TECHNICAL REPORT

Project Name:

Design of 9-Year School "Emin Duraku",

Tirana Municipality

Programme Title: ***EU for Schools***

Financed by: ***European Union EU***

Design Team: ***HT Construction (High Tech Construction) ltd*** Hydajet Tota Digitally signed by Hydajet Tota Date: 2022.02.01 03:22:24 +02'00'

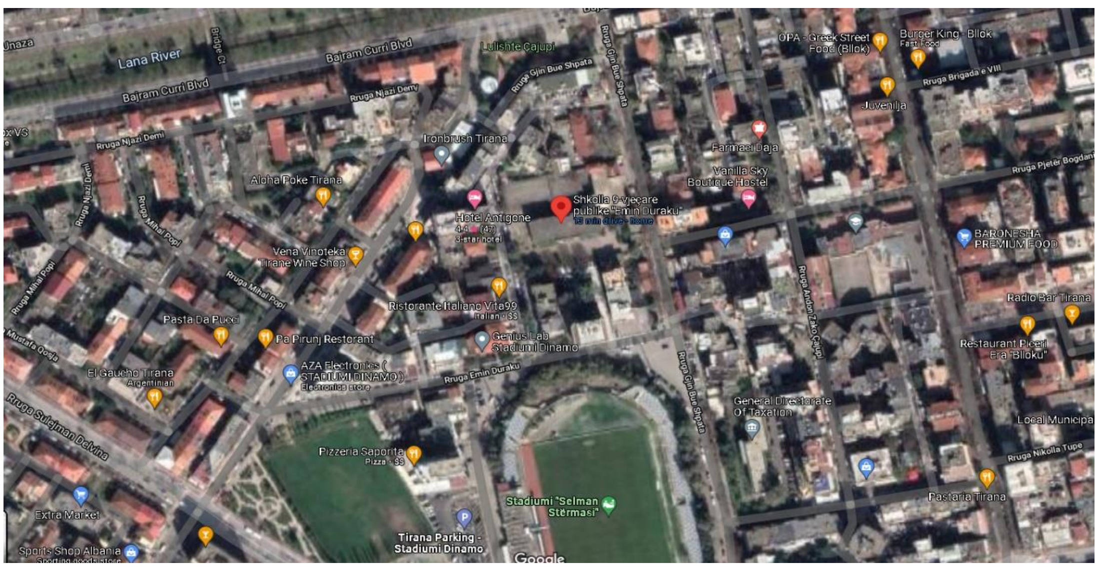
TIRANA, JANUARY 2022

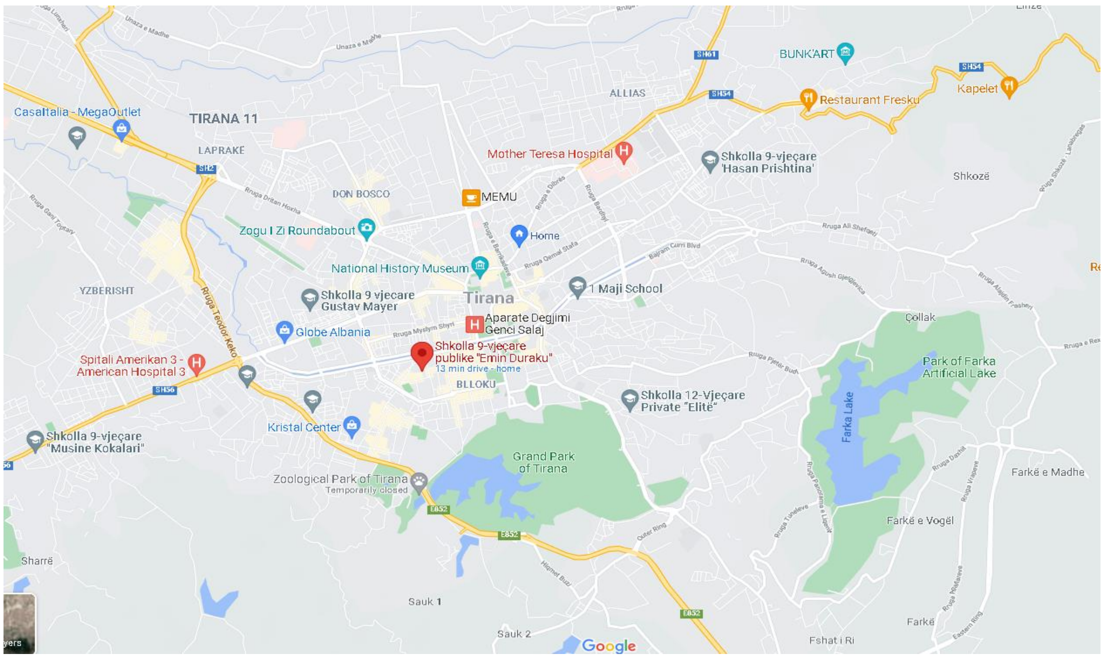
STRUCTURAL TECHNICAL REPORT

Content:

1. Introduction

The construction site of this building is located in "Gjin Bue Shpata" street, Tirana.





The structure of "Reconstruction of 9-Year School "Emin Duraku", Tirana Municipality" is composed of two buildings. "Emin Duraku" school, Tirana, was damaged by the earthquake of November 26, 2019 and was declared unusable.
The new school building is composed of two structures separated by joints expansion.
The gym and entrance are also new structures
The four buildings will be subject of this technical report.

2. General Description of the Structural Calculations

2.1. General Description of the Calculations

The structural system applied is represented by a spatial frame which is connected constructively with cross reinforced concrete beams, which are the principal elements in supporting the vertical and the horizontal loads.

The structures have been analyzed, calculated and dimensioned according to the European Norms of Design of reinforced concrete and steel:

- EuroCode 0

- EuroCode 1
- EuroCode 2
- EuroCode 7
- EuroCode 8

The structural analyze it is also based on:

- Architectonical Design
- Geological and Geotechnical Report
- Engineering- Seismological Report

The calculation of the structures is done by modeling them with Etabs and Sap2000 software. In these software’s the modeling is made with planes. This means that the dimensions of the elements (like beams, columns walls etc) are determined for each floor and level of altitude, always having a spatial view of the structures.
The determination of loads is done as shell elements, but there are also other options like uniformly loads and concentrated loads.

After deterring the geometry of the structure and of the loads (both processes are being made at the same time), we determine the type of analysis (static, pseudo static, dynamic, etc) also the calculating method.

2.2. Design Working Life:

The longevity of the building is determined by Eurocode 0 2.3 Table 2.1 and is 50 years:

Table 2.1 - Indicative design working life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

3. Materials

3.1. Concrete C25/30

For the foundations it's been used concrete C 25/30.

Self weight

$\gamma = 24\ kN/m^3$ (EN1-Annex -A Tab. A.1)

Characteristic compressive cubic strength of concrete at 28 days

$f_{cu} = 30$ MPa. (EN2-3.1.3 Tab. 3.1)

Characteristic compressive cylinder strength of concrete at 28 days

$f_{ck} = 25$ MPa. (EN2-3.1.3 Tab. 3.1)

Modulus of elasticity of concrete
E_c=31 GPa. (EN2-3.1.3 Tab. 3.1)

Design value of concrete compressive strength fcd = 16.67 MPa. (EN2-3.1.6)

ku:fcd =αcc * fck / yc (EN2-3.1.6)

y_c = 1.5 (EN-8 -3.3.3.1 Tabela 3.1)

Table 2.1N: Partial factors for materials for ultimate limit states

Design situations	γ_C for concrete	γ_S for reinforcing steel	γ_S for prestressing steel
Persistent & Transient	1,5	1,15	1,15
Accidental	1,2	1,0	1,0

α_{cc}=0.8-1 (EN2-3.1.6)

f_{ctm} = 0.3 x f_{ck} ^ (2/3) =2.6 MPa. (EN2-3.1.3 Tabela 3.1)

(f_{ctk} 0.05=0.7 x f_{ctm}) =1.8 MPa. (EN2-3.1.3 Tabela 3.1)

Poisson coefficient

ν=0.2 (EN2-3.1.3(4))

3.2. Concrete C30/37

C30 / 37 concrete was used for the other elements

Self weight

γ = 24 kN/m3 (EN1-Annex -A Tab. A.1)

Characteristic compressive cubic strength of concrete at 28 days

f_{cu} = 37 MPa. (EN2-3.1.3 Tab. 3.1)

Characteristic compressive cylinder strength of concrete at 28 days

f_{ck} = 30 MPa. (EN2-3.1.3 Tab. 3.1)

Modulus of elasticity of concrete

Ec=33 GPa. (EN2-3.1.3 Tab. 3.1)

Design value of concrete compressive strength

f_{cd} = 20 MPa. (EN2-3.1.6)

ku:$f_{cd} = \alpha_{cc} * f_{ck} / y_c$ (EN2-3.1.6)

$y_c = 1.5$ (EN-8 -3.3.3.1 Tabela 3.1)

Table 2.1N: Partial factors for materials for ultimate limit states

Design situations	γ_C for concrete	γ_S for reinforcing steel	γ_S for prestressing steel
Persistent & Transient	1,5	1,15	1,15
Accidental	1,2	1,0	1,0

α_{cc}=0.8-1 (EN2-3.1.6)

f_{ctm} = 0.3 x f_{ck} ^ (2/3) =2.9 MPa. (EN2-3.1.3 Tabela 3.1)

(f_{ctk} 0.05=0.7 x f_{ctm}) =2.03 MPa. (EN2-3.1.3 Tabela 3.1)

Poisson coefficient

ν=0.2 (EN2-3.1.3(4))

EN 1992-1-1:2004 (E)

Table 3.1 Strength and deformation characteristics for concrete

	Strength classes for concrete														Analytical relation / Explanation
f_{ck} (MPa)	12	16	20	25	30	35	40	45	50	55	60	70	80	90	
$f_{ck,cube}$ (MPa)	15	20	25	30	37	45	50	55	60	67	75	85	95	105	
f_{cm} (MPa)	20	24	28	33	38	43	48	53	58	63	68	78	88	98	$f_{cm} = f_{ck}+8$(MPa)
f_{ctm} (MPa)	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1	4,2	4,4	4,6	4,8	5,0	$f_{ctm}=0{,}30\times f_{ck}^{(2/3)}$ ≤C50/60; $f_{ctm}=2{,}12\cdot\ln(1+(f_{cm}/10))$ > C50/60
$f_{ctk,0,05}$ (MPa)	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9	3,0	3,1	3,2	3,4	3,5	$f_{ctk;0,05} = 0{,}7\times f_{ctm}$ 5% fractile
$f_{ctk,0,95}$ (MPa)	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3	5,5	5,7	6,0	6,3	6,6	$f_{ctk;0,95} = 1{,}3\times f_{ctm}$ 95% fractile
E_{cm} (GPa)	27	29	30	31	33	34	35	36	37	38	39	41	42	44	$E_{cm} = 22[(f_{cm})/10]^{0,3}$ (f_{cm} in MPa)
ε_{c1} (‰)	1,8	1,9	2,0	2,1	2,2	2,25	2,3	2,4	2,45	2,5	2,6	2,7	2,8	2,8	see Figure 3.2; ε_{c1}(‰) $= 0{,}7\, f_{cm}^{0,31} < 2{,}8$
ε_{cu1} (‰)	3,5									3,2	3,0	2,8	2,8	2,8	see Figure 3.2; for $f_{ck} \geq 50$ Mpa ε_{cu1}(‰)$=2{,}8+27[(98-f_{cm})/100]^4$
ε_{c2} (‰)	2,0									2,2	2,3	2,4	2,5	2,6	see Figure 3.3; for $f_{ck} \geq 50$ Mpa ε_{c2}(‰)$=2{,}0+0{,}085(f_{ck}-50)^{0,53}$
ε_{cu2} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.3; for $f_{ck} \geq 50$ Mpa ε_{cu2}(‰)$=2{,}6+35[(90-f_{ck})/100]^4$
n	2,0									1,75	1,6	1,45	1,4	1,4	for $f_{ck} \geq 50$ Mpa $n=1{,}4+23{,}4[(90-f_{ck})/100]^4$
ε_{c3} (‰)	1,75									1,8	1,9	2,0	2,2	2,3	see Figure 3.4; for $f_{ck} \geq 50$ Mpa ε_{c3}(‰)$=1{,}75+0{,}55[(f_{ck}-50)/40]$
ε_{cu3} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.4; for $f_{ck} \geq 50$ Mpa ε_{cu3}(‰)$=2{,}6+35[(90-f_{ck})/100]^4$

3.3. Environmental Condition

- The environmental conditions taken into consideration for the slabs are XC1

- The environmental conditions taken into consideration for the foundation tiles and the walls of the basement are XC2
- The environmental conditions taken into consideration for beams and columns are XC3

Table 4.1: Exposure classes related to environmental conditions in accordance with EN 206-1

Class designation	Description of the environment	Informative examples where exposure classes may occur
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity
2 Corrosion induced by carbonation		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2
3 Corrosion induced by chlorides		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete components exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4 Corrosion induced by chlorides from sea water		
XS1	Exposed to airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5. Freeze/Thaw Attack		
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents
XF3	High water saturation, without de-icing agents	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation with de-icing agents or sea water	Road and bridge decks exposed to de-icing agents Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zone of marine structures exposed to freezing
6. Chemical attack		
XA1	Slightly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA2	Moderately aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA3	Highly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water

According to the rate of exposition of the table above has been determined the minimal Class of the concrete for the structure.

Exposure classes EN (EN-2-Annex -E Table E.1.N)

Table E.1N: Indicative strength classes

	Exposure Classes according to Table 4.1									
Corrosion										
	Carbonation-induced corrosion				Chloride-induced corrosion			Chloride-induced corrosion from sea-water		
	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2	XS3
Indicative Strength Class	C20/25	C25/30	C30/37		C30/37		C35/45	C30/37	C35/45	

Damage to Concrete							
	No risk	Freeze/Thaw Attack			Chemical Attack		
	X0	XF1	XF2	XF3	XA1	XA2	XA3
Indicative Strength Class	C12/15	C30/37	C25/30	C30/37	C30/37		C35/45

For the foundations it will be used the C25/30 concrete

For the columns, walls, beams, staircases and slabs will be used the C30/37 concrete.

3.4. Defining the Cover of the Concrete

It has been determined according to the Eurocode (Eurocode 2- 4.4.1.2 Table 4.3.N) the classification of the structure for the reduction or the increase of the class of the structure based on the level of exposure of the concrete class:

Table 4.3N: Recommended structural classification

Structural Class							
Criterion	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1	XD2 / XS1	XD3 / XS2 / XS3
Design Working Life of 100 years	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2	increase class by 2
Strength Class [1) 2)]	≥ C30/37 reduce class by 1	≥ C30/37 reduce class by 1	≥ C35/45 reduce class by 1	≥ C40/50 reduce class by 1	≥ C40/50 reduce class by 1	≥ C40/50 reduce class by 1	≥ C45/55 reduce class by 1
Member with slab geometry (position of reinforcement not affected by construction process)	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1
Special Quality Control of the concrete production ensured	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1	reduce class by 1

According to the table above, the structure is classified as S-4 structure (Eurocode 2 4.4.1.2 Table 4.4.N)

Table 4.4N: Values of minimum cover, $c_{min,dur}$, requirements with regard to durability for reinforcement steel in accordance with EN 10080.

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

Also, according to the Eurocode (Eurocode 2 4.4.1.2 formula 4.2) it has been determinate the minimum concrete cover value:

$$c_{min} = \max \{c_{min,b};\ c_{min,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add};\ 10 \text{ mm}\} \quad (4.2)$$

Where $c_{min,b}$ is determined according to Eurocode: (Eurocodi 2 4.4.1.2 Tabela 4.2)

Table 4.2: Minimum cover, $c_{min,b}$, requirements with regard to bond

Bond Requirement	
Arrangement of bars	Minimum cover $c_{min,b}$*
Separated	Diameter of bar
Bundled	Equivalent diameter (ϕ_n)(see 8.9.1)
*: If the nominal maximum aggregate size is greater than 32 mm, $c_{min,b}$ should be increased by 5 mm.	

And $c_{min,dur}$ is determined according to the Eurocode (Eurocode 2 4.4.1.2 Table 4.2.N)

According to all the above information we have considered for our structure the minimum concrete cover value:

- 20 mm for the slabs and staircases,
- 30mm for the beams, reinforced concrete walls and columns
- 40 mm for the foundation beams.

3.5. Reinforced Steel

According to the Eurocode 2 and 8 the reinforcement will be of class C with these properties:

Table C.1: Properties of reinforcement

Product form	Bars and de-coiled rods			Wire Fabrics			Requirement or quantile value (%)
Class	A	B	C	A	B	C	-
Characteristic yield strength f_{yk} or $f_{0,2k}$ (MPa)	400 to 600						5,0
Minimum value of $k = (f_t/f_y)_k$	≥1,05	≥1,08	≥1,15 <1,35	≥1,05	≥1,08	≥1,15 <1,35	10,0
Characteristic strain at maximum force, ε_{uk} (%)	≥2,5	≥5,0	≥7,5	≥2,5	≥5,0	≥7,5	10,0
Bendability	Bend/Rebend test			-			
Shear strength	-			0,3 $A f_{yk}$ (A is area of wire)			Minimum
Maximum deviation from nominal mass (individual bar or wire) (%) — Nominal bar size (mm): ≤ 8 / > 8	± 6,0 / ± 4,5						5,0

Table C.2N: Properties of reinforcement

Product form	Bars and de-coiled rods			Wire Fabrics			Requirement or quantile value (%)
Class	A	B	C	A	B	C	-
Fatigue stress range (MPa) (for N ≥ 2 x 10^6 cycles) with an upper limit of βf_{yk}	≥150			≥100			10,0
Bond: Minimum relative rib area, $f_{R,min}$ — Nominal bar size (mm): 5 - 6 / 6,5 to 12 / > 12	0,035 / 0,040 / 0,056						5,0

The reinforcement of the structure BSt-500s type with the following properties:

Self weight

γ = 78.5 kN/m3 (EN-1-Annex -A Tab. A.4)

Characteristic yield strength of reinforcement

f_{yk} = 500 Mpa

Characteristic tensile strength of reinforcement

f_{tk} = 600 MPa

Modulus of elasticity of steel

E_c = 200 GPa (EN-2-3.2.7 (4))

The coefficient of relative extension > 12 %

As>12%

(f_{tk}/f_{yk}) = 1.2

Partial factor for reinforcing steel:

γ_s = 1.15 (EN-8 -3.3.3.1Tabela 3.1)

Table 2.1N: Partial factors for materials for ultimate limit states

Design situations	γ_C for concrete	γ_S for reinforcing steel	γ_S for prestressing steel
Persistent & Transient	1,5	1,15	1,15
Accidental	1,2	1,0	1,0

Design yield strength of reinforcement

f_{yd} = 43.47 kN/cm2

$f_{yd} = f_{yk}/\gamma_s$ (EN-2-3.2.7)

3.6. Steel Structure

Structural steel is made of weldable carbon of type S-355 with below charachteristics:

Self weight

γ = 7850 Kg/m^3 (EN-1-Annex -A Tab. A.4)

f_u = 430 N/mm^2

Characteristic yield strength of reinforcement

f_y = 275 N/cm^2

Modulus of elasticity of steel

E_s = 210000 N/cm^2 (EN-2-3.2.7 (4))

$(f_u / f_y) >= 1.1$

Partial factor for reinforcing steel:

γ_s = 1.15 (EN-8 -3.3.3.1Tabela 3.1)

Design yield strength of reinforcement:

f_{yd} = 308.7 N/cm^2

Design Strength for concrete, steel and structural steel is by reducing its charachteristic strength with partial factor:

$f_{cd} = f_{ck} / \gamma_c$ (EC2-3.1.6)

$f_{yd} = f_{yk} / \gamma_s$ (EC2-3.2.7)

where; γ_s = Partial factor for reinforcing steel = 1.15, (EN-3 2.4.2.4)

and γ_c = Partial factor for reinforcing steel = 1.5 (EN-2 2.4.2.4)

Table 3.1: Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm²]	f_u [N/mm²]	f_y [N/mm²]	f_u [N/mm²]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550
EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	510	335	490
EN 10025-6				
S 460 Q/QL/QL1	460	570	440	550

3.6.1. *Dimensioning of Main Elements of Steel Structure*

- The steel structure of the Gym is made of two IPE 330 main beams joined by a tyrant 150X150x4 mm and of which connects t with the reinforced concrete columns. The main beams are connecting with the each other with secondary beams IPE 220. The gym columns are reinforced concrete.
- The steel structure of the Entrance is composed of several elements; The main beams are created from plates with thicknesses of 10,12,15 and 20 mm. These beams are connected to each other with elements IPE240 and IPE270. The entrance columns are reinforced concrete

Details of the steel elements of the gym and entrance are given in the detailed drawings that accompany this report. After calculation the below facts were controlled:

a. Bending

$M_{Ed}/M_{c,Rd} \leq 1$ (6.10) (EC3 6.2.5)

Where:

M_{Ed} - maximal moment from loads

$M_{c,Rd}$ - maximal capacity moment

$M_{c,Rd} = Ë_{pl}\, f_y/\gamma_{M0}$ (EC3 6.2.5)

b. Shearing:

$V_{Ed}/V_{c,Rd} \leq 1$ (6.12) (EC3 6.2.6)

$V_{c,Rd} = A_v\, (f_y/\sqrt{3})/\gamma_{M0}$

$A_v = 1.2\, h_ë \times t_ë$ (EC3 6.2.6)

Where:

$h_ë$ - width of flange elements

$t_ë$ - thickness of flange elements

Elements of joints connections (plate) will be made of steel with characteristic strength not lower than elements that it is going to connect. Bolts and other connection elements (plated) are required to be Bolt class 10.9 (EN-3-1-83.1.1 (tabela 3.1):

Table 3.1: Nominal values of the yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolts

Bolt class	4.6	4.8	5.6	5.8	6.8	8.8	10.9
f_{yb} (N/mm^2)	240	320	300	400	480	640	900
f_{ub} (N/mm^2)	400	400	500	500	600	800	1000

4. *Computer Calculation and Analysis*

4.1 *Static and Dynamic Analysis*

4.1.1. *Static Analysis*

The structural static analysis includes solving the system of the following linear equations:

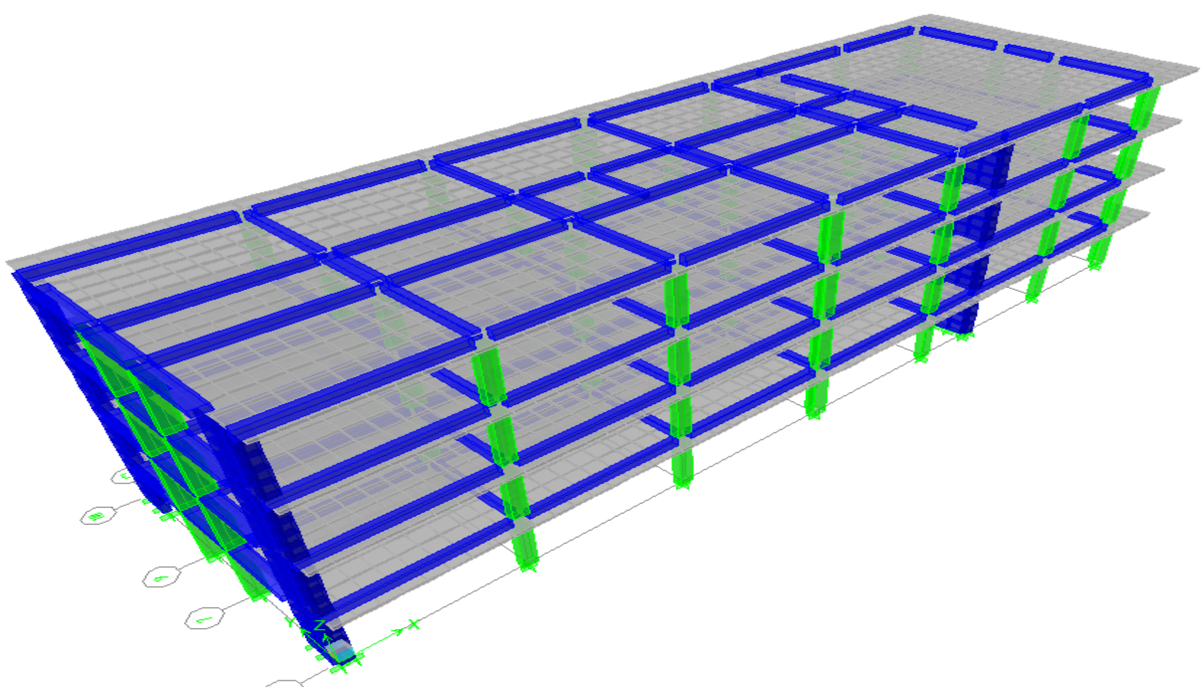
K * u= r (3.1.1)

Where: K- is the matrix of stiffness.

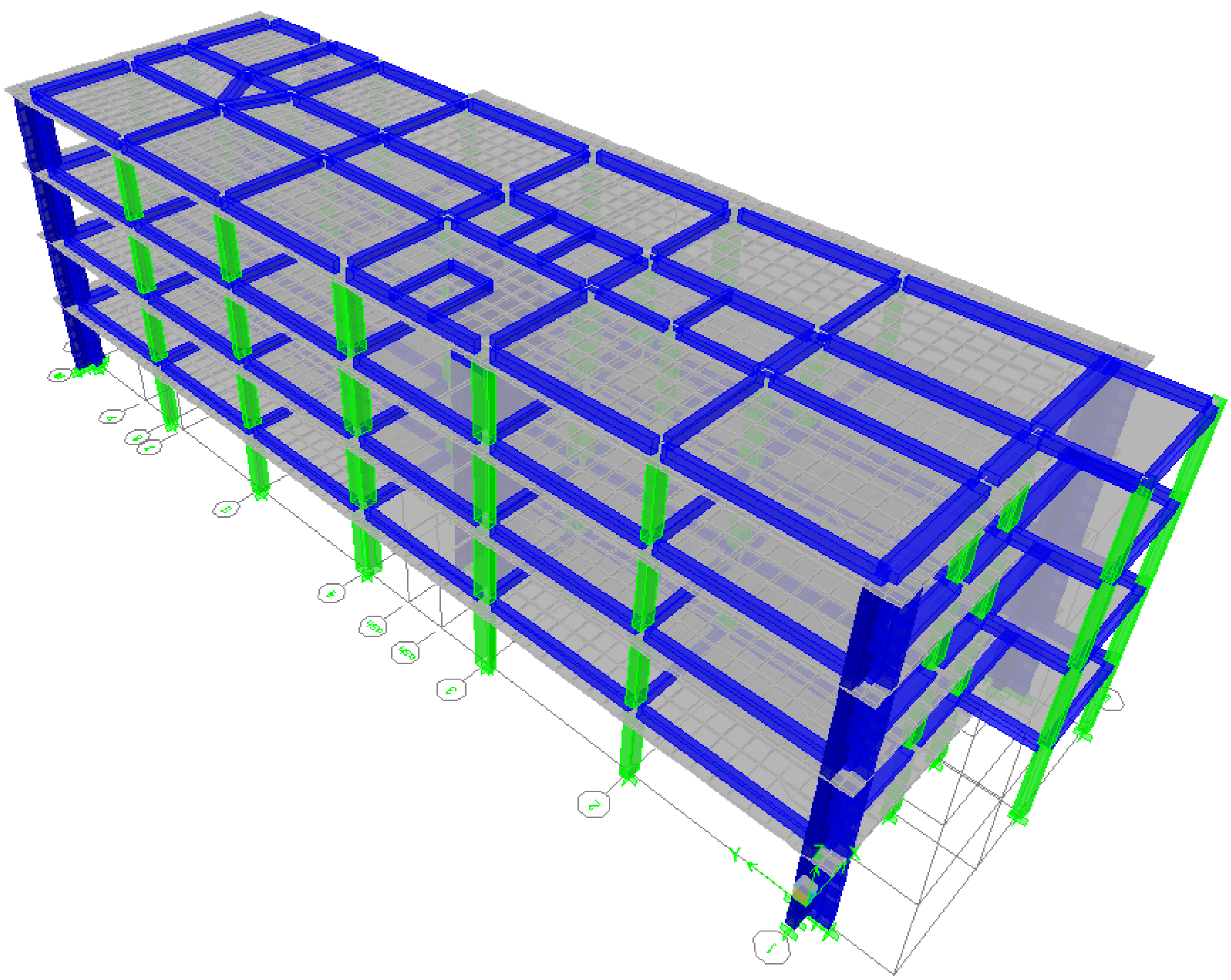
r- is the loads vector that acts on the structure

u- is the displacement vector.

For any case of loading the program automatically creates the "r" vector and determines the displacement vector by solving the system of linear equations (3.1.1).After determining the displacements of all the nodal points it is possible to determine all the values of the generalized internal forces (M22, M33-bending moment according to two directions,Q22, Q33-shear forces according to two directions ,N- axial force , T- torsional moment for each element “frame”, or F11, F22, F12-axial forces for each direction and the bending moments M11, M22, M12-in the perpendicular planes and for each planes for shell elements. Naturally the modeling of the structure and for every element in general, is made according to the finite elements method (FEM) which is an approximate and practical method used widely nowadays due to the superiority of the conditions created by the use of the software’s.



3D Model of Object 1



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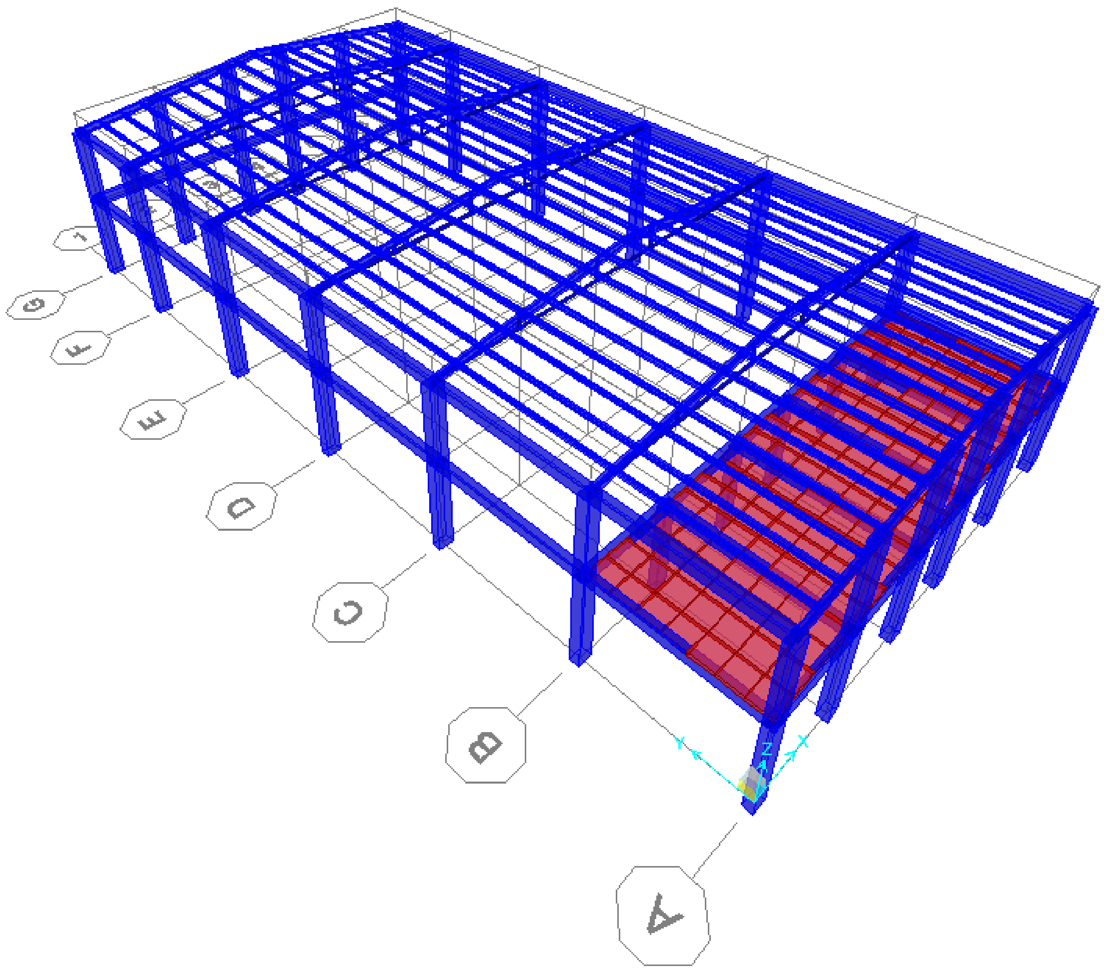
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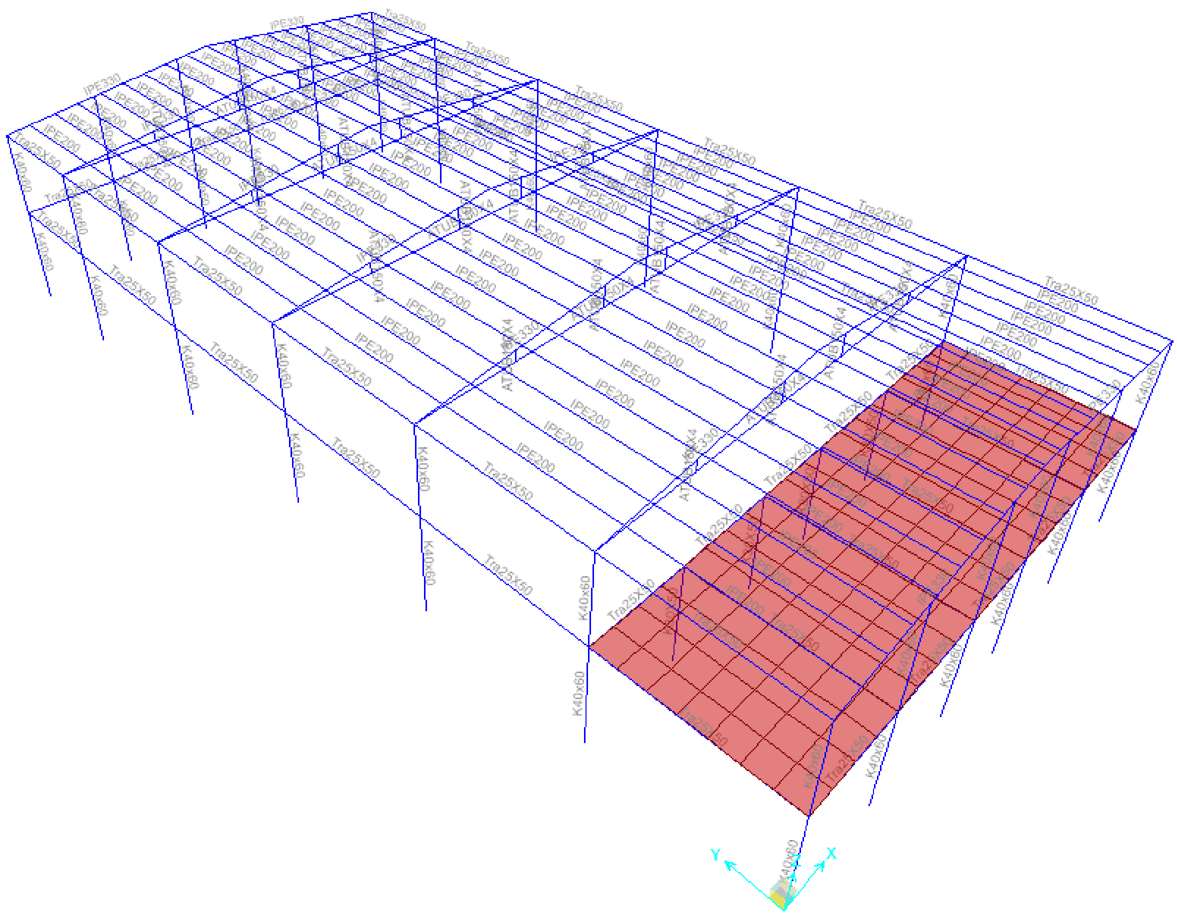
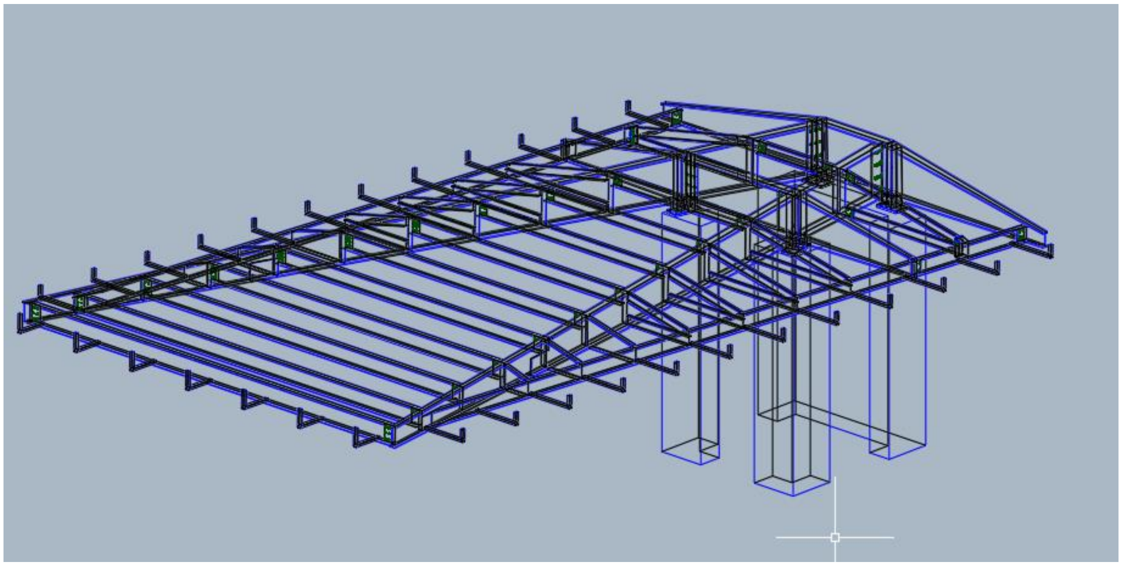


3D Model of the Gym



3D Model of the Entrance

4.1.2. Dynamic Analysis

The Dynamic Analysis of the structure consists on the modal analysis with the specter of reaction method. The designed dynamic loads (seismic) are defined as static equivalent loads and are applied at the points of the concentrated masses.

5. Designed Loads

The following loads have been used for this structure:

5.1. Permanent Loads

Permanent loads in this structure:

- Reinforced slab h=20cm:
  - Solid reinforced slab 500 daN/m²
  - Concrete layers + Tiles 10 cm 180 daN/m²
  - Suspended ceilings + HVAC installations 20 daN/m²

Total	575 daN/m²

- Reinforced slab h=15cm:
  - Solid reinforced slab — 625 daN/m²
  - Concrete layers + Tiles 10 cm — 180 daN/m²
  - Suspended ceilings + HVAC installations — 20 daN/m²

Total	825 daN/m²

- Reinforced slab h=15cm:
  - Solid reinforced slab — 375 daN/m²
  - Concrete layers + Tiles 10 cm — 180 daN/m²
  - Suspended ceilings + HVAC installations — 20 daN/m²

Total	575 daN/m²

Note: The loads of the foundation slab, the columns, reinforced walls and of the beams are taken in consideration from the software by using real dimensions, weight and measurements, according to the information of the materials mentioned at paragraph 3.

5.2. Vertical Linear Loads of the Walls and the other Elements

In case when we have brick walls, the load will be:

- 25cm Wall (bricks with horizontal holes + plaster) — 950 daN/ml
- 12cm Wall (brick with horizontal holes + plaster) — 550 daN/ml
- Gypsum walls (drywall) — 50 daN/ml
- Reinforced concrete parapet — 375 daN/ml
- Structural facade — 300 daN/ml

5.3. Imposed Loads

According to the Eurocode 1, the imposed loads for the structure are determined as:

C1	Table 6.1	(EN1 -6.3.1.1)
H	Table 6.9	(EN-1 -6.3.4.2)

Table 6.1 - Categories of use

Category	Specific Use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B, and D[1])	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3:** Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1:** Areas in general retail shops **D2**: Areas in department stores

[1] Attention is drawn to 6.3.1.1(2), in particular for C4 and C5. See EN 1990 when dynamic effects need to be considered. For Category E, see Table 6.3

NOTE 1 Depending on their anticipated uses, areas likely to be categorised as C2, C3, C4 may be categorised as C5 by decision of the client and/or National annex.

NOTE 2 The National annex may provide sub categories to A, B, C1 to C5, D1 and D2

NOTE 3 See 6.3.2 for storage or industrial activity

And specifically, the imposed loads are:

- Service facilities 3 **kN /m²** Table 6.2 (EN1 -6.3.1.2)
- Staircas facilities 3 **kN /m²** Table 6.2 (EN1 -6.3.1.2)
- Terrace cover 1 **kN /m²** Table 6.9, 6.10 (EN1 -6.3.1.2)
- Atrium cover 0.4 **kN /m²** Table 6.9, 6.10 (EN1 -6.3.1.2)
- Entrance canopy 0.4 kN /**m²** Table 6.9, 6.10 (EN1 -6.3.1.2)

EN 1991-1-1:2002 (E)

Table 6.9 - Categorization of roofs

Categories of loaded area	Specific Use
H	Roofs not accessible except for normal maintenance and repair.
I	Roofs accessible with occupancy according to categories A to D
K	Roofs accessible for special services, such as helicopter landing areas

Table 6.10 - Imposed loads on roofs of category H

Roof	q_k [kN/m^2]	Q_k [kN]
Category H	q_k	Q_k

NOTE 1 For category H q_k may be selected within the range 0,00 kN/m^2 to 1,0 kN/m^2 and Q_k may be selected within the range 0,9 kN to 1,5 kN.

Where a range is given the values may be set by the National Annex. The recommended values are:

$$q_k = 0,4 \text{ kN/m}^2,\ Q_k = 1,0\text{kN}$$

NOTE 2 q_k may be varied by the National Annex dependent upon the roof slope.

NOTE 3 q_k may be assumed to act on an area A which may be set by the National Annex. The recommended value for A is 10 m^2, within the range of zero to the whole area of the roof.

NOTE 4 See also 3.3.2 (1)

Table 6.2 - Imposed loads on floors, balconies and stairs in buildings

Categories of loaded areas	q_k [kN/m^2]	Q_k [kN]
Category A		
- Floors	1,5 to2,0	2,0 to 3,0
- Stairs	2,0 to4,0	2,0 to 4,0
- Balconies	2,5 to 4,0	2,0 to 3,0
Category B	2,0 to 3,0	1,5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
category D		
- D1	4,0 to 5,0	3,5 to 7,0 (4,0)
- D2	4,0 to 5,0	3,5 to 7,0

5.4. Horizontal Loads of the Parapet

According to the Eurocode the horizontal loads are being determined as it follows:

- Horizontal loads of the parapet 0.5 kN /ml Tabela 6.12 EC1-6.4 (Kategoria C1)

Table 6.12 - Horizontal loads on partition walls and parapets

Loaded areas	q_k **[kN/m]**
Category A	q_k
Category B and C1	q_k
Categories C2 –to C4 and D	q_k
Category C5	q_k
Category E	q_k
Category F	See Annex B
Category G	See Annex B

NOTE 1 For categories A, B and C1, q_k may be selected within the range 0,2 to 1,0 (0,5).
NOTE 2 For categories C2 to C4 and D q_k may be selected within the range 0,8 kN/m –to 1,0 kN/m.
NOTE 3 For category C5 q_k may be selected within the range 3,0 kN/m to 5,0 kN/m.
NOTE 4 For category E q_k may be selected within the range 0,8 kN/m to 2,0 kN/m. For areas of category E the horizontal loads depend on the occupancy. Therefore the value of q_k is defined as a minimum value and should be checked for the specific occupancy.
NOTE 5 Where a range of values is given in Notes 1, 2, 3 and 4, the value may be set by the National Annex. The recommended value is underlined.
NOTE 6 The National Annex may prescribe additional point loads Q_k and/or hard or soft body impact specifications for analytical or experimental verification.

5.5. *Seismic Loads*

5.5.1. *Seismic Coefficients in the Structure*

In the modeled structure, the seismic coefficients taken in consideration are as it follows:

According to the seismic report (Eurocode Specter I) (EN8 -3.2.2.2)

Ground acceleration a_{gR}=0.275

According to the seismic report (Eurocode -8)
Soil category: C

There are no risks of cracking of the land, instability of slopes and permanent decrease caused by liquefaction or compression (densification) in case of earthquake.
The topographical amplification is not taken into consideration (EN 1998-1, 3.2.2.1(6))

Importance factor: γ_I **=1.2** Table 4.3 (EN8 -3.2.5 (Cat. III))

Table 5.1: Basic value of the behaviour factor, q_o, for systems regular in elevation

STRUCTURAL TYPE	DCM	DCH
Frame system, dual system, coupled wall system	$3,0\alpha_u/\alpha_1$	$4,5\alpha_u/\alpha_1$
Uncoupled wall system	3,0	$4,0\alpha_u/\alpha_1$
Torsionally flexible system	2,0	3,0
Inverted pendulum system	1,5	2,0

$\mathbf{q_0} = 3.0/a_u/a_1$

wall-equivalent dual, or coupled wall systems: α_u/α_1=1,2. (EN8 -5.2.2.2, 5,b)-)

Our structure is considered irregular in the plan.

For buildings which are not regular in plan (see 4.2.3.2), the approximate value of αu/α1 that may be used when calculations are not performed for its evaluation are equal to the average of (a) 1,0 and of (b) the value given in

In this case:

α_u/α_1=1,1

The behavior factor of the structure by X axes q= 3.60

The behavior factor of the structure by Y axes q= 3.60

The structure is regular in height.

Since our design team will also be supervising the construction of the building, rigorous implementation of the criteria will be required. This may allow us to increase the behavior factor by 20%, which we are leaving in favor of the construction:
If a special and formal Quality System Plan is applied to the design, procurement and construction in addition to normal quality control schemes, increased values of qo may be allowed. The increased values are not allowed to exceed the values given in Table 5.1 by more than 20%. (EN8 -5.2.2.2, 10)

5.5.2. Design Spectrum (calculative) of the Accelerations according to EN-8 (Design of Structures for earthquake Resistance)

The design spectrum ofthe horizontal seismic accelerations for horizontal seismic action according to EN-8,is obtained from the expressions:

$$0 \le T \le T_B : S_d(T) = a_g \cdot S \cdot \left[\frac{2}{3} + \frac{T}{T_B} \cdot \left(\frac{2.5}{q} - \frac{2}{3}\right)\right]$$ (4.3.2.a) (EN-8 -3.2.2.2)

$$T_B \le T \le T_C : S_d(T) = a_g \cdot S \cdot \frac{2.5}{q}$$ (4.3.2.b) (EN-8 -3.2.2.2)

$$T_C \le T \le T_D : S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2.5}{q} \cdot \left[\frac{T_C}{T}\right] \\ \ge \beta \cdot a_g \end{cases}$$ (4.3.2.c) (EN-8 -3.2.2.2)

$$T_D \le T : S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2.5}{q} \cdot \left[\frac{T_C T_D}{T^2}\right] \\ \ge \beta \cdot a_g \end{cases}$$ (4.3.2.d) (EN-8 -3.2.2.2)

where:

S-the soil factor (note the Table 3.2 and 3.3 and the inputs of the seismic-engineering study given as above)

T-the period of the linear structural system with singledegree of freedom considered.

β=0.2 the lower level of the design spectrum for horizontal seismic action

The behavior factor of the structure according to - X axes q=3.0

The behavior factor of the structure according to - Y axes q=3.0

Refering to the recommandations of the (EC-8), the soil is classified as type C with these values of horizontal sprectrum parametres:

S=1.2 T_B(s) =0.15 T_C(s)=0.5 T_D(s)=2 Tabela3.3 (EN-8 -3.2.2.2)

6. Fundamental Requirement

6.1. No Collapse Requirement

a_{gR}=0.275g is the design ground acceleration (type C of the site according to the seismic report and the Eurocode -8)

This a_{gR}=0.275g given from the seismic report represents the reference seismic action associated with a reference probability of exceedance, *P*NCR=10

where T_{NCR}=475 γ= 1.20 (EN8 - 2.2.1)

6.2. Damage Limitation Requirement

a_{gR}=0.1116 g is the design ground acceleration (type C of the site according to the seismic report and Eurocode -8)

This a_{gR} is given from the seismic study for the damage limitation requirement and the probability of exeedance, *PNCR*=10
Where P_{NCR}=95 γ= 1.2 (EN8 - 2.2.1)

To find the maximum possible value of the seismic reaction, it is used the superposition method according to the "complete quadratic combination" (CQC). This type of modal superposition gives more exact results comparing with the combination of the "square root of the sum of squares" (SRSS) for structures with values of consecutive periods (successive) close to each other.

The combination of the directions of the seismic reaction is done basing on the square root of the sum of the squares (SRSS), considering their simultaneous acceptance according to three directions.

The numerical values taken from the seismic spectrum of the structure, are subject to the combinations given in the paragraph 5.1.

7. Designing Criteria

The structure has been calculated for the Ultimate Limit States (ULS) and for the Serviceability Limit States (SLS)

The loads are combined as it follows, where:

IE - is the seismic action for the allowed state under examination,

Gt - is the characteristic value of the permanent action,

Q_{1k} - the characteristic value of the variable action of the situation created by the loads,

Q_{ik} - the characteristic value of the variable i,

γ_g, γ_p and γ_q- are the factors of the partial security,

ψ_{0i}- is a combination factor which gives 95% of the value of the variable action I,

ψ_{2i}- is the combination factor which gives the approximate value of the temporary action of the variable i.

<u>Loads Combination</u>

ULS

Fundamental	$\gamma_g G_k + \gamma_q [Q_{1k} + \Sigma i(\psi_{0i} Q_{ik})]$	(EN0 -6.4.3.4 (6.10))
Seismic	$IE + G_k + \Sigma_i(\Psi_{2i} Q_{ik})$	(EN0 -6.4.3.4 (6.12b))

SLS

Seldom	$G_k + Q_{1k} + \Sigma i(\psi_{0i} Q_{ik})$	(EN0 -6.5.3 (6.14b))
Frequent	$G_k + \psi_{11} Q_{1k} + \Sigma i(\psi_{2i} Q_{ik})$	(EN0 -6.5.3 (6.15b))
Semi permanent	$G_k + \Sigma_i(\psi_{2i} Q_{ik})$	(EN0 -6.5.3 (6.16b))

Coefficients values of temporary loads combination are taken into consideration as it follows:

γ_g= 1.35 (Or 1 if its contribution gives more security)

γ_q= 1.5 (Or 1 if its contribution gives more security)

ψ_{oi}= 0.7, Tab. A1.1 (EN0- A1 2.2)

ψ_{1i} = 0.7, Tab.A1.1 (EN0- A1 2.2)

ψ_{2i} = 0.6, Tab. A1.1 (EN0- A1 2.2)

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0
NOTE The ψ values may be set by the National annex. * For countries not mentioned below, see relevant local conditions.			

Horizontal components of the seismic actions

The seismic action has been taken into consideration with both its orthogonal components, nominated as IEx and IEy, where the two respective actions of the components represent the same reaction spectrum and complete the quadratic combination (CQC) method which is used as combination of the two components.

The two possible combinations are as it follows:

E_{Edx} "+" $0,3*E_{Edy}$ (EN8 -4.3.3.5.2 (4.18))

$0,3*E_{Edx}$ "+" E_{Edy} (EN8 -4.3.3.5.2 (4.19))

Where the '+' implies "to be combined with "

E_{EdX} represents the action effects due to the application of the seismic action along the choosen horizontal axis x of the structure.

E_{Edy} represents the action effects due to the application of the seismic action along the chosen horizontal axis y of the structure.

(1) The internal effect of the design seismic action shall be evaluated by taking into consideration the presence of the masses associated with the gravity loads appearing in the following combinations of actions:

$Gk + \Sigma_i(\psi_{Ei}Q_{ik})$ (EN8 -3.2.4 (3.17))

Where the $\psi_E$is the combination coefficient for the variable action i.

The minimum value of the coefficient combination ψ_{Ei} presented to calculate the effect of the seismic action will be categorized according to the following expressions:

$\psi_{Ei}= \psi_{2i}$ x Φ Tabela 4.2 (EN-8 -4.2.4)

Roof: $\psi_{Ei} = \psi_{2i}$ xΦ =0,6 x 1 = 0,6 (EN-1-Cat C3)

Independently occupied storey: $\psi_{Ei}= \psi_{2i}$ x Φ =0,6x 0,5 =0.3 (EN1-Cat C3)

Stairs : $\psi_{Ei}= \psi_{2i}$ x Φ =0,6x 0,8 = 0,48 (EN1-Cat C3)

Type of variable action	Storey	φ
Categories A-C*	Roof Storeys with correlated occupancies Independently occupied storeys	1,0 0,8 0,5
Categories D-F* and Archives		1,0

7.1. Ultimate Limit State ULS

As the design criteria of this limit state, is the supporting from the structure of a strong earthquake relatively rare,with not strong structural damages as subversion,sliding or total demolition,which may be a risk for the human life.The spectral parameters of this earthquake "the design earthquake",correspond to a repetition period of 475 years and to a non-excess probability of 90% and to a 50 years period of time,given in the forth point.The structure after the earthquake preserves its integrity and considerable bearing capacity.

The combination of the loads is given according to the table:

Load Combinations

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Load Combinations

	Combo	Type	Case	Factor	CaseType	SortID
▶	COMB1	ADD	DEAD	1.0000	Static	1
	COMB1		LIVEAMBIENTE	0.6000	Static	2
	COMB1		LIVETARACE	0.6000	Static	3
	COMB1		LIVESHKALLE	0.6000	Static	4
	COMB1		SPEKX	1.0000	Spectrum	5
	COMB2	ADD	DEAD	1.0000	Static	6
	COMB2		LIVEAMBIENTE	0.6000	Static	7
	COMB2		LIVETARACE	0.6000	Static	8
	COMB2		LIVESHKALLE	0.6000	Static	9
	COMB2		SPEKY	1.0000	Spectrum	10
	DCON2	ADD	DEAD	1.3500	Static	11
	DCON2		LIVEAMBIENTE	1.5000	Static	12
	DCON2		LIVETARACE	1.5000	Static	13
	DCON2		LIVESHKALLE	1.5000	Static	14
	DCON3	ADD	DEAD	1.0000	Static	15
	DCON3		LIVEAMBIENTE	0.3000	Static	16
	DCON3		LIVETARACE	0.3000	Static	17
	DCON3		LIVESHKALLE	0.3000	Static	18
	DCON3		SPEKX	1.0000	Spectrum	19
	DCON4	ADD	DEAD	1.0000	Static	20
	DCON4		LIVEAMBIENTE	0.3000	Static	21
	DCON4		LIVETARACE	0.3000	Static	22
	DCON4		LIVESHKALLE	0.3000	Static	23
	DCON4		SPEKY	1.0000	Spectrum	24
	DCON5	ADD	DEAD	1.0000	Static	25
	DCON5		SPEKX	1.0000	Spectrum	26
	DCON6	ADD	DEAD	1.0000	Static	27
	DCON6		SPEKY	1.0000	Spectrum	28

For the determination of the inputs, as it is described above, the calculation of the structure is done

7.2. Importance Classes for Buildings, Importance Factor and Behaviour Factor

According to EN-8 the building is classified as:

Building whose integrity during earthquakes is of vital importance for civil protection (e.g. schools, assembly halls, cultural institutions etc)

Coefficient of importance of the building: **1.2** Table 4.3 (EN8 -3.2.5 (Kat. IV))

Table 4.3 Importance classes for buildings

Importance class	Buildings
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.
II	Ordinary buildings, not belonging in the other categories.
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.

NOTE Importance classes I, II and III or IV correspond roughly to consequences classes CC1, CC2 and CC3, respectively, defined in EN 1990:2002, Annex B.

7.3. Criteria for Structural Regularity

1. Structural regularity in plan:

The structure we are analyzing is not regular in the plan because:

The plan configuration shall be compact, i.e., each floor shall be delimited by a polygonal convex line. If in plan set-backs (re-entrant corners or edge recesses) exist, regularity in plan may still be considered as being satisfied, provided that these set-backs do not affect the floor in-plan stiffness and that, for each set-back, the area between the outline of the floor and a convex polygonal line enveloping the floor does not exceed 5 % of the floor area. (EN8 -4.2.3.2. (3)

2. Criteria for regularity in elelvation

To determine the regularity in elevation started from the following point:

(3) Both the lateral stiffness and the mass of the individual stories shall remain constant or reduce gradually, without abrupt changes, from the base to the top of a particular building. (EN8 -4.2.3.3. (3)

In eurocode do not suggest or recommended a quantitative critter for reducing stiffness and mass at height, we consider the structure to be relatively regular.

In our judgment the structure can be considered relatively regular in height.

To take this fact into account we have reduced the behavioral factor by 10%.

7.4. The Behaviour Factor of the Structure

The behavior factor in the object is calculated by the following expression:

$q=q_0k_w>1.5$ (5.1) (EN8 -5.2.2.2)

Ku:

q_0 – according to the recommendation of the Eurocode is taken for mixed structures, for DCM (Medium Ductility) is equal to 3.0 α_u / α_1,

$k_w= 1$ (5.2) (EN-8 -5.2.2.2)

$q=3.0\ \alpha_u/\alpha_1$ Table 5.1 (EN-8 -5.2.2.2)

Table 5.1: Basic value of the behaviour factor, q_o, for systems regular in elevation

STRUCTURAL TYPE	DCM	DCH
Frame system, dual system, coupled wall system	$3,0\alpha_u/\alpha_1$	$4,5\alpha_u/\alpha_1$
Uncoupled wall system	3,0	$4,0\alpha_u/\alpha_1$
Torsionally flexible system	2,0	3,0
Inverted pendulum system	1,5	2,0

$\alpha_u/\alpha_1 = 1.2$ wall-equivalent wall system

so, q=3.0*1.20=3.60

The behavior Factor of the structure by X and by Y axis is **q= 3.60**

Our structure is classified as "wall – equivalent" dual system in the direction X and Y

7.5. Accidental Torsional Effects

In order to account for uncertainties in the location of masses and in the spatial variation of the seismic motion, the calculated centre of mass at each floor i shall be considered as being displaced from its nominal location in each direction by an accidental eccentricity:

$$e_{1i} = \pm 0.05 L_i$$ (EN-8 -4.3.2 (4.3))

where: e_{li} - is the accidental eccentricity of storey mass *i* from its nominal location, applied in the same direction at all floors

L_i - is the floor dimension perpendicular to the direction of the seismic action.

8. The Table of the Modal Participation Factor and the Modal Shape

8.1. The Table of the Modal Participation Factor

Modal Participation Factors

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Modal Participation Factors

Mode	Period	UX	UY	UZ	RX	RY	RZ	ModalMass	ModalStiff
1	0.731082	-621.484313	-1.789334	2.014328	22.706747	-7467.18538	76.083061	1.000000	73.863204
2	0.672878	3.417867	-566.962171	0.172710	7096.130142	41.125372	2876.165342	1.000000	87.194006
3	0.582387	4.364282	189.852597	-0.235634	-2295.515281	59.506463	8773.792474	1.000000	116.395421
4	0.227759	-46.955184	0.124642	88.676237	-7.308766	-1485.456839	5.860001	1.000000	761.041927
5	0.224301	-228.181166	-0.131825	-24.002855	4.574339	537.942058	21.883377	1.000000	784.686923
6	0.179509	-0.491930	0.084915	63.942727	-5.005508	-1091.747500	0.809720	1.000000	1225.150856
7	0.178215	0.330973	-267.586404	-0.374818	476.848694	6.041927	853.758056	1.000000	1242.996247
8	0.176264	0.088587	-0.856366	-106.981091	10.082437	1837.557983	3.916212	1.000000	1270.665182
9	0.174161	5.507416	1.073256	-118.466439	7.170083	2032.919888	-10.964186	1.000000	1301.536461
10	0.158197	1.003639	52.202171	0.620779	-90.420099	1.779000	4038.606979	1.000000	1577.487022
11	0.124678	0.872162	-18.886013	0.603728	-416.781272	0.435230	-347.177547	1.000000	2539.674210

OK

The table of the modal participation factor Object 1

Modal Participation Factors

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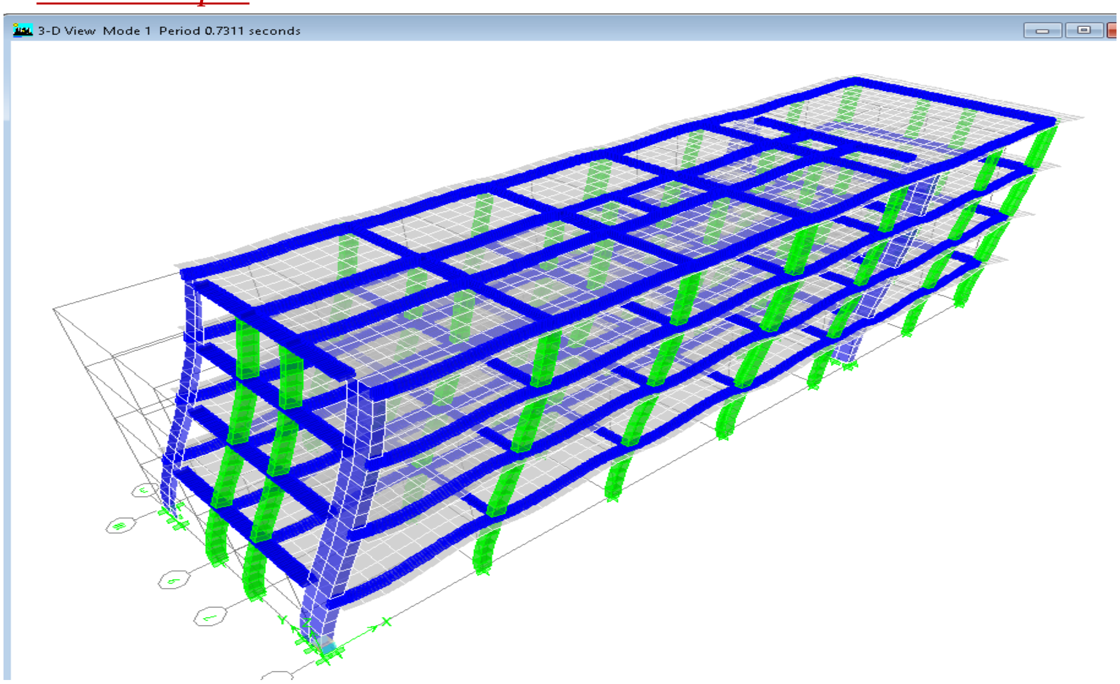
Modal Participation Factors

Mode	Period	UX	UY	UZ	RX	RY	RZ	ModalMass	ModalStiff
1	0.664850	239.195785	-566.080848	0.258857	6896.891872	2956.918751	1192.705716	1.000000	89.312454
2	0.614081	471.084223	247.088898	-1.347585	-3000.091124	5884.182028	4815.218312	1.000000	104.690906
3	0.579635	302.564828	55.586392	1.564383	-670.130913	3756.925957	-8460.34610	1.000000	117.503298
4	0.186835	64.337767	-253.186497	-1.747242	269.407568	82.294297	-41.677424	1.000000	1130.950797
5	0.160357	174.743643	33.661993	2.789314	-22.484683	310.082743	3385.672203	1.000000	1535.263207
6	0.152526	213.007137	61.242035	-2.619444	-229.127943	399.455540	-2779.552002	1.000000	1696.959451
7	0.108214	0.161296	0.127108	-19.045023	-533.994676	-128.040785	-9.392428	1.000000	3371.288626
8	0.104194	-0.999346	-12.272079	140.332244	-2864.503552	166.171415	-22.285878	1.000000	3636.424327
9	0.102843	1.361346	5.929256	-247.365895	-2137.801517	-823.581231	-30.624468	1.000000	3732.589033
10	0.100702	-2.062742	8.886502	-6.225565	784.431010	137.936426	4.583133	1.000000	3892.975280

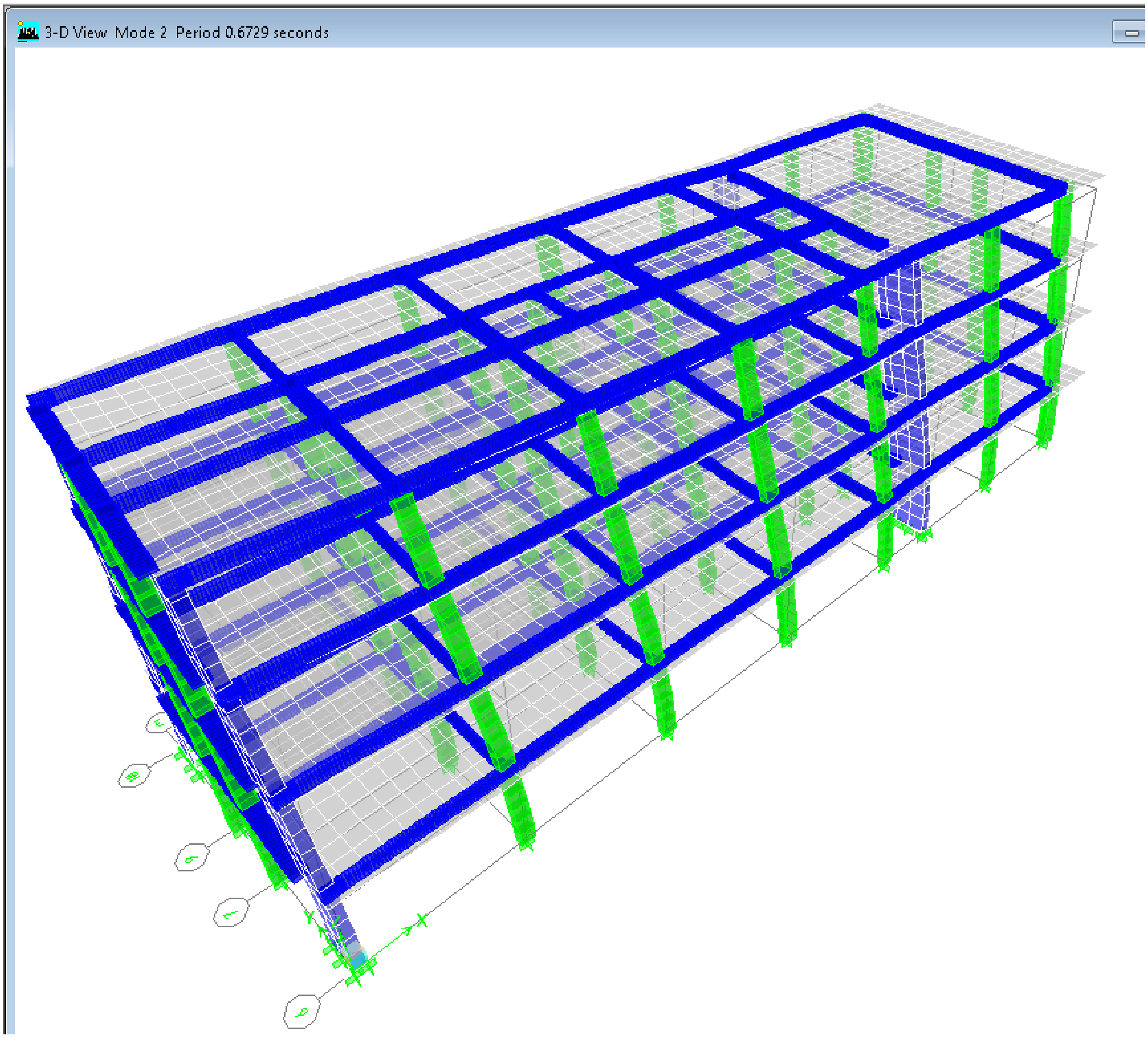
OK

The table of the modal participation factor Object 2

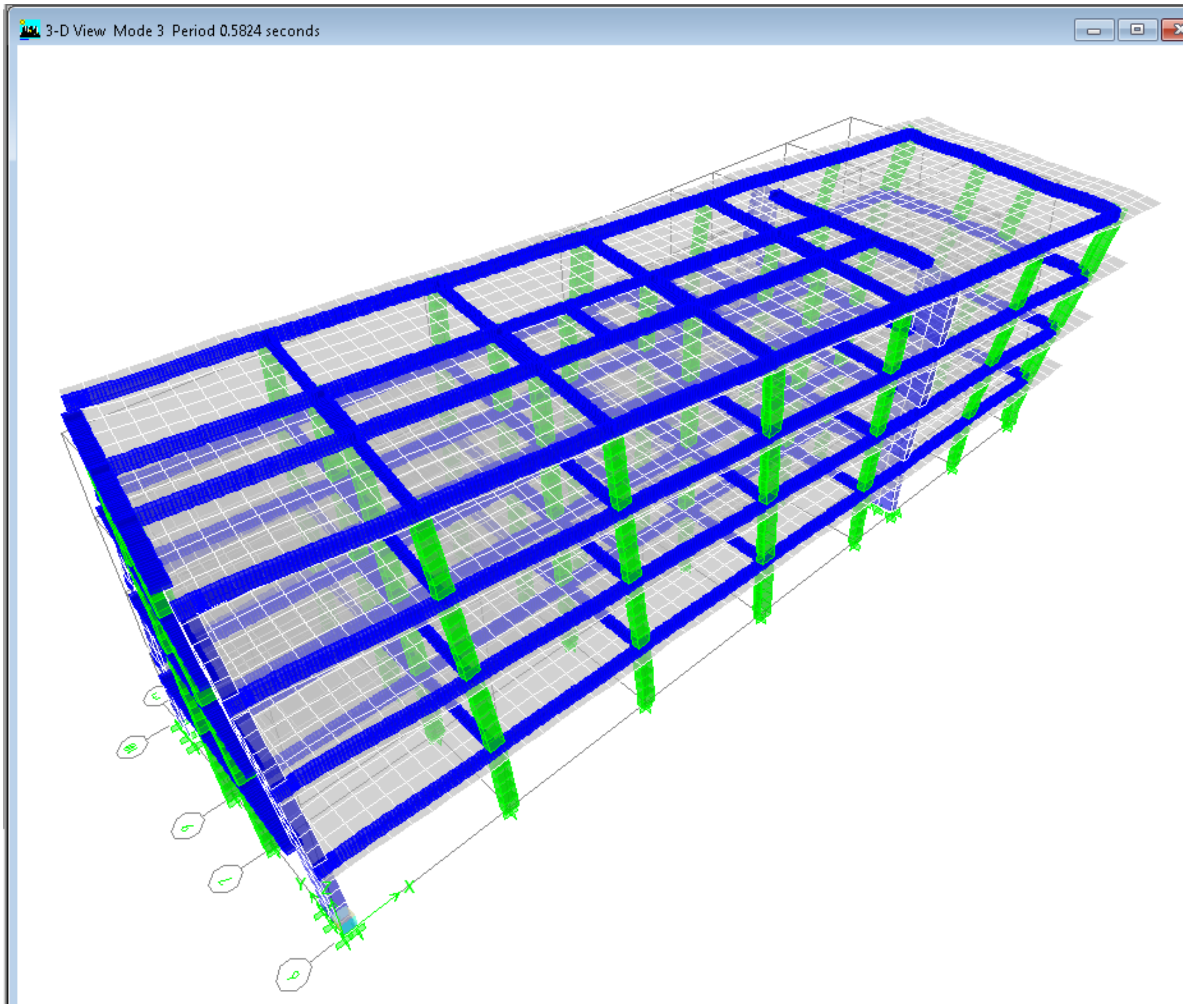
8.2. Modal Shapes



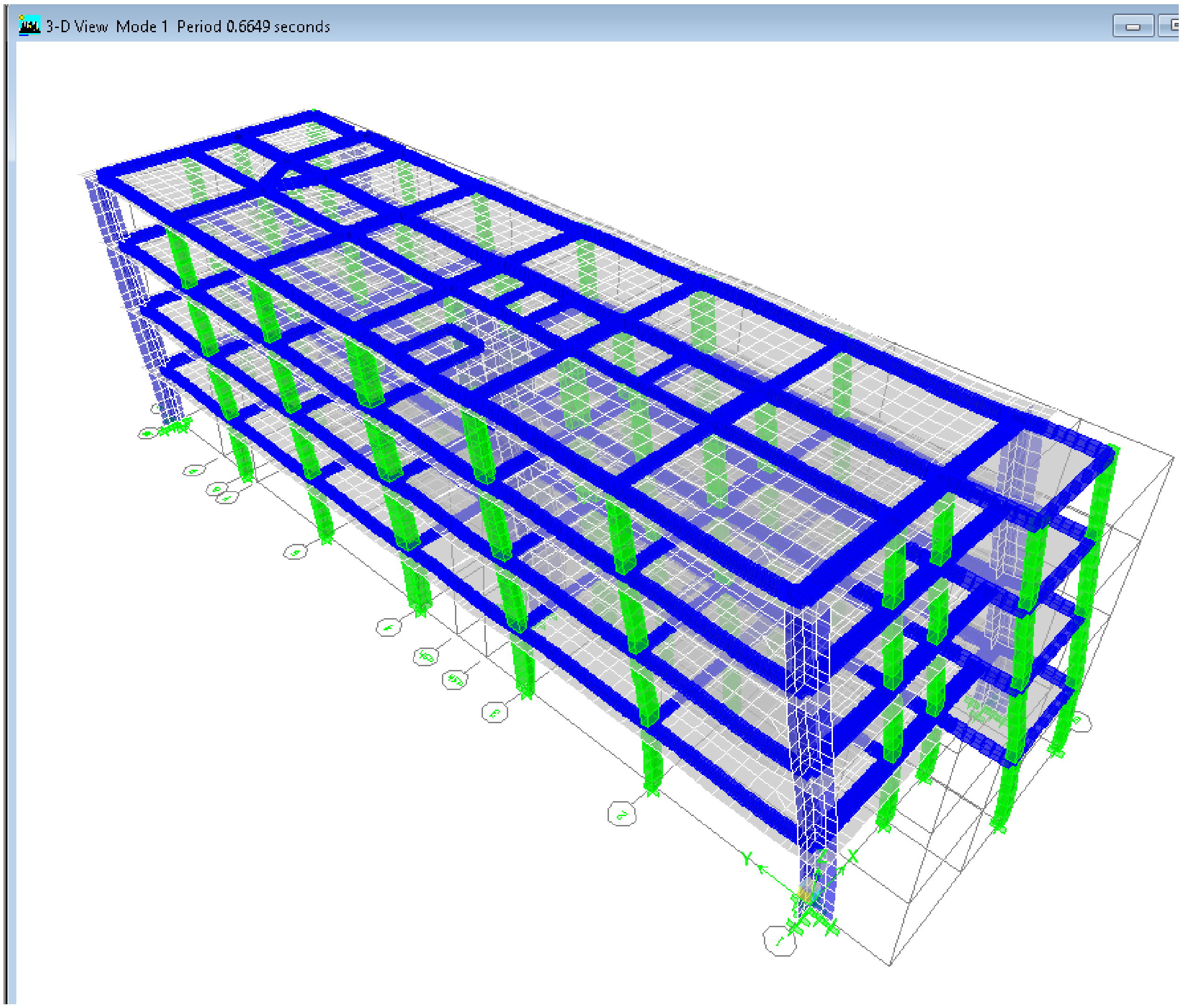
First mode of shape Object 1



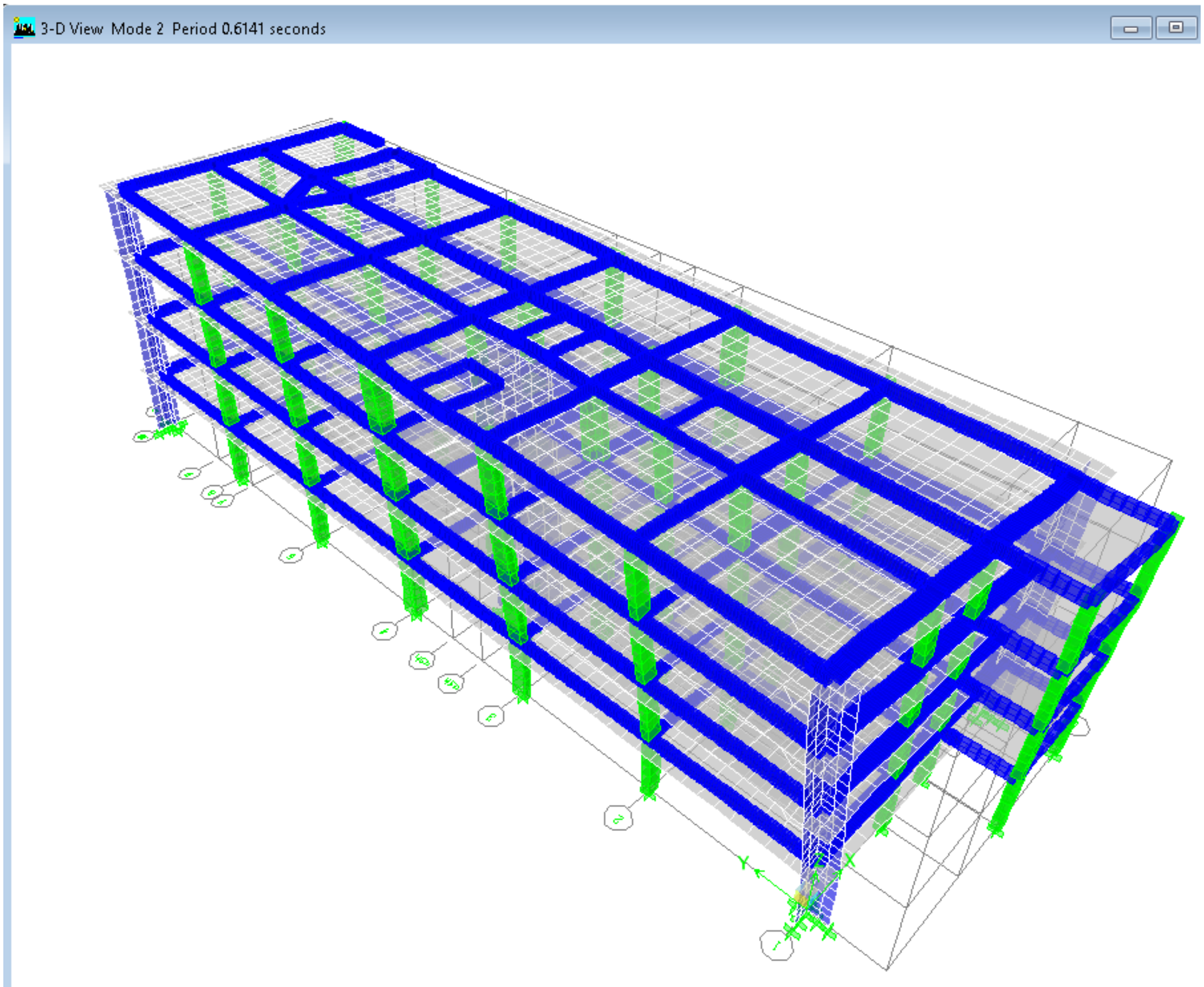
Second mode of shape Object 1



Third mode of shape Object 1



First mode of shape Object 2



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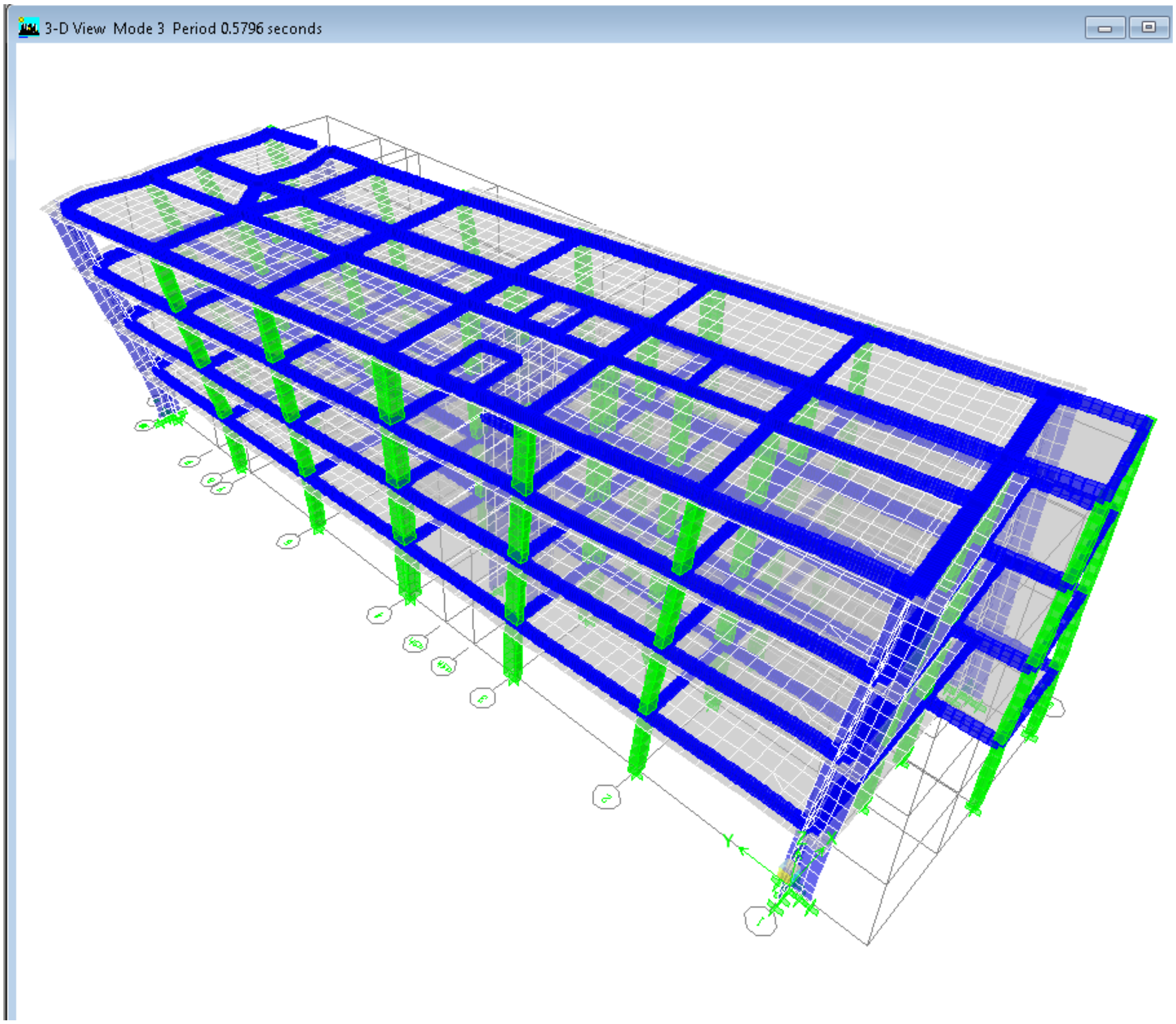
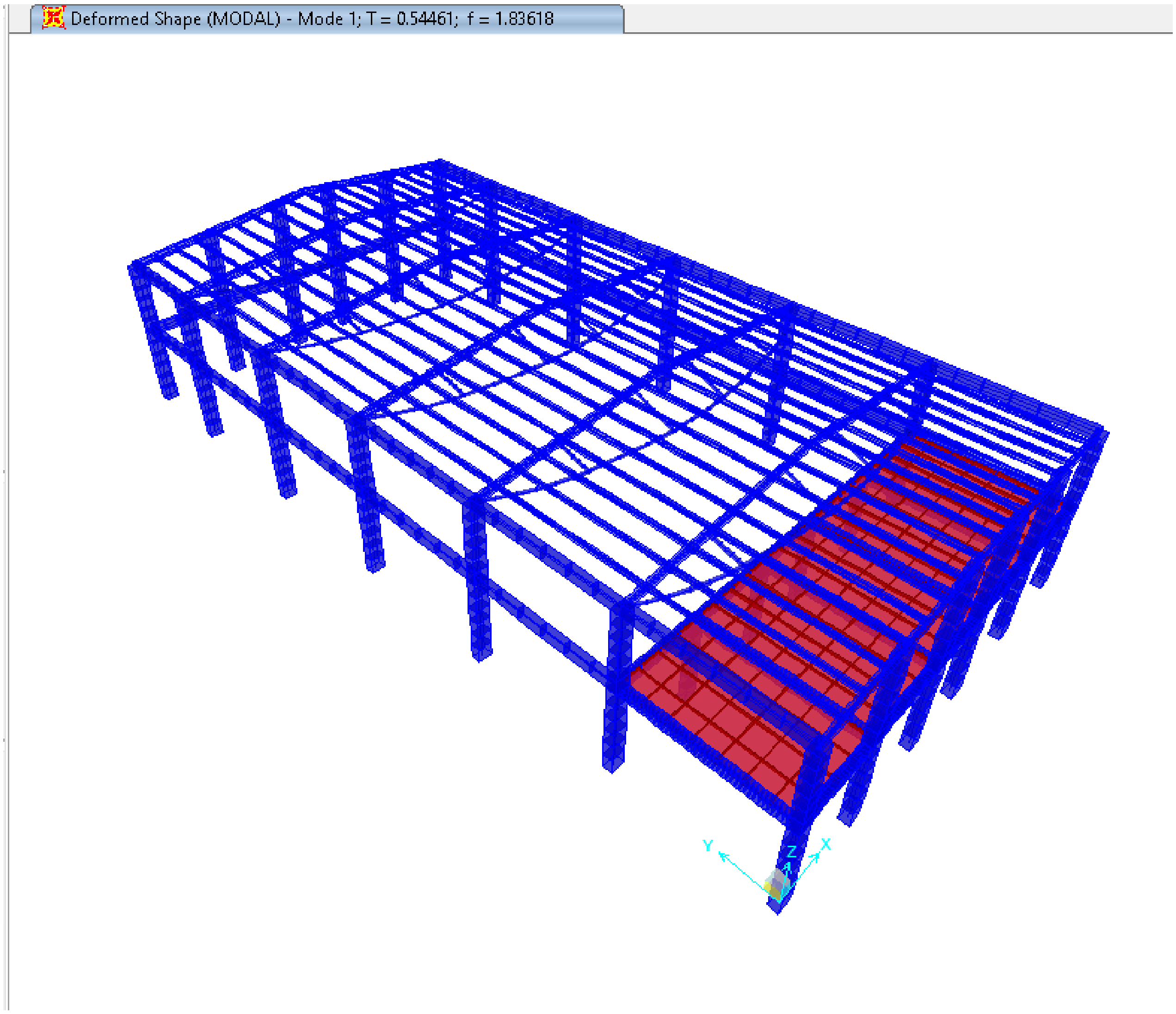
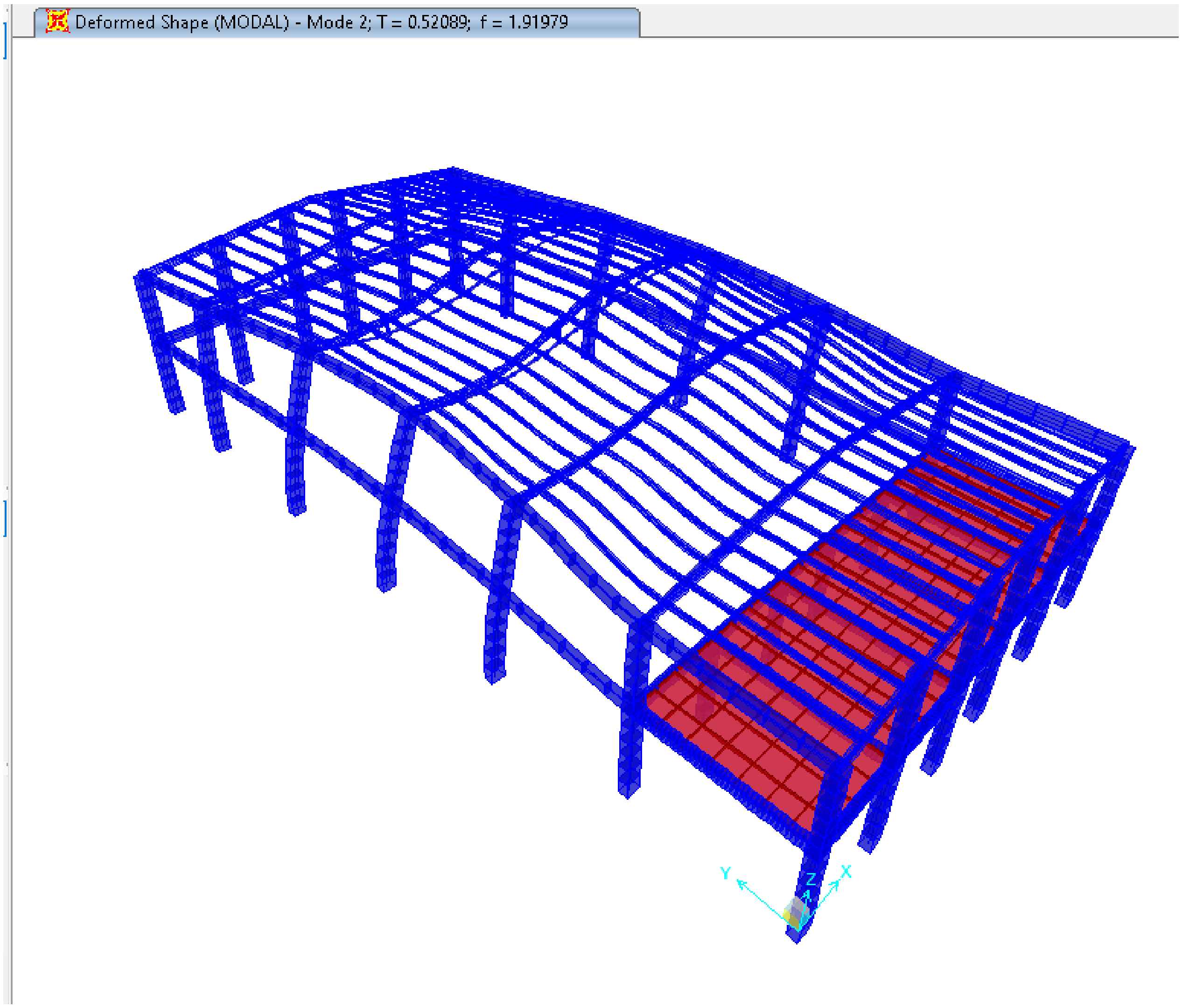


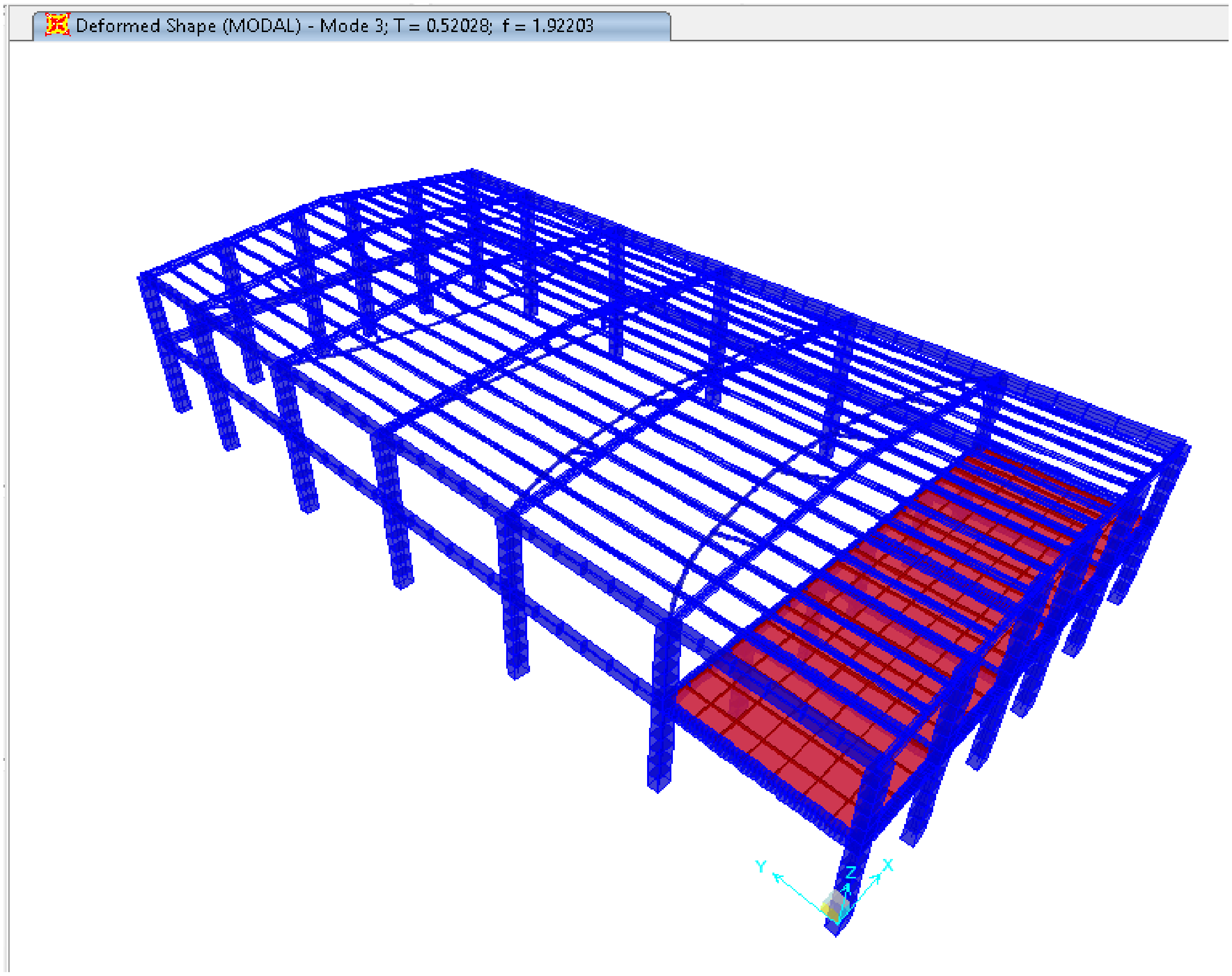
Third mode of shape Object 2



First mode of shape Gym



Second mode of shape Gym



Third mode of shape Gym

9. Drifts

9.1 The Relative Displacement of the Interfloors According to Two Directions

The relative displacement of the inter floors according to two directions

The drift of the inter story above will be determinate in a table, considering the non-excessed the limit values for the structures with not constructive elements and non-ductile

$d_r \cdot \upsilon \leq 0.005 \cdot h$ (EN8 -4.4.3.2) (4.31)

where:

dr-is the design interring story drift as defined in **4.4.2.2(2)**;

υ -is the reduction factor which takes into account the lower return period of the seismic action associated with the damage limitation requirement. (EN8-4.4.3.2)

h-is the storey height;

The allowed design value of the inter story drift for the structure is dr=0.005x408/0.4=5.1 cm

According to the given response spectrum from the seismic report, the drift calculation are:

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 41453

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY 2-1	3.653175	0.848087	0.001593	0.000500
STORY 2	3.020838	0.646024	0.002509	0.000625
STORY 1	2.007739	0.392395	0.002980	0.000620
STORY 0	0.794211	0.139664	0.001947	0.000342

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 39983

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY 2-1	-3.234502	-1.668243	0.002105	0.000979
STORY 2	-2.382904	-1.272941	0.002408	0.001222
STORY 1	-1.404937	-0.776615	0.002269	0.001230
STORY 0	-0.480195	-0.275293	0.001177	0.000675

Displacement in Object 1

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 41210

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY 2-1	3.991231	-1.694647	0.002563	0.000998
STORY 2	2.951830	-1.291742	0.002983	0.001242
STORY 1	1.738739	-0.787571	0.002827	0.001248
STORY 0	0.586269	-0.278942	0.001437	0.000684

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 41396

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY 2-1	2.136245	3.146100	0.001377	0.001729
STORY 2	1.576367	2.450747	0.001600	0.002279
STORY 1	0.924679	1.526891	0.001507	0.002393
STORY 0	0.310073	0.551510	0.000760	0.001352

Displacement in Object 2

According to the table, the drift values are within the design inter story drift.

10. *Description of the Component Elements of the Structure*

10.1. *Foundations*

Consists of a reinforced concrete foundation slabs, reinforced concrete beams and reinforced concrete footings, determinates according to the geometrical shape of the structure, the geological formation where the foundation is going to be placed, the importance of the structure and the vertical load that will be transmitted in this foundation from the structure.

The design anchorage length of the bars according to Eurocode is determinate as below

$l_{bd} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,rqd} \geq l_{b,min}$ (Eurocodi 2-8.4.1 formula 8.4)

where from thw table below: $\alpha_1=1$, $\alpha_2=1$, $\alpha_3=1$, $\alpha_4=0.7$, $\alpha_5=1$

Table 8.2: Values of α_1, α_2, α_3, α_4 and α_5 coefficients

Influencing factor	Type of anchorage	Reinforcement bar: In tension	Reinforcement bar: In compression
Shape of bars	Straight	$\alpha_1 = 1,0$	$\alpha_1 = 1,0$
	Other than straight (see Figure 8.1 (b), (c) and (d)	$\alpha_1 = 0,7$ if $c_d > 3\phi$ otherwise $\alpha_1 = 1,0$ (see Figure 8.3 for values of c_d)	$\alpha_1 = 1,0$
Concrete cover	Straight	$\alpha_2 = 1 - 0,15\,(c_d - \phi)/\phi$ $\geq 0,7$ $\leq 1,0$	$\alpha_2 = 1,0$
	Other than straight (see Figure 8.1 (b), (c) and (d))	$\alpha_2 = 1 - 0,15\,(c_d - 3\phi)/\phi$ $\geq 0,7$ $\leq 1,0$ (see Figure 8.3 for values of c_d)	$\alpha_2 = 1,0$
Confinement by transverse reinforcement not welded to main reinforcement	All types	$\alpha_3 = 1 - K\lambda$ $\geq 0,7$ $\leq 1,0$	$\alpha_3 = 1,0$
Confinement by welded transverse reinforcement*	All types, position and size as specified in Figure 8.1 (e)	$\alpha_4 = 0,7$	$\alpha_4 = 0,7$
Confinement by transverse pressure	All types	$\alpha_5 = 1 - 0,04p$ $\geq 0,7$ $\leq 1,0$	-

where:
λ = $(\Sigma A_{st} - \Sigma A_{st,min})/ A_s$
ΣA_{st} cross-sectional area of the transverse reinforcement along the design anchorage length l_{bd}
$\Sigma A_{st,min}$ cross-sectional area of the minimum transverse reinforcement = 0,25 A_s for beams and 0 for slabs
A_s area of a single anchored bar with maximum bar diameter
K values shown in Figure 8.4
p transverse pressure [MPa] at ultimate limit state along l_{bd}

* See also 8.6: For direct supports l_{bd} may be taken less than $l_{b,min}$ provided that there is at least one transverse wire welded within the support. This should be at least 15 mm from the face of the support.

$l_{b,rqd} = (\varphi / 4)\ (\sigma_{sd} / f_{bd})$ (Eurocodi 2-8.4.1 formula 8.3)

$f_{bd} = 2{,}25\ \eta_1\ \eta_2\ f_{ctd}$ (Eurocodi 2-8.4.1 formula 8.2)

ku: $\eta_1=1$, $\eta_2=1$

$f_{ctd} = \alpha_{cc}\ f_{ctk,0.05}/\gamma c$ (Eurocodi 2-3.1.6 formula 3.16)

y_c = 1.5 (EC2 -2.4.2.4 Tabela 2.1N)

Table 2.1N: Partial factors for materials for ultimate limit states

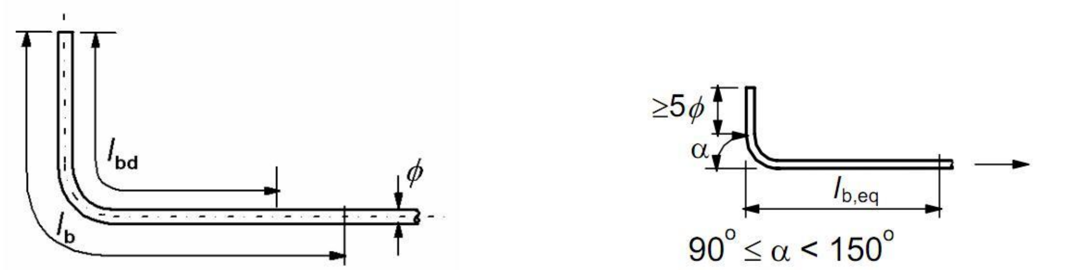
Design situations	γ_C for concrete	γ_S for reinforcing steel	γ_S for prestressing steel
Persistent & Transient	1,5	1,15	1,15
Accidental	1,2	1,0	1,0

α_{cc} =0.8-1

f_{ctm} = 0.3 x f_{ck} ^ (2/3) =2.6 MPa. (EC2-3.1.3 Tabela 3.1)

(f_{ctk} 0.05=0.7 x f_{ctm}) =1.8 MPa. (EC2-3.1.3 Tabela 3.1)

f_{ctd} = 1.8/1.5=1.2 MPa.



a) Basic tension anchorage length, l_b, for any shape measured along the centreline

b) Equivalent anchorage length for standard bend

According to the formula above and from the table 8.2 (Eurocode 2-8.4.1 table 8.2):

f_{bd}= 2.25x1x1x1.2=2.7 Mpa

$l_{b,rqd}$=(20/4)x(435/2.7)=805 mm

l_{bd}=1x1x1x0.7x805 mm=563 mm > $l_{b\ min}$ =0.6x805=483 mm for anchorages in compression: lb,min > max{0,6lb,rqd; 10φ; 100 mm}

According to the above results and the thickness of the foundation beams satisfies all the conditions.
According to the above results foundation beam thickness will be 200 cm and anchorages will 115cm.
The foundation slab is designed to be placed in an elastic formation, placed in a ballast layer with 20 cm. The formation where the ballast layer is placed, is relatively well represented from gravels with low level of humidity and compressed. According to the geological report of the soil where the structure is placed, the bearing capacity of the soil is 1.8 kg/cm^2 according to geological study.
The design model of the foundation formation is the Winkler's model. It is taken in consideration in the calculations the static coefficients of the stiffness and specifically the degrees of freedom belonging to the vertical displacements and the rotations according to the perpendicular axis which lay on the lower level of the foundation beams as the most representatives (3 degrees of freedom). The other three degrees of freedom of the formation in the design model are accepted as blocked.

The static coefficients are calculated considering the sliding module of the formation G(t/m^2) and the dimensions of the foundation in plan. G is determinates from the three inputs of the seismic-engineering report, as a derivate of the velocity of the extension of the crossing wave in the formation and the density of the soil:

[vs= 475(m/s), ρ=γ/g=0.21 (ts^2/m^4)].

10.1.1. Reinforced Foundation Slab

The thickness of the slab foundation is 50 cm cm. It is placed in the quote -2.00 m from quote +/-0.00. typical reinforced it represented above.

The foundation slab is reinforced with double grill in both directions, placing additional reinforcement at the areas with highest concentration of stresses under the columns, the walls etc. The spaces among the bars for all the grills in the foundation slab is uniform, simplifying simultaneously its construction.

10.1.2. Reinforced Foundation Beams

The reinforcement for the foundation beams is done considering the main combination results, but it is checked for the seismic combination.

10.1.3. Reinforced Footings

The reinforcement for the footings is done considering the main combination results, but it is checked for the seismic combination.

The concrete class is C 25/30 and the steel is Sidenor (BSt-500S)
The cover layer of the foundation reinforcement beams is 4 cm
It is checked the bearing capacity and the stability of the formation to resist the loads transmitted from the structure, like the below formulas show:

$E_d < R_d$ EC 7-2.4.7.3.1 (2.5)

$E_d=(F*\gamma_f + N)/F$

$E_d=(490*2.5*9.81*1.35+0.6+33522)/490=(9733+31522)/490=41255/490=84$ kPa

$\gamma_f=1.35$ EC 7-Annex-A.3.1 (1)

$R_d=X_k/\gamma_m$

X_k – bearing capacity (σ =180 kPa)

$\gamma_m=1.2$ EC 7-Annex-A.3.2 (1)

84kPa<180/1.2=150

10.2. Reinforced Concrete Frame

It represents the main element of the structure. It is composed of bars or one dimensioned column elements, two dimensioned walls and the beams.
The vertical and horizontal structure is dimensioned considering the conditions of EN-8 for the reinforced concrete elements.

10.2.1. Reinforced Concrete Columns and Walls

The reinforced concrete columns and walls, as main elements of the structure, are designed with different dimensions, considering the balance of the stiffness according to both directions in plan to considerably avoid the addition effects from the torsion.

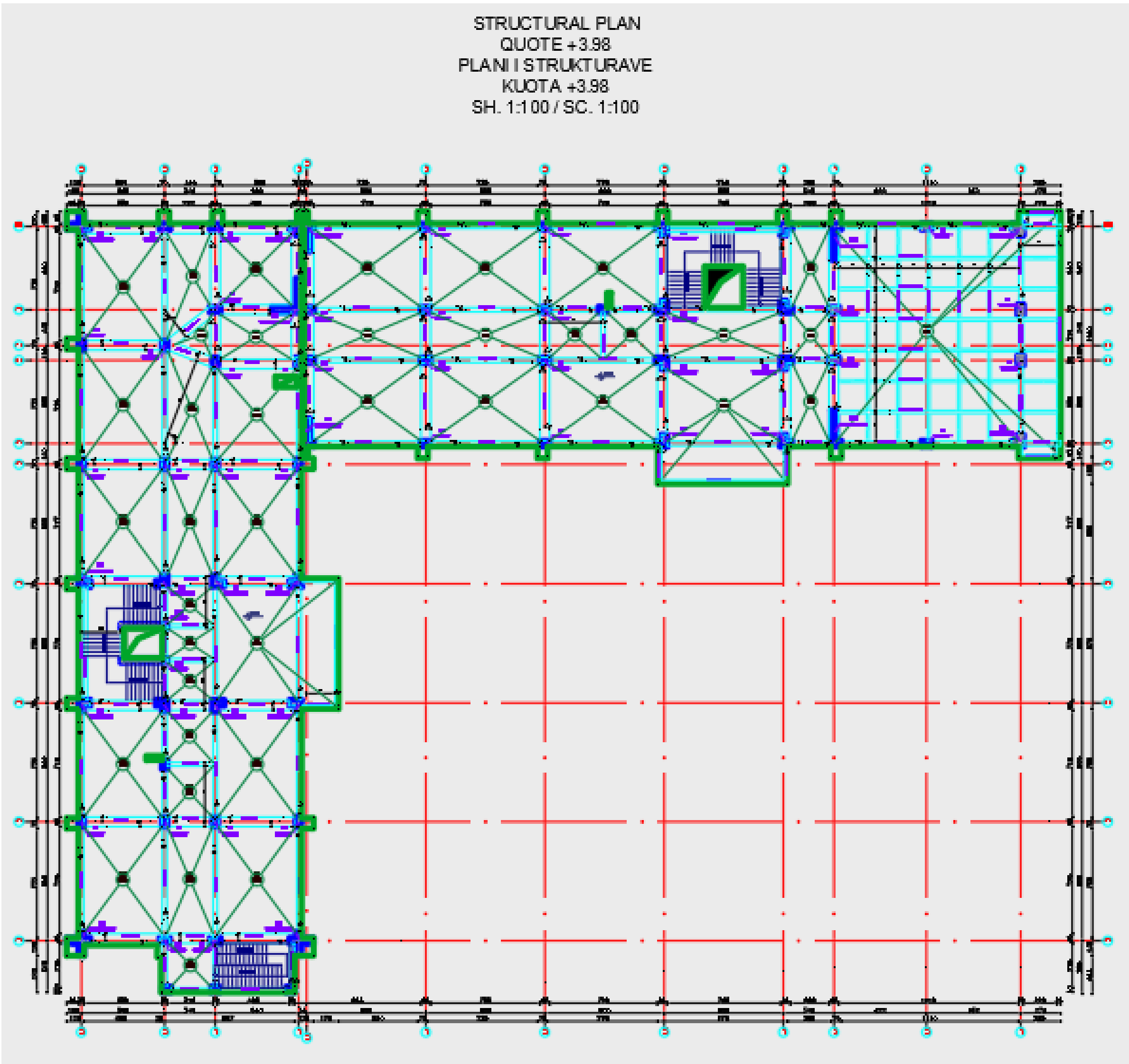
They are the main elements of the vertical bearing capacity and the horizontal bearing capacity during the seismic reaction.
In the determination of the dimensions of these elements, it is considered all the Eurocode criteria and respectively EN 8.5.4.1.2. Their cross-sections are rectangular. The step of the columns is determinates according to the architecture of the structure and are 8.00 m; 8.14 m; 7.86 m; 3.40 m and 6.30 m according to the X direction and 5.45m; 3.40m; 5.6 m according to the Y direction (Building_1); 5.6 m; and 3.40 m according to the X direction and 3.50m; 8.11 m; 7.89 m; 7.86 m; 8.14 m; 8.00 m; 6.85m; 3.70m; 5.45m according to the Y direction (Building_2);. The class of concrete is C30/37 and the steel is Sidenor (BSt-500S).
After the analyzing of the structure from the software, the verification of the columns differs from the verification of the beams concerning the reinforcement placement, in this case the reinforcement is realized symmetric(remind that before the modeling and during the modeling of the structure, the division between the beam and column elements is already done from the user).The placement of the walls is done mainly in the zones where the architectural design is not harmed, also in the other places of the structure where it is decided to have a better accordance between the center of the gravity or the center of the plane figure (planes) with the center of inertia. The thickness of the vertical walls is 35 cm. The columns are rectangular with dimension 40x70 cm and "L" with dimensions 80X40cm. The reinforcement of the columns and the walls is done according to the results of the most unfavorable combinations respecting the Eurocode's main principles.

10.2.2. Reinforced Concrete Beams

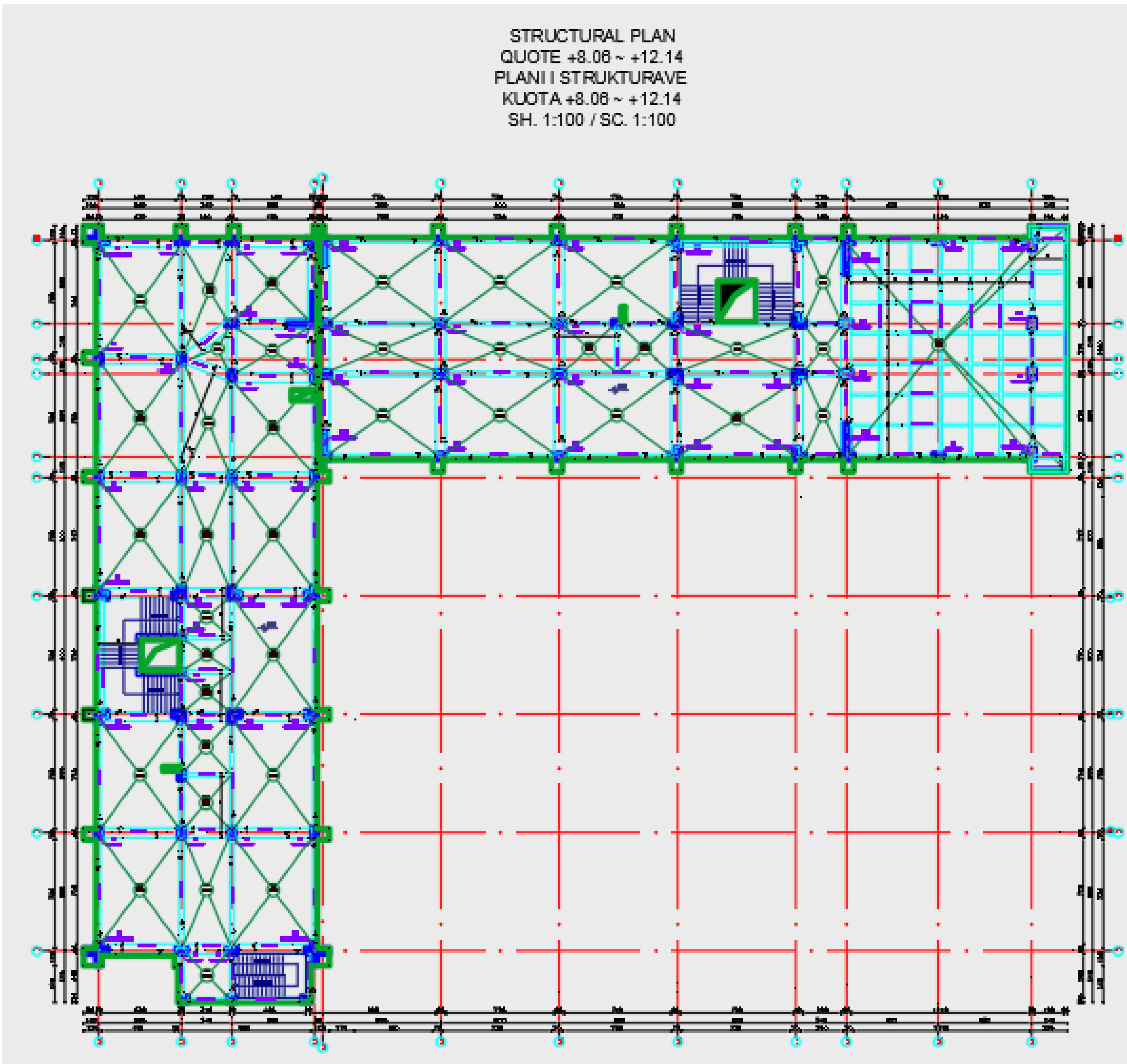
Consist the horizontal reinforced concrete frame, which mainly support the vertical load of the slabs above them, transmit the horizontal seismic load to the vertical elements and supporting a considerable part of it. The beams are considered deep, with the dimensions as described: 30X60 cm; 30X50 cm; 30X40 and 65X40 cm. The class of the concrete is C30/37 and the steel Sidenor (BSt-500 S)
The beam reinforcement is done according to the results taken from the most unfavorable combination respecting the main principles of Eurocode, respecting also the limitations for the minimal and maximal reinforcement percentages, given in the (EN 8.5.4.3.2.1)

10.2.3. Slabs

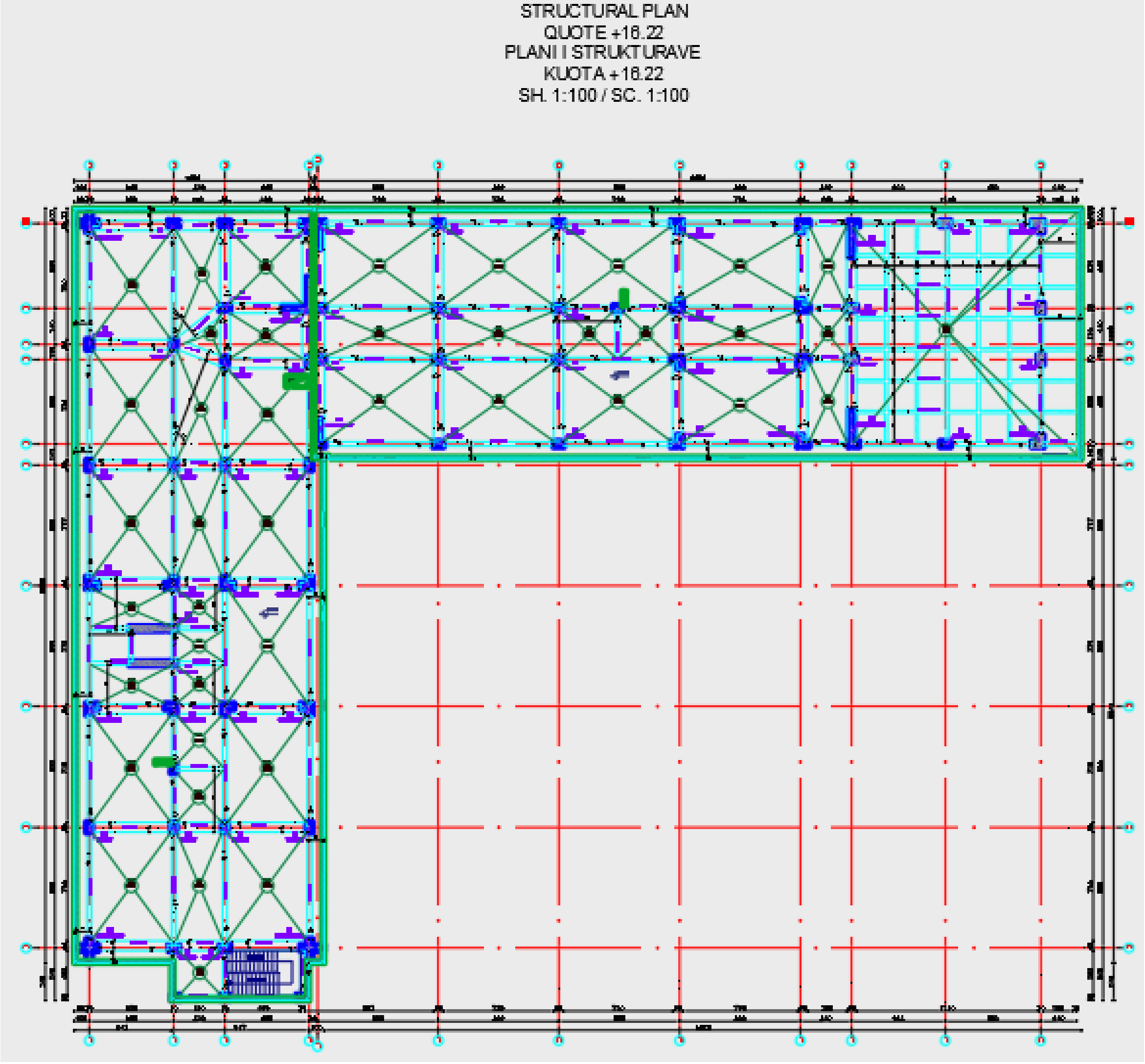
The slabs of the structure, according to the Eurocodes, for the structure of this category, are monoliths. Their thickness are determinates according to the axis and the loads are 25 cm and 20 cm.
The class of the concrete is C 30/37 and the steel is Sidenor (BSt - 500S).



The structural plan at the quote +3.98



The structural plan at the quote +8.06; +12.14



The structural plan at the quote +16.22

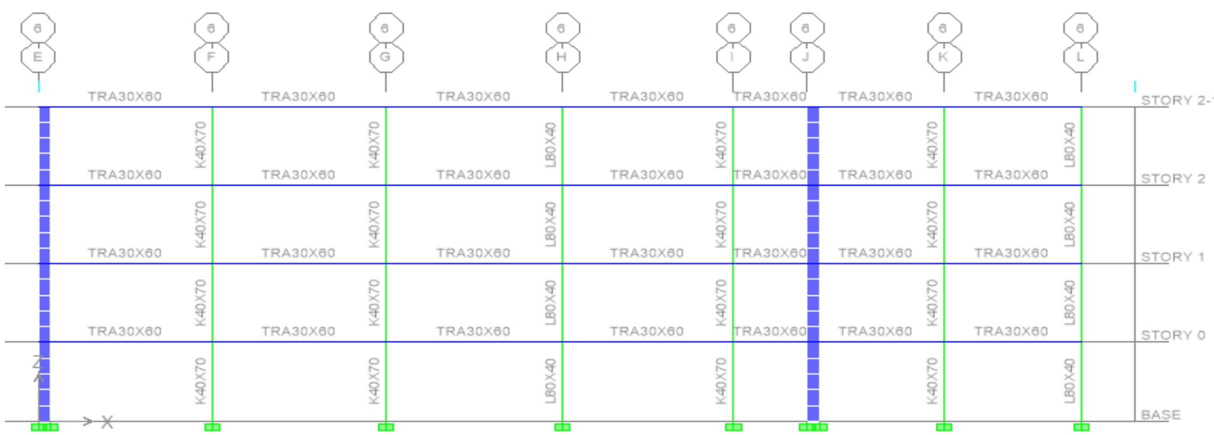
10.2.4. Reinforced Concrete Staircases

The design of the reinforced concrete staircases is done by analogy with the slabs. They are designed to be monoliths with thickness according to the drawings in the project.

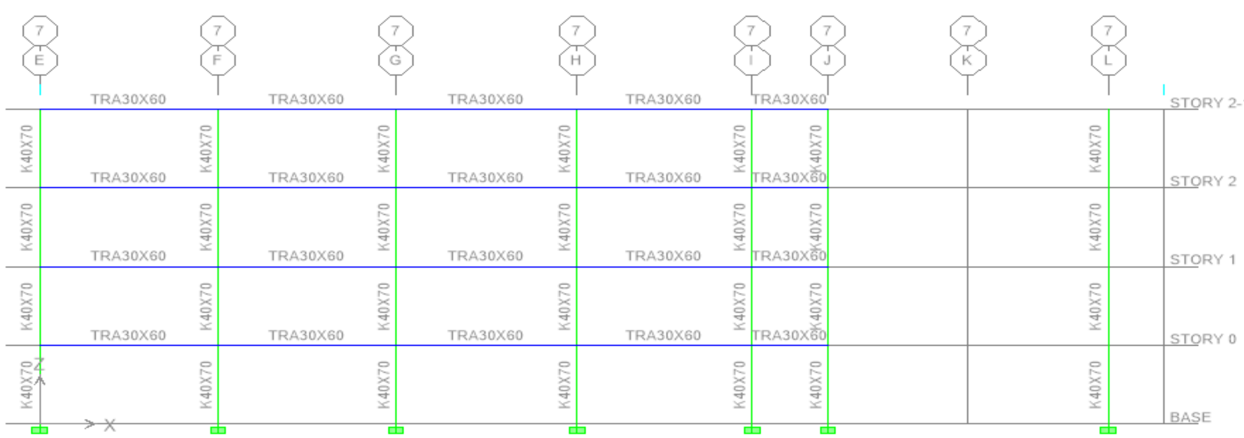
The class of concrete is C 30/37 and the steel is Sidenor (BSt-500 S)

11. Schemes of Dimensioning of Representative Elements of the Structure

11.1. Object 1



Axis 6



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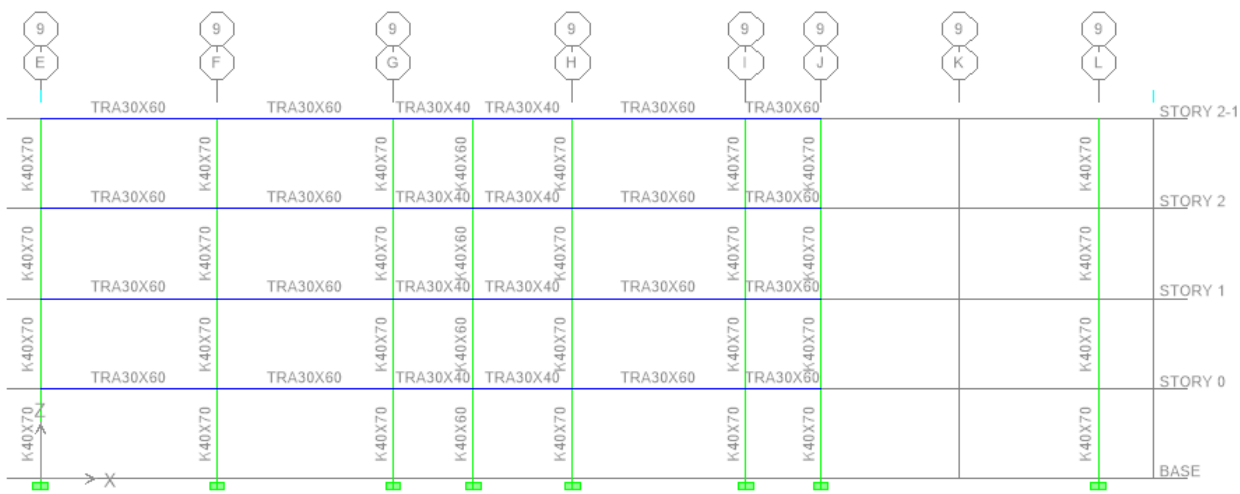

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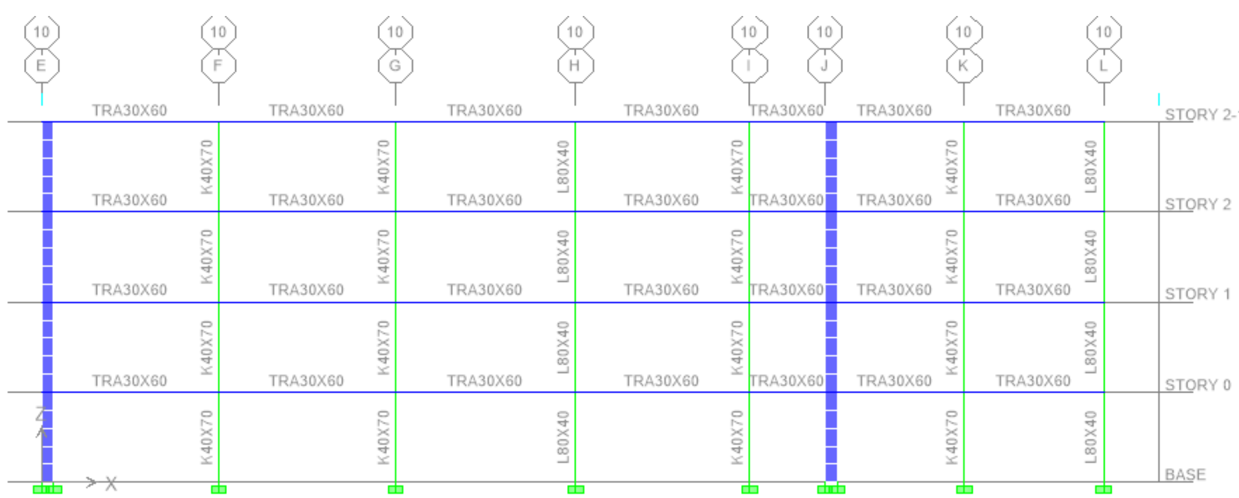

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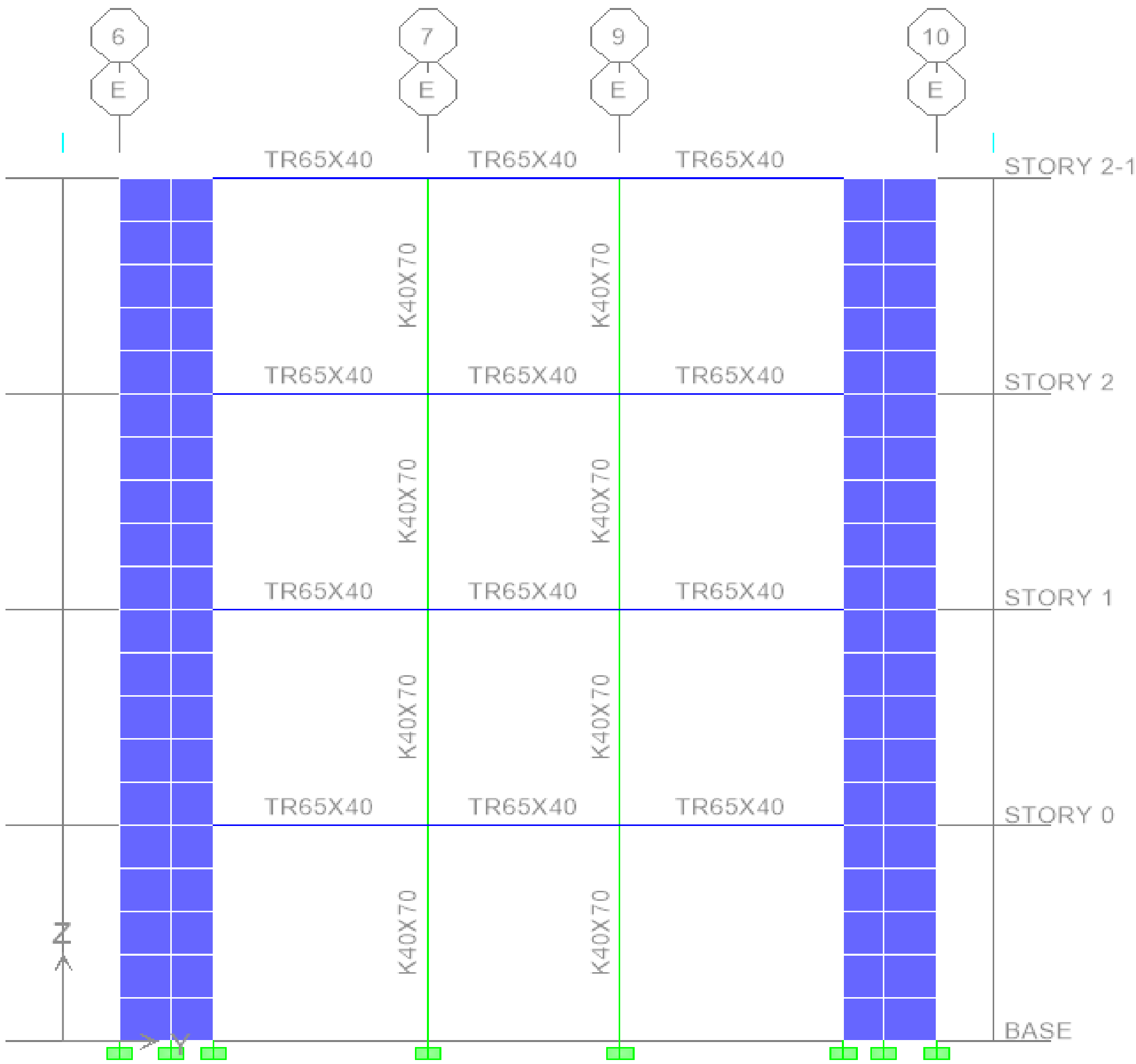
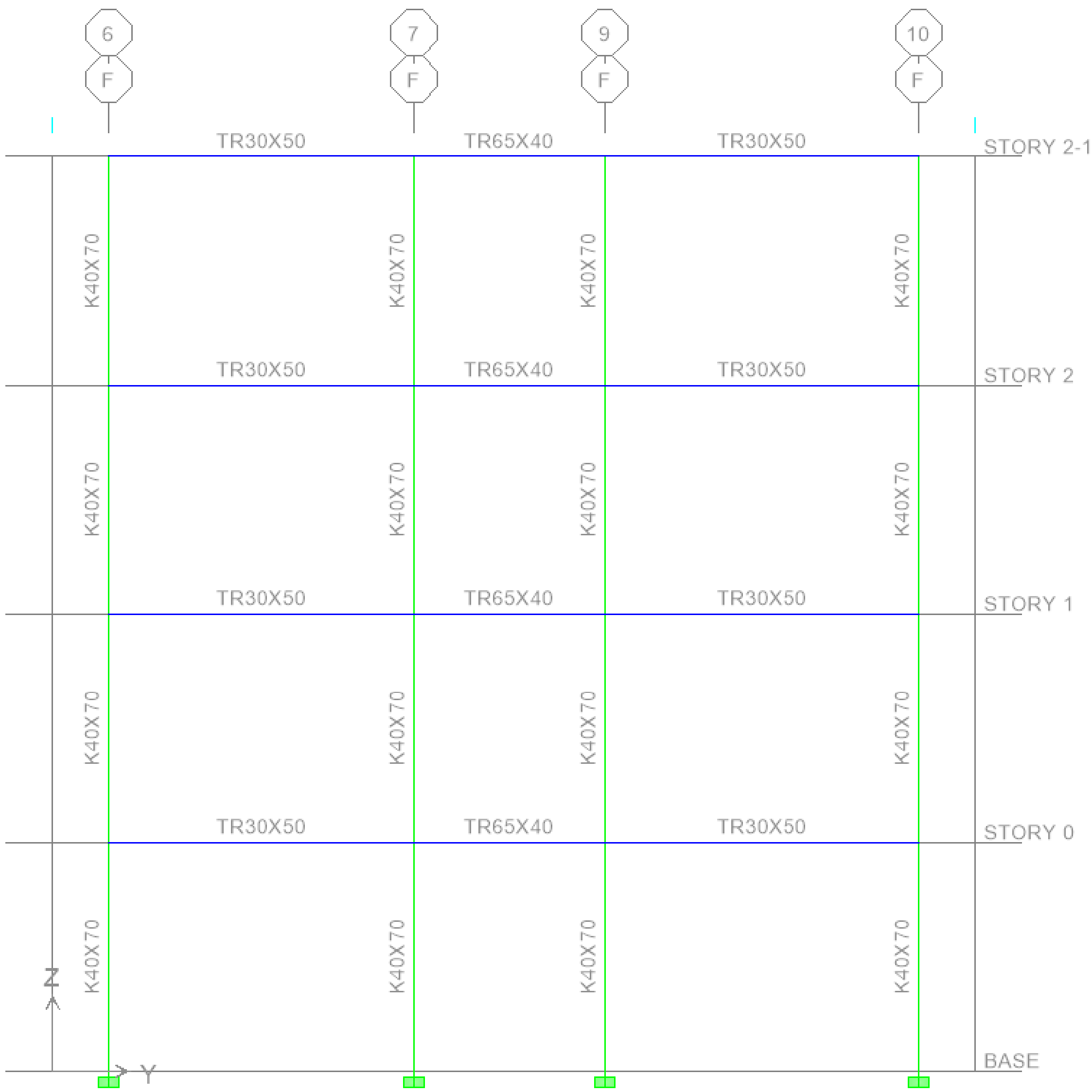


Axis E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7
9
10
F
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STORY 1
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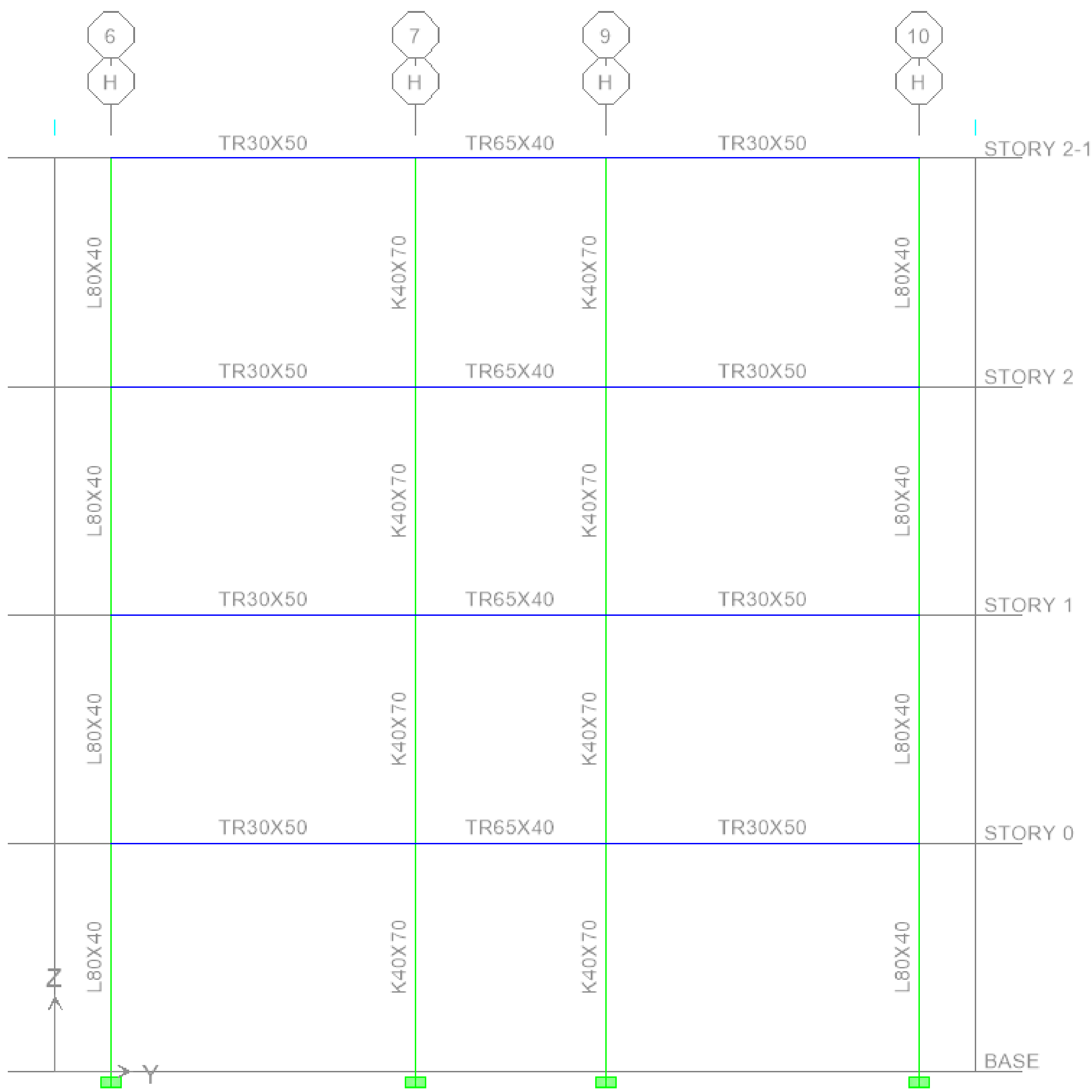
Z
Y

Axis F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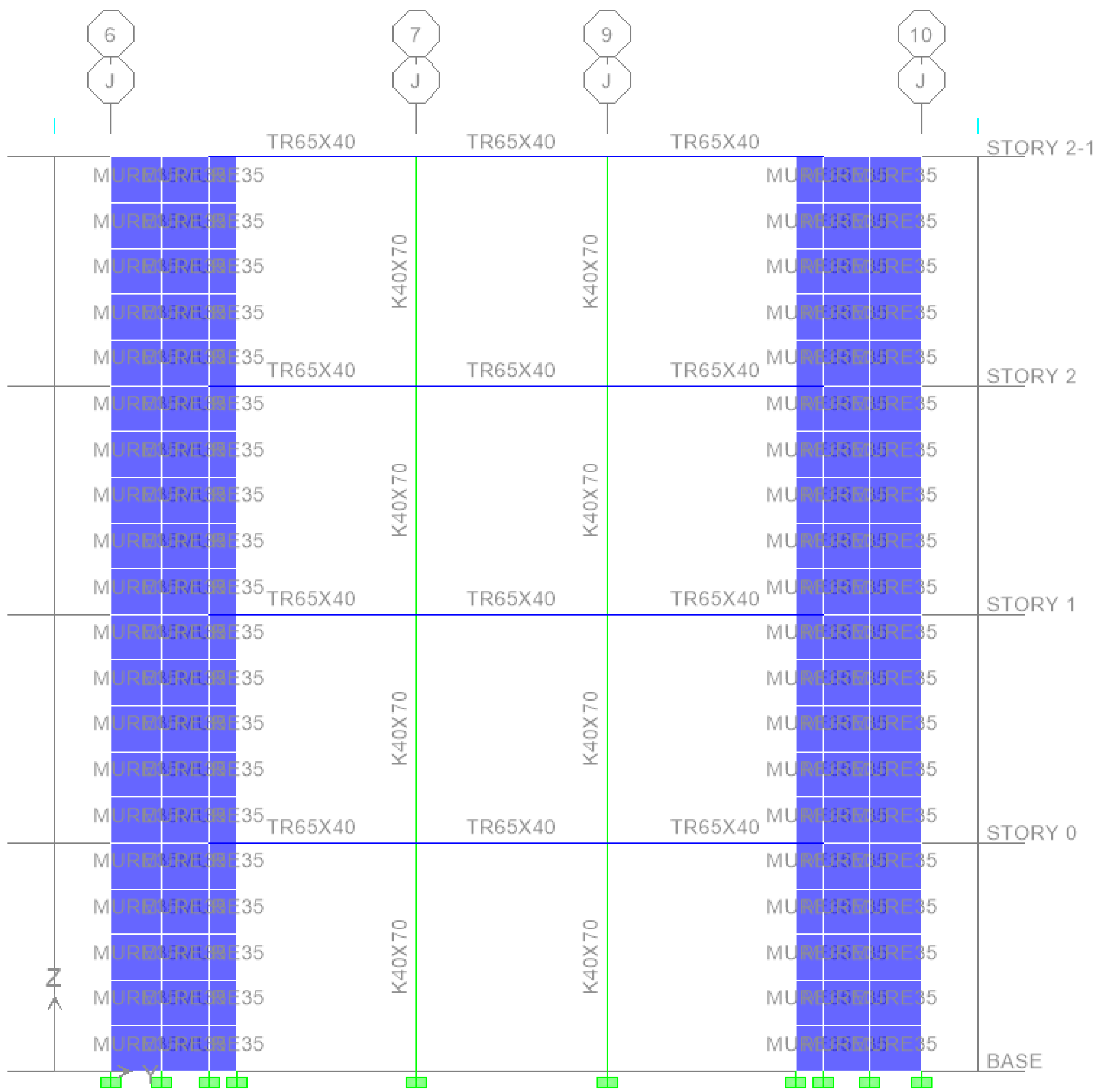
Axis H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K40X70
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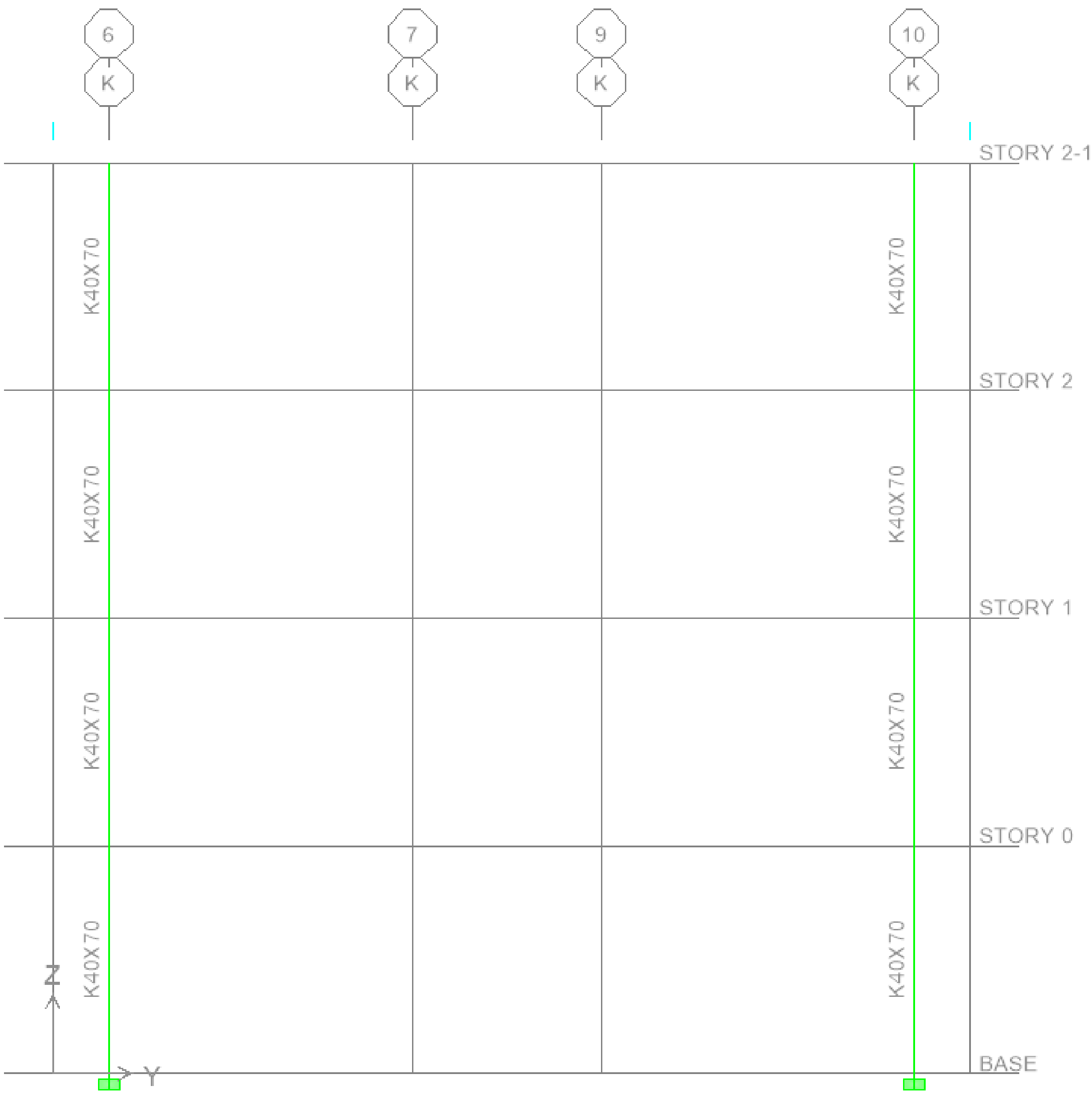
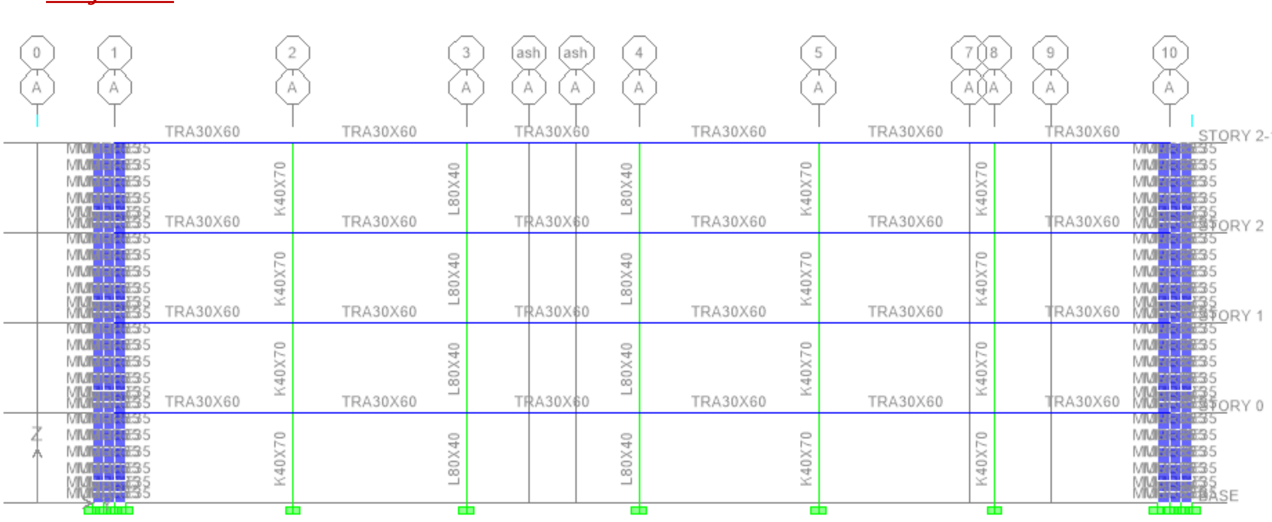
Y

Axis J

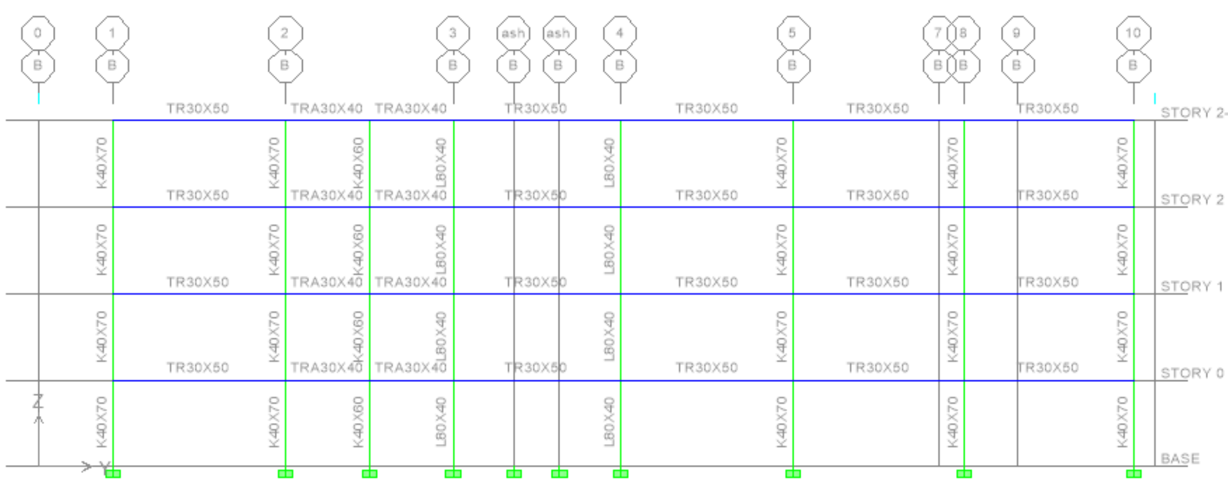


Axis K

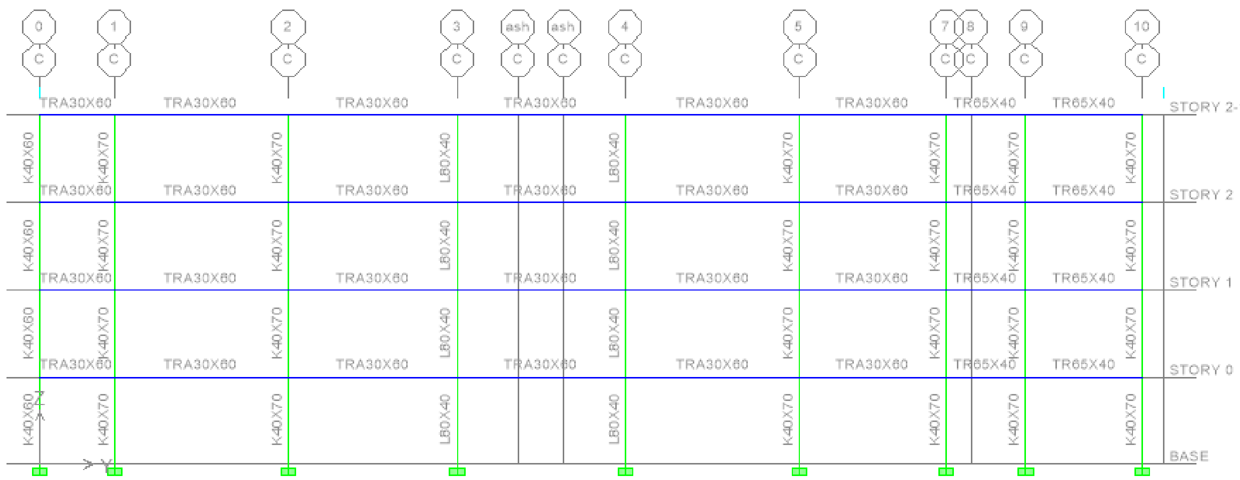
11.2. Object 2



Axis A



Axis B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2
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ash
ash
4
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7
8
9
10
C
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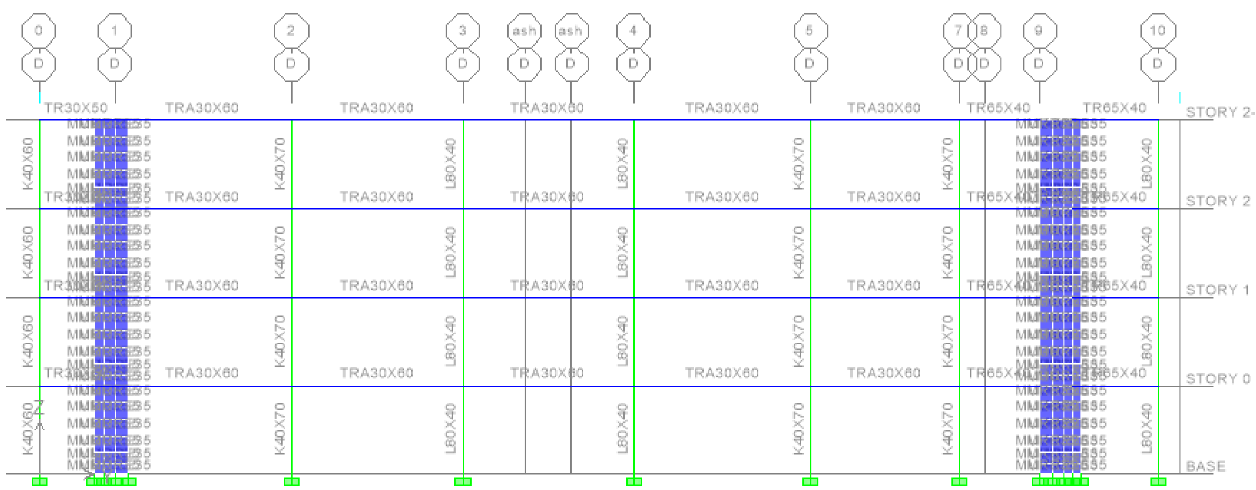
L80X40

Axis C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D
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K40X70
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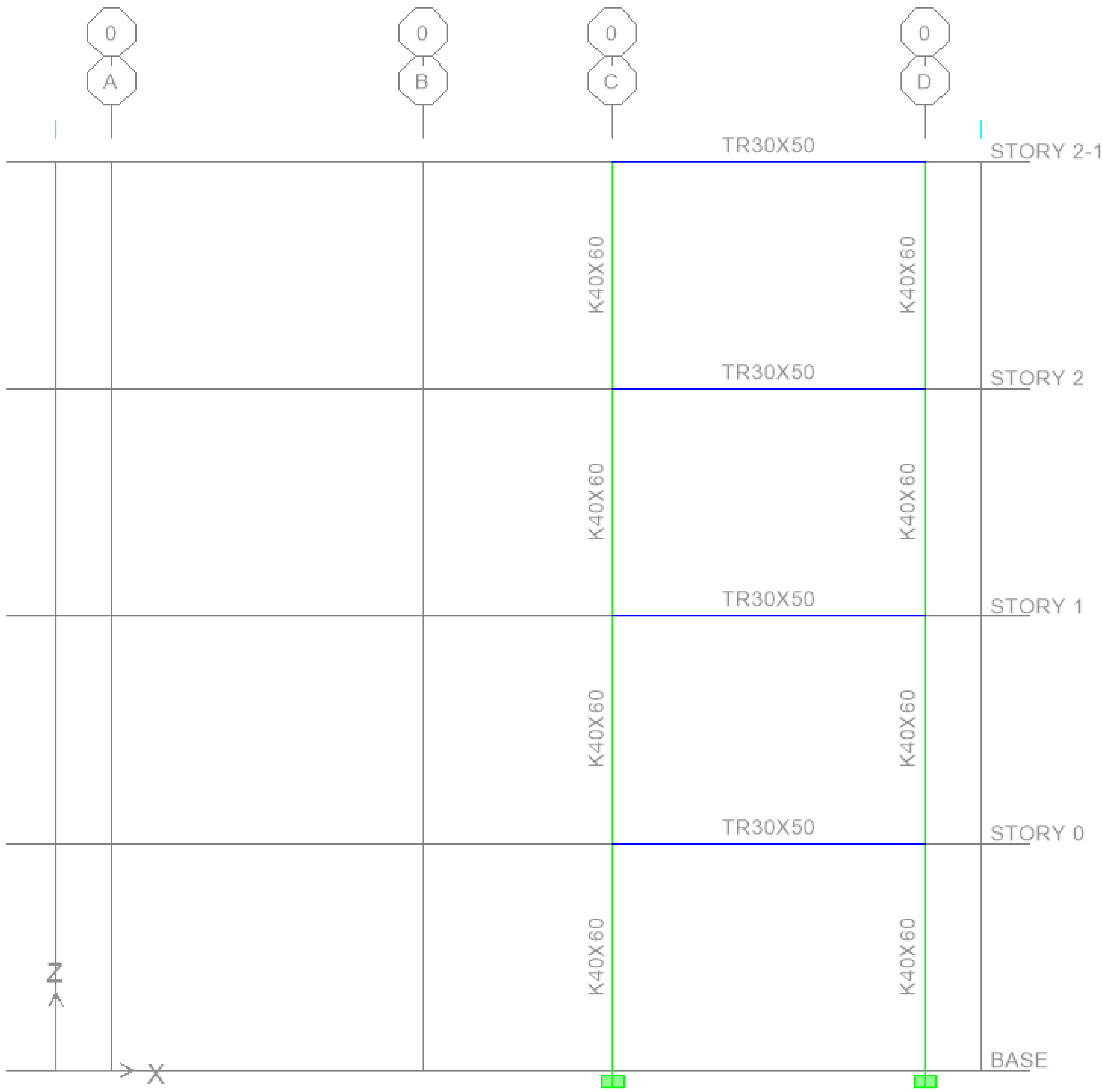
Axis D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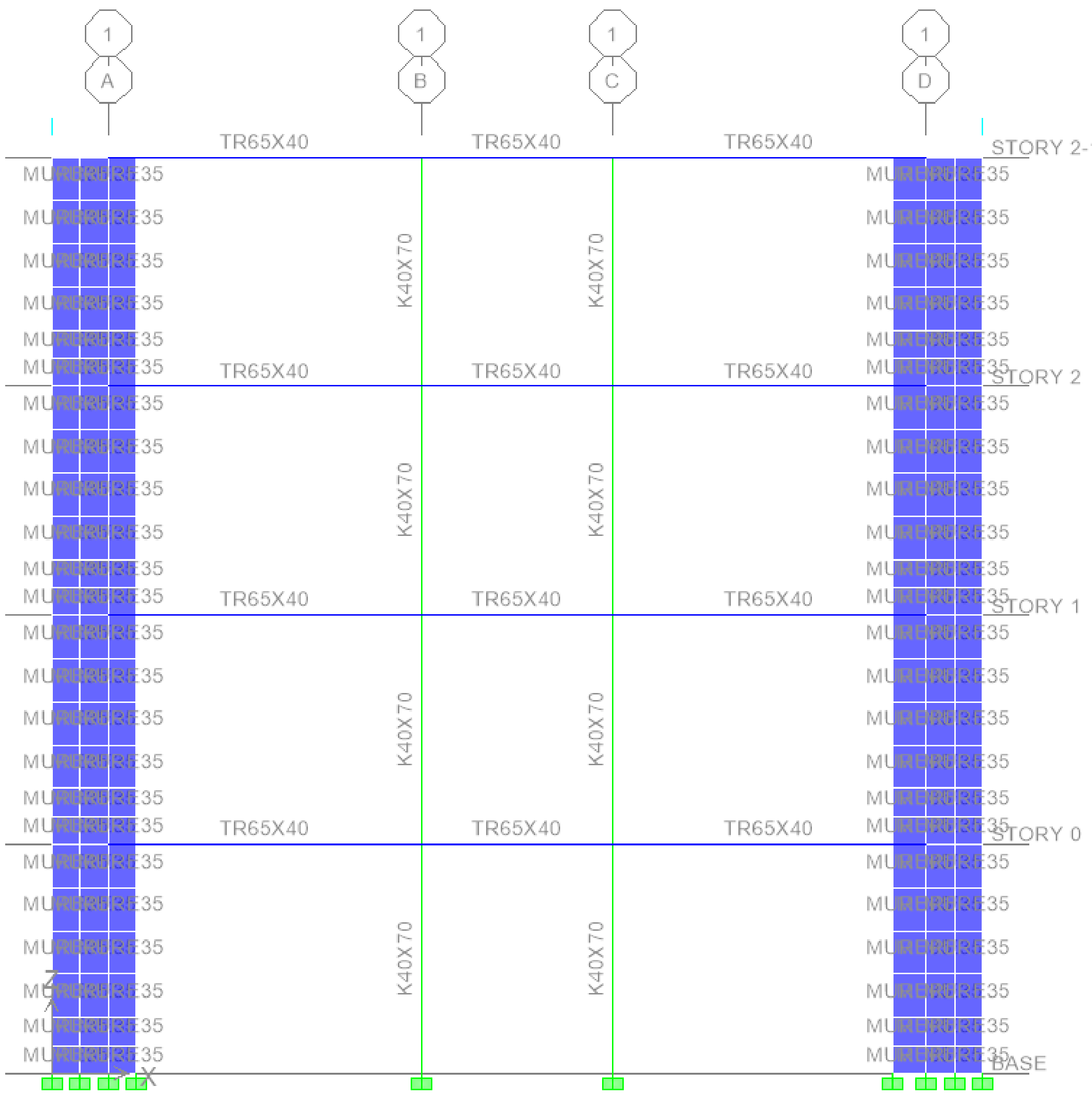
X

Axis 0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TR65X40
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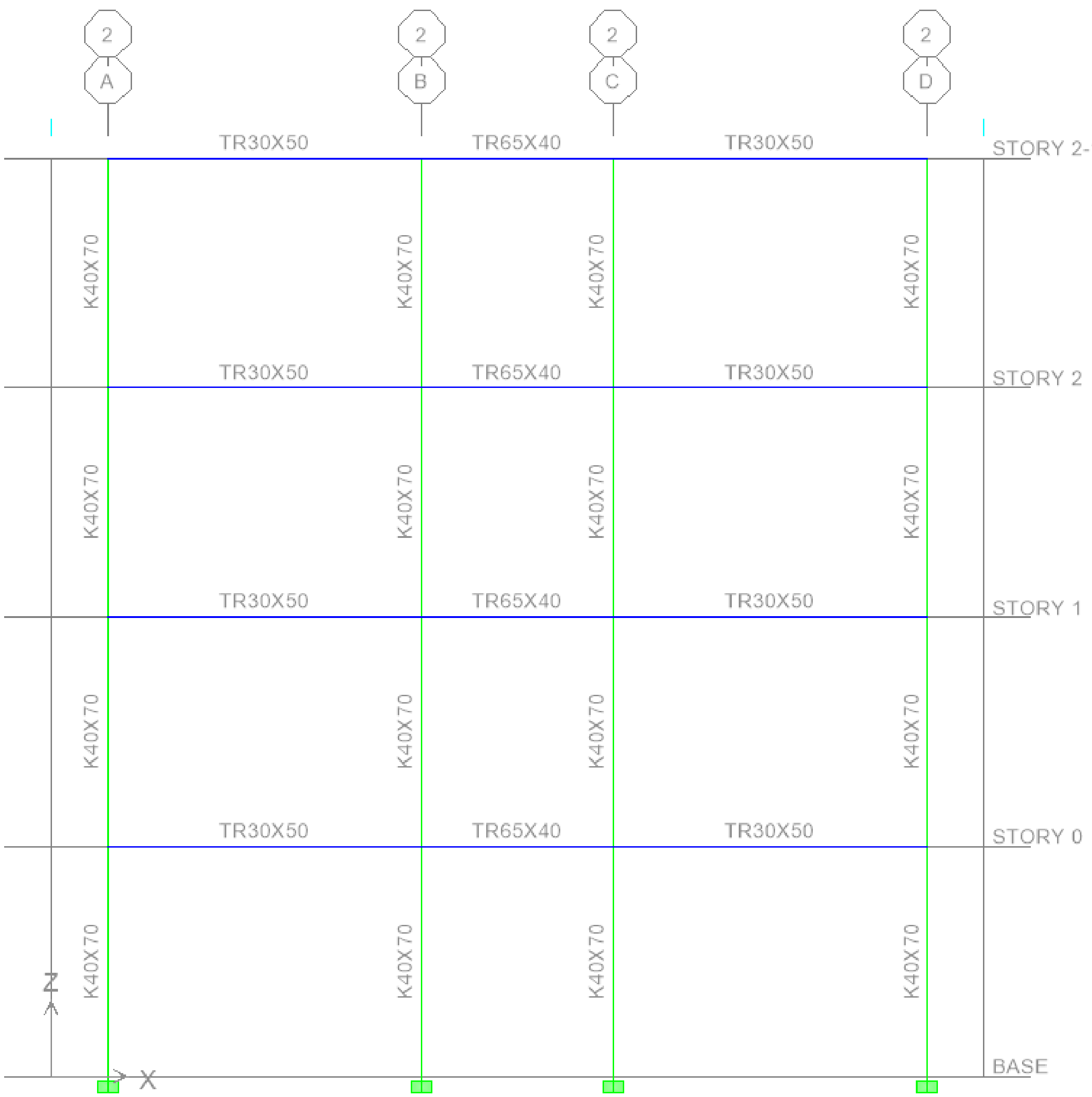
BASE

Axis 1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C
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D
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TR30X50
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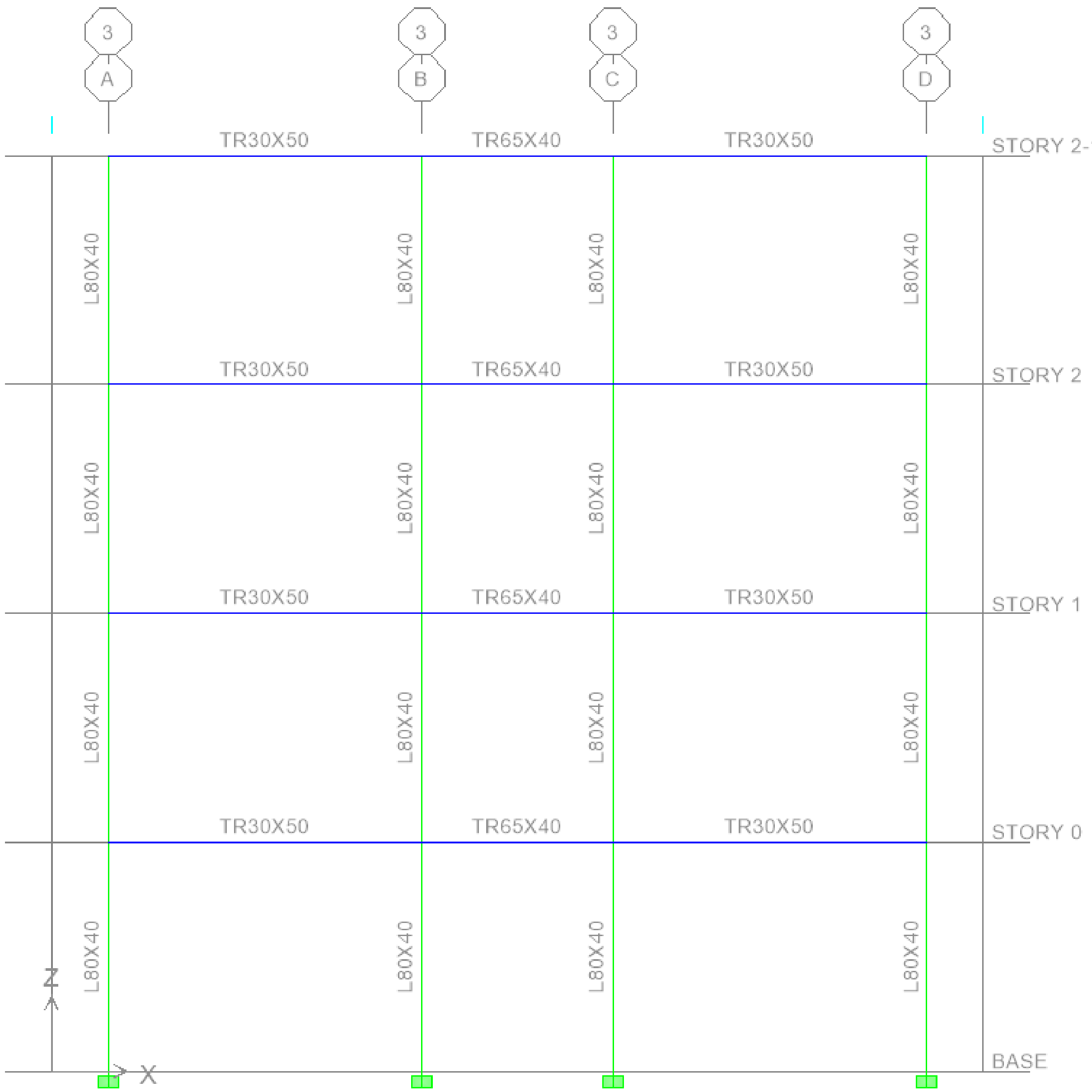
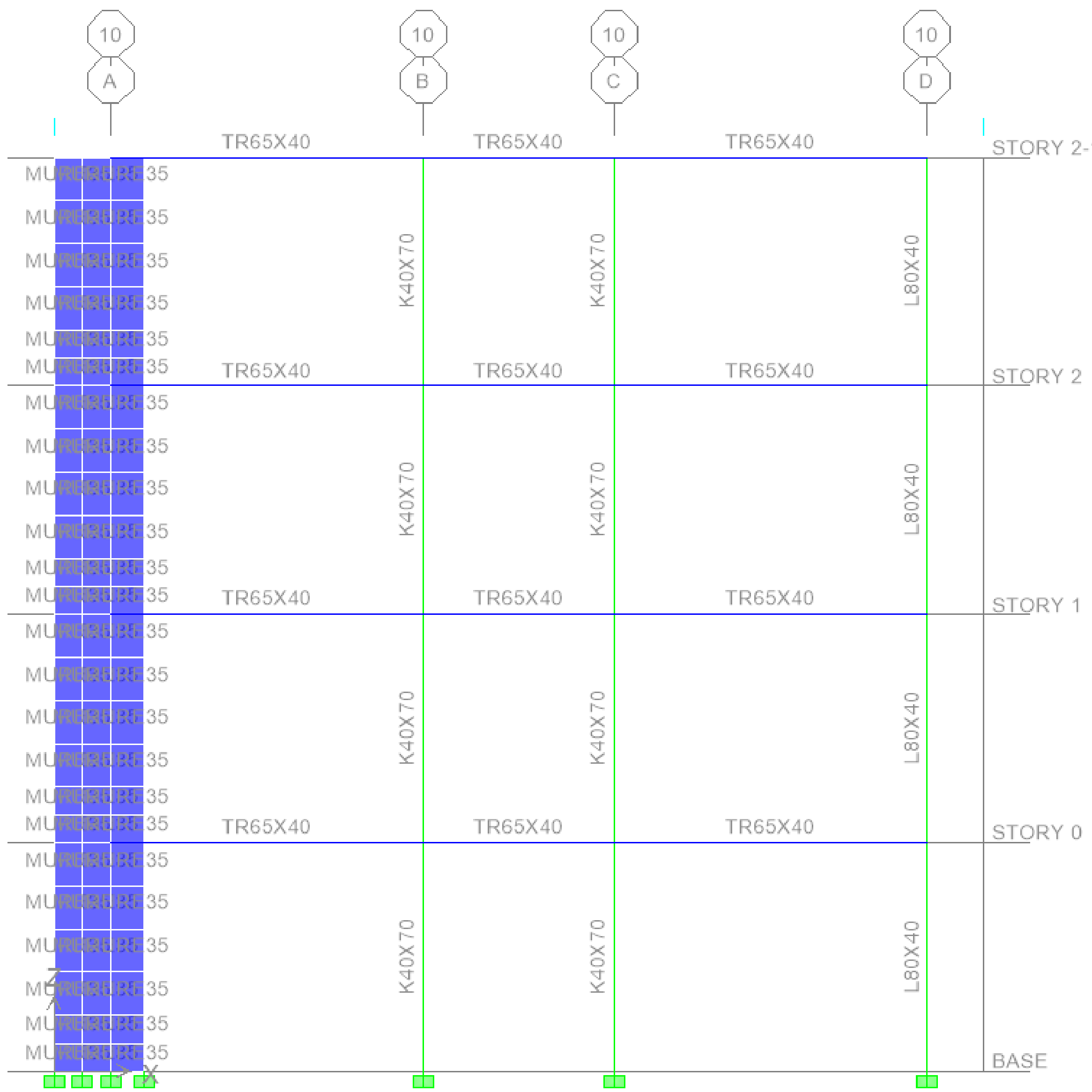
K40X70
STORY 2
STORY 1
STORY 0
BASE
Z
X

Axis 2

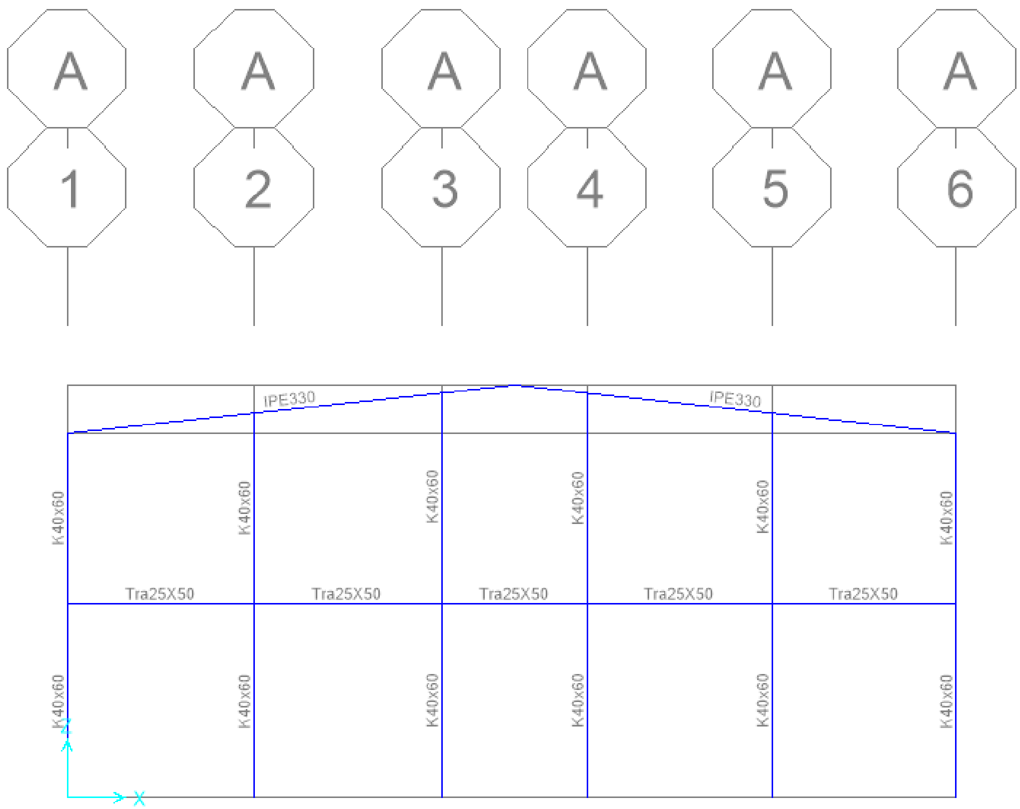

3
A
3
B
3
C
3
D
TR30X50
TR65X40
TR30X50
STORY 2-1
L80X40
L80X40
L80X40
L80X40
TR30X50
TR65X40
TR30X50
STORY 2
L80X40
L80X40
L80X40
L80X40
TR30X50
TR65X40
TR30X50
STORY 1
L80X40
L80X40
L80X40
L80X40
TR30X50
TR65X40
TR30X50
STORY 0
L80X40
L80X40
L80X40
L80X40
Z
X
BASE

Axis 3

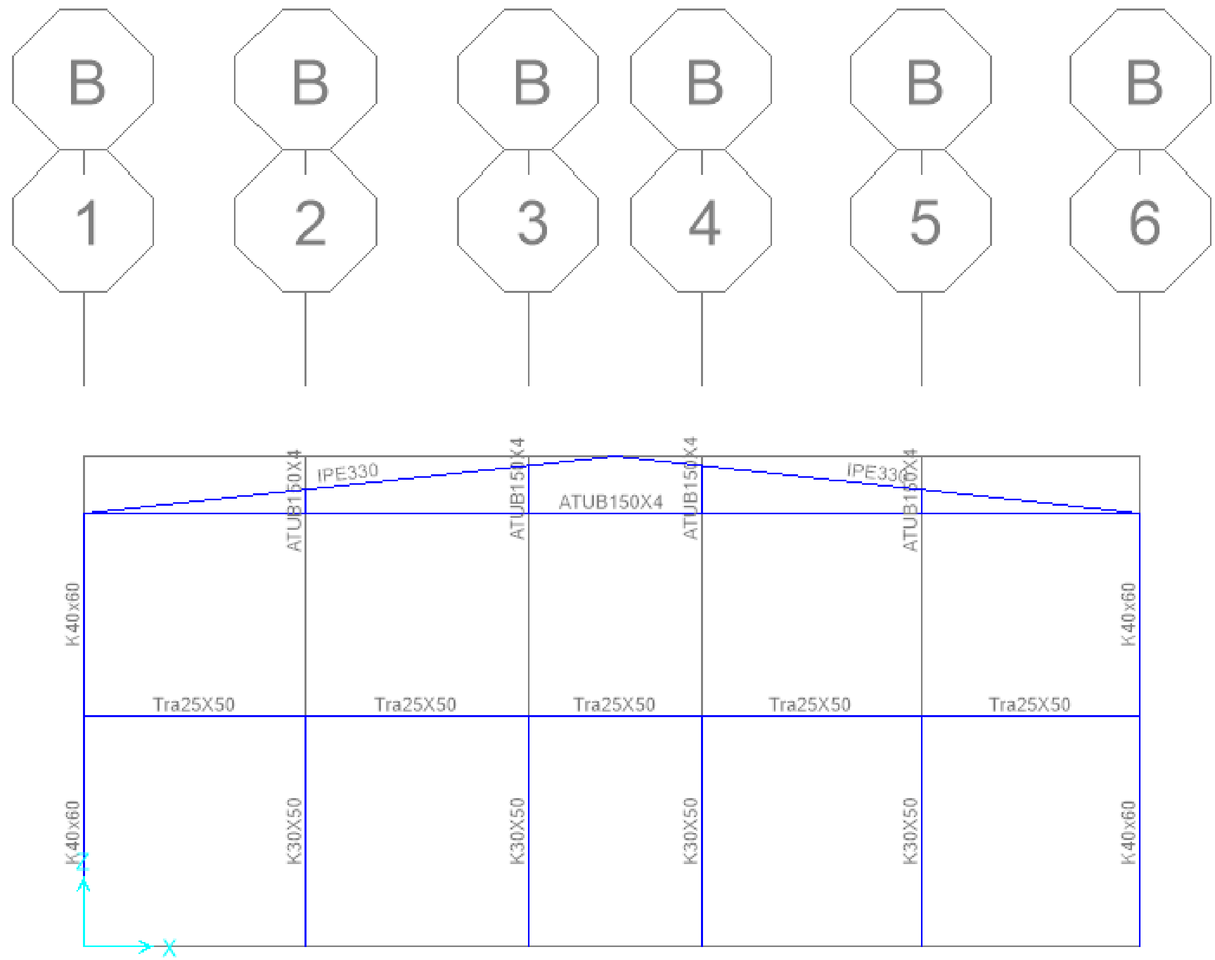

10
A
B
C
D
TR65X40
K40X70
L80X40
STORY 2-1
STORY 2
STORY 1
STORY 0
BASE
35

Axis 10

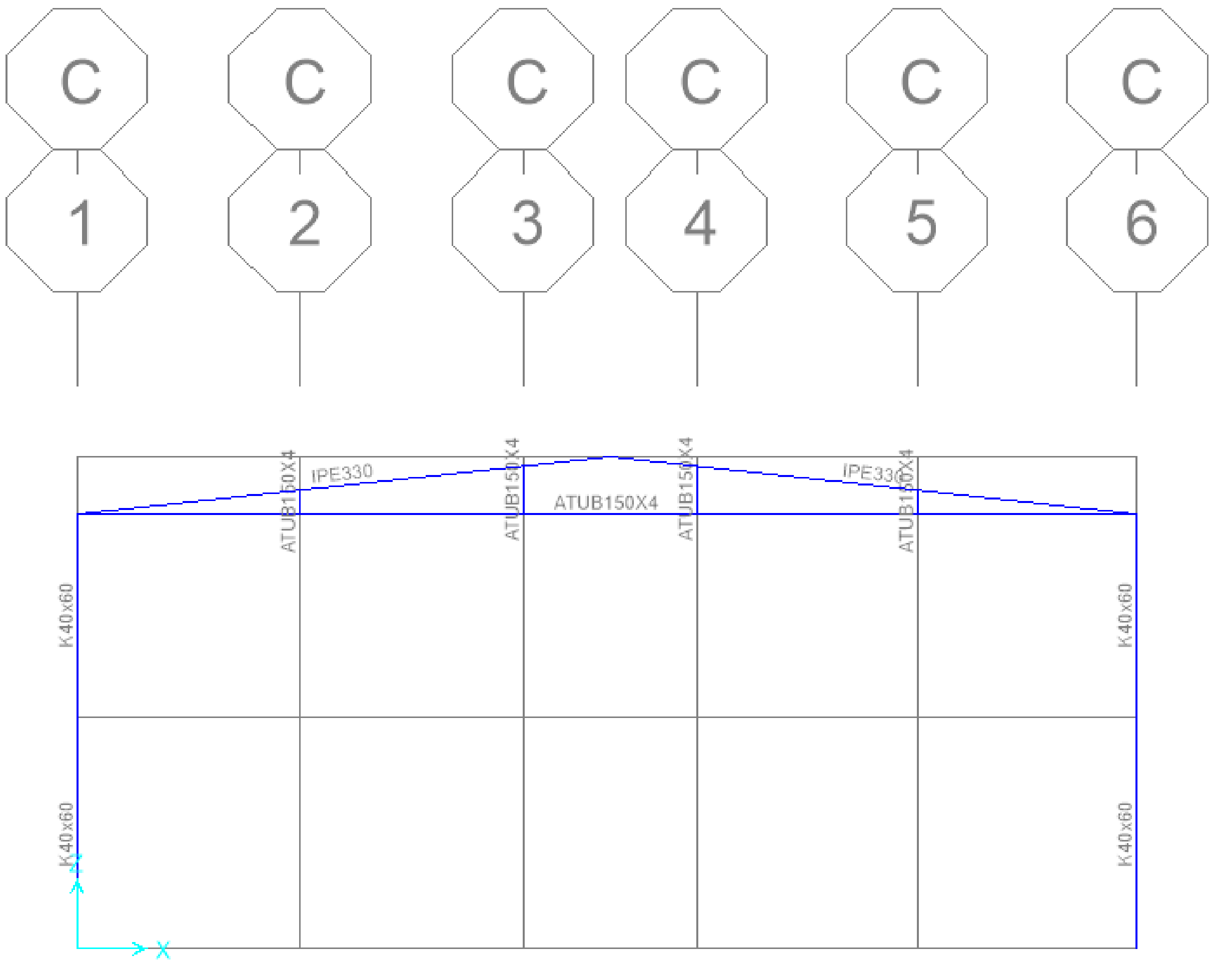
11.3.Gym



Axis A and G


B 1
B 2
B 3
B 4
B 5
B 6
IPE330
ATUB150X4
IPE330
ATUB150X4
ATUB150X4
ATUB150X4
ATUB150X4
K40x60
K40x60
Tra25X50
Tra25X50
Tra25X50
Tra25X50
Tra25X50
K40x60
K30X50
K30X50
K30X50
K30X50
K40x60

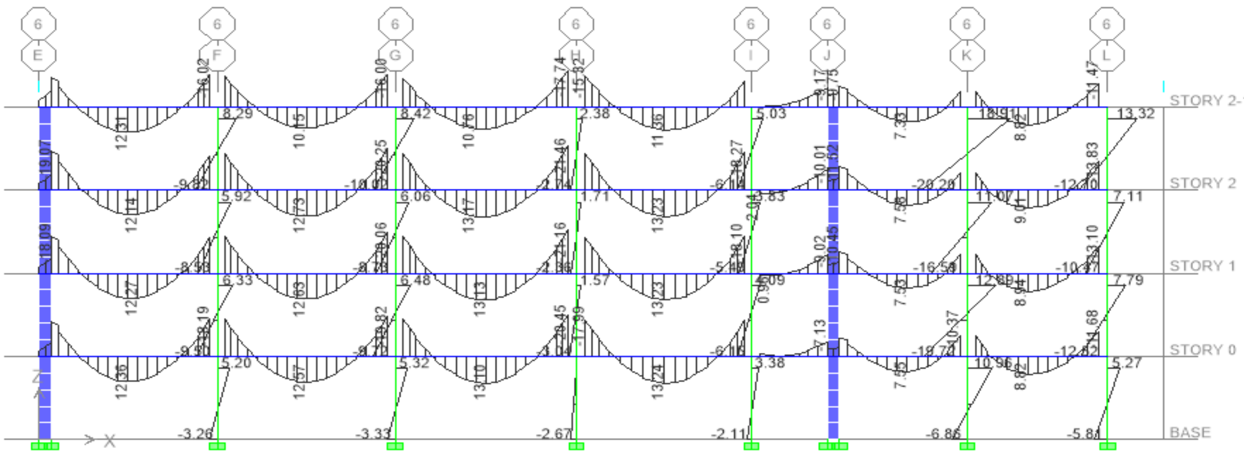
Axis B



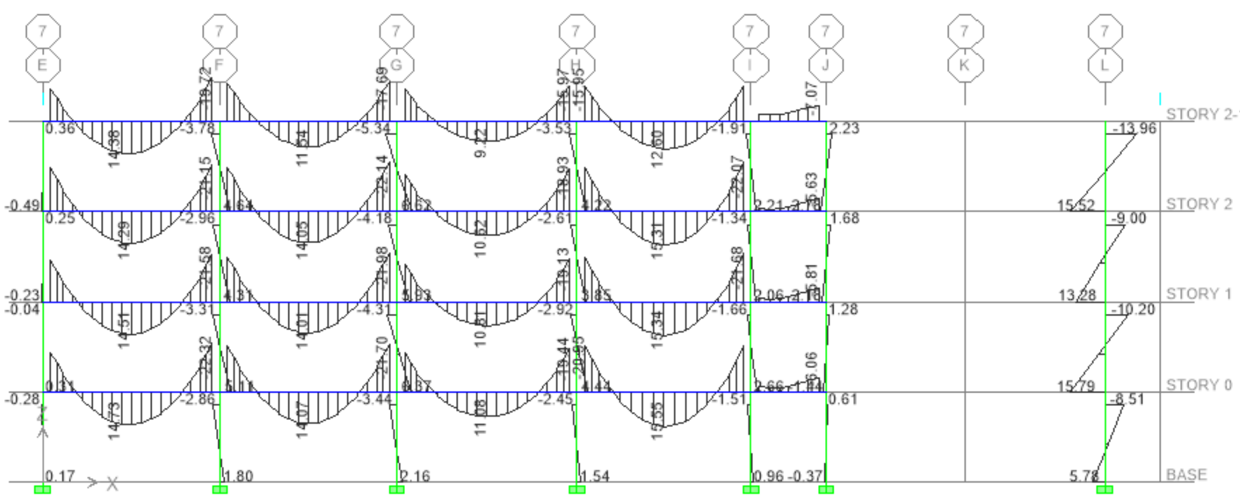
Axis C, D, E and F

12. Schemes of Moments in the Representative Elements of the Structure

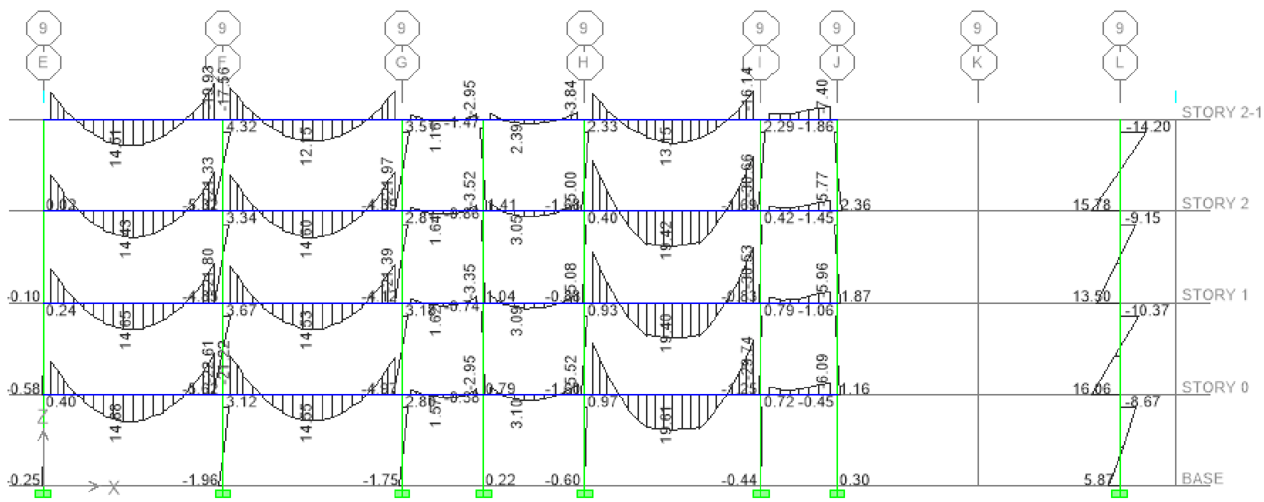
12.1. Object 1



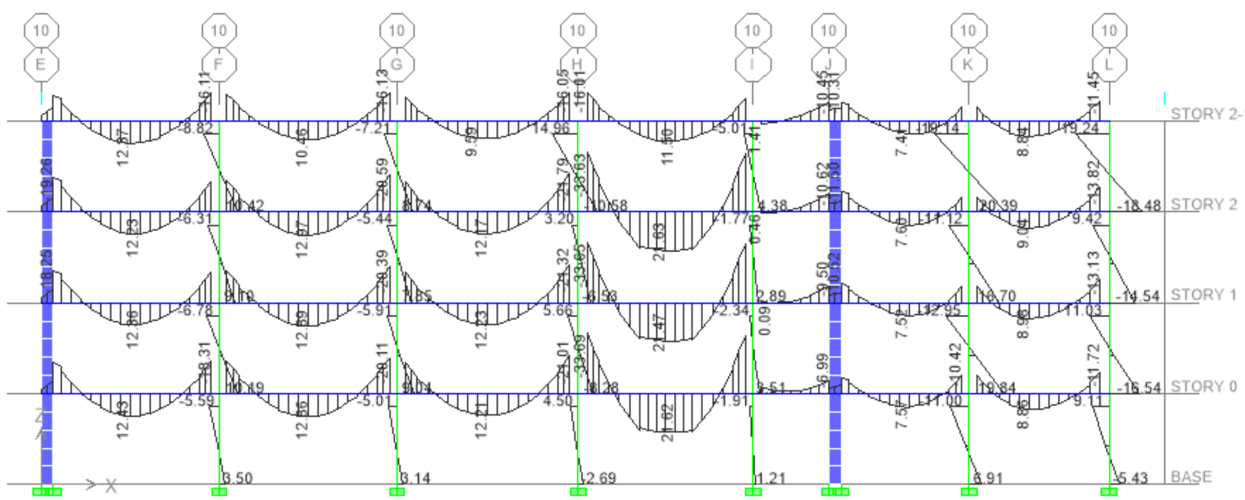
Moments in Axis 6 (DCON2)



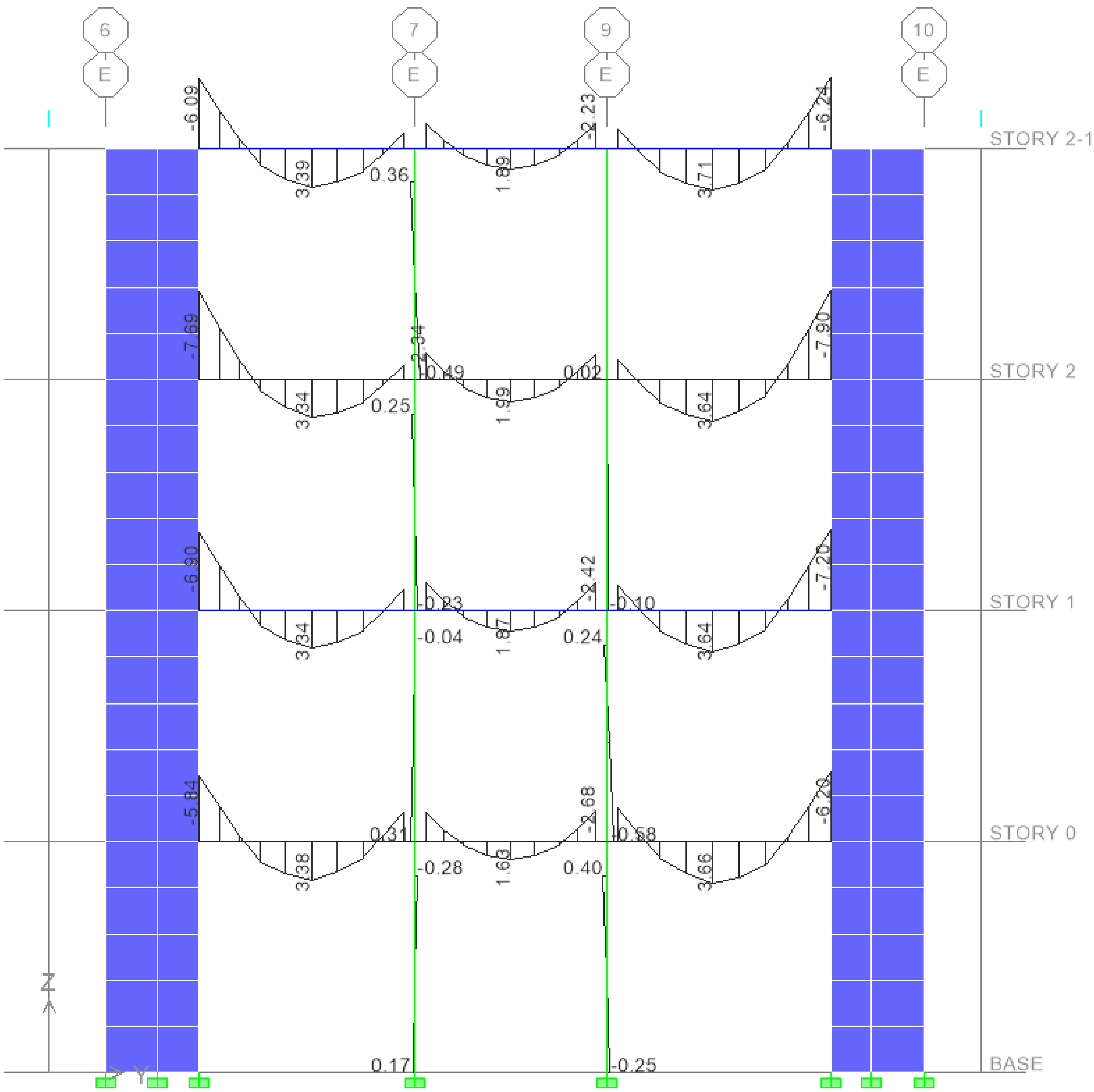
Moments in Axis 7 (DCON2)



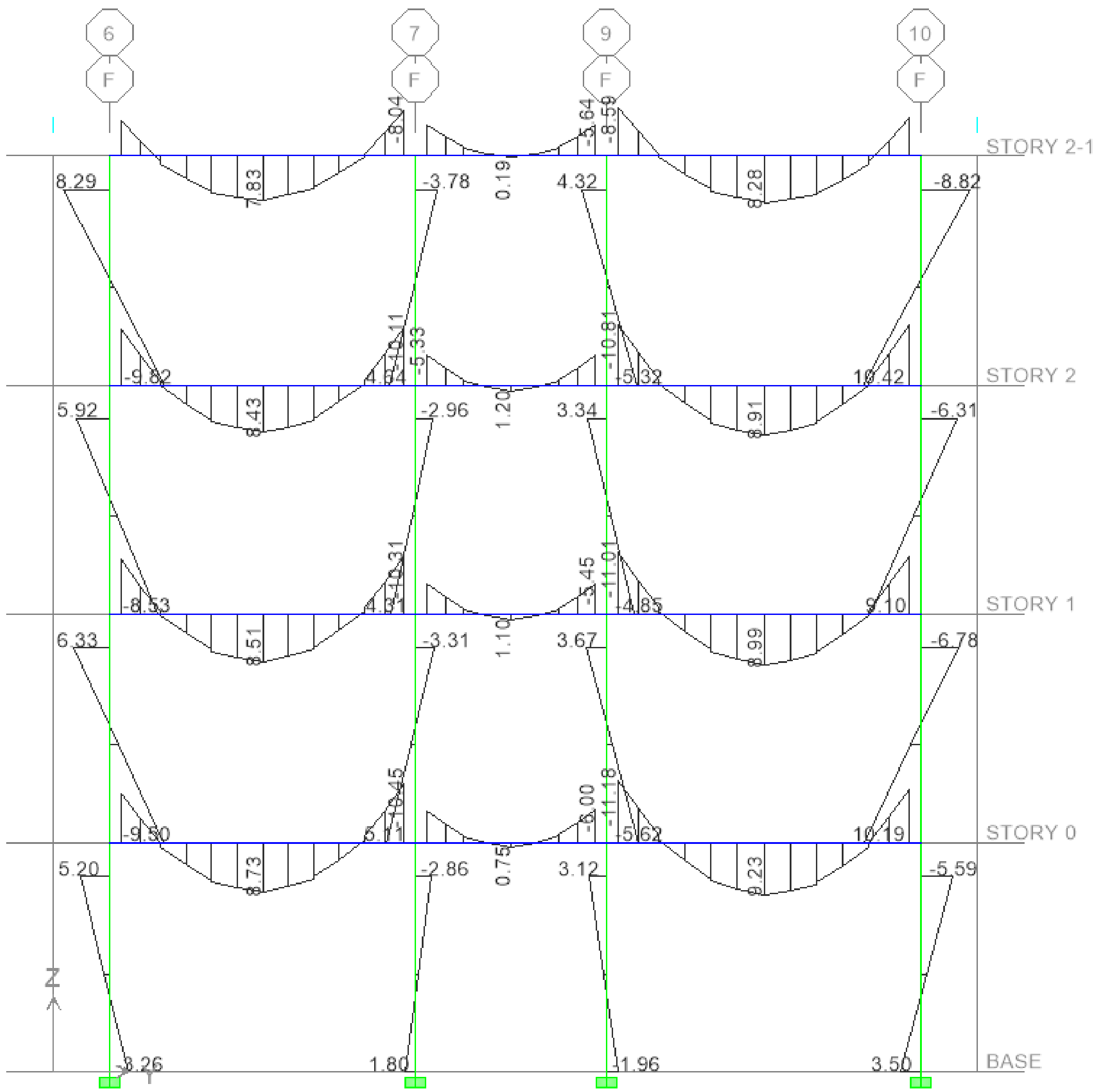
Moments in Axis 9 (DCON2)



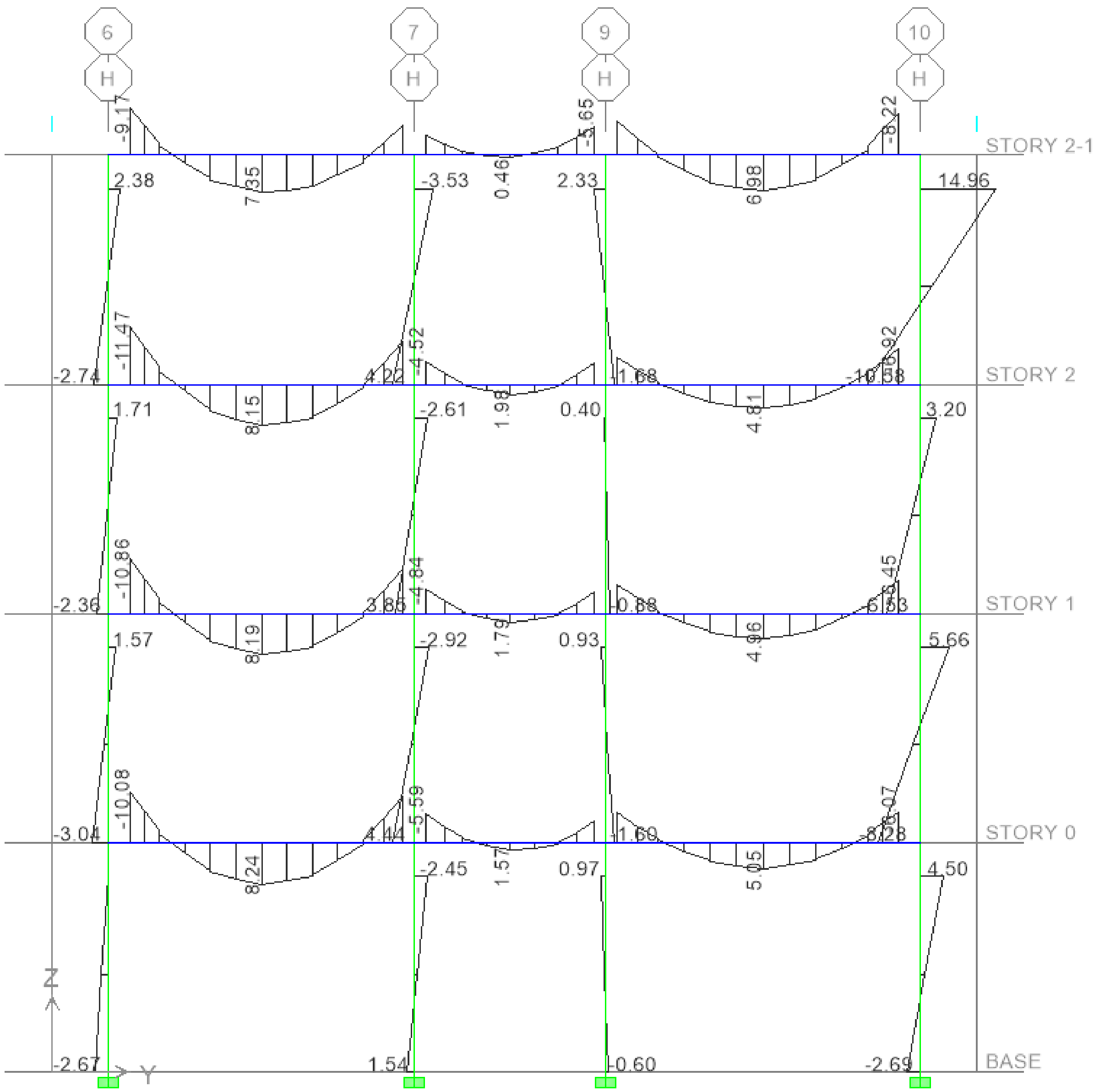
Moments in Axis 10 (DCON2)



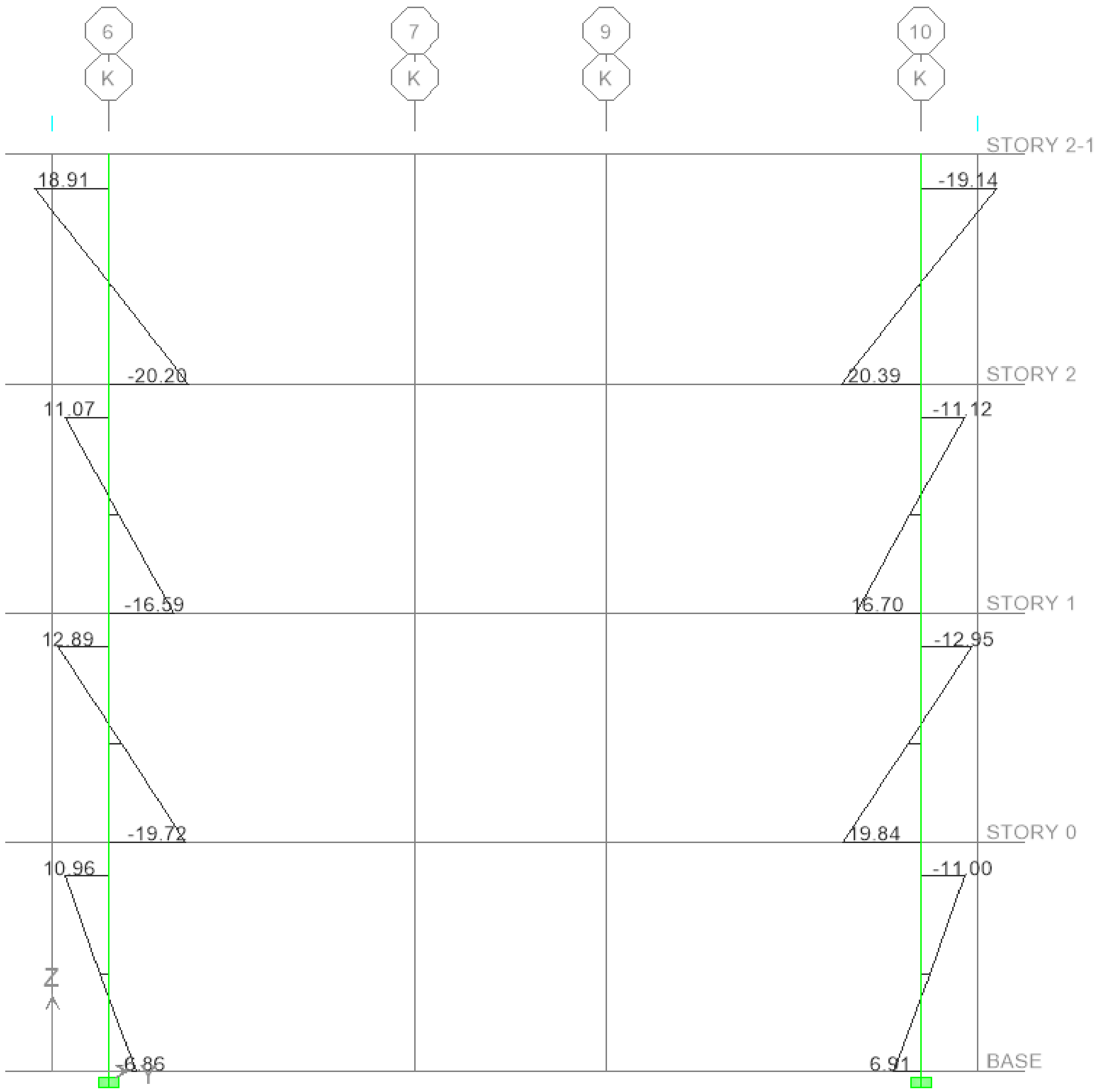
Moments in Axis E (DCON2)



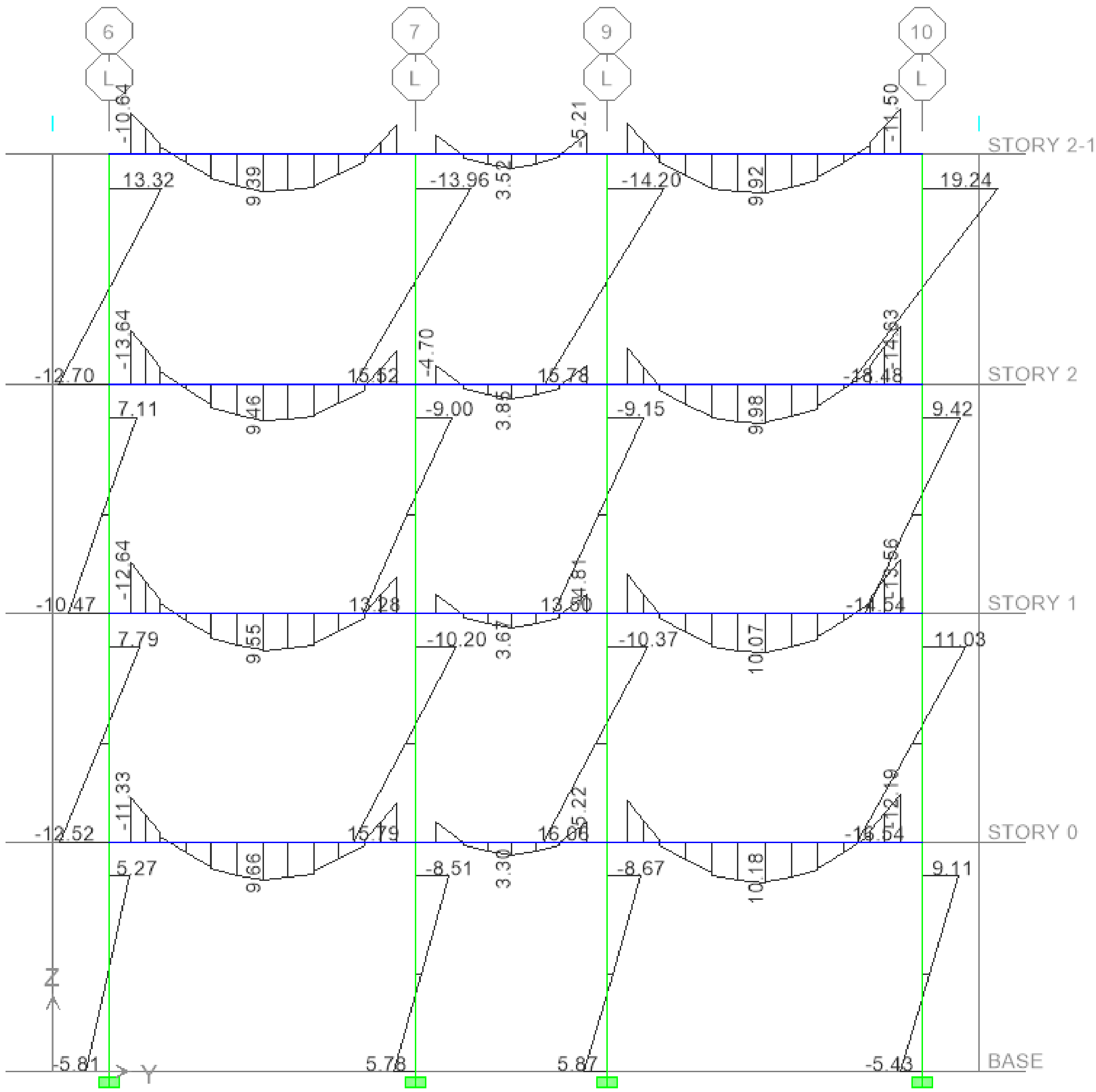
Moments in Axis F (DCON2)



Moments in Axis H (DCON2)

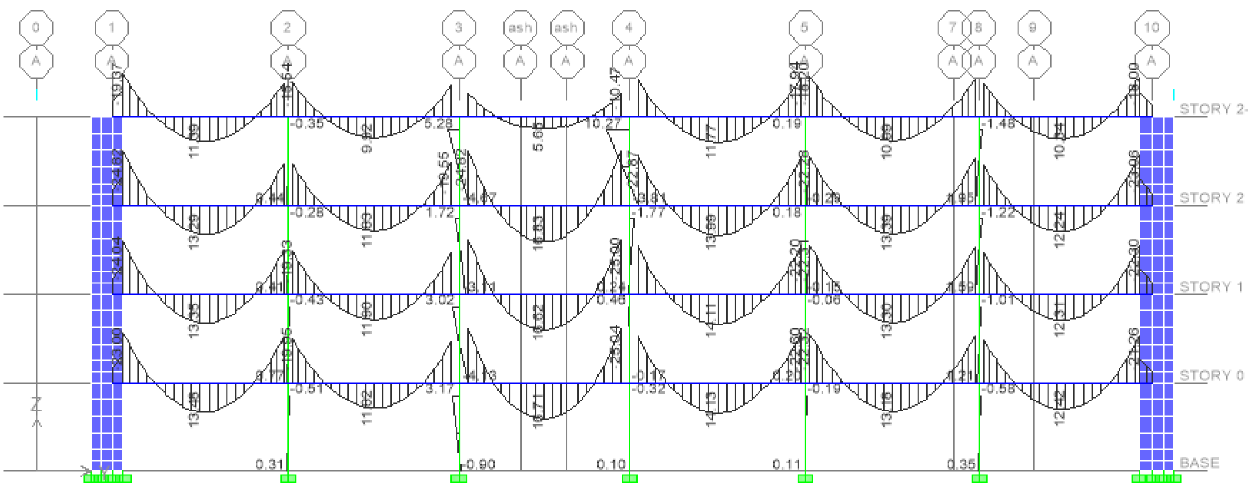


Moments in Axis K (DCON2)

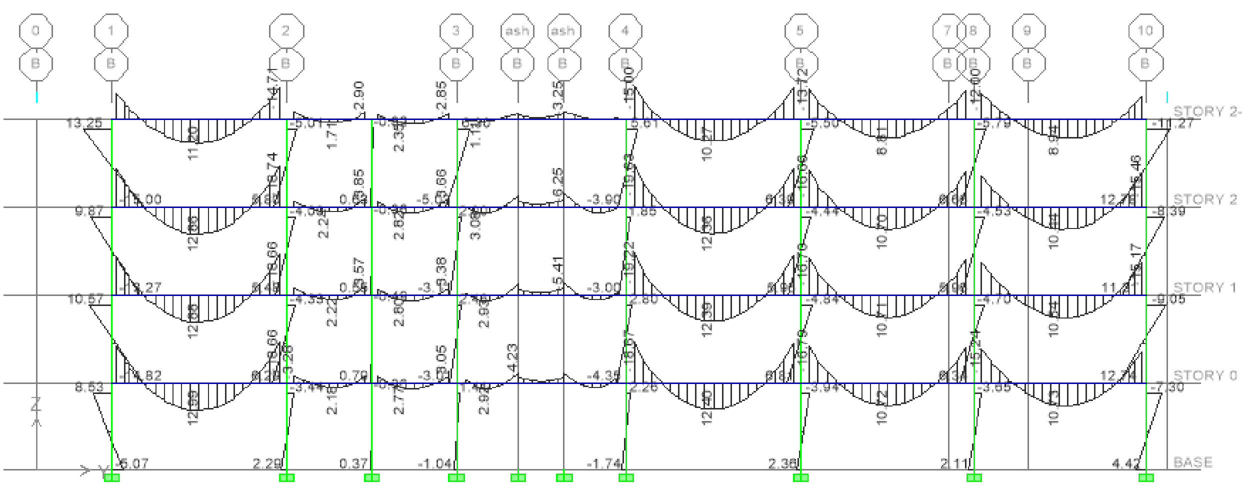


Moments in Axis L (DCON2)

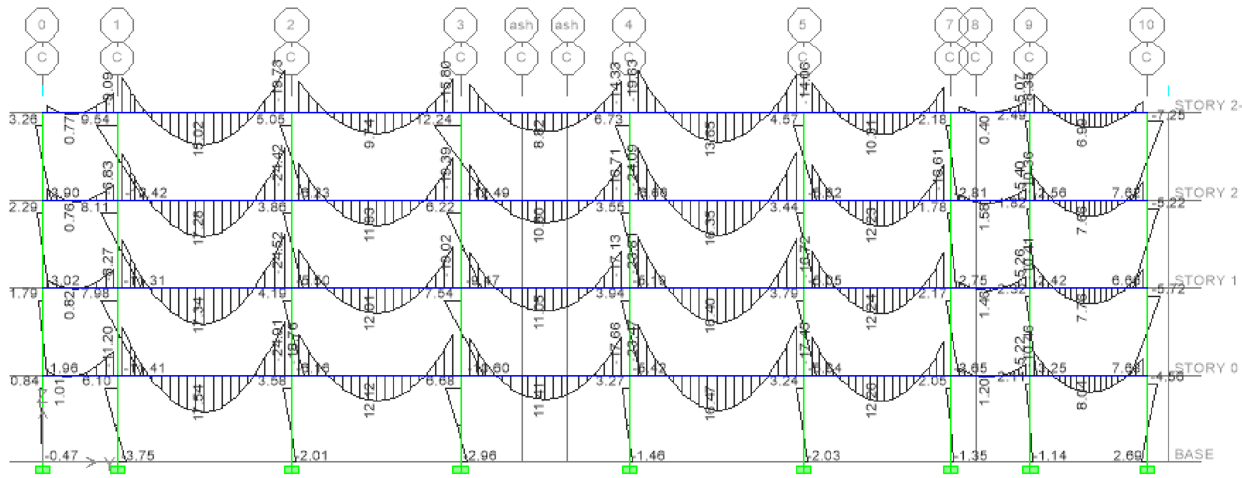
12.2. Object 2



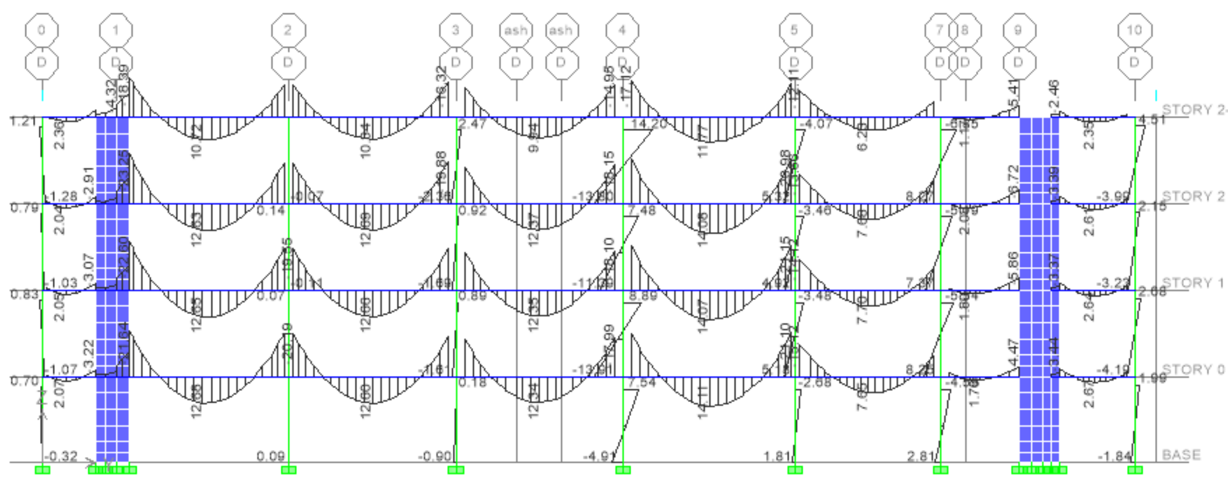
Moments in Axis A (DCON2)



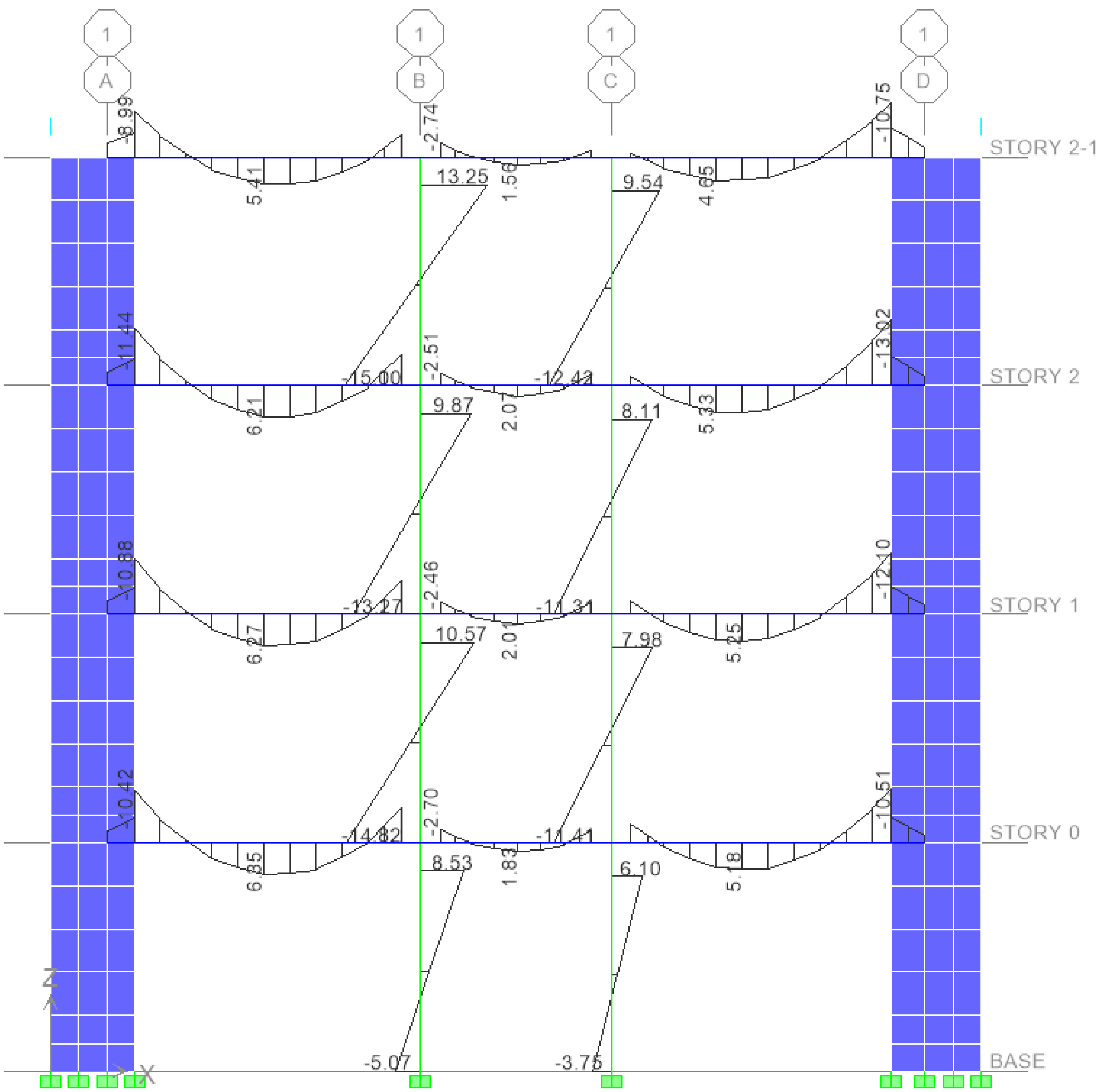
Moments in Axis B (DCON2)



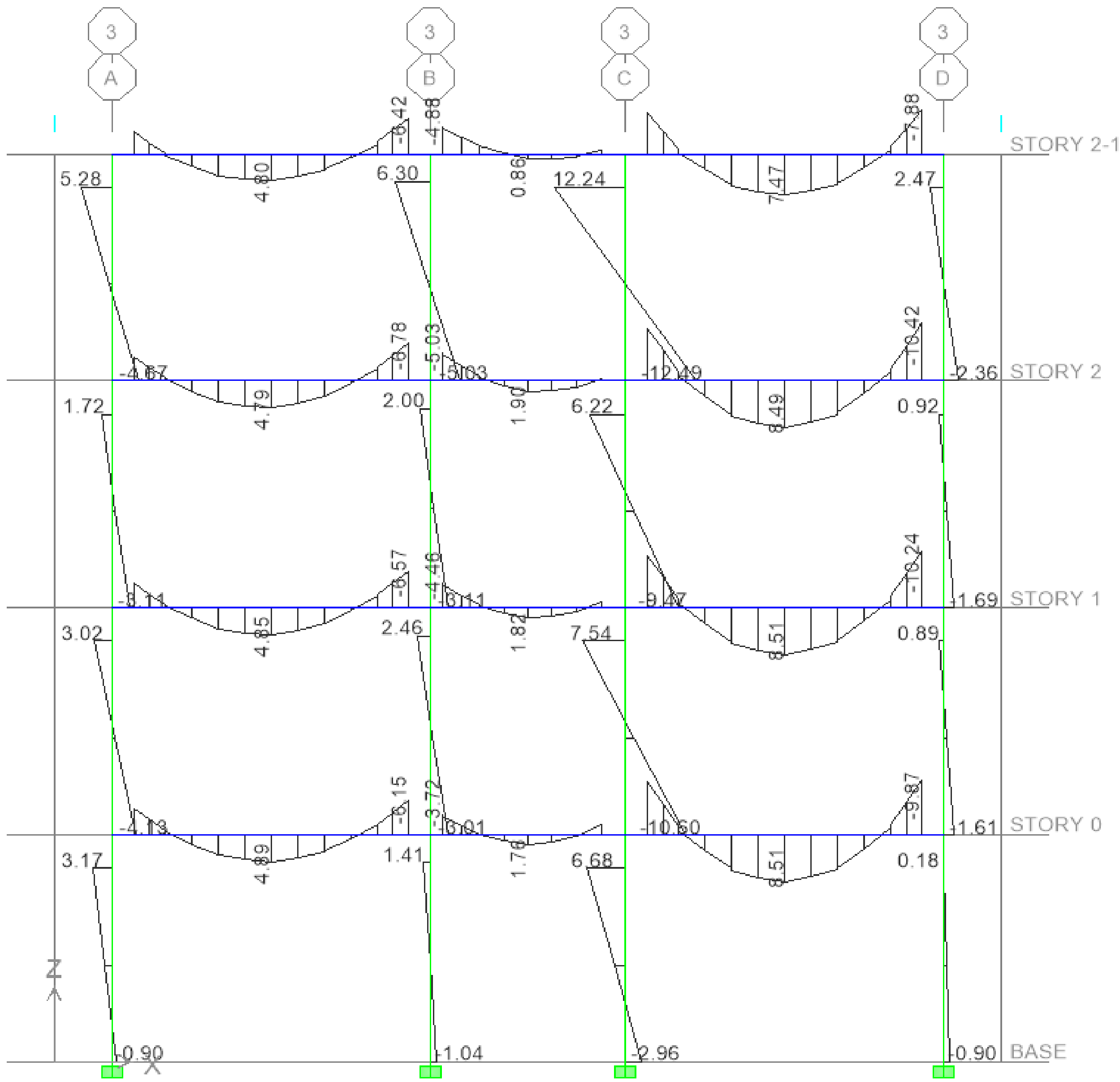
Moments in Axis C (DCON2)



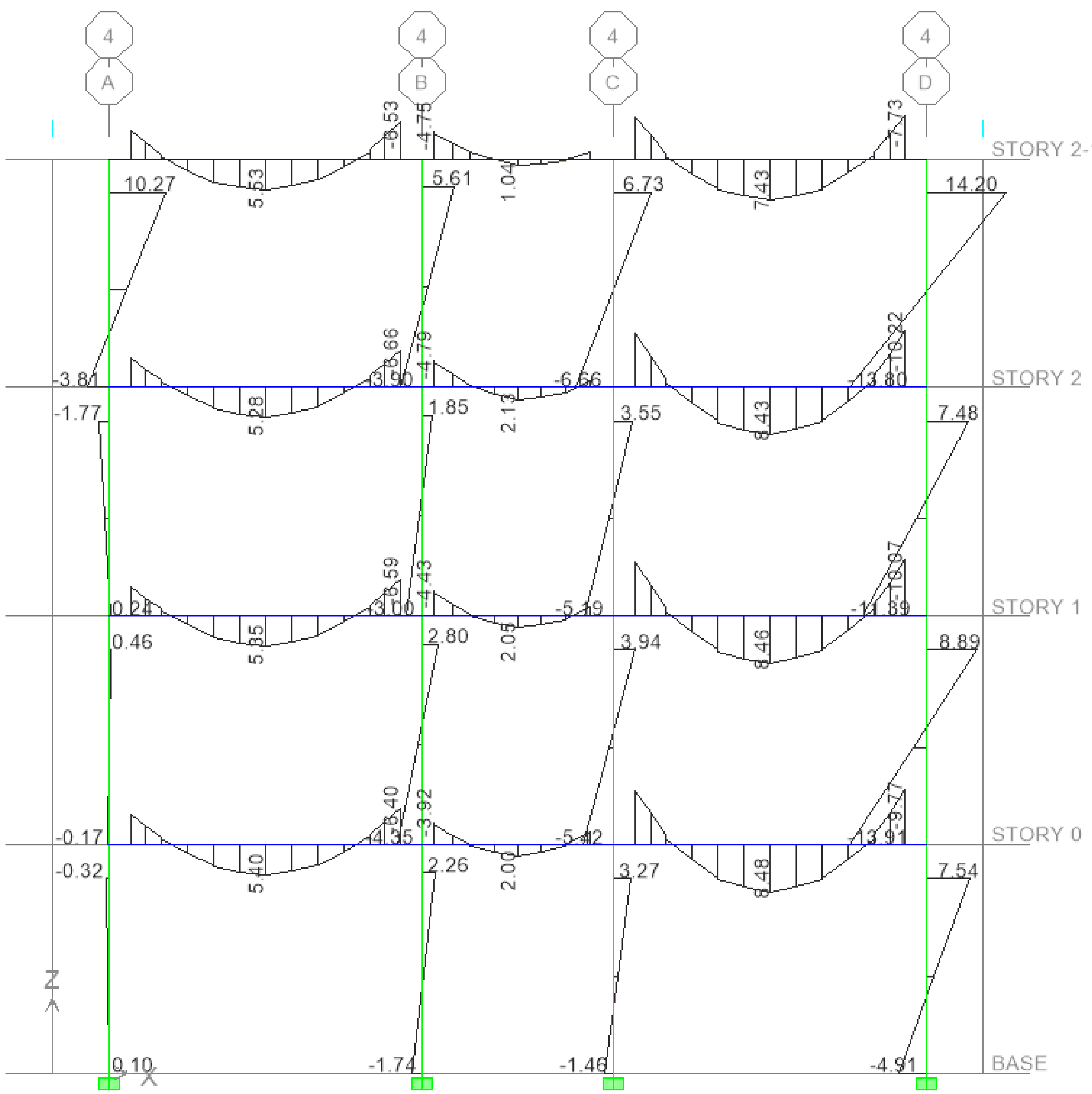
Moments in Axis D (DCON2)



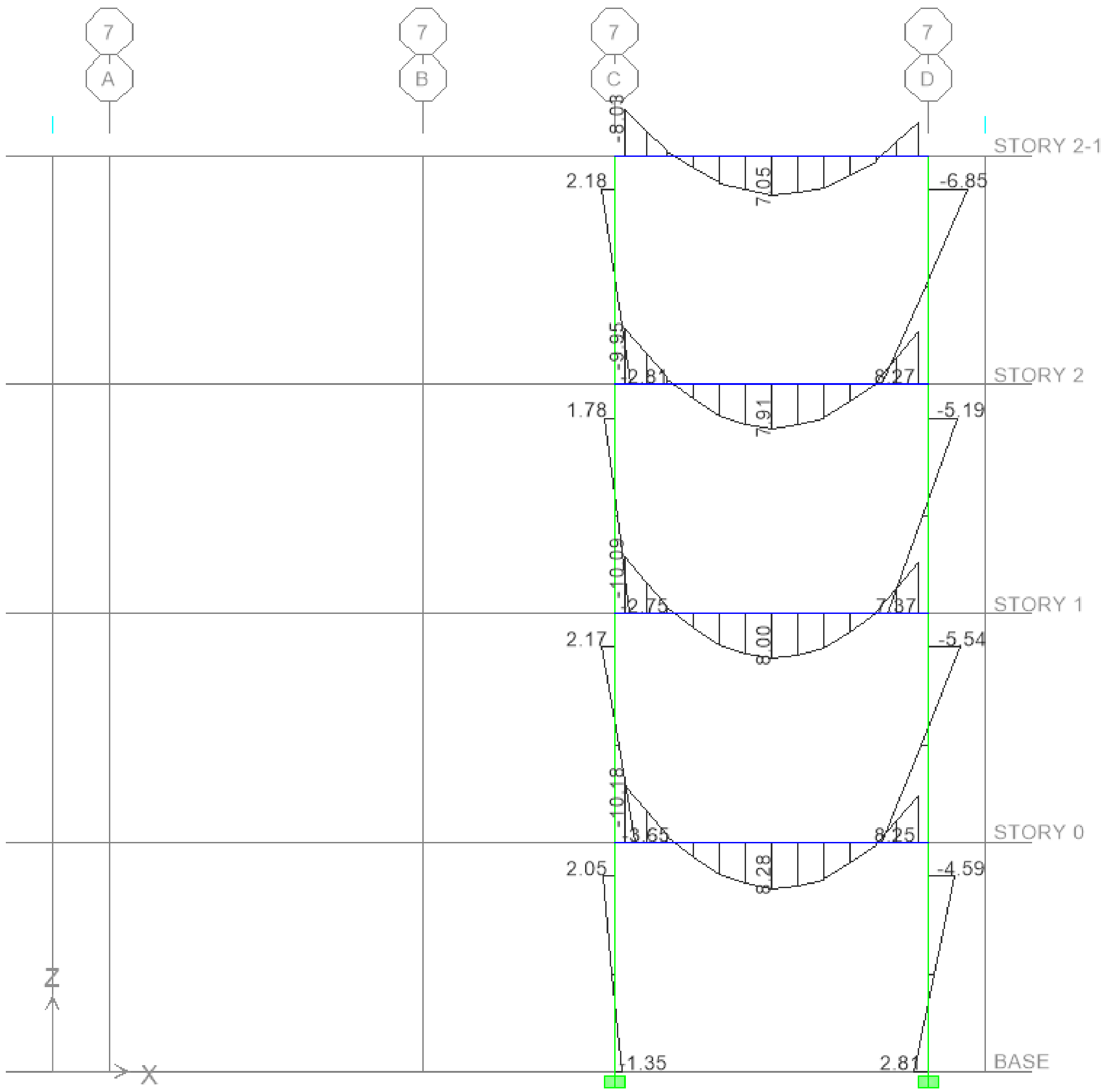
Moments in Axis 1 (DCON2)



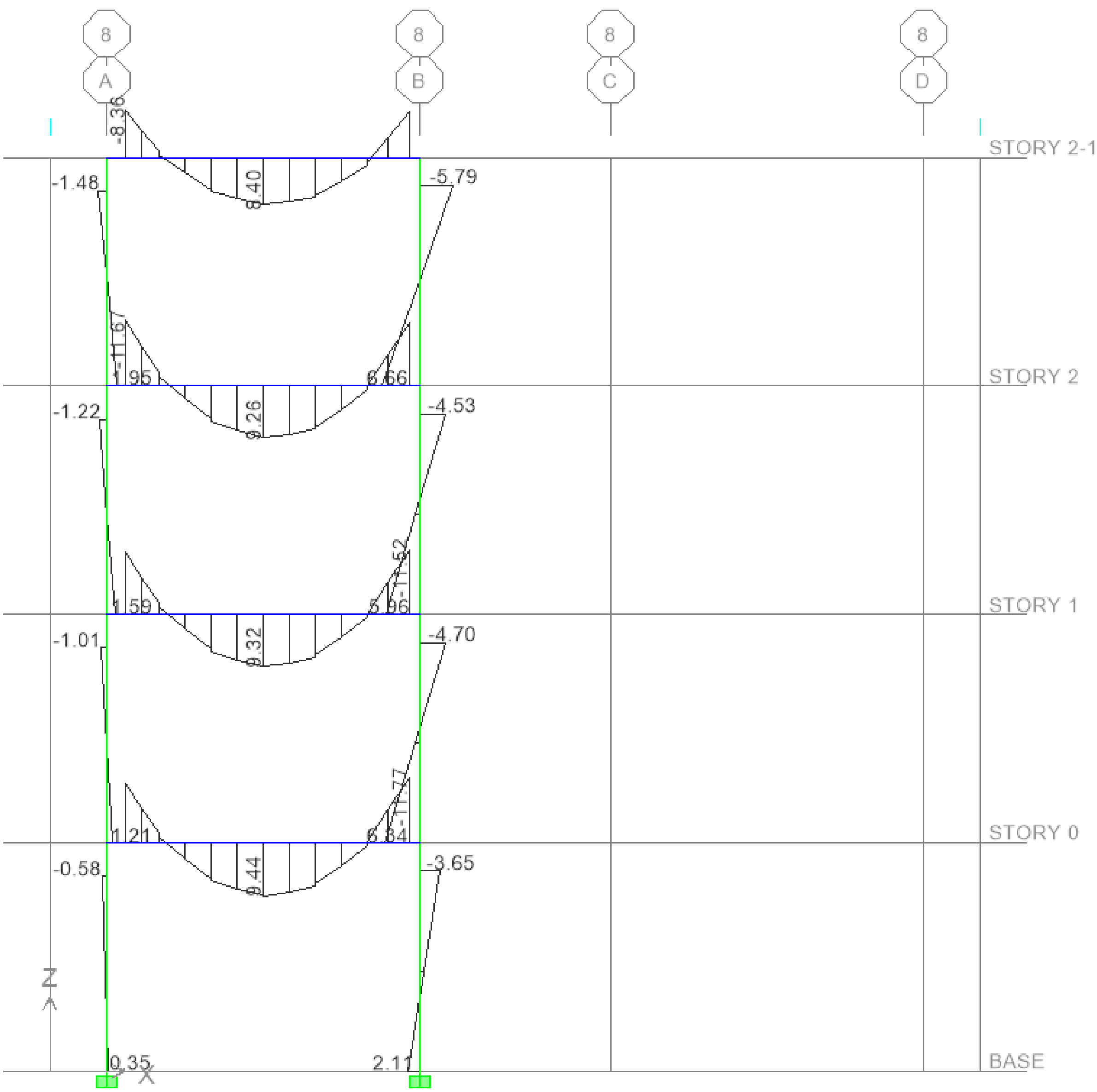
Moments in Axis 3 (DCON2)



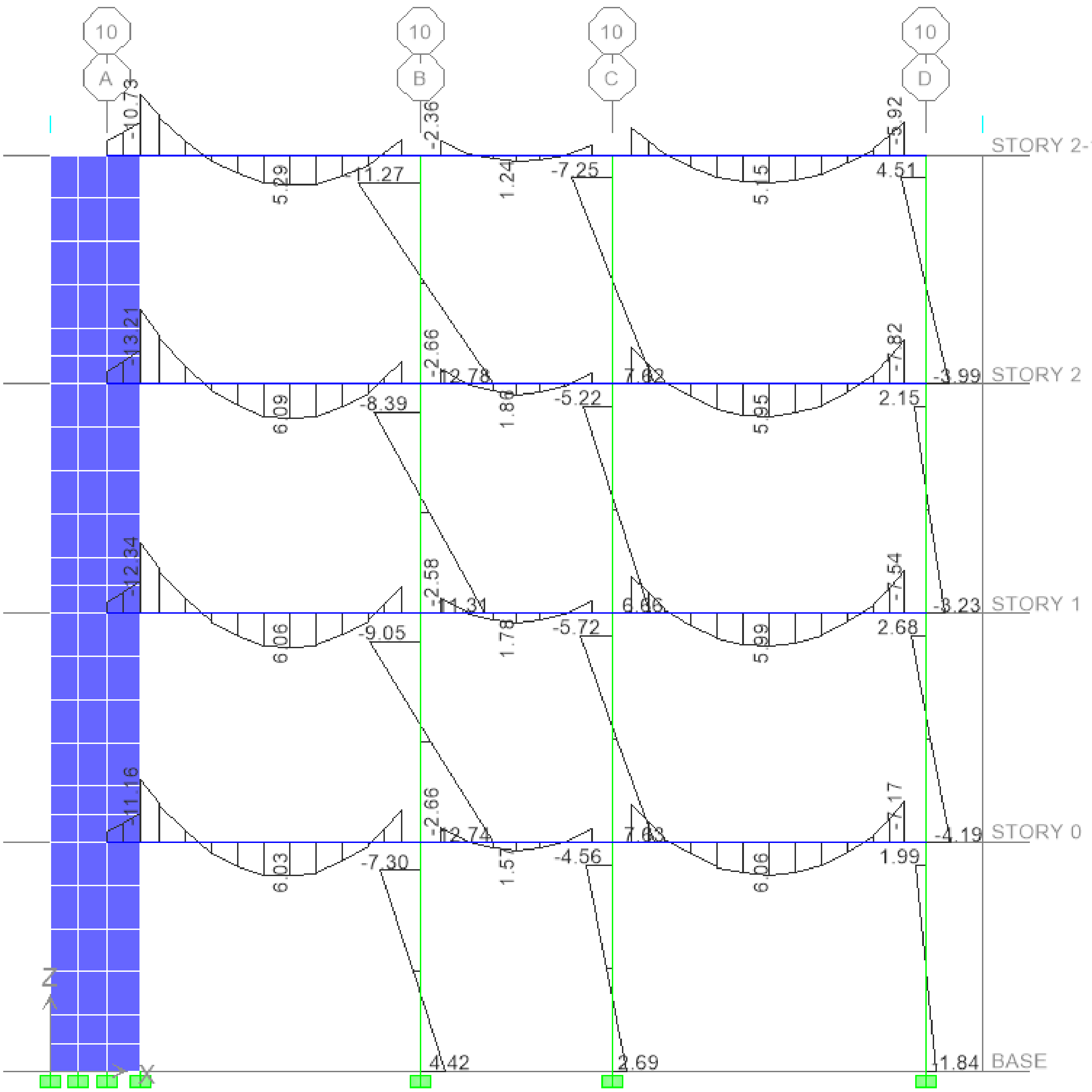
Moments in Axis 4 (DCON2)



Moments in Axis 7 (DCON2)

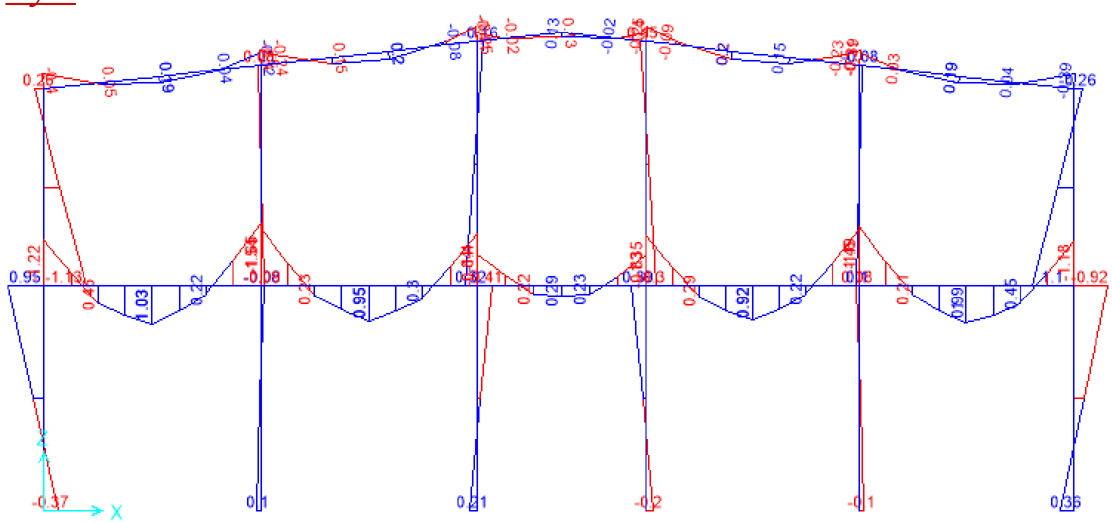


Moments in Axis 8 (DCON2)

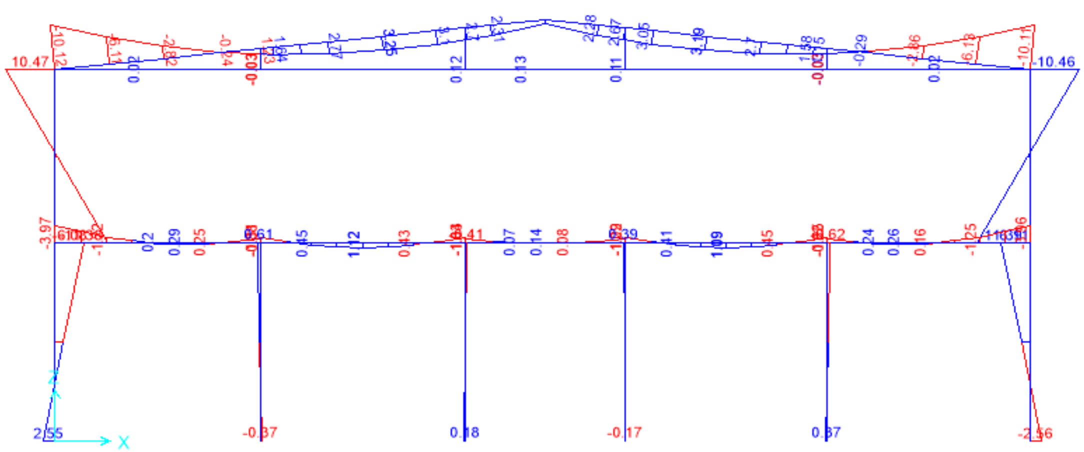


Moments in Axis 10 (DCON2)

12.3. Gym



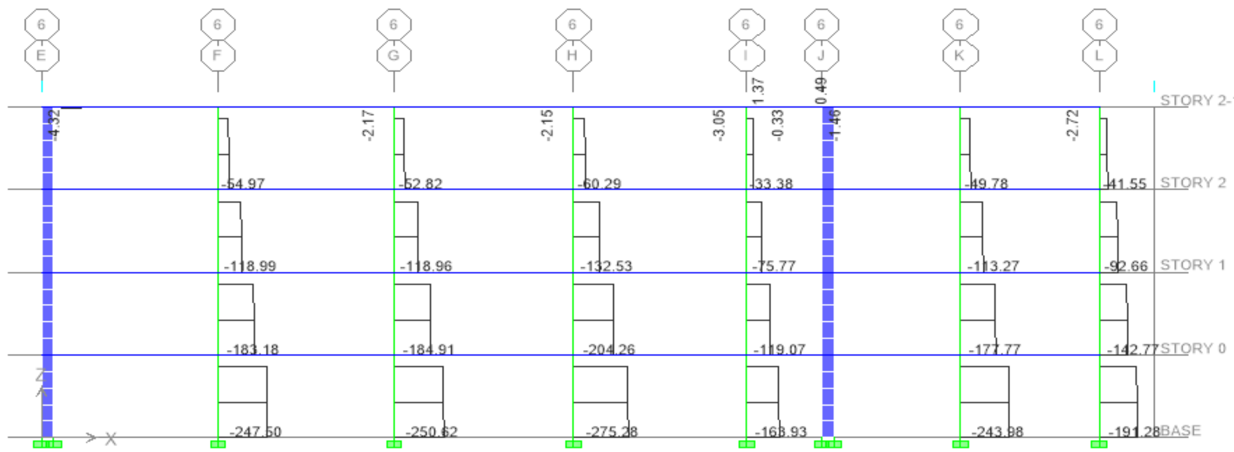
Moments in Axis A (DCON2)



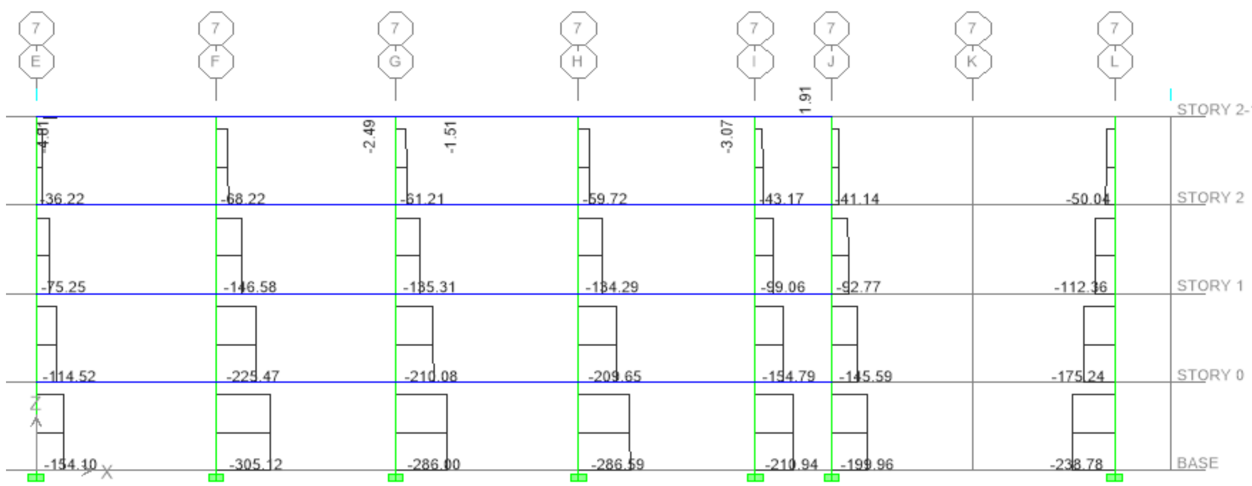
Moments in Axis B (DCON2)

13. Schemes of Axial Forces in the Representative Elements of the Structure

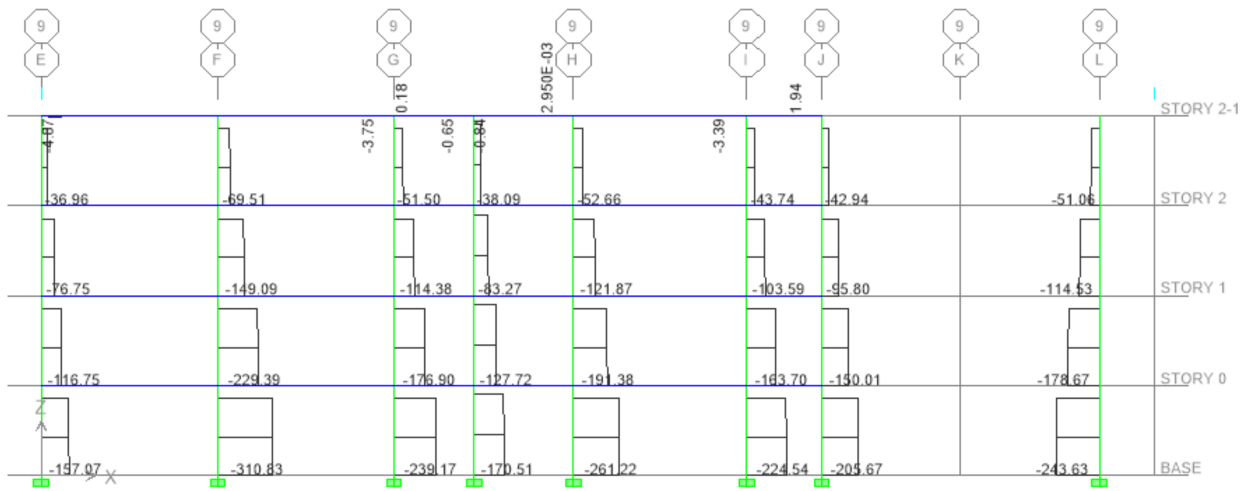
13.1. Object 1



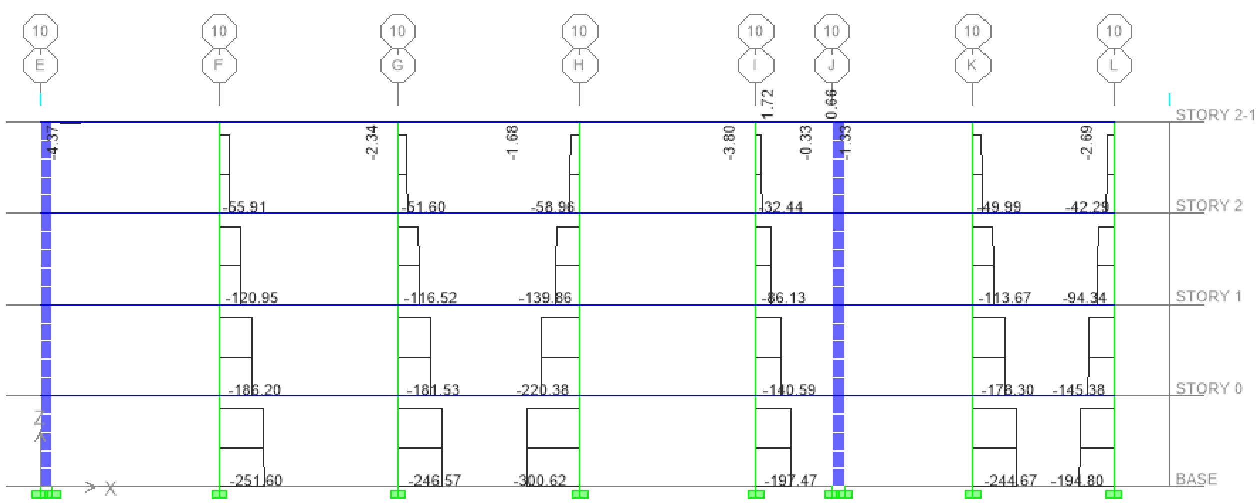
Axial Force in Axis 6 (DCON2)



Axial Force in Axis 7 (DCON2)

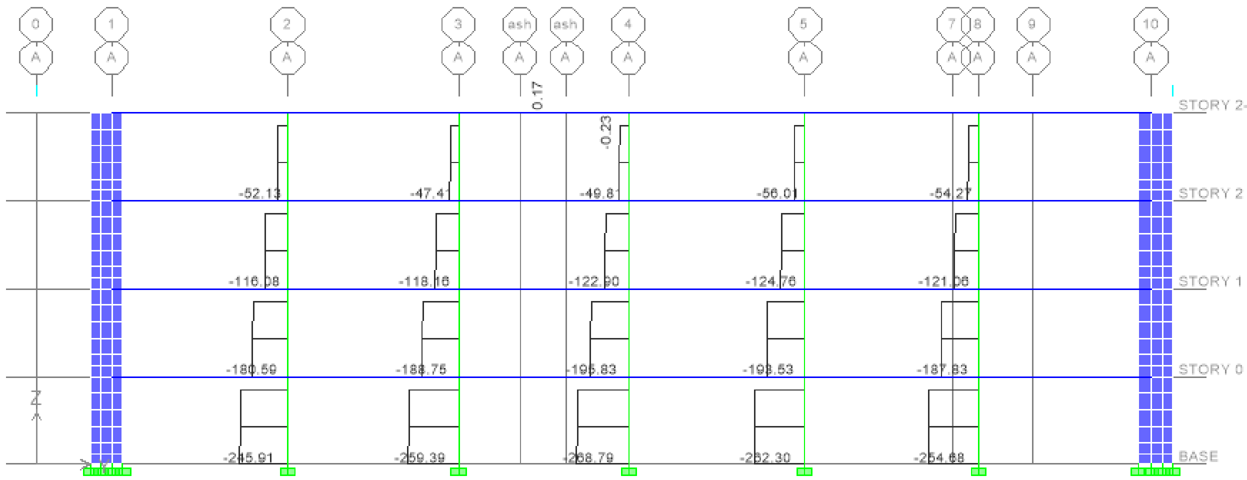


Axial Force in Axis 9 (DCON2)

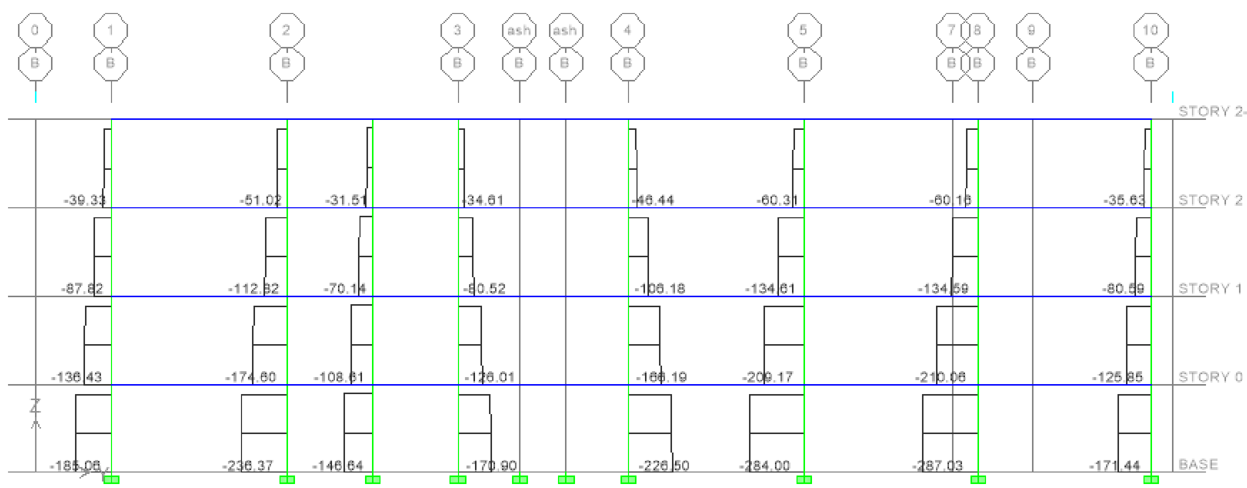


Axial Force in Axis 10 (DCON2)

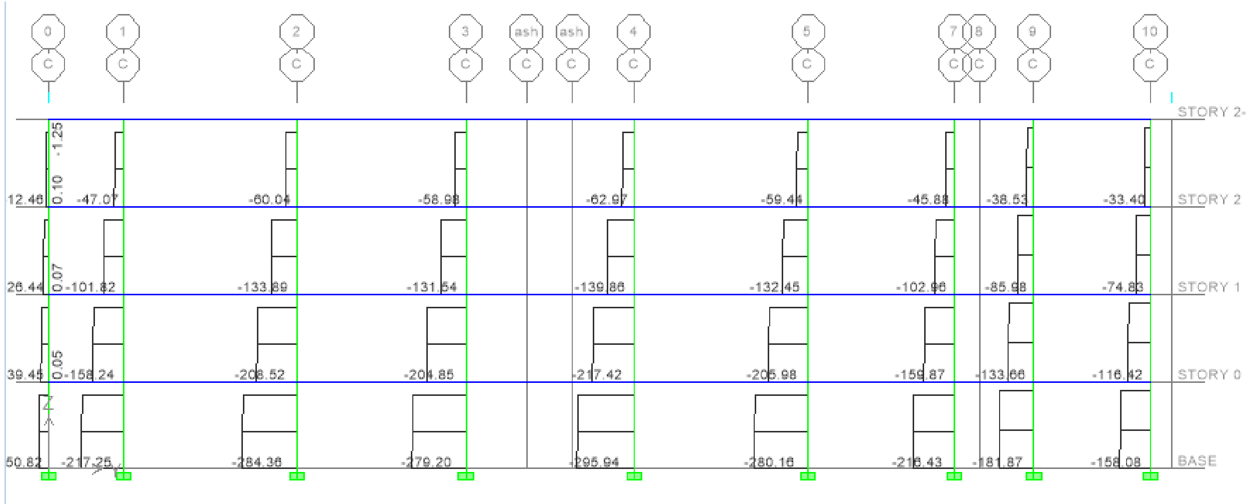
13.2. Object 2



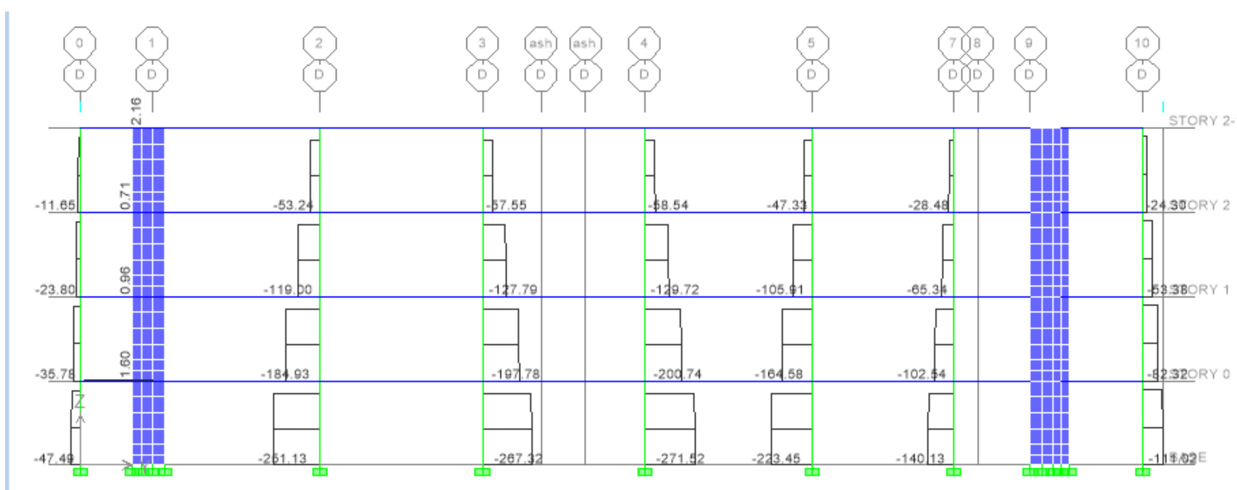
Axial Force in Axis A (DCON2)



Axial Force in Axis B (DCON2)

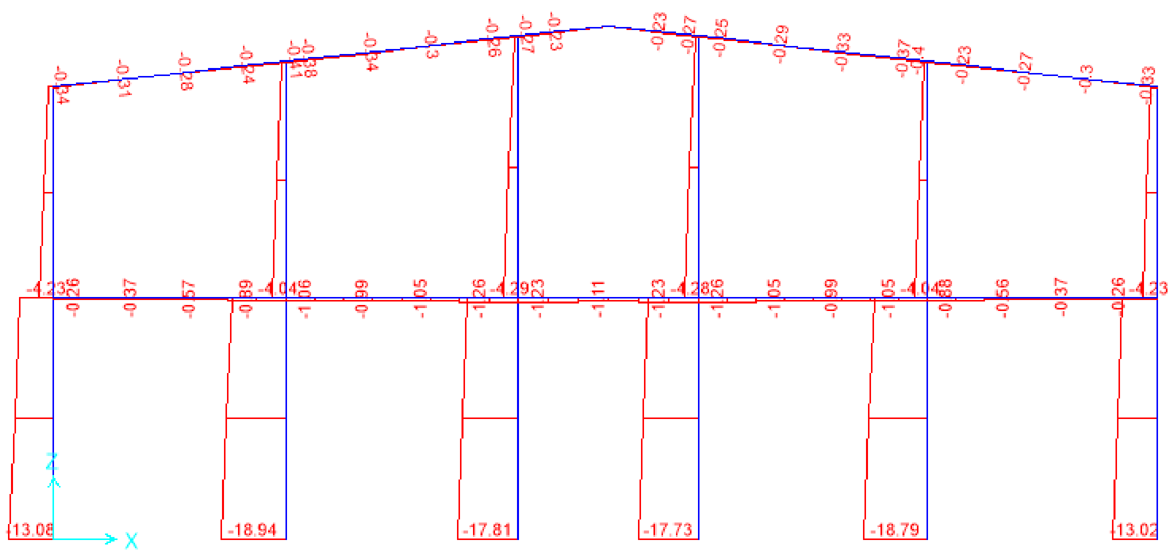


Axial Force in Axis C (DCON2)

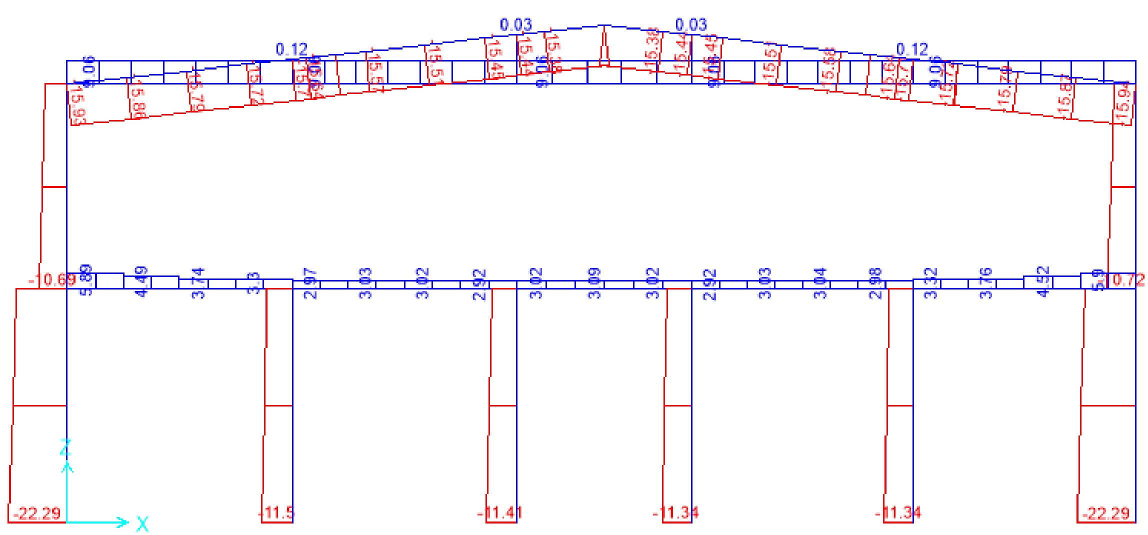


Axial Force in Axis D (dCON2)

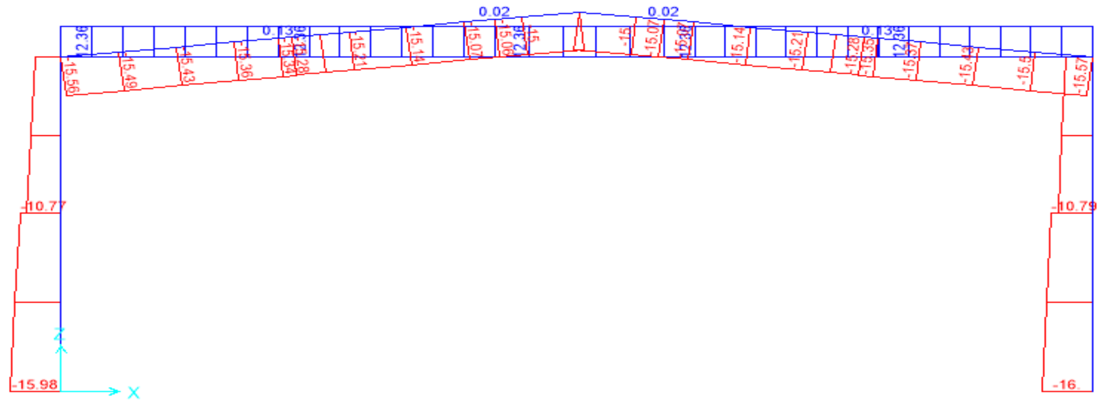
13.3. Gym



Axial Force in Axis A (DCON2)



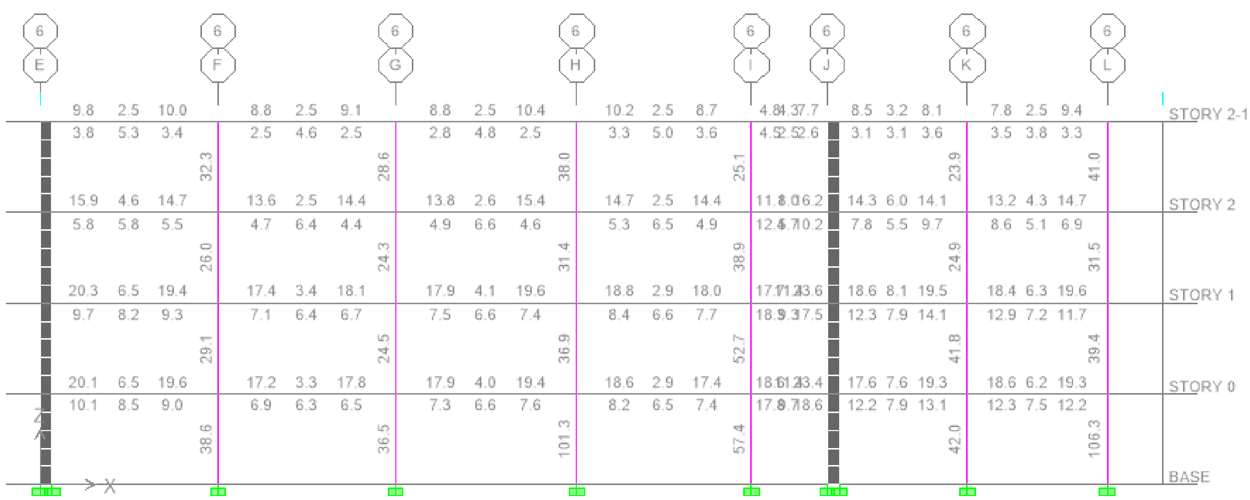
Axial Force in Axis B (DCON2)



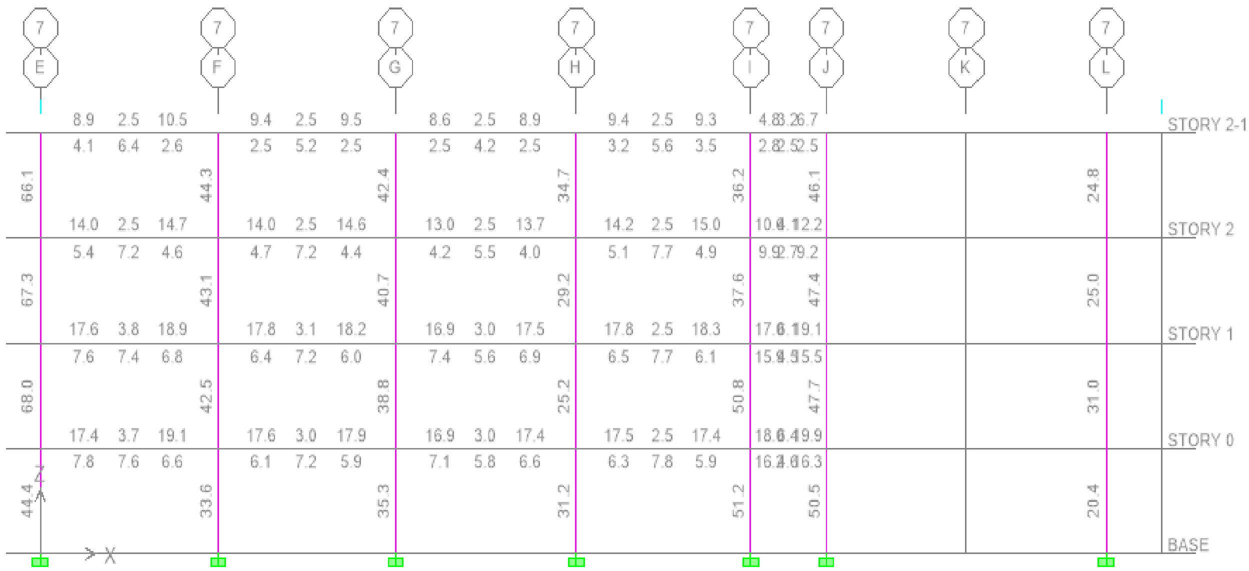
Axial Force in Axis C (DCON2)

14. Schemes of the Reinforcement Results from the Most Unfavorable Combination

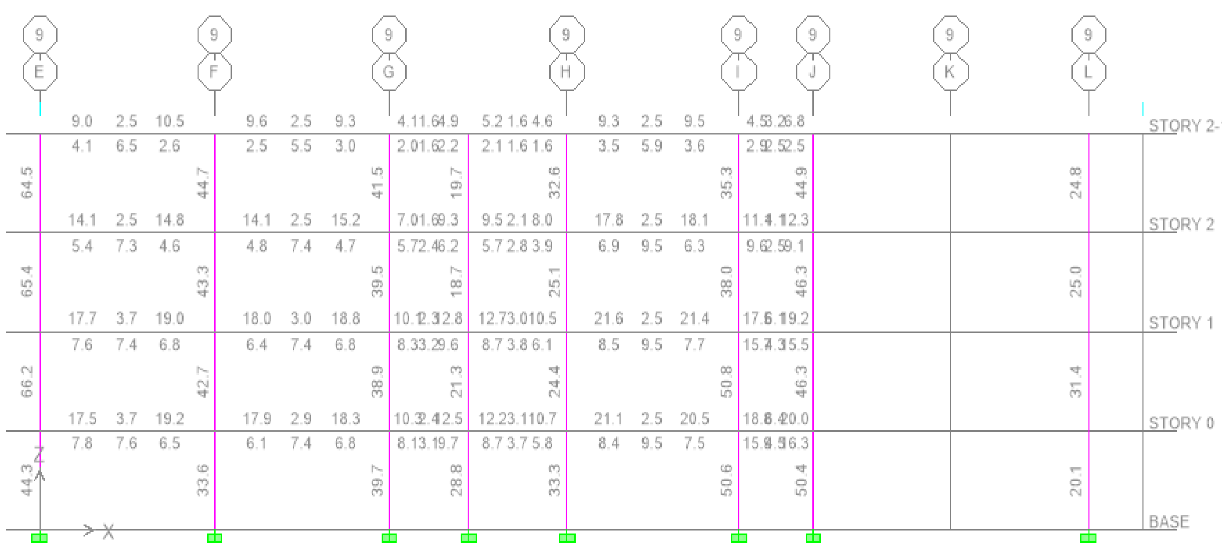
14.1. Object 1



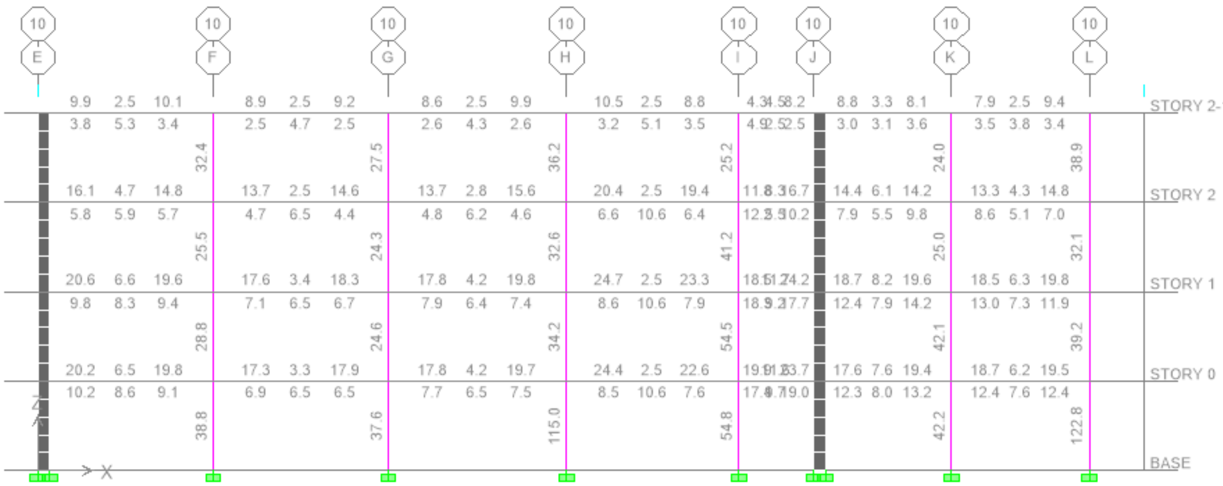
Reinforcement in Axis 6



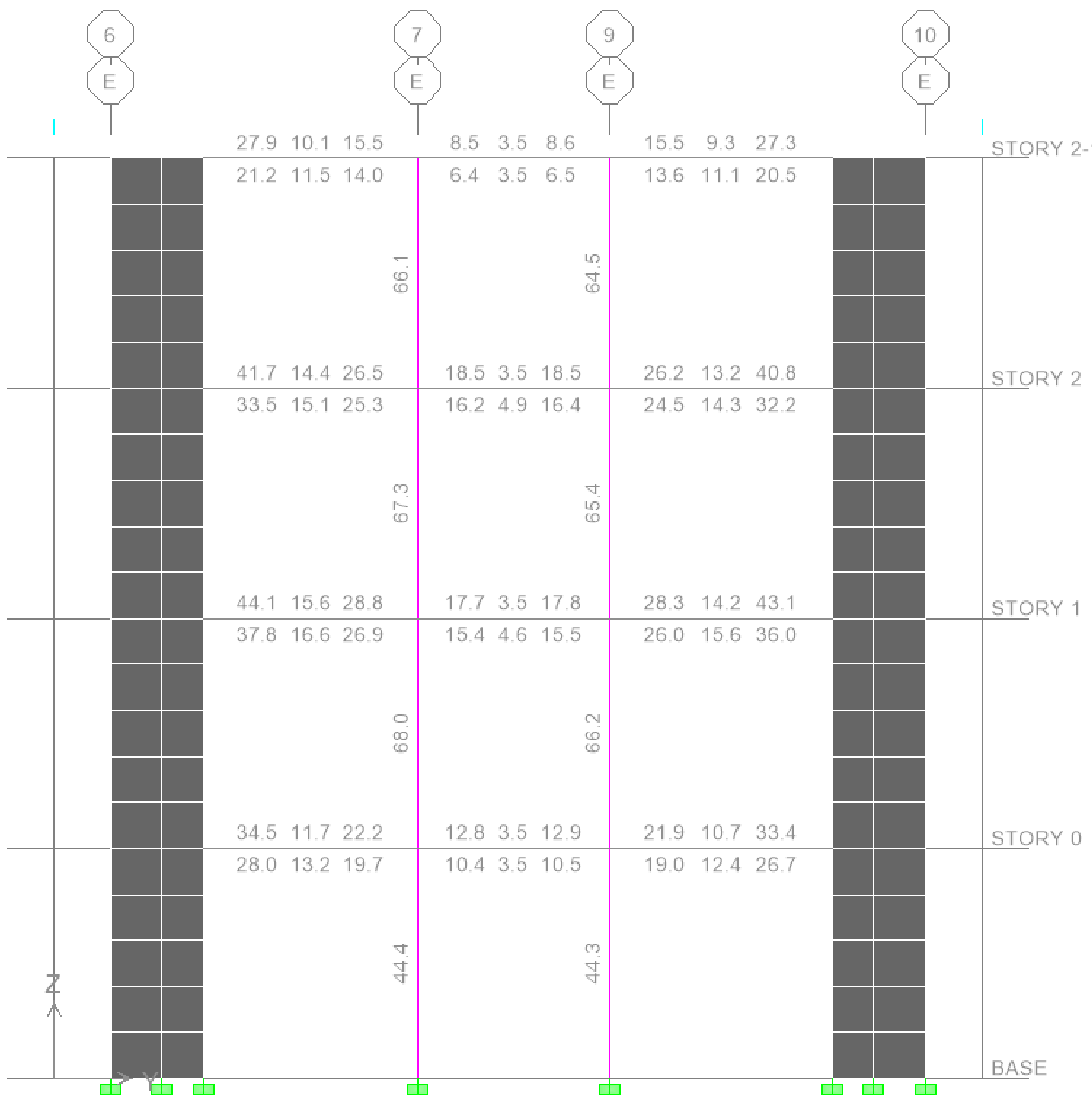
Reinforcement in Axis 7



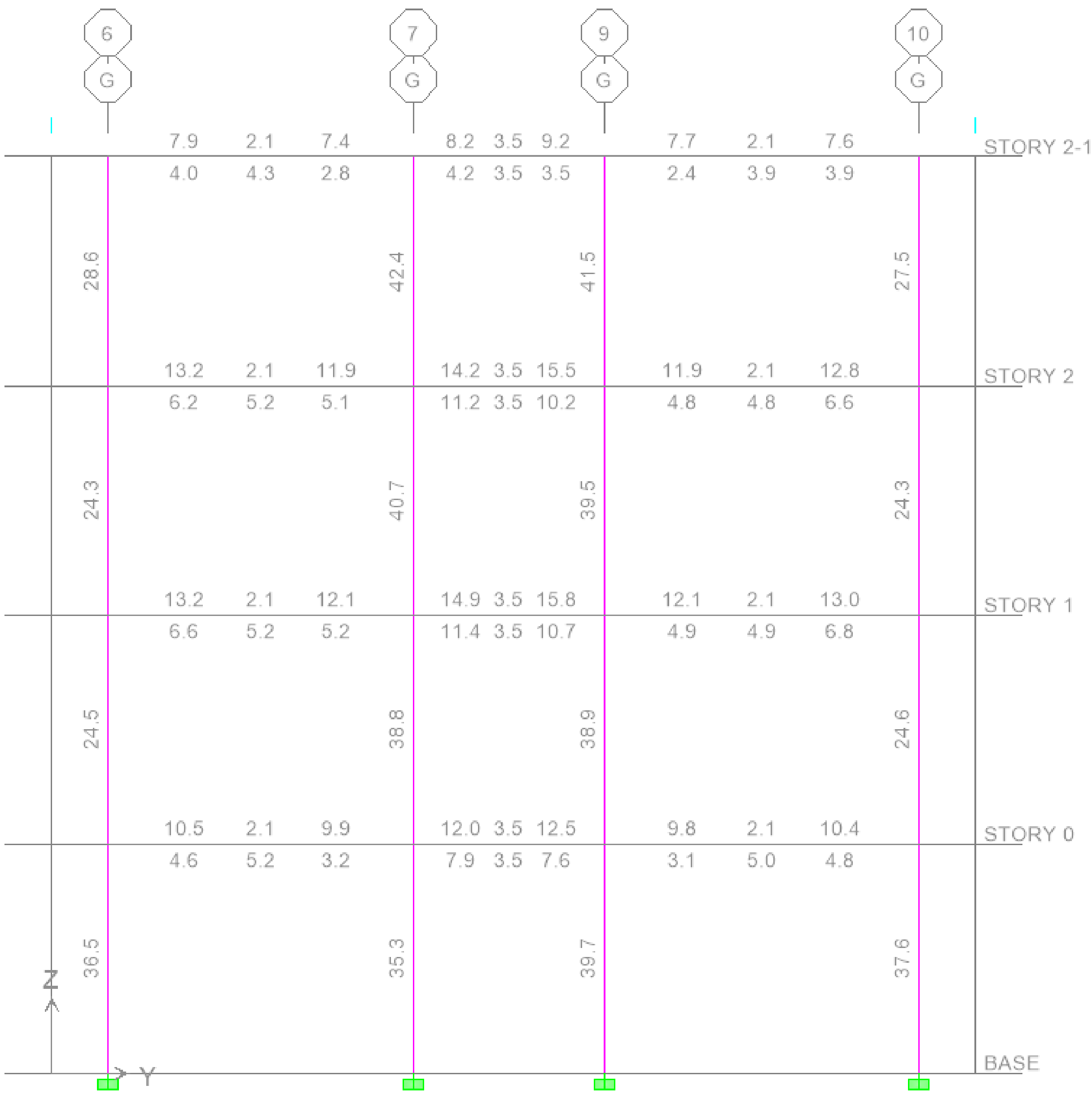
Reinforcement in Axis 9



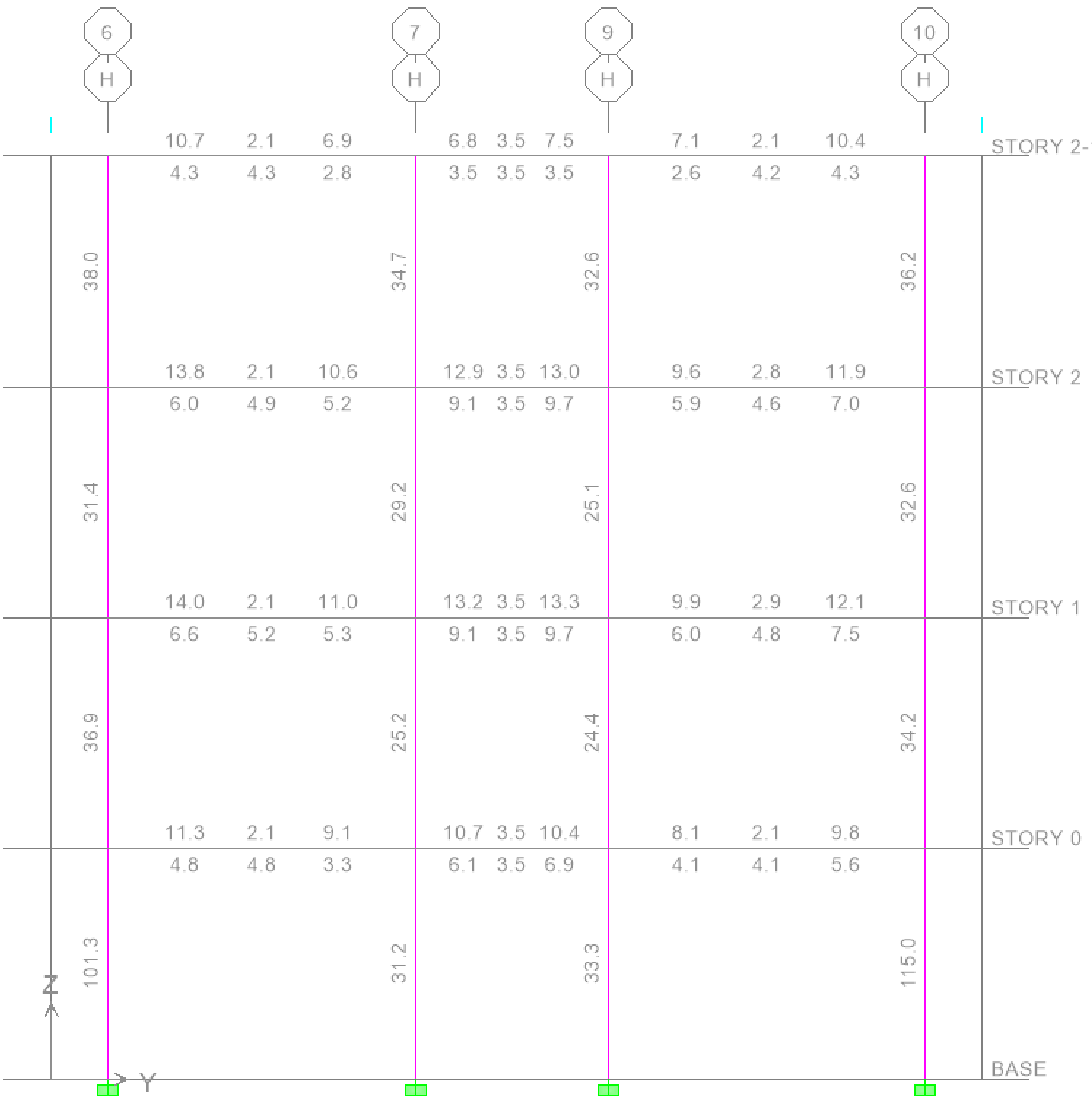
Reinforcement in Axis 10



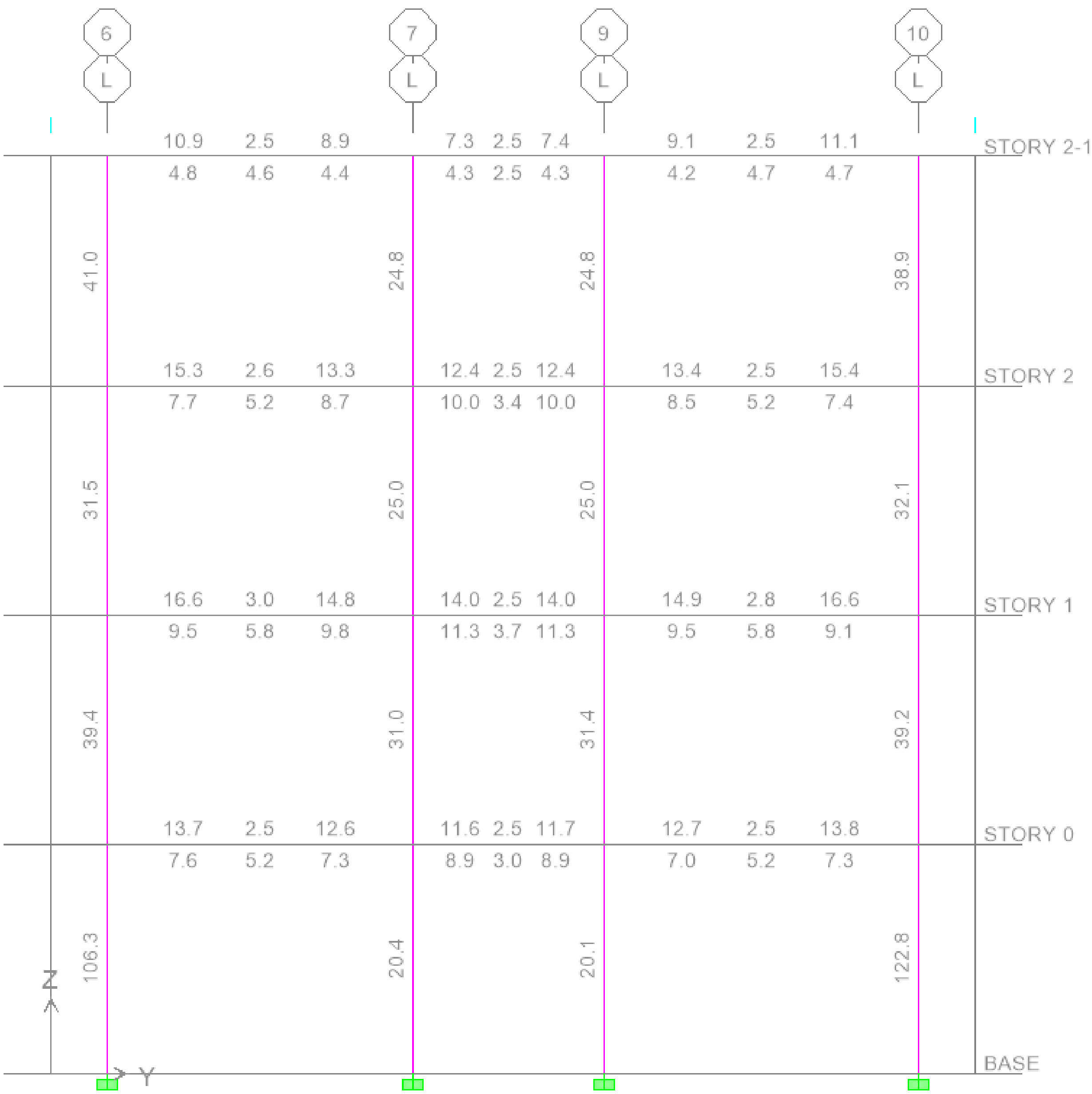
Reinforcement in Axis F



Reinforcement in Axis G

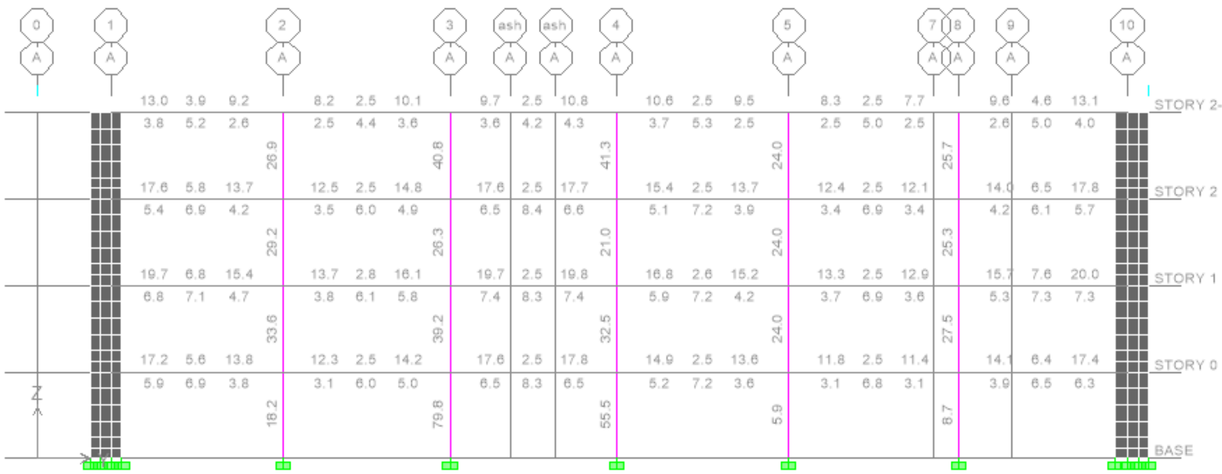


Reinforcement in Axis H

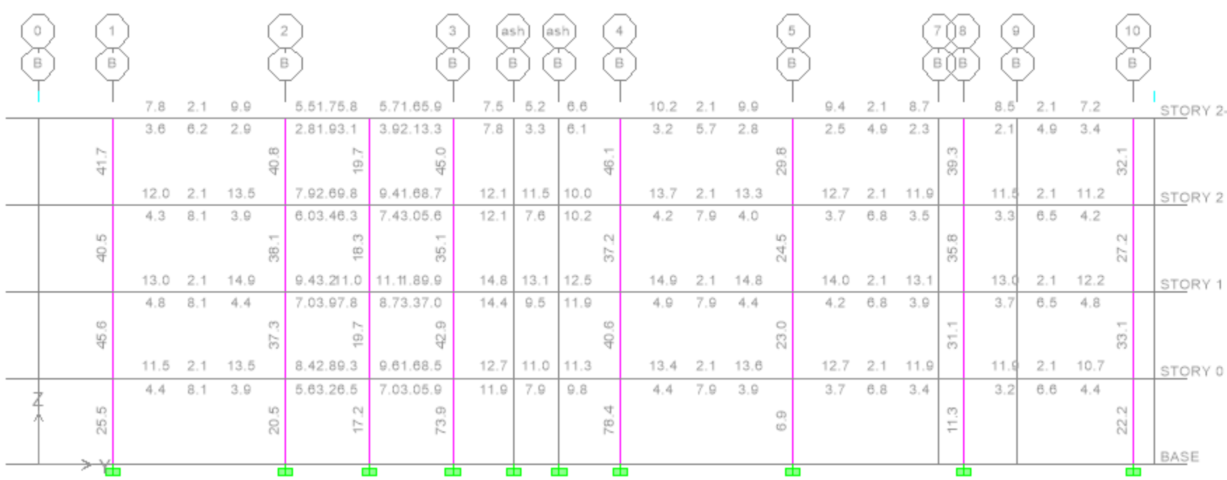


Reinforcement in Axis L

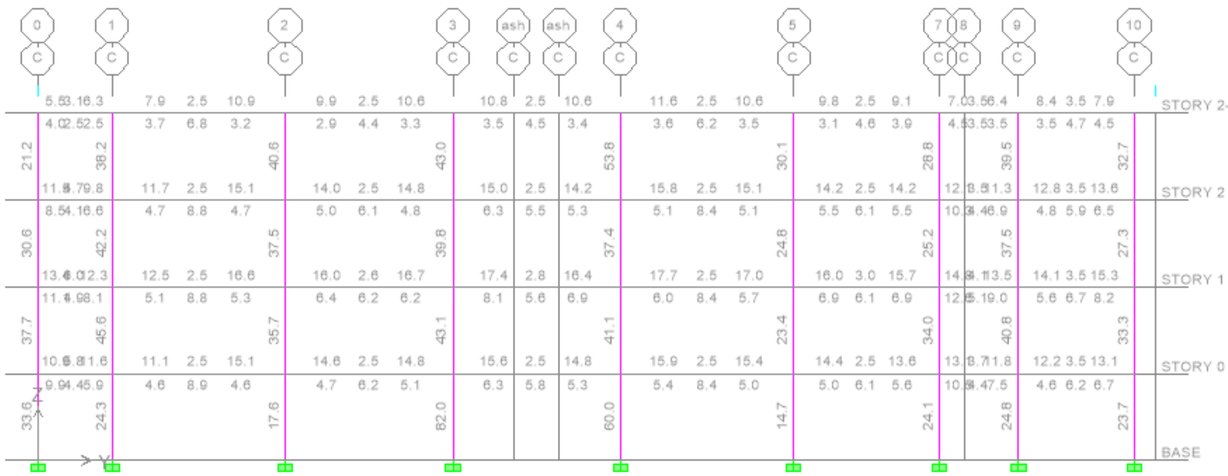
14.2. Object 2



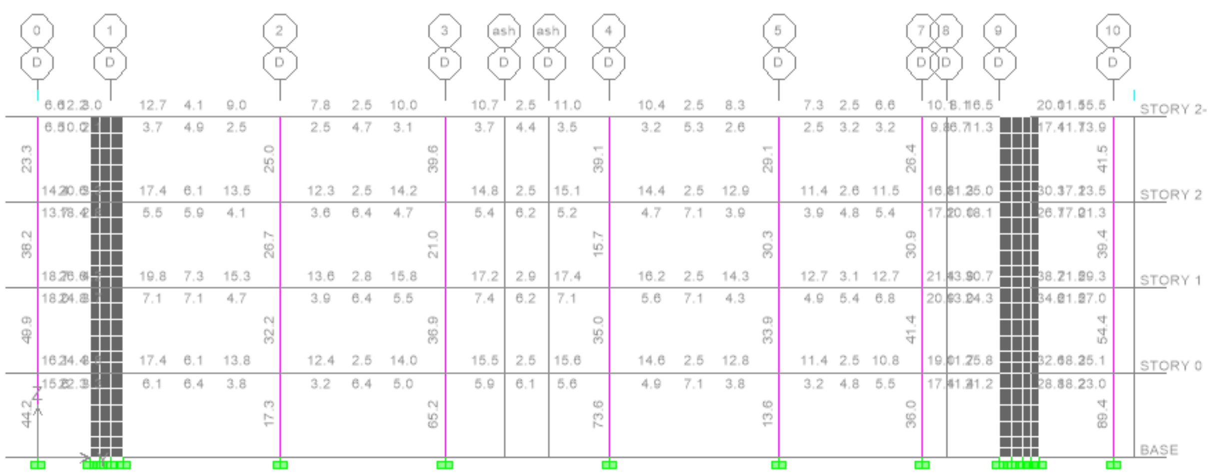
Reinforcement in Axis A



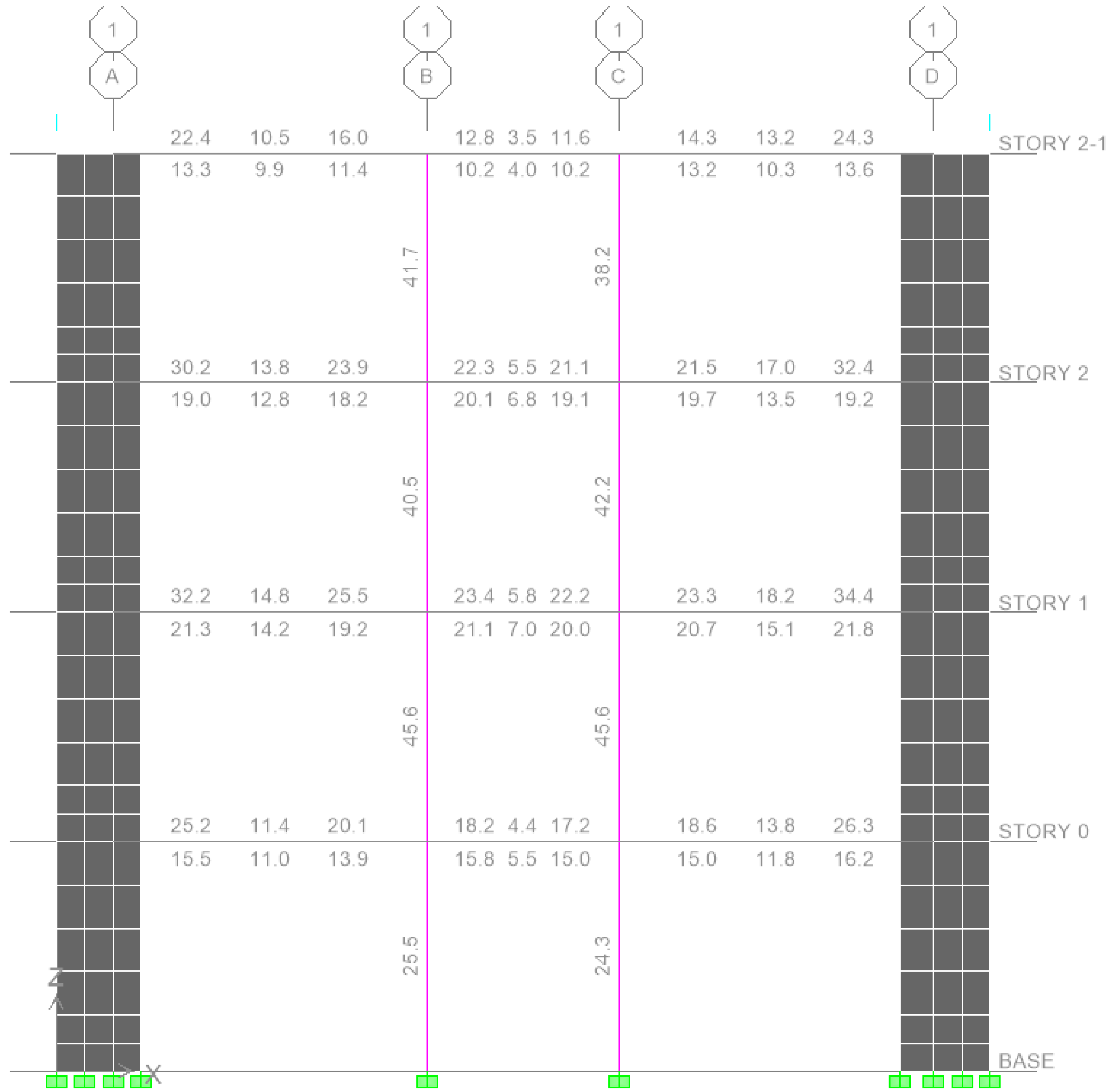
Reinforcement in Axis B



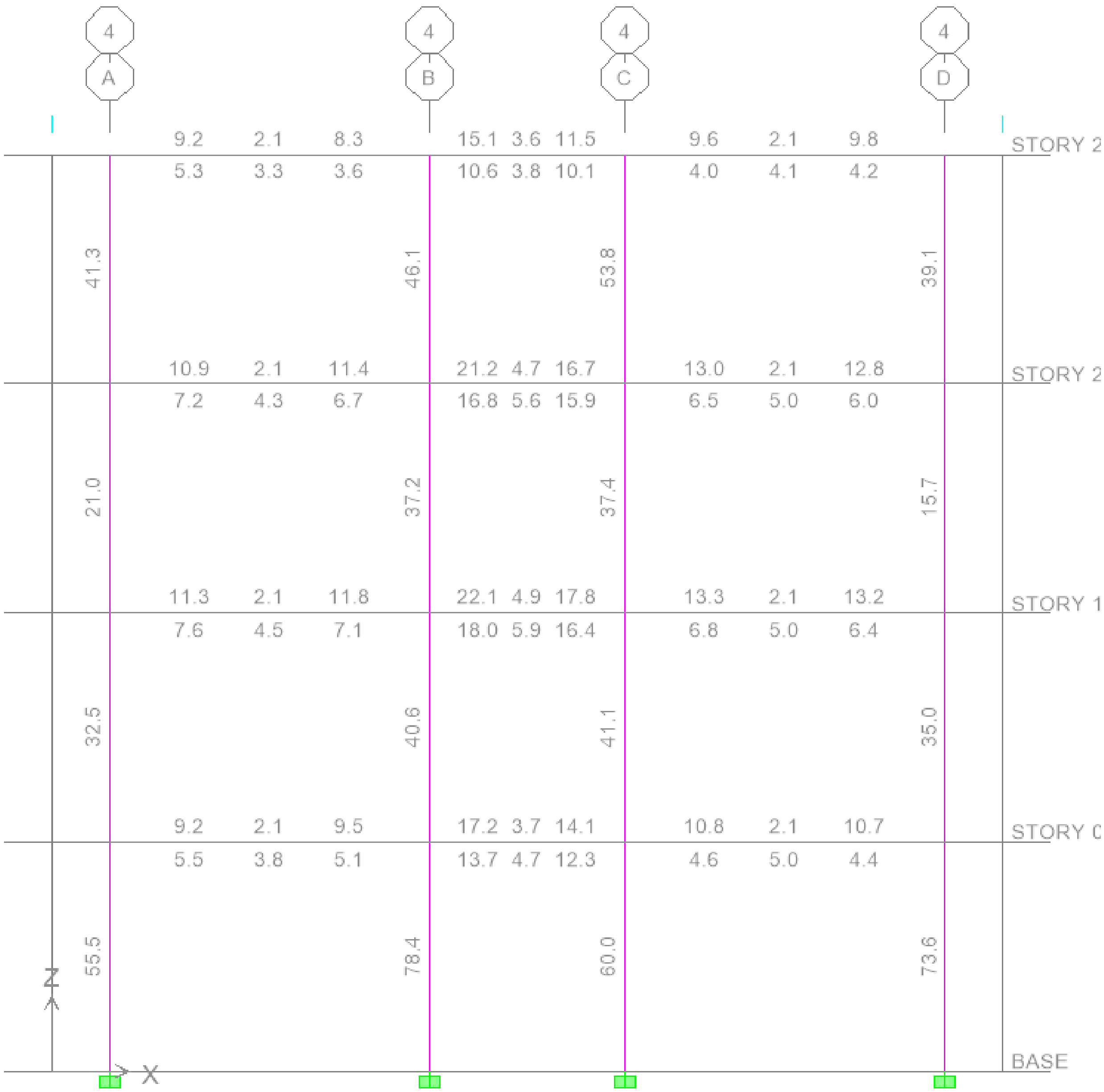
Reinforcement in Axis C



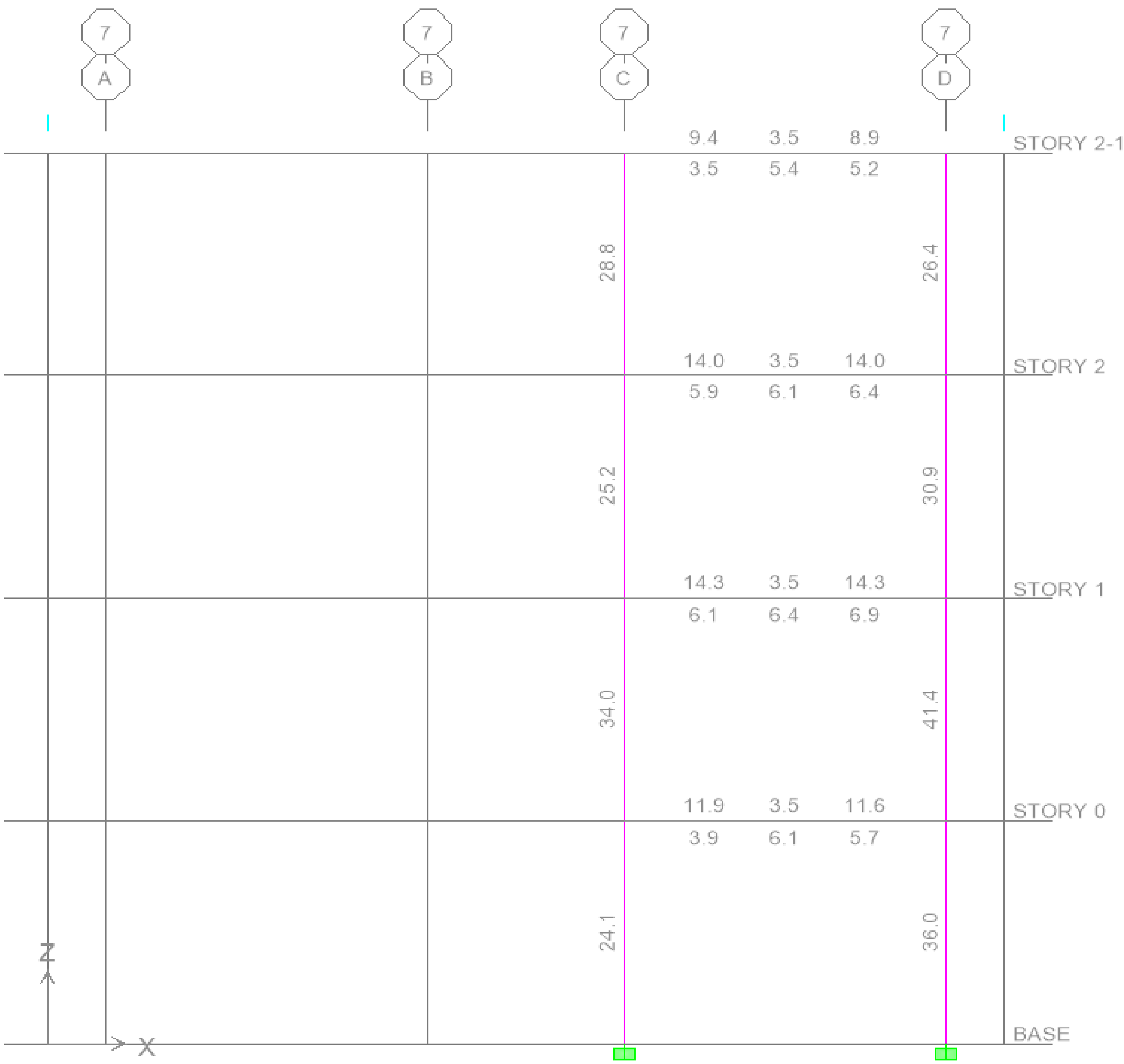
Reinforcement in Axis D



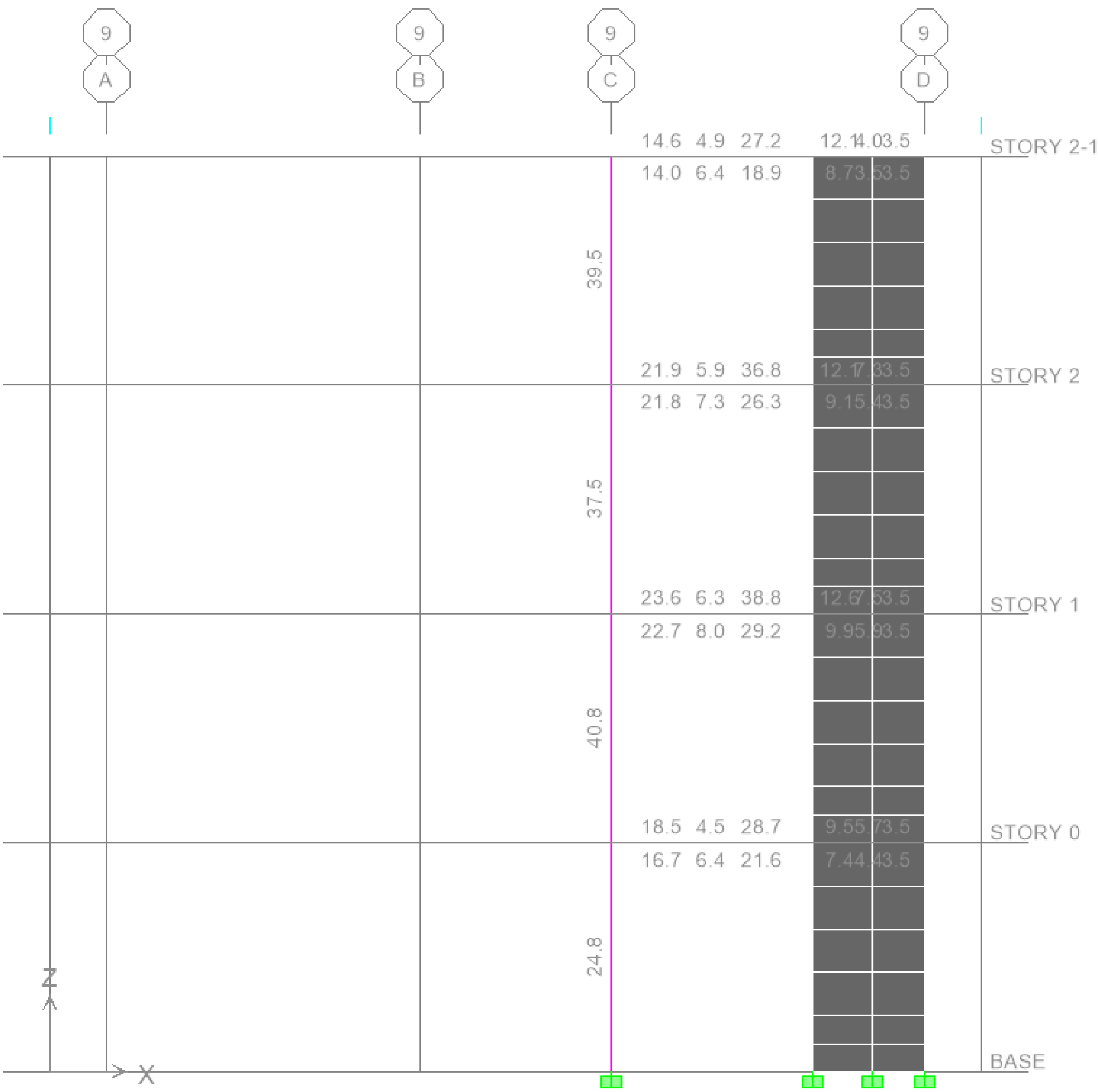
Reinforcement in Axis 1



Reinforcement in Axis 4

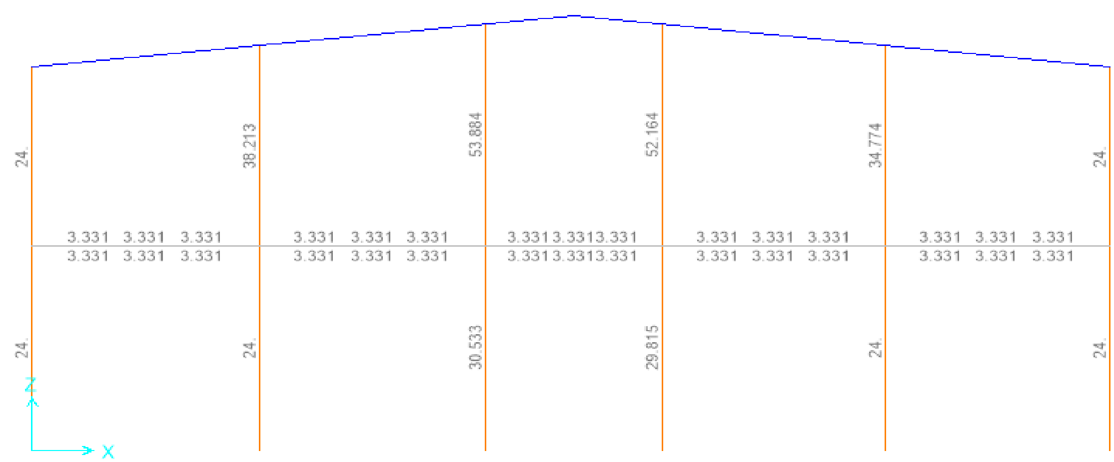


Reinforcement in Axis 7

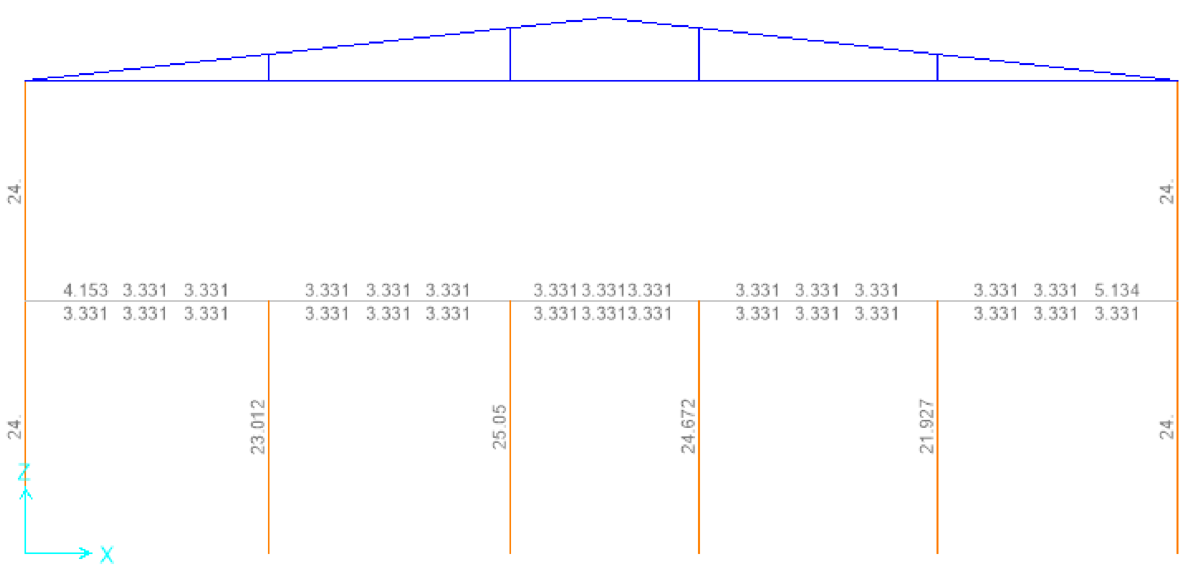


Reinforcement in Axis 9

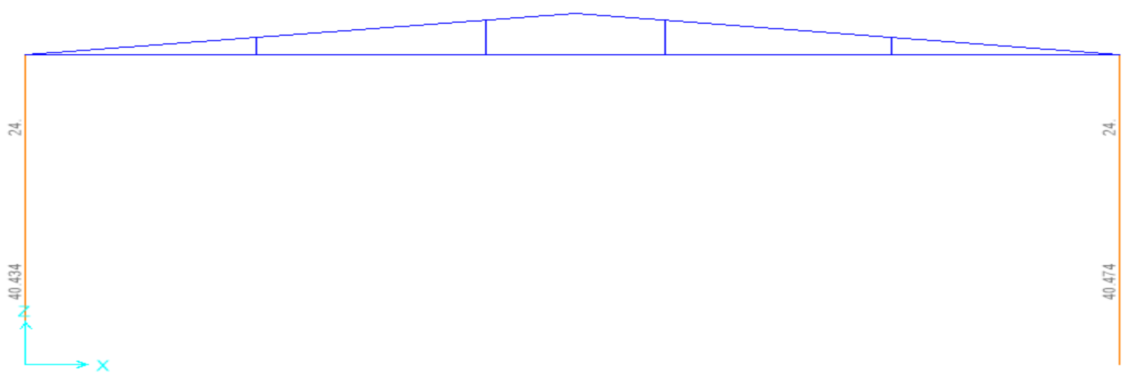
14.3. Gym



Reinforcement in Axis A



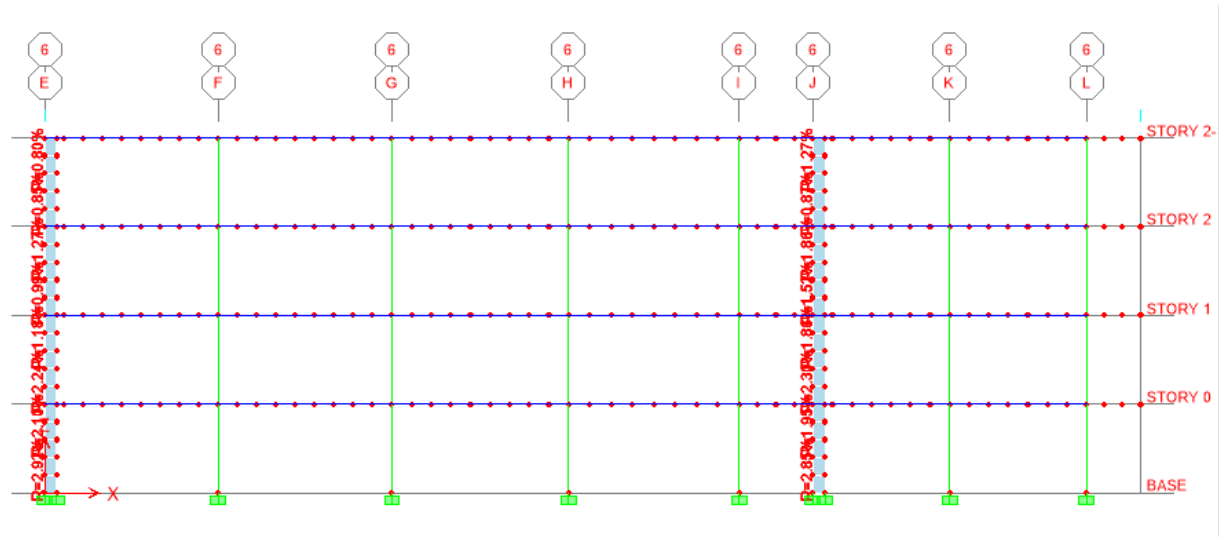
Reinforcement in Axis B



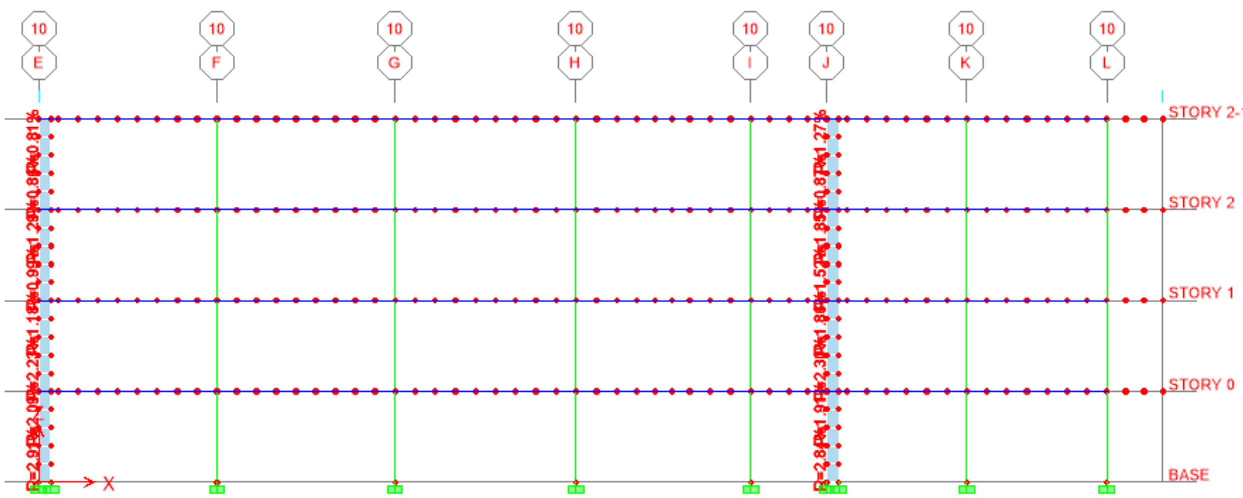
Reinforcement in Axis C

15. Percentage of Reinforcement in the R/C Walls

15.1. Object 1

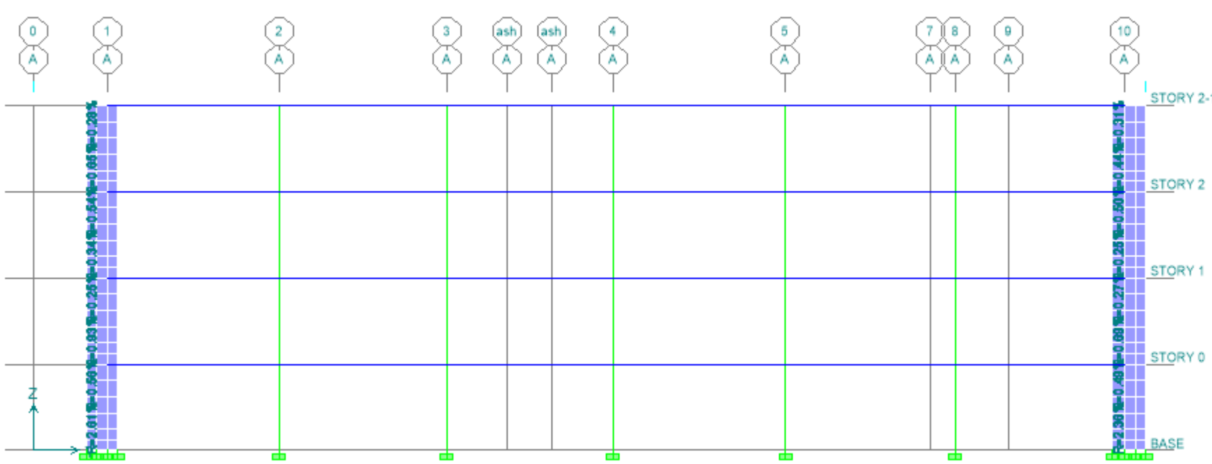


Percentage of reinforcement in Axis 6

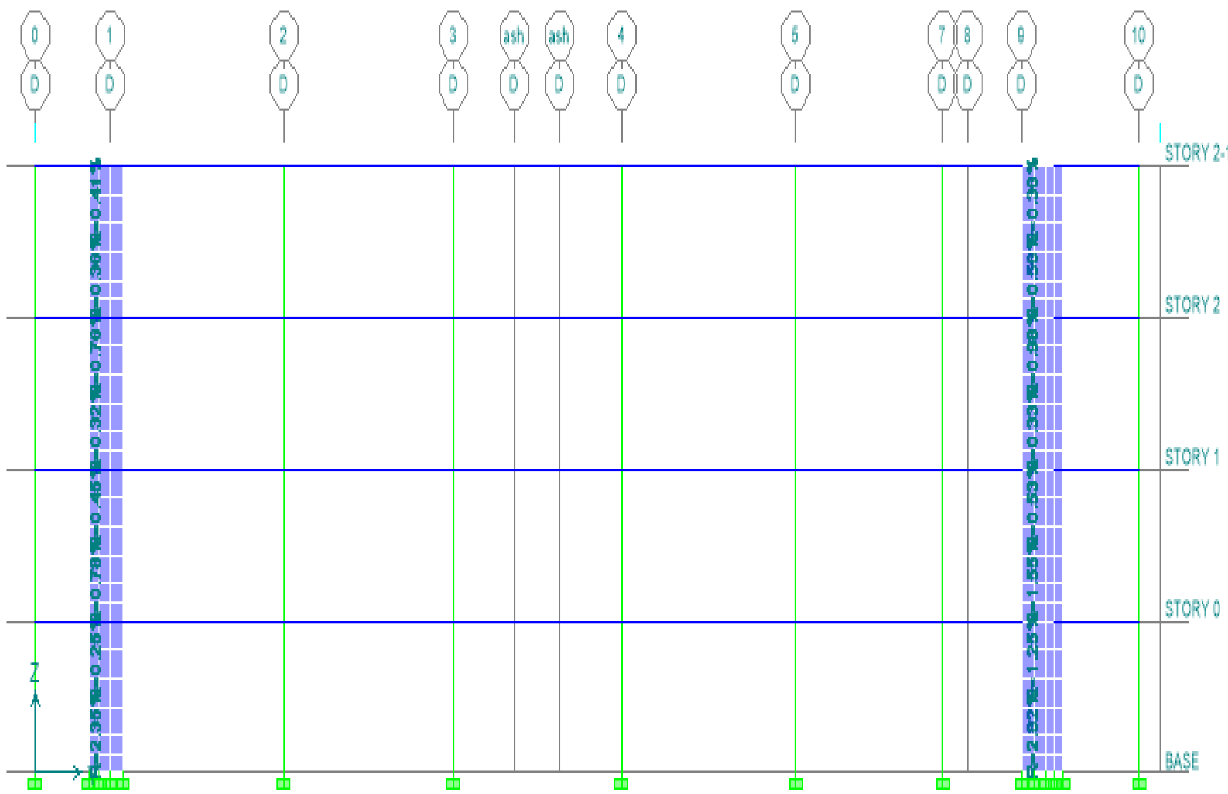


Percentage of reinforcement in Axis 10

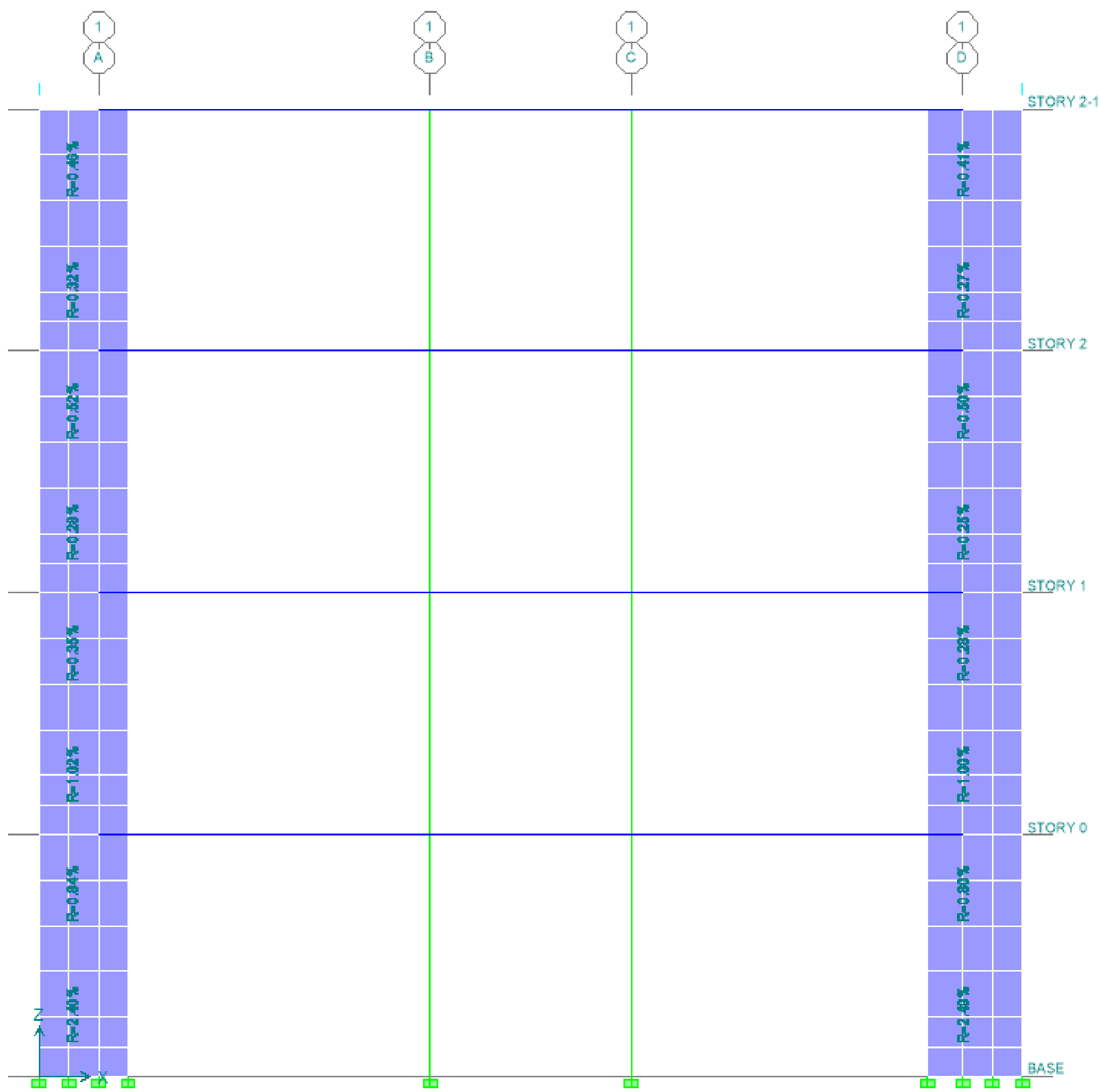
15.2. Object 2



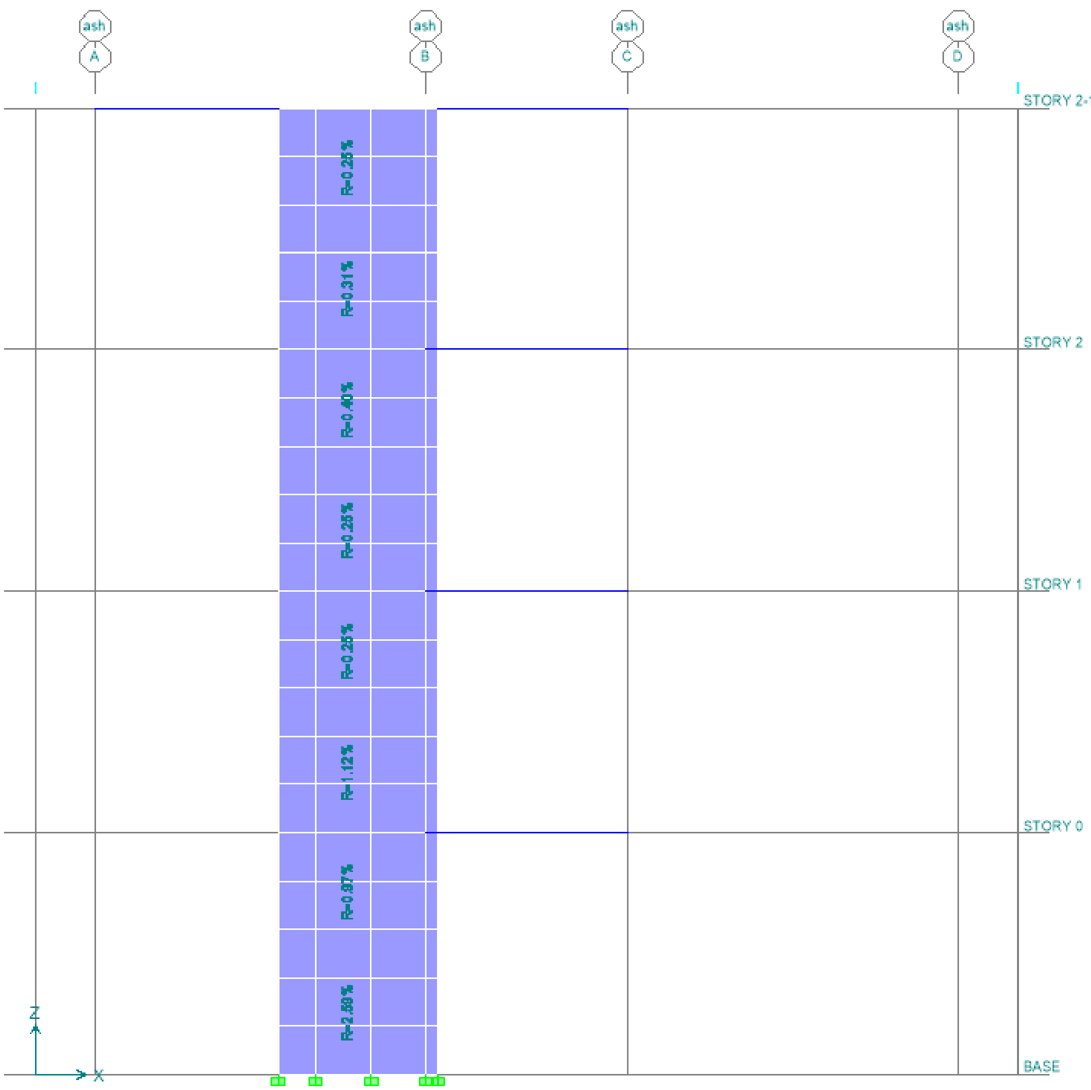
Percentage of reinforcement in Axis A



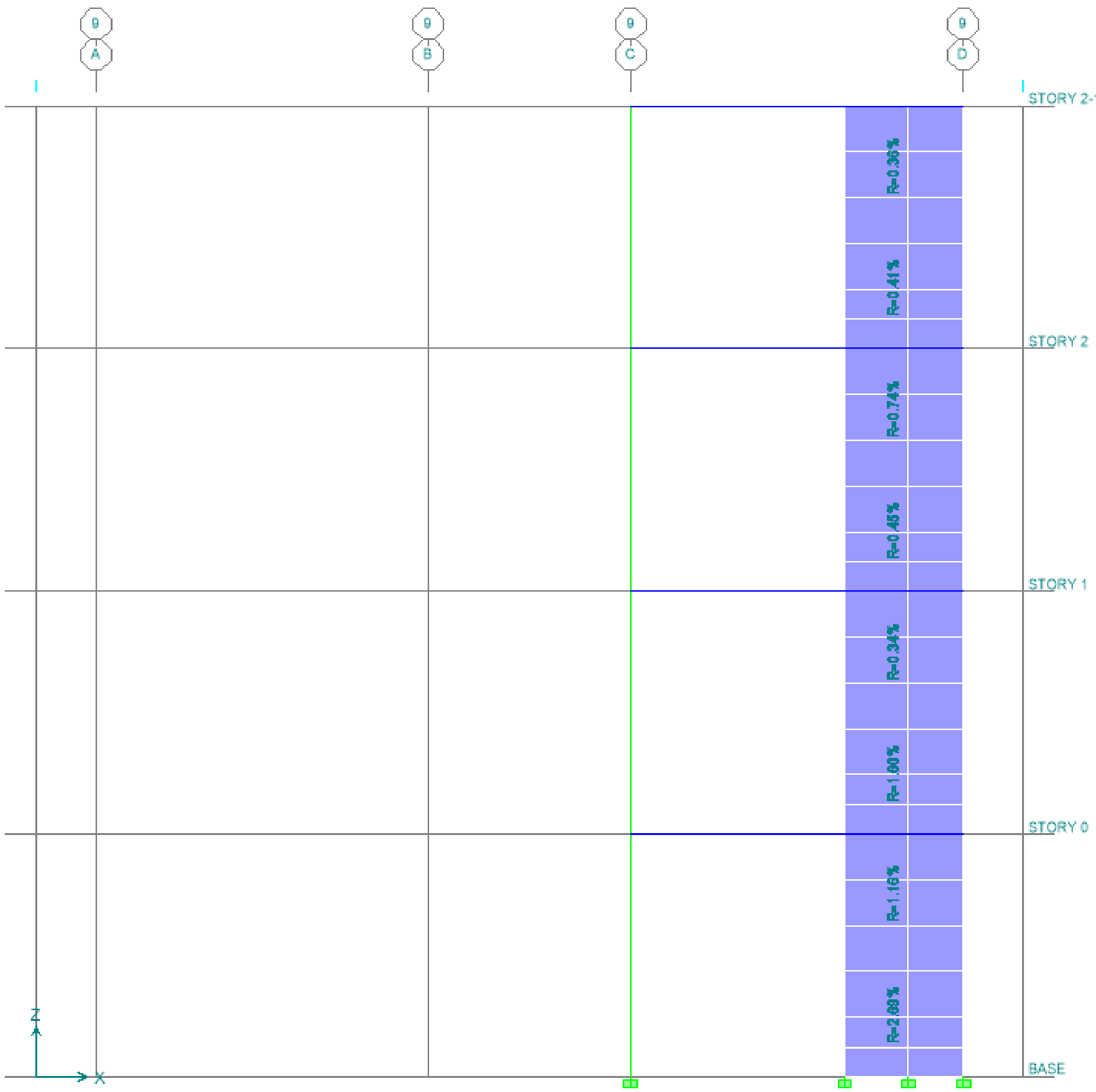
Percentage of reinforcement in Axis D



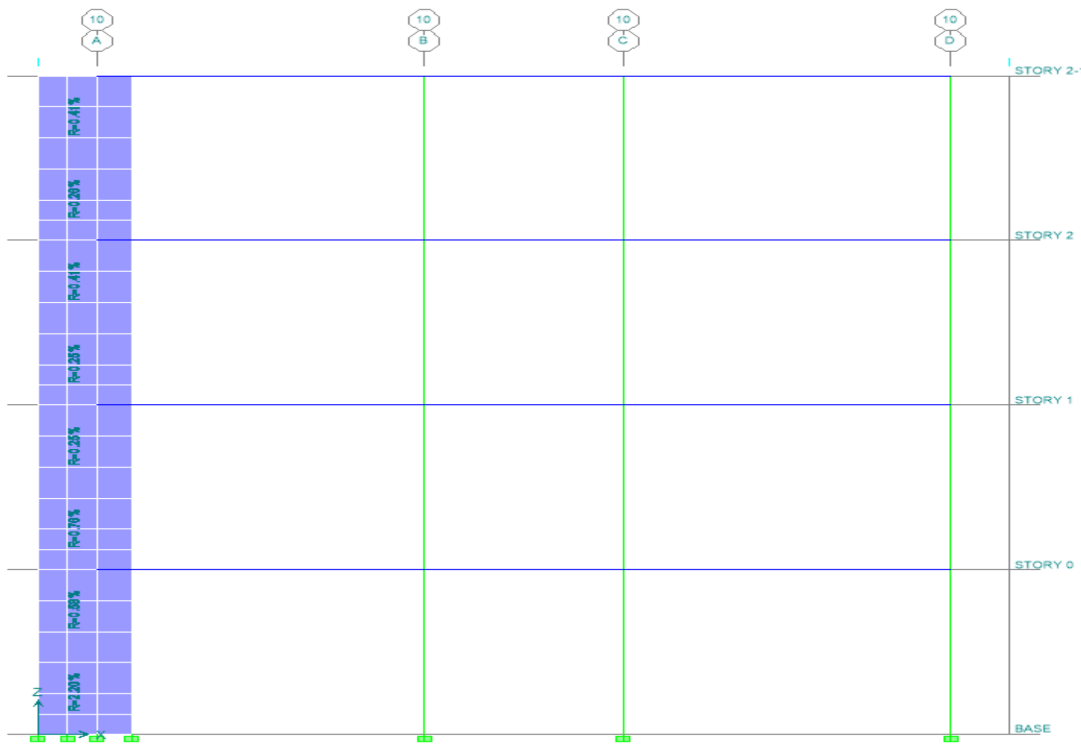
Percentage of reinforcement in Axis 1



Percentage of reinforcement in Axis ash



Percentage of reinforcement in Axis 9



Percentage of reinforcement in Axis 10

16. Conclusions

The structure has been designed according to the Eurocode recommendations, with ETABS software, a software specialized for the calculation of the composed structures. The recommendation of Eurocode have been respected in the dimensioning and constructing of all the elements.

Hydajet TOTA

Legal Representative of

HT Construction (High Tech Construction) ltd

Lic. N.6886/3