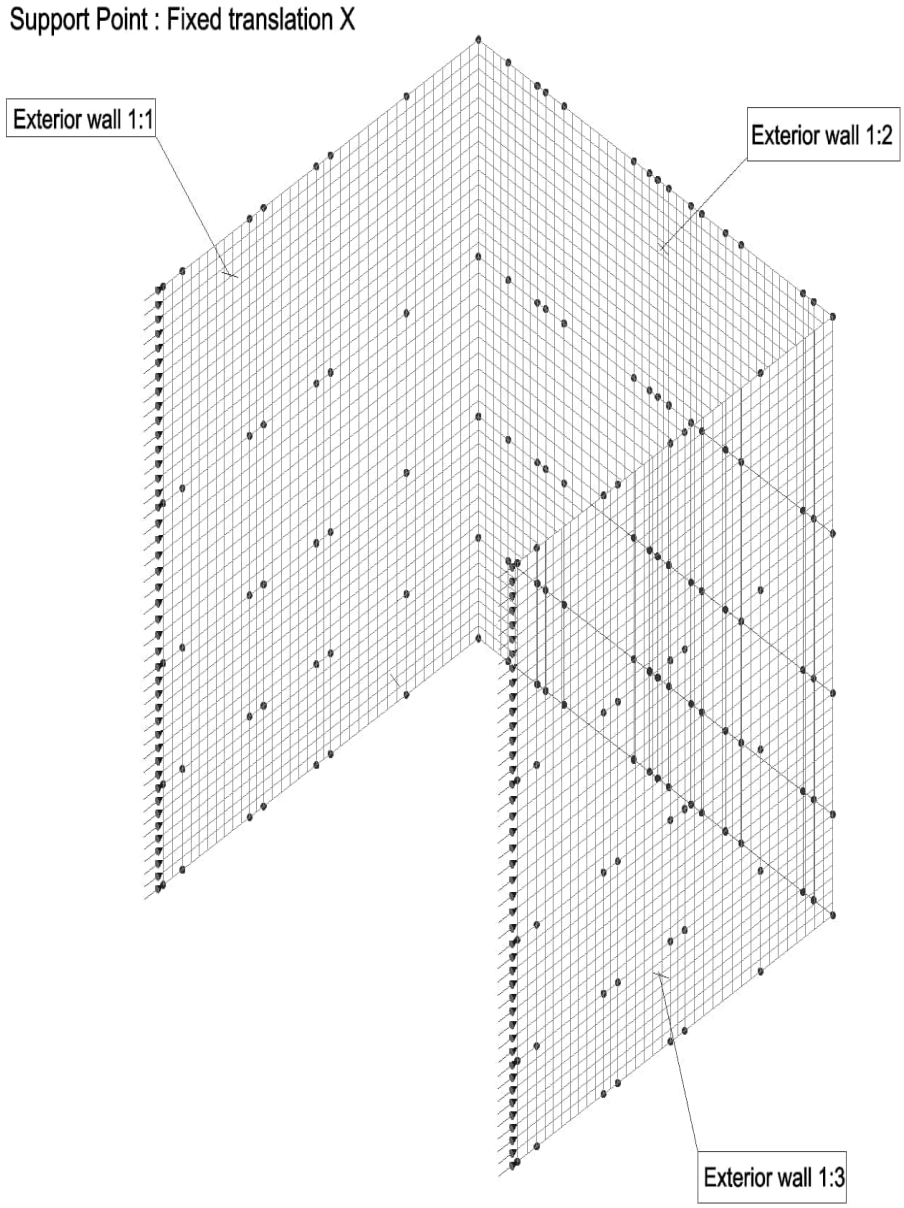


Stiffness	Value
$C_{\Delta, x}$	Fixed
$C_{\Delta, y}$	Fixed
$C_{\Delta, z}$	Fixed
$C_{\varphi,\ x\text{-}x}$	Fixed
$C_{\varphi,\ y\text{-}y}$	Fixed
$C_{\varphi,\ z\text{-}z}$	Fixed

2.5.2 Boundry at basline 2 : “Fixed in translation X”



View – "Point: fixed in translation X"



Stiffness	Value
$C_{\Delta, x}$	Fixed
$C_{\Delta, y}$	Free
$C_{\Delta, z}$	Free
$C_{\varphi, x\text{-}x}$	Free
$C_{\varphi, y\text{-}y}$	Free
$C_{\varphi, z\text{-}z}$	Free

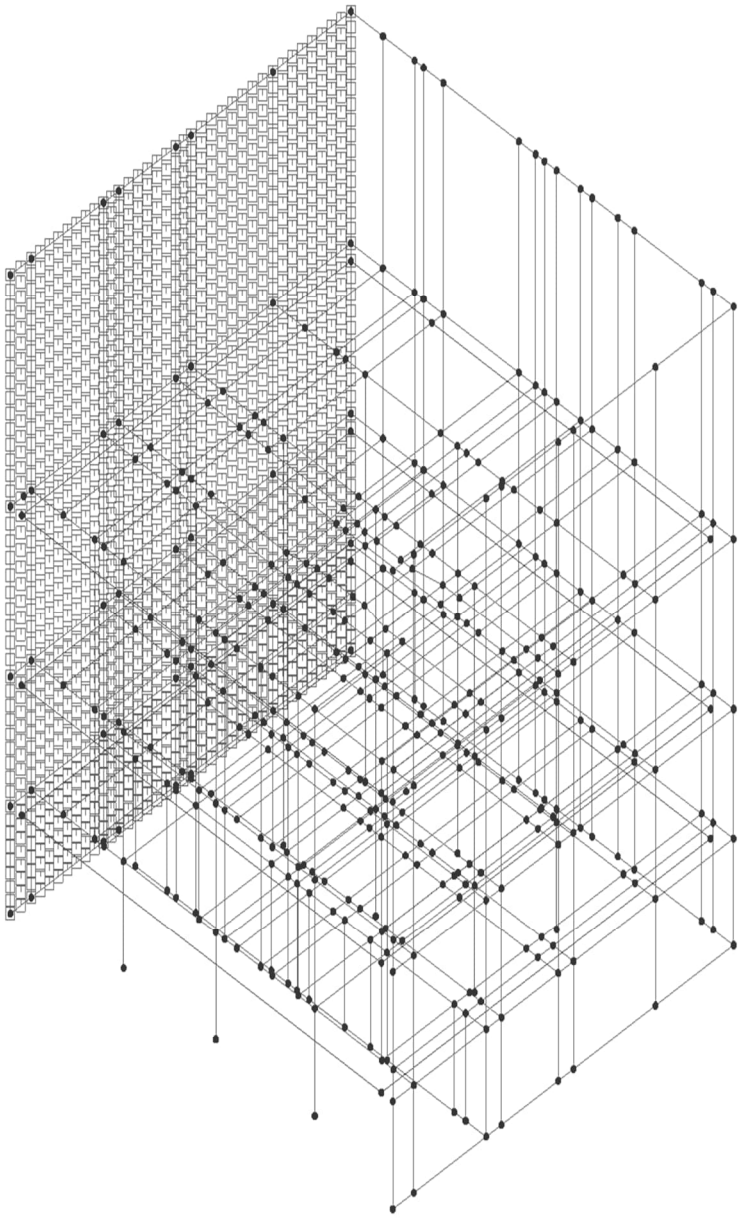
2.6 SEARCH AREA

Discrete loads are applied to various load areas. These are termed *Search Area*.

For the analysis 6 *Search Area´*s are defined consisting om structural elements.

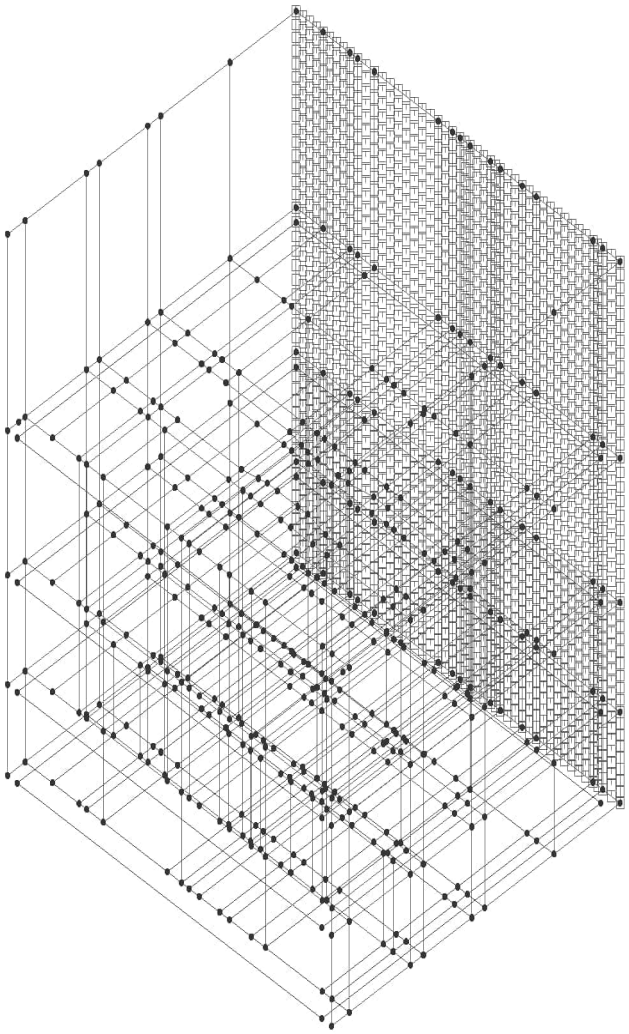
2.6.1 *Search* area : *Exterior wall 1*

Structural elements : Exterior wall 1:1 / Exterior wall 1:2 / Exterior wall 1:3 / Exterior wall 1:4



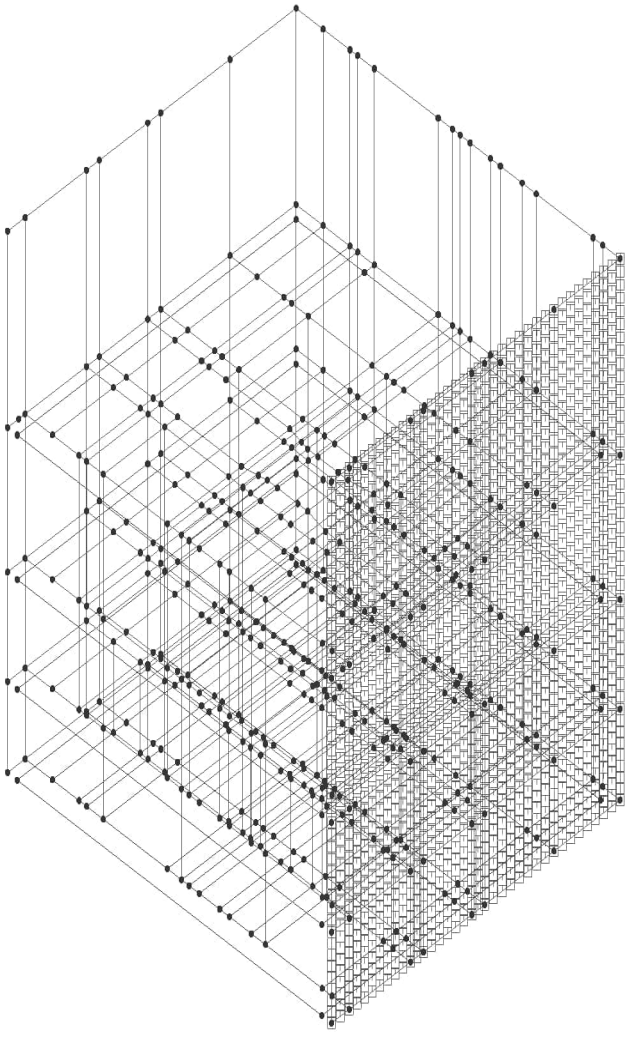
3.7.2 Search area : *Exterior wall 2*

Structural elements : Exterior wall 2:1 / Exterior wall 2:2 / Exterior wall 2:3 / Exterior wall 2:4



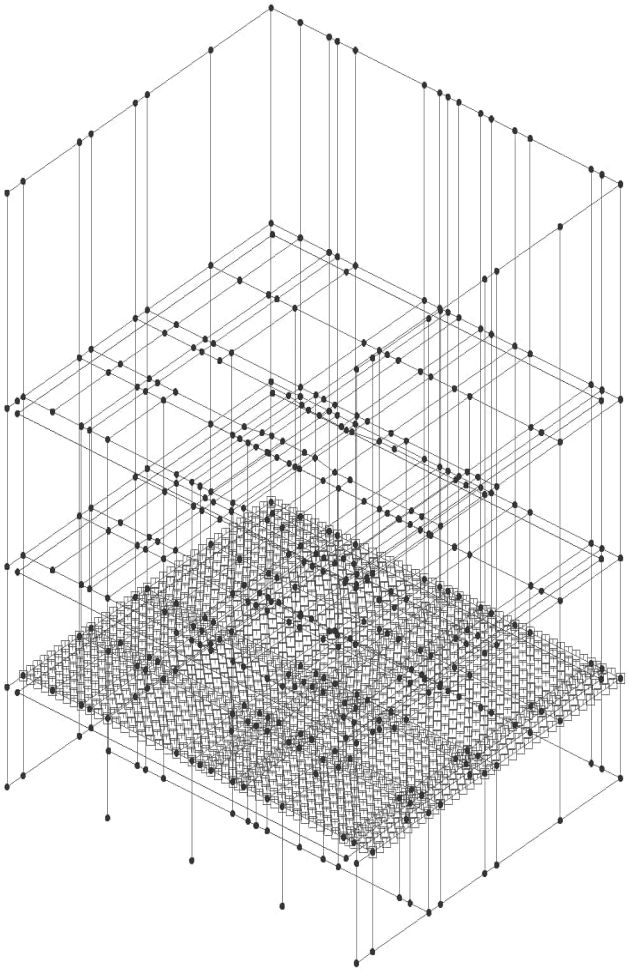
2.6.3 Search area : *Exterior wall 3*

Structural elements : Exterior wall 3:1 / Exterior wall 3:2 / Exterior wall 3:3 / Exterior wall 3:4



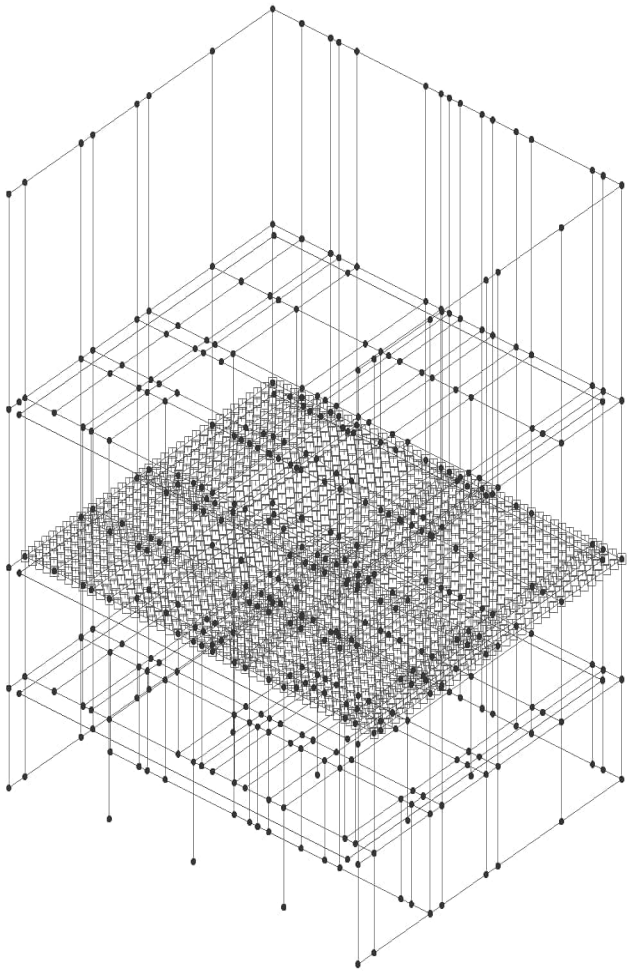
2.6.4 Search ar*ea : Slab level +56.65*

Structural elements : Slab 1



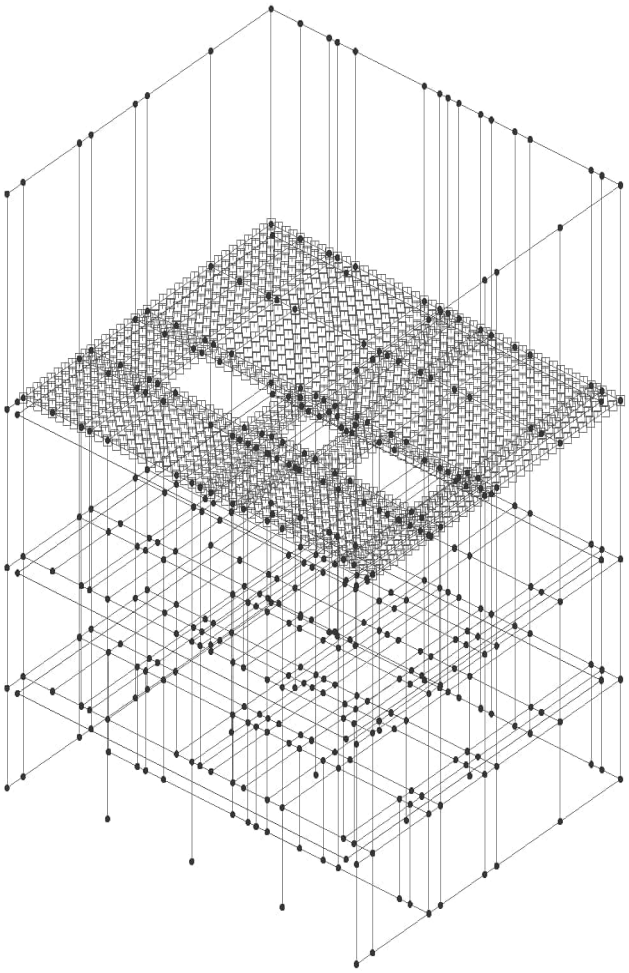
3.7.5 Search area : *Slab level +61.05*

Search area consists of surfaces : Slab 2



2.6.6 Search area : *Slab level +66.85*

Search area consists of surfaces : Slab 3



3. LOADS

3.1 DEAD WEIGHT

3.1.1 Reinforced concrete

$\gamma_{btg} = 24 \ \frac{kN}{m^3}$

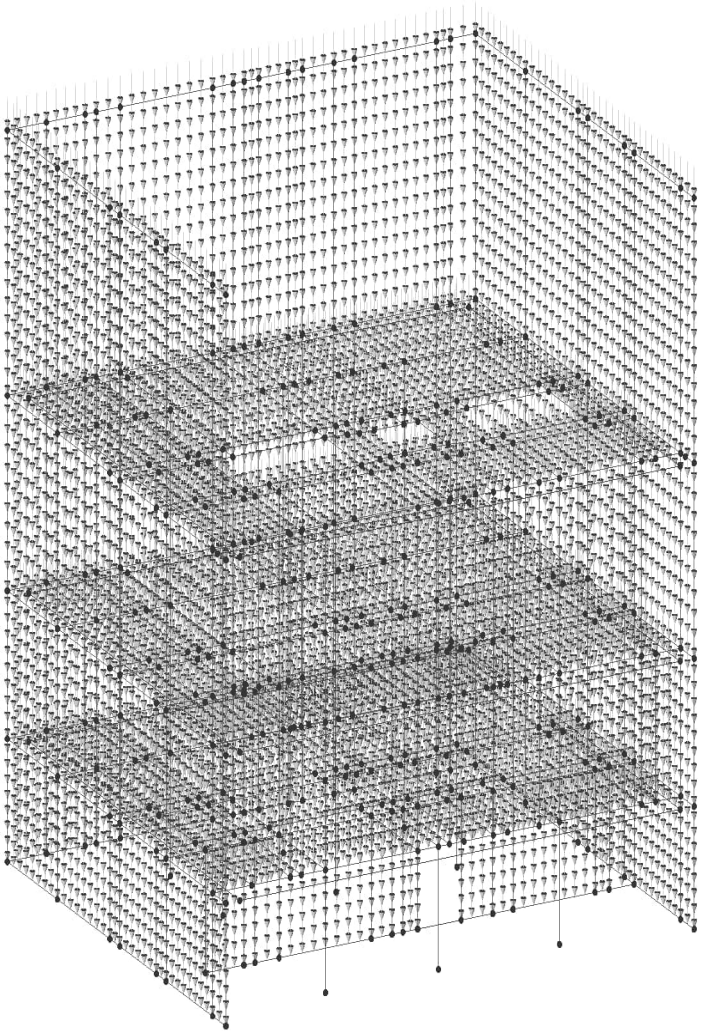
Loadcase : Dead weight 1

Structural loading : Body force

Acceleration in z direction (a_z) : -10 $\frac{m}{s^2}$

Component	Value
Linear acceleration in X	0.0
Linear acceleration in Y	0.0
Linear acceleration in Z	-10.0
Angular velocity about X axis	0.0
Angular velocity about Y axis	0.0
Angular velocity about Z axis	0.0
Angular acceleration about X axis	0.0
Angular acceleration about Y axis	0.0
Angular acceleration about Z axis	0.0

Attribute Dead weight 1 (1)



Shell elements : $q = a_z \cdot t \cdot \rho_{btg}$

Beam elements : $p = a_z \cdot A \cdot \rho_{btg}$

Remark Load intensity is found by applying density and geometric properties to all LINES/SURFACES.

3.1.2 Steel structure

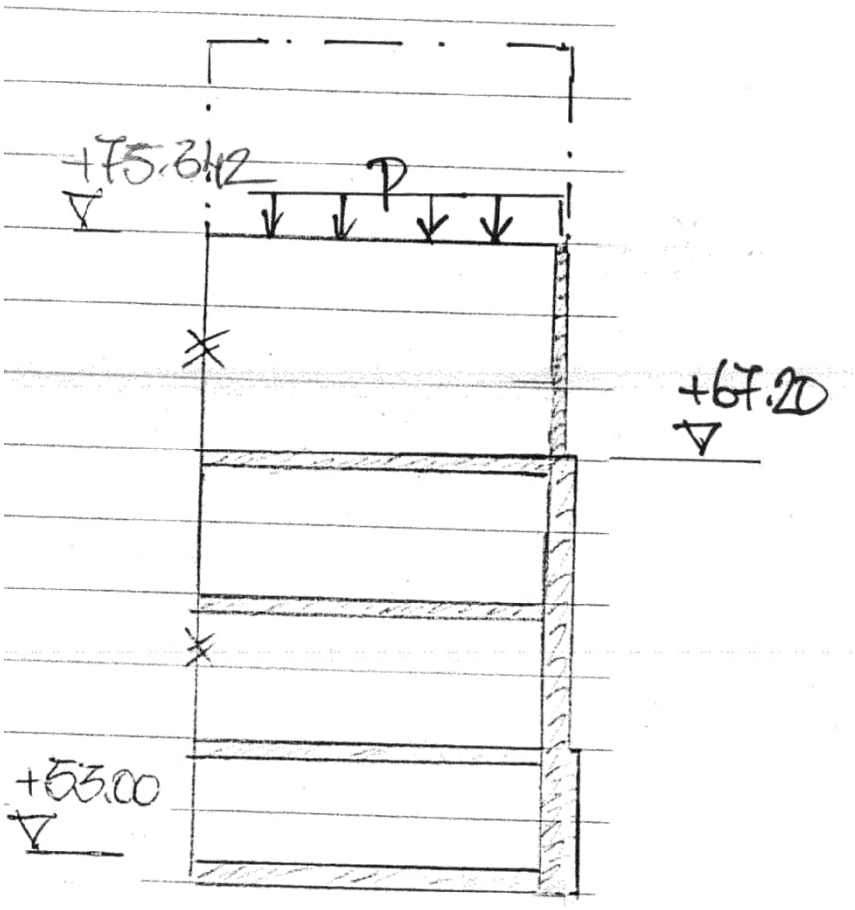
The load is an approximation of the steelstructure above level +75.342.

The load intensity is set to 1 kPa and distributed along concrete walls I X-direction.

$$A = b \cdot l = 18.7m \cdot 21.7m = 406m^2$$

$$P_{tot} = A \cdot 1kPa = 406kN$$

$$p = \frac{P_{tot}}{2l'} = \frac{406kN}{2 \cdot 17.9m} = 11.3\frac{kN}{m}$$

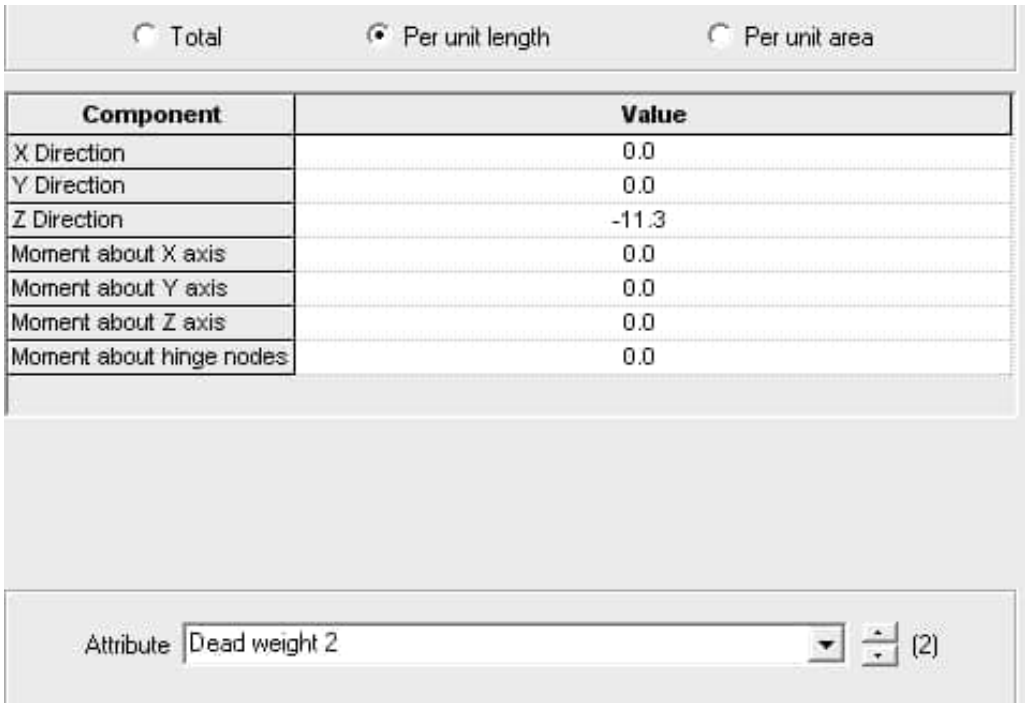


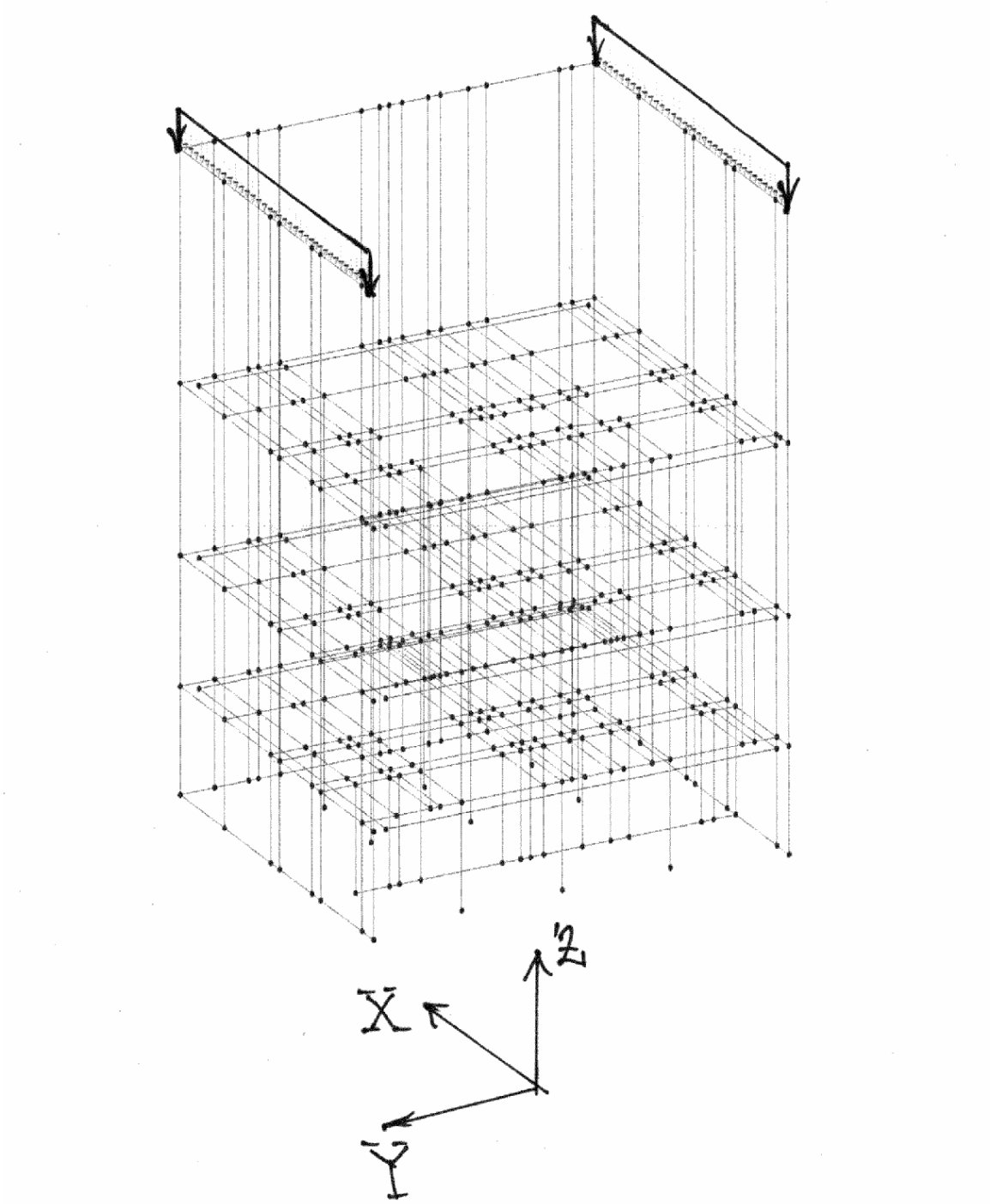
Loadcase : Dead weight 2

Structural loading : Global distributed

Force type : Per unit length

Component z direction : -11.3 $\frac{kN}{m}$




Z
X
Y

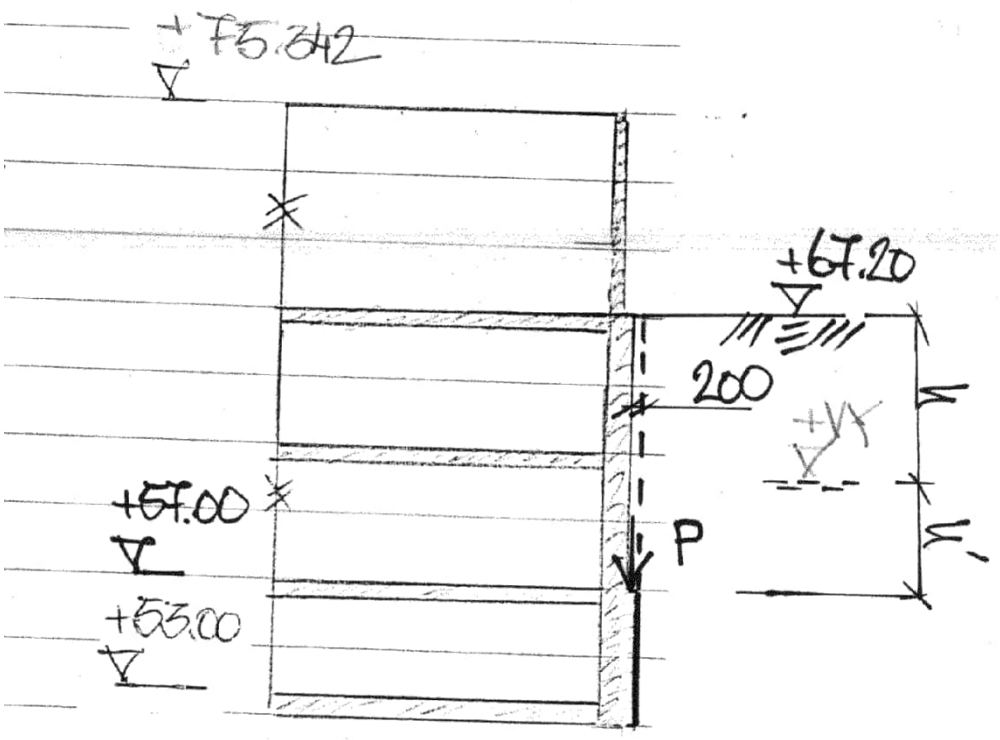
3.1.3 Earth filling

Load is introduced at level +57.00 due to an increase of wall thickness by 200 mm.

The load is comparetively low. For this reason the load is modelled with intensity of water level LLW. The effect of water level HHW is concidered using a reduced load ceofficient.

LLW = + 53.53 $\Rightarrow$ h = (67.20-57.00) = 10.20 m ; h´= 0 m

HHW = +62.94 $\Rightarrow$ h = (67.20-62.94) = 4.26 m ; h´= 10.20 – 4.26 = 5.94 m



$$p_{LLW} = 0.2m \cdot (\gamma \cdot h + \gamma' \cdot h') = 0.2m \cdot (18\frac{kN}{m^3} \cdot 10.20m + 11\frac{kN}{m^3} \cdot 0m) = 37\frac{kN}{m}$$

$$p_{HHW} = 0.2m \cdot (\gamma \cdot h + \gamma' \cdot h') = 0.2m \cdot (18\frac{kN}{m^3} \cdot 4.26m + 11\frac{kN}{m^3} \cdot 5.94m) = 28\frac{kN}{m}$$

$$\Rightarrow \quad \frac{q_{HHE}}{q_{LLW}} = 0.76$$

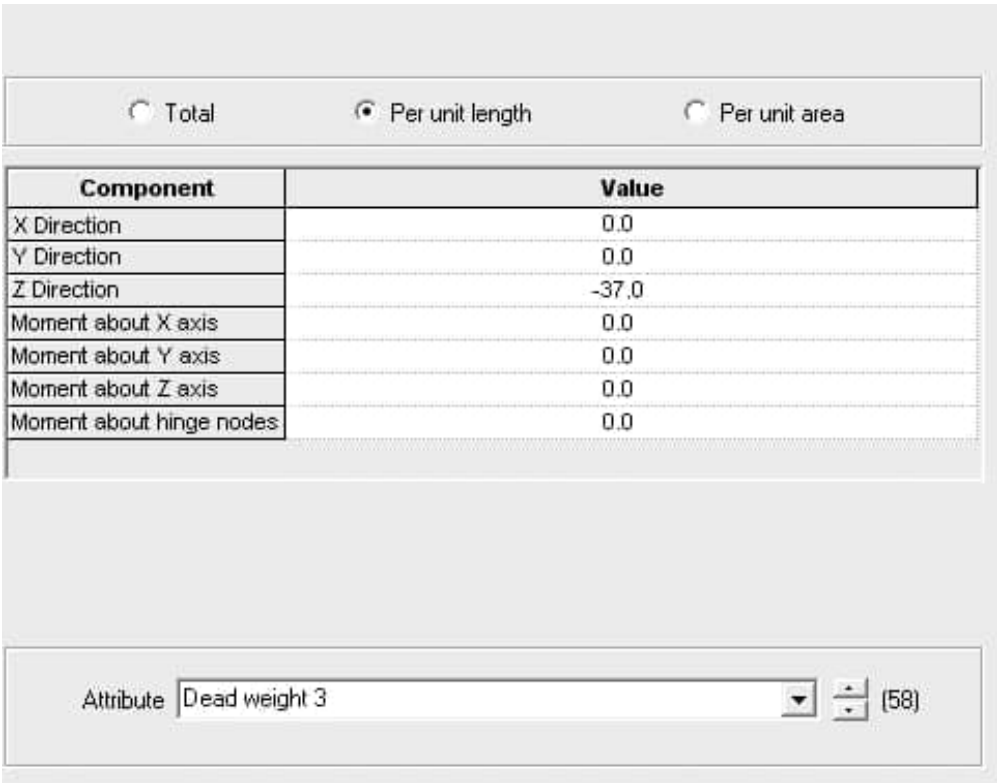
Remark The effect of water at top is neglected since is balanced with same force at bottom of slab +53.00 when designing the studied structure.

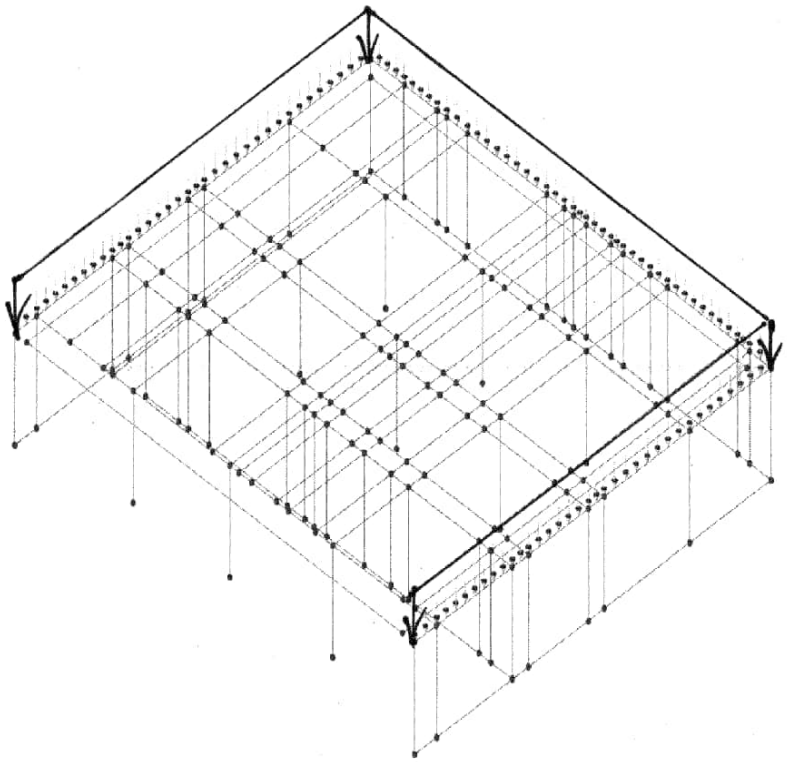
Loadcase : Dead weight 3

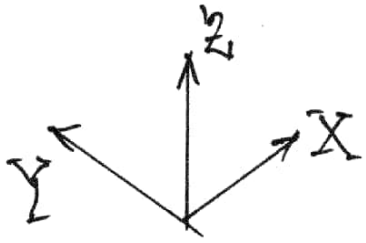
Structural loading : Global distributed

Force type : Per unit length

Component z direction : -37 $\frac{kN}{m}$






Z
X
Y

3.1.4 Load combinations

Load combination smart : *Dead weight*

Loadcase	Permanent factor	Variable factor
Dead weight 1	1.00	0
Dead weight 2	1.00	0
Dead weight 3	0.76	0.24

3.2 WATER LOAD

Waterflow varies between +53.63 to +62.94(+64.50) as seen in table listed bellow.

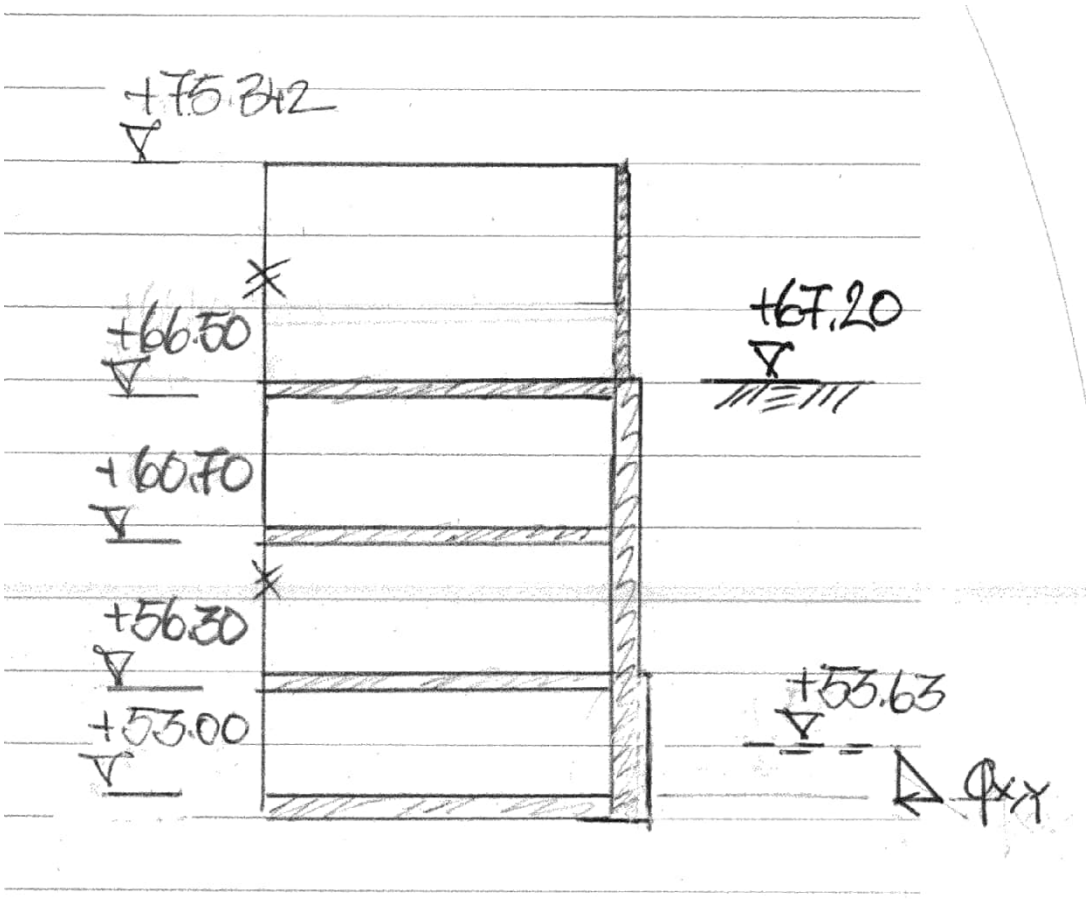
Level	Flow	Remark
+62.94	8110	10000 year
+61.62	5859	1000 year
+55.10	240	Design flow*
+53.63	13.4	Ecological flow
m	m^3/s	-

* = Corresponds to 100 year flow

3.2.1 "Low" water level

Level +53.63 corresponding to ecological flow is used.

$$q_{x,y} = (53.63m - 53.00m) \cdot 1.0 \cdot 10 \frac{kN}{m^3} = 6.3kPa$$



Loadcase : Water LLW qx1

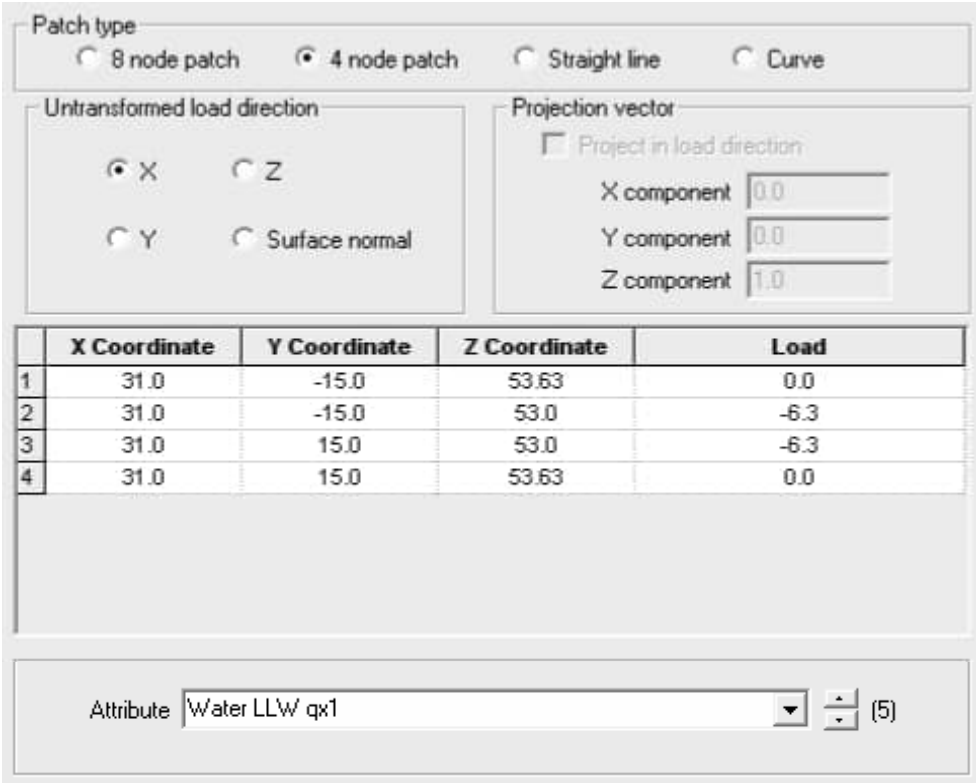
Structural loading : Discrete patch load

Search area : Exterior wall 2

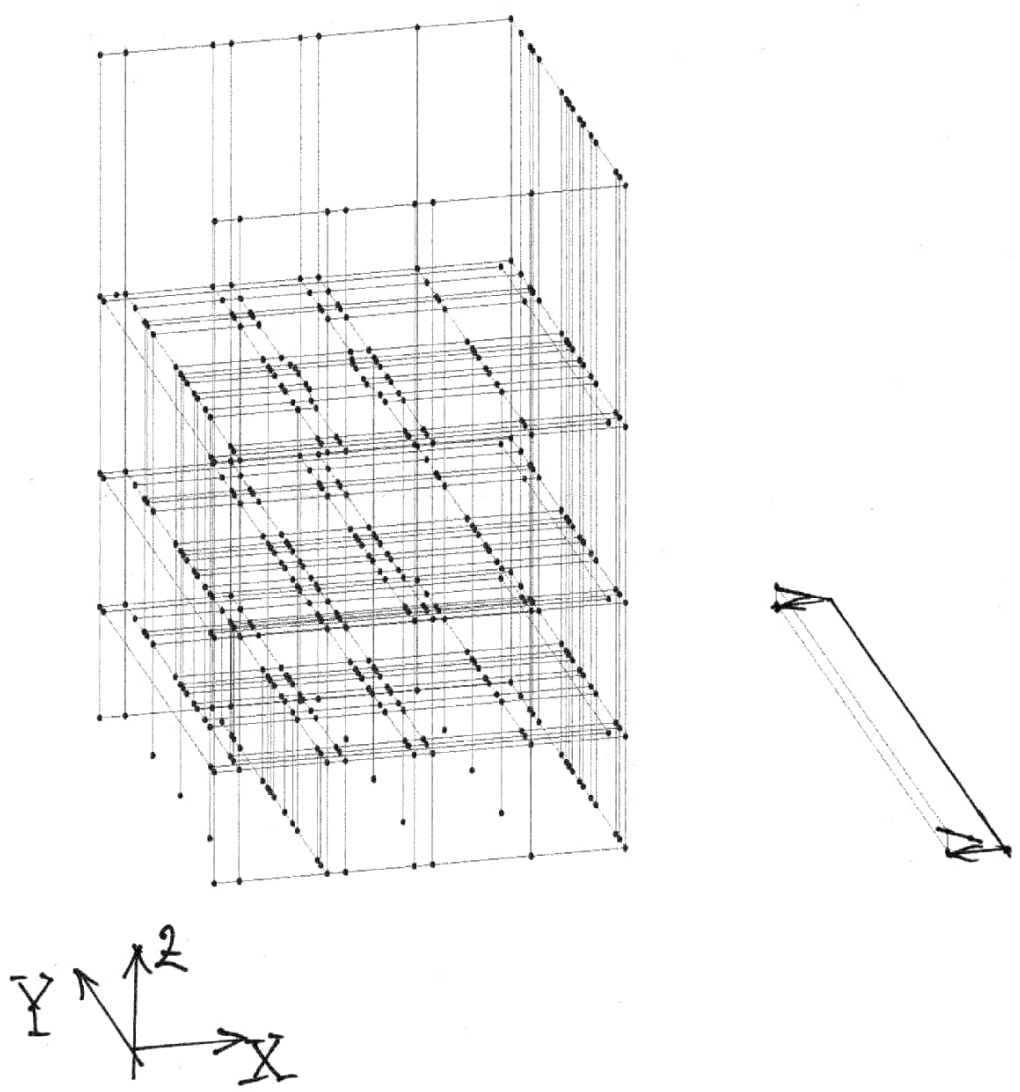
Force type : Per unit area

Component x direction : -6.3 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	31.0	-15.0	53.63	0.0
2	31.0	-15.0	53.0	-6.3
3	31.0	15.0	53.0	-6.3
4	31.0	15.0	53.63	0.0


Y
Z
X

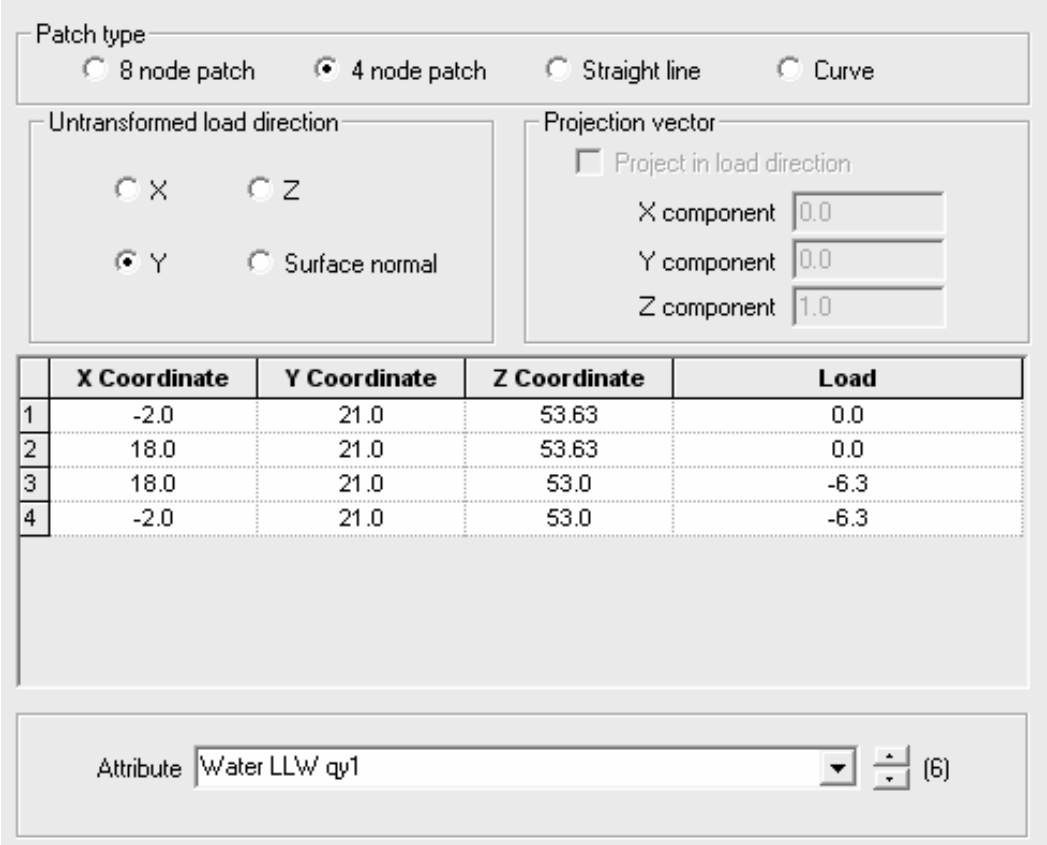
Loadcase : Water LLW qy1

Structural loading : Discrete patch load

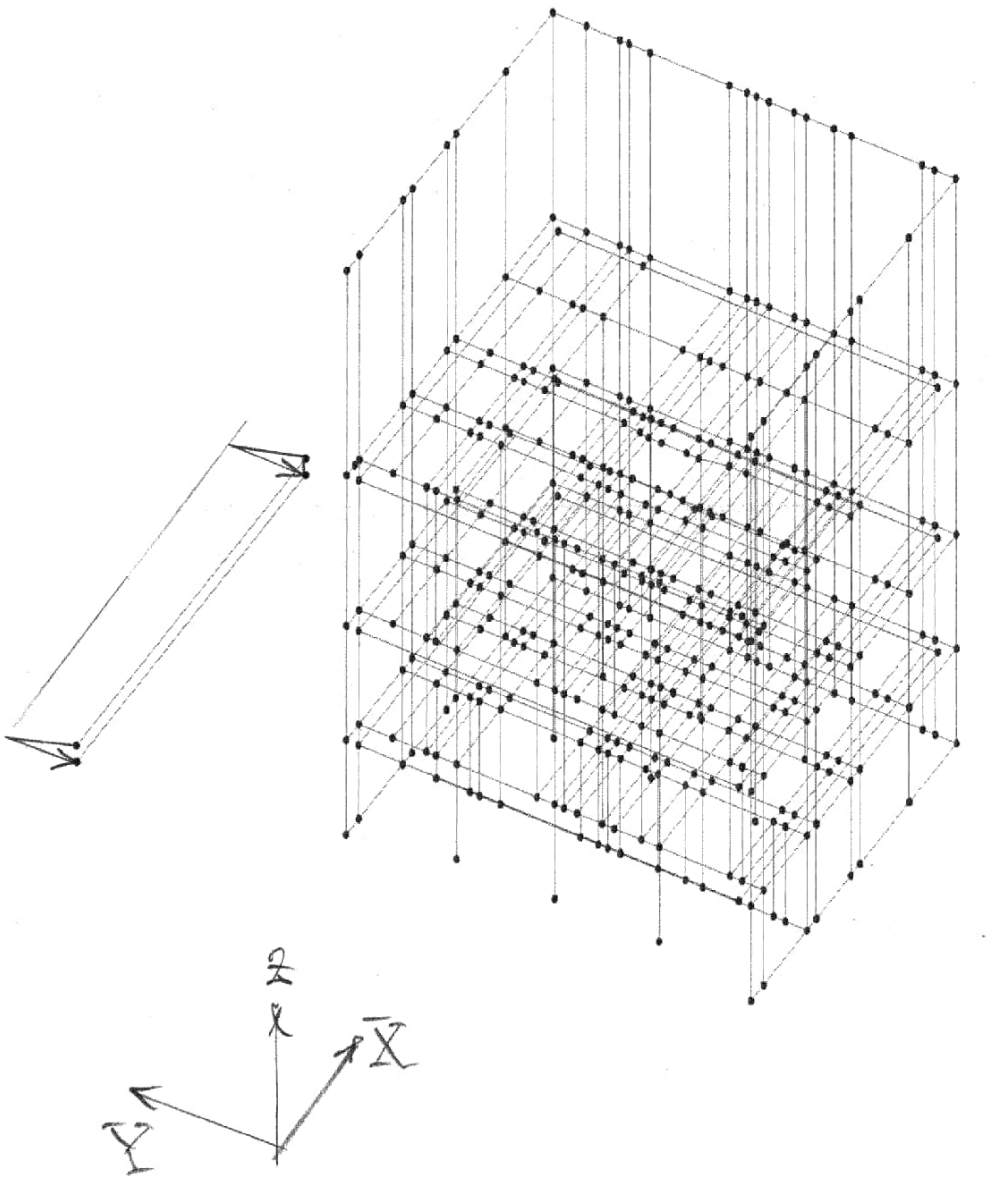
Search area : Exterior wall 1

Force type : Per unit area

Component y direction : -6.3 kPa



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	-2.0	21.0	53.63	0.0
2	18.0	21.0	53.63	0.0
3	18.0	21.0	53.0	-6.3
4	-2.0	21.0	53.0	-6.3


Z
X
Y

Loadcase : Water LLW qy2

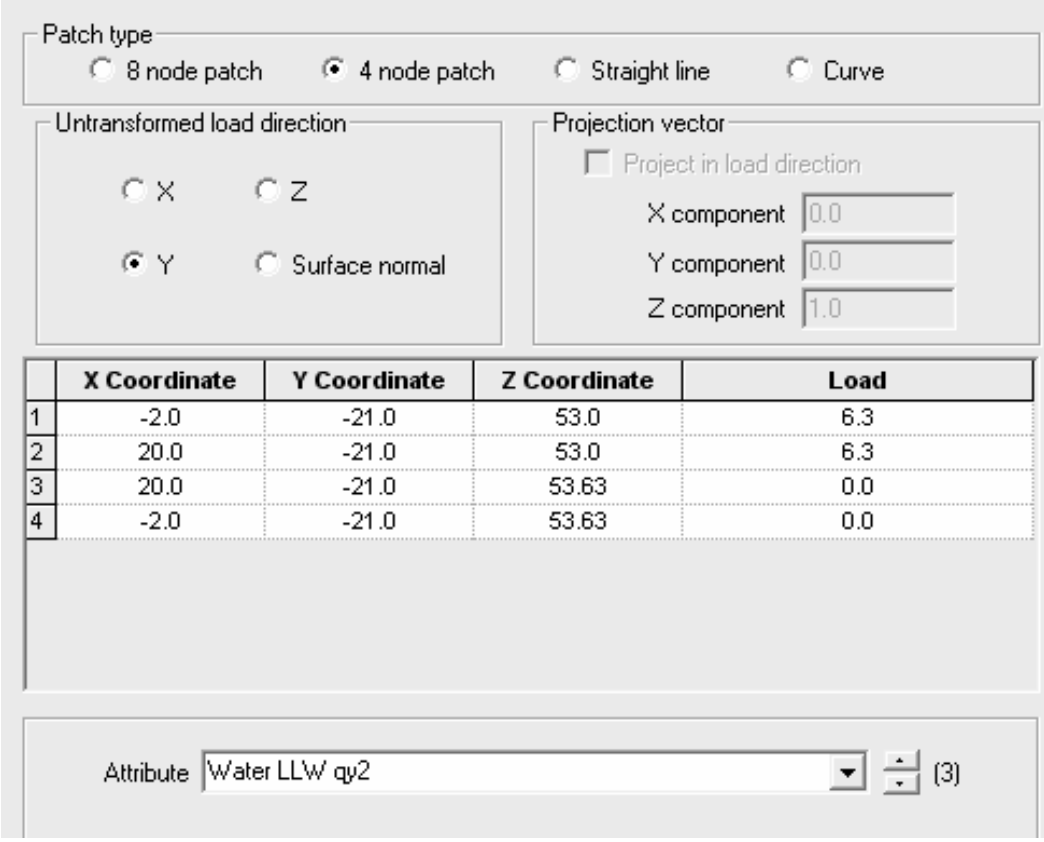
Structural loading : Discrete patch load

Search area : Exterior wall 3

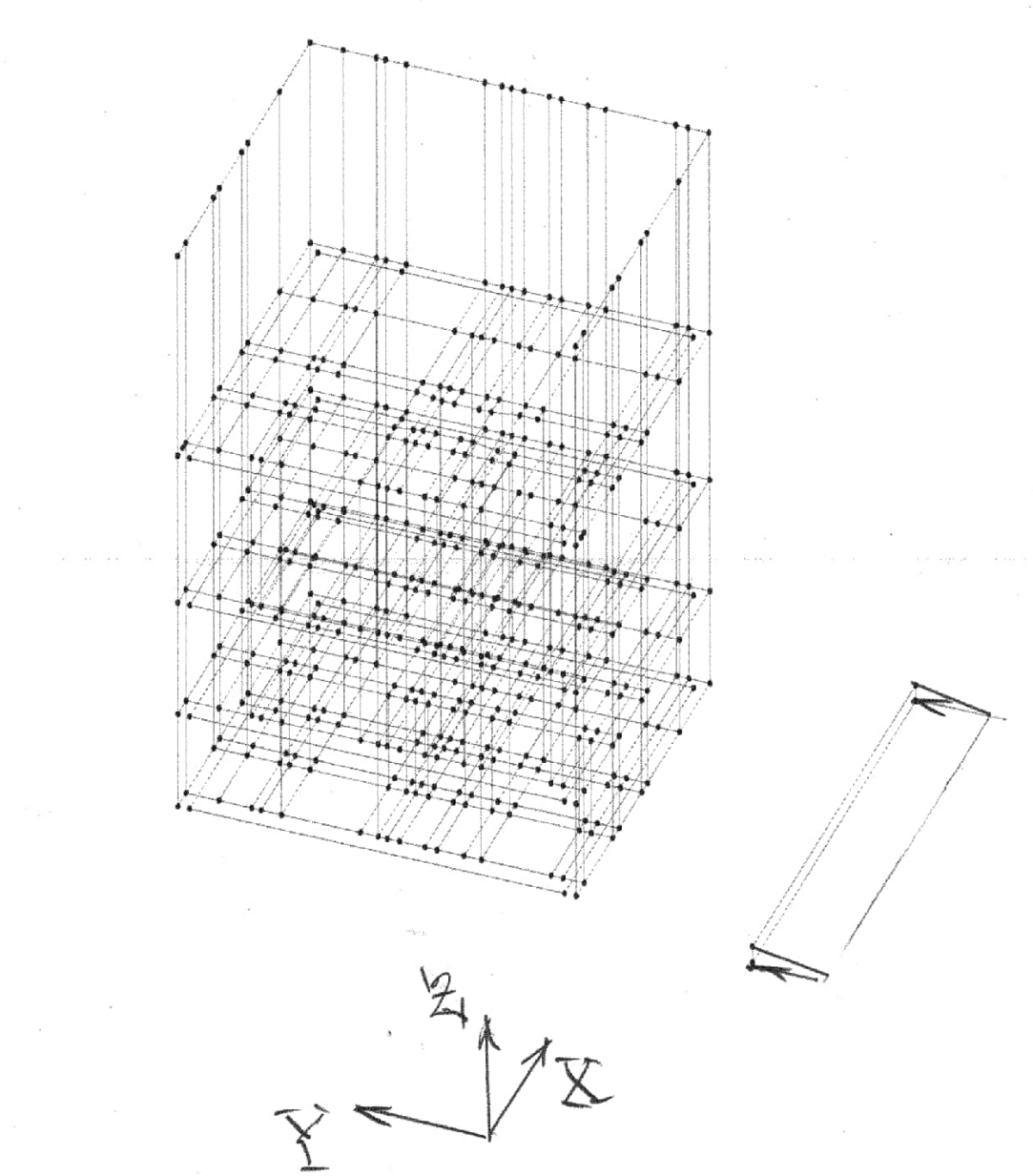
Force type : Per unit area

Component y direction : +6.3 kPa

Options for load outside search area : Exclude All Load



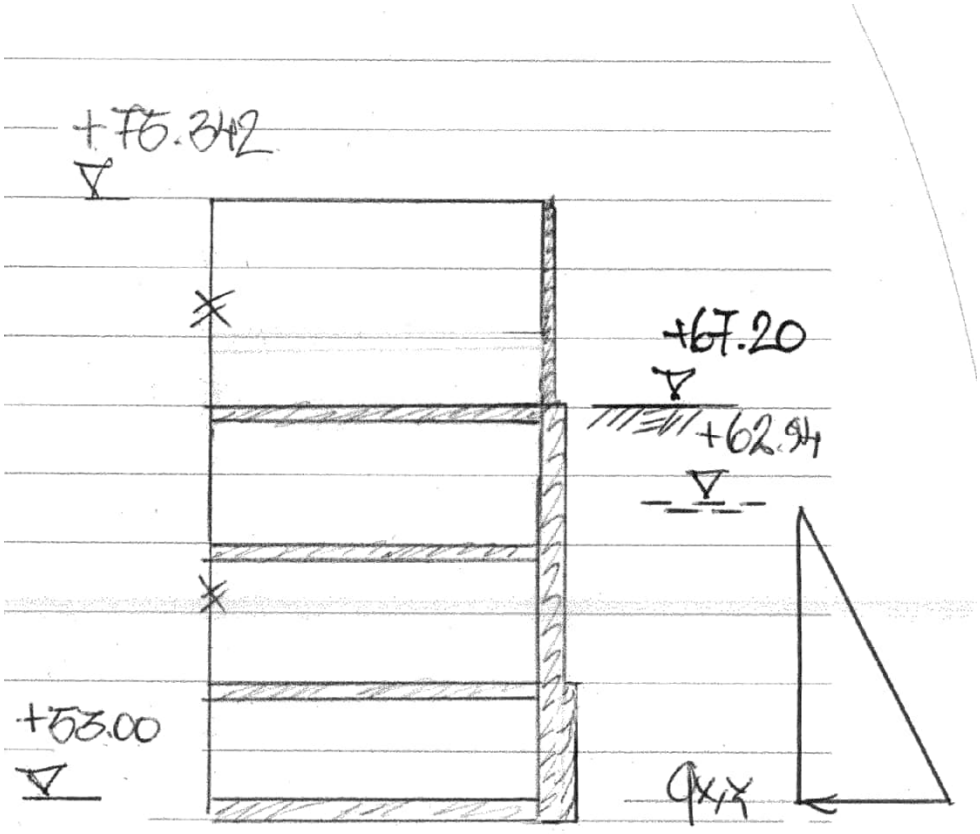
	X Coordinate	Y Coordinate	Z Coordinate	Load
1	-2.0	-21.0	53.0	6.3
2	20.0	-21.0	53.0	6.3
3	20.0	-21.0	53.63	0.0
4	-2.0	-21.0	53.63	0.0


Z
X
Y

3.2.2 “High” water level

Level +62.94 corresponding to 10000 year flow is used.

$$q_{x,y} = (62.94m - 53.00m) \cdot 1.0 \cdot 10 \frac{kN}{m^3} = 99.4kPa$$



Loadcase : Water HHW qx1

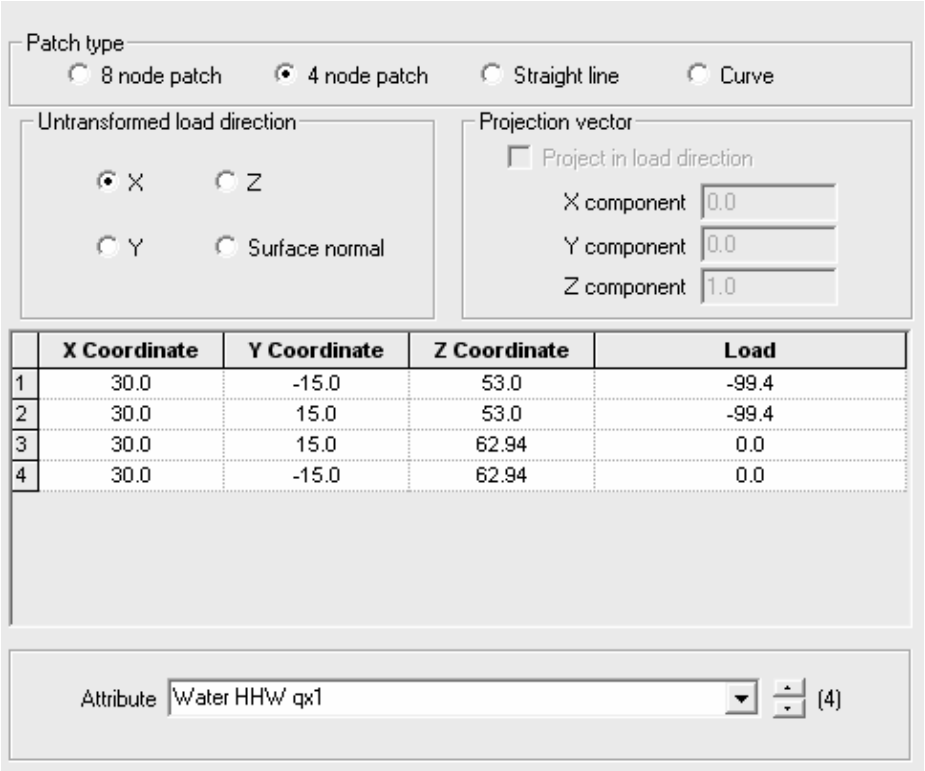
Structural loading : Discrete patch load

Search area : Exterior wall 2

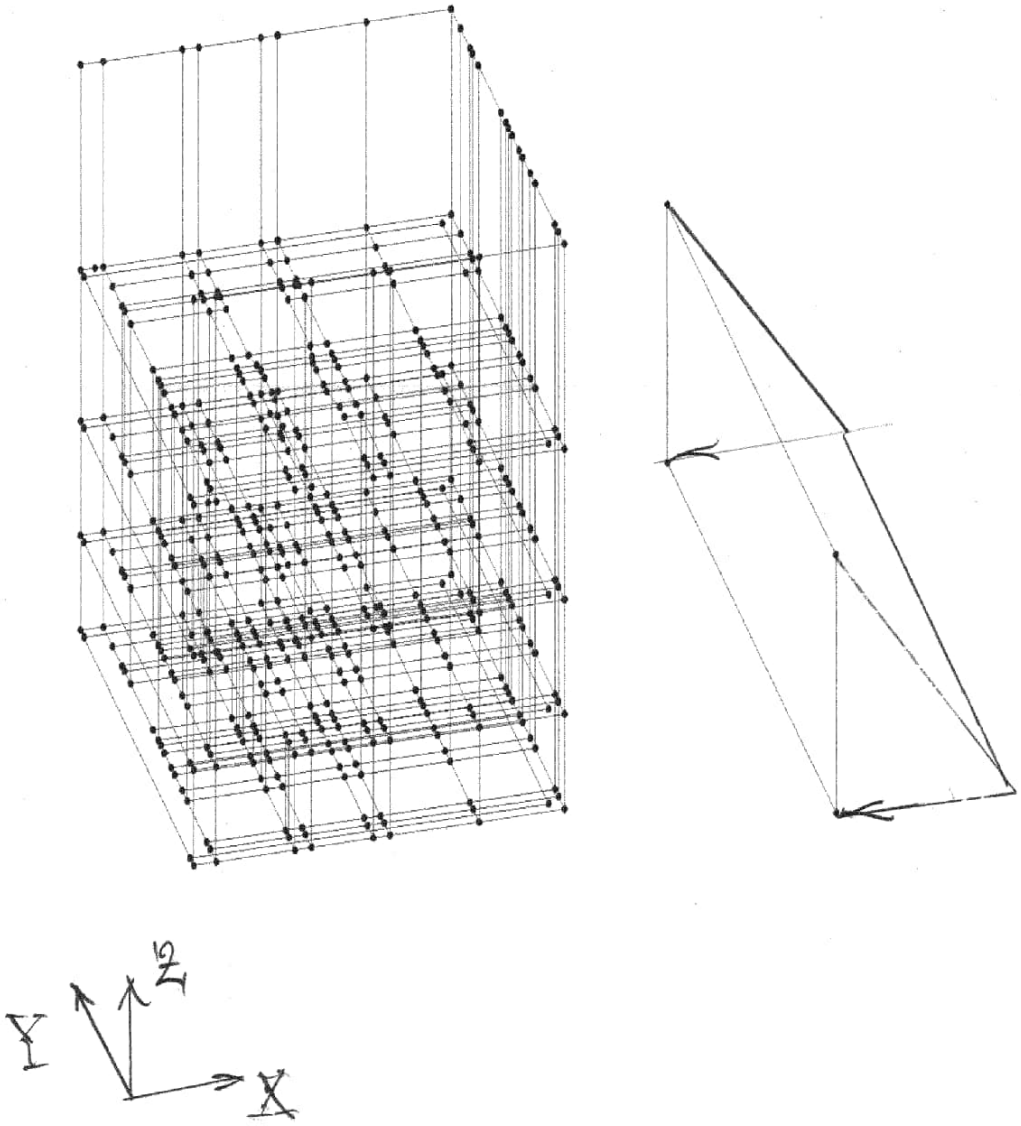
Force type : Per unit area

Component x direction : -99.4 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	30.0	-15.0	53.0	-99.4
2	30.0	15.0	53.0	-99.4
3	30.0	15.0	62.94	0.0
4	30.0	-15.0	62.94	0.0


Z
Y
X

Loadcase : Water HHW qy1

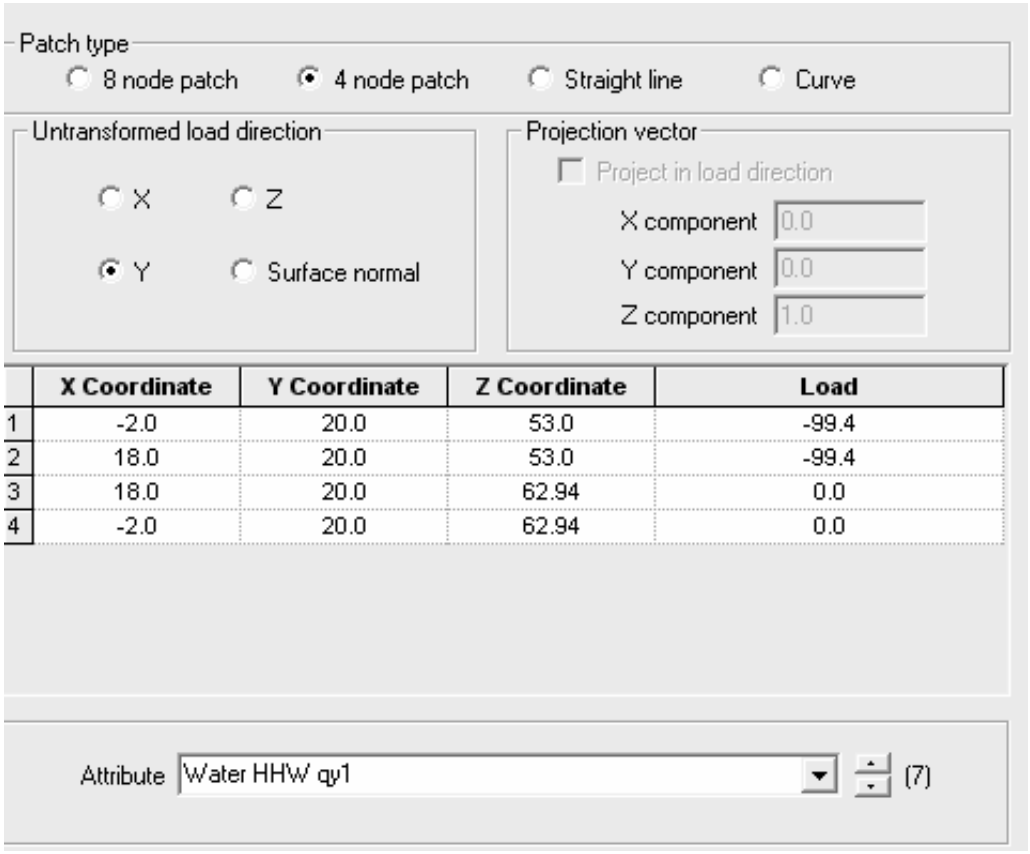
Structural loading : Discrete patch load

Search area : Exterior wall 1

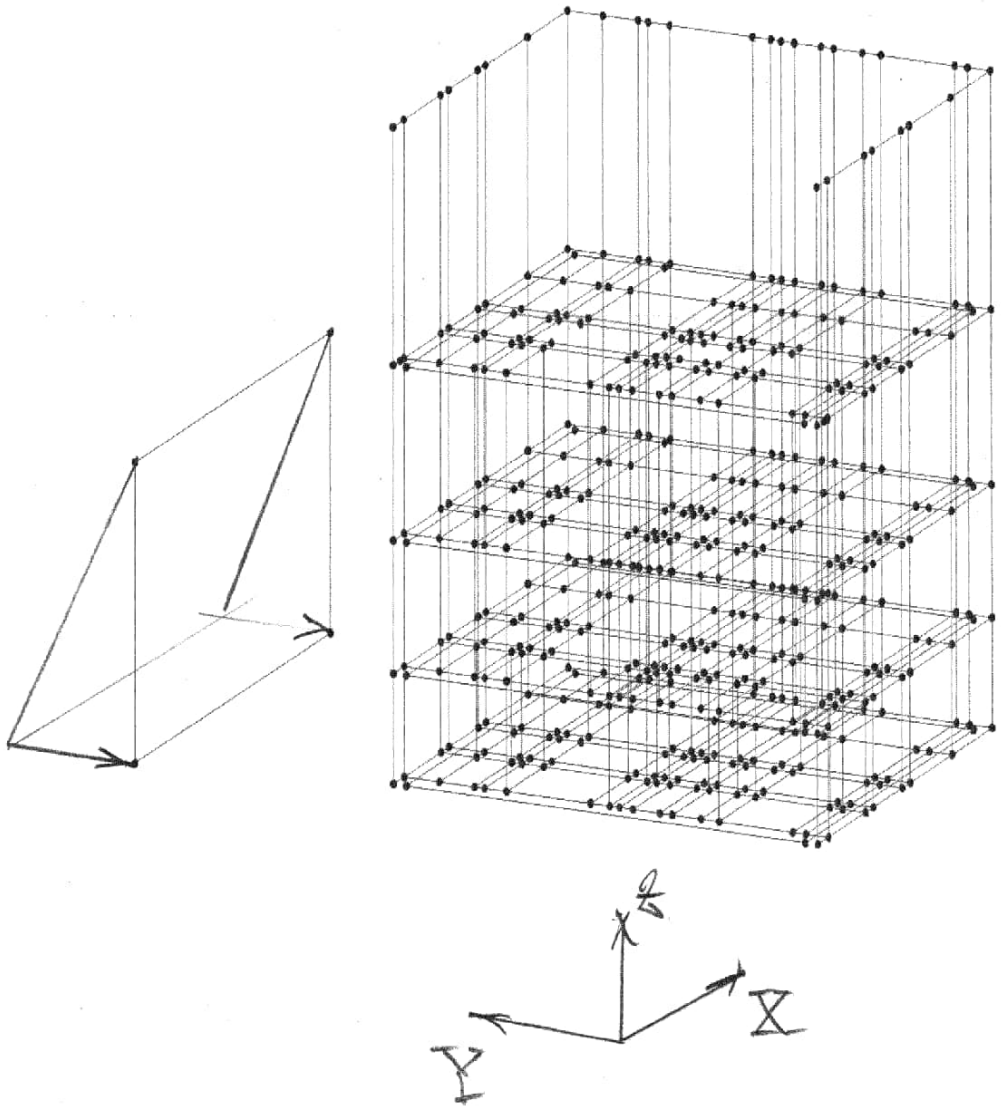
Force type : Per unit area

Component y direction : -99.4 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	-2.0	20.0	53.0	-99.4
2	18.0	20.0	53.0	-99.4
3	18.0	20.0	62.94	0.0
4	-2.0	20.0	62.94	0.0



Loadcase : Water HHW qy2

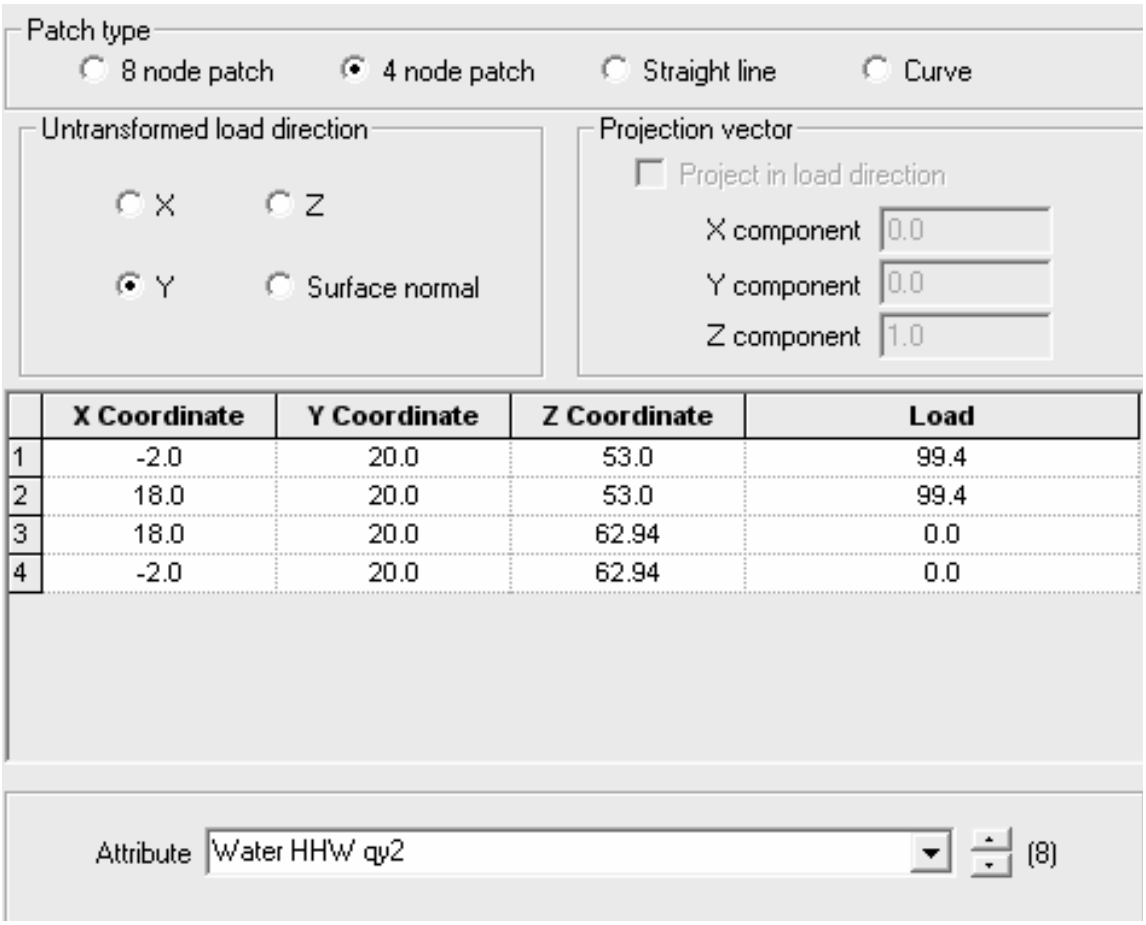
Structural loading : Discrete patch load

Search area : Exterior wall 3

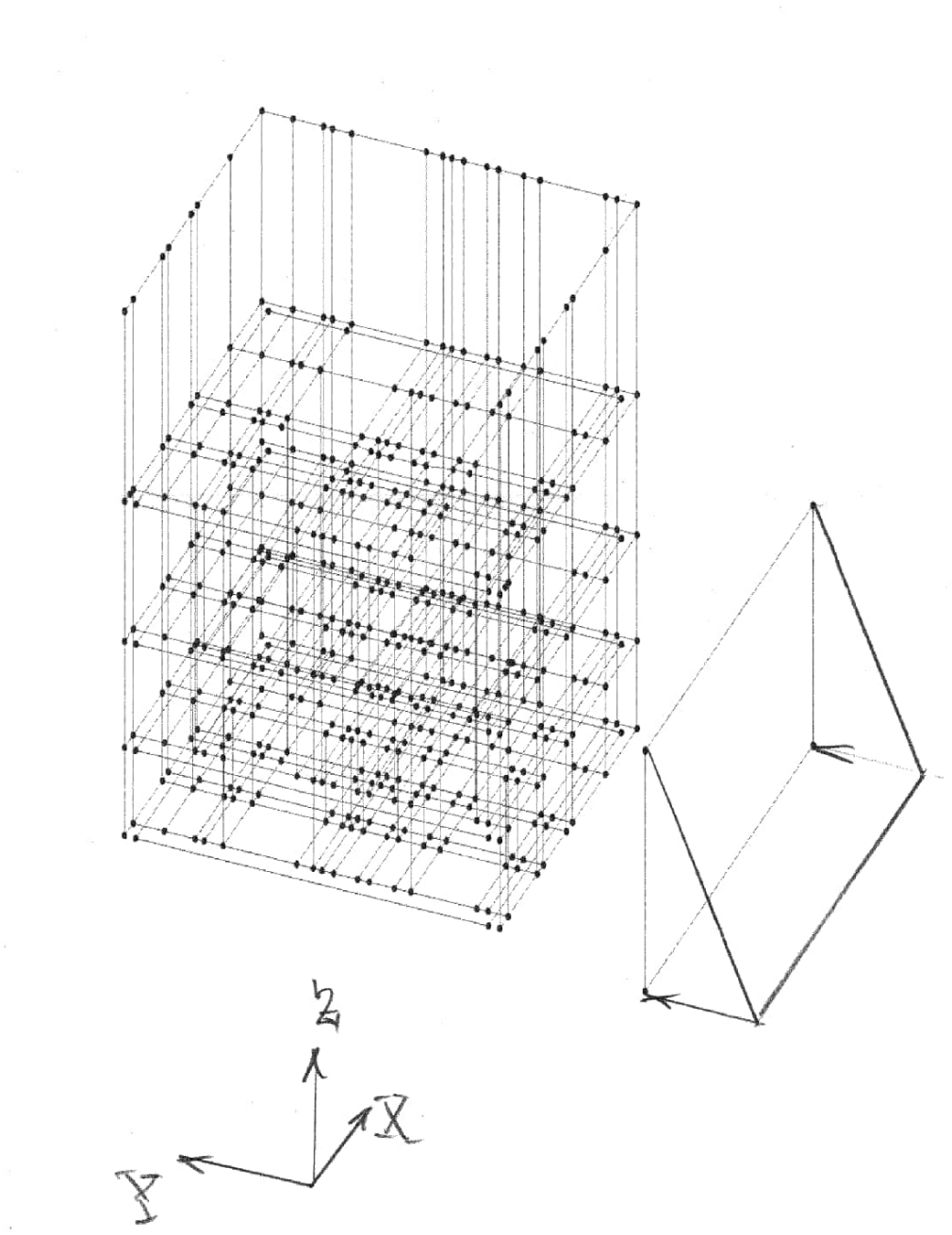
Force type : Per unit area

Component y direction : +99.4 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	-2.0	20.0	53.0	99.4
2	18.0	20.0	53.0	99.4
3	18.0	20.0	62.94	0.0
4	-2.0	20.0	62.94	0.0


Z
X
Y

3.2.3 Load combinations

Loadcombination basic : Water LLW

Loadcase	Factor
Water LLW qx1	1.00
Water LLW qy1	1.00
Water LLW qy2	1.00

Loadcombination basic : Water HHW

Loadcase	Factor
Water HHW qx1	1.00
Water HHW qy1	1.00
Water HHW qy2	1.00

3.3 EARTH PRESSURE

Earth properties listed bellow are used in the design.

$K_0 = \sin 40^o = 0.38$

$\gamma = 18 \frac{kN}{m^3}$

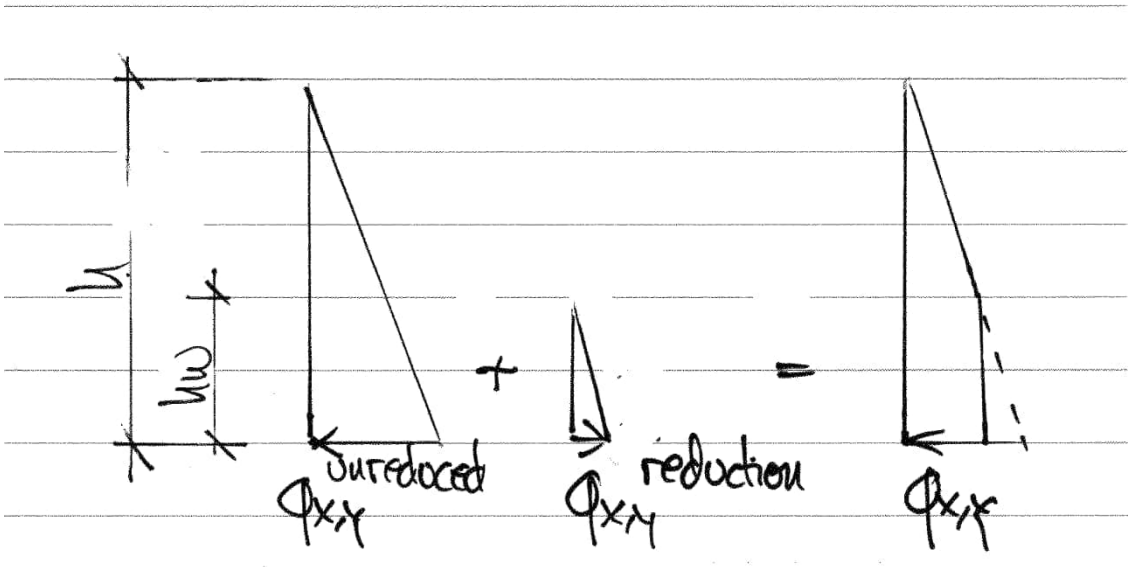
$\gamma' = 11 \frac{kN}{m^3}$

Water level varies between LLW=+53.53 and HHW=+62.94. Both levels are studied.

$q_{x,y}^{\ unreduced} = K_0 \cdot h \cdot \gamma$: unreduced earth pressure

$q_{x,y}^{\ reduction} = K_0 \cdot h_w \cdot (\gamma - \gamma')$: reduction due to reduced density beneath water

$q_{x,y} = q_{x,y}^{\ unreduced} - q_{x,y}^{\ reduction}$: reduced earth pressure

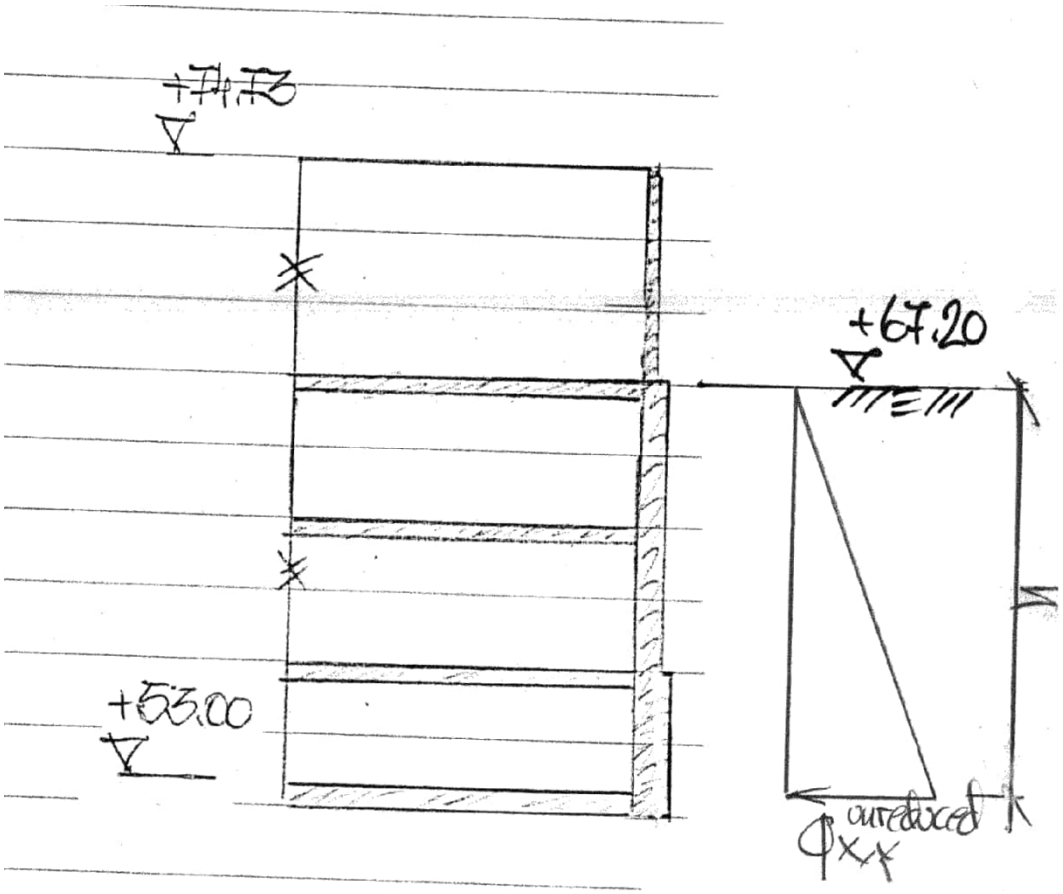


3.3.1 Earth pressure unreduced

Unreduced earth pressure bellow assumes a water level below +53.00.

$$h = 67.20 - 53.00 = 14.20m$$

$$q_{x,y}^{\ unreduced} = 0.38 \cdot 14.2m \cdot 18\frac{kN}{m^3} = 97kPa$$



Loadcase : Earth pressure unreduced qx1

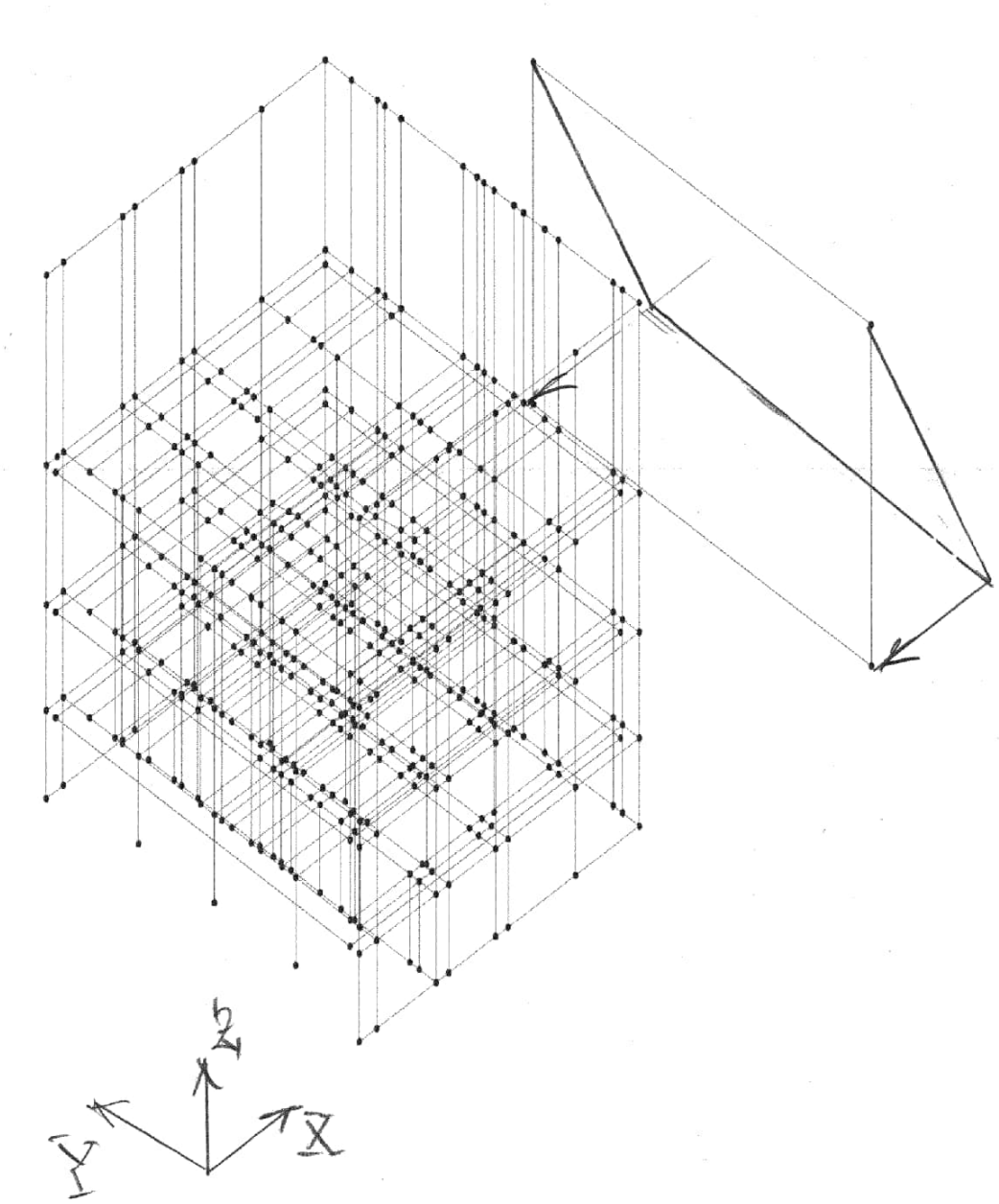
Structural loading : Discrete patch load

Search area : Exterior wall 2

Force type : Per unit area

Component x direction : { 0 -97 } kPa

Options for load outside search area : Exclude All Load


Z
Y
X

Loadcase : Earth pressure unreduced qy1

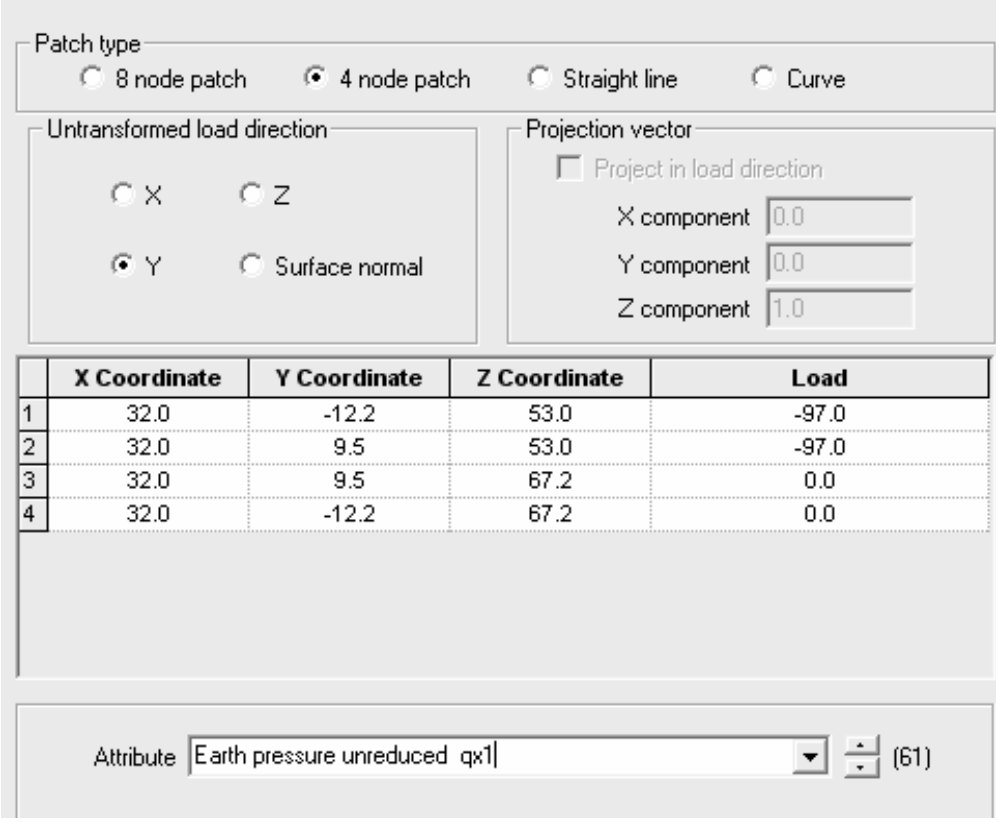
Structural loading : Discrete patch load

Search area : Exterior wall 1

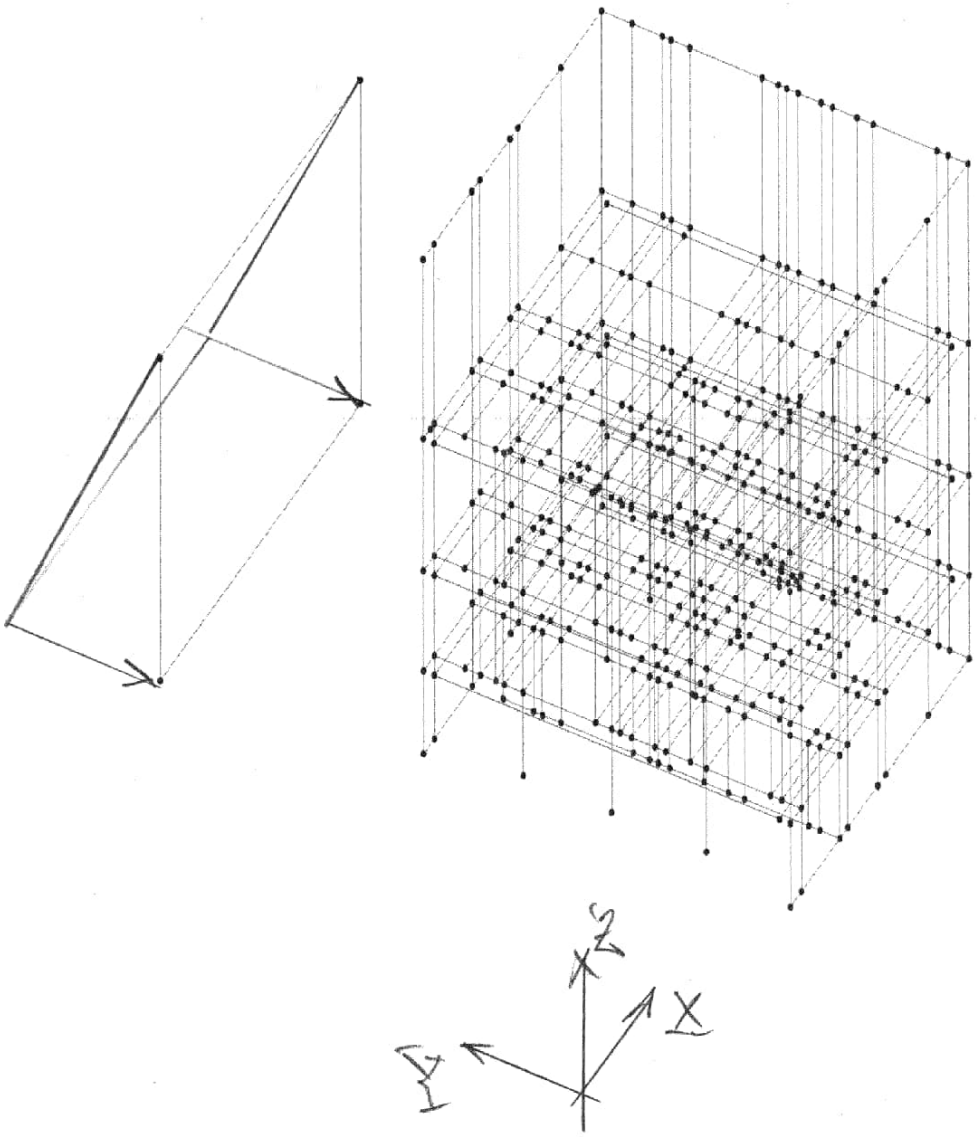
Force type : Per unit area

Component y direction : { 0 -97 } kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	32.0	-12.2	53.0	-97.0
2	32.0	9.5	53.0	-97.0
3	32.0	9.5	67.2	0.0
4	32.0	-12.2	67.2	0.0


Z
X
Y

Loadcase : Earth pressure unreduced qy2

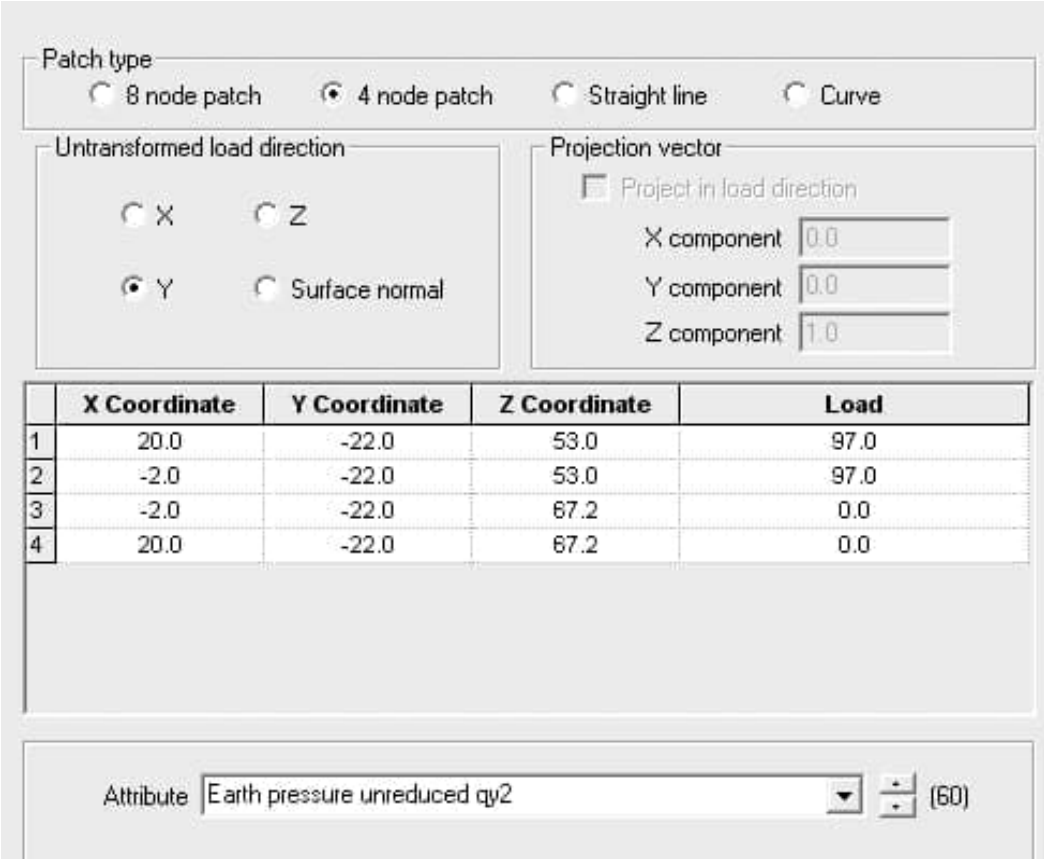
Structural loading : Discrete patch load

Search area : Exterior wall 3

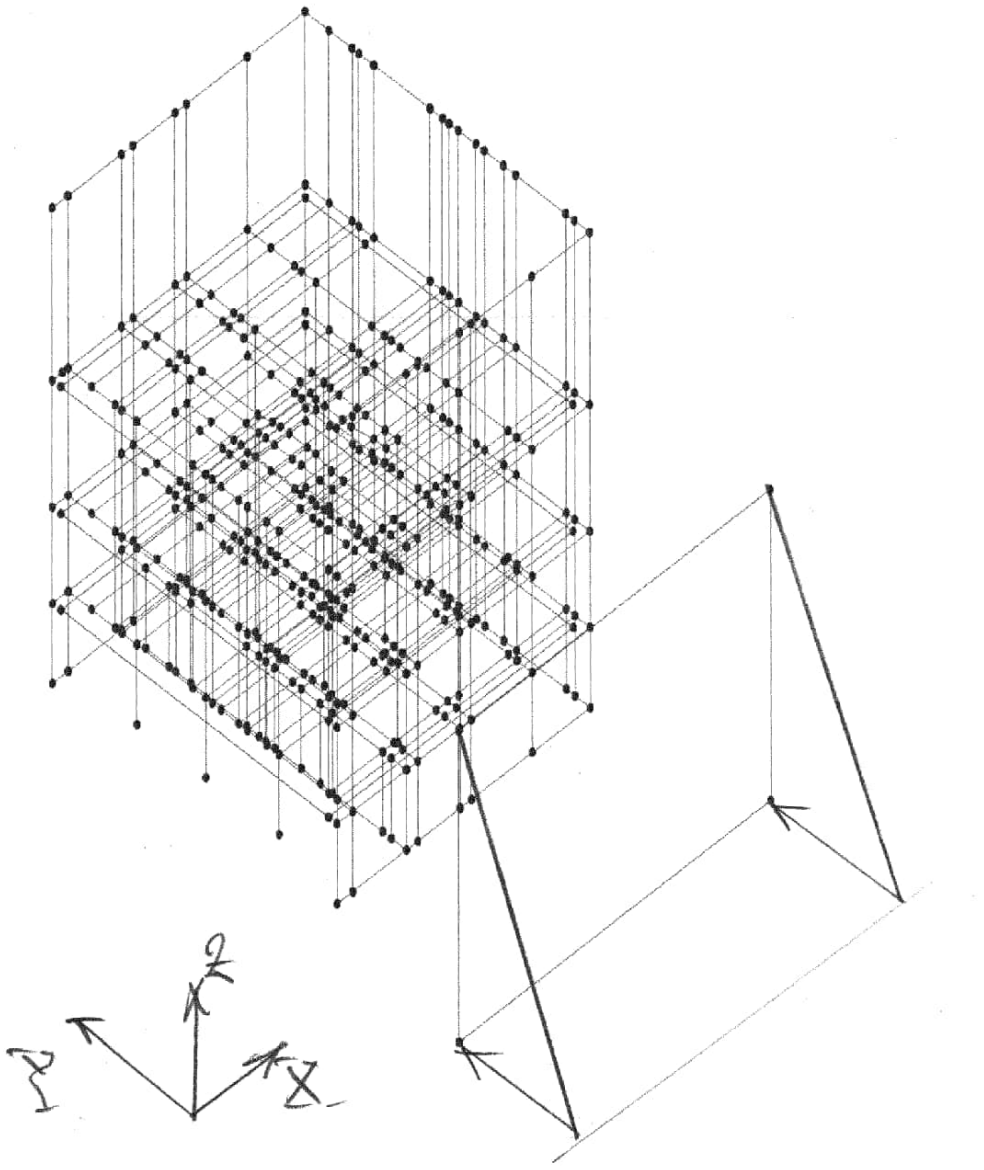
Force type : Per unit area

Component y direction : { 0 +97 } kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	20.0	-22.0	53.0	97.0
2	-2.0	-22.0	53.0	97.0
3	-2.0	-22.0	67.2	0.0
4	20.0	-22.0	67.2	0.0

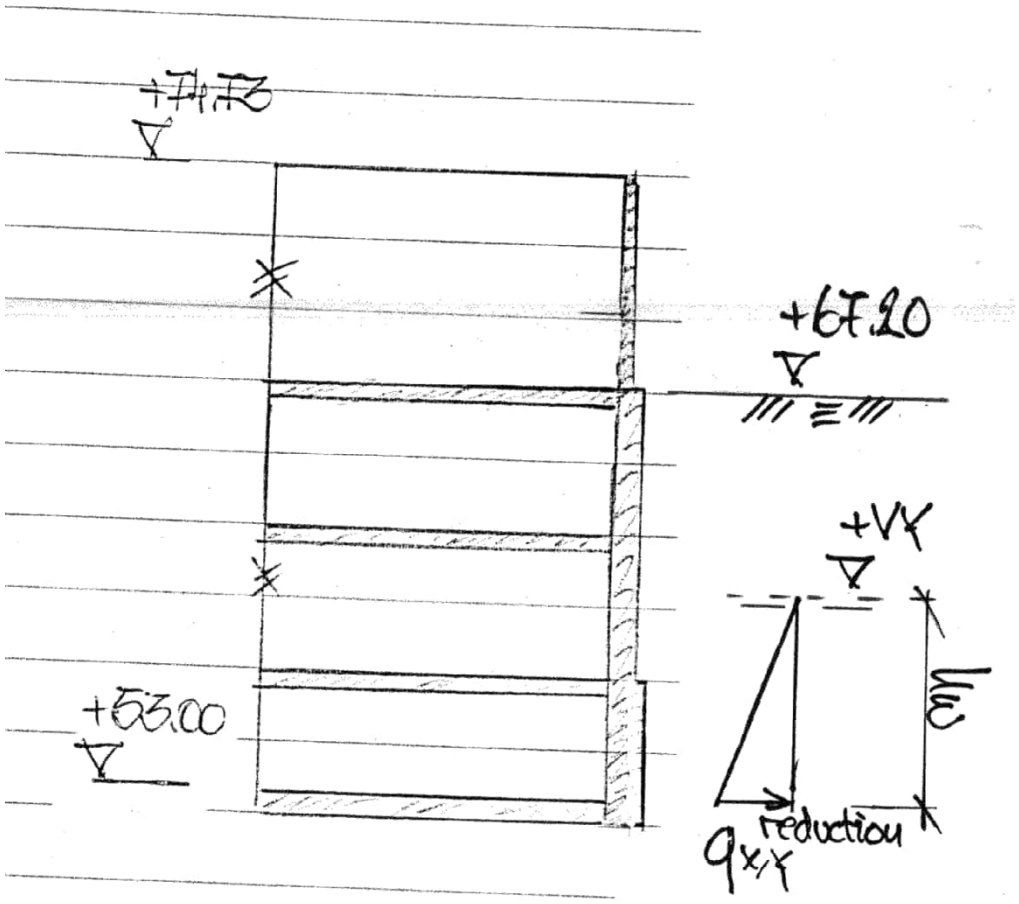

Z
Y
X

3.3.2 Reduction of earth pressure due to water level LLW

Reduction due to water level +53.63.

$$h_w = 53.63 - 53.00 = 0.63m$$

$$q_{x,y}^{\ reduction} = 0.38 \cdot 0.63m \cdot (18\frac{kN}{m^3} - 11\frac{kN}{m^3}) = 1.7kPa$$

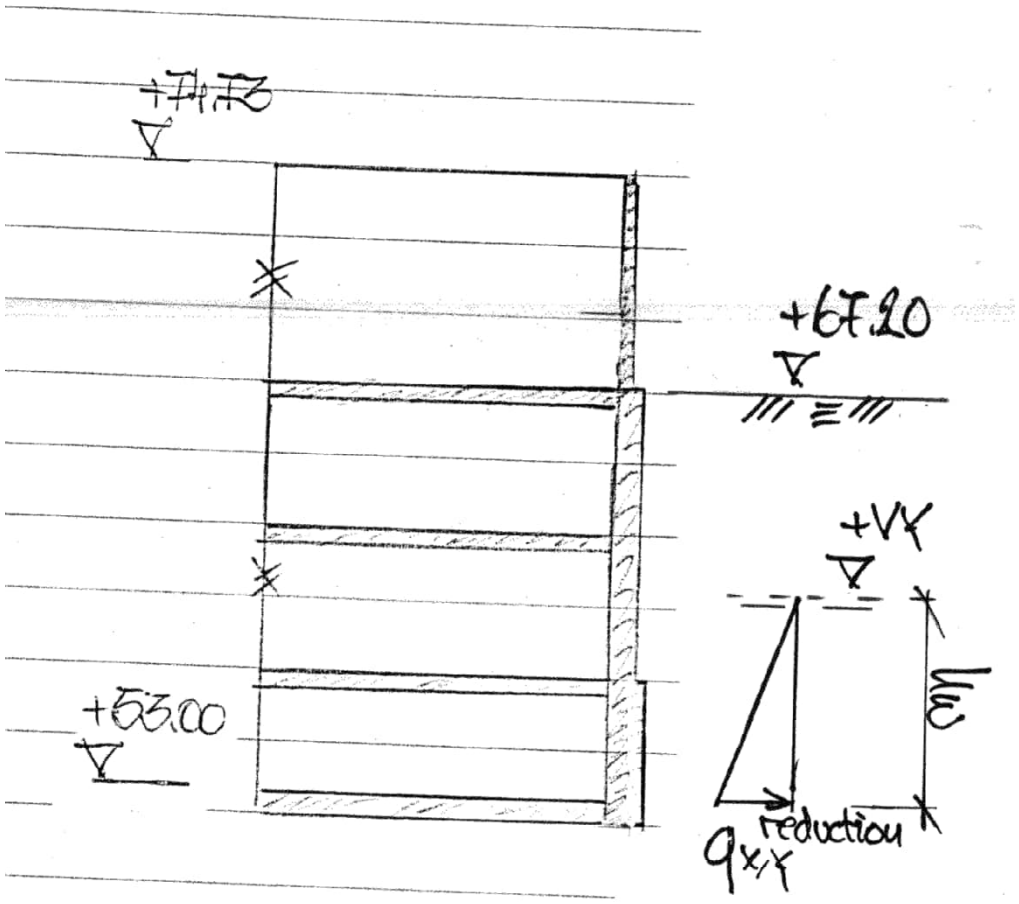


3.3.3 Reduction of earth pressure due to water level HHW

Reduction due to water level +62.94.

$$h_w = 62.94 - 53.00 = 9.94m$$

$$q_{x,y}^{\ reduction} = 0.38 \cdot 9.94m \cdot (18\frac{kN}{m^3} - 11\frac{kN}{m^3}) = 24.5kPa$$



3.3.4 Load combinations

Load combination basic : Earth pressure LLW

Loadcase	Factor
Water LLW qx1	-0.27*
Water LLW qy1	-0.27*
Water LLW qy2	-0.27*
Earth pressure unreduced qx1	1.00
Earth pressure unreduced qy1	1.00
Earth pressure unreduced qy2	1.00

$$* = \frac{-1.7kPa}{+6.3kPa} = -0.27$$

Load combination basic : Earth pressure HHW

Loadcase	Factor
Water HHW qx1	-0.25**
Water HHW qy1	-0.25**
Water HHW qy2	-0.25**
Earth pressure unreduced qx1	1.00
Earth pressure unreduced qy1	1.00
Earth pressure unreduced qy2	1.00

$$** = \frac{-24.4kPa}{+99.4kPa} = -0.25$$

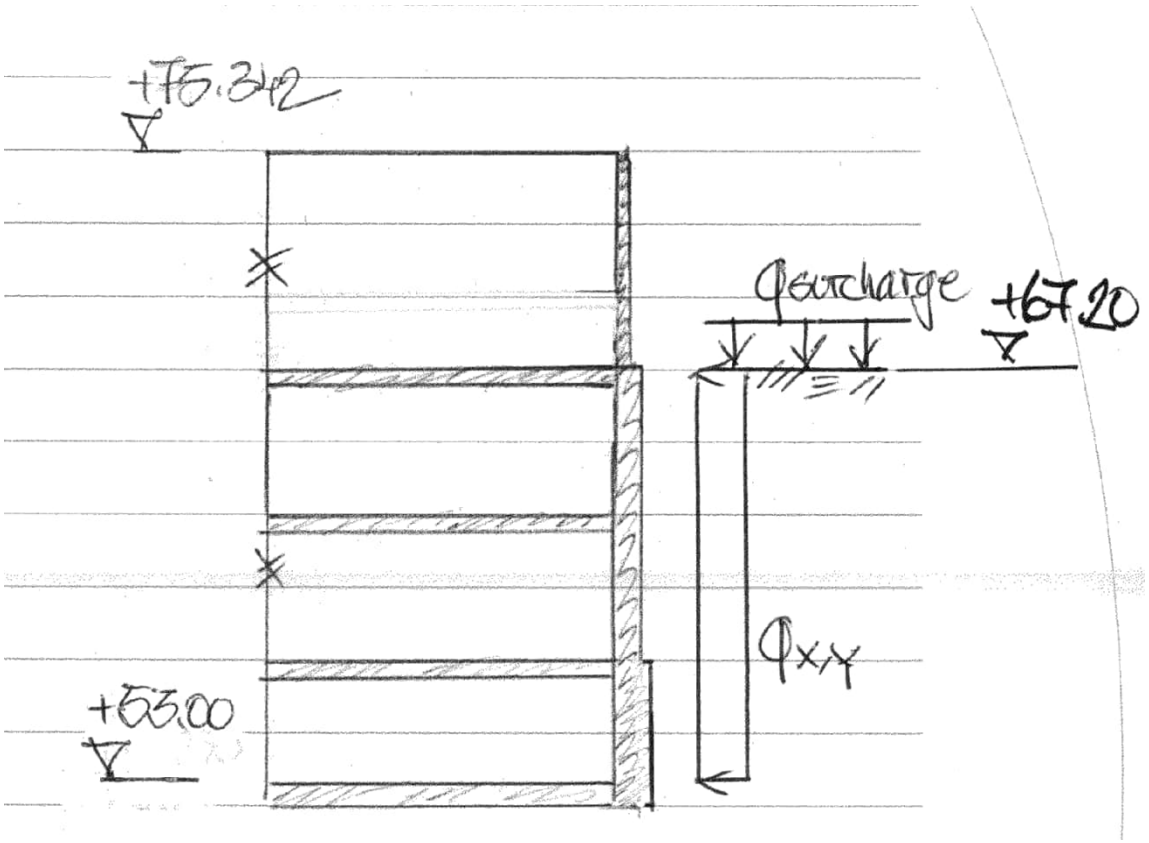
3.4 SURCHARGE

Earth properties listed bellow are used in the design.

$K_0 = 0.38$

$q_{surcharge} = 10kPa$

$q_{x,y} = K_0 \cdot q_{surcharge} = 3.8kPa$



Loadcase : Surcharge qx1

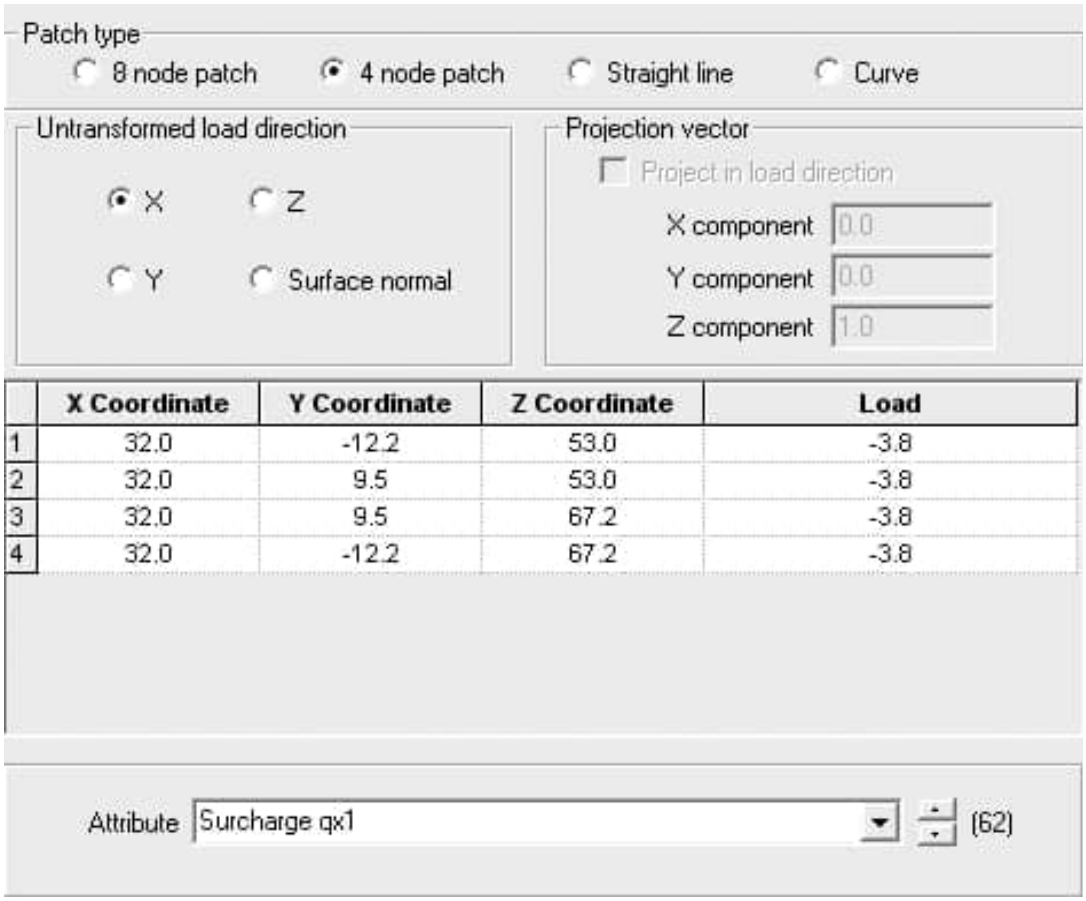
Structural loading : Discrete patch load

Search area : Exterior wall 2

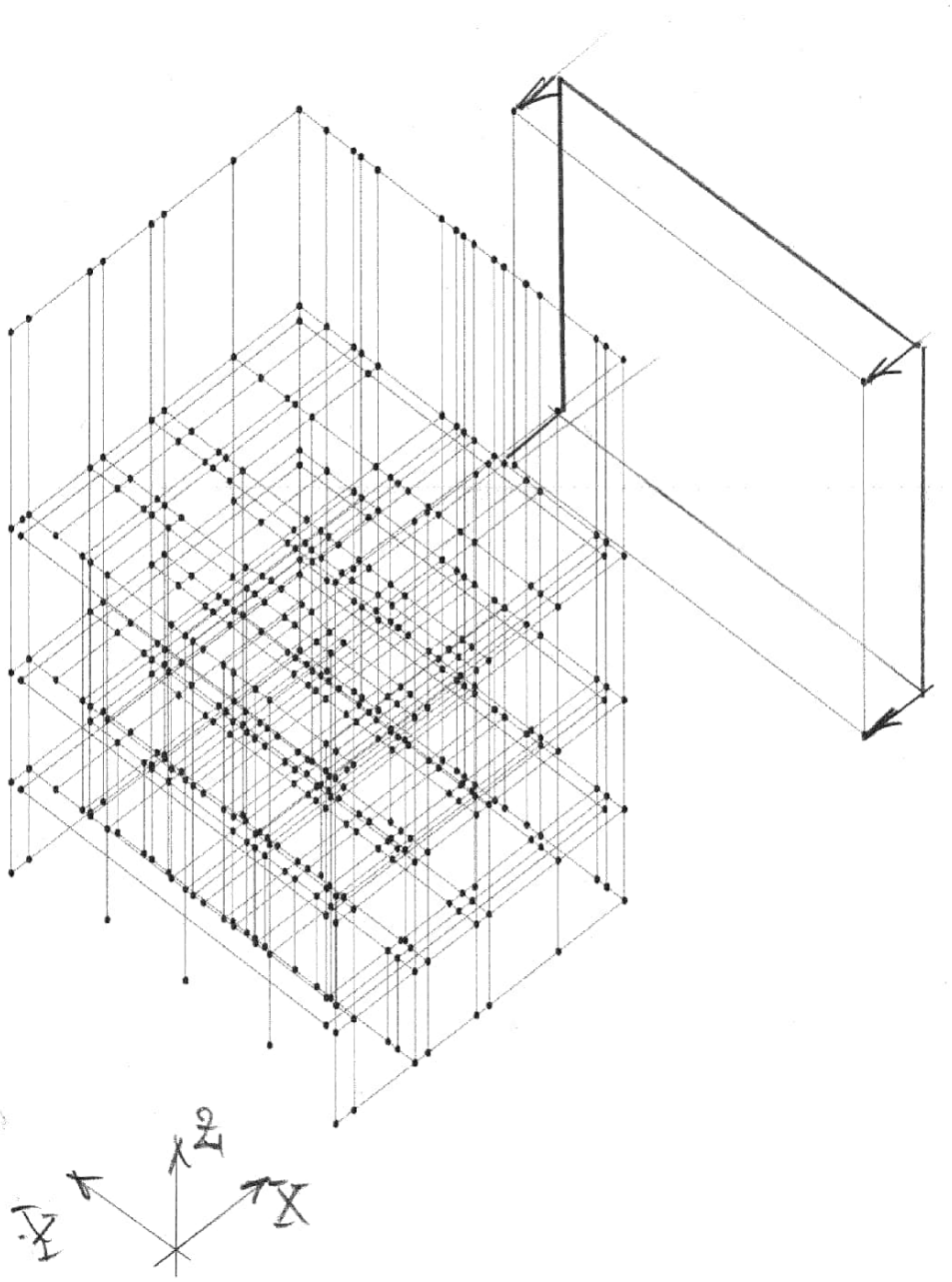
Force type : Per unit area

Component x direction : -3.8 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	32.0	-12.2	53.0	-3.8
2	32.0	9.5	53.0	-3.8
3	32.0	9.5	67.2	-3.8
4	32.0	-12.2	67.2	-3.8


Z
X
Y

Loadcase : Surcharge qy1

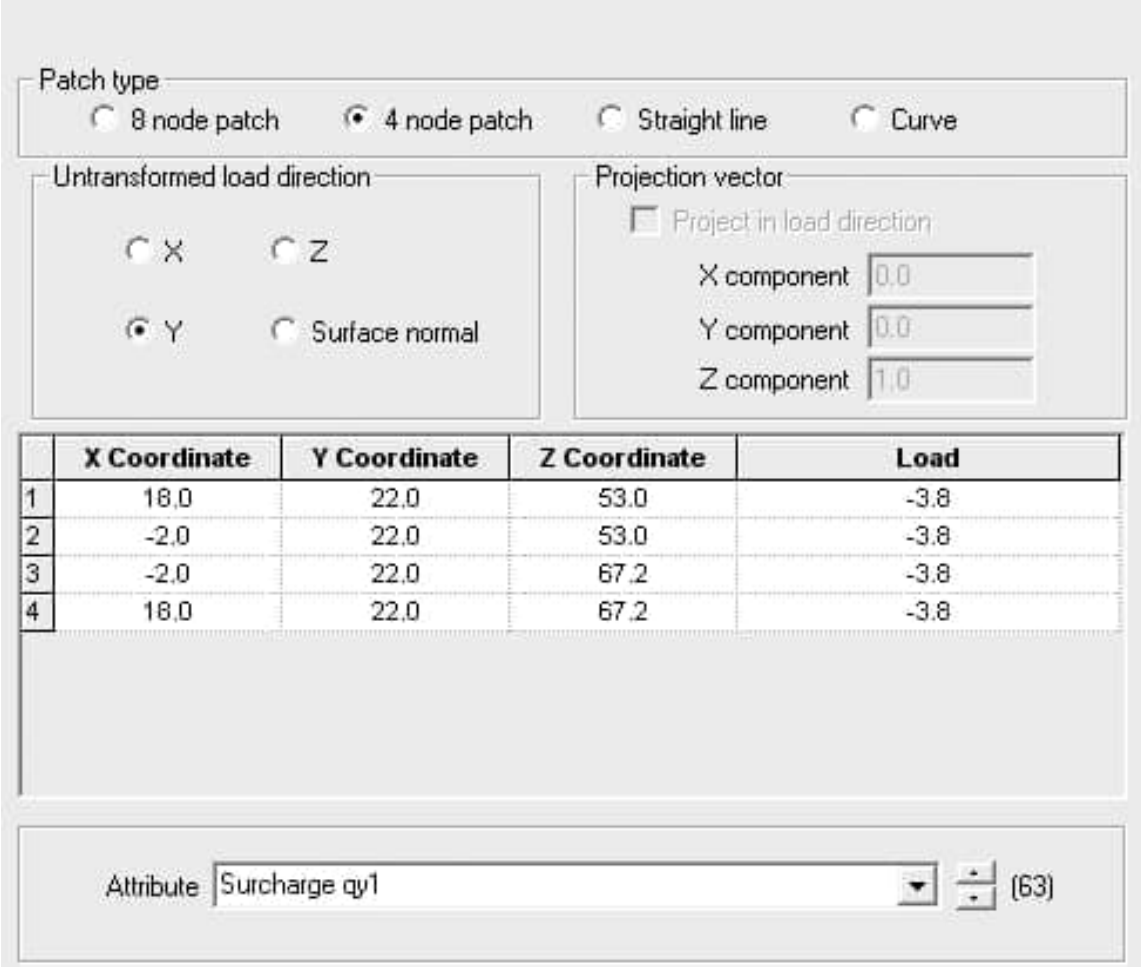
Structural loading : Discrete patch load

Search area : Exterior wall 1

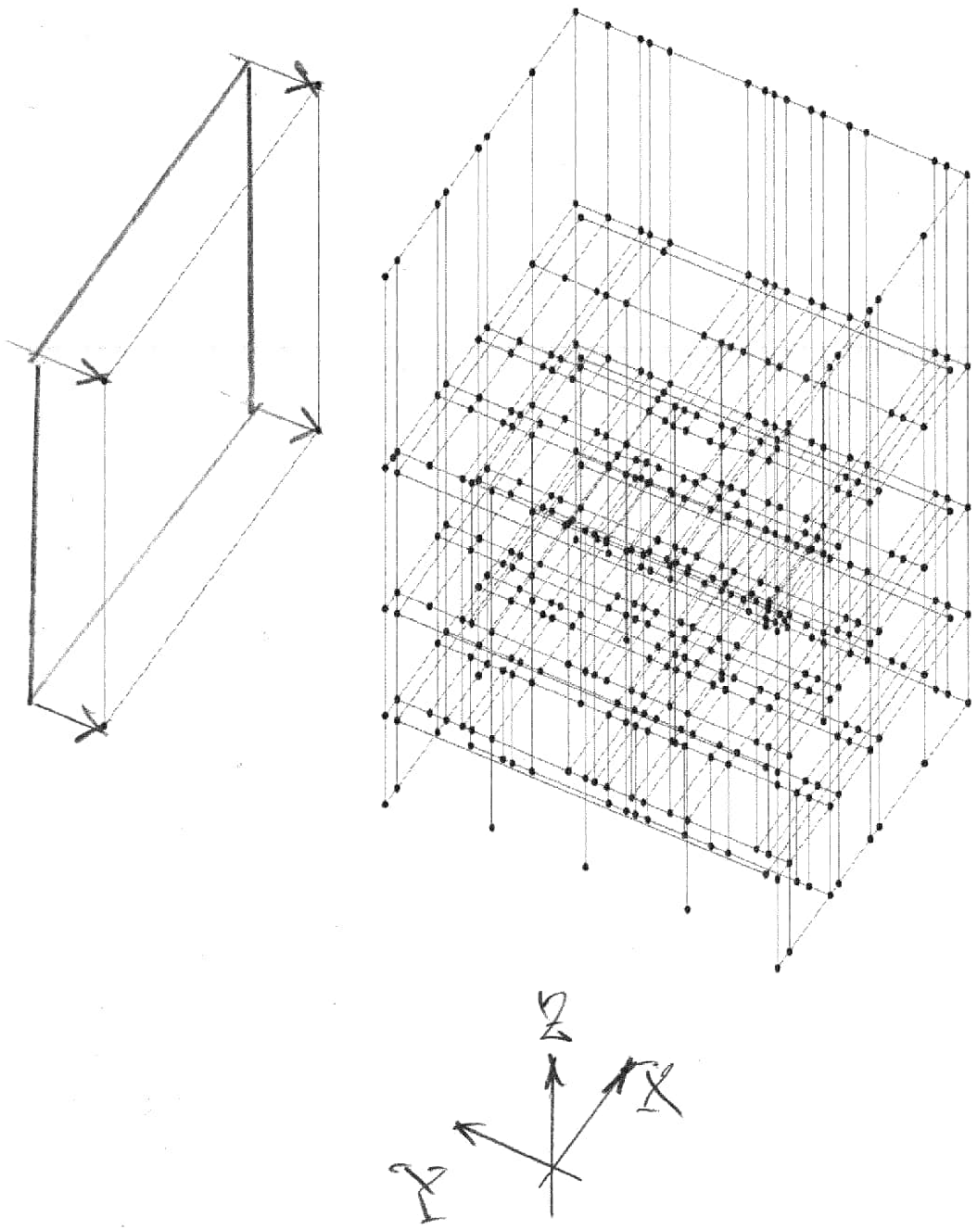
Force type : Per unit area

Component y direction : -3.8 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	16.0	22.0	53.0	-3.8
2	-2.0	22.0	53.0	-3.8
3	-2.0	22.0	67.2	-3.8
4	16.0	22.0	67.2	-3.8


Z
Y
X

Loadcase : Surcharge qy2

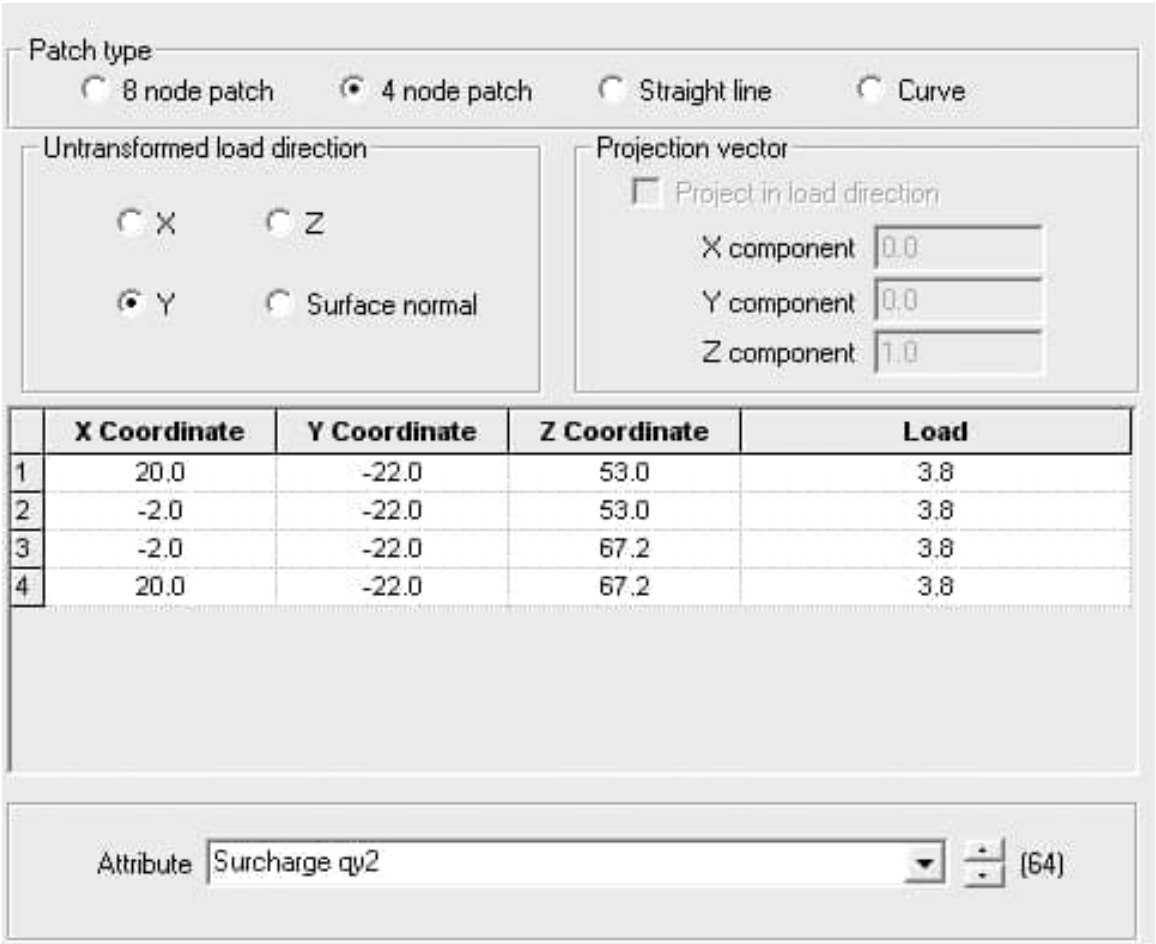
Structural loading : Discrete patch load

Search area : Exterior wall 3

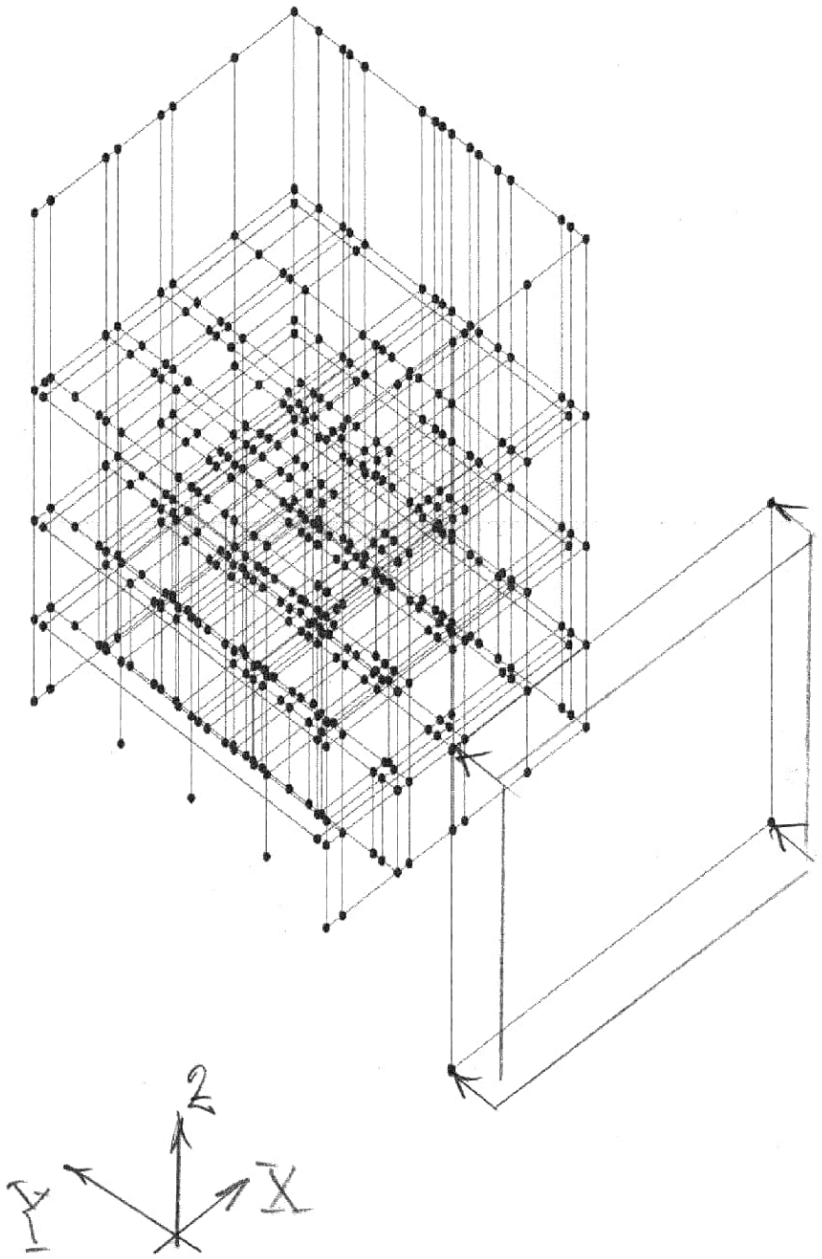
Force type : Per unit area

Component y direction : +3.8 kPa

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	20.0	-22.0	53.0	3.8
2	-2.0	-22.0	53.0	3.8
3	-2.0	-22.0	67.2	3.8
4	20.0	-22.0	67.2	3.8

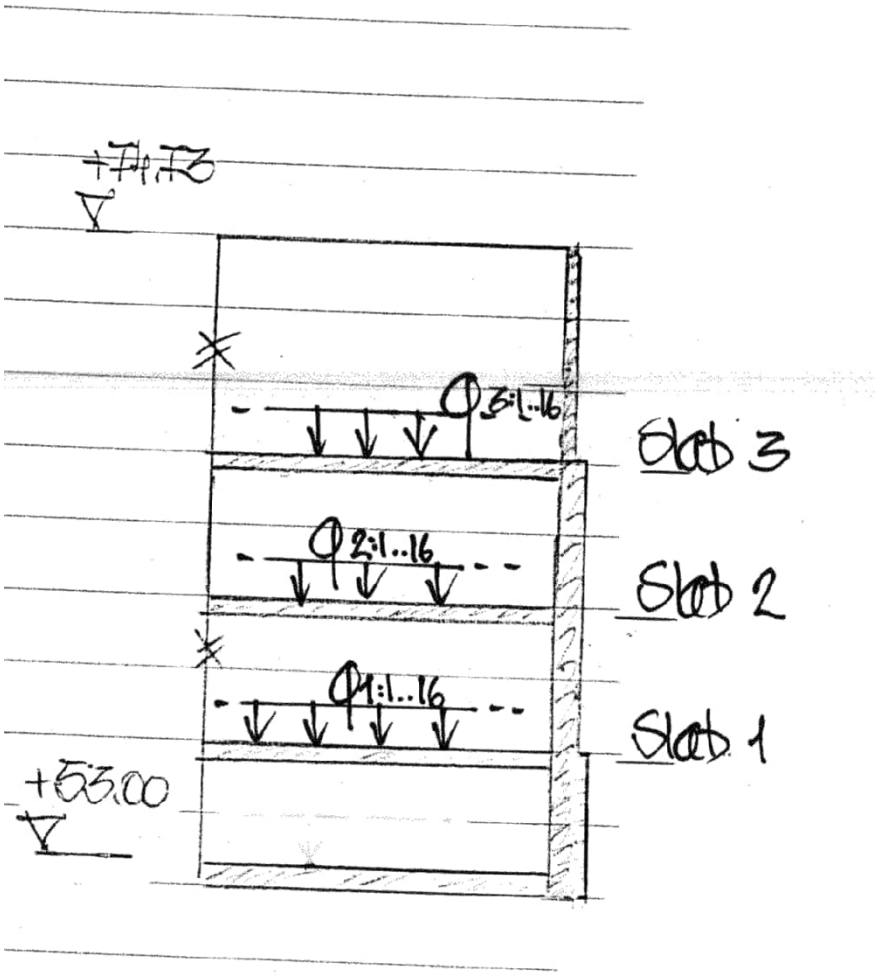

Z
Y
X

Load combination smart : *Surcharge*

Loadcase	Permanent factor	Variable factor
Surcharge qx1	0	1.00
Surcharge qy1	0	1.00
Surcharge qy2	0	1.00

3.5 LIVE SURFACE LOAD

Slabs 1-3 are designed to handle live surface load corresponding to 10 kPa.



3.5.1 Load on slab 1

Loadcases : Surface 1:1-1:16

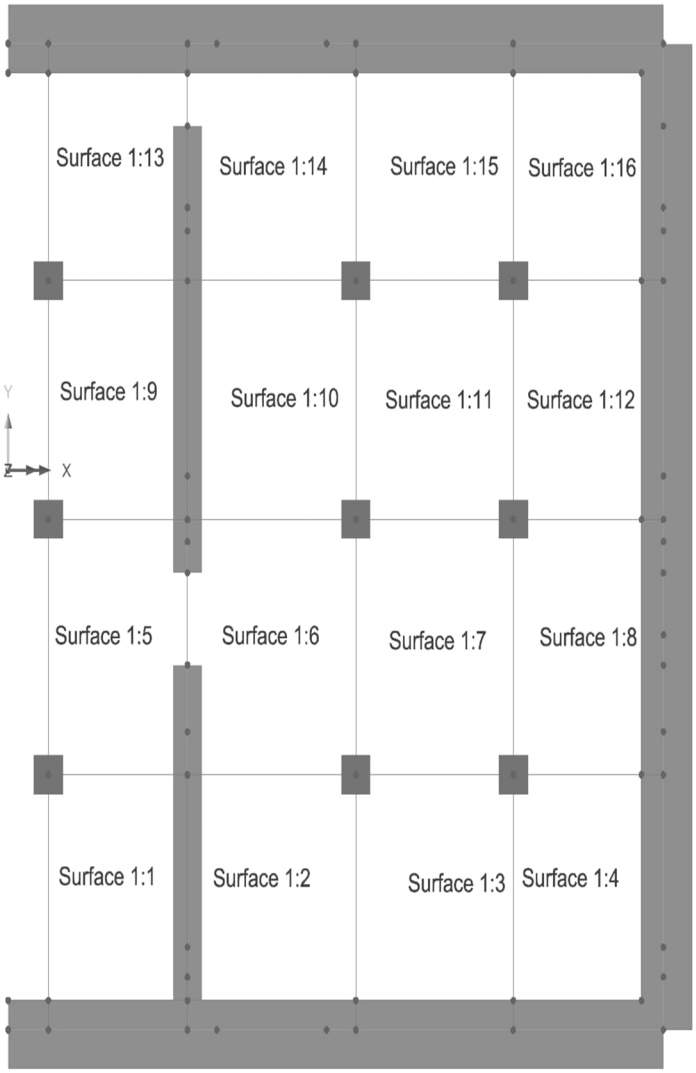
Structural loading : Discrete patch load

Search area : Slab 1

Force type : Per unit area

Component z direction :-10 kPa

Options for load outside search area : Exclude All Load



3.5.2 Load on slab 2

Loadcases : Surface 2:1-2:16

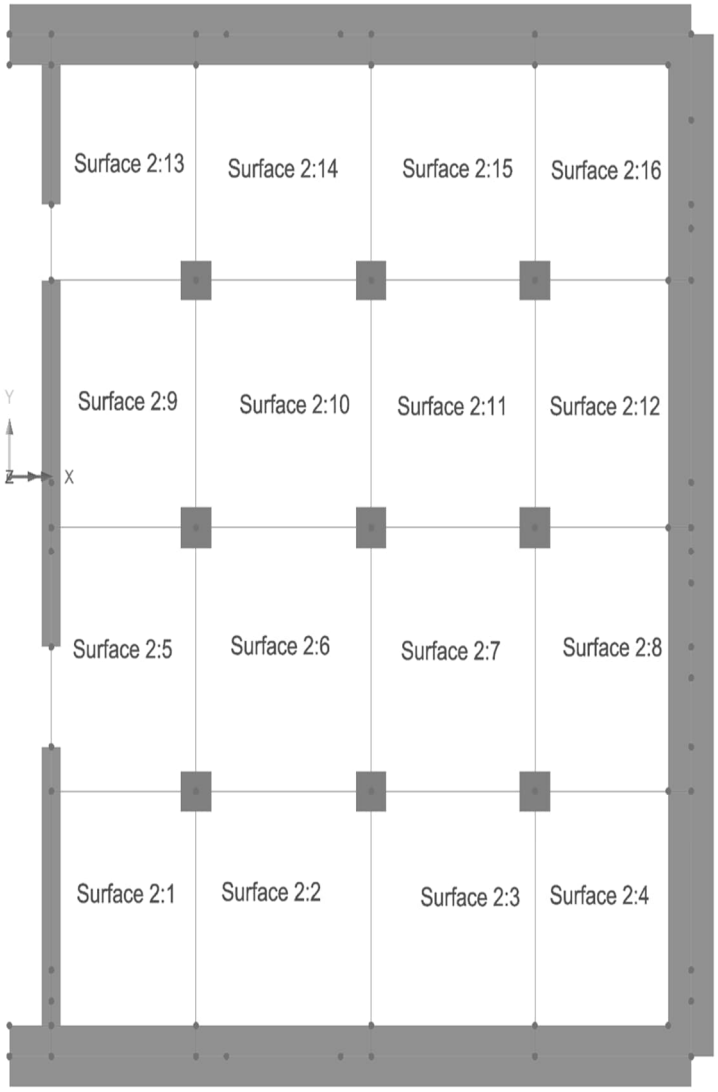
Structural loading : Discrete patch load

Search area : Slab 2

Force type : Per unit area

Component z direction :-10 kPa

Options for load outside search area : Exclude All Load



Remark Coordinate table of surface load see Appendix 1.

3.5.3 Load on slab 3

Loadcases : Surface 3:1-3:16

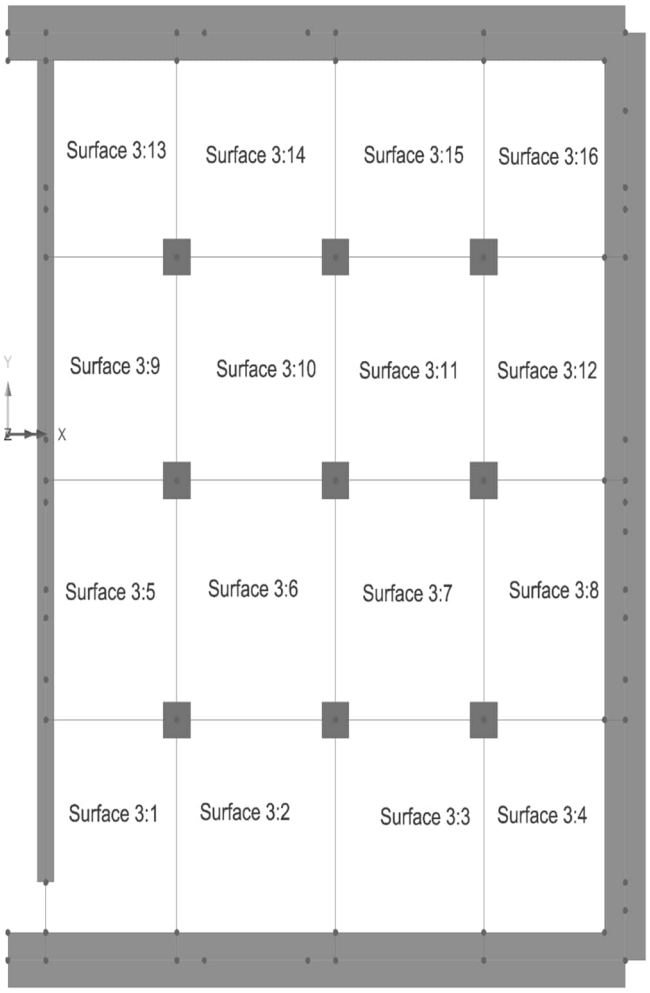
Structural loading : Discrete patch load

Search area : Slab 3

Force type : Per unit area

Component z direction :-10 kPa

Options for load outside search area : Exclude All Load



Remark Coordinate table of surface load see Appendix 1.

3.5.4 Load combinations

Smart loadcombination : Surface load

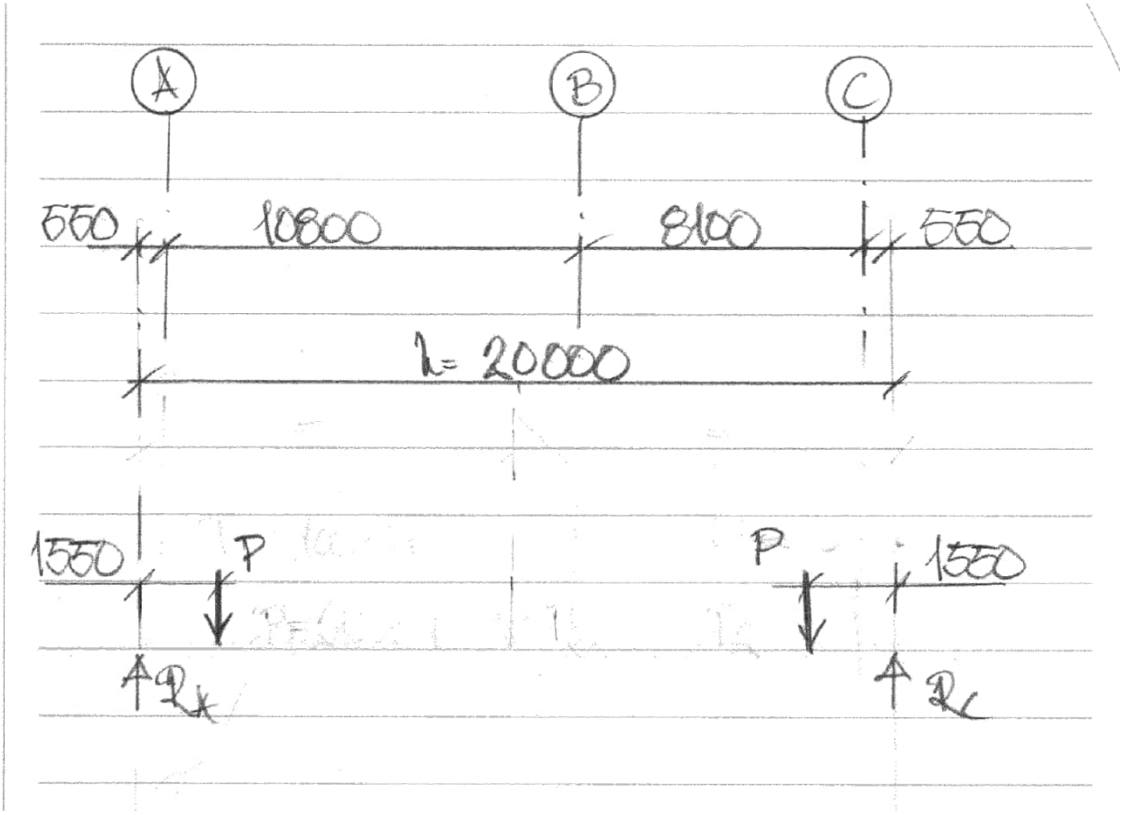
Loadcase	Permanent factor	Variable factor
Surface 1:1…1:16	0	1.00
Surface 2:1…2:16	0	1.00
Surface 3:1…3:16	0	1.00

3.6 CRANE LOAD

The crane load is chosen to be the same as the capacity of crane.

There are two hooks one main ($\therefore$ 2100 kN) and one auxillary ($\therefore$ 150 kN). Only the main hook is considered due to its higher capacity.

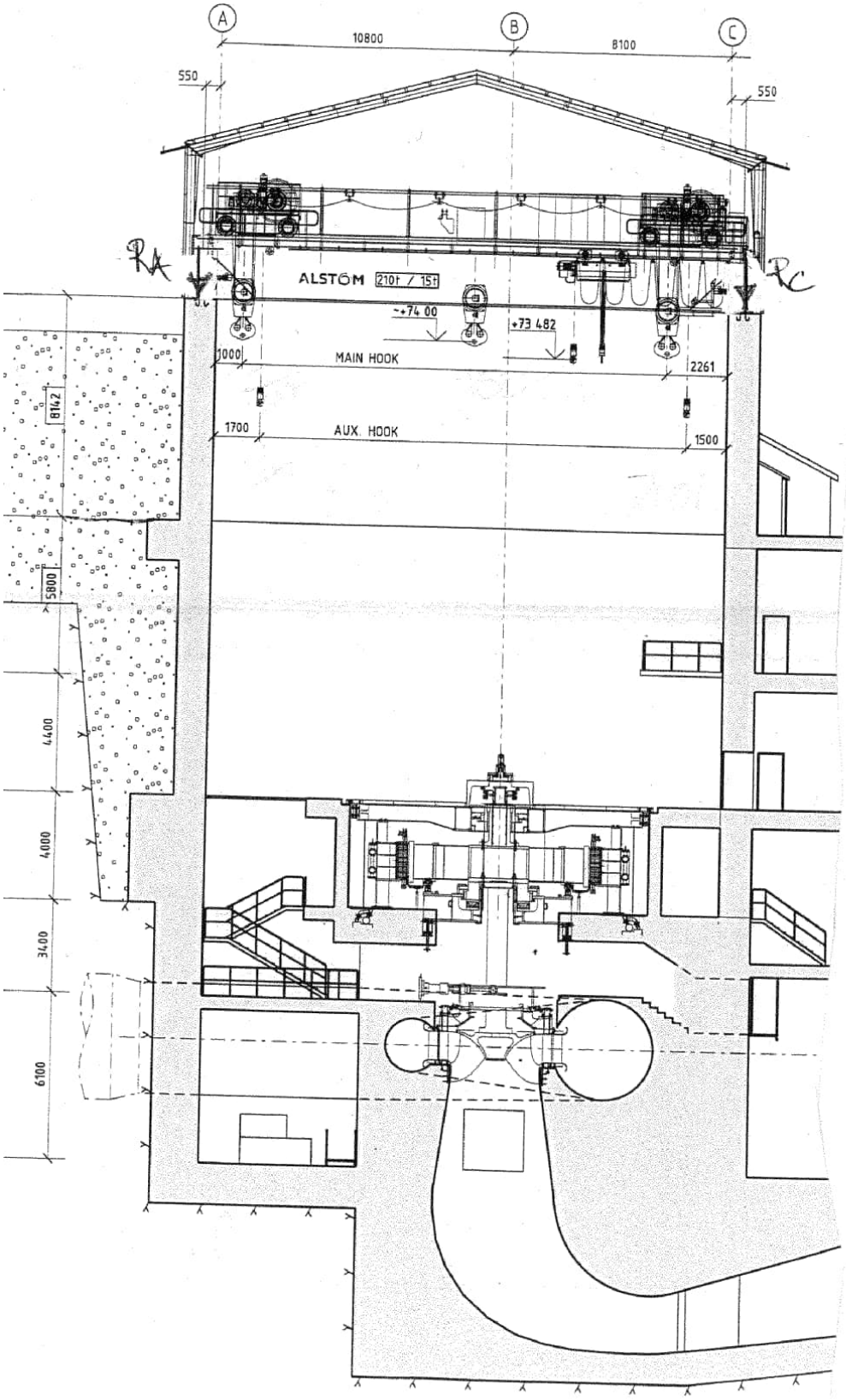
The most dangerous position arises when hook main hook is positioned 1000 mm from basline A or basline C.



$$P = 2100kN$$

$$R_A = R_C = P \cdot \frac{L - 1.55m}{L} = 2100kN \cdot \frac{20.0m - 1.55m}{20.0m} = 1937kN$$

Remark The effect of breaking/friction and excentric load positioning is neglected since it is considered marginal when designing the studied structure.


A
B
C
10800
8100
550
550
ALSTÖM 210t / 15t
+74 00
+73 482
MAIN HOOK
1000
2261
AUX. HOOK
1700
1500
8142
5800
4400
4000
3400
6100

Structural load : Crain

Component	Value
Concentrated load in X Dir	0.0
Concentrated load in Y Dir	0.0
Concentrated load in Z Dir	-1.937E3
Moment about X axis	0.0
Moment about Y axis	0.0
Moment about Z axis	0.0
Moment about hinge nodes	0.0
Pore pressure	0.0

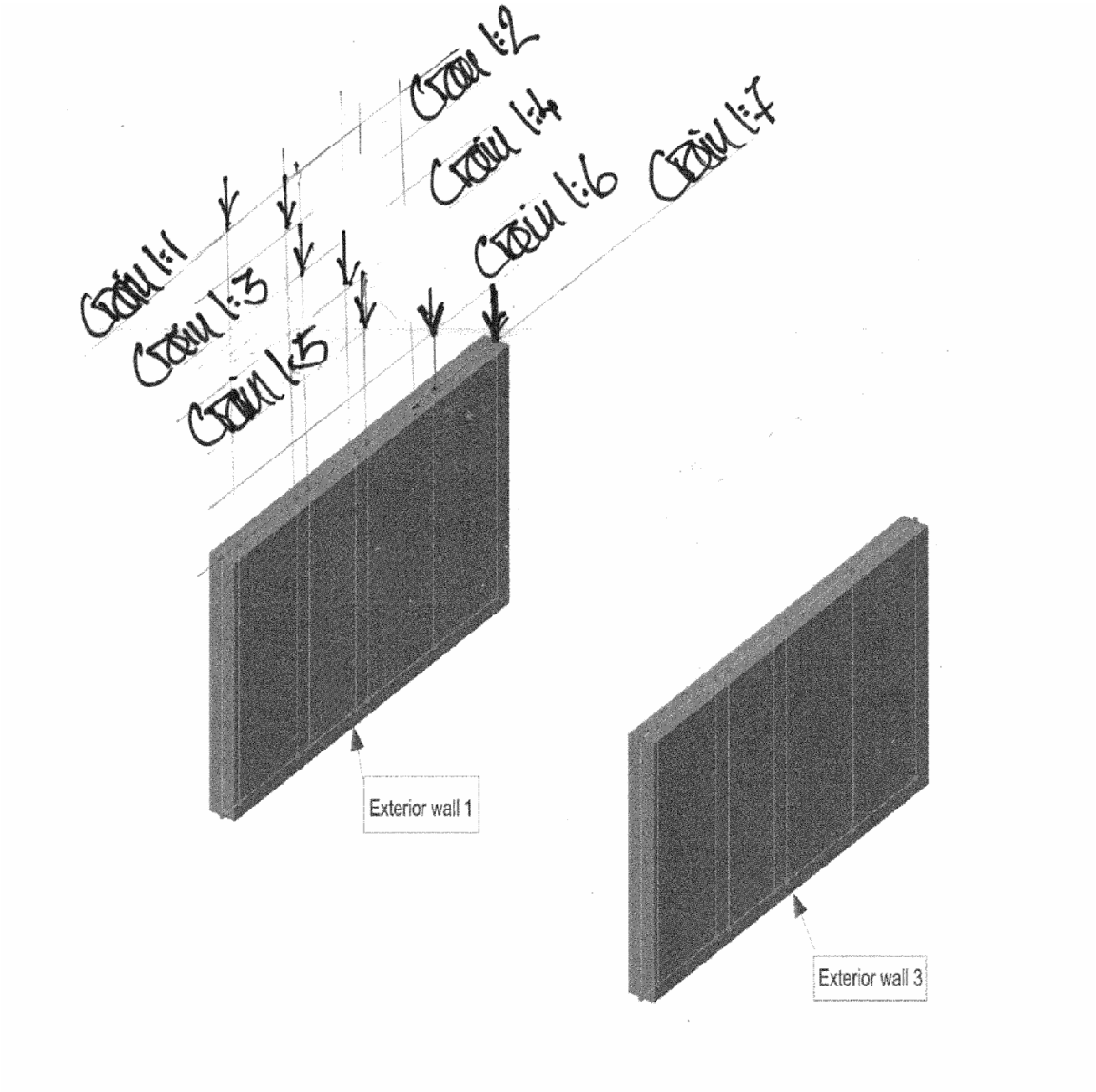
3.6.1 Load on exterior wall 1

Loadcase : Crain 1:1-1:7

Structural loading : Global distributed

Structural load : Crain

Load type : Concentrated load



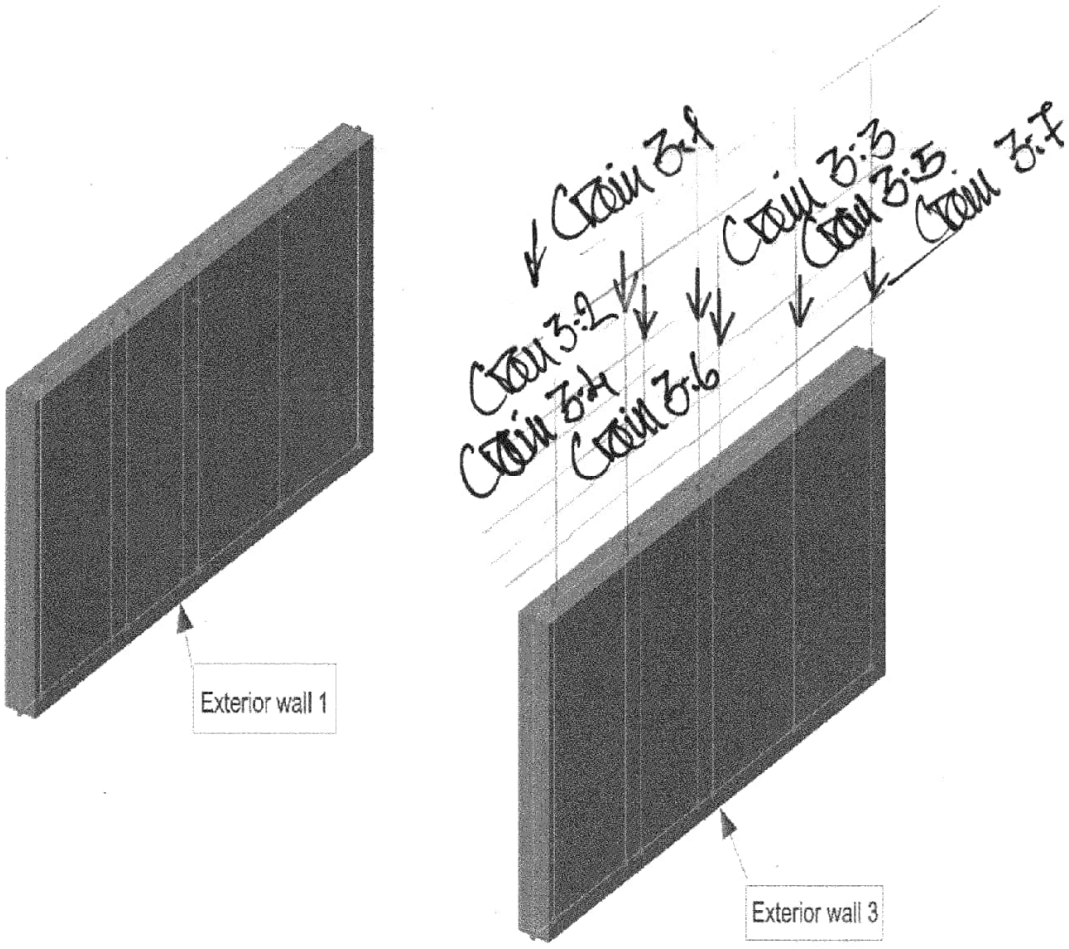
3.6.2 Load on exterior wall 3

Loadcase : Crain 3:1-3:7

Structural loading : Global distributed

Structural load : Crain

Load type : Concentrated load



3.6.3 Envelope

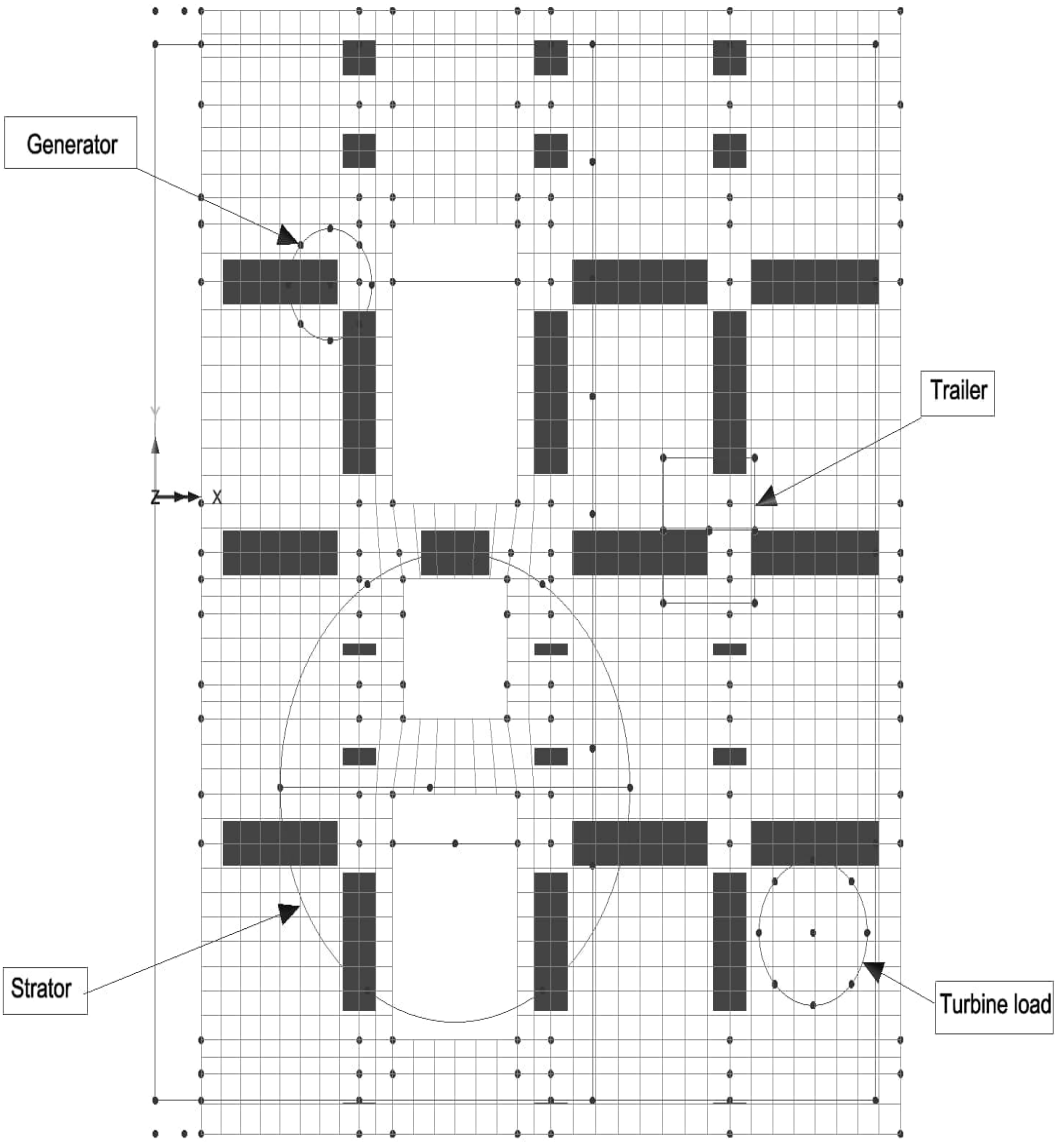
Envelope : *Crain load*

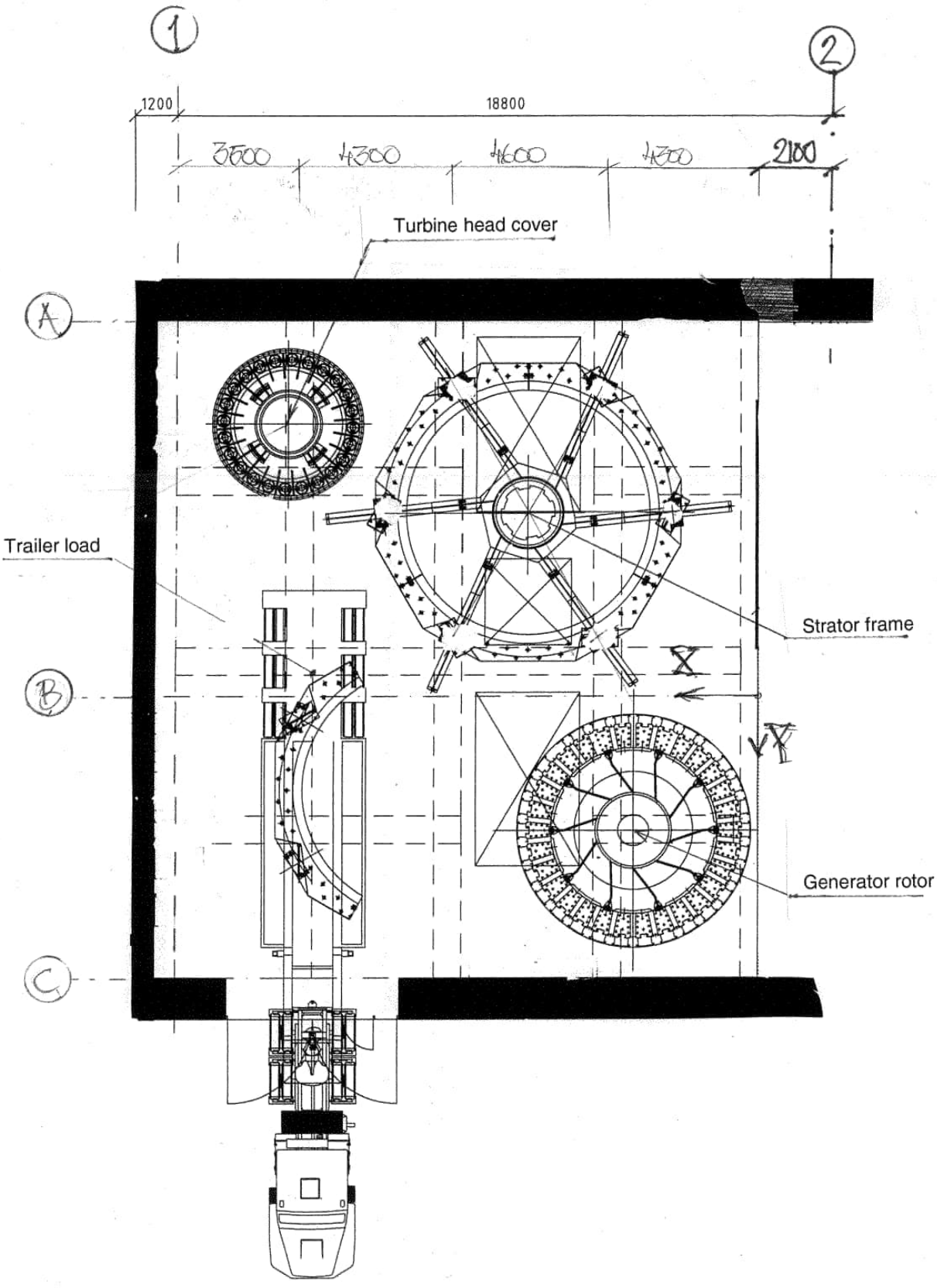
Loadcase	Factor
Crain 1:1…1:7	1
Crain 3:1…3:7	1

3.7 MACHINE LOAD

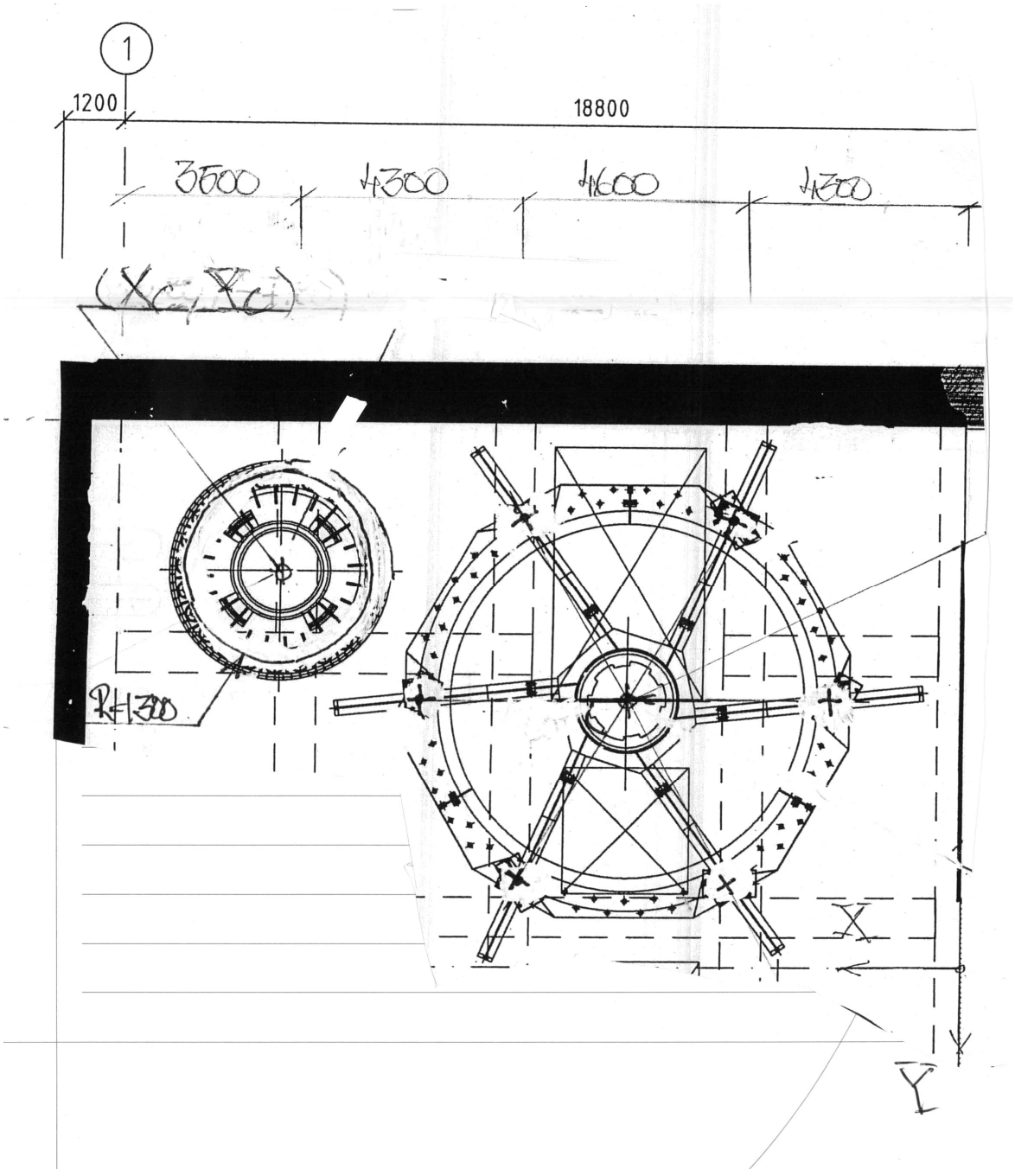
The repair bay floor +67.20 is loaded with the following mashine loads during assembly.

- Turbine head cover (line load) : 130 kN
- Stator frame (point loads) : 1200kN
- Generator rotor (line load) : 2000 kN
- Trailer load (point load) : 130 kN




1
2
1200
18800
3500
4300
4600
4300
2100
Turbine head cover
A
B
C
Trailer load
Strator frame
X
X
Generator rotor

3.7.1 Turbine head cover



X_c = +15.80 m

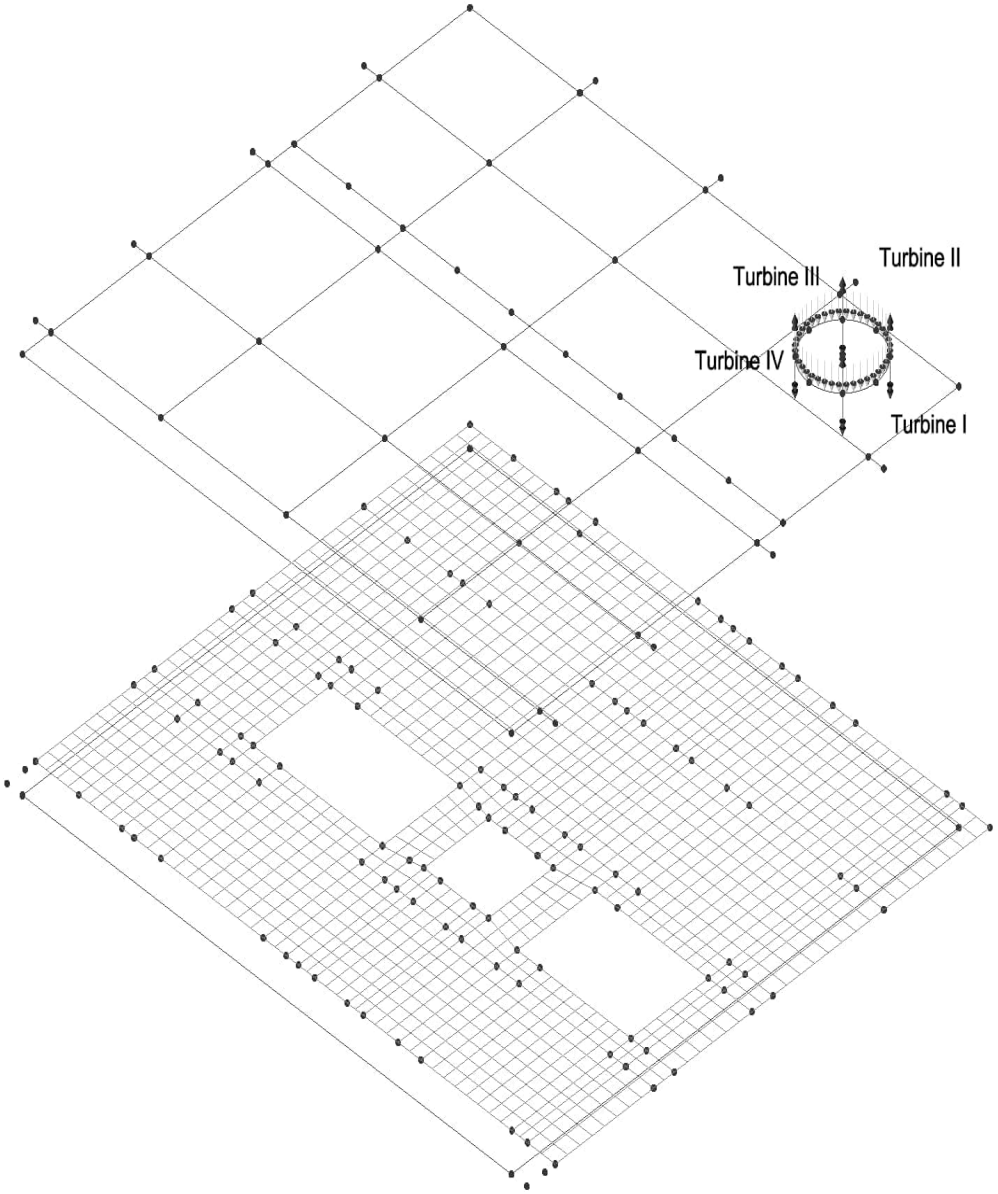
Y_c = -7.80 m

The load is considered a line load with circular form. In order to model this load it is divided into 4 separate parts I-IV.

R = 1.30 m

ΣP = 130 kN

$$p = \frac{P}{2\pi R} = \frac{130kN}{2\pi \cdot 1.30m} = 16\frac{kN}{m}$$



Loading: Turbine I

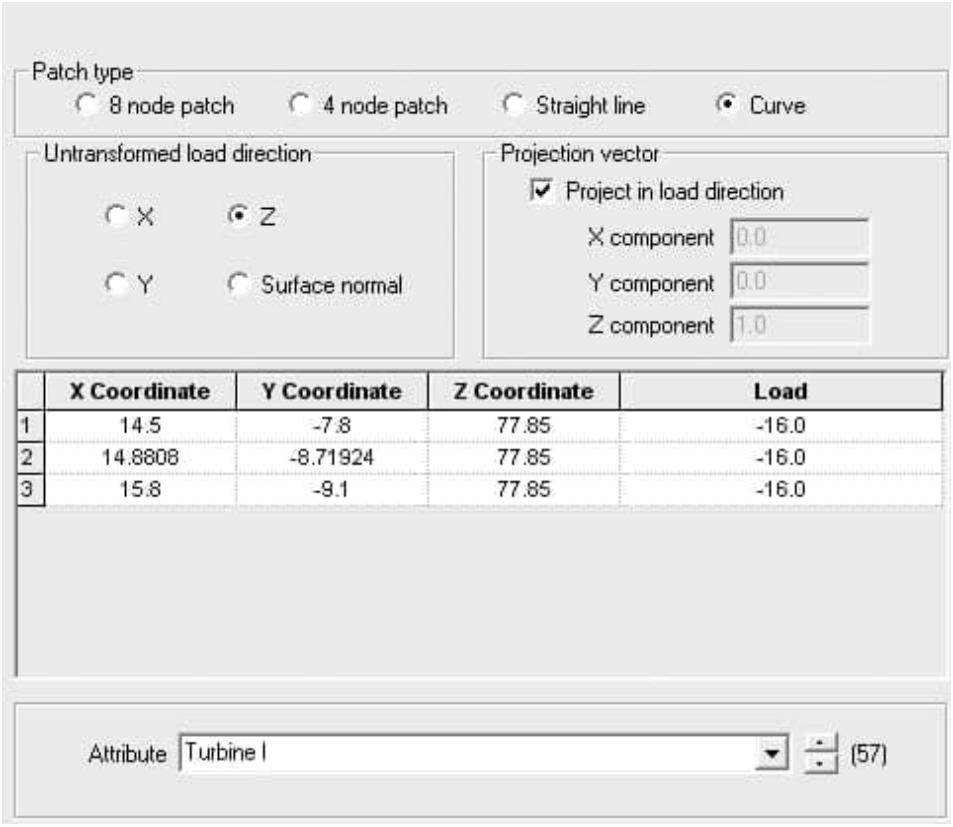
Structural loading : Discrete patch load

Search area : Slab 3

Force type : Per unit area

Component z direction : $-16\frac{kN}{m}$

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	14.5	-7.8	77.85	-16.0
2	14.8808	-8.71924	77.85	-16.0
3	15.8	-9.1	77.85	-16.0

Loading: Turbine II

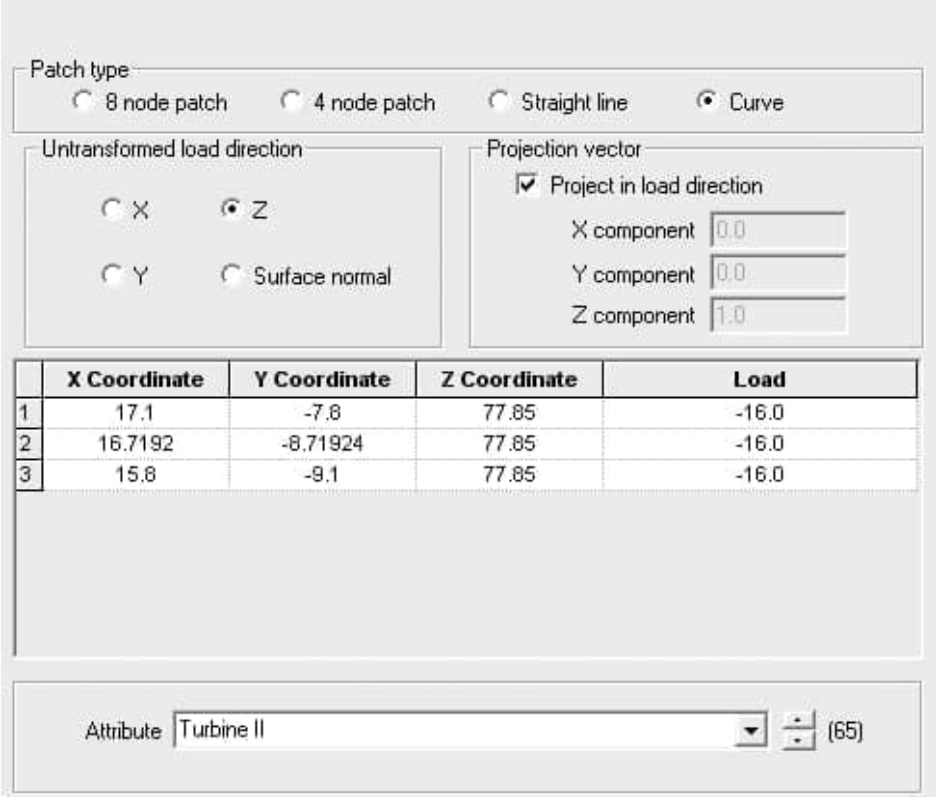
Structural loading : Discrete patch load

Search area : Slab 3

Force type : Per unit area

Component z direction : $-16\frac{kN}{m}$

Options for load outside search area : Exclude All Load



Loading: Turbine III

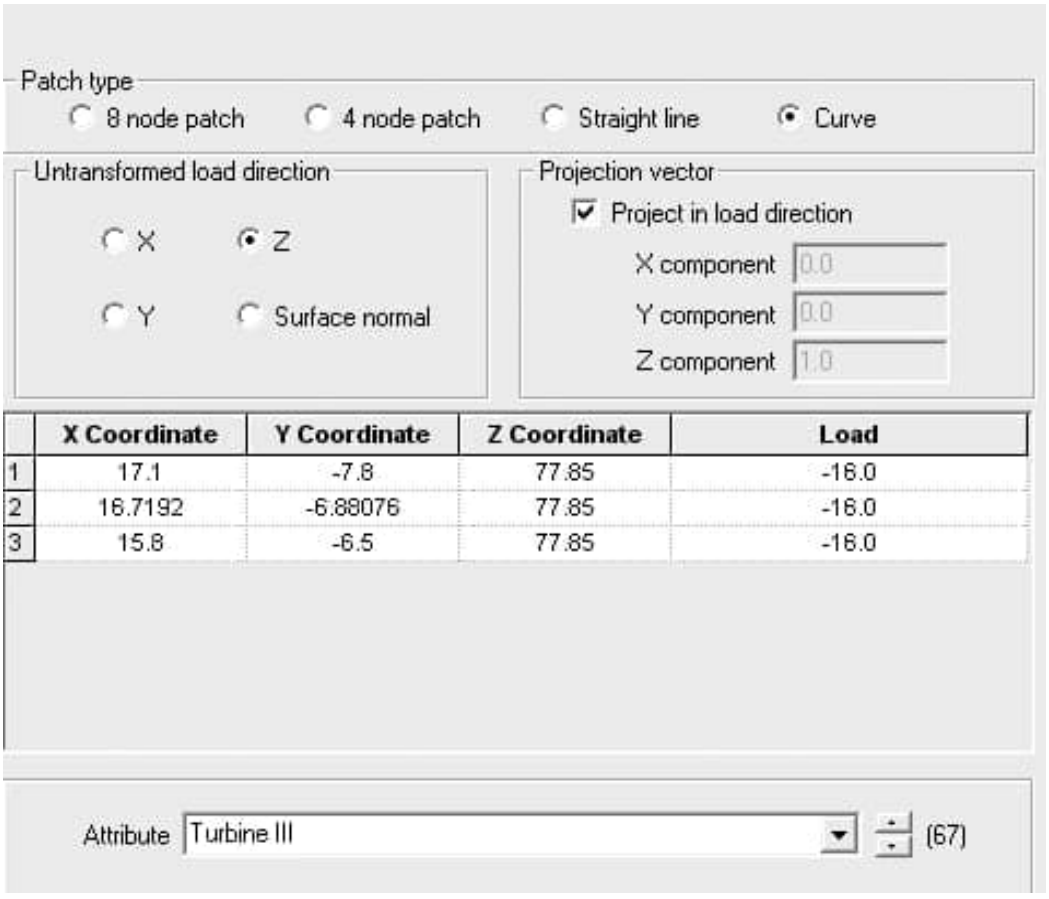
Structural loading : Discrete patch load

Search area : Slab 3

Force type : Per unit area

Component z direction : $-16\frac{kN}{m}$

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	17.1	-7.8	77.85	-16.0
2	16.7192	-6.88076	77.85	-16.0
3	15.8	-6.5	77.85	-16.0

Loading: Turbine IV

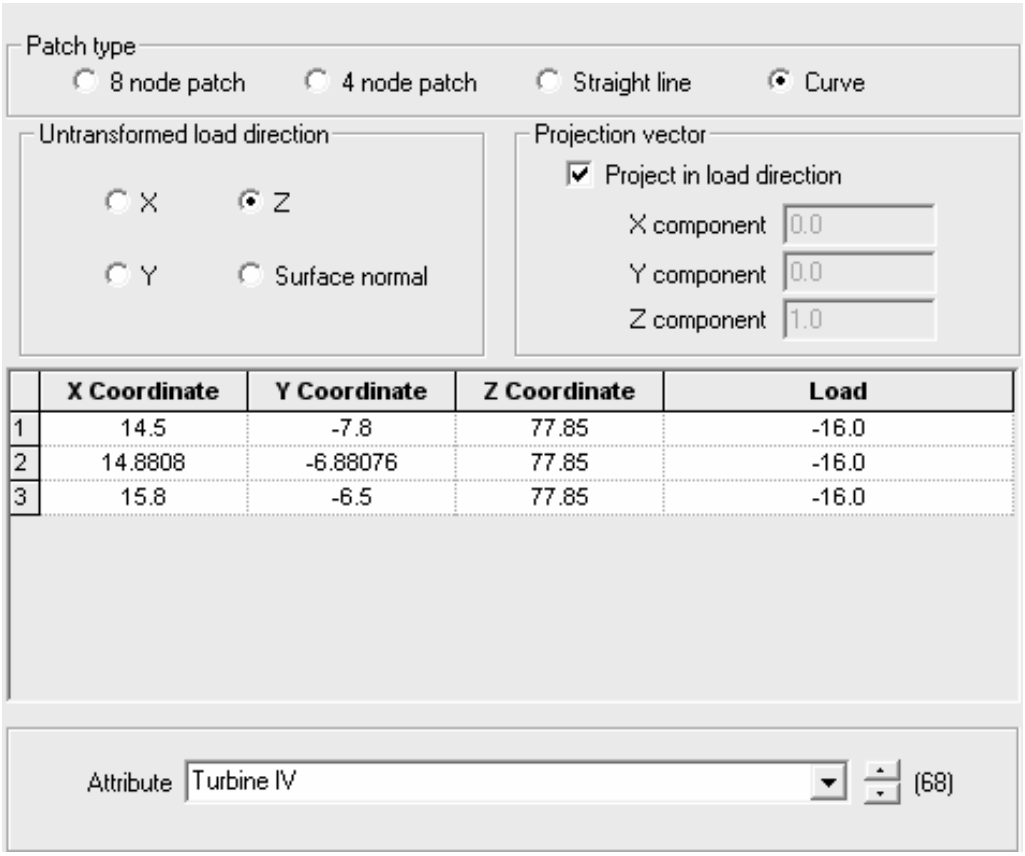
Structural loading : Discrete patch load

Search area : Slab 3

Force type : Per unit area

Component z direction : $-16\frac{kN}{m}$

Options for load outside search area : Exclude All Load

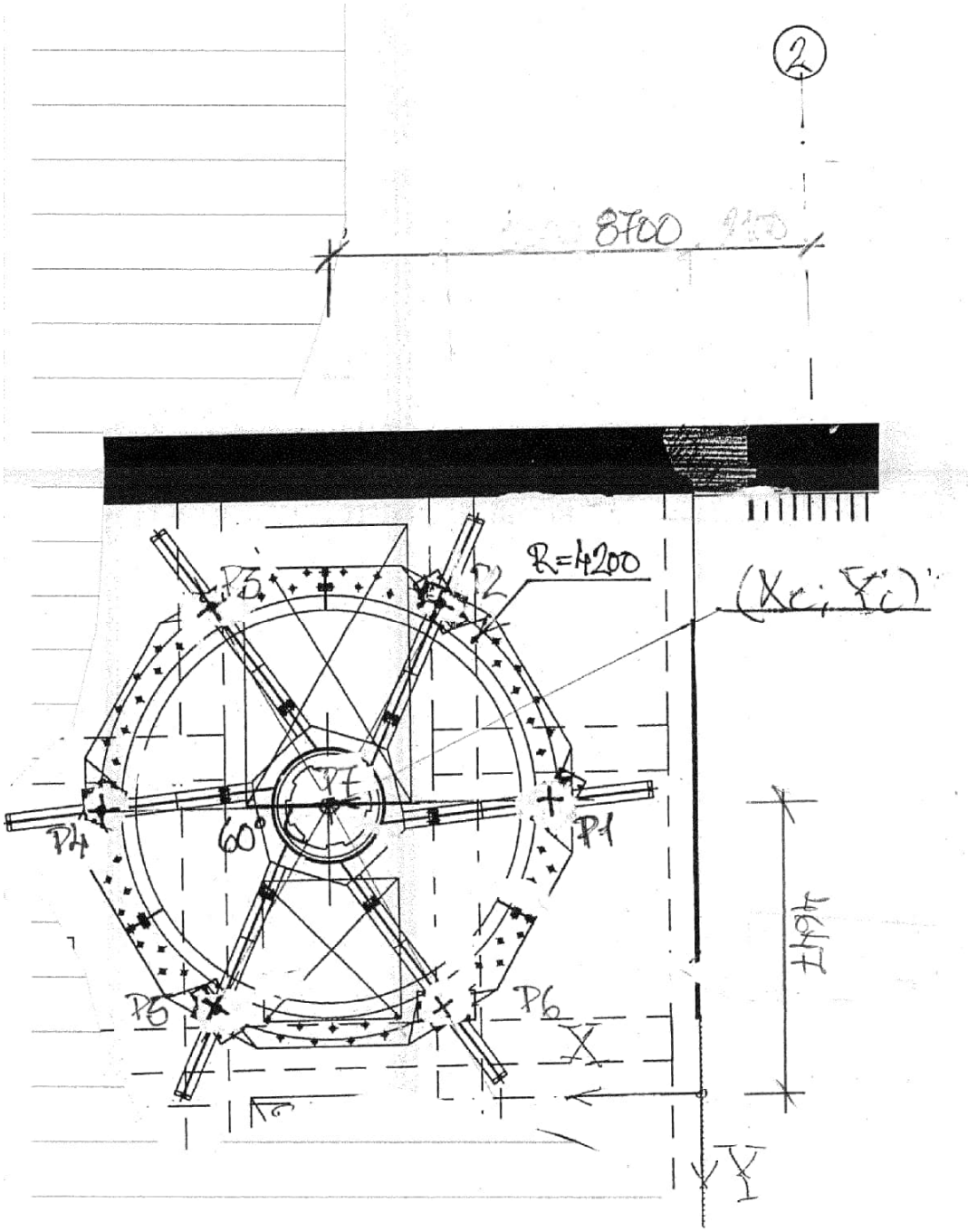


	X Coordinate	Y Coordinate	Z Coordinate	Load
1	14.5	-7.8	77.85	-16.0
2	14.8808	-6.88076	77.85	-16.0
3	15.8	-6.5	77.85	-16.0

Loadcase: Turbine

Loading : Turbine I / Turbine II / Turbine III / Turbine IV

3.7.2 Stator frame



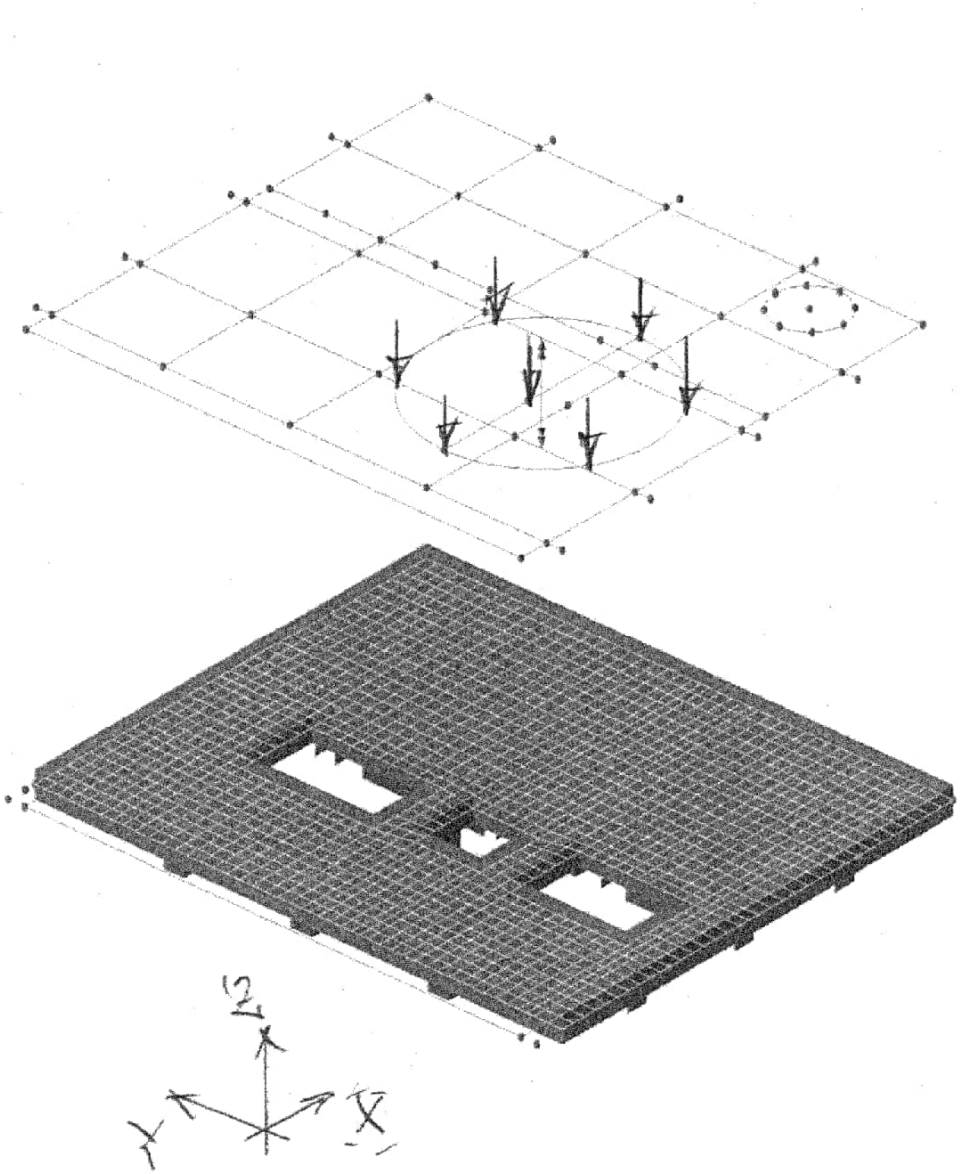
X_c = +7.20 m

Y_c = -4.647 m

The load is considered as 7 point loads.

$\Sigma P = 1200$ kN

$$P = \frac{\Sigma P}{7} = 171 kN$$



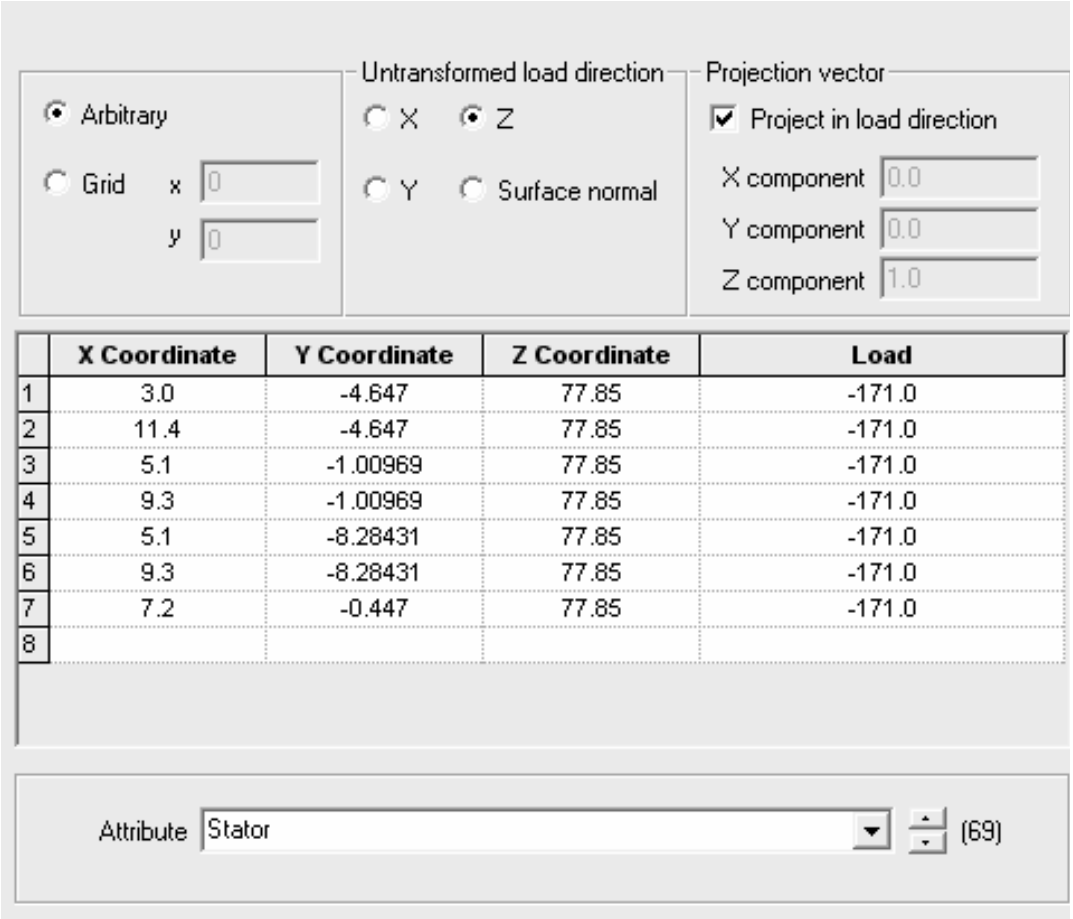
Loadcase: Stator

Structural loading : Discrete patch load

Search area : Slab 3

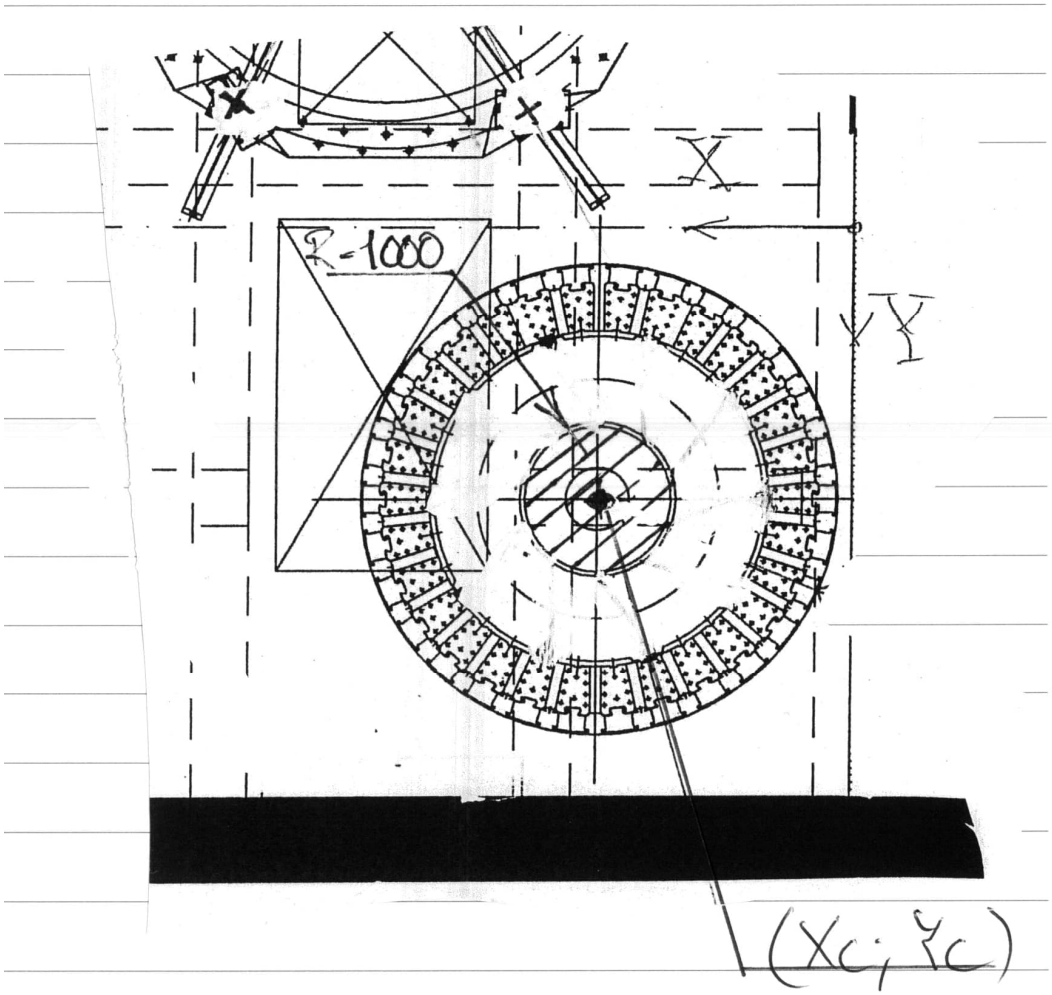
Discrete load : Stator

Options for load outside search area : Exclude All Load



	X Coordinate	Y Coordinate	Z Coordinate	Load
1	3.0	-4.647	77.85	-171.0
2	11.4	-4.647	77.85	-171.0
3	5.1	-1.00969	77.85	-171.0
4	9.3	-1.00969	77.85	-171.0
5	5.1	-8.28431	77.85	-171.0
6	9.3	-8.28431	77.85	-171.0
7	7.2	-0.447	77.85	-171.0
8				

3.7.3 Generator rotor



The load is considered as a line load with circular form. In order to model this load it is divided into 4 separte parts I-IV

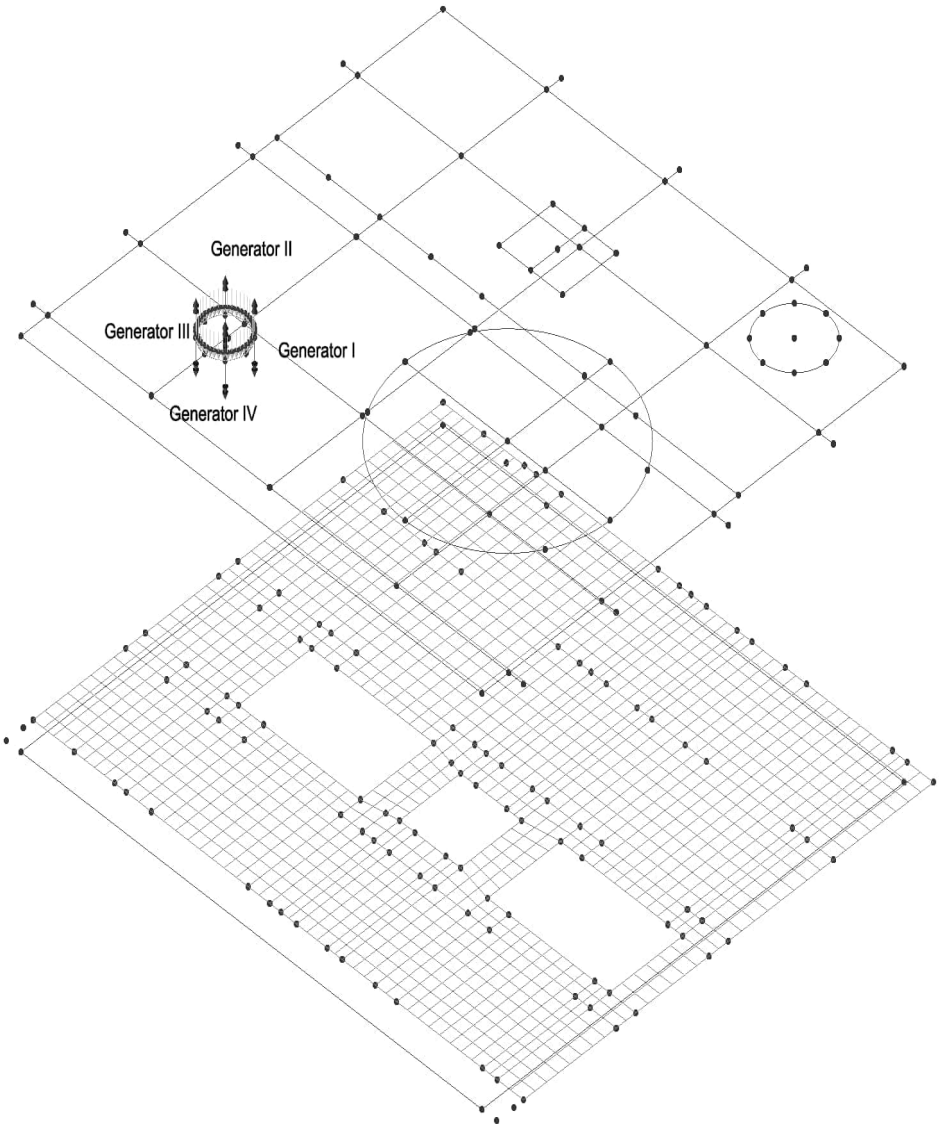
$\Sigma P = 2000$ kN

R = 0.85 m

$$p = \frac{\Sigma P}{2\pi R} = 375 \frac{kN}{m}$$

$X_c = +4.15$ m

$Y_c = +3.875$ m


Generator II
Generator III
Generator I
Generator IV

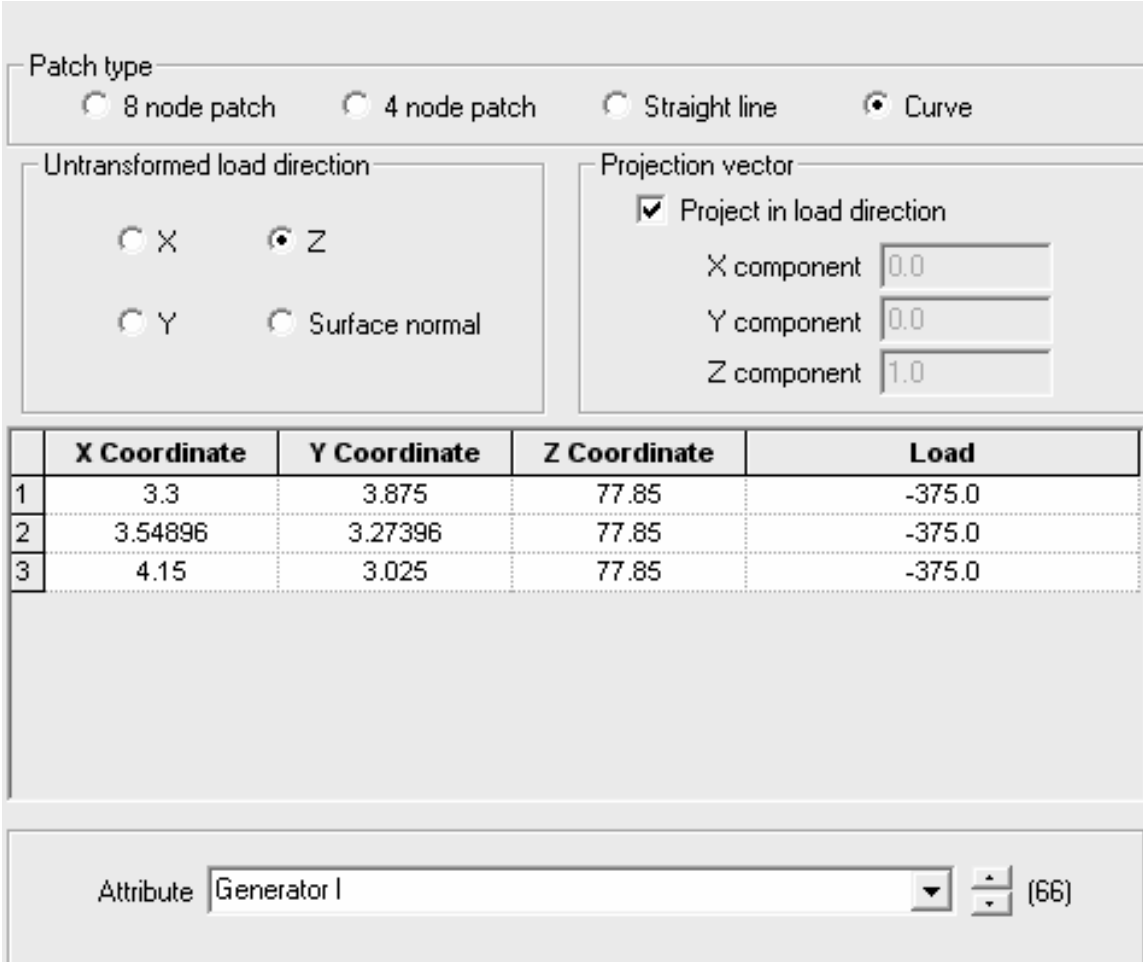
Loadcase: Generator I

Search area : Slab 3

Force type : Per unit area

Component z direction : $-375\frac{kN}{m}$

Options for load outside search area : Exclude All Load



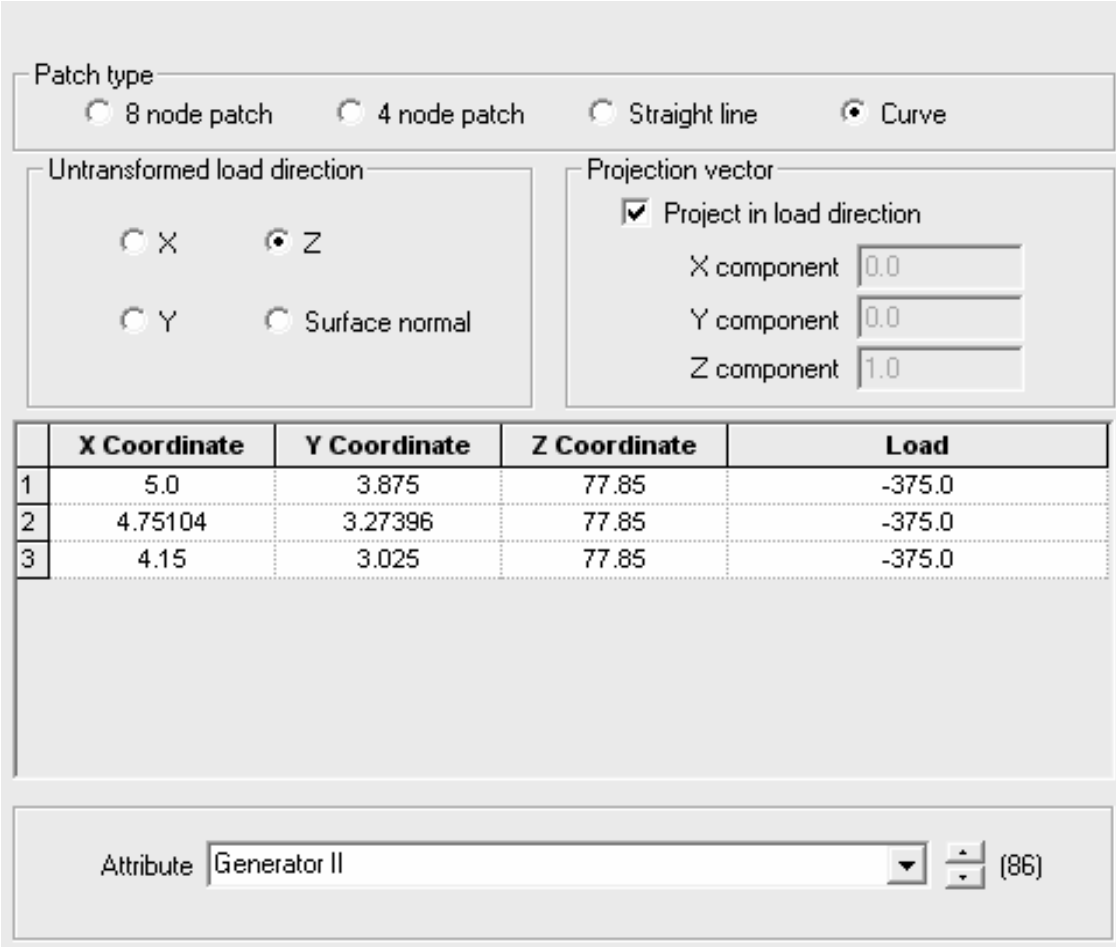
Loadcase: Generator II

Search area : Slab 3

Force type : Per unit area

Component z direction : $-375\frac{kN}{m}$

Options for load outside search area : Exclude All Load



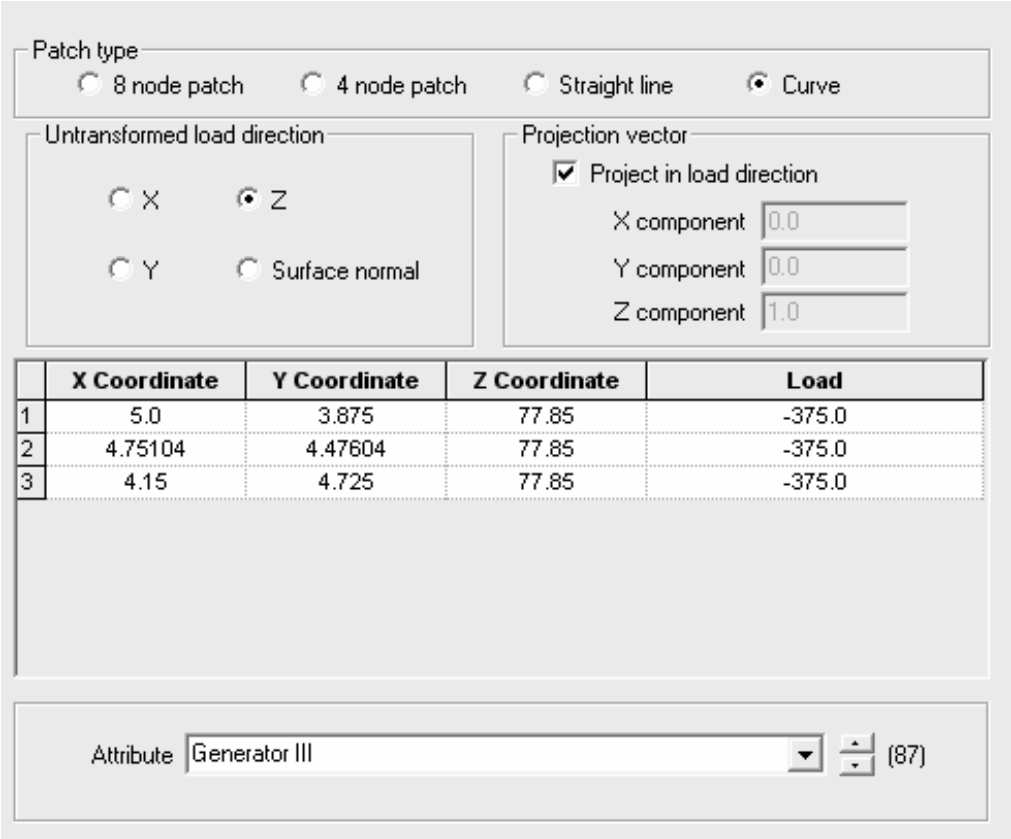
Loadcase: Generator III

Search area : Slab 3

Force type : Per unit area

Component z direction : $-375\frac{kN}{m}$

Options for load outside search area : Exclude All Load



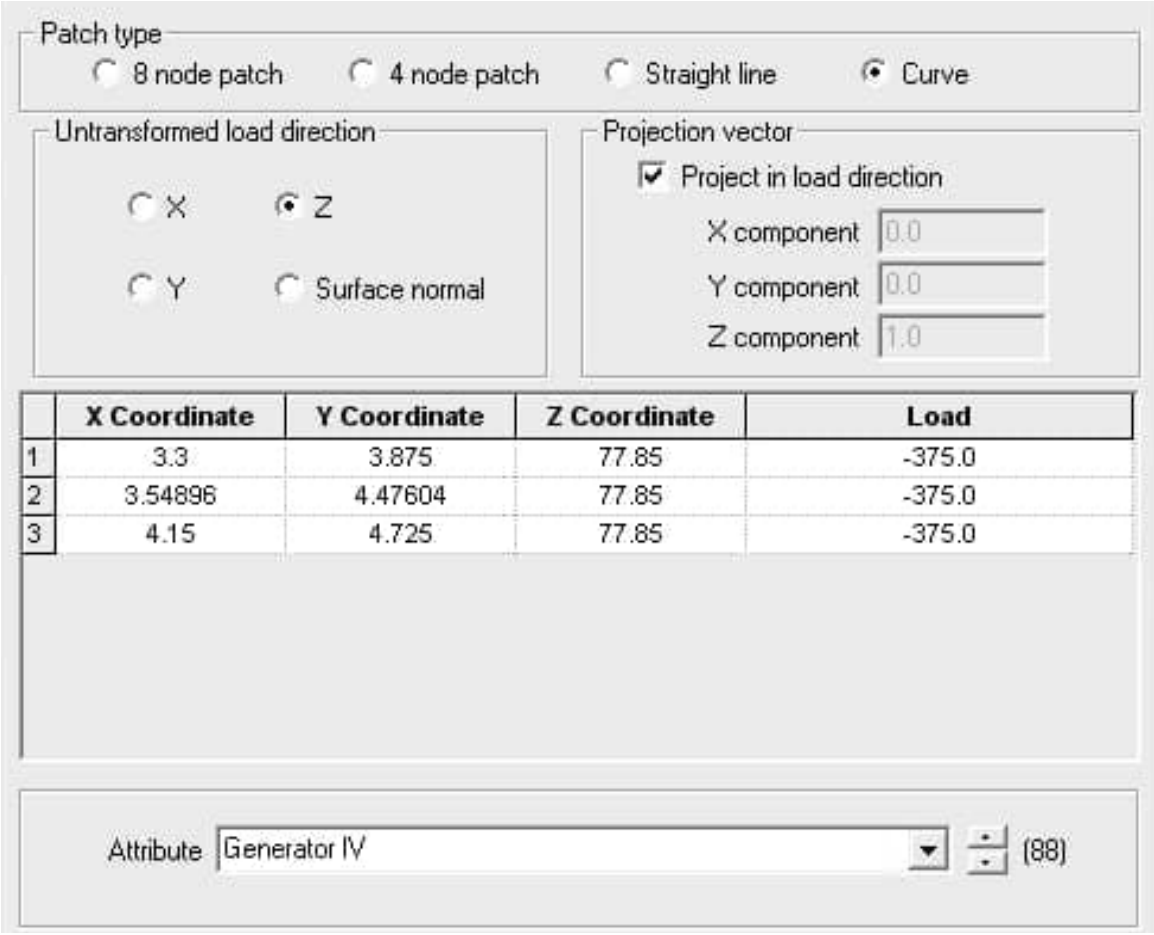
Loadcase: Generator IV

Search area : Slab 3

Force type : Per unit area

Component z direction : $-375\frac{kN}{m}$

Options for load outside search area : Exclude All Load

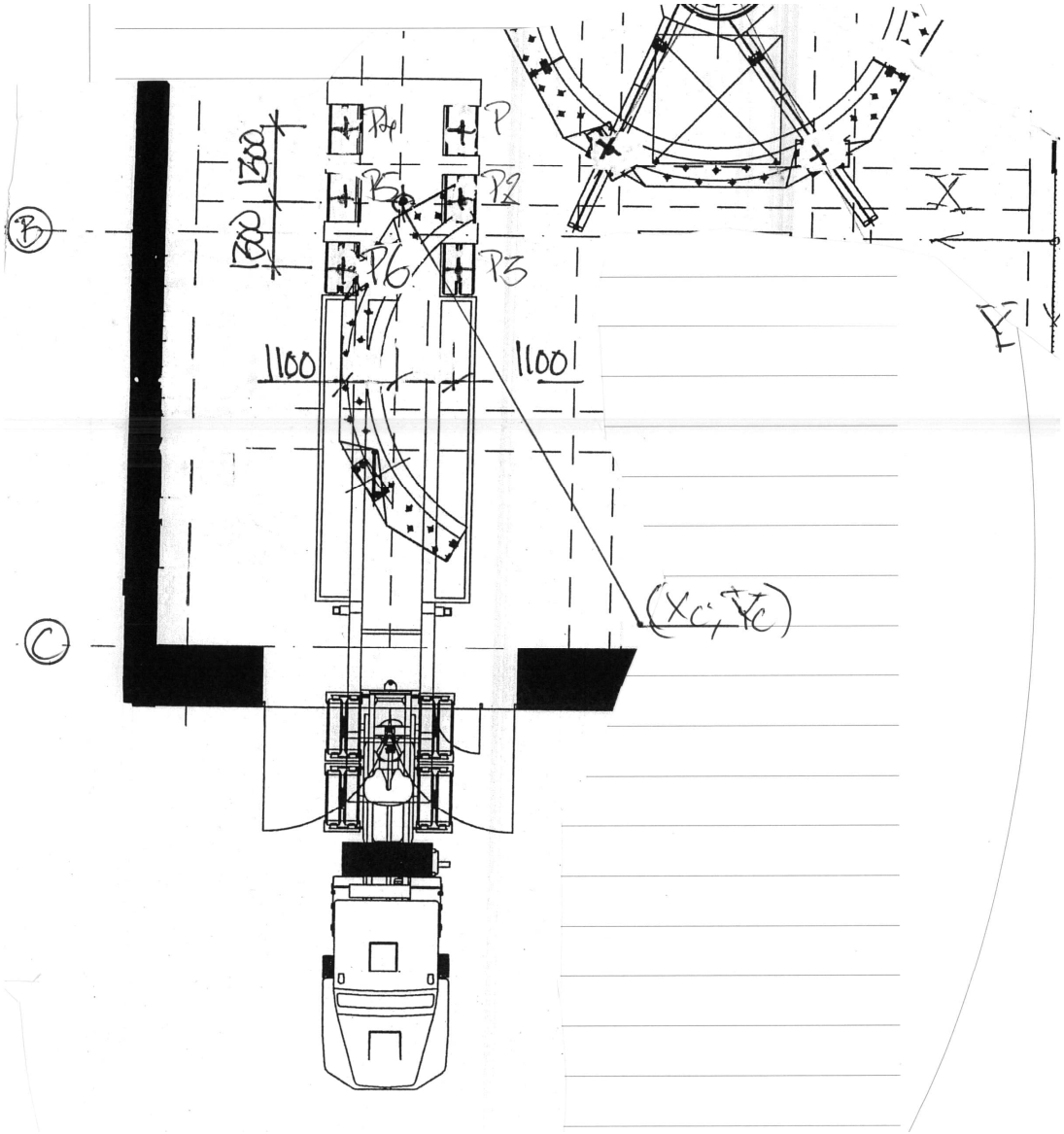


	X Coordinate	Y Coordinate	Z Coordinate	Load
1	3.3	3.875	77.85	-375.0
2	3.54896	4.47604	77.85	-375.0
3	4.15	4.725	77.85	-375.0

Loadcase: Generator

Loading : Generator I / Generator II / Generator III / Generator IV

3.7.4 Trailer load



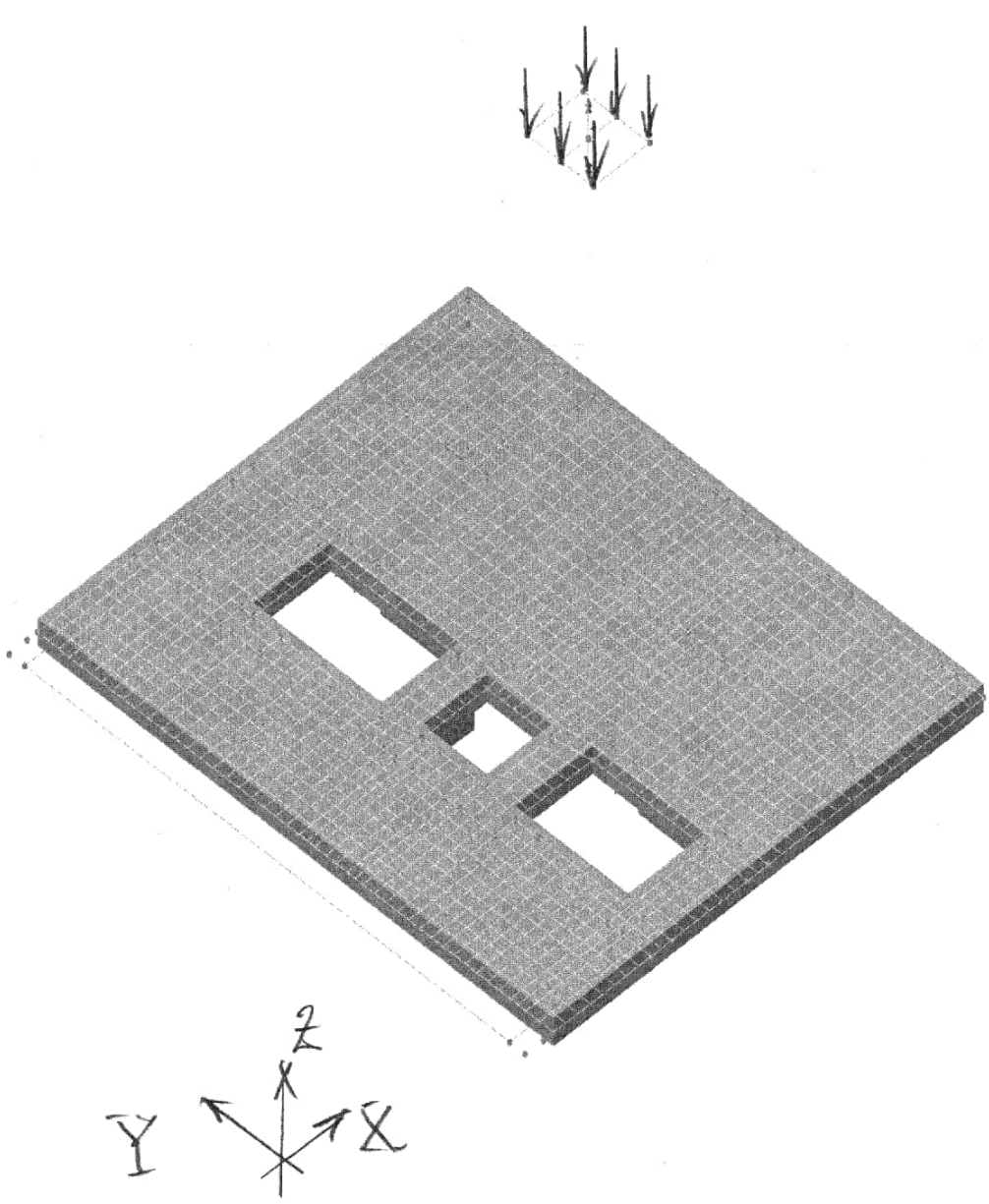
The load is considered as 6 point loads.

$\Sigma P = 130$ kN

$$P = \frac{\Sigma P}{6} = 22kN$$

X_c = +13.30 m

Y_c = +77.85 m



Loadcase: Trailer

Structural loading : Discrete patch load

Search area : Slab 3

Discrete load : Trailer

Options for load outside search area : Exclude All Load

$$P = \frac{\sum P}{6} = \frac{130kN}{6} = 22kN$$

3.7.5 Load combinations

Smart loadcombination : Machine load

Loadcase	Permanent factor	Variable factor
Turbine	0	1.00
Strator	0	1.00
Generator	0	1.00
Trailer	0	1.00

3.8 WIND LOAD

The effect of wind is neglected at the study of concrete structure since it is considered neglectable.

3.9 EARTHQUAKE LOADS

The effect of earthquake is considered by using at simplified method. The method increases the effect of dead weight as seen below (see also OTR 5.6.4).

3.9.1 Unusual loading

The effect is considered by increasing loadcase Dead Weight by 10 % in both vertical and horizontal directions.

Load effect of earthquake (E) : 1.9·0.10D =0.19D

Loadcase surcharge/dead weight are used to create loadcase earthquake. This is a simplification but considered on the safe side since the resultant of horizontal force is higher than assumed due to the fact that exterior wall is thicker at the bottom than at the top of the structure.

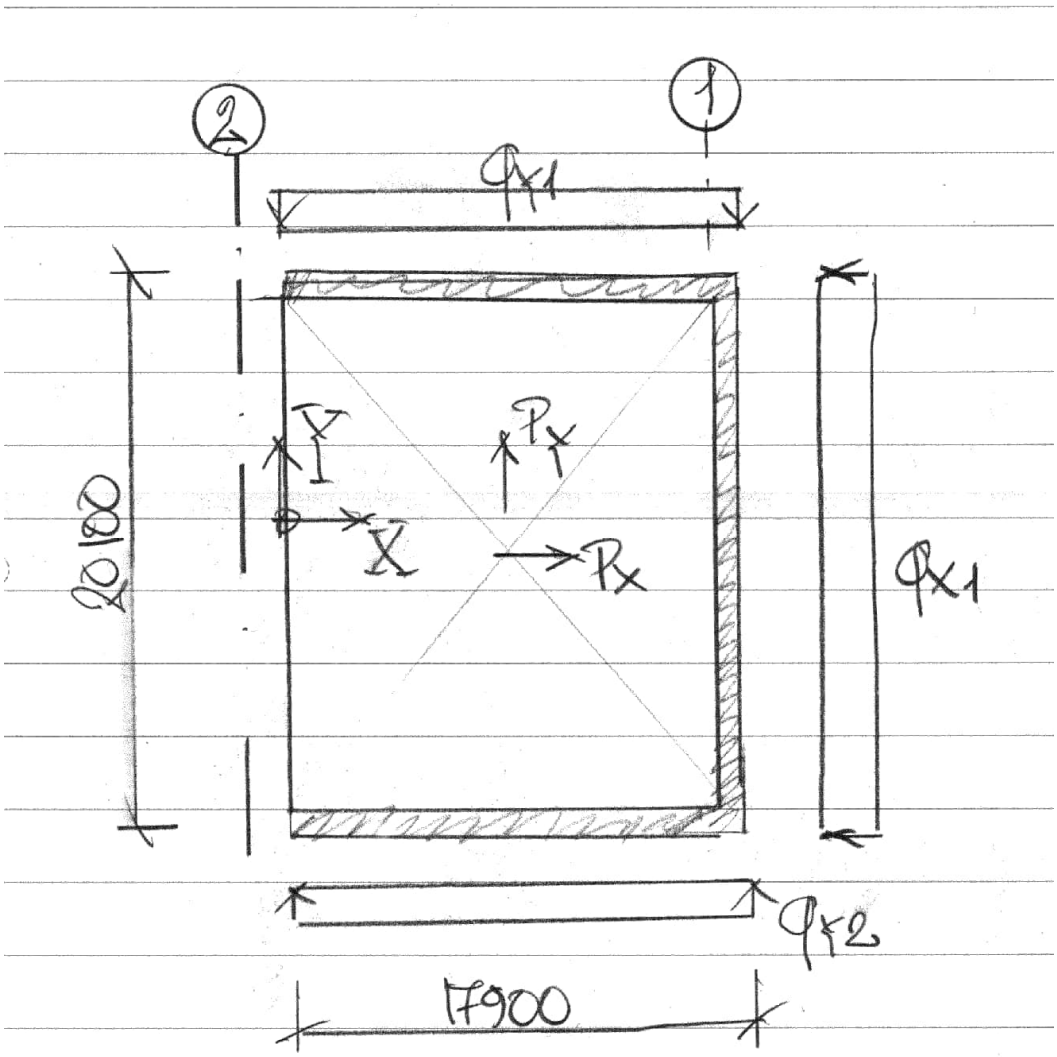
Loading in vertical direction :

The load effect is transformed using load case *Dead Weight*.

$f_E = 0.10$

Loading in horizontal direction :

The load effect is transformed using load case *Surcharge*.



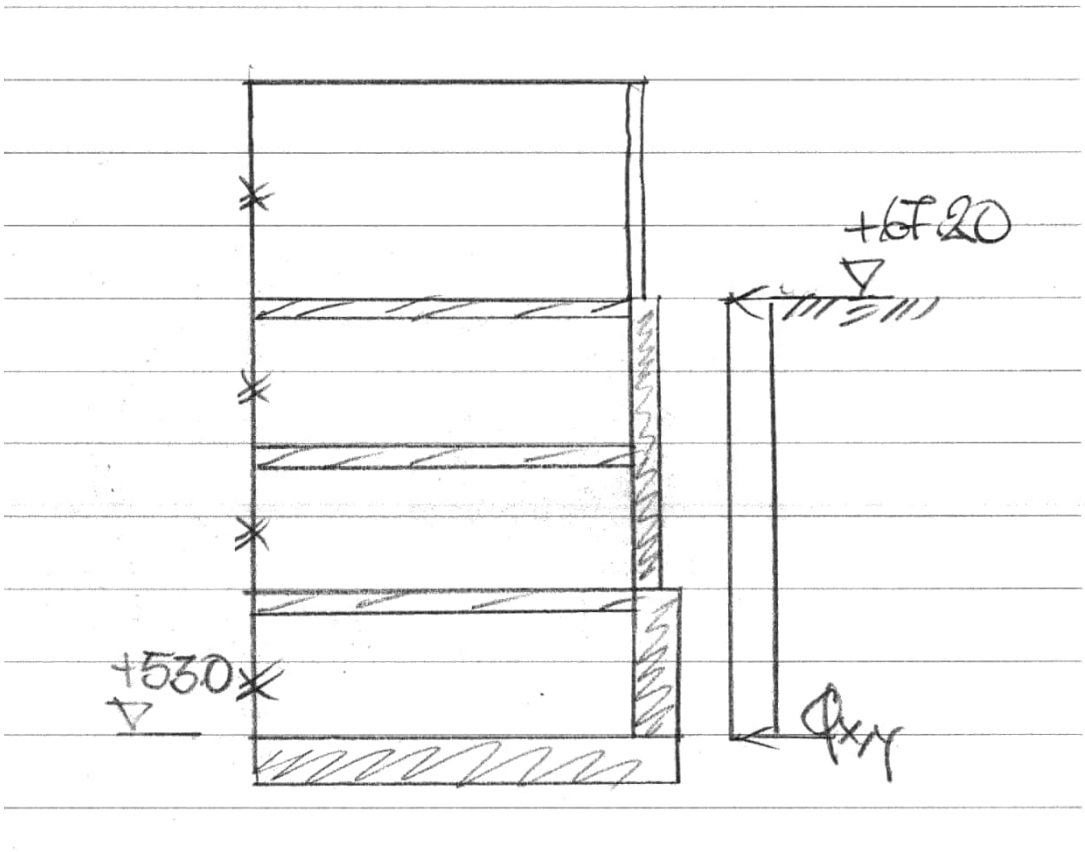
Total dead weight : ΣP= 53440 kN

$P_x = P_y = 0.1 \cdot \Sigma P = 5344$ kN

Surcharge qx1 : P_x =1054 kN $\Rightarrow f_{E.x1} = \frac{5344kN}{1054kN} = 5.1$

Surcharge qy1 : P_y =965 kN $\Rightarrow f_{E.y1} = \frac{5344kN}{965kN} = 5.5$

Surcharge qy2 : P_y =965 kN $\Rightarrow f_{E.y2} = \frac{5344kN}{965kN} = 5.5$



Basic loadcombinations :

Loadcombinations	Loadcase	Load factor
Earthquake max qx	Surcharge qx1	+5.10
Earthquake min qx	Surcharge qx1	-5.10
Earthquake max qy	Surcharge qy1	+5.50
Earthquake min qy	Surcharge qy2	+5.50
Earthquake max qz	Dead weight 1	+0.10
Earthquake min qz	Dead weight 1	-0.10

Smart loadcombination : Earthquake

Loadcombinations	Permanent factor	Variable factor
Earthquake max qx	0	1
Earthquake min qx	0	1
Earthquake max qy	0	1
Earthquake min qy	0	1
Earthquake max qz	0	1
Surcharge qy2	0	1

3.9.2 Extreme loading

The effect is considered by increasing loadcase Dead Weight by 15 % in both vertical and horizontal directions.

Load effect of earthquake (E) : $1.25 \cdot 0.15D = 0.1875D$

Since $0.19D > 0.1875D$ the effect of earthquake is neglected.

3.10 LOAD COMBINATIONS

Document OTR part B chapter 5.5.3 requires control of 6 loading conditions as seen bellow.

L.C.1 Construction stage loading
L.C.2 Operating stage loading
L.C.3 Design flood loading
L.C.4 Earthquake during operating loading
L.C.5 Earthquake during construction stage loading
L.C.6 Post earthquake loading

Control is conducted for L.C.2 and L.C.4 which are considered most dangerous

Remark

In order to avoid checking service state reinforcement the load effect for ultimate state is increased by 33 % (see ACI 10.5.3) when designing.

The hydraulic factor $H_f = 1.3$ applied to load effect in order to avoid using $0.9 \cdot 1.3$ when studying unfavourable effect of permanent loads.

Since extreme earthquake load is less dangerous than unusual earthquake load when appling correct load coefficent it is not considered, see page A3:82.

3.10.1 L.C.2

Presented load combination “Ultimate State” corresponds to normal loading corresponds during operating stage.

Normal loading – Max : $U_h = 1.7 \cdot (D+W+E+L)$

Normal loading – Min : $U_h = 0.9 \cdot (D+W+E) + 1.7 \cdot L$

Loadcase	Permanent factor	Variable factor
Dead loads (D)	0.90	0.80
Water loads (W)	0.90	0.80
Earth pressure (E)	0.90	0.80
Surcharge (L)	0	1.70
Surface load (L)	0	1.70
Crain load (L)	0	1.70
Machine load (L)	0	1.70

Loadcombination smart *Permanent Ultimate:LLW*

Loadcase	Permanent factor	Variable factor
Dead weight	0.90	0.70
Water LLW	0.90	0.70
Earth pressure LLW	0.90	0.70

Loadcombination smart *Permanent Ultimate:HHW*

Loadcase	Permanent factor	Variable factor
Dead weight	0.90	0.70
Water HHW	0.90	0.70
Earth pressure HHW	0.90	0.70

Envelope *Permanent Ultimate*

Loadcombination
Permanent Ultimate:LLW
Permanent Ultimate:HHW

Loadcombination smart *Variable Ultimate*

Loadcases to concider : 4

Variable cases : 4

Loadcase	Permanent factor	Variable factor
Surcharge	0	1.70
Surface load	0	1.70
Crain load	0	1.70
Machine load	0	1.70

Loadcombination smart *Ultimate*

Loadcase	Permanent factor	Variable factor
Permanent Ultimate	1.00	0
Variable Ultimate	0	1.00

3.10.2 L.C.4

Presented load combination "Accident State" corresponds to unusual loading corresponds during operating stage.

Unusual loading – Max : $U_h = 1.7 \cdot (D+W+E+L) + 1.9 \cdot E$

Unusual loading – Min : $U_h = 0.9 \cdot (D+W+E) + 1.7 \cdot L + 1.9 \cdot E$

Loadcase	Permanent factor	Variable factor
Dead loads (D)	0.90	0.80
Water loads (W)	0.90	0.80
Earth pressure (E)	0.90	0.80
Surcharge (L)	0	1.70
Surface load (L)	0	1.70
Crain load (L)	0	1.70
Machine load (L)	0	1.70

Loadcombination smart *Permanent Accident:LLW*

Loadcase	Permanent factor	Variable factor
Dead weight	0.90	0.70
Water LLW	0.90	0.70
Earth pressure LLW	0.90	0.70

Loadcombination smart *Permanent Accident:HHW*

Loadcase	Permanent factor	Variable factor
Dead weight	0.90	0.70
Water HHW	0.90	0.70
Earth pressure HHW	0.90	0.70

Envelope *Permanent Accident*

Loadcombination
Permanent Accident:LLW
Permanent Accident:HHW

Loadcombination smart *Variable Accident*

Loadcases to concider : 5

Variable cases : 5

Loadcase	Permanent factor	Variable factor
Surcharge	0	1.70
Surface load	0	1.70
Crain load	0	1.70
Machine load	0	1.70
Earthquake	0	1.90

* = Vertical contribution of earthquake loading
** = Horisontall contribution of earthquake loading

Loadcombination smart *Accident*

Loadcase	Permanent factor	Variable factor
Permanent Accident	1.00	0
Variable Accident	0	1.00