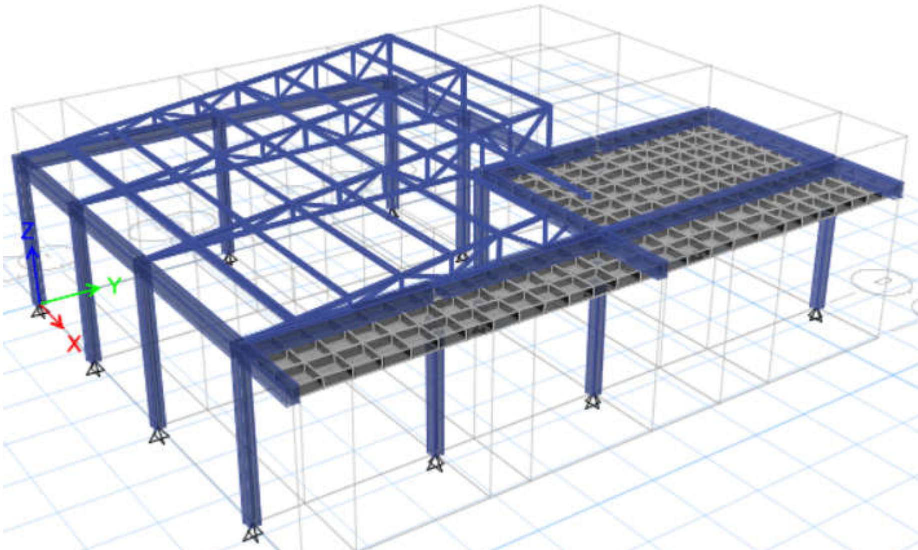
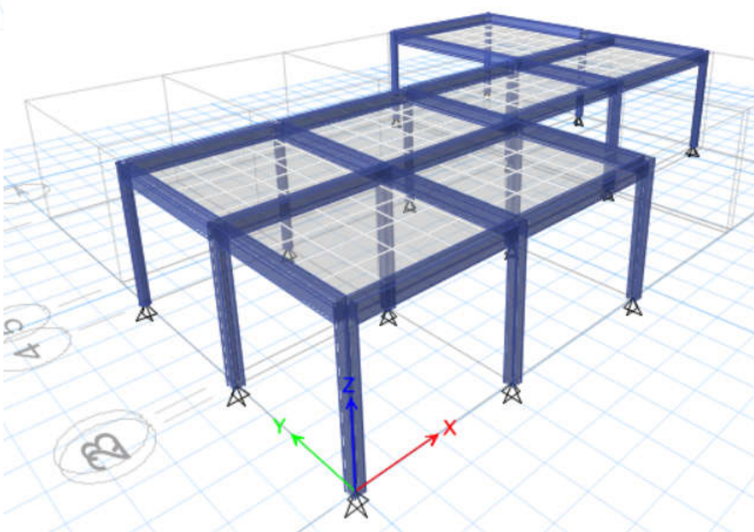
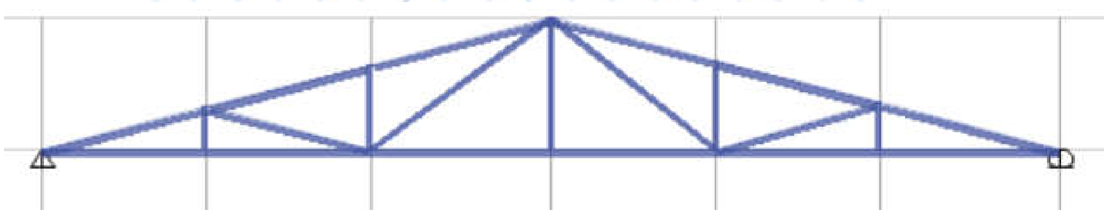
STRUCTURAL DESIGN REPORT

PROJECT: REHABILITATION OF SAUDI MATERNITY HOSPITAL, KASSALA, EAST SUDAN







PREPARED BY:

ASFAW E. (PPST / 040)

SEPTEMBER 2020

REHABILITATION OF SAUDI MATERNITY HOSPITAL

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SECTION-1: DESIGN STATEMENT

SAUDI MATERNITY HOSPITAL (SMH)
REHABILITATION OF SAUDI MATERNITY HOSPITAL
PACKAGE 135 (BLOCK-A, J, M & L)

STRUCTURAL DESIGN STATEMENT

CONTENTS

1 INTRODUCTION

1.1 Project Data

Title of the Project:	Master Plan, Design for Rehabilitation of Existing Facilities and design of a new General Surgical Unit (GSU) at Kassala Health Citadel, Sudan;
Project Assignment:	Rehabilitation of Saudi Maternity Hospital;
Beneficiaries:	Kassala Health Citadel & the people of Kassala;
	Sudan Ministry of Health;
Location:	Kassala, East Sudan
Structural Design:	Asfaw Eshetu (Registered Practicing Structural Engineer - PPST-040)

1.2 Project Background

Based on the agreement between UNOPS and Agency for Italian Development Cooperation (AICS). In supporting the infrastructure of the secondary and Tertiary hospitals in East Sudan and in favor of the FMOH for the definition of the civil works and equipment standards of the public health's structures

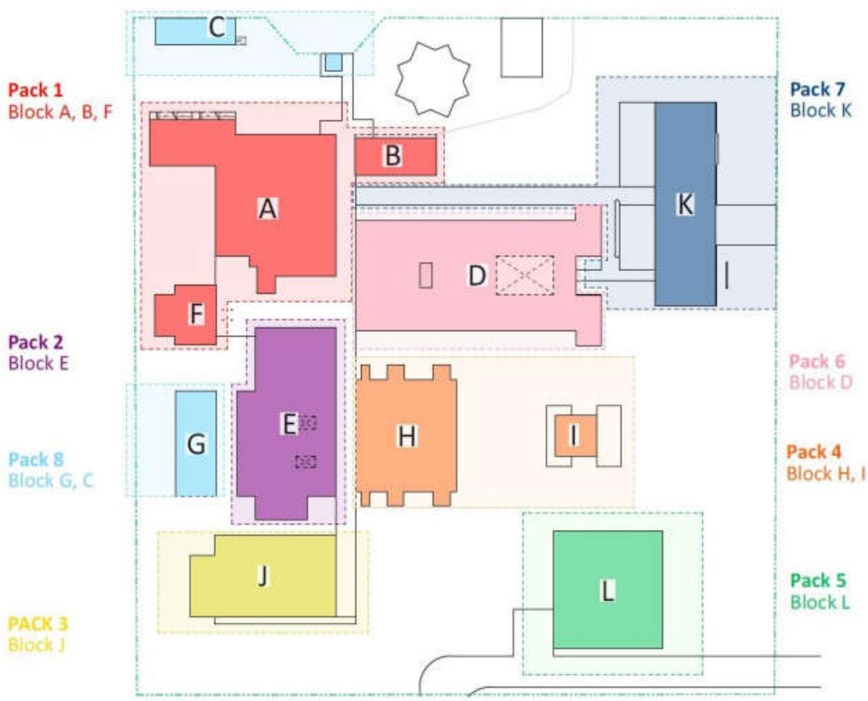
Kassala Health Citadel is a newly designated tertiary healthcare centre established to provide holistic healthcare services for a population of nearly one million in Kassala and nearby districts, as well as serving the refugee camps in the area. The project shall be implemented in conjunction with the initiative "Supporting the infrastructure of the secondary and tertiary hospitals in East Sudan in favour of the Ministry of Health (MoH) for the definition of the civil works and equipment standards of the public health structures" and with particular reference to the Phase 1 intervention of "Master Plan, Rehabilitation of existing facilities and design of a new General Surgical Unit (GSU) at Kassala Health Citadel, Kassala, Sudan"

This project aims at providing a safe environment for patient and the health care professionals in the Citadel by rehabilitating the existing facilities in order to raise the level of healthcare service provision at the Kassala Health Citadel with the specific goal of rehabilitating and upgrading the existing healthcare facilities at Kassala Health Citadel, Kassala. The initiative seeks improved quality healthcare facilities capable of supporting high quality healthcare services while at the same time targeting of full rationalization and integration of healthcare provision in the existing facilities in Kassala Health Citadel including maximization of utilization physical facilities.

The site included the following facilities as designated into blocks and packages for handling the design and construction works.

- Block A: outpatient's department and outpatient's HIV department;

- Block B: administration;
- Block C: security and toilet (visitors);
- Block D: wards 01;
- Block E: operating theatre and nursery;
- Block F: toilets (staff);
- Block G: technical building;
- Block H: delivery department;
- Block I: future toilets (visitors);
- Block J: ICU, staff facilities and laundry
- Block K: co-patient facilities;
- Block L: wards 2 (new private)



Source: AMPC, 2020

For ease and convenience, the blocks are further grouped into packages as shown above. This report would refer to Package 1, Package 3 and Package 5. Since there exists no structural intervention on Block-B and Block F, the report is further limited to Block-A, Block-J and Block-L.

1.3 Project Scope

This report would refer to the structural analysis and design of:

- The extension at the waiting area of Block-A,
- Disable toilet- Block-A south;
- Block-J (Extension to the West – on call be bed room)
- Block-M (Roofing structure in the conversion of the Mosque into Lecture room)
- Block-L (Concrete Ramp).

The structural analysis and design of the building is conducted with regard to the fulfilment of fundamental design requirements in accordance with relevant international building codes and standards as shown in the following sections. The highlight of which consists of design considerations:

- That the project during its intended design life furnish appropriate degrees of reliability in an economic way,
- That the project ensures adequate structural safety, serviceability and durability,
- That the structural drawings to be delivered are complete, detailed and consistent with the corresponding envisaged architectural working drawings to an acceptable degree and detailed for construction operations.

The design has considered the locally available construction materials and the construction skilled labour force in East Sudan. The design envisages the use of reinforced concrete for the main structural frame, solid concrete roof and floor slab Columns and beams

Under this structural report, an attempt is made to present the structural system layout and the 3D conceptual framework of the building as it is to be subjected to all induced vertical and lateral actions due to dead, live and wind loads. The report indicated the basic assumptions and considerations which will be applied in the detailed frame analysis and structural design approach in accordance with the provisions and requirements of series volumes of the latest European Building Code Standards.

2 DESIGN REFERENCES

2.1 Briefing Documents

- Scope of Works, Specifications, Drawings and Bill of Quantities prepared by the Ampc International Health Consultants;
- Geo-technical Information included separately;
- Topographic Information of the sites and;

2.2 Design Codes and Standards

In the absence of local design codes, The UNOPS Planning and Design Manual permits for the use of acceptable International Codes and Standards. In view of this, the relevant sections of European Codes (Euro Code) have been used.

- Euro code 1 EN 1991-1-4-2004: Actions on structures — General actions — Part 1-4: Wind actions;
- Euro code 2: EN 1992- 1-1 - 2004 Design of concrete structures - Part 1-1 : General rules and rules for buildings;
- Euro code 3 EN 1993 -1-8: 2005: Design of steel structures - Part 1-8: Design of joints;
- Euro code 8 EN 1998-1:2004: : Design of structures for earthquake resistance;
- European Standard EN 1991-1-1 'Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings' 2009;

2.3 Design Software: Modelling

The analysis and design has been carried out by modelling the buildings as 3-D spatial model using the latest ETABS Version 2016 Non-Linear finite element design software. Slab-Column-Beam arrangement is idealized for the structural system of the building in three dimensional systems that would more resemble real situation and would enable to study the simultaneous effect of out-of-plane and in-plane external actions.

Columns & Beams: Modeled as three dimensional frame elements to resist self weights as well as actions from the roofing system, planar structure and seismic actions that generally encompass biaxial bending, torsion, axial deformation and biaxial shear deformations.

Roof Steel Truss: Modeled as three dimensional frame elements to resist self weights as well as actions from the live and wind loads, and all in plane and out of plane reactions have been analysed using the ETAB Version 2016 software.

Foundations: Strip Masonry Foundation along external and internal walls.

Roof Slab: SFAE 2016 Finite Element Method of slab analysis

3 MATERIALS SPECIFICATIONS

3.1 Concrete

Foundations, Columns, Beams: Structural concrete grade C25 (150mm cube yield strength of 25N/mm^2 minimum) with 20 mm maximum size of aggregate has been used.

3.2 Reinforcing Steel

Reinforcement: Grade 460 (Characteristics yield strength of fyk = 400 MPa) high strength reinforcing steel of Class B in ES EN 1992:2015 Part 1.1 shall be used.

f_{yk} = 460 Mpa
E_{cm} = 210 GPa
Ductility 'k' = f_t/f_{yk} > 1.08

3.3 Structural Steel

Truss Members - : Tensile Strength = 415 Mpa
Yield Strength = 275 Mpa

Connection Bolts: Grade 4.6
f_{yb} = 240 N/mm2
f_{ub}= 400 N/mm2

4 DURABILITY REQUIREMENTS

4.1 Concrete Cover to Reinforcement

The following cover to main reinforcement shall be used for the following areas: -

• Stairs and slabs	25mm:
• Beams	38 mm
• Columns	38mm
• All substructure (below ground level)	50mm

4.2 Protection of Steelwork

Protection of structural steelwork shall comprise the following:

- Surface preparation by blast cleaning, pickling process or where approved by wire brushing;
- Application of one coat of an approved pre-fabrication primer e.g. zinc chromate;
- Application of one coat of approved primer after fabrication;
- Two coats of an approved paint system to be proposed by the Architect, one applied in the shop and the other applied on site after erection.

4.3 Fire Requirements

The design ensures the building has a minimum of 1.0 hrs of fire resistance pursuant to the UNOPS Design Planning Manual for Buildings. The concrete covers specified above are based on this period of fire resistance and minimum section sizes are adopted to support this requirement.

5 DESIGN ASSUMPTIONS

5.1 Soil Profile

The borehole drilled at the location indicated a general subsoil profile that consists of two layers.

- The First top layer of 2.0m thick is very stiff silty sandy CLAY soil of high plasticity was encountered.
- A very thick and medium dense to dense layer of silty SAND soil was encountered between 2.5.0m to 6.0m and very stiff silty sandy CLAY soil of high plasticity extended down to the end of the borehole at 15m depth.
- Ground water table was not encountered at 15.0m depth for all boreholes

Since the buildings are relatively light structures, strip masonry foundation of 500mm width at a minimum depth of 1500 mm would suffice to support the loading from the superstructure. The recommendation from the soil investigation has shown the possible use of strip masonry foundation on Layer-1 with allowable design bearing capacity of 200 KPa.

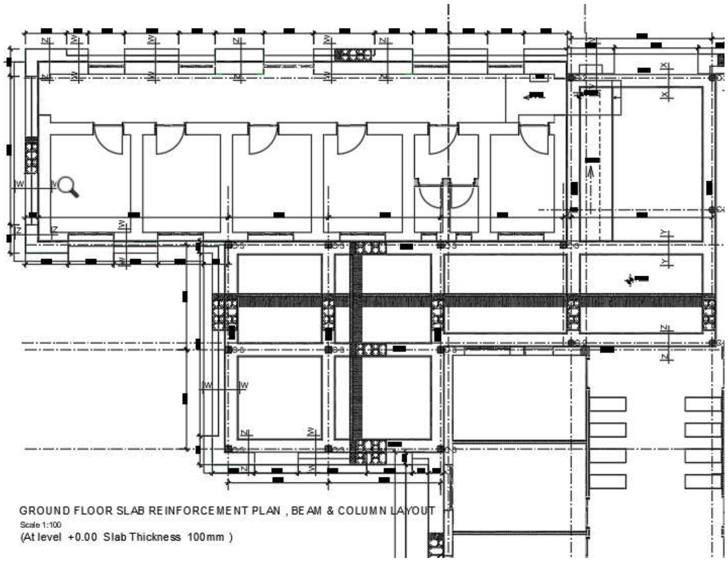
5.2 Building Superstructure

Generally a **spatial 3D Model analysis** has been conducted for the building superstructure. The Limit State design has been followed in accordance with the provision of the different volumes of the European Building Code Standard in the design of structural elements that comprise foundations, columns, and solid slab. Since the Finite Element Method (FEM) option is used for the plate analysis of the structural frame, shell element internal stress and force contours will form the platform for the design of the slab having both regular and irregular shapes. The thickness of the slab has been determined from the consideration of resistance against shear and deflections pursuant with the relevant codes. The solid slab designed and analysed in the 3D Model in the form of planar frame and reinforcement details carried out based on the response contour developed in the Model. Section and reinforcement detail of beams and columns has been determined using the software in accordance with resistance against biaxial moments and axial forces including the iterative P-Delta effect.

i) Block-A Extension (Waiting Room & Toilet at the rea side of the building)

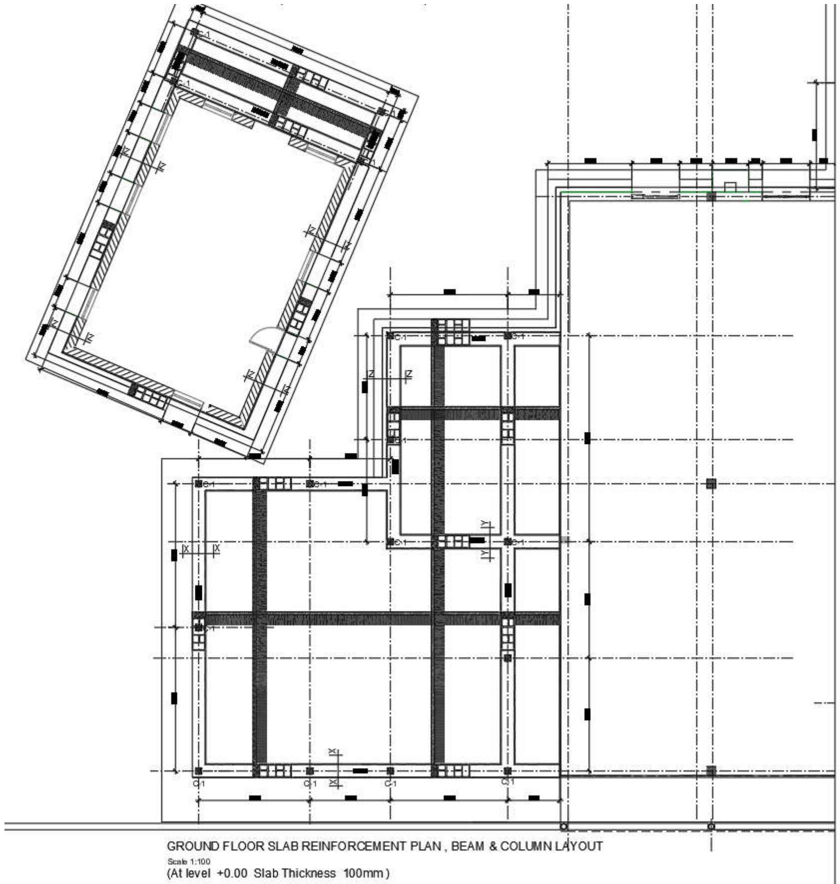
- Strip Masonry Foundation at 2.0 m minimum depth from floor finish level and minimum of 1.5m from Natural Ground Level.;
- 200 x 450 mm reinforced concrete ground beam;
- 200 x 200 mm or Diameter 200mm reinforced concrete column founded on the strip masonry foundation and 3.2m high;
- 200 x 300 mm reinforced concrete ring beam bracing the columns and Walls at top;
- 100 mm thick Reinforced Ground Floor Slab;

- 200mm thick reinforced concrete roof slab;



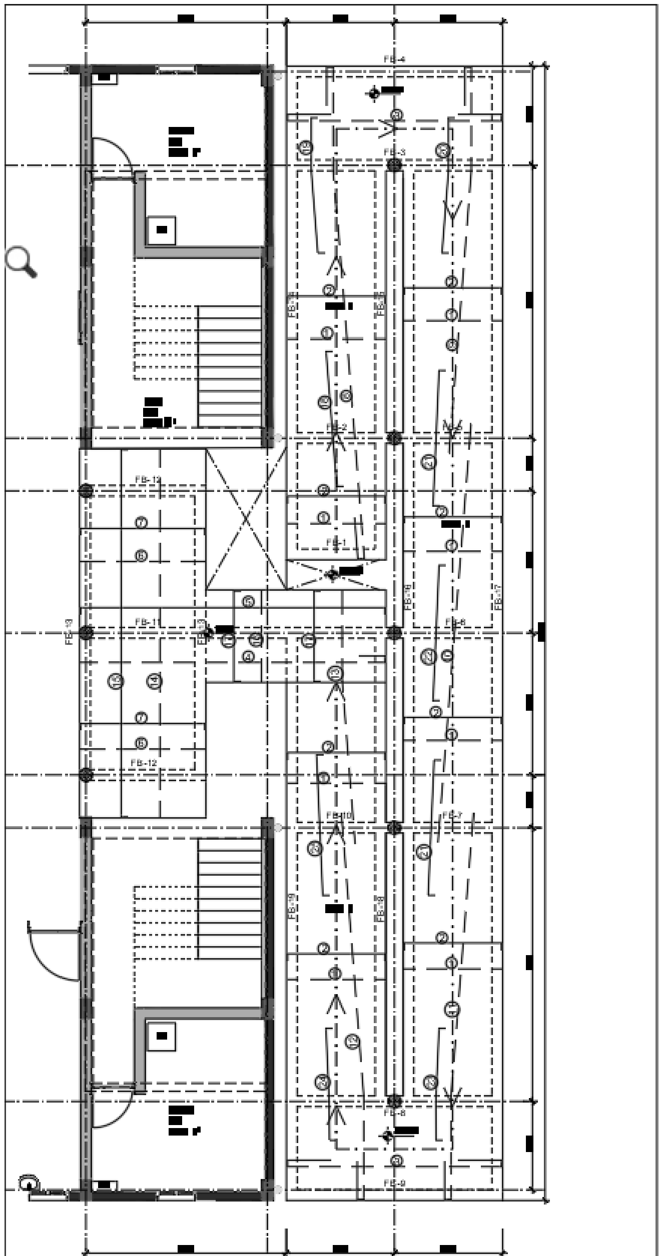
ii) Block-J and Block-M

- Strip Masonry Foundation at 2.0 m minimum depth from floor finish level and minimum of 1.5m from Natural Ground Level.;
- 200 x 450 mm reinforced concrete ground beam;
- 200 x 200 mm or Diameter 200mm reinforced concrete column founded on the strip masonry foundation and 3.2m high;
- 200 x 300 mm reinforced concrete ring beam bracing the columns and Walls at top;
- 100 mm thick Reinforced Ground Floor Slab;
- 200mm thick reinforced concrete roof slab;
- Roof Purlin (RHS 80 x 40 x 3.0 mm, spacing every 1000 mm and span Max. of 4000mm between the truss supporting the iron sheet;
- Steel rectangular hollow section Truss made of upper and lower chord of RHS 60 x 60 x 3.0 mm and internal bracings of RHS 40x40x3 mm spanning Max of 9.0 m span and pinned on concrete ring beams.



iii) Block-L (Provision of Concrete Ramp)

- Isolated Footings at 2.0 m minimum depth from floor finish level and minimum of 1.5m from Natural Ground Level.;
- 250 x 400 mm reinforced concrete ground beam;
- 300 mm - 500 mm diameter reinforced concrete column founded on isolated footings and 3.9m – 6.1m high depending on the level of the ramp roofing;
- 250 x 400 mm reinforced concrete beam bracing the columns at the ramp and roofing levels;
- 100 mm thick Reinforced Ground Floor Slab;
- 200mm thick reinforced concrete ramp and roof slab;



RAMP SLAB REINFORCEMENT PLAN & BEAM LAYOUT

Scale 1:100

(At level +3.20 Slab Thickness 200mm)

6 LOADS

6A- Steel Truss Roofing System (Block-J & M)

I Permanent Action:

Dead Loads (G)

A) Truss Load. (Truss spacing every 4000mm)

- Weight of Roof system on Truss = 0.0314 KN/m^2 * 4.0m = 0.126 KN/m

(Weight of iron sheet of 0.4mm thick = 78.5 KN/m^3 * 0.0004m = 0.0314 KN/m^2
Truss spacing every 4000 mm)

- Own weight of purlin & Truss = 0.169 KN/m
- Ceiling weight = 0.1 KN/m

Total (G) = 0.395 KN/m (Gravity Load) (Load on Truss)

B) Purlin Load (Purlin spacing every 1000mm)

- Weight of roof system on purlin = 0.0314 KN/m^2*1.0 = 0.0314 KN/m
- Own weight of purling (RHS 80X40X3mm) = 0.056 KN/m

Total (G) = 0.0874 KN/m (Gravity Load) (Load on Purlin)

II Variable Actions (Q)

A) Live load for maintenance *(q_1)* = 0.5 KN/m^2 - Gravity Load

Live load Maintenance *(q_1)* = 0.5 KN/m^2 * 4.0m = 2.0 KN/m (Truss Load)

Live load Maintenance *(q_1)* = 0.5 KN/m^2 * 1.0m = 0.5 KN/m (Purlin Load)

B) Wind Load (q_2)

- The Basic Wind Velocity

(V_b) = 25 m/s (Storm, whole gale considered);

- The mean Wind Velocity (V_m)

V_m (Z)= C_r (Z) . Co(Z). V_b ; C_r (Z) - Roughness Factor

Co(Z) - Orography Factor

The site area belongs to Category-I as per table 4.1.

Table 4.1 — Terrain categories and terrain parameters

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
The terrain categories are illustrated in Annex A.1.			

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max}$$

Z = 5.0 m;
Z_{min} = 1.0 m (For Category-I of Table 4.1)
Z_{max} - 200 m
Zo = 0.01 m (Roughness Length for Category-I in table 4.1)

kr: terrain factor depending on the roughness length z_0 calculated using

$$k_r = 0,19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0,07}$$

Kr = 0.1698
C_r (Z) = 1.055
Co(Z) = 1.0 (Relatively flat land)
V_m (Z)= C_r (Z) . Co(Z). V_b
= 1.055 * 1.0 * 25 = 26.38 m/s

- Peak Velocity Pressure ($q_p(Z)$)

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

Where;

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_l}{c_o(z) \cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max}$$

k_l is the turbulence factor. The recommended value is k_l = 1,0.

$I_v(Z)$ = 0.161, ρ *= 1.12 Kg/m³*
$q_p(Z)$ = 0.83 KN/m²

Wind Pressure

External Pressure

$$w_e = q_p(z_e) \cdot c_{pe}$$

C_{pe} = Pressure Coefficient of external pressure - (Table 7.3a EN 1991-1-4-2004)

a) For Monopitch Roof ; θ =180^0 ; 5^0 pitch angle;
Max Cpe = -1.3 (Upward)

b) For Monopitch Roof ; θ =90^0 ; 5^0 pitch angle;
Cpe = -1.8 (Upward)

Internal Pressure

$$w_i = q_p(z_i) \cdot c_{pi}$$

C_{pi} = Pressure Coefficient of internal pressure
C_{pi} = 0.0 (Figure 7.13 - EN 1991-1-4-2004)

Net Pressure

$W_n = W_e - W_i$
Worst Scenario: θ= 90° ; Cpe = -1.8 (Upward)
Cpi = 0.0
Wn = 0.40 KN/m^2 * (-1.8-0.0)
Wn = - 72 KN/m^2 (Upward)

Wind load on Truss (q_2) = 0.72 KN/m^2 *4.0 m = 2.88 KN/m (Uplift)

Wind load on Purlin (q_2) = 0.72 KN/m^2 *1.0 m = 0.72 KN/m (Uplift)

b) Wind load on Vertical Wall

External Pressure

$$w_e = q_p(z_e) \cdot c_{pe}$$

C_{pe} = Pressure Coefficient of external pressure - (Table 7.1 EN 1991-1-4-2004)

Cpe = +0.70 (Windward), -0.3 (Leeward)

Internal Pressure

$$w_i = q_p(z_i) \cdot c_{pi}$$

C_{pi} = Pressure Coefficient of internal pressure
C_{pi} = 0.33 (Windward and Leeward) (Figure 7.13 - EN 1991-1-4-2004)

Net Pressure

$W_n = W_e - W_i$
Wn = 0.95 KN/m^2 * (0.7-0.33) = 0.35 KN/m^2 (Windward)
Q4 = 0.35 *3.87 = 1.35KN/m (Horizontal load on Columns- Windward)

Wn = 0.95 KN/m^2 * (-0.3-0.33) = 0.60 KN/m^2 (Leeward)

Q4 = 0.6 * 3.87 = 2.32 KN/m (Horizontal Load on Columns - Leeward)

6B - Concrete Roof Slab (Block- A, J & L)

Two Way Solid Slab (Roof Slab): (Max. 5470mm x 4675 mm)

- ### Thickness - EC Section 7.4.2

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho} + 3{,}2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] \quad \text{if } \rho \leq \rho_0$$

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] \quad \text{if } \rho > \rho_0$$

ρ_0 is the reference reinforcement ratio = $10^{-3}\sqrt{f_{ck}}$ AC1
= 0.0045

ρ is the required tension reinforcement ratio at mid-span to resist the moment due to the design loads (at support for cantilevers)
Assume 200mm thickness, Reinforcement Diameter 12mm c/c 200mm at support
= (6 x 113)/(1000 x 174)
= 0.0039

$\rho < \rho_o$ - The first equation applies

K = 1.5 = Table 7.4N of EC

l/d = 29.4 ; d = 4675/29.4 = 159mm

D = 159 + 20 + 5 = 184 mm ; Use 200 mm

- ### Load

Dead Load

- Slab (200)	= 0.20*25	= 5.0
- Finish (50)	= 0.03*27+0.02*20	= 1.21
- Base plaster (20)	= 0.02*20	= 0.40
- Light weight for slope	= 0.08 *20	= 1.60

G_k = 8.21KN/m^2

Live Load

$Q_k = 0.5\ KN/m^2$

Design Load

$w_d = 1.35 * 8.21 + 1.5 * 0.5 = 11.83\ KN/m^2$

7. Load Combinations

Load combinations according to the building design code ES-EN 1990:2015 for Ultimate limit states of equilibrium and resistance would be used. Serviceability limit state would be checked according to the combinations set out in the same code.

7.1 Ultimate Limit State

A) Persistent and Transient Combinations

$$\Sigma\gamma_{G,j}G_{k,j} \text{ “+” } \gamma_{Q,1}\psi_{0,i}Q_{k,1} \text{ “+” } \Sigma\gamma_{Q,i}\psi_{0,i}Q_{k,i}$$

Comb1	1.35*DL + 1.5*LL
Comb2	1.35*DL + 1.5LL + 0.9 WL
Comb3	1.35*DL + 1.5WL + 1.05LL

B) Seismic Load Combinations

$$\sum_{j\geq1} G_{k,j} + A_{Ed} + \sum_{i\geq1} \psi_{2,i} Q_{k,i}$$

Area under non-seismic zone

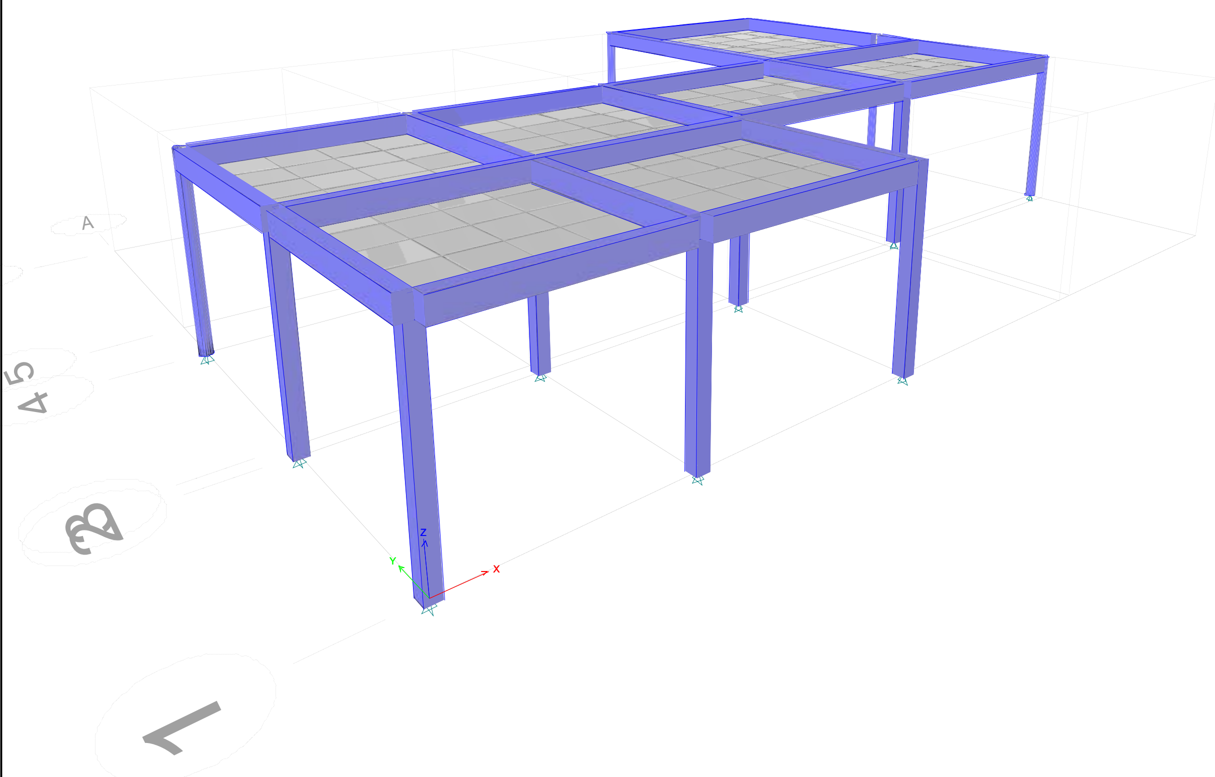
7.2 Serviceability Limit State

$$\sum_{j\geq1} G_{k,j} \text{ "+" } \psi_{1,1}Q_{k,1} \text{ "+" } \sum_{i>1} \psi_{2,i}Q_{k,i}$$

Comb 4 = 1.0*DL + 1.0*LL

Comb 5 = 1.0*DL + 1.0*WL

SECTION-2: GENERAL ARRANGEMENT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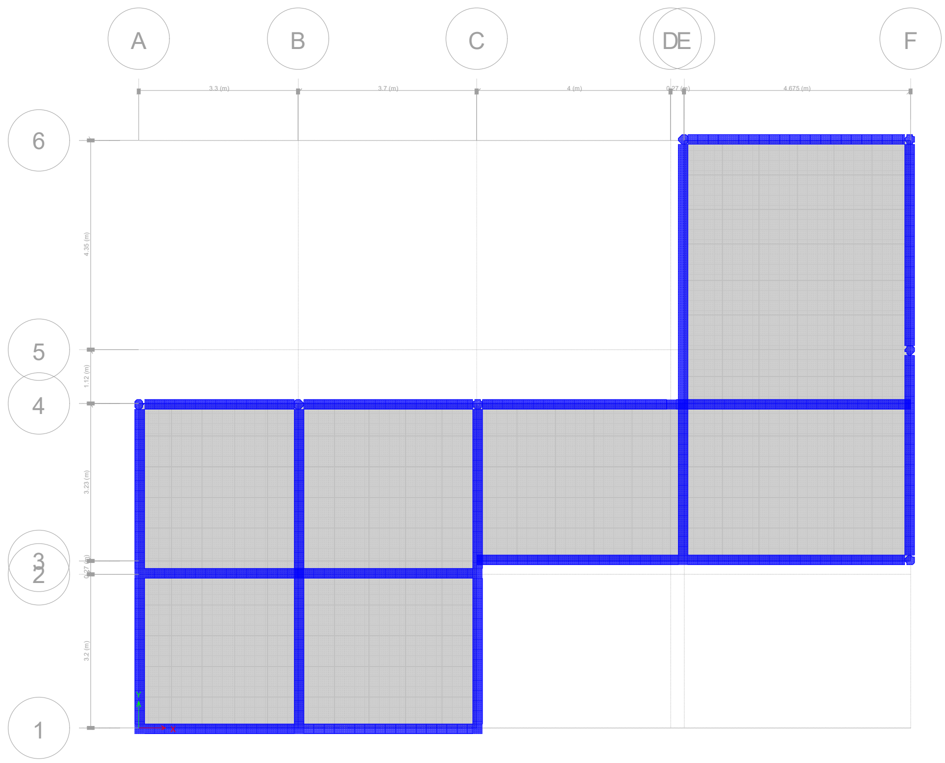
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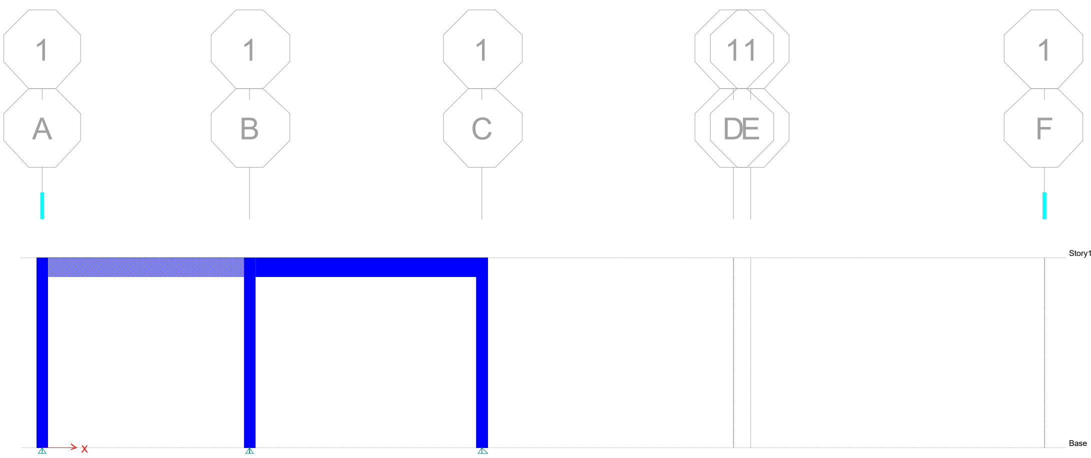
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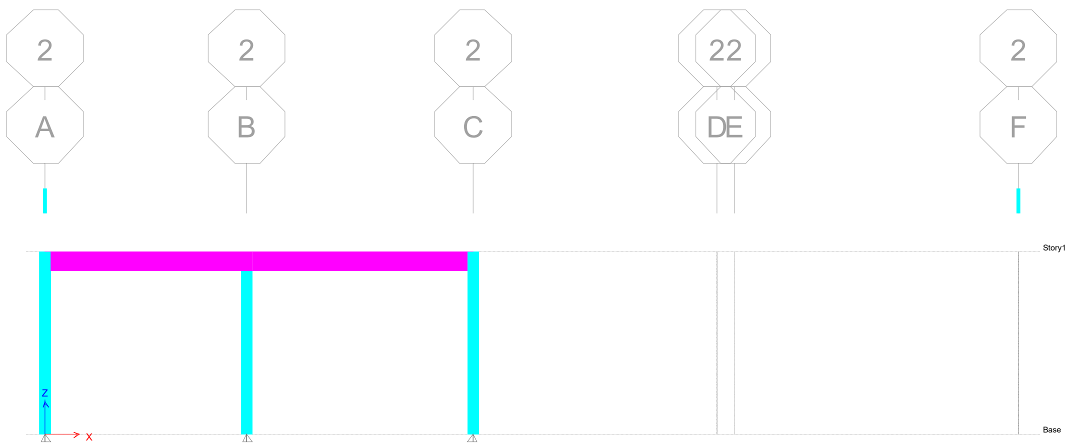
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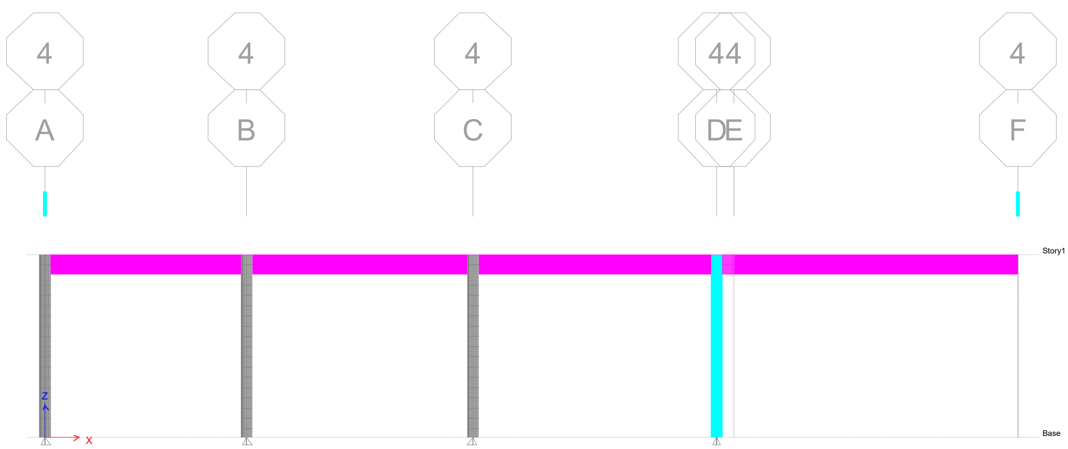
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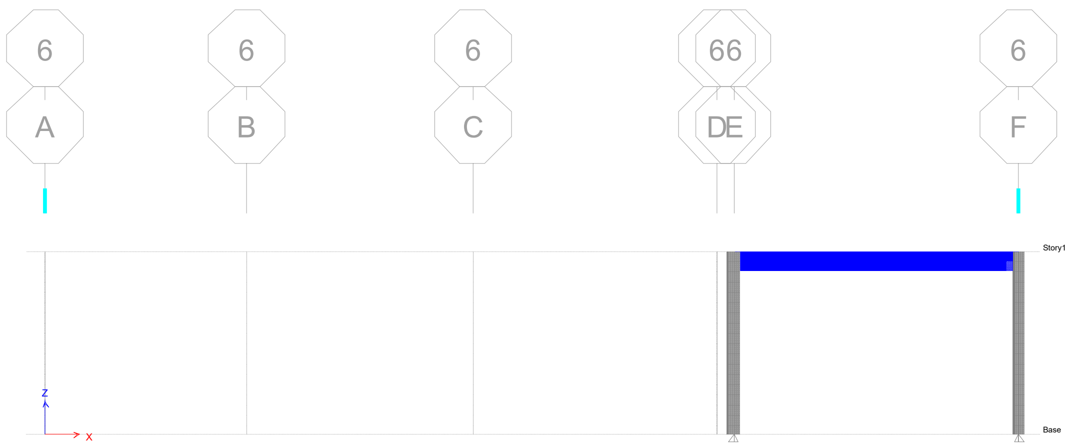
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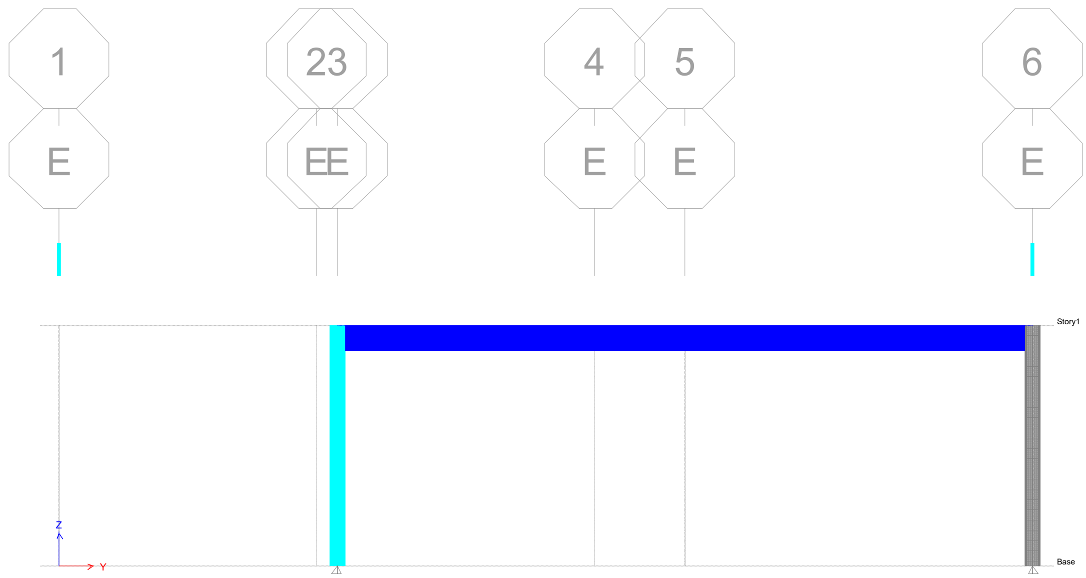
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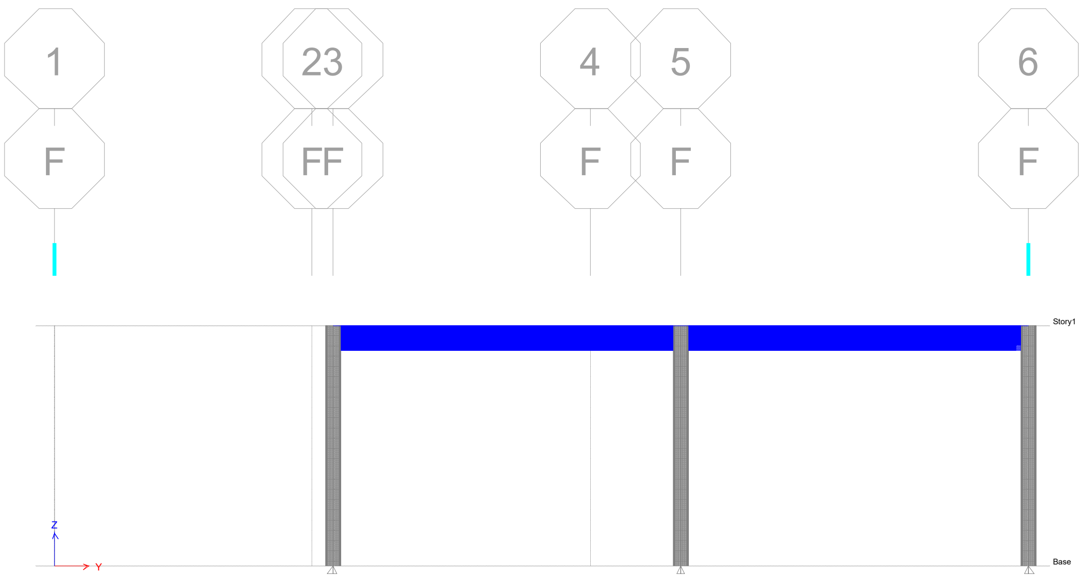
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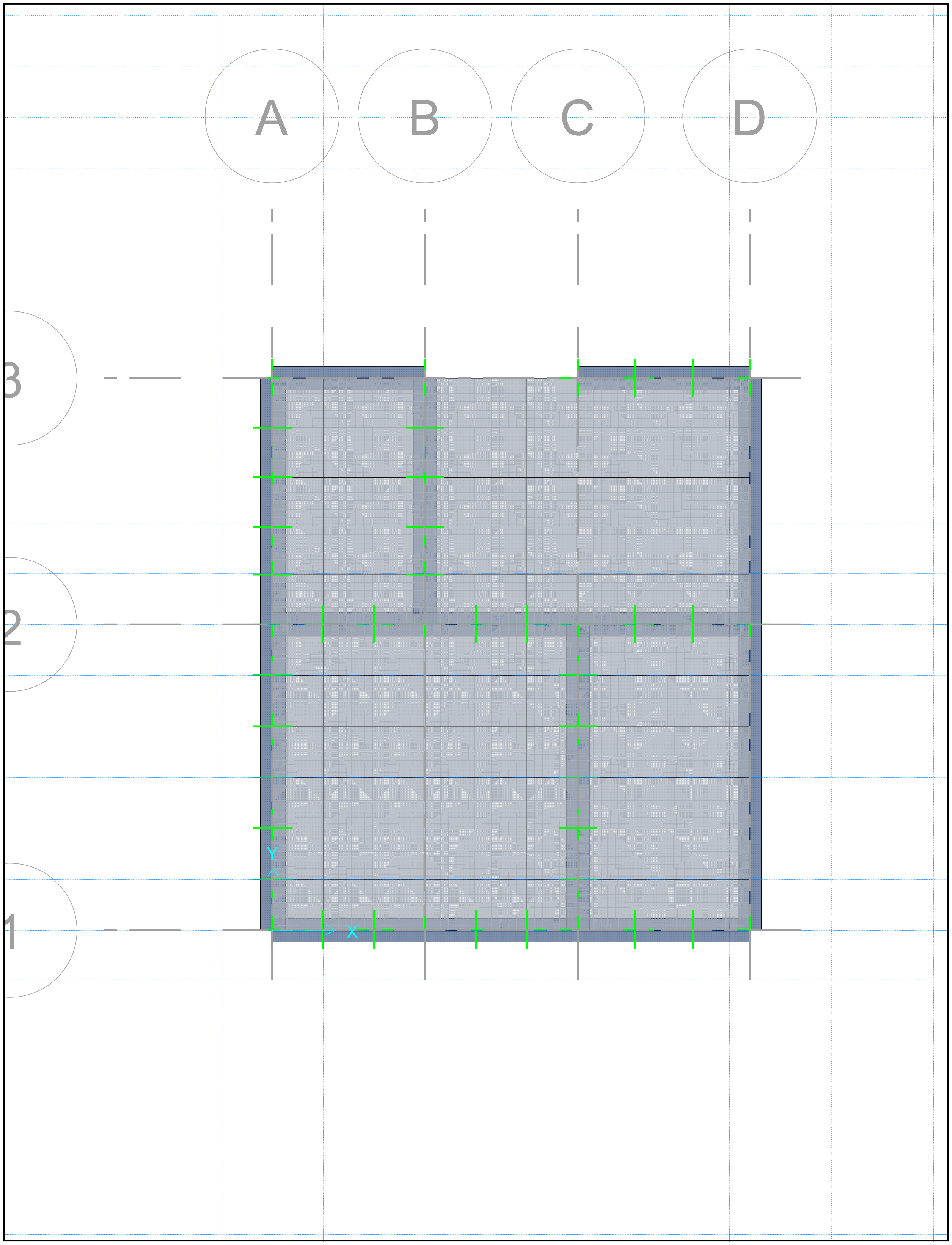
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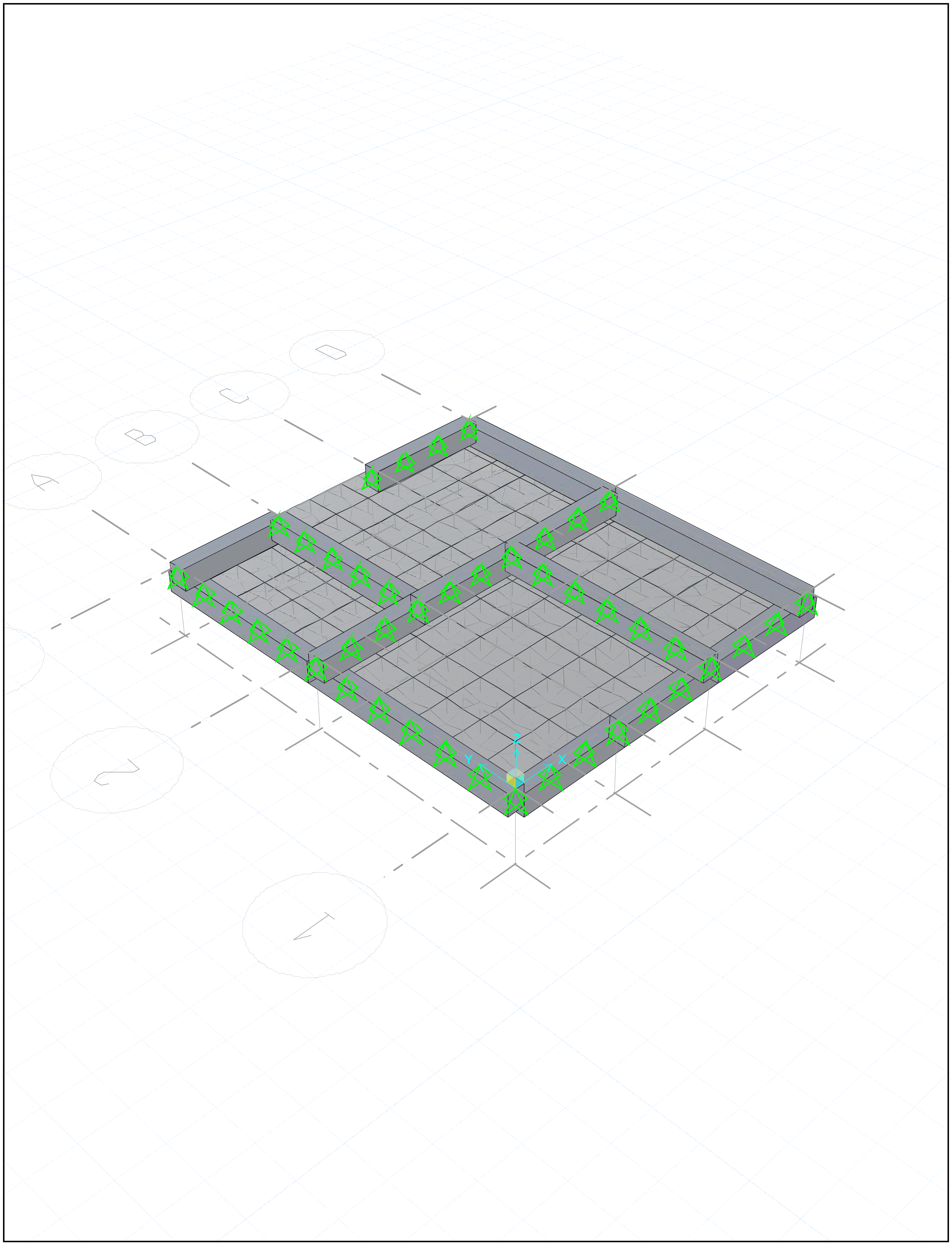
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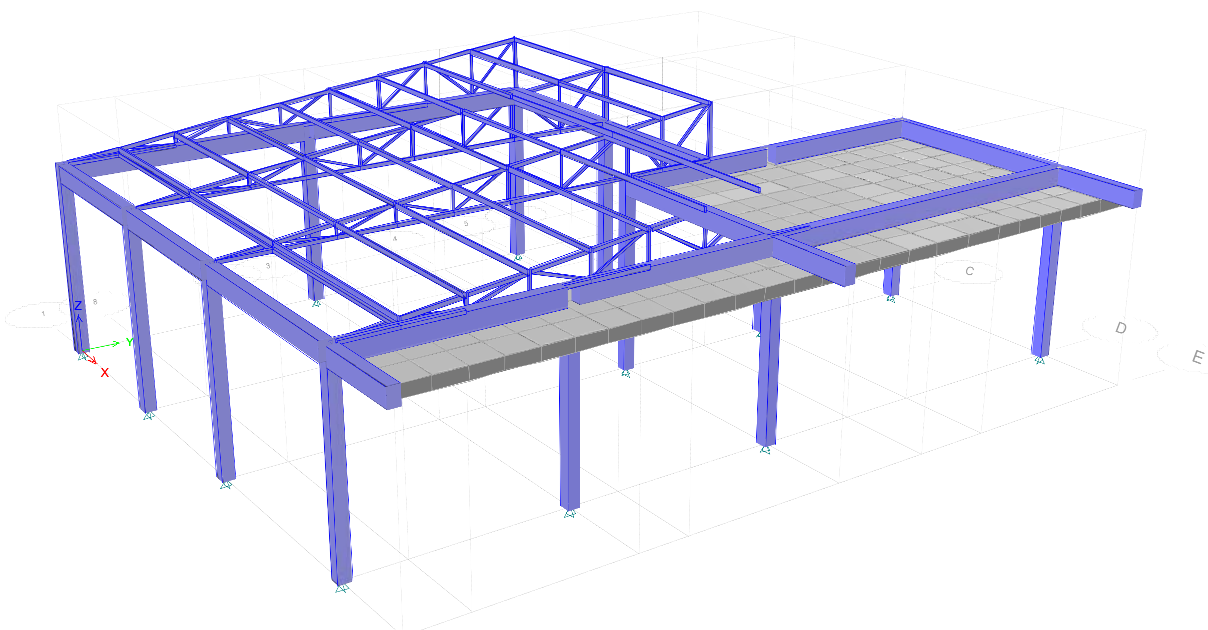

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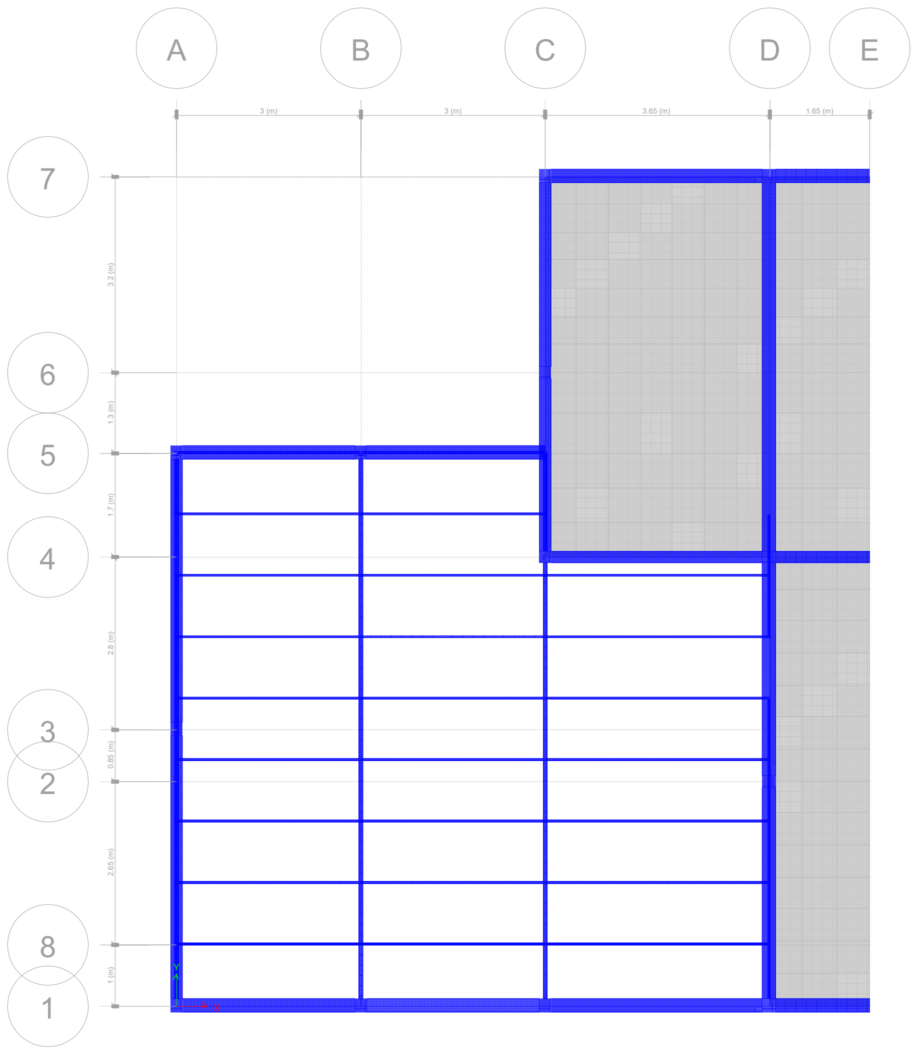
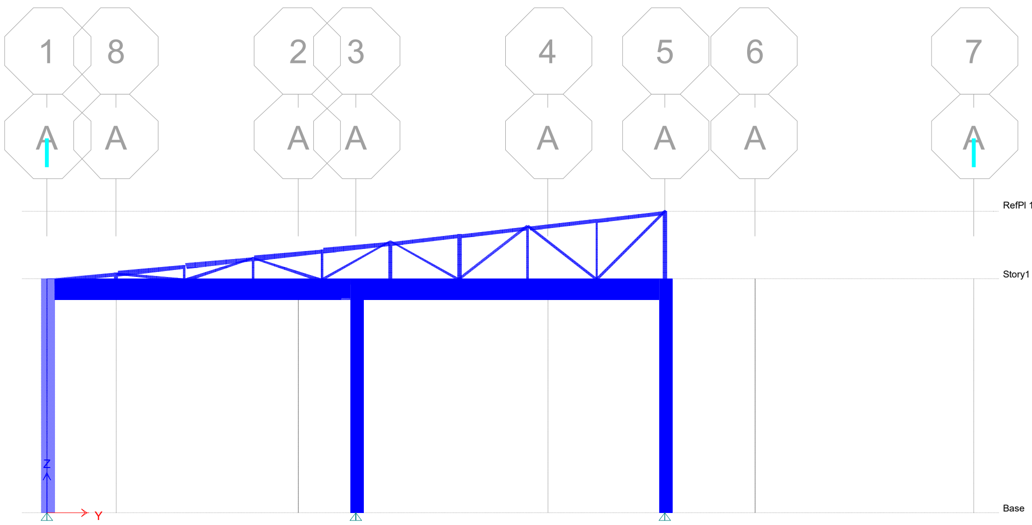
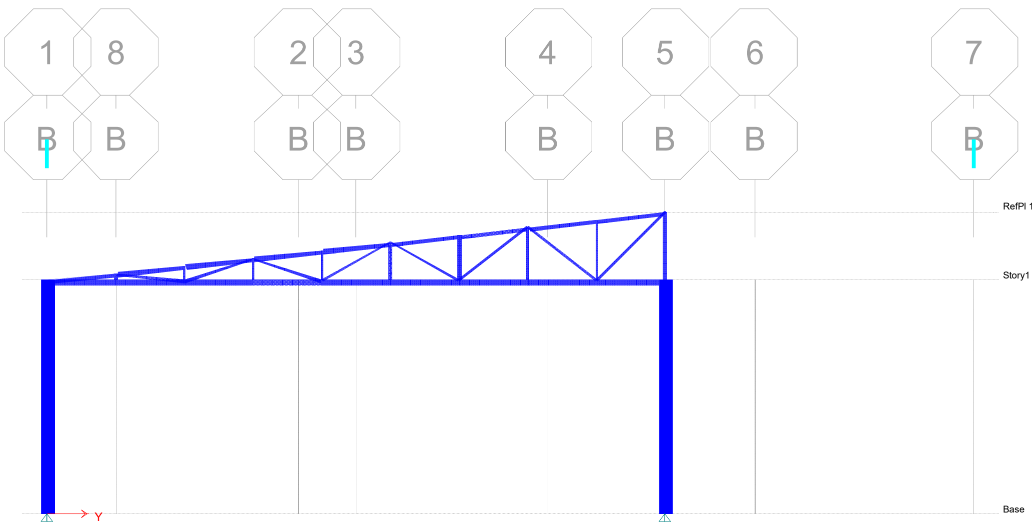
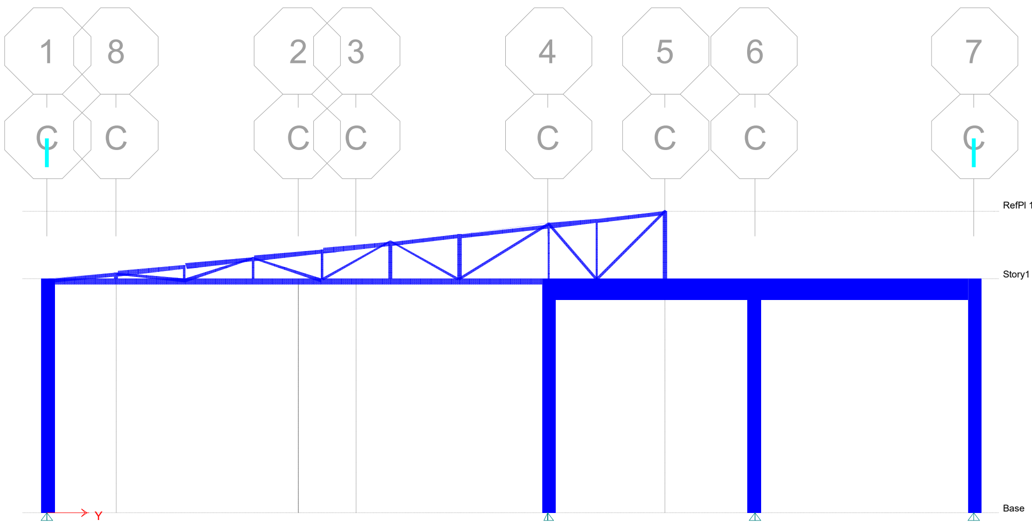
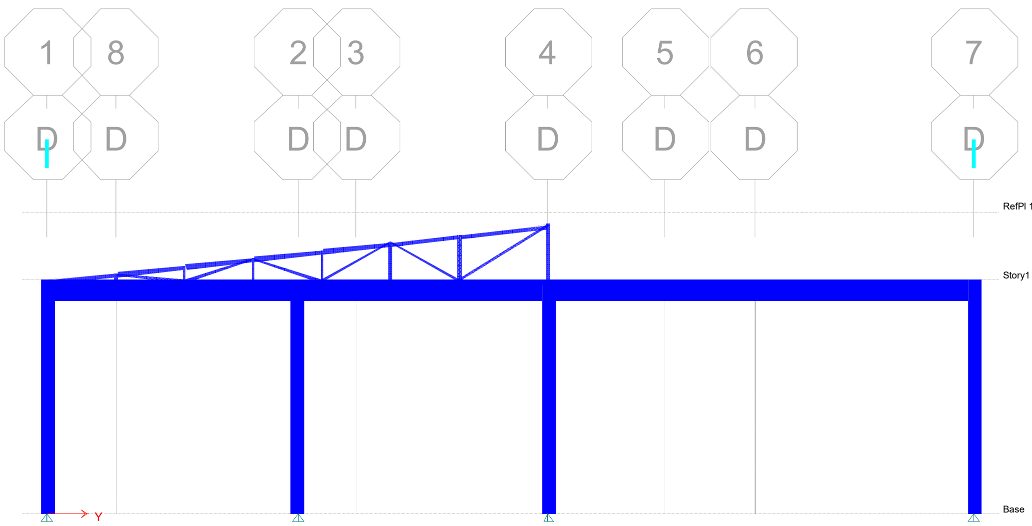
D
E

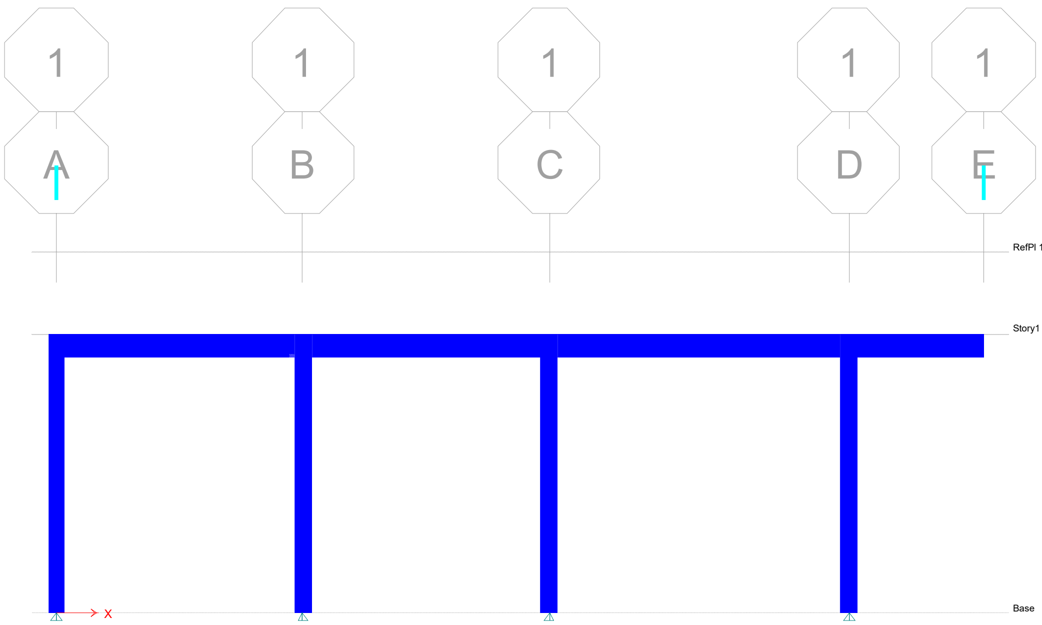

A
B
C
D
E
3 (m)
3 (m)
3.65 (m)
1.65 (m)
7
6
5
4
3
2
8
1
3.2 (m)
1.3 (m)
1.7 (m)
2.8 (m)
0.85 (m)
2.65 (m)
1 (m)

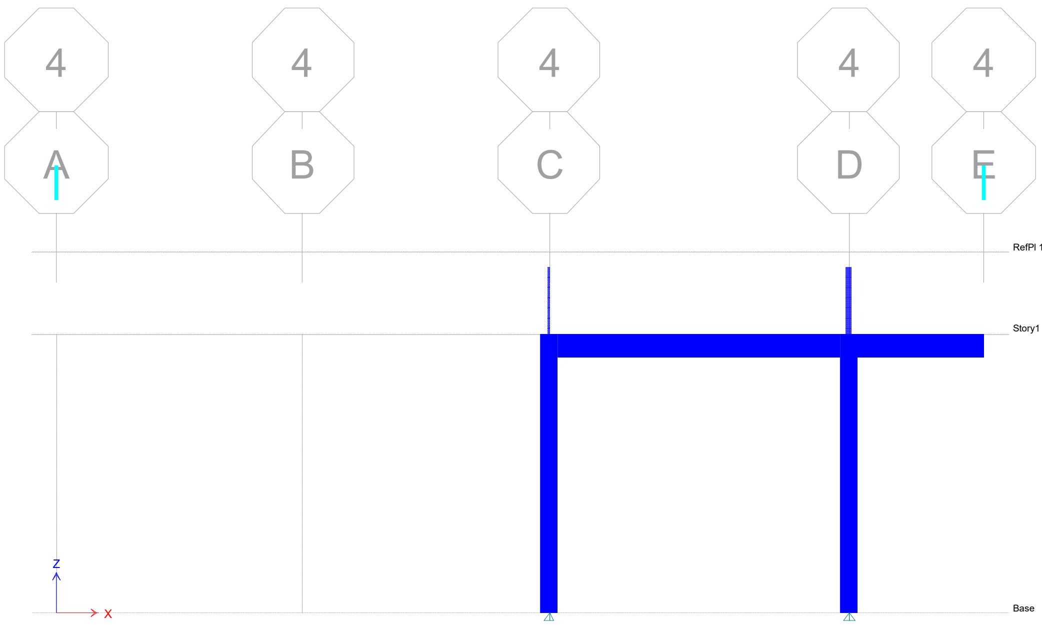

1
8
2
3
4
5
6
7
A
A
A
A
A
A
A
A
RefPl 1
Story1
Base
Z
Y

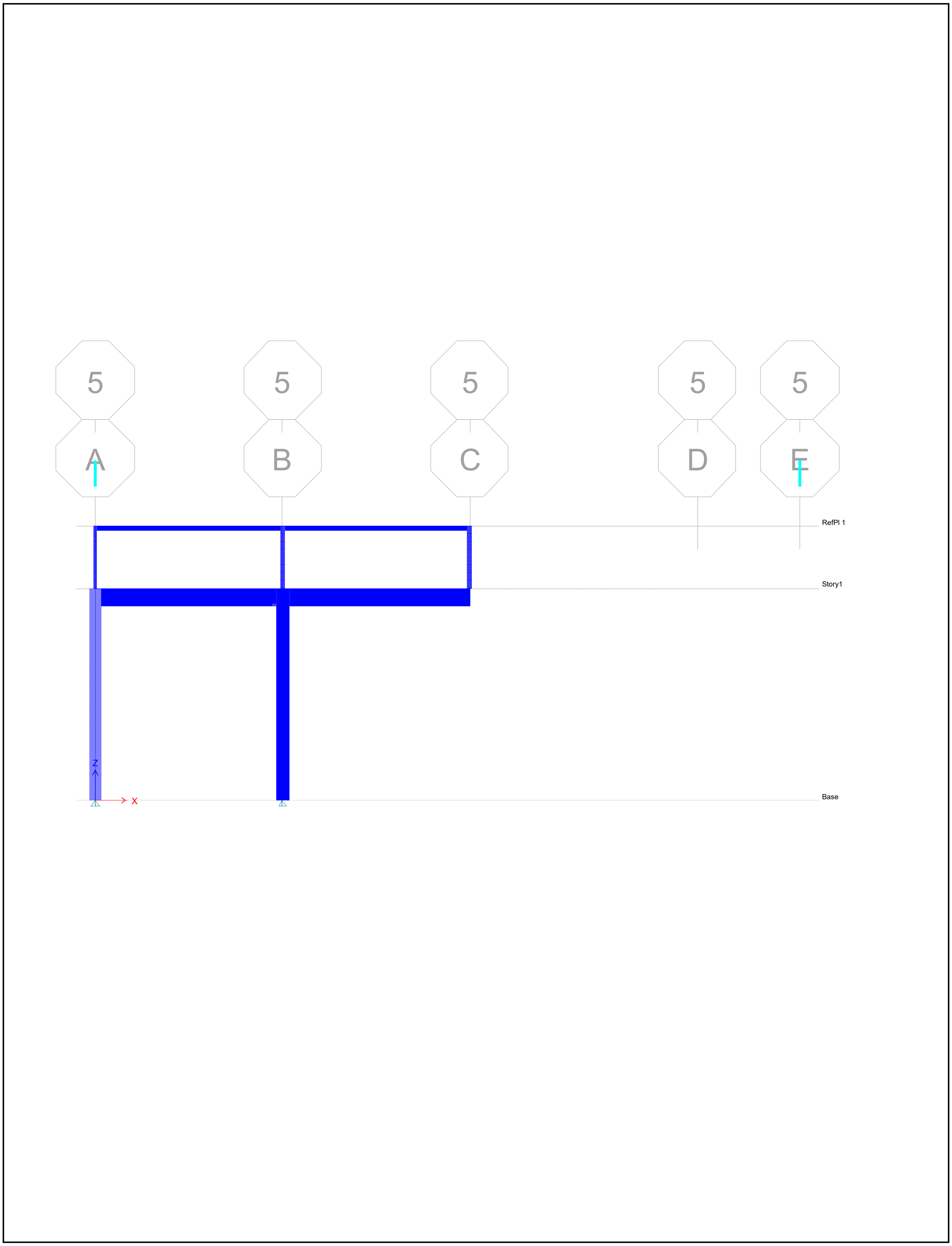

1
8
2
3
4
5
6
7
B
B
B
B
B
B
B
B
RefPl 1
Story1
Base
Y

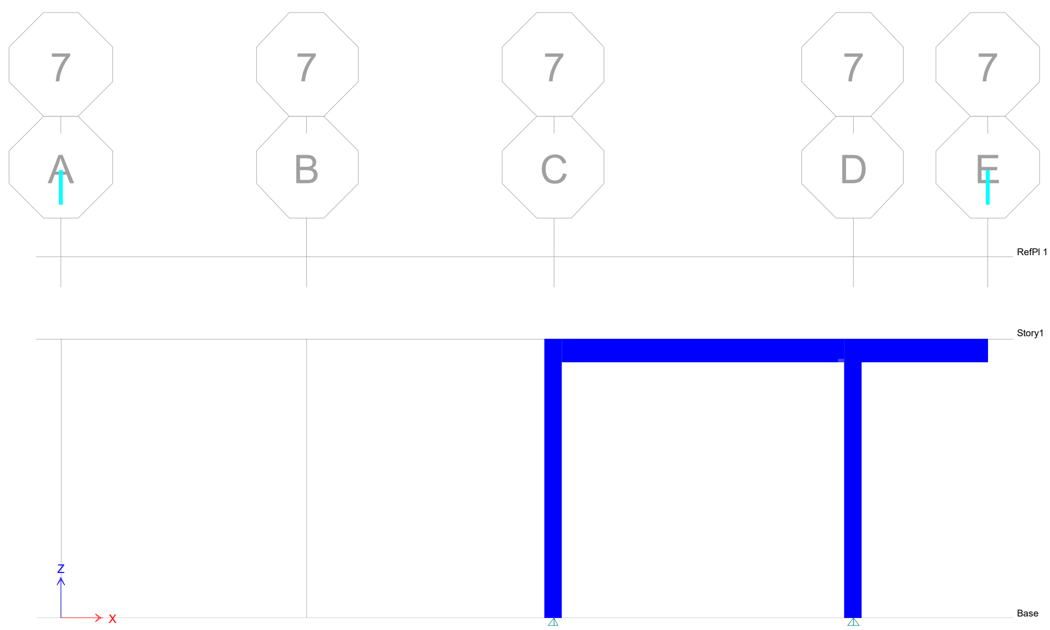

1
8
2
3
4
5
6
7
C
C
C
C
C
C
C
C
RefPl 1
Story1
Base
Y

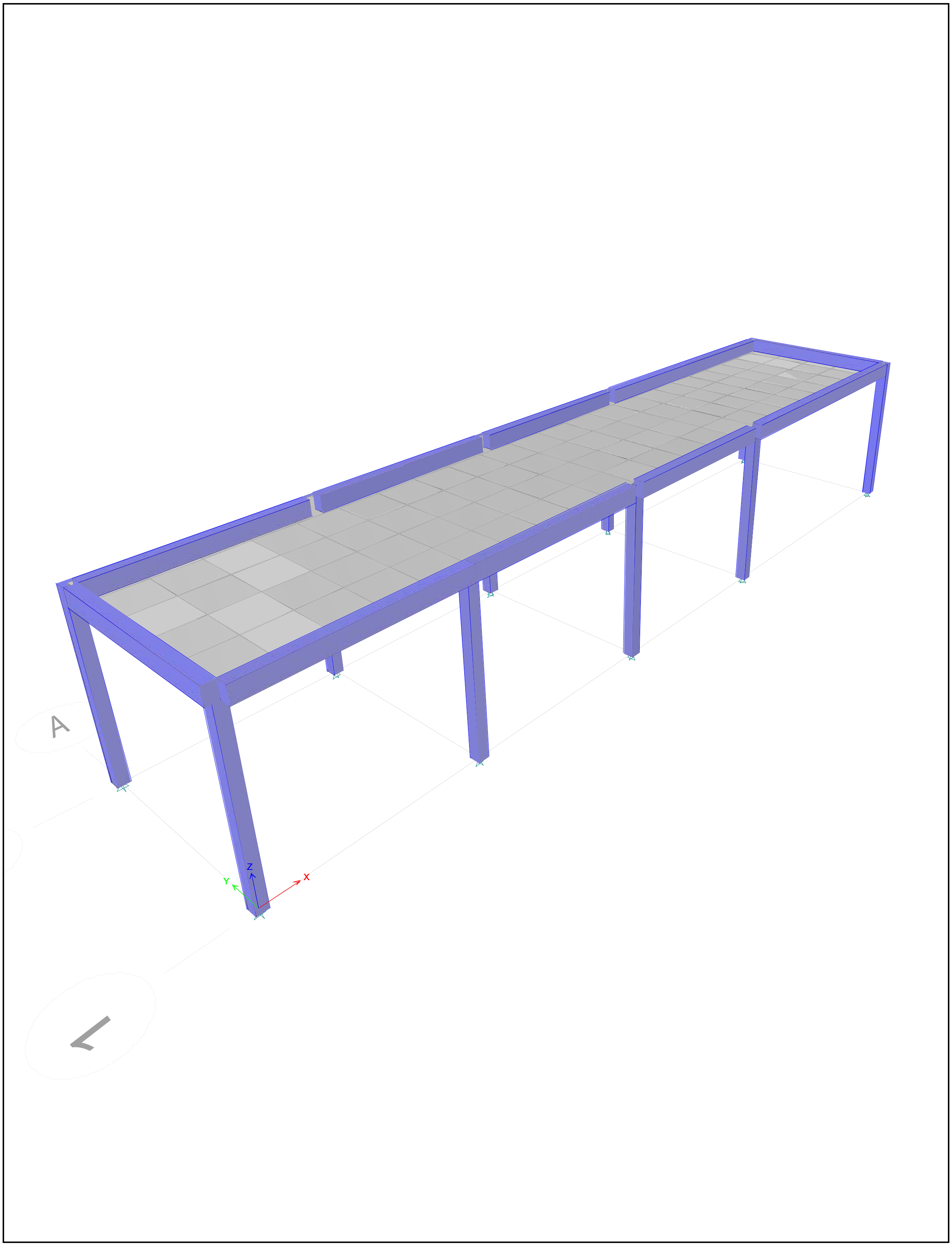

1
8
2
3
4
5
6
7
D
D
D
D
D
D
D
D
RefPl 1
Story1
Base
Y

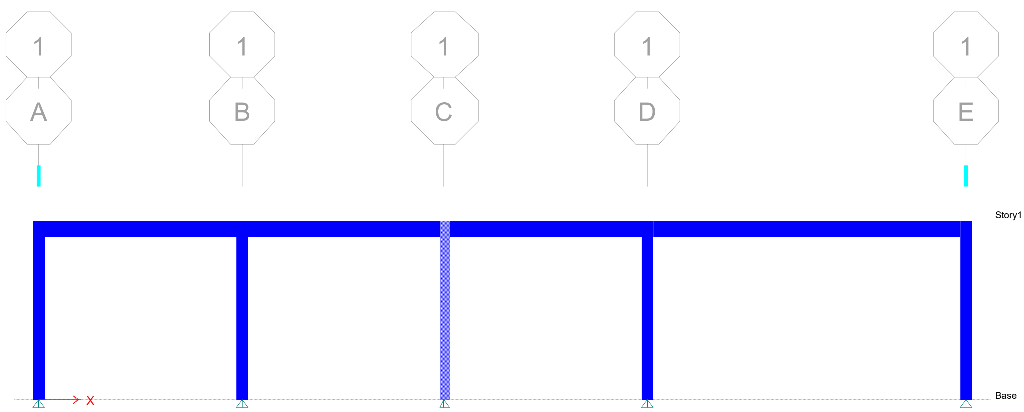

1
1
1
1
1
A
B
C
D
E
RefPl 1
Story1
Base
X

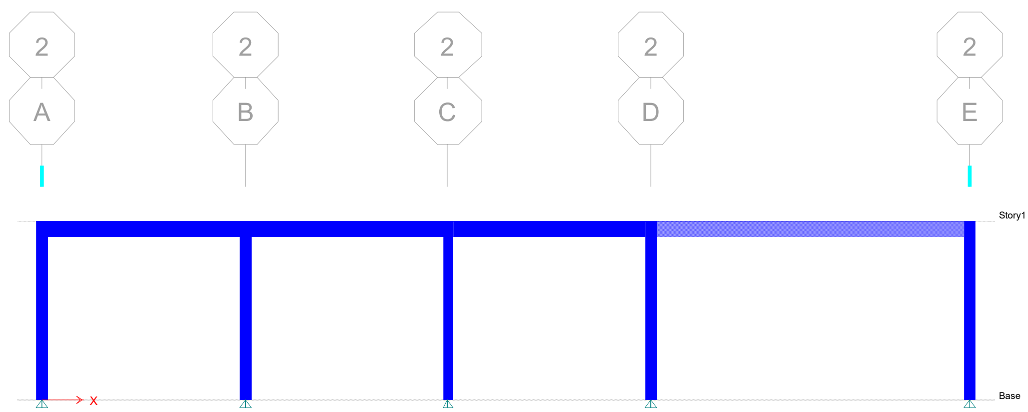

4
4
4
4
4
A
B
C
D
E
RefPl 1
Story1
Base
Z
X

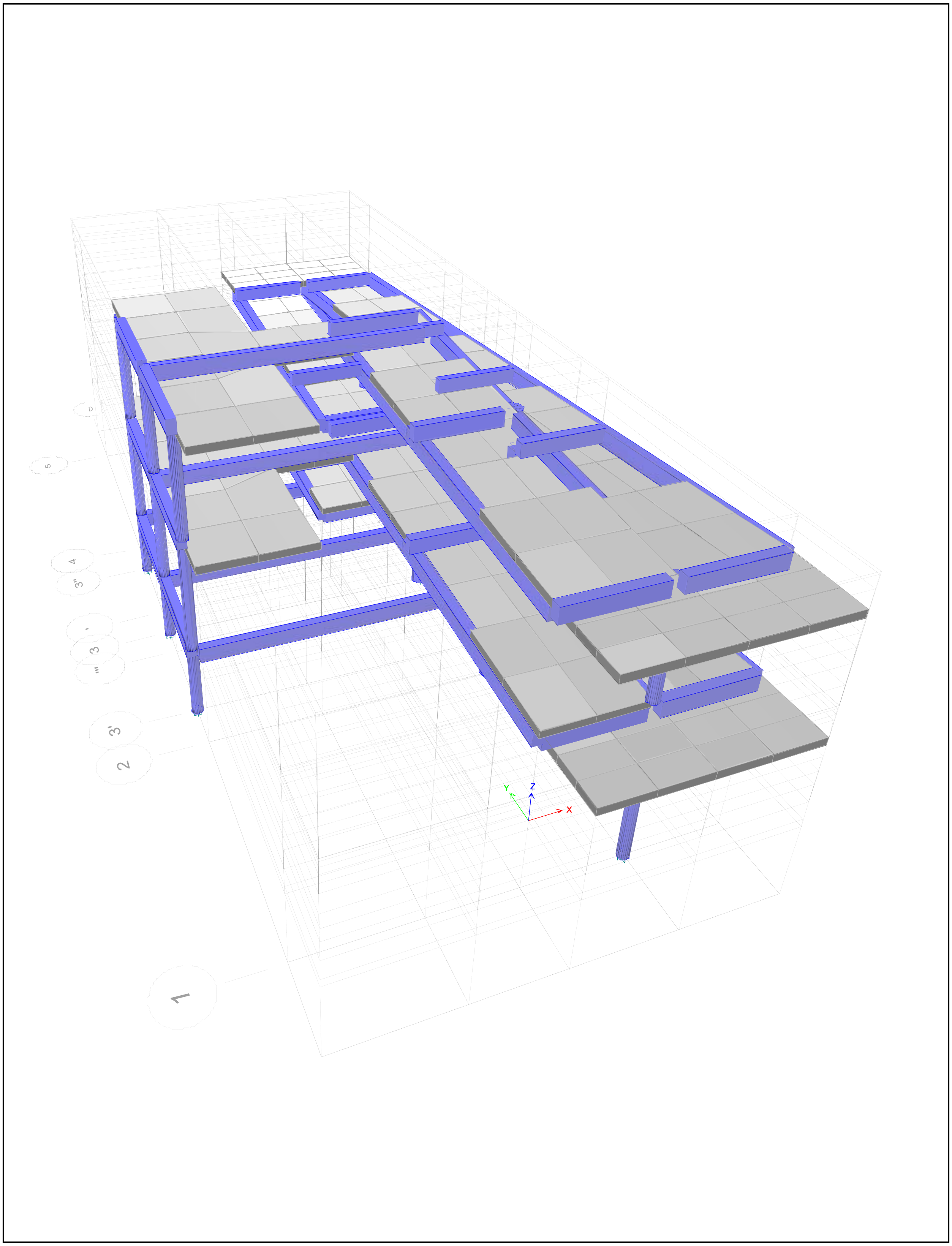

5
5
5
5
5
A
B
C
D
E
RefPl 1
Story1
Base
Z
X

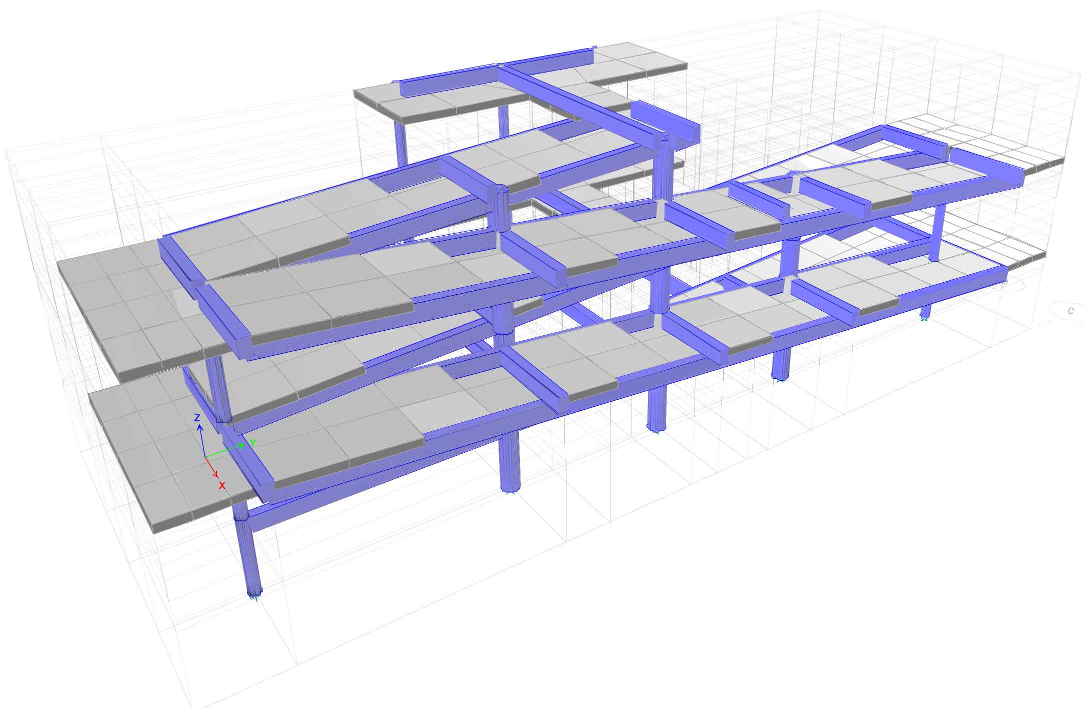

7
7
7
7
7
A
B
C
D
E
RefPl 1
Story1
Base
Z
X


A
Z
Y
X

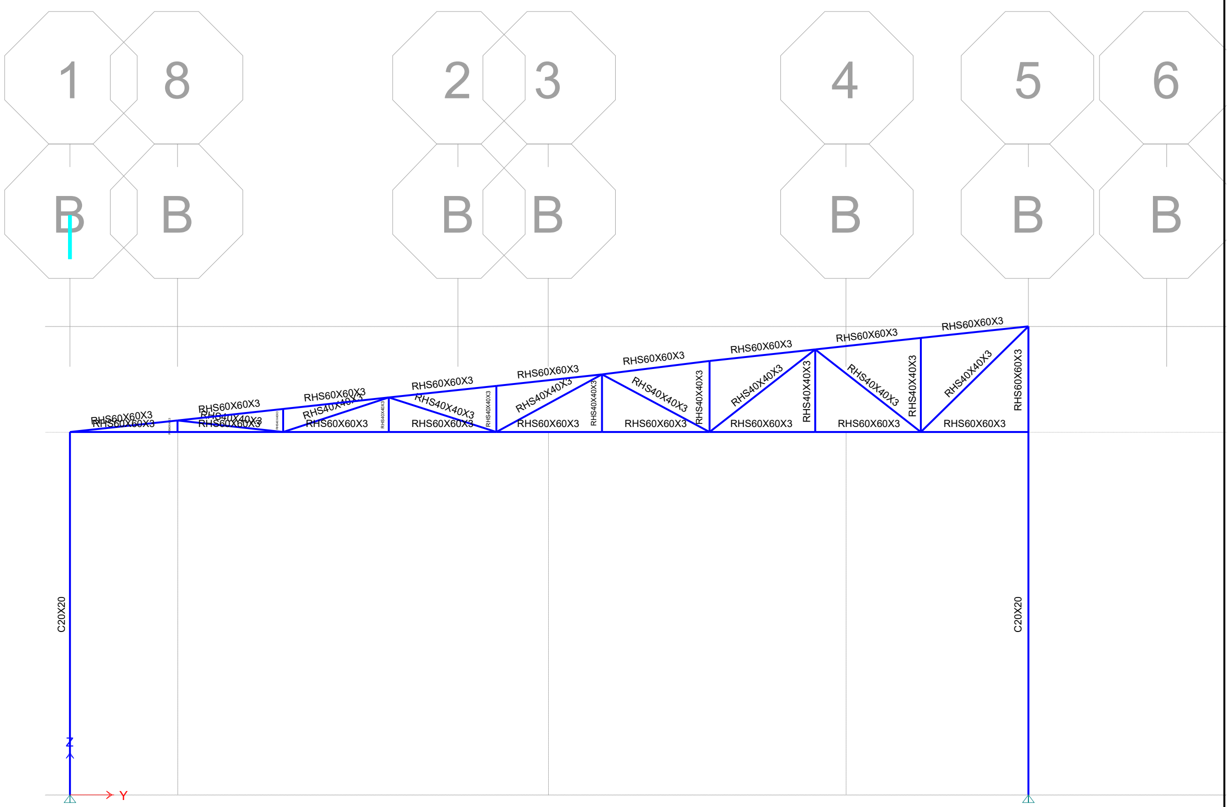

1
A
1
B
1
C
1
D
1
E
Story1
Base
X

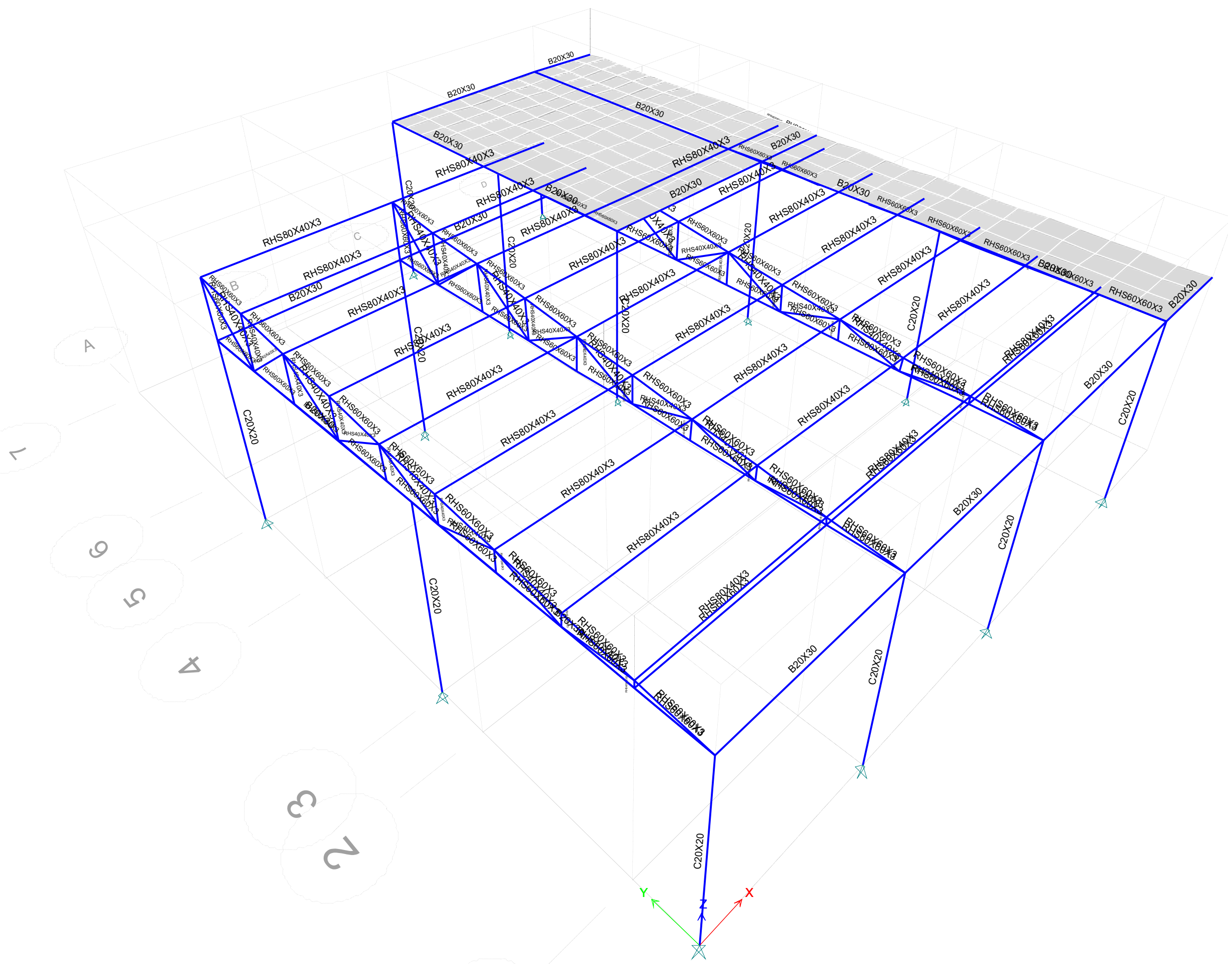

2
A
2
B
2
C
2
D
2
E
Story1
Base
X


Y
Z
X


Z
Y
X

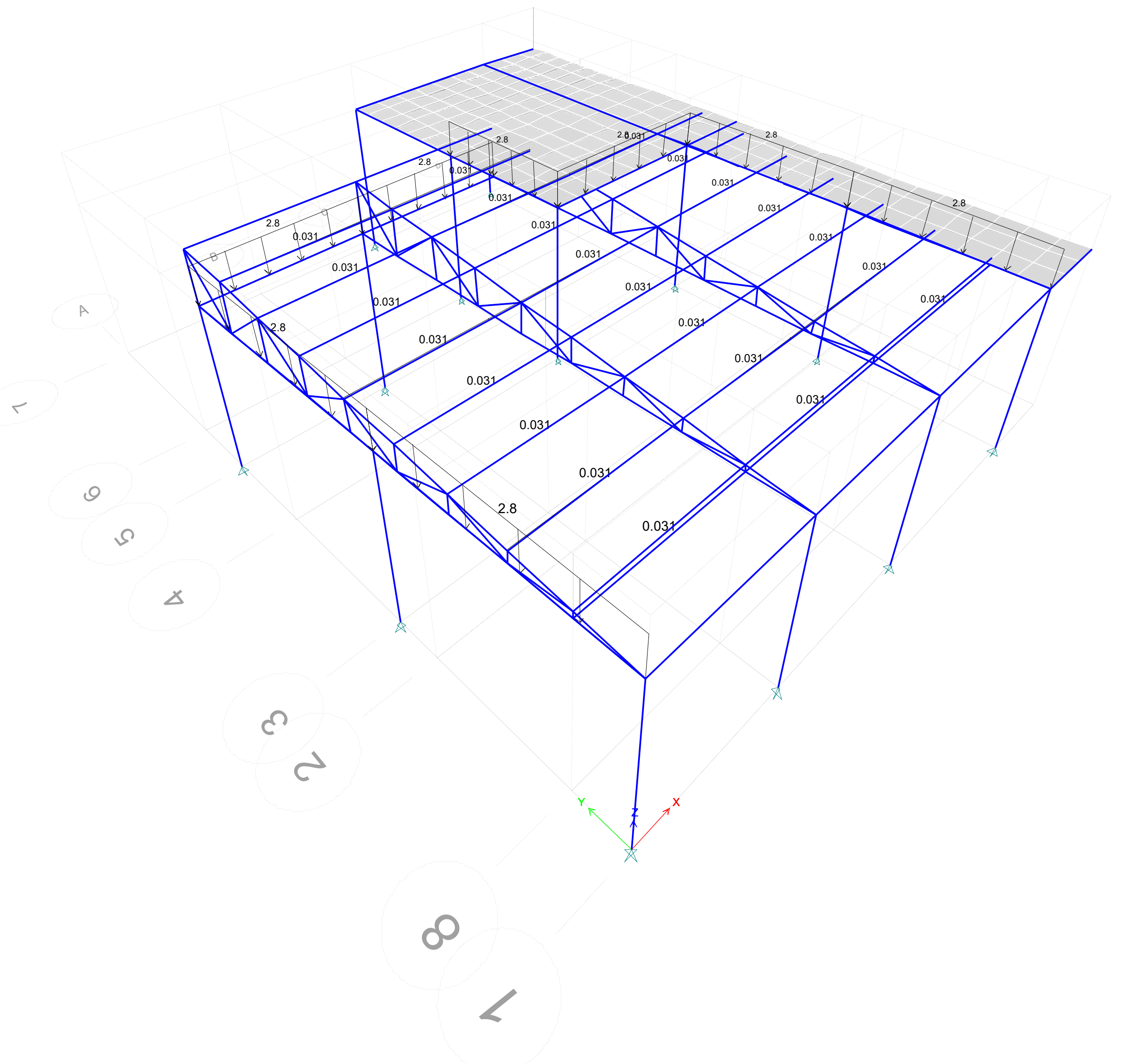
SECTION-3: ROOF: STEEL TRUSS

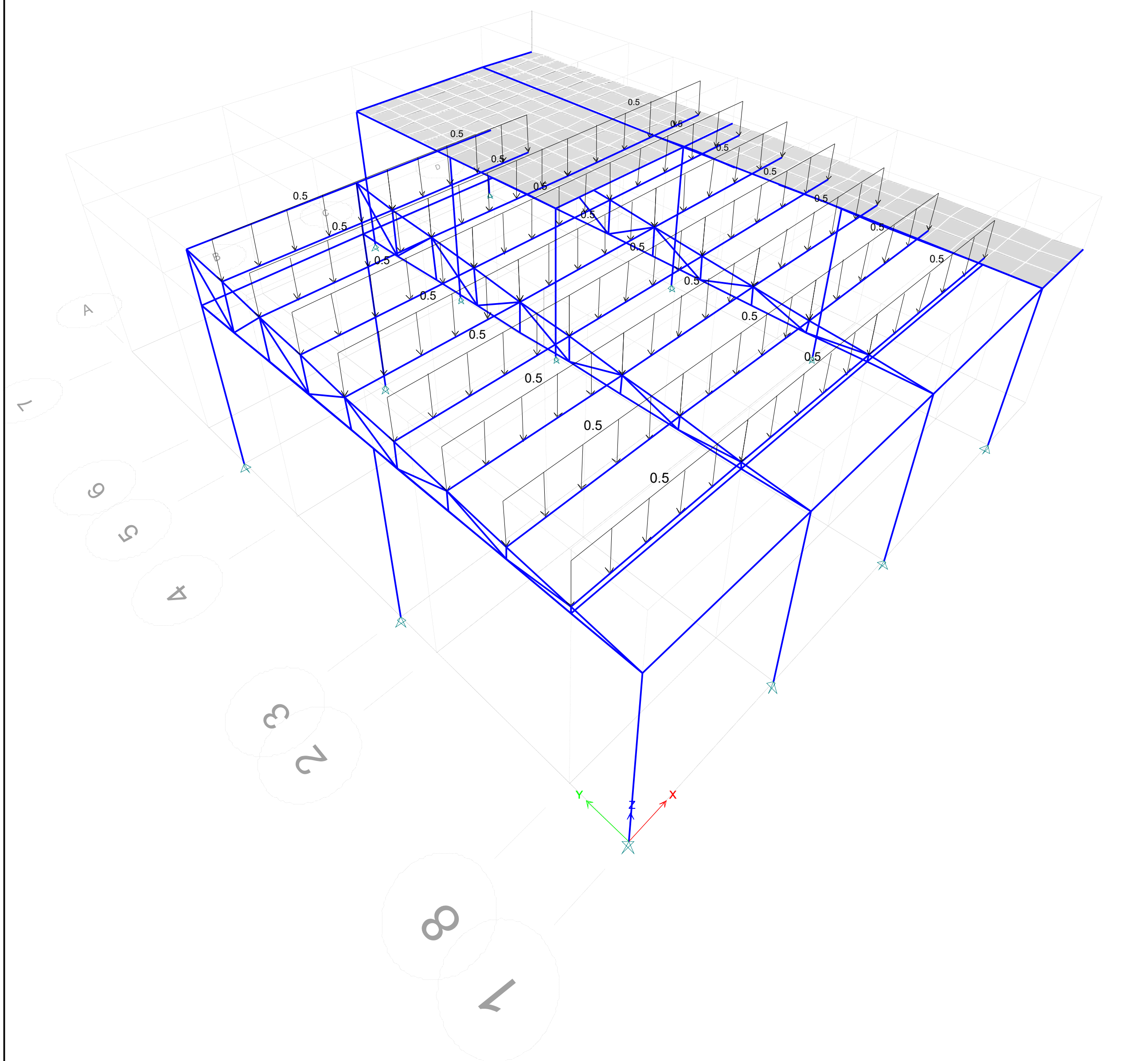

1
8
2
3
4
5
6
B
B
B
B
B
B
B
RHS60X60X3
RHS40X40X3
RHS40X40X3
RHS60X60X3
C20X20
C20X20
Z
Y

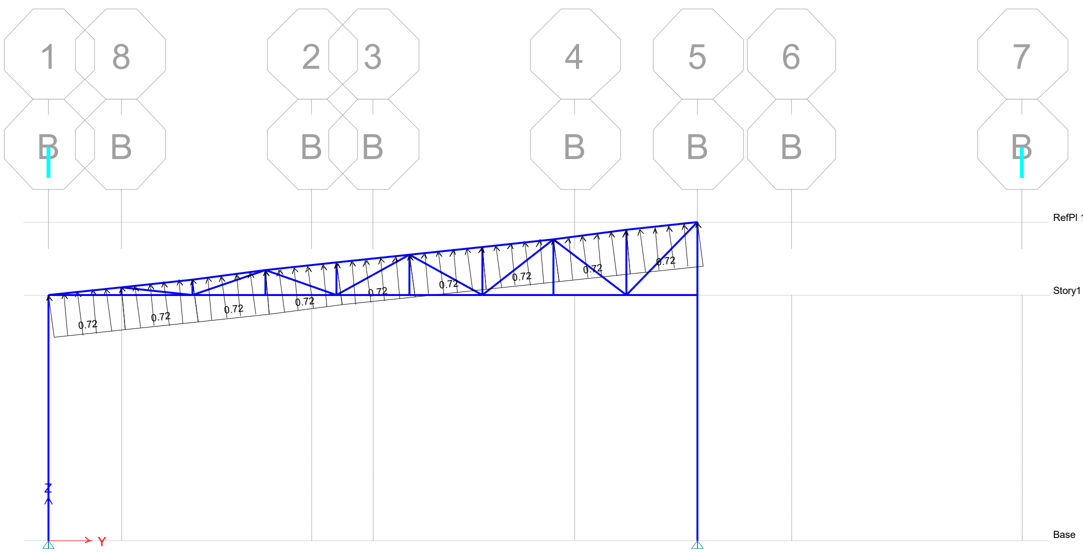


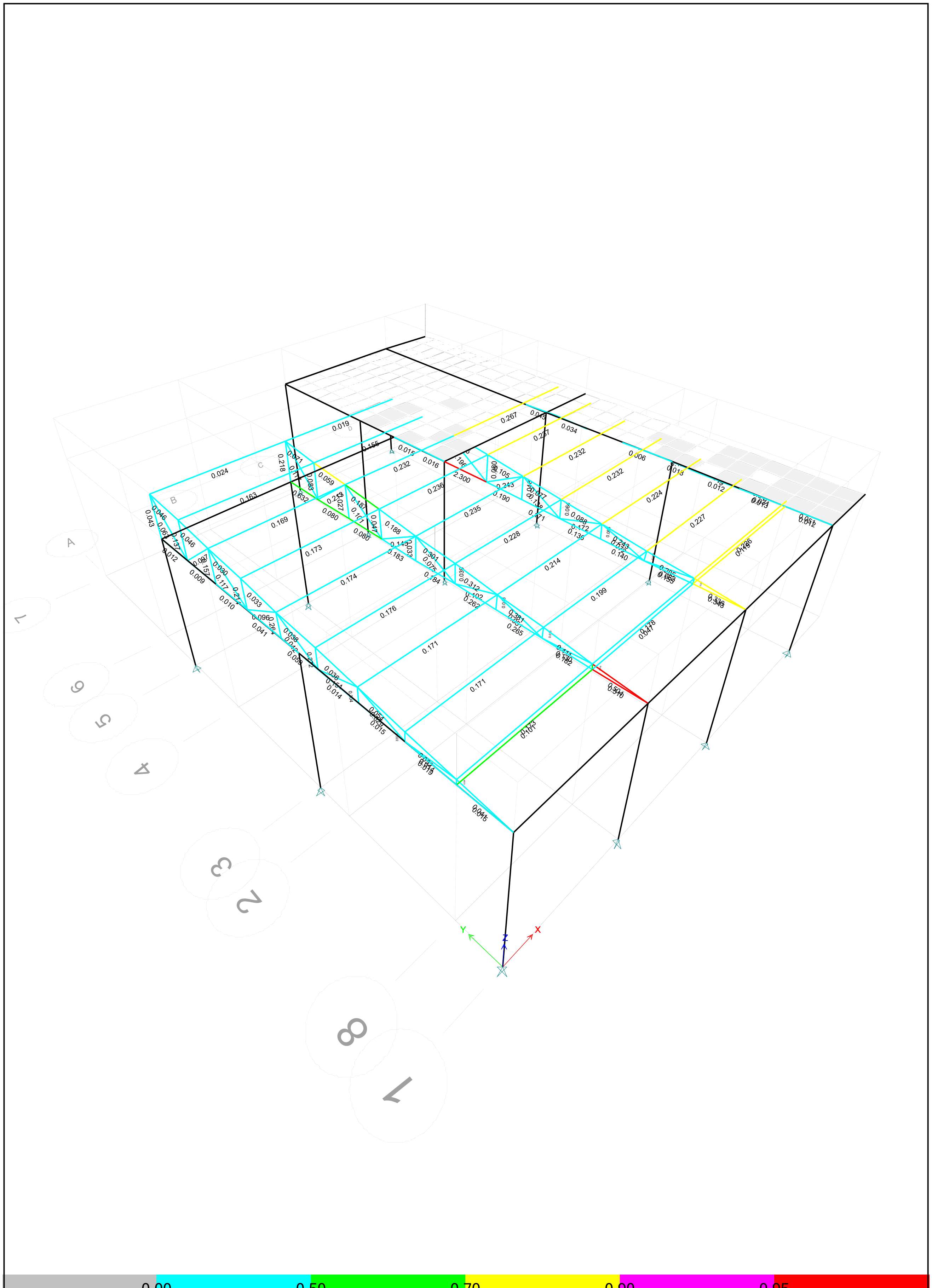
Member Section:

Purlin- RHS 80x40x3mm;
Truss Upper Chord - RHS 60x60x3mm
Truss Lower Chord - RHS 60X60X3mm
Internal Members - RHS 40X40X2.5mm

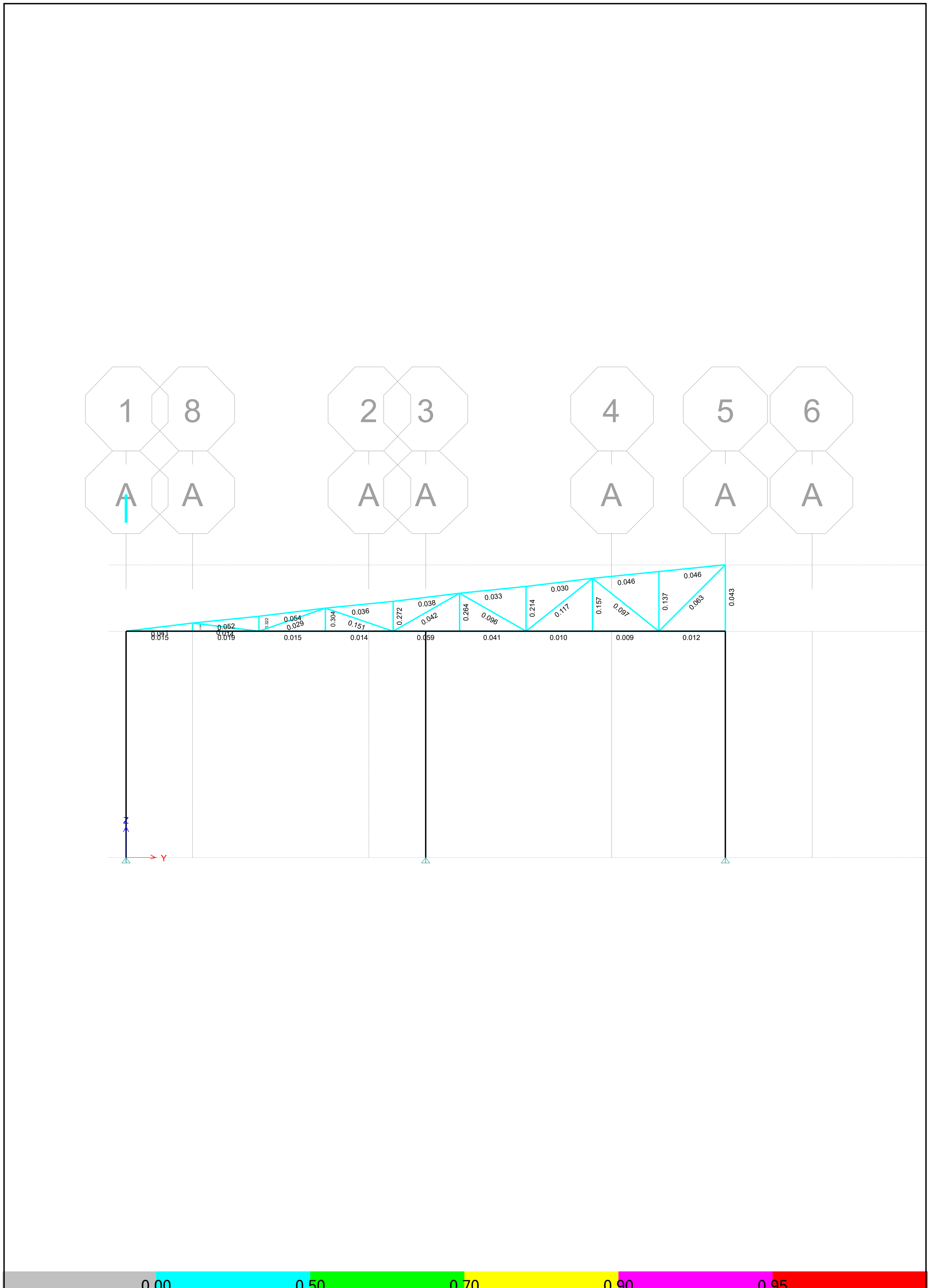

2.8
0.031
A
B
C
1
2
3
4
5
6
7
8
X
Y
Z


0.5
X
Y
Z
A
B
C
D
1
2
3
4
5
6
7
8

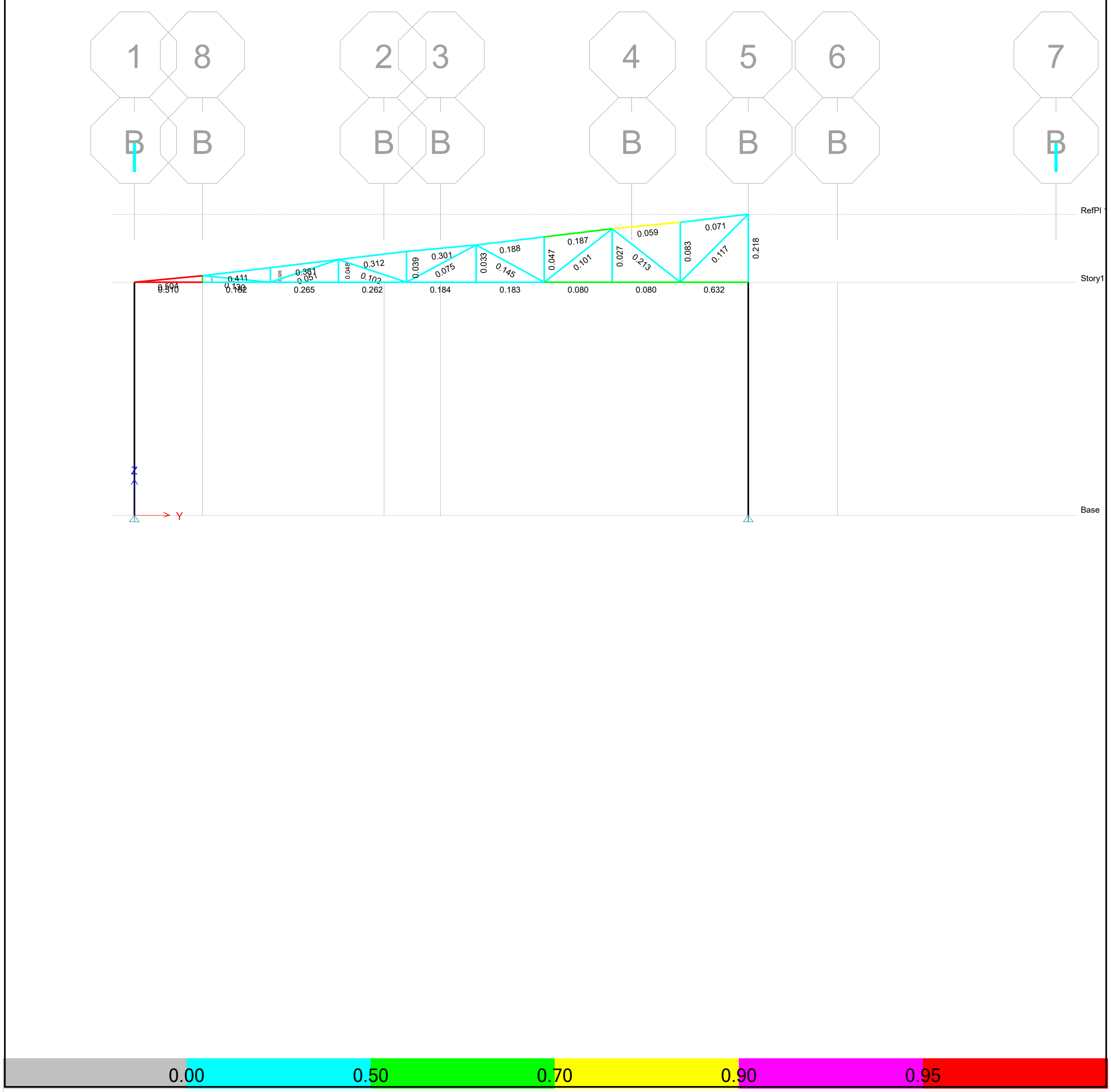

1
8
2
3
4
5
6
7
B
B
B
B
B
B
B
B
RefPl 1
Story1
Base
0.72
0.72
0.72
0.72
0.72
0.72
0.72
0.72
0.72
Z
Y



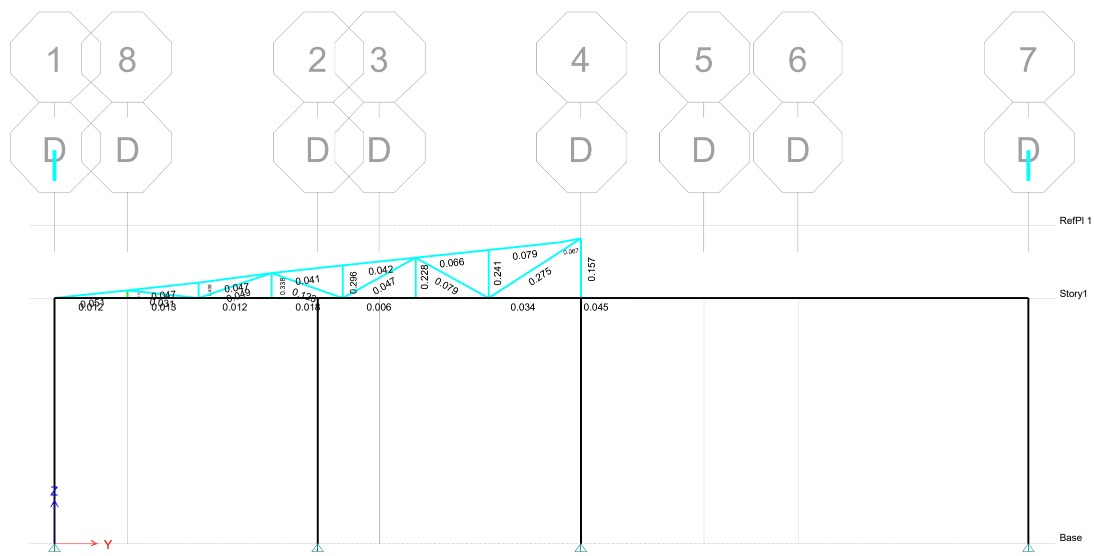
Block-J Staff Rest Rooms.EDB 3-D View Steel P-M Interaction Ratios (Eurocode 3-2005)



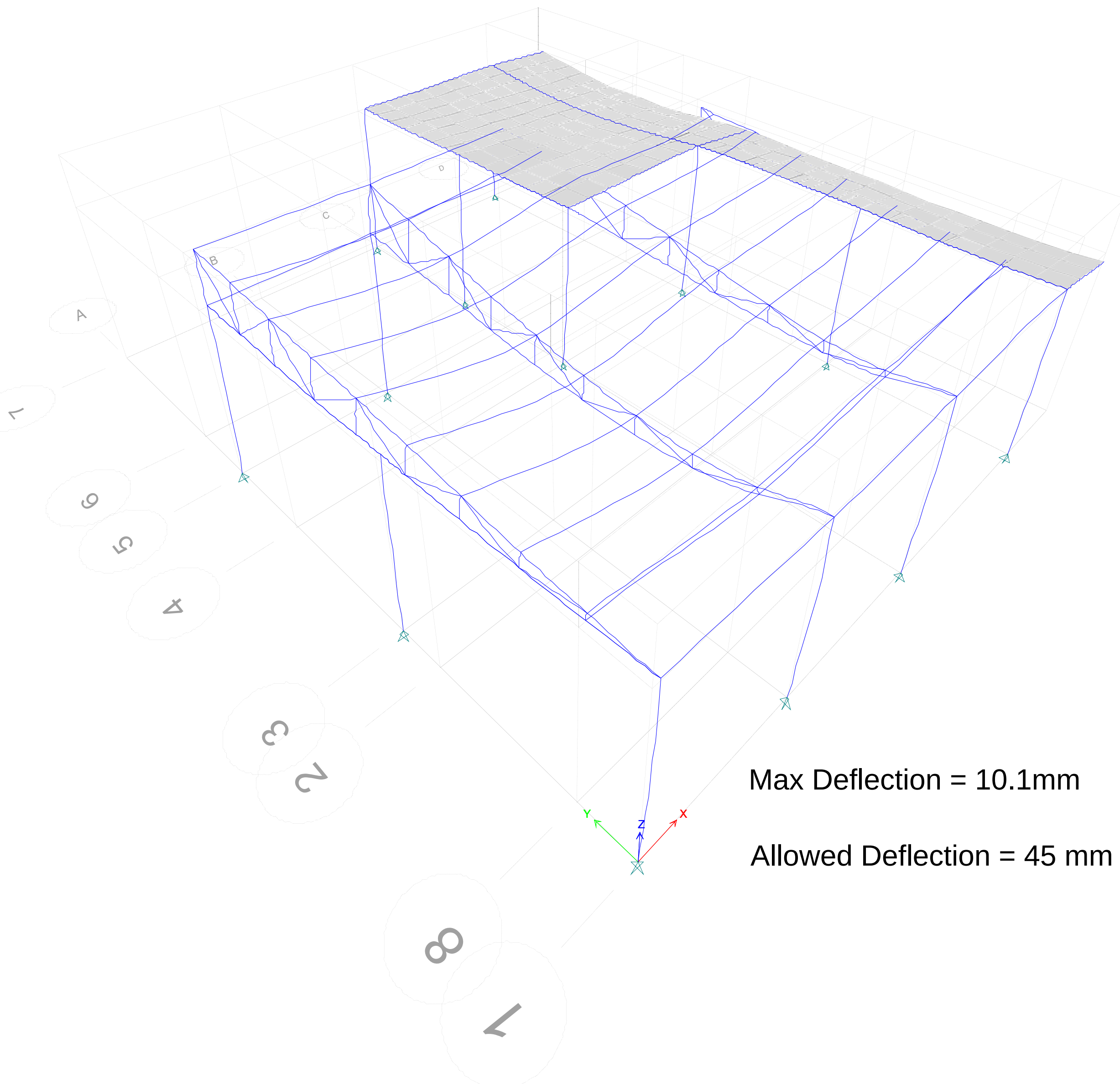
Block-J Staff Rest Room.EDB Elevation View - A Steel P-M Interaction Ratios (Eurocode 3-2005)



Block-J Staff Rest Room.EDB Elevation View - B Steel P-M Interaction Ratios (Eurocode 3-2005)

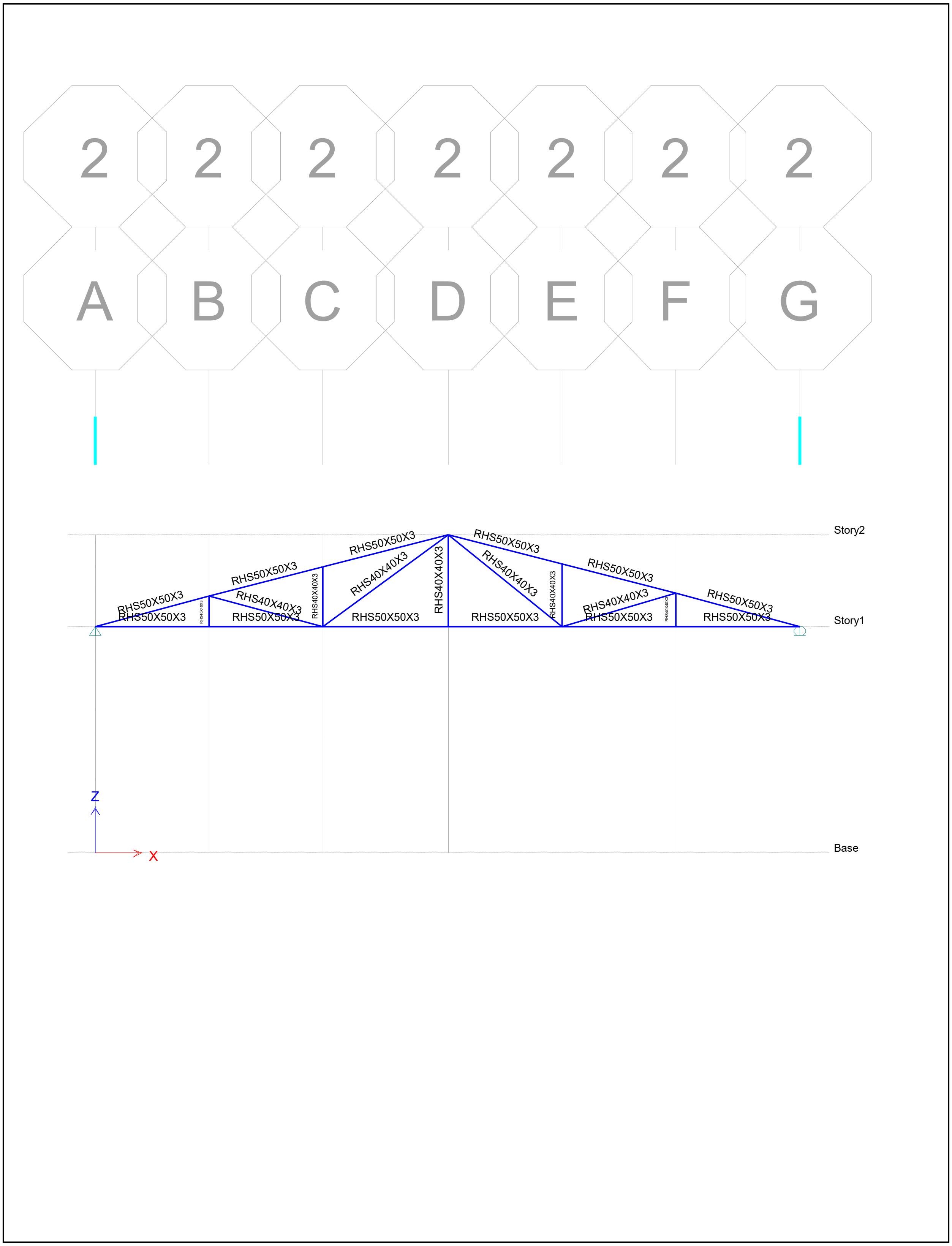


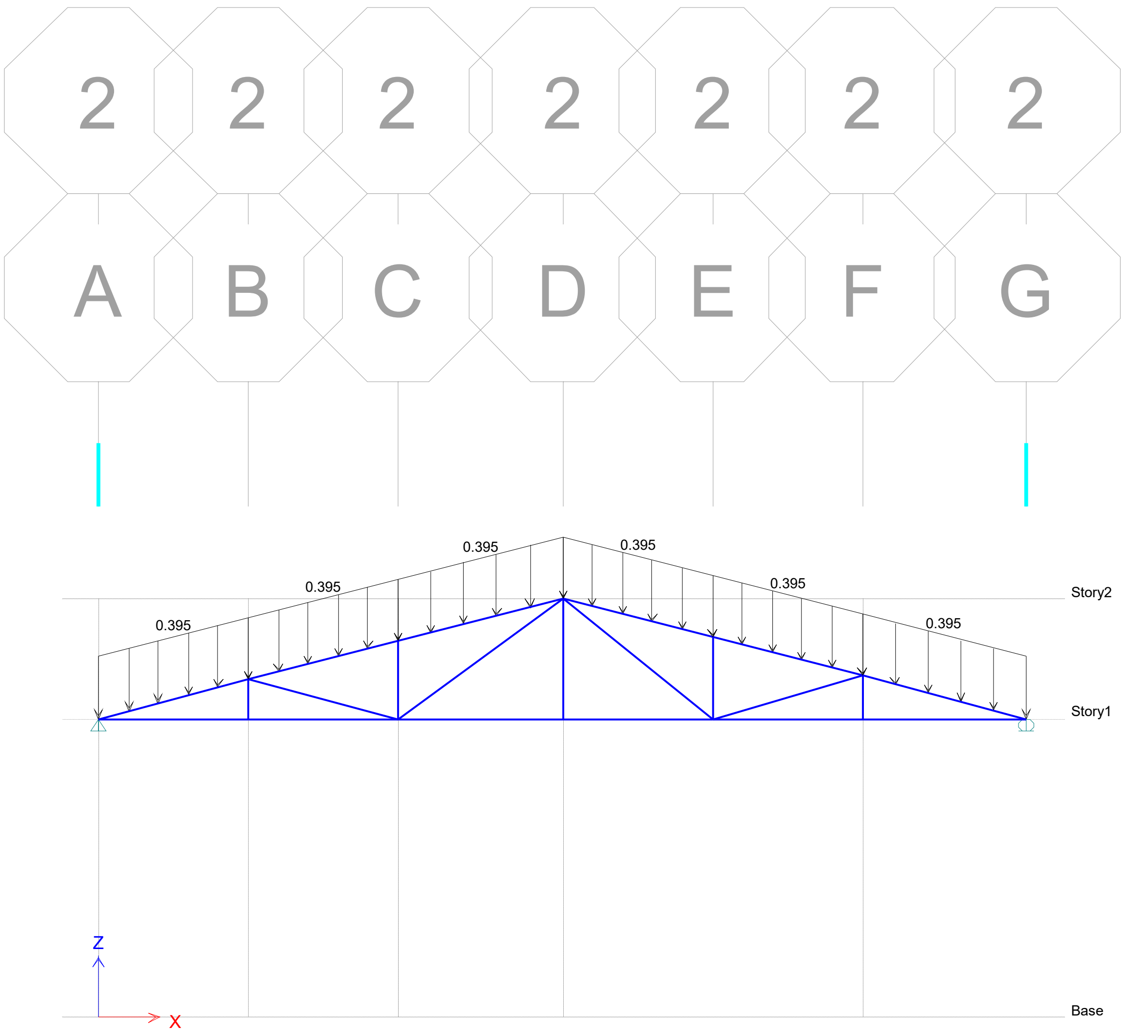
Block-J Staff Rest Room.EDB Elevation View - D Steel P-M Interaction Ratios (Eurocode 3-2005)

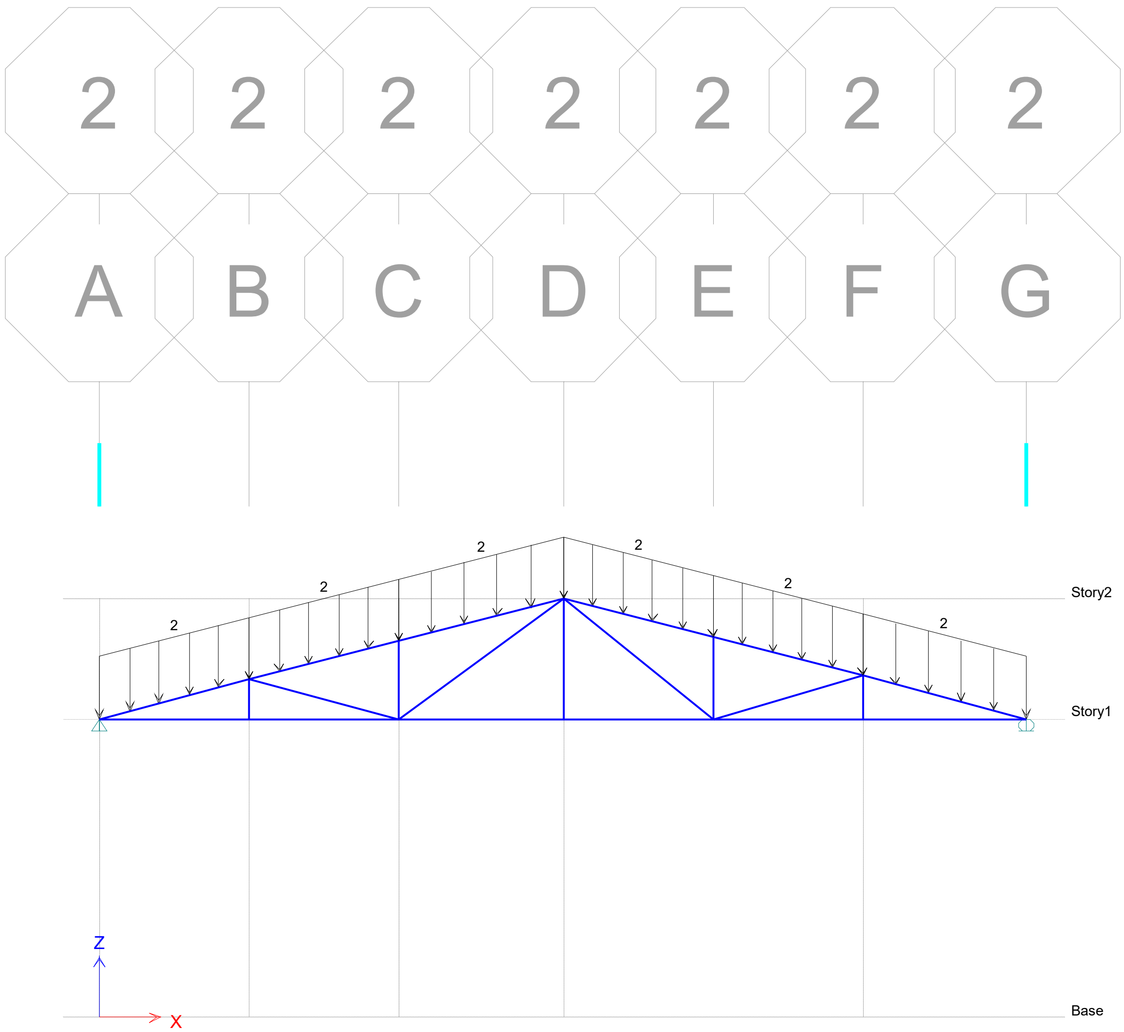


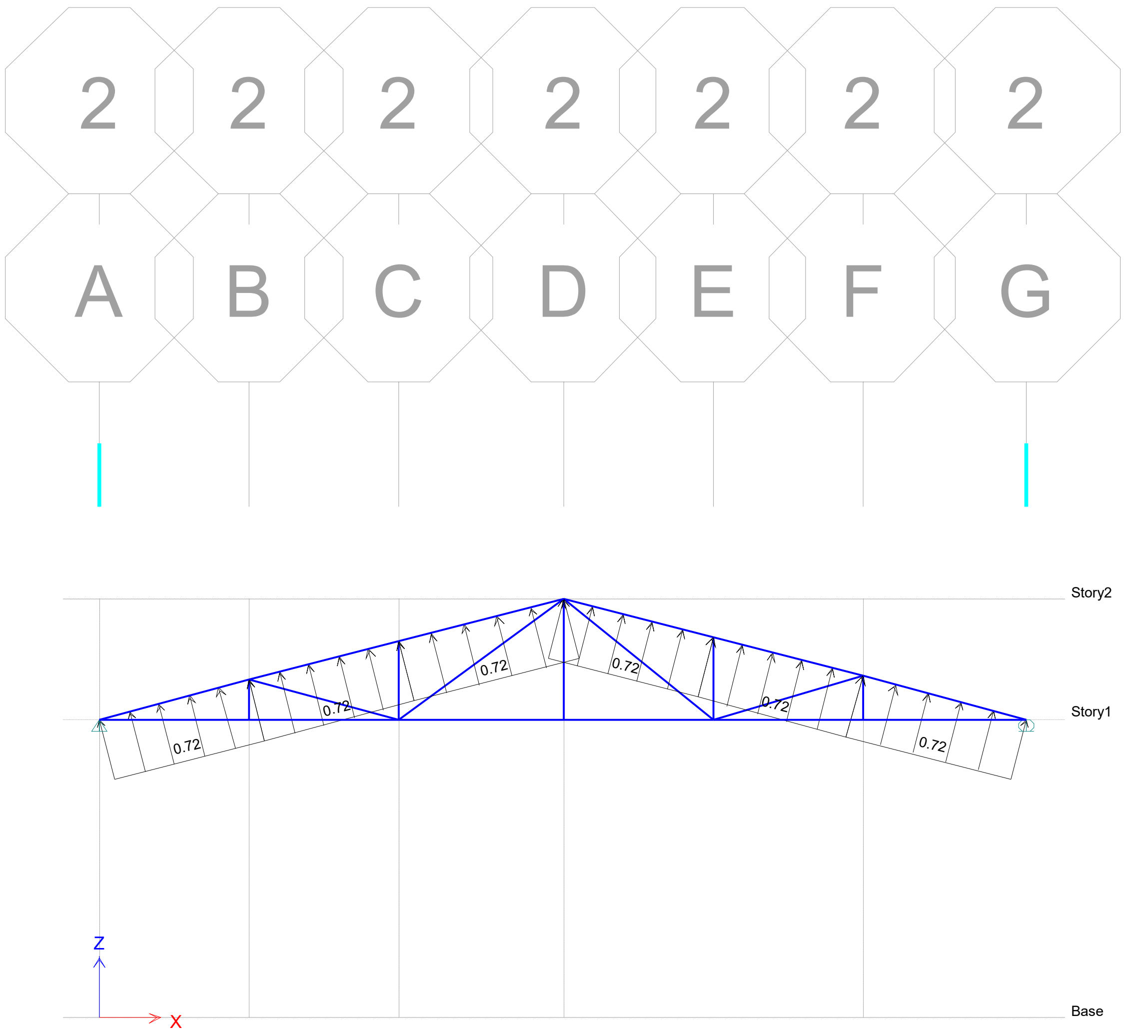
Max Deflection = 10.1mm

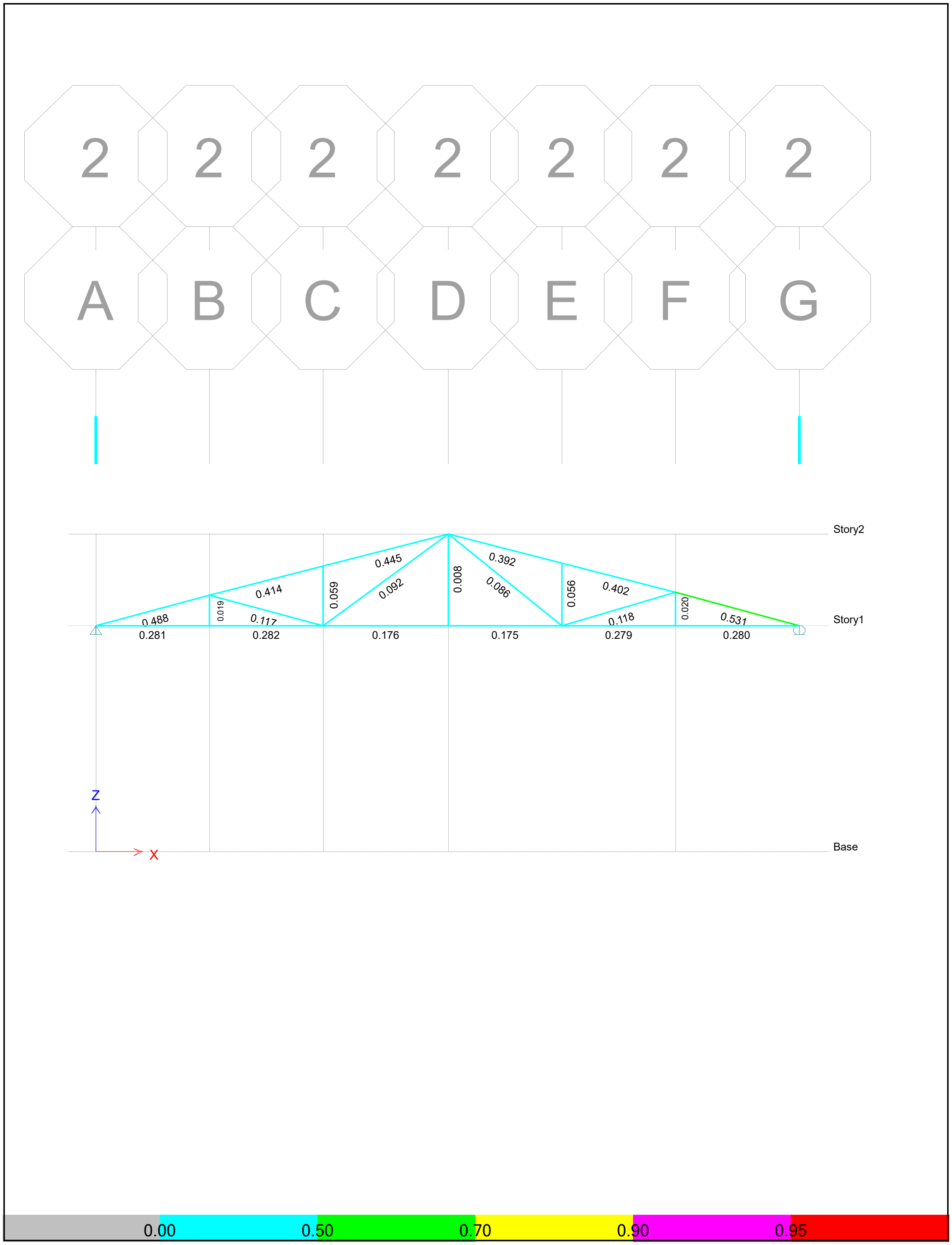
Allowed Deflection = 45 mm


2
A
B
C
D
E
F
G
Story2
Story1
Base
RHS50X50X3
RHS40X40X3
Z
X

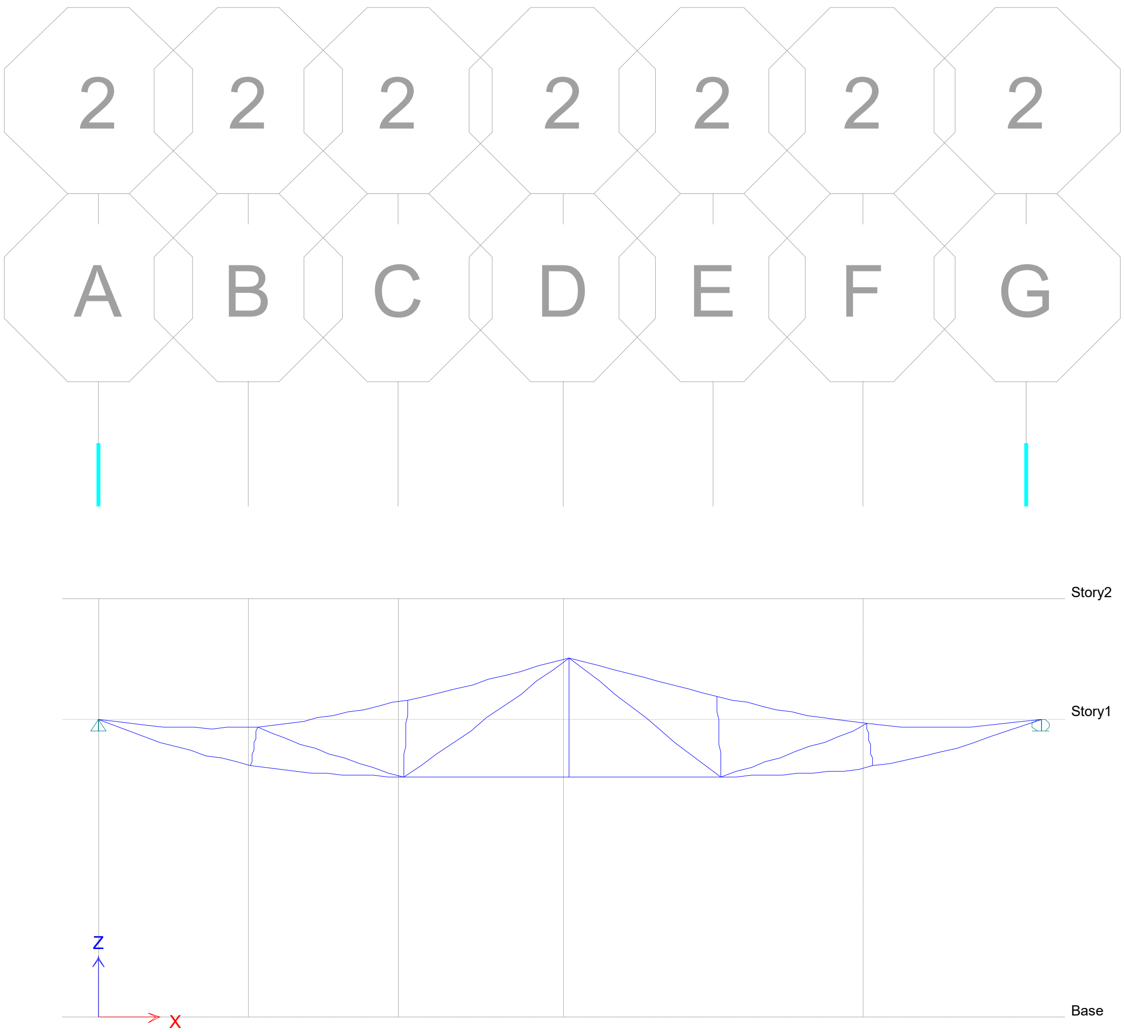

2
2
2
2
2
2
2
A
B
C
D
E
F
G
0.395
0.395
0.395
0.395
0.395
0.395
Story2
Story1
Base
Z
X


2
2
2
2
2
2
2
A
B
C
D
E
F
G
2
2
2
2
2
2
Story2
Story1
Z
X
Base


2
2
2
2
2
2
2
A
B
C
D
E
F
G
Story2
Story1
Base
0.72
0.72
0.72
0.72
0.72
0.72
Z
X



Block-M Truss.EDB Elevation View - 2 Steel P-M Interaction Ratios (Eurocode 3-2005)



Max. Deflection = 6.1mm

Allowed Deflection = 30mm

Design Resistance of Bolts for Truss Connection:

Block-J and M: Maximum Reactions

- Connection Reactions from Analysis:
  - Comb-1: Compression = 104.3 KN; Shear = 88.79 KN;
  - Comb 2: Compression = 98.13 KN; Shear = 84.15 KN;
  - Comb 3: Compression – 91.81 KN; Shear = 79.16 KN;

- Check Shear Resistance - 4 Diameter 16 bolts of Grade 4.6

$$F_{v,Rd} = \frac{\alpha_v \; f_{ub} \; A}{\gamma_{M2}}$$

= (0.6 * (400) * 4*201)/1.25 = 154.4 KN .... Okay

- Check Bearing Resistance - 4 Dia 16 bolts of Grade 4.6 and plate thickness of 8mm

$$\text{AC}_2 \; F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, d \, t}{\gamma_{M2}} \; \text{AC}_2$$

= (2.5 * 0.83 * 235 * 4*16*8)/1.25 = 199.7 KN .... Okay

- Check Punching Shear Resistance - 4 Diameter 16 bolts of Grade 4.6

$$B_{p,Rd} = 0{,}6 \, \pi \, d_m \, t_p \, f_u / \gamma_{M2}$$

= (0.6 * 3.14 * 4*16*8*235)/1.25 = 181.3 KN .... Okay

SECTION-4: DESIGN OF CONCRETE ROOF SLAB

Solid Slab & Cantilever - Loading

Block-A (New Extension)

i) Two Way Solid Slab (Roof Slab): (Max. 5470mm x 4675 mm)

- **Thickness - EC Section 7.4.2**

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho} + 3{,}2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] \quad \text{if } \rho \le \rho_0$$

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] \quad \text{if } \rho > \rho_0$$

ρ_0 is the reference reinforcement ratio = $10^{-3}\sqrt{f_{ck}}$ AC1
= 0.0045

ρ is the required tension reinforcement ratio at mid-span to resist the moment due to the design loads (at support for cantilevers)
Assume 200mm thickness, Reinforcement Diameter 12mm c/c 200mm at support
= (6 x 113)/(1000 x 174)
= 0.0039

$\rho < \rho_o$ - The first equation applies

K = 1.5 = Table 7.4N of EC

l/d = 29.4 ; d = 4675/29.4 = 159mm

D = 159 + 20 + 5 = 184 mm ; Use 200 mm

- **Load**

Dead Load

- Slab (200)	= 0.20*25	= 5.0
- Finish (50)	= 0.03*27+0.02*20	= 1.21
- Base plaster (20)	= 0.02*20	= 0.40
- Light weight for slope	= 0.08 *20	= 1.60

G_k = 8.21 KN/m^2

Live Load

Q_k = 0.5 KN/m^2

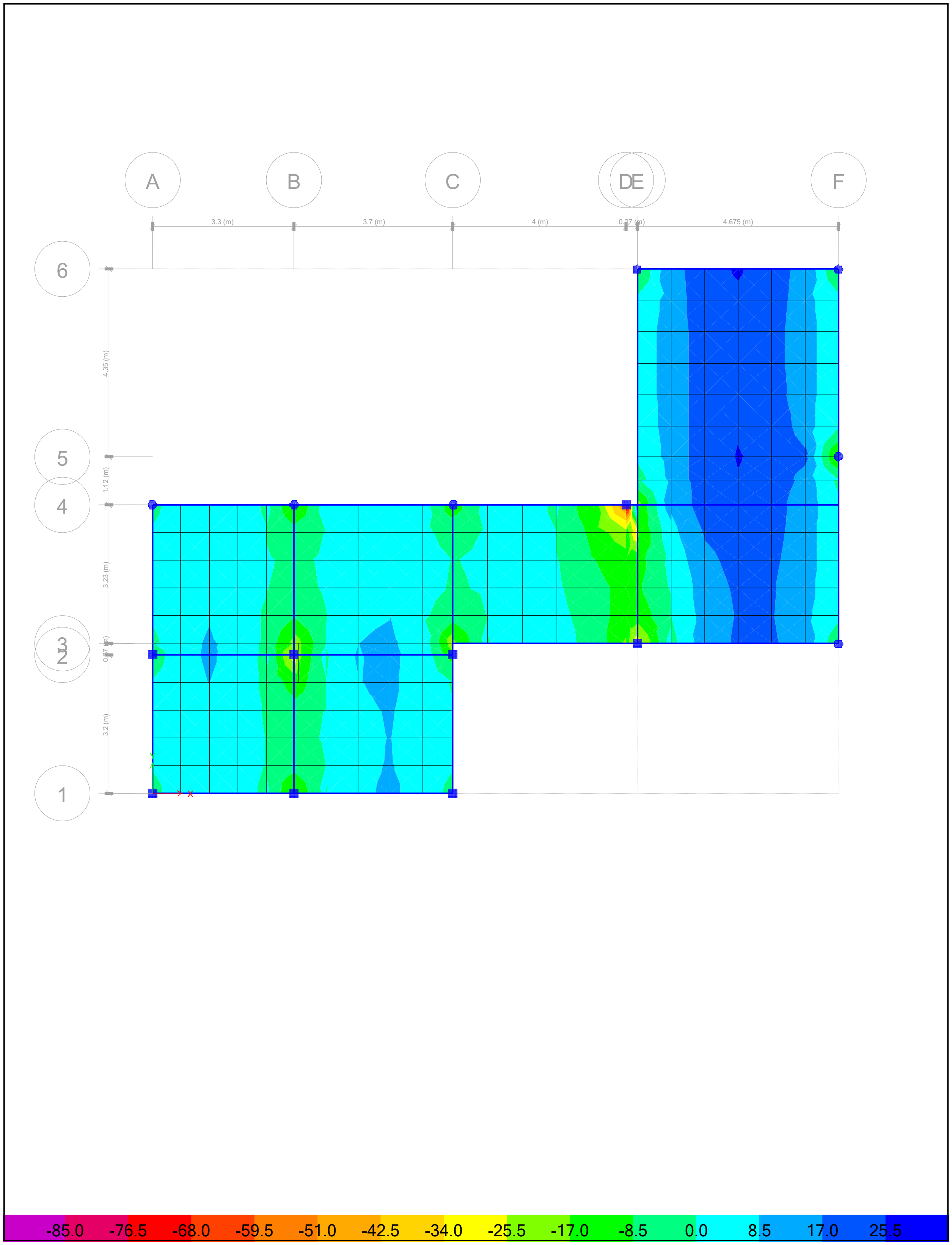
Design Load

w_d = 1.35 * 8.21 + 1.5 * 0.5 = 11.83 KN/m^2

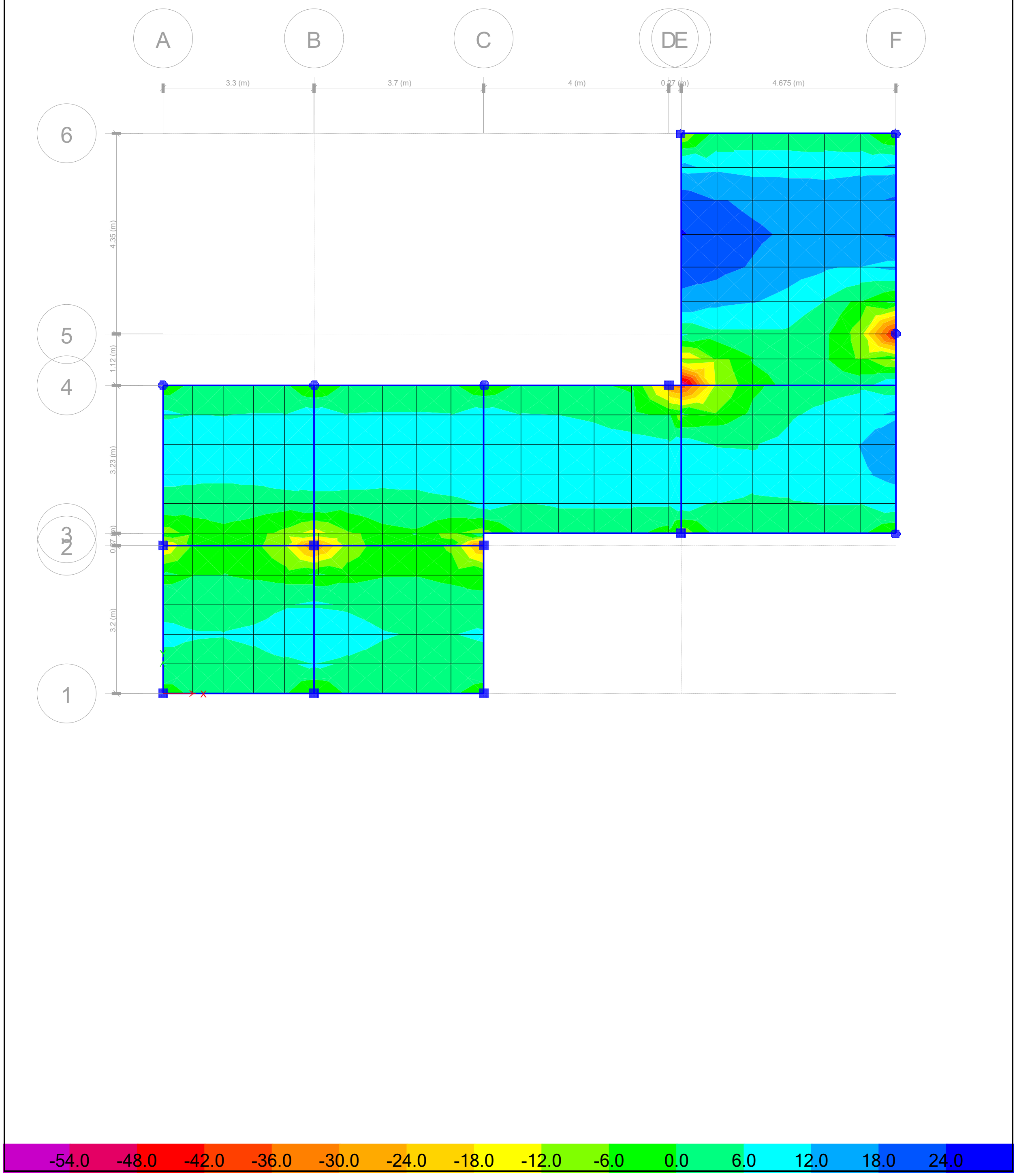
- **Individual Panel Moment & End Reaction**

$$M_i = \alpha_i w_d L_x^2 \quad ; \quad V_i = \beta_i w_d L_x$$

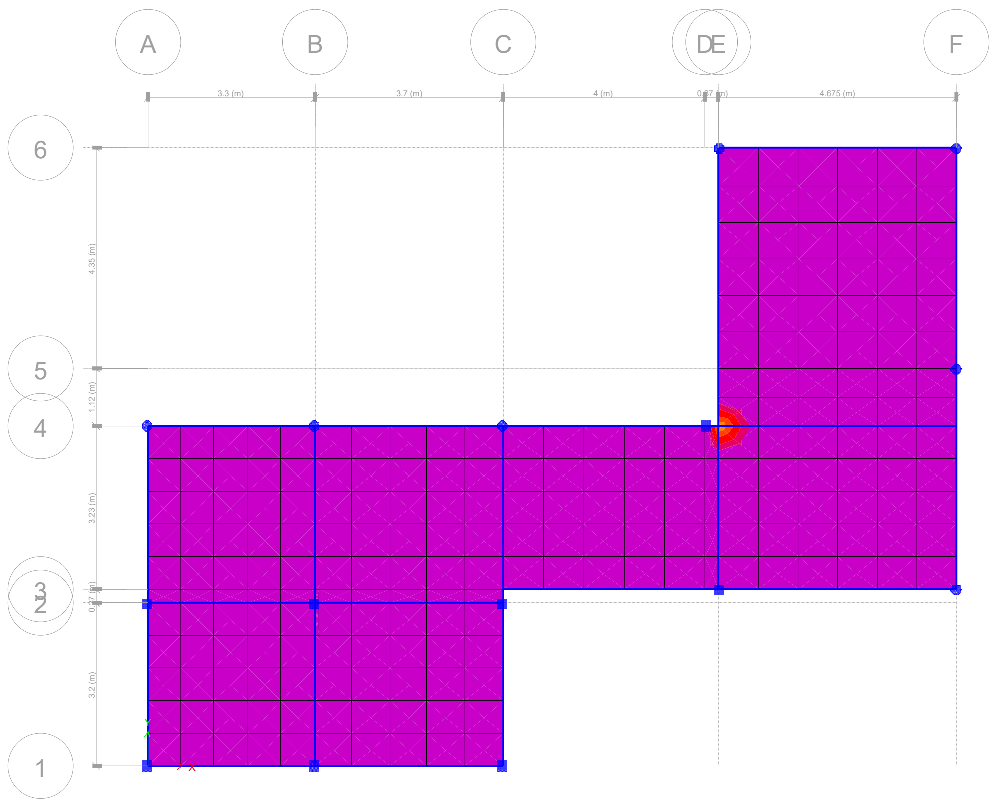
- The analysis and design of roof slab carried out using ETAB Software has been printed hereunder.



Block-A Extension.EDB Plan View - Story1 - Z = 3 (m) Resultant M11 Diagram (Comb1) [kN-m/m]



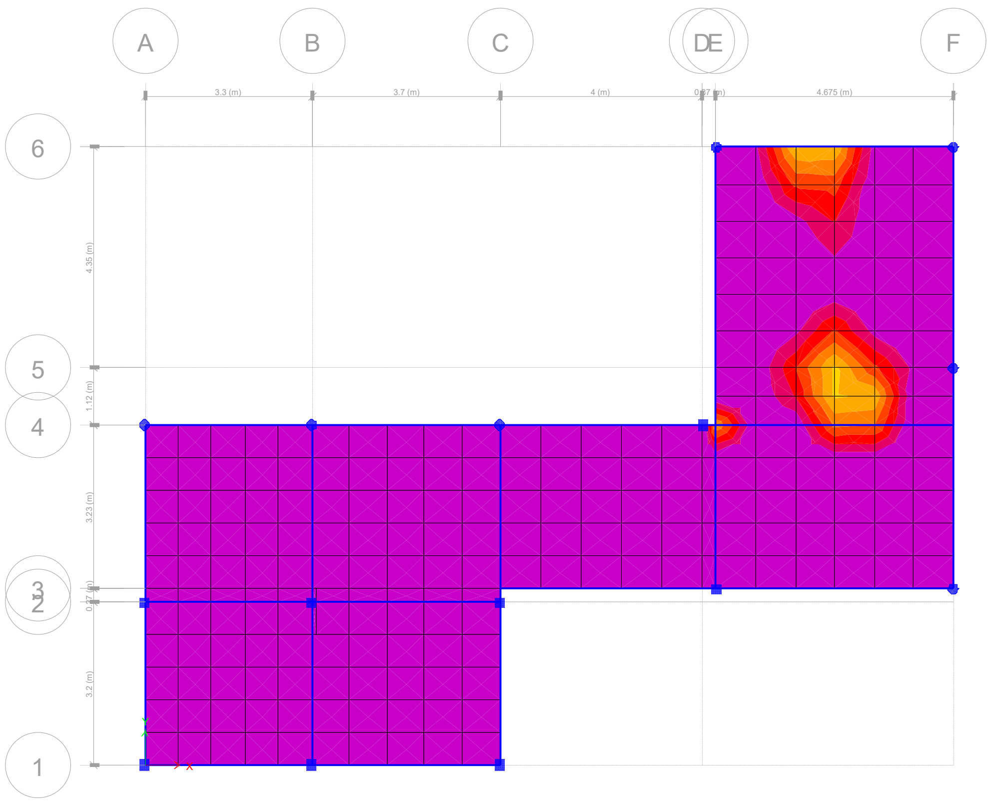
Block-A Extension.EDB Plan View - Story1 - Z = 3 (m) Resultant M22 Diagram (Comb1) [kN-m/m]



n - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1 - Additional to 10 @ 150 mm

Block-A Extension.EDB

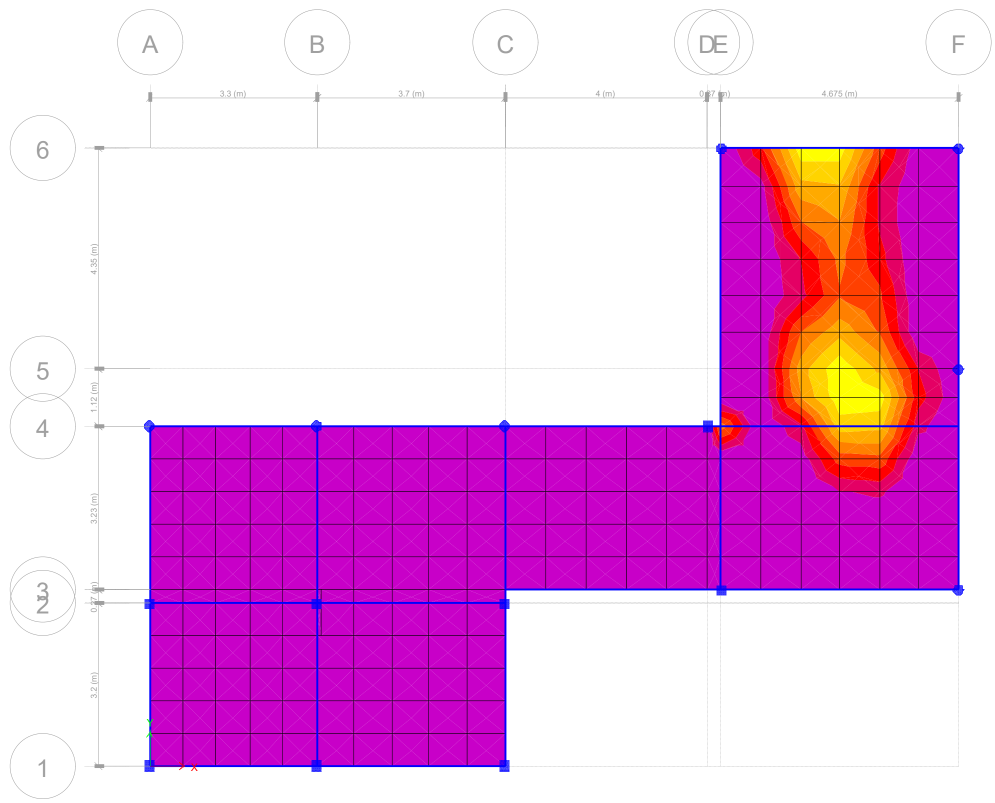
6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0 58.5 65.0 71.5 78.0 84.5 91.0 E-3



ab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1 - Additional to 10 @ 200 r

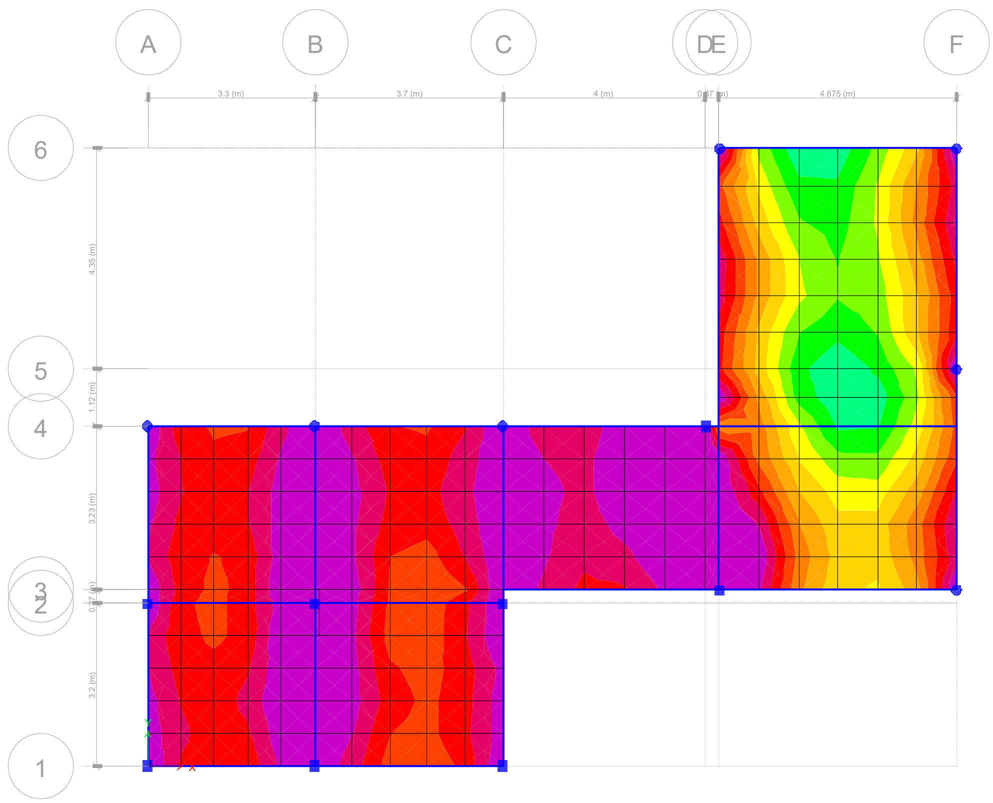
Block-A Extension.EDB

15	30	45	60	75	90	105	120	135	150	165	180	195	210	E-3



nite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1 - Additional to 10 @ 250 mm

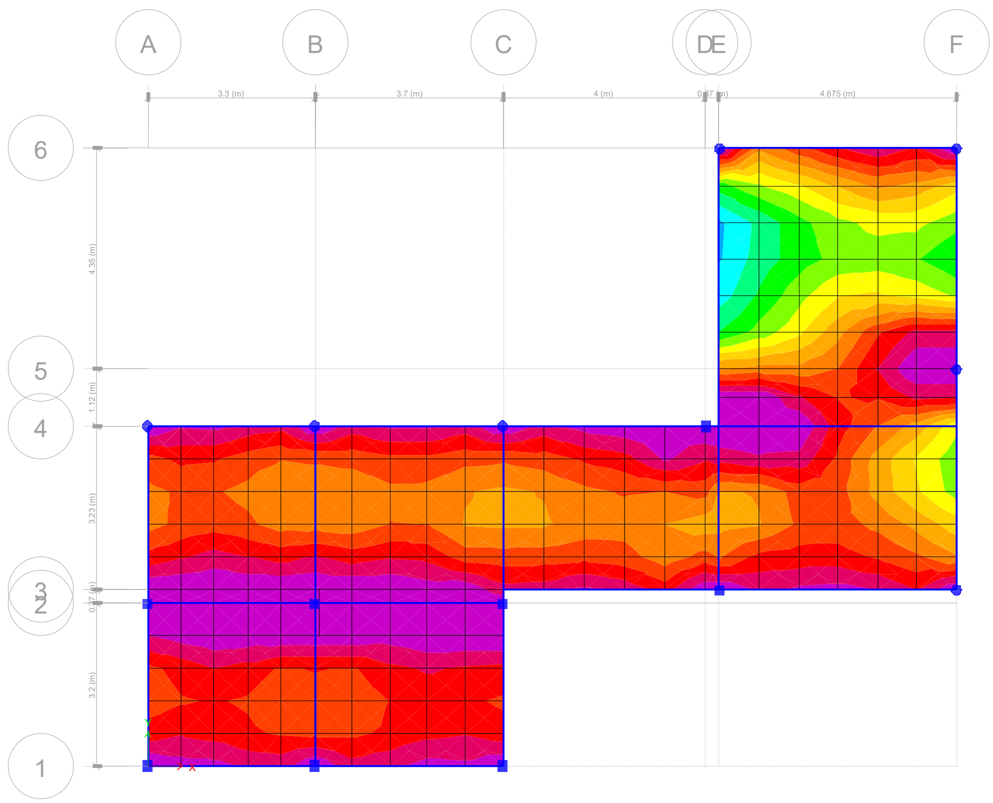
Block-A Extension.EDB



Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1

Block-A Extension.EDB

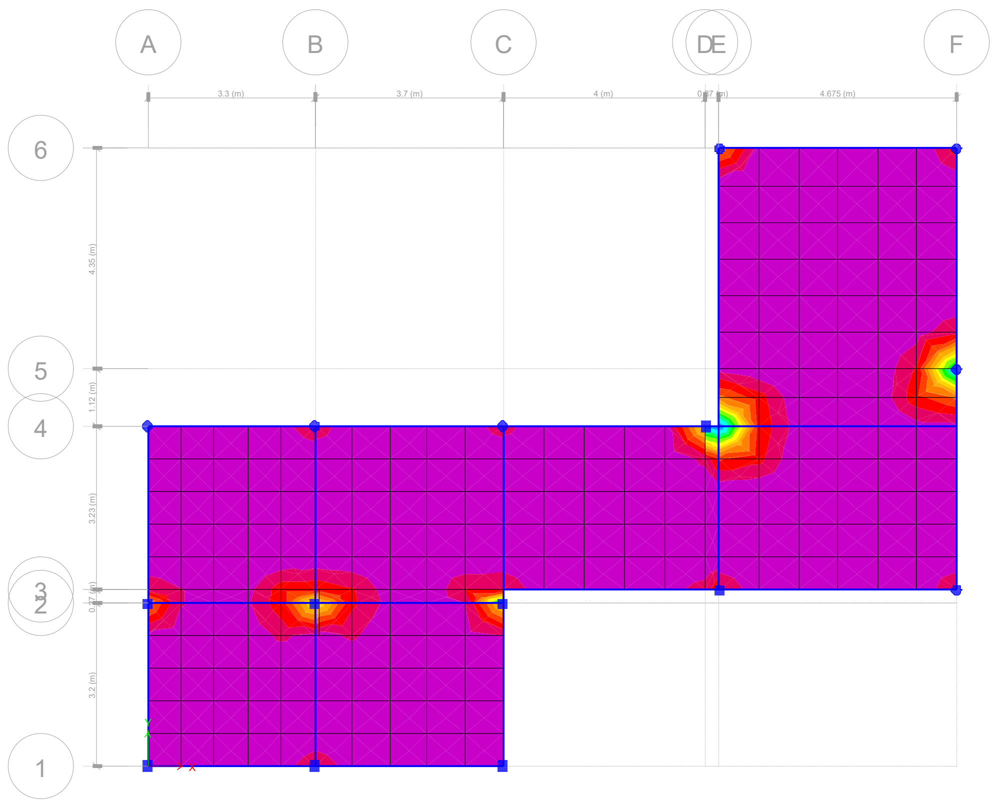
45 90 135 180 225 270 315 360 405 450 495 540 585 630 E-3



Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 2

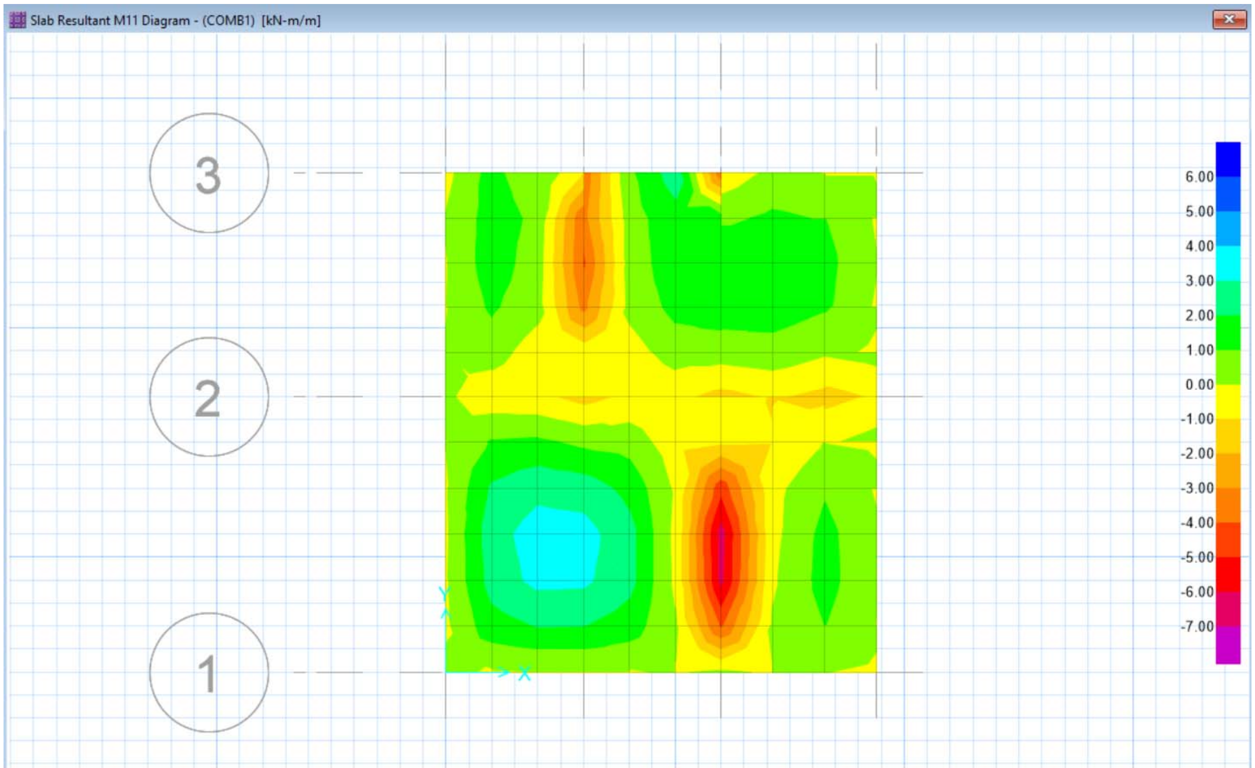
Block-A Extension.EDB

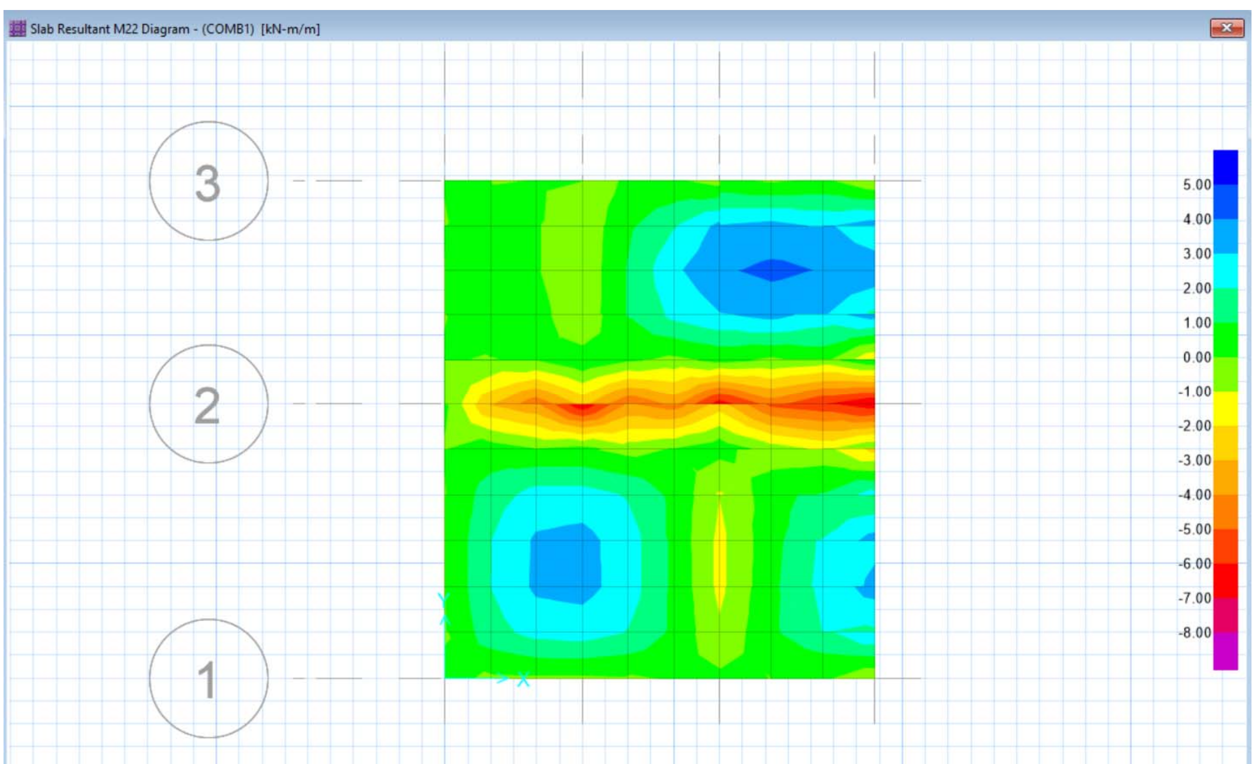
Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 1

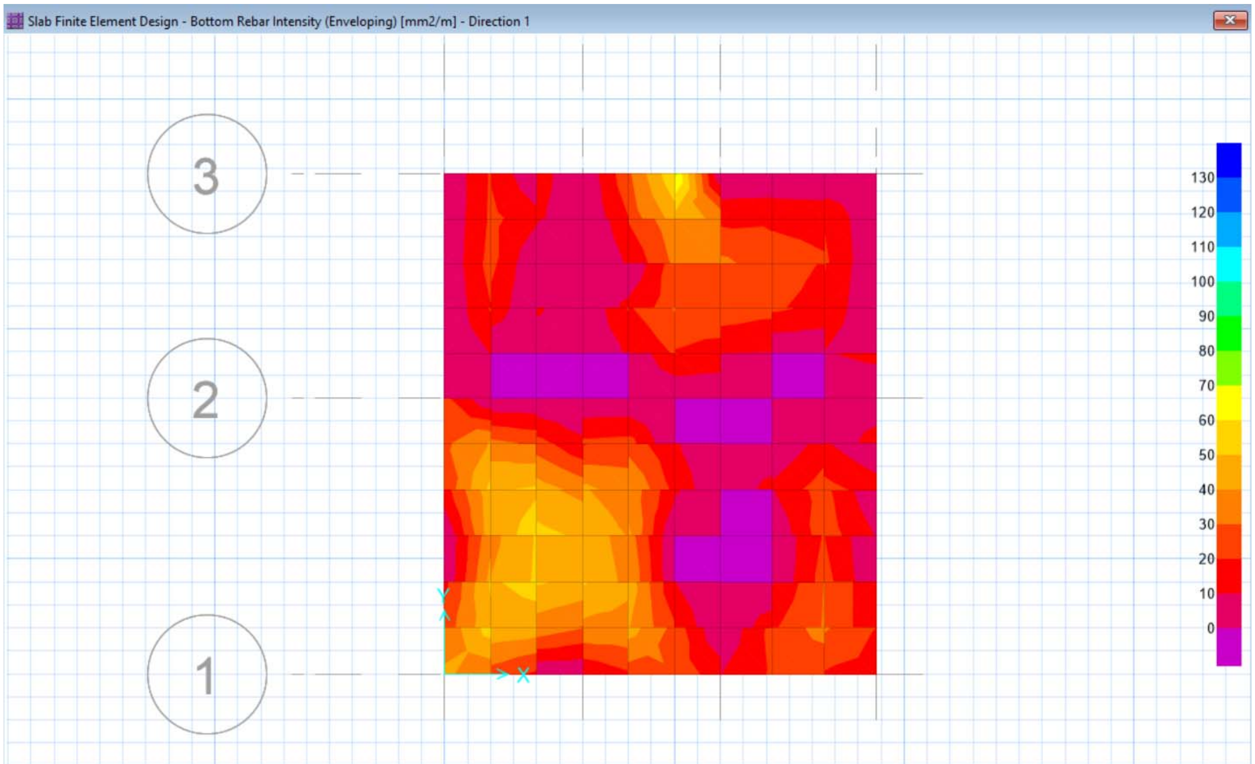


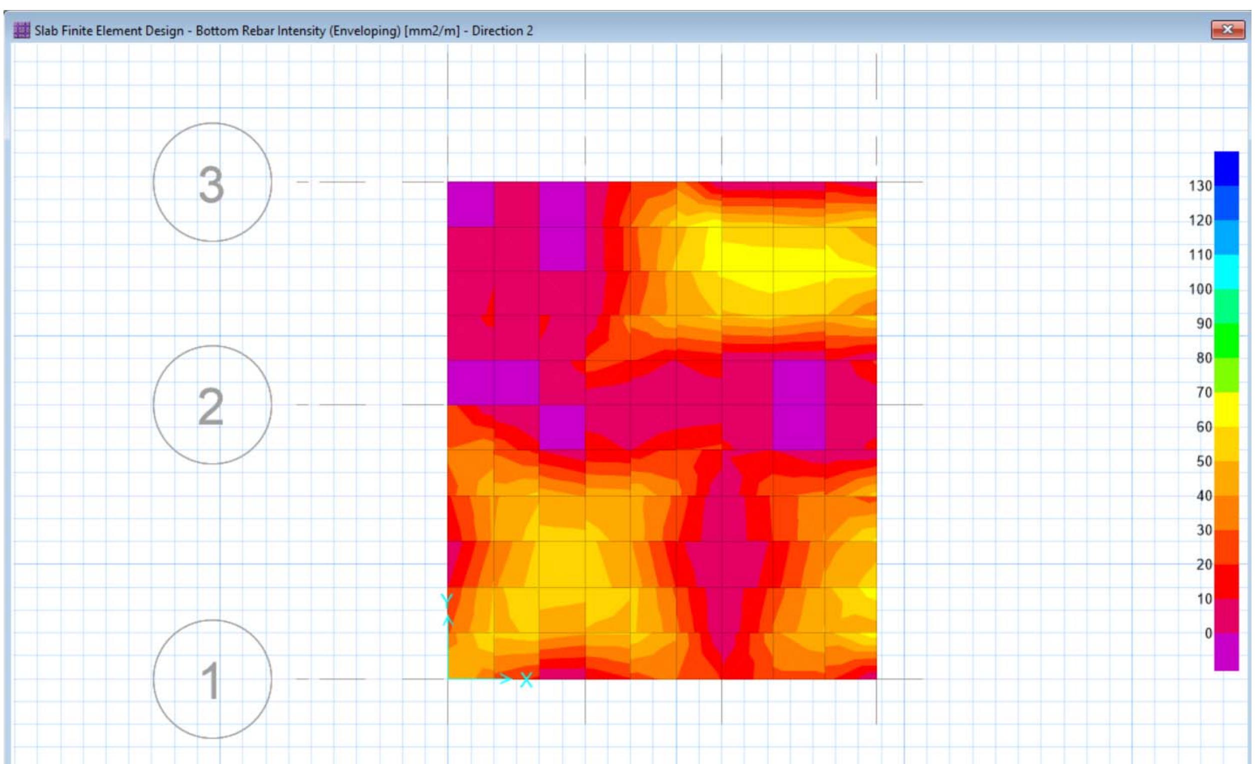
Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 2

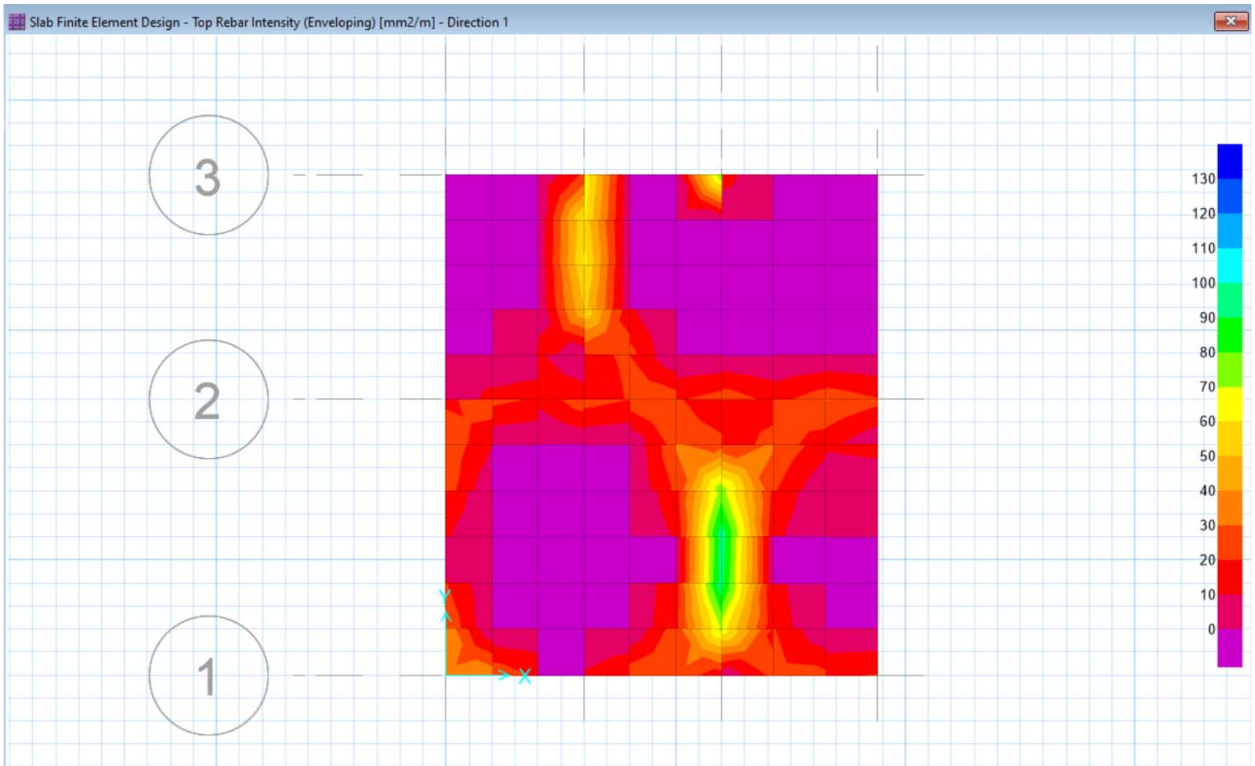
Block-A Extension.EDB

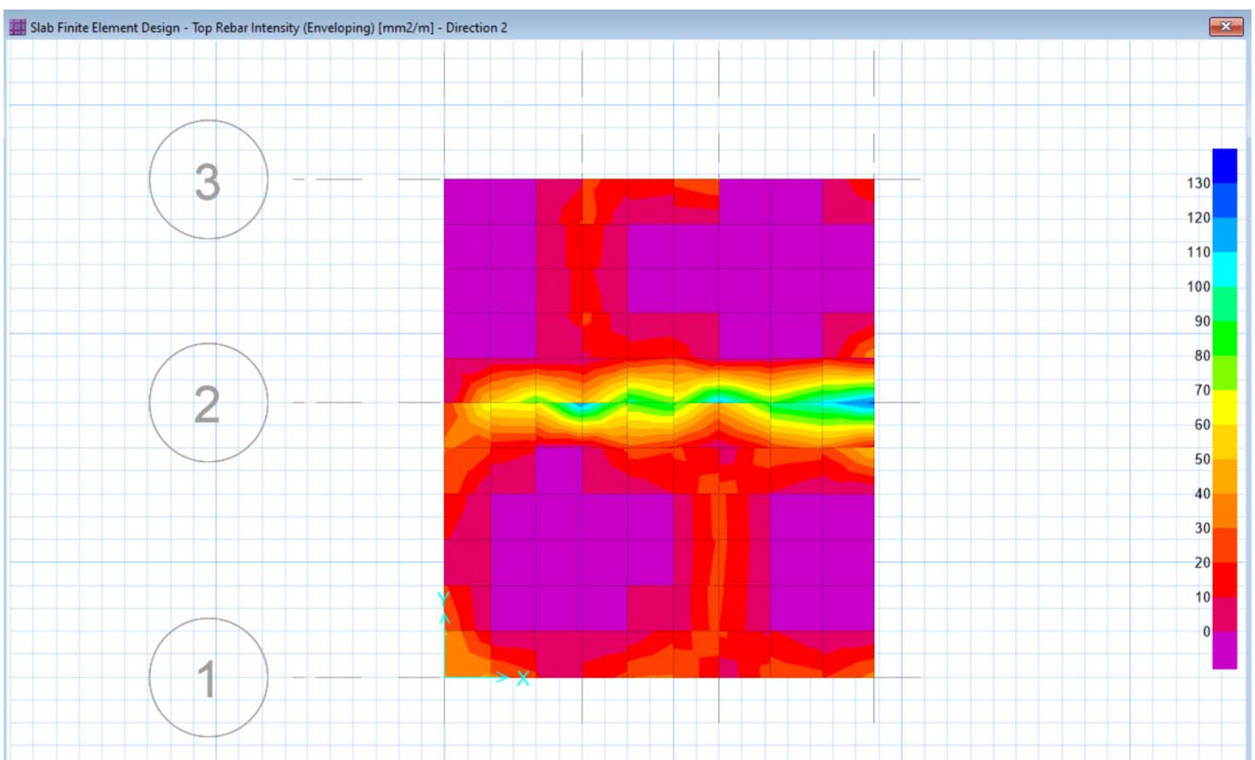

Slab Resultant M11 Diagram - (COMB1) [kN-m/m]
3
2
1
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00


Slab Resultant M22 Diagram - (COMB1) [kN-m/m]
3
2
1
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00


Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm2/m] - Direction 1
3
2
1
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm2/m] - Direction 2
3
2
1
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm2/m] - Direction 1
3
2
1
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm2/m] - Direction 2
3
2
1
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Solid Slab & Cantilever - Loading

Block-J (New Extension)

i) Two-way simply supported slab (Roof Slab): (Max. 3650 x 6400 mm)

- **Thickness - EC Section 7.4.2**

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho} + 3{,}2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] \quad \text{if } \rho \leq \rho_0$$

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] \quad \text{if } \rho > \rho_0$$

ρ_0 is the reference reinforcement ratio = $10^{-3}\sqrt{f_{ck}}$ (AC1

= 0.0045

ρ is the required tension reinforcement ratio at mid-span to resist the moment due to the design loads (at support for cantilevers)

Assume 200mm thickness, Reinforcement Diameter 12 mm c/c 200mm at support

= (6 x 113)/(1000 x 174)

= 0.0039

$\rho < \rho_o$ - The first equation applies

K = 1.0 = Table 7.4N of EC

l/d = 21.5 ; d = 3650/21.5 = 170 mm

D = 170 + 20 + 5 = 195 mm ; Use 200 mm

- **Load**

Dead Load

- Slab (200)	= 0.20*25	= 5.0
- Finish (50)	= 0.03*27+0.02*20	= 1.21
- Base plaster (20)	= 0.02*20	= 0.40
- Light weight for slope	= 0.08 *20	= 1.60

G_k = 8.21 KN/m^2

Live Load

Q_k = 0.5 KN/m^2

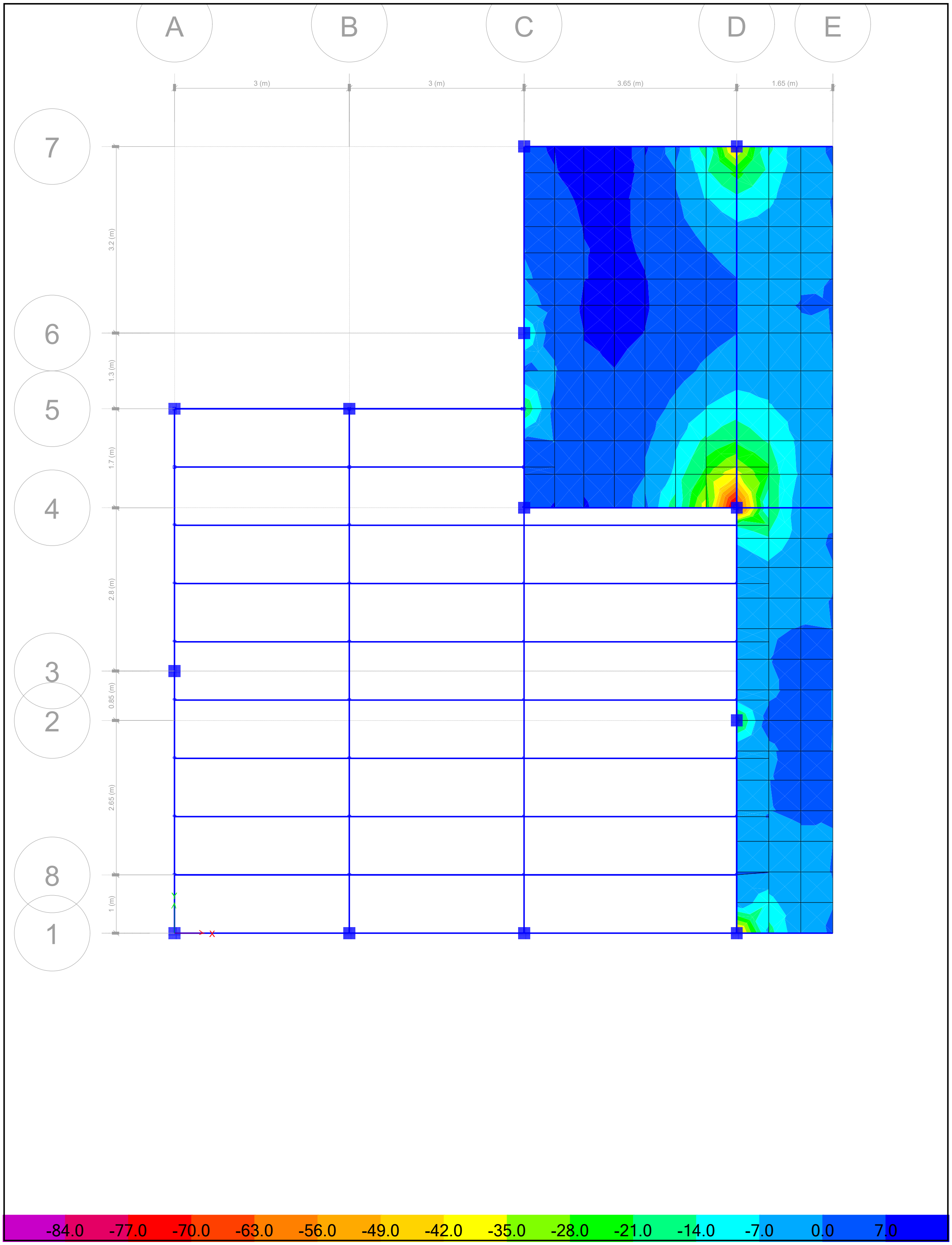
Design Load

w_d = 1.35 * 8.21 + 1.5 * 0.5 = 11.83 KN/m^2

- **Individual Panel Moment & End Reaction**

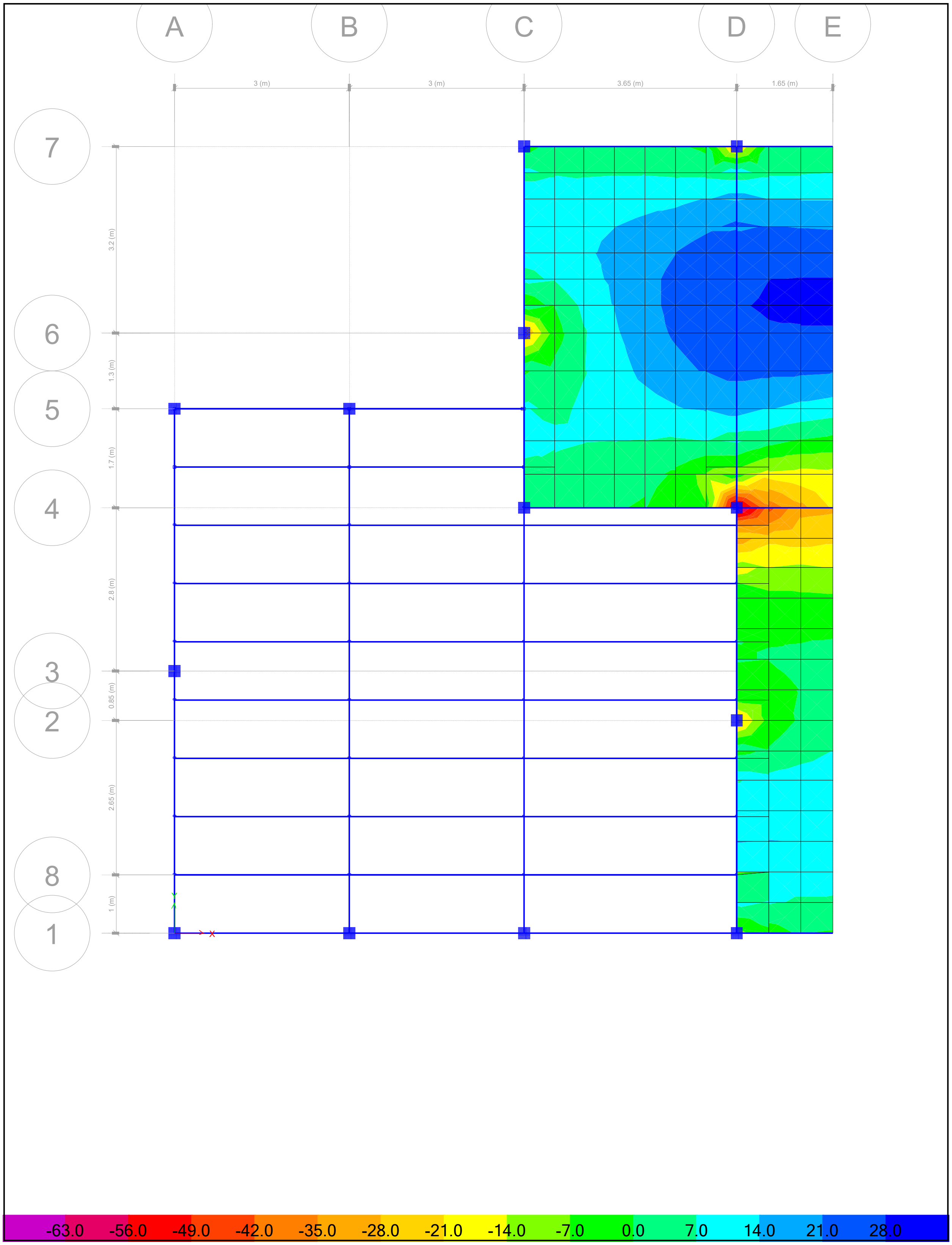
$$M_i = \alpha_i w_d L_x^2 \quad ; \quad V_i = \beta_i w_d L_x$$

- The analysis and design of roof slab carried out using ETAB Software has been printed hereunder.

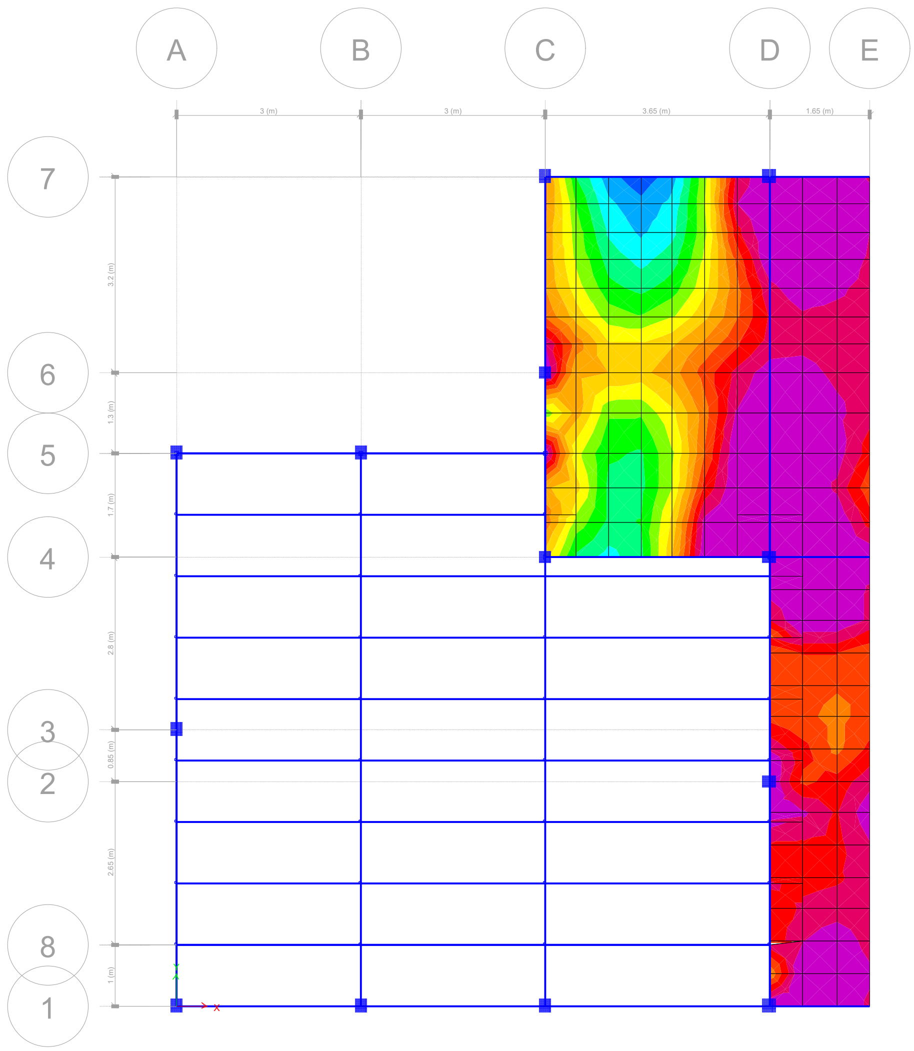


Block-J Staff Rest Room.EDB Plan View - Story1 - Z = 3.4 (m) Resultant M11 Diagram (Comb1) [kN-m/m]

ETABS 2016 16.2.0 5/29/2019



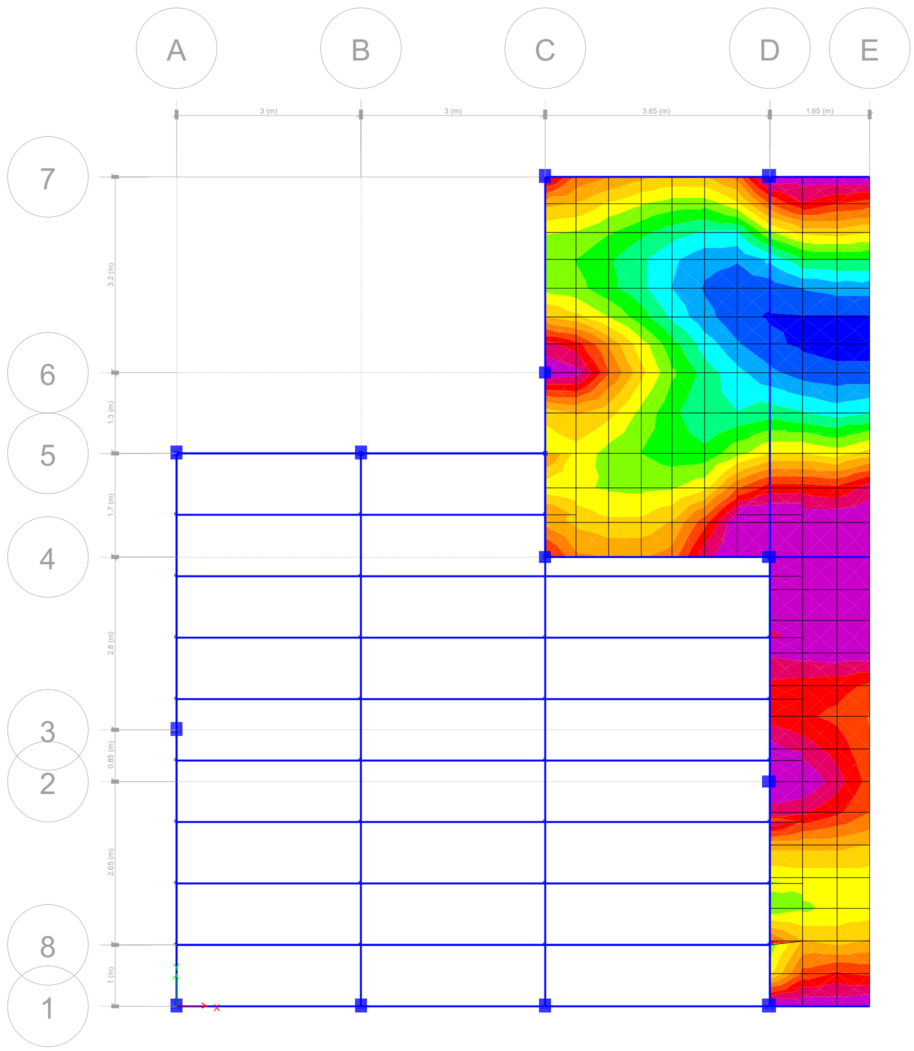
Block-J StaffRestRoom.EDB Plan View - Story1 - Z = 3.4 (m) Resultant M22 Diagram (Comb1) [kN-m/m]



Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1

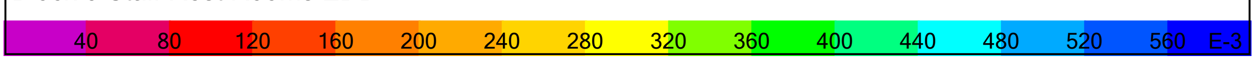
Block-J Staff Rest Rooms.EDB

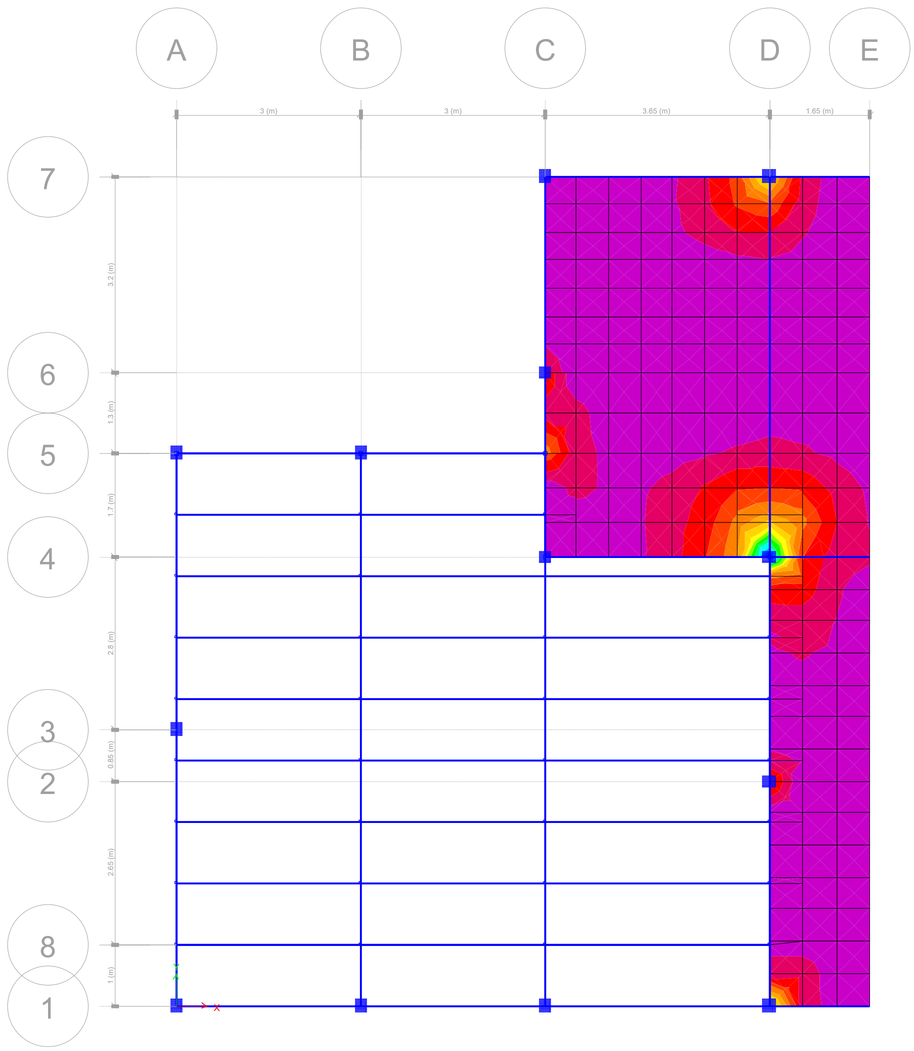
25 50 75 100 125 150 175 200 225 250 275 300 325 350 E-3



Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 2

Block-J Staff Rest Rooms.EDB

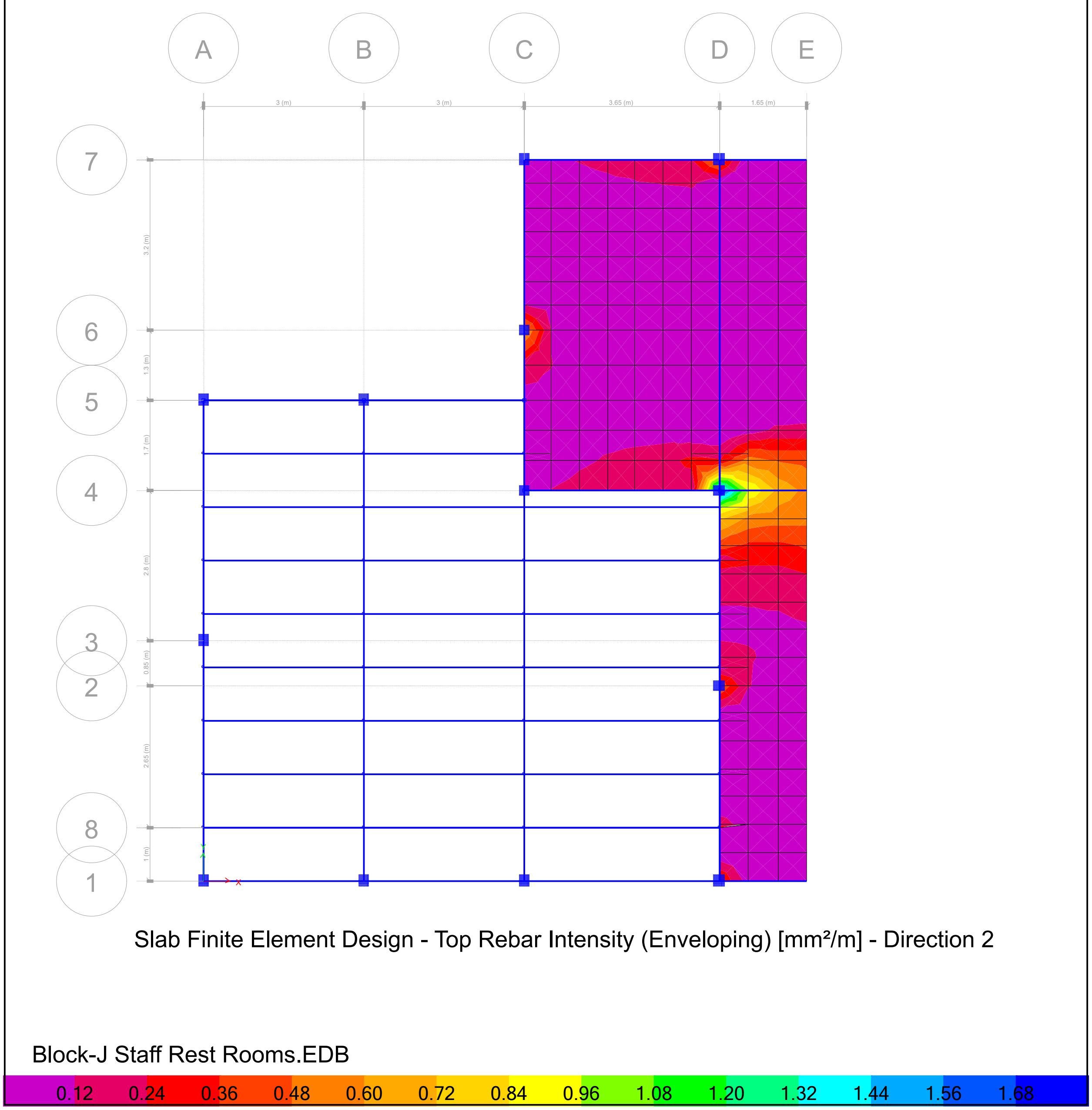




Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 1

Block-J Staff Rest Rooms.EDB

0.12 0.24 0.36 0.48 0.60 0.72 0.84 0.96 1.08 1.20 1.32 1.44 1.56 1.68



Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 2

Block-J Staff Rest Rooms.EDB

Solid Slab & Cantilever - Loading

Block-J (Walkway Roof Cover)

i) Two way -Simply Supported Slab (Roof Slab): (l = 3700 mm)

- **Thickness - EC Section 7.4.2**

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho} + 3{,}2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right] \quad \text{if } \rho \leq \rho_0$$

$$\frac{l}{d} = K\left[11 + 1{,}5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho_0}}\right] \quad \text{if } \rho > \rho_0$$

ρ_0 is the reference reinforcement ratio = $10^{-3}\sqrt{f_{ck}}$ AC1
= 0.0045

ρ is the required tension reinforcement ratio at mid-span to resist the moment due to the design loads (at support for cantilevers)
Assume 200mm thickness, Reinforcement Diameter 12mm c/c 200mm at support
= (6 x 113)/(1000 x 174)
= 0.0039

$\rho < \rho_o$ - The first equation applies

K = 1.0 = Table 7.4N of EC

l/d = 23.5 ; d = 3700/21.5 = 172 mm

D = 172 + 20 + 5 = 197 mm ; Use 200 mm

- ## Load

Dead Load

- Slab (200)	= 0.20*25	= 5.0
- Finish (50)	= 0.03*27+0.02*20	= 1.21
- Base plaster (20)	= 0.02*20	= 0.40
- Light weight for slope	= 0.08 *20	= 1.60

G_k = 8.21 KN/m^2

Live Load

Q_k = 0.5 KN/m^2

Design Load

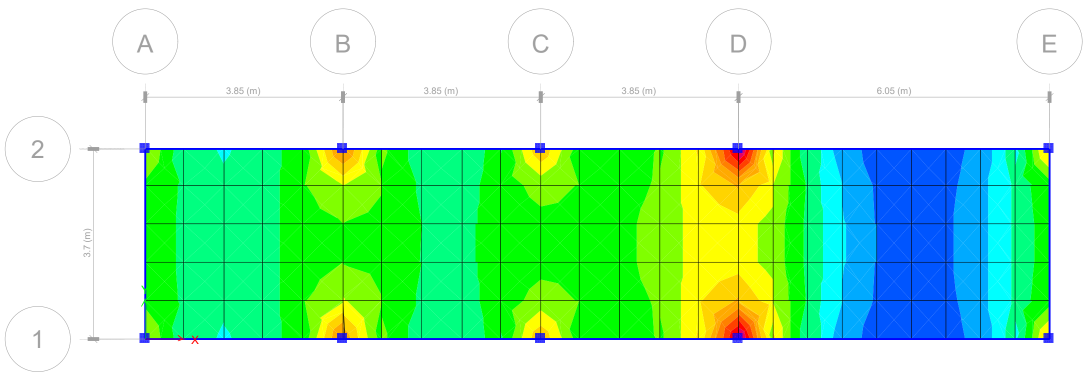
w_d = 1.35 * 8.21 + 1.5 * 0.5 = 11.83 KN/m^2

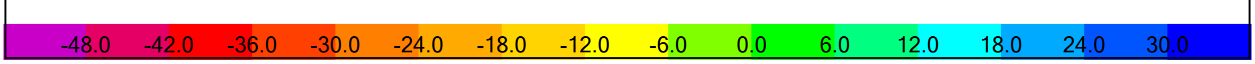
- ## Individual Panel Moment & End Reaction

$$M_i = \alpha_i w_d L_x^2 \quad ; \quad V_i = \beta_i w_d L_x$$

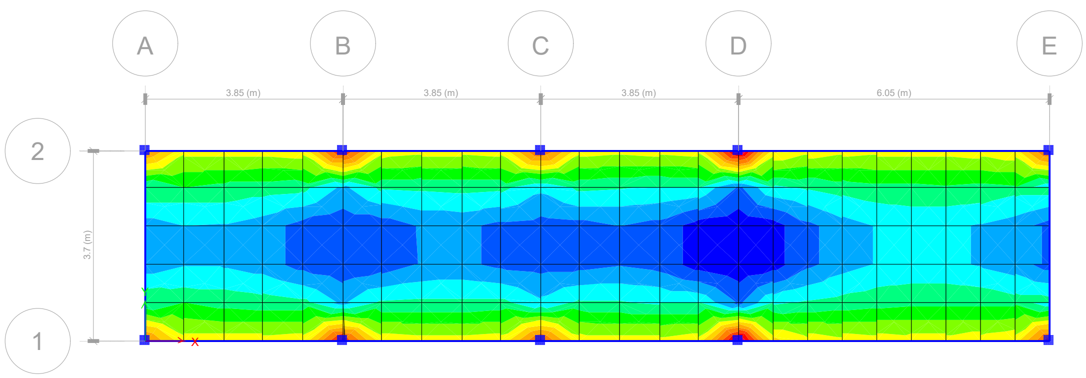
- The analysis and design of roof slab carried out using ETAB Software has been printed hereunder.

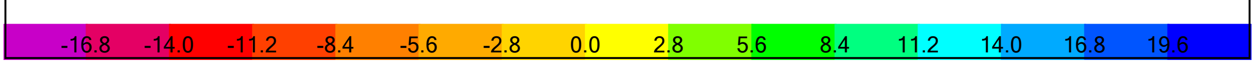
ETABS 2016 16.2.0 5/29/2019



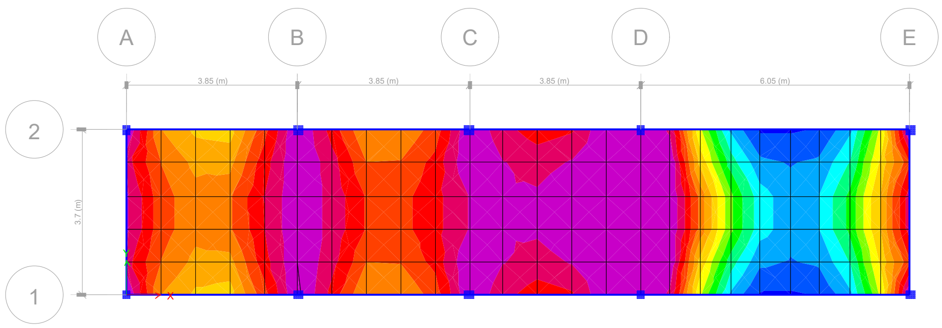


Block-J Walkway.EDB Plan View - Story1 - Z = 3.4 (m) Resultant M11 Diagram (Comb1) [kN-m/m]



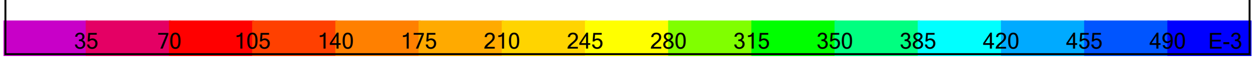


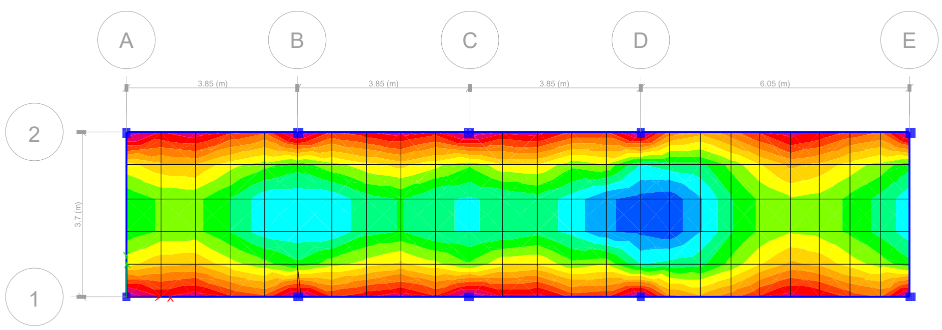
Block-J WalkWay.EDB Plan View - Story1 - Z = 3.4 (m) Resultant M22 Diagram (Comb1) [kN-m/m]



Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1

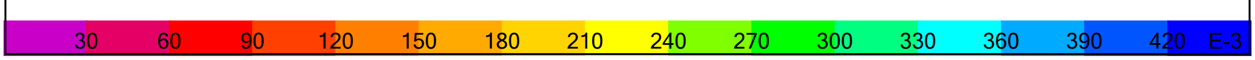
Block-J Walkway.EDB

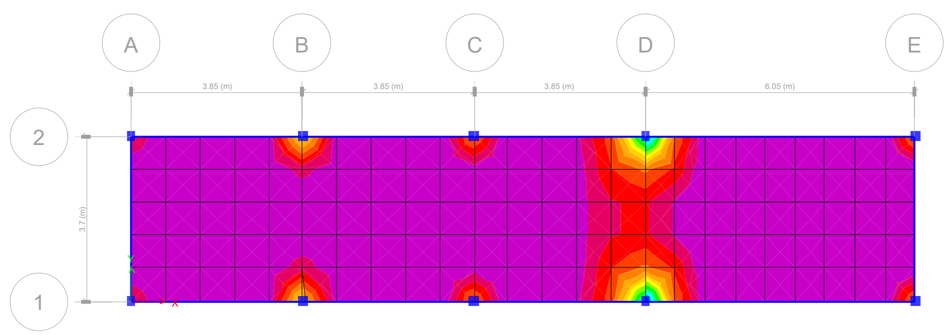




Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 2

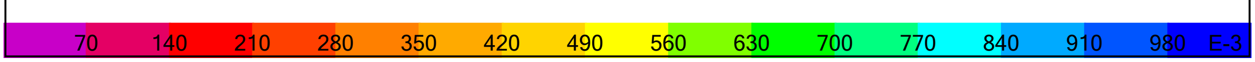
Block-J Walkway.EDB

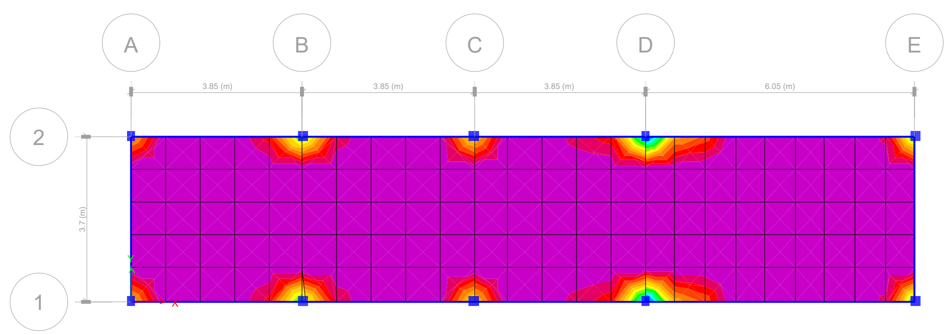




Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 1

Block-J Walkway.EDB

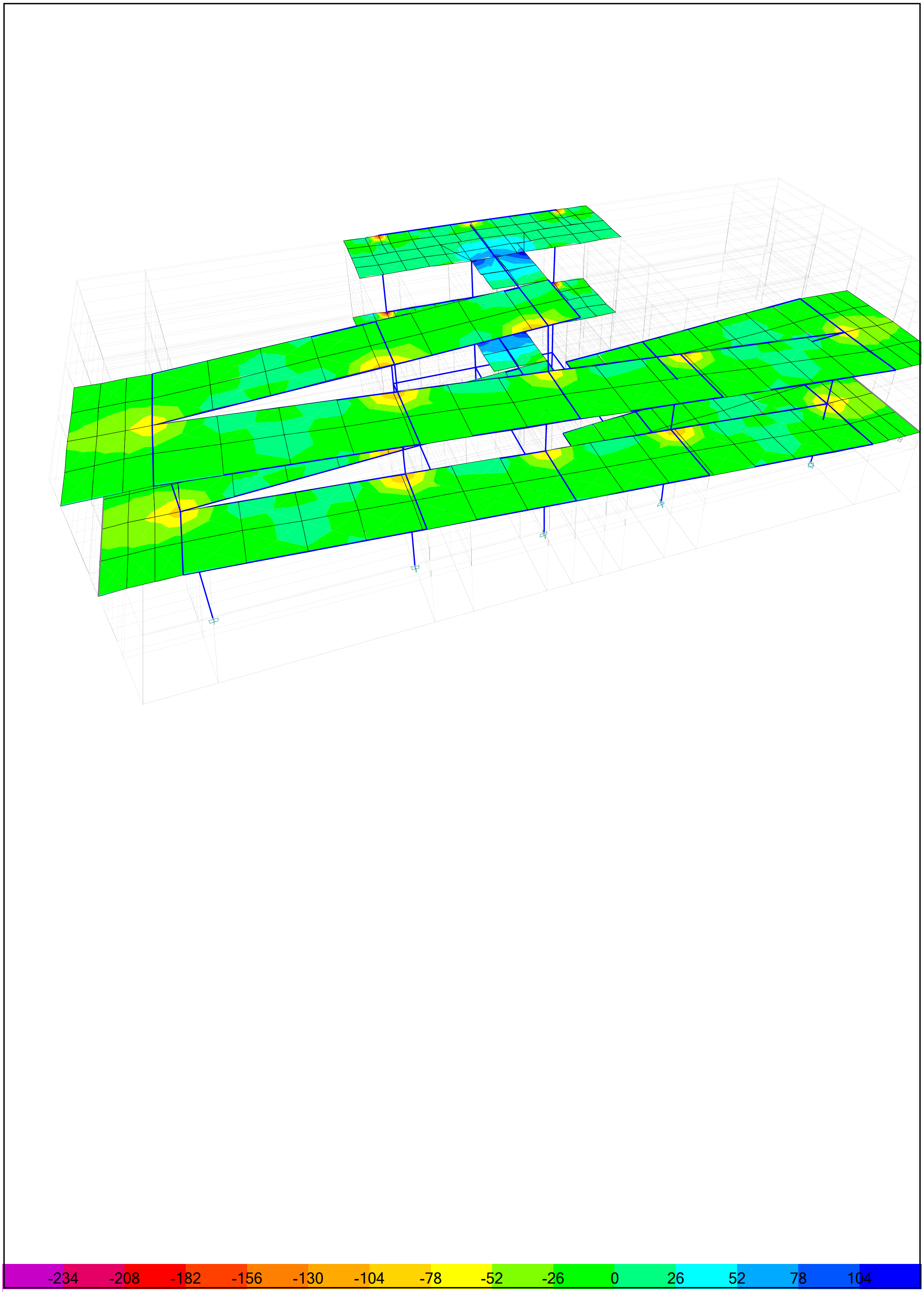




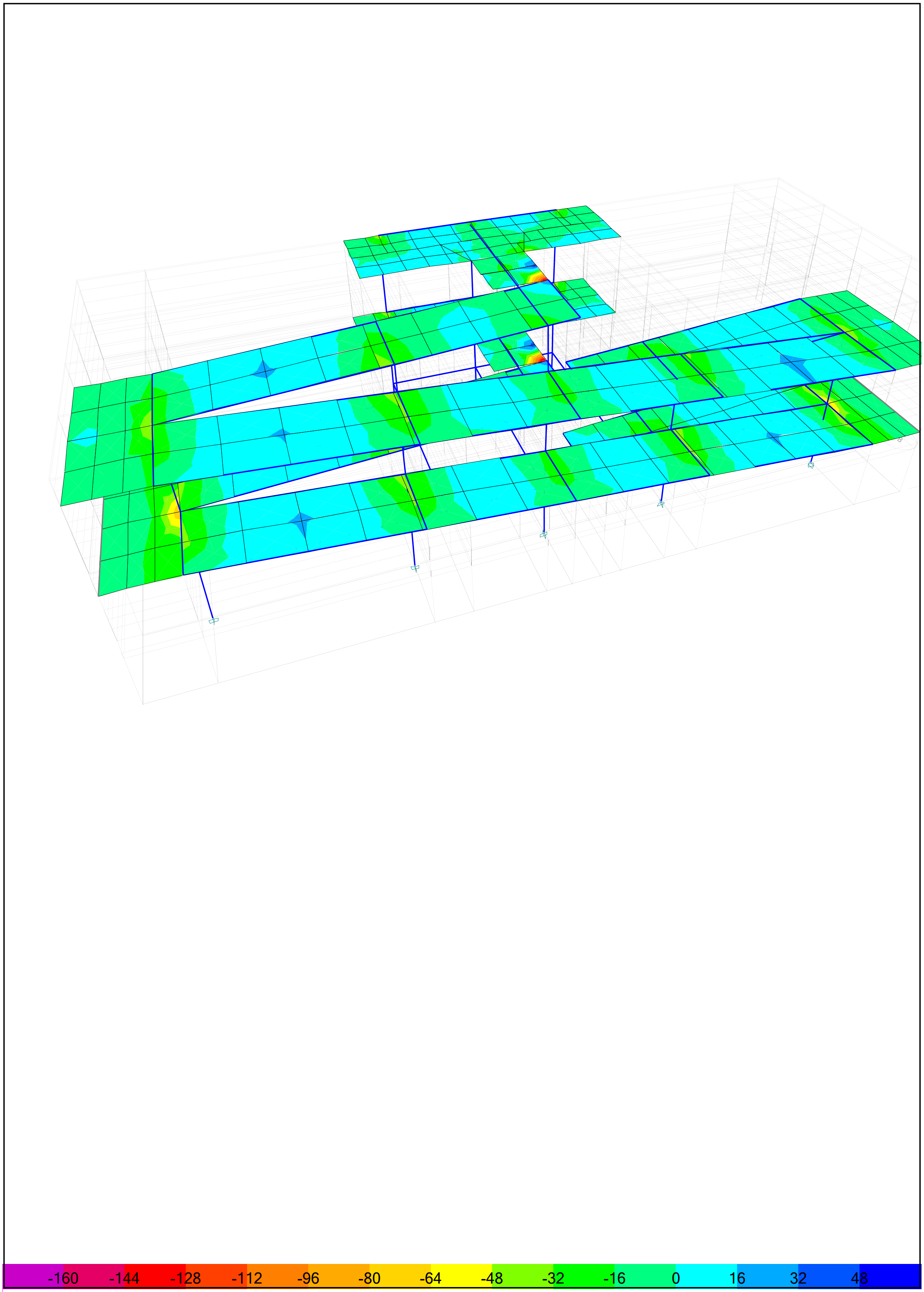
Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 2

Block-J Walkway.EDB

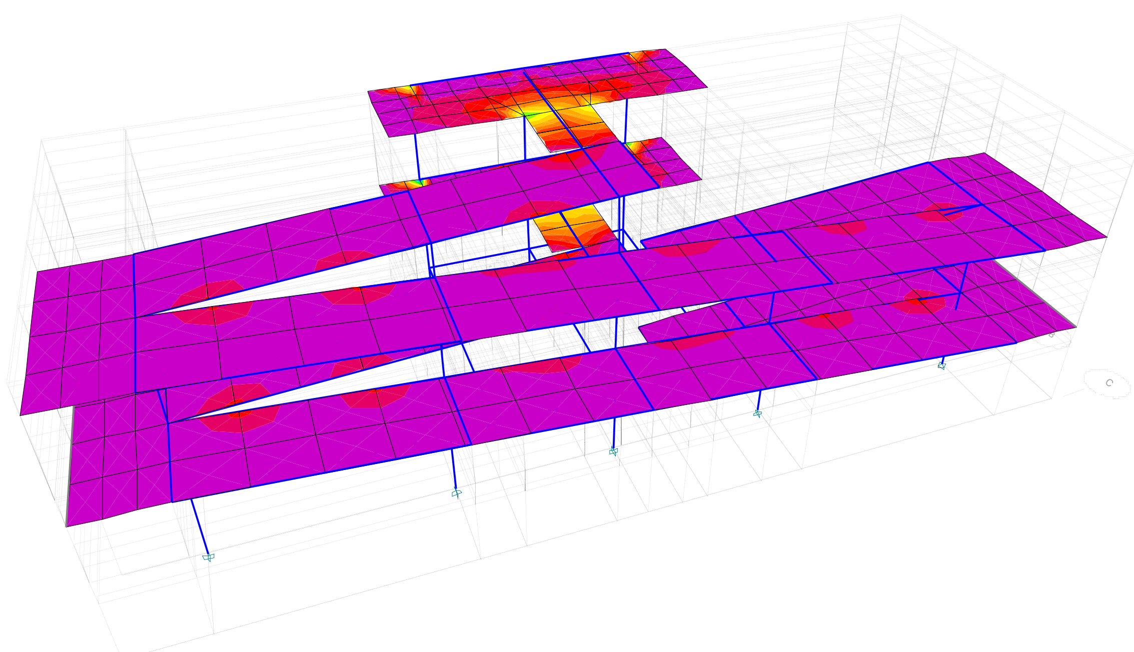
28 56 84 112 140 168 196 224 252 280 308 336 364 392 E-3



Kassa Health Citadel Ramp-EDB 3-D View Resultant M11 Diagram (Comb1) [kN-m/m]

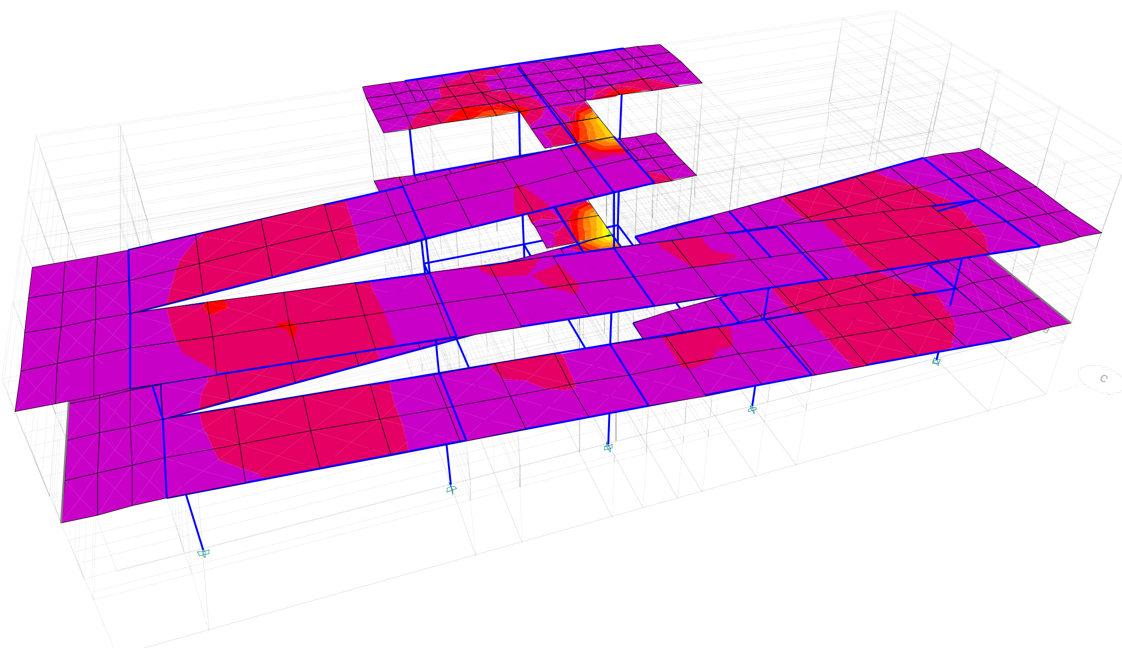


Kassa Health Citadel Ramp.EDB 3-D View Resultant M22 Diagram (Comb1) [kN-m/m]



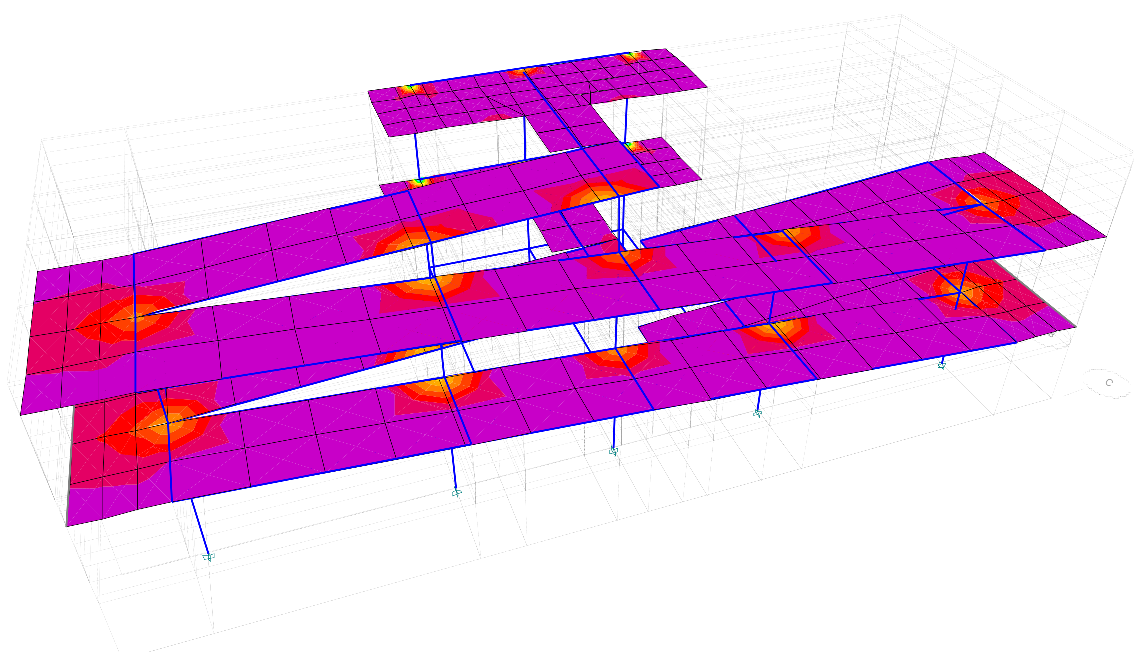
Kassa Health Citadel Ramp.EDB

3-D View Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 1



Kassa Health Citadel Ramp.EDB

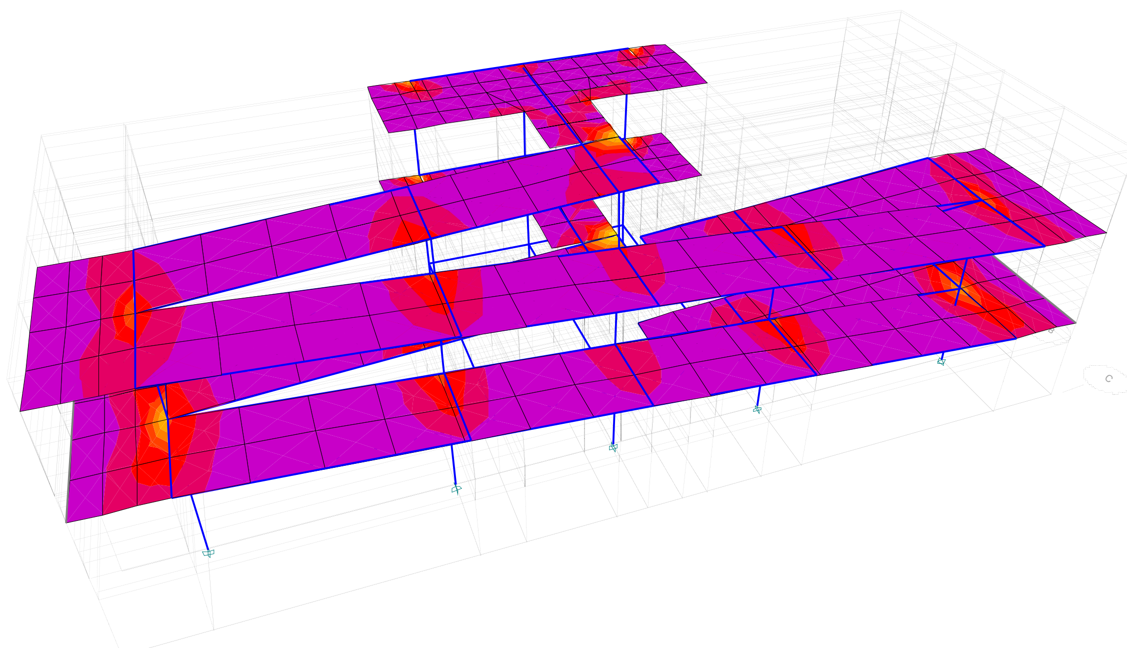
3-D View Slab Finite Element Design - Bottom Rebar Intensity (Enveloping) [mm²/m] - Direction 2



Kassa Health Citadel Ramp.EDB

0.35	0.70	1.05	1.40	1.75	2.10	2.45	2.80	3.15	3.50	3.85	4.20	4.55	4.90

3-D View Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 1

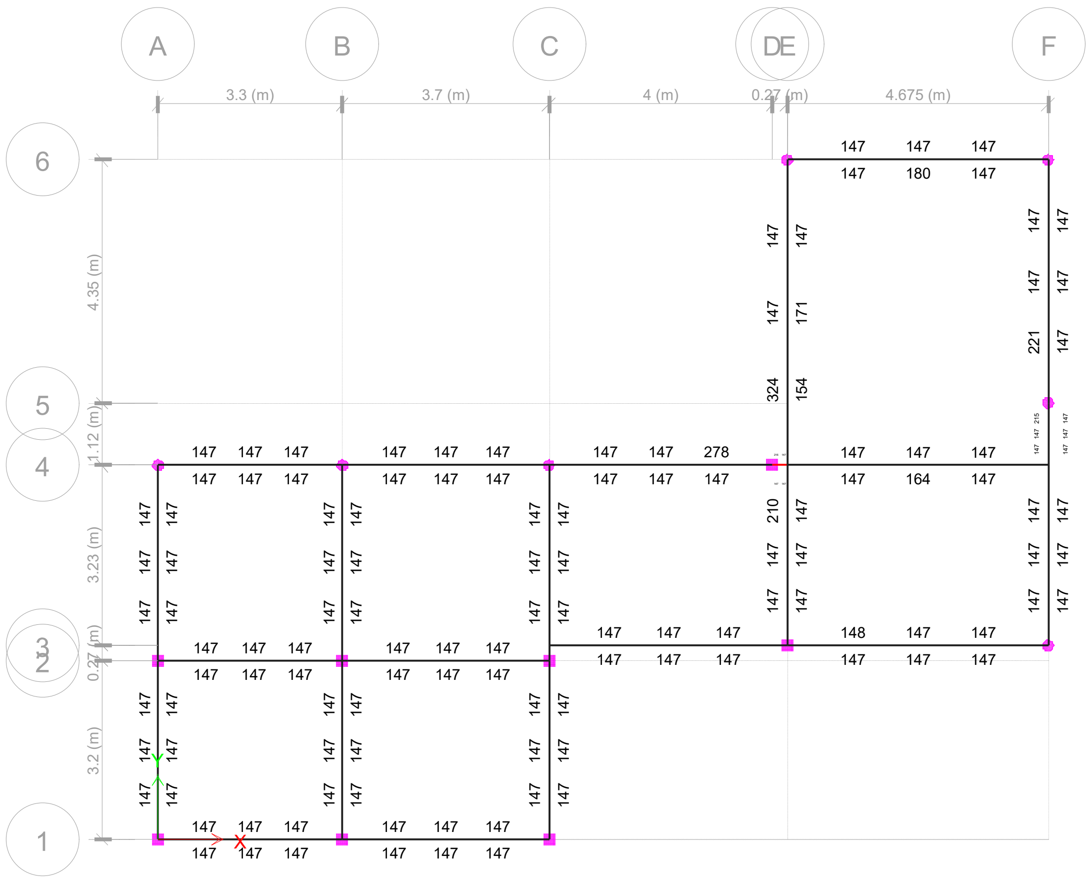


Kassa Health Citadel Ramp.EDB

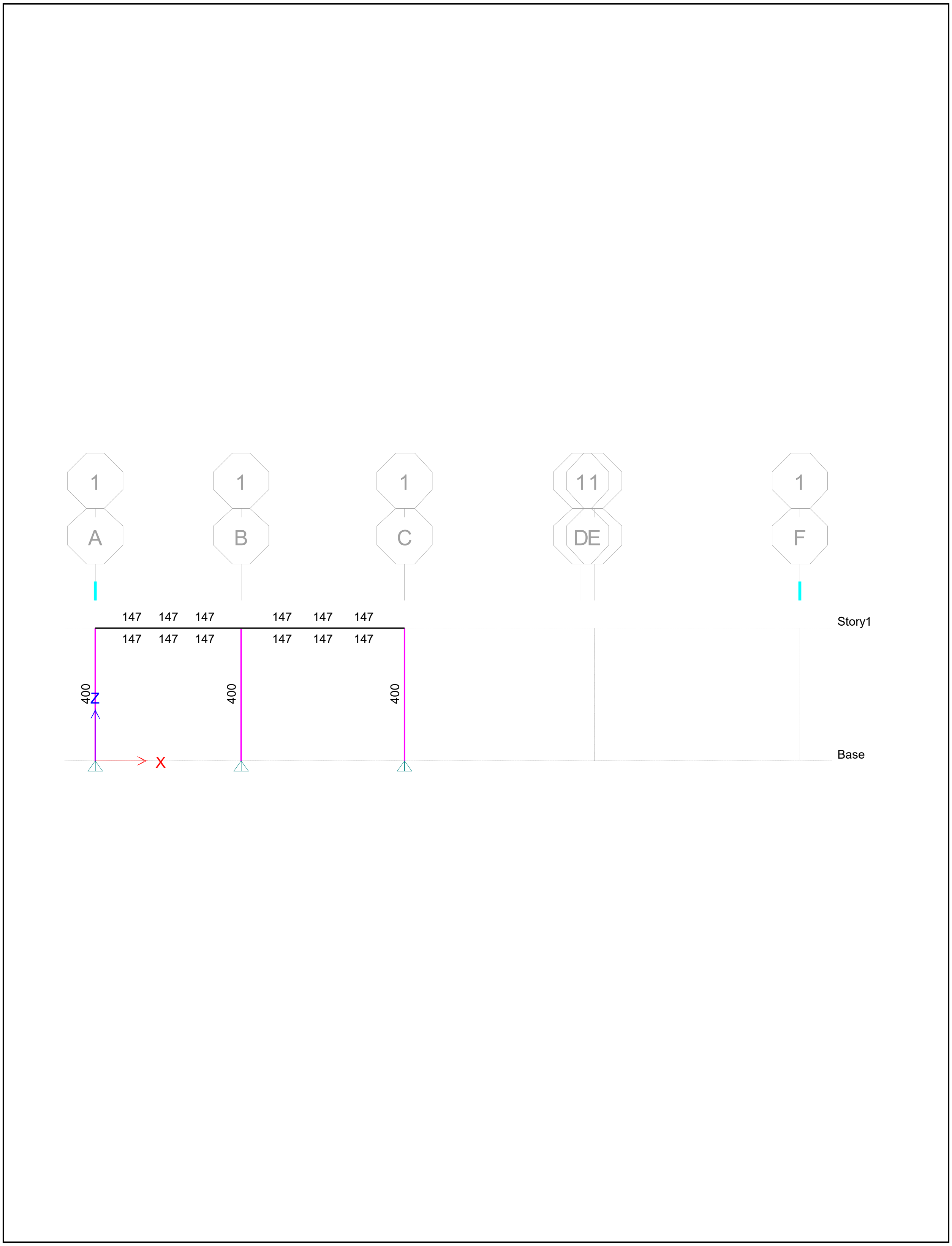
0.28	0.56	0.84	1.12	1.40	1.68	1.96	2.24	2.52	2.80	3.08	3.36	3.64	3.92

3-D View Slab Finite Element Design - Top Rebar Intensity (Enveloping) [mm²/m] - Direction 2

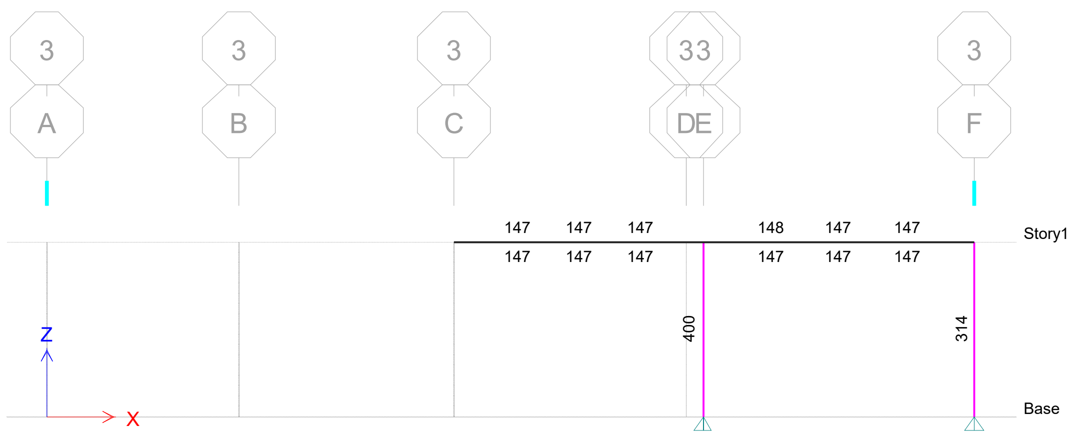
SECTION-5: DESIGN OF CONCRETE BEAMS & COLUMNS



Block-A Extension.EDB Plan View - Story1 - Z = 3 (m) Longitudinal Reinforcing (Eurocode 2-2004)



Block-A Extension.EDB Elevation View - 1 Longitudinal Reinforcing (Eurocode 2-2004)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3
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A
B
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Story1
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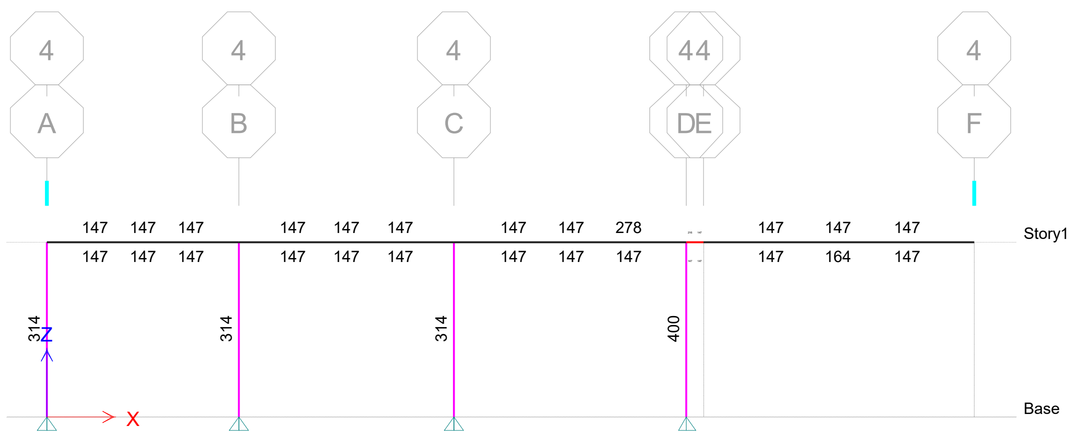
400
314
Z
X
Base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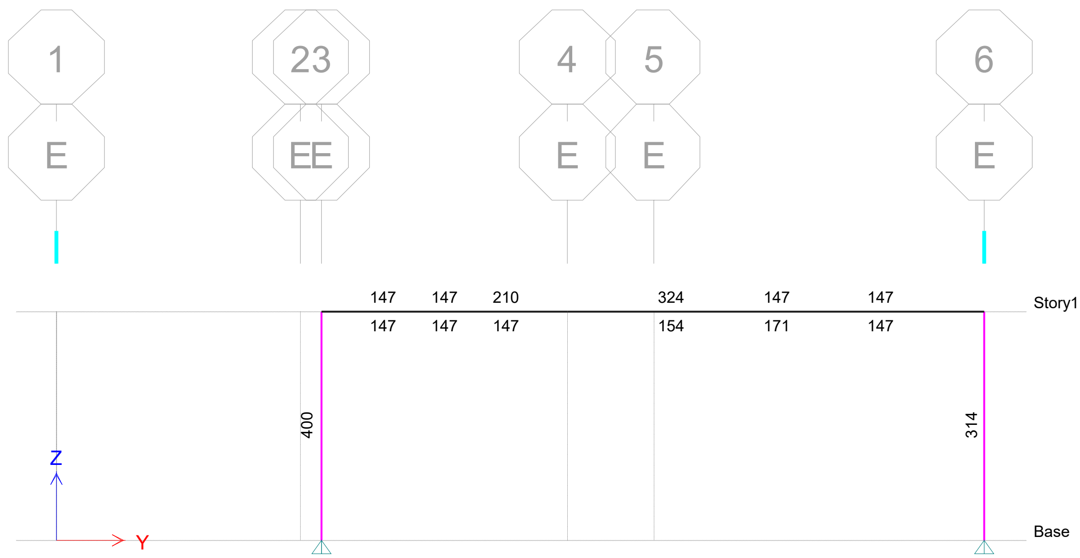
400
Z
X
Story1
Base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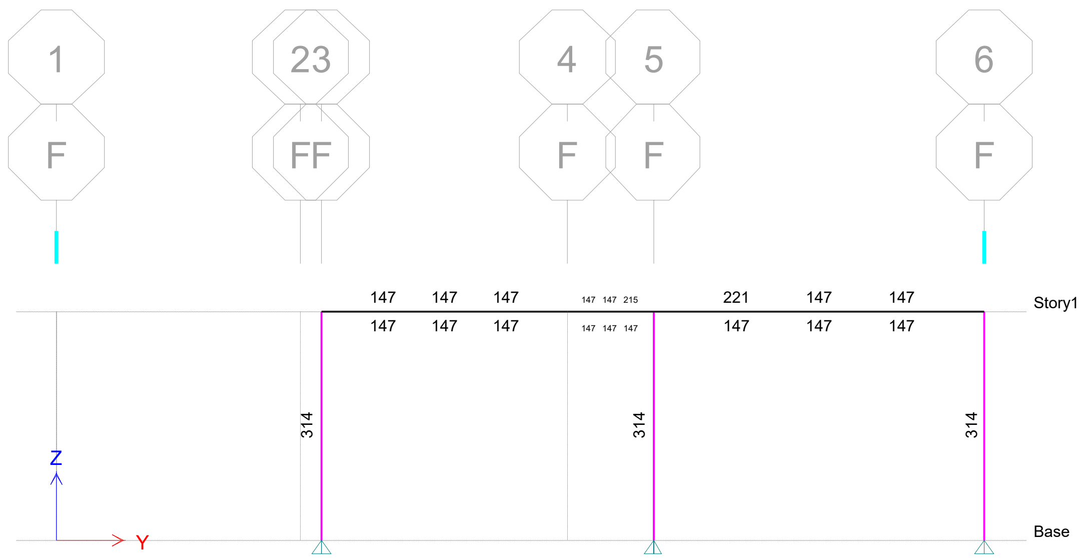
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Story1
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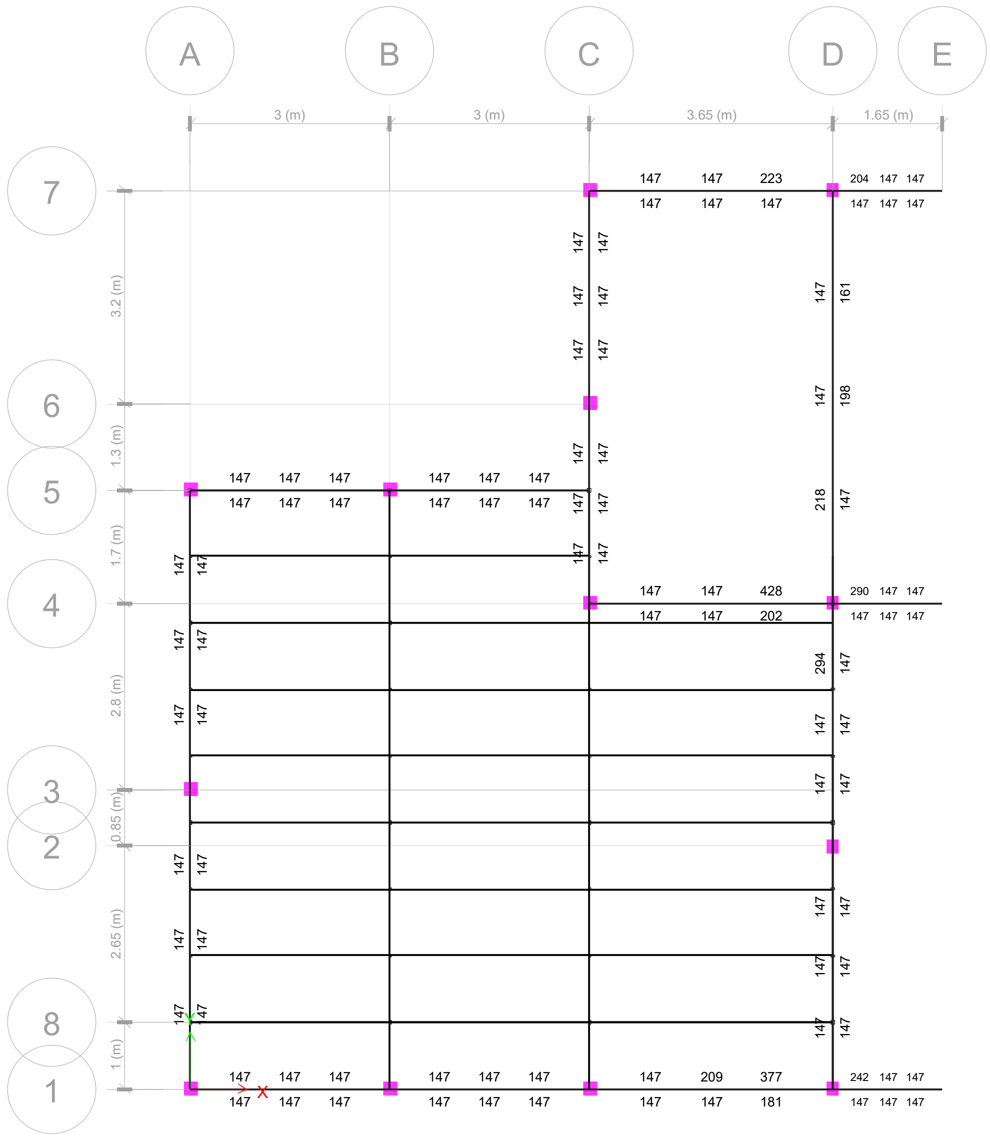
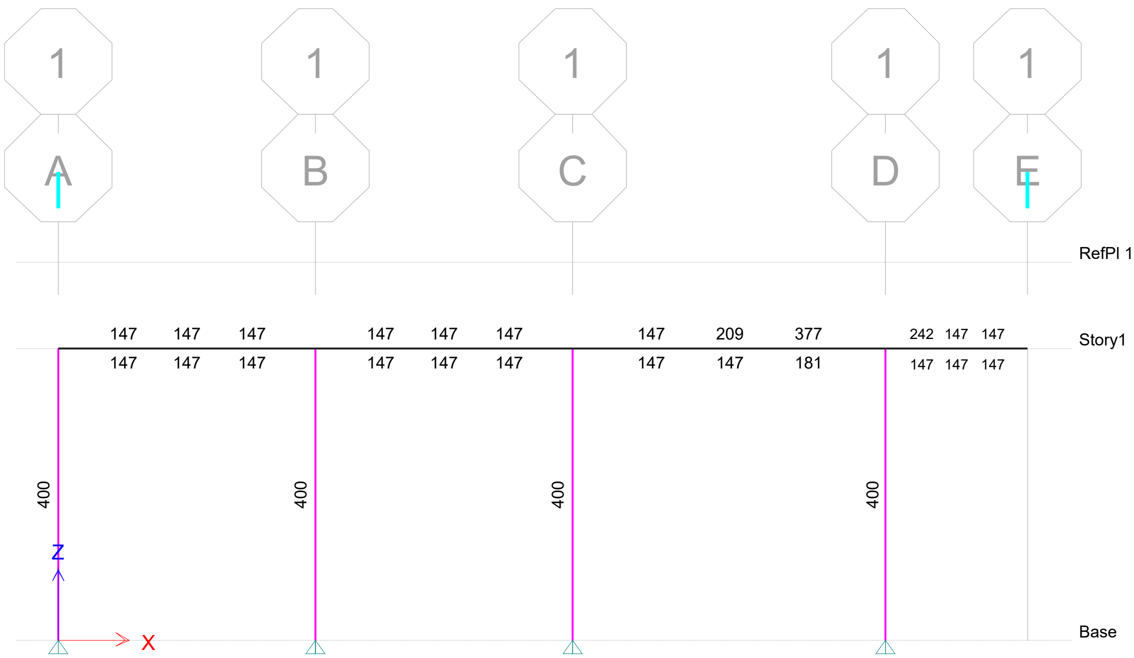


Block-J Staff Rest Rooms.EDB Plan View - Story1 - Z = 3.4 (m) Longitudinal Reinforcing (Eurocode 2-2004)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E
RefPl 1
Story1
Base
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400
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Z
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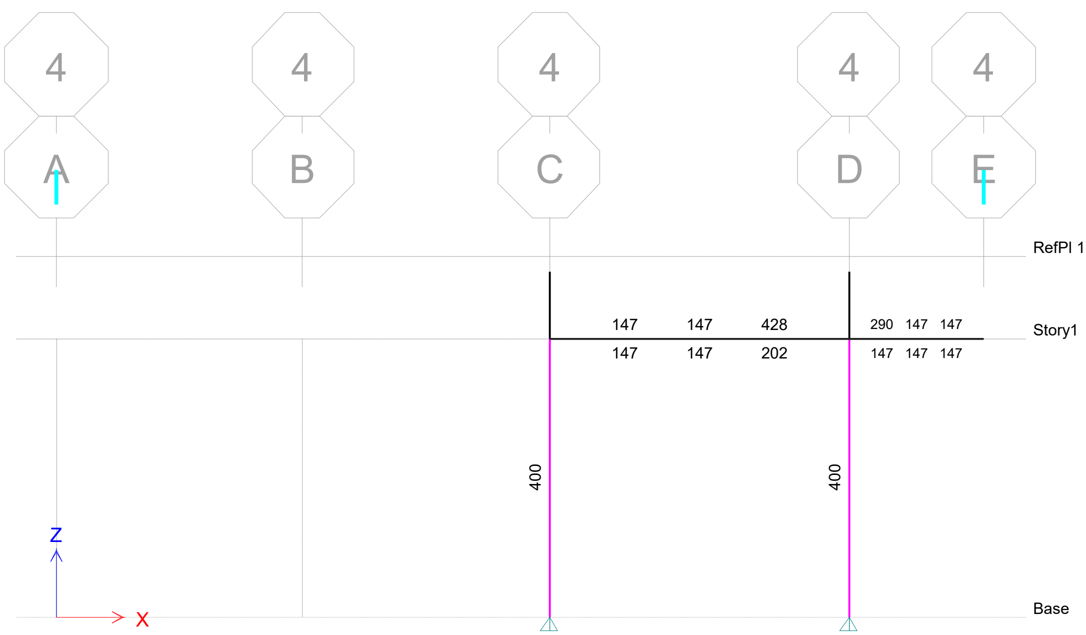
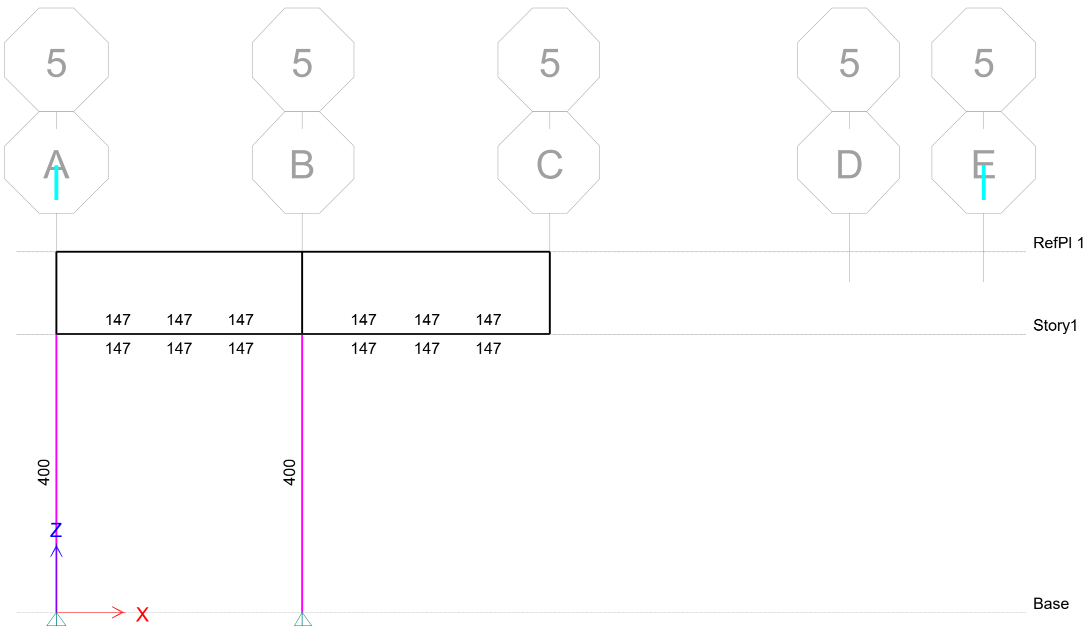
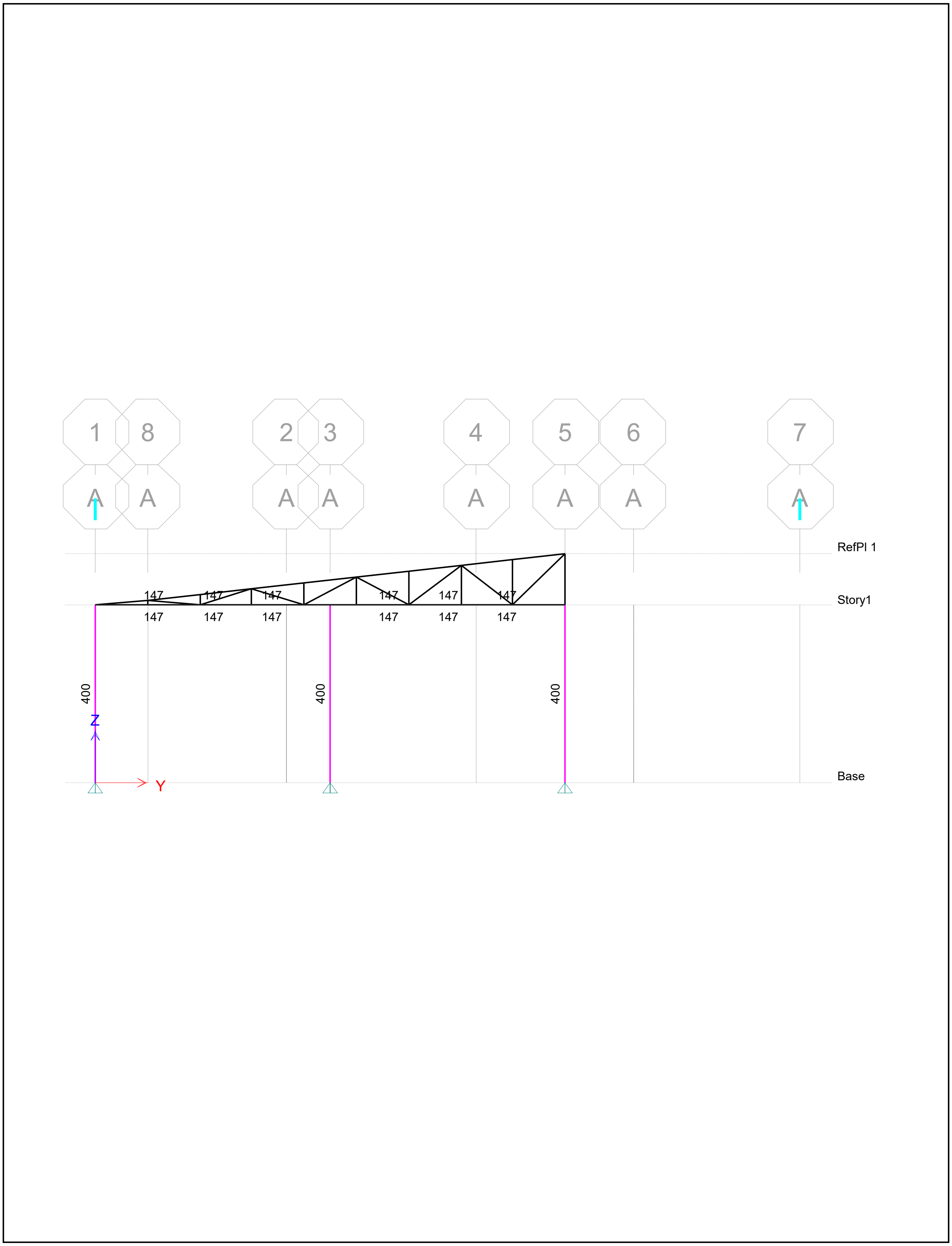


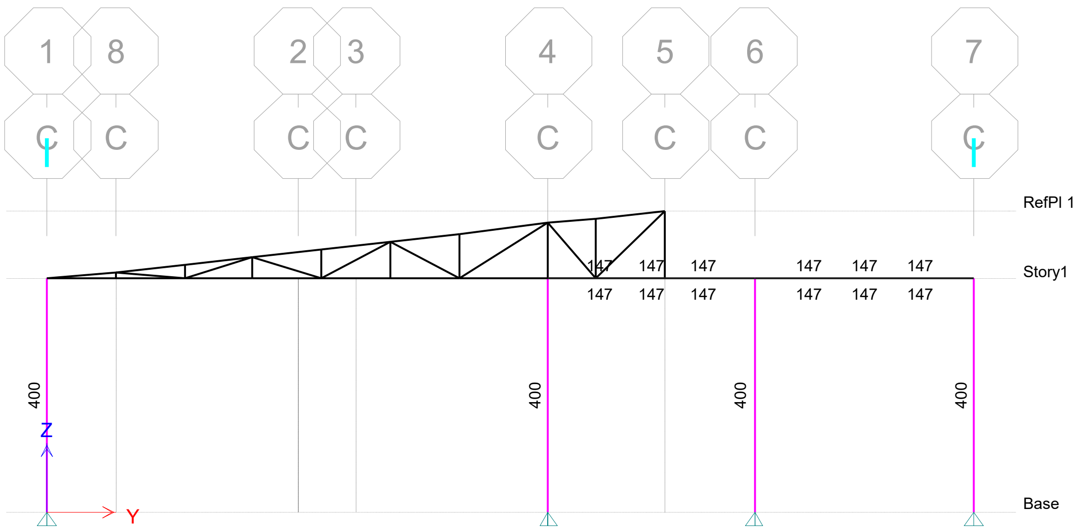
Block-J Staff Rest Room.EDB Elevation View - 4 Longitudinal Reinforcing (Eurocode 2-2004)



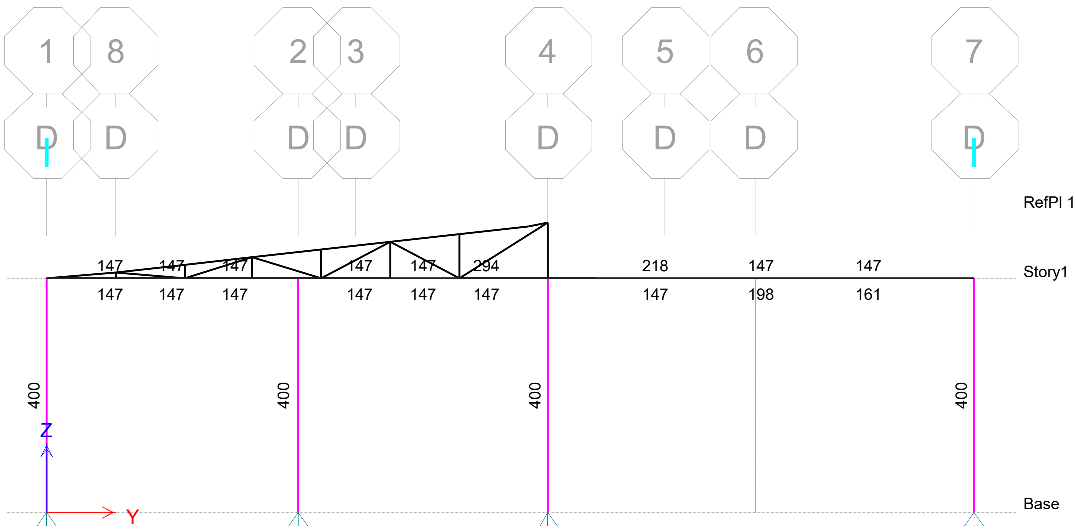
Block-J Staff Rest Room.EDB Elevation View - 5 Longitudinal Reinforcing (Eurocode 2-2004)



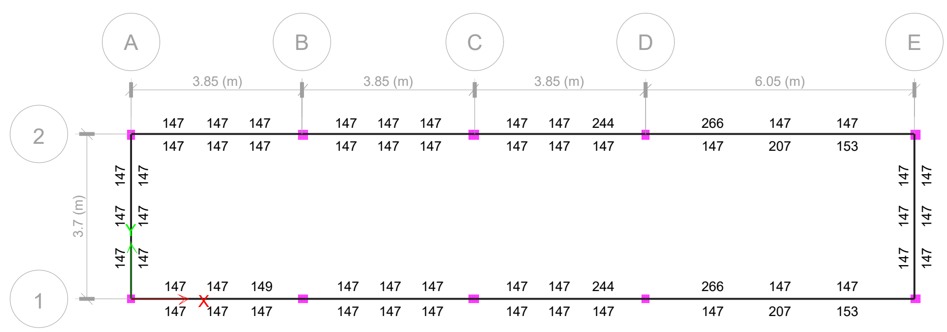
Block-J Staff Rest Room.EDB Elevation View - A Longitudinal Reinforcing (Eurocode 2-2004)



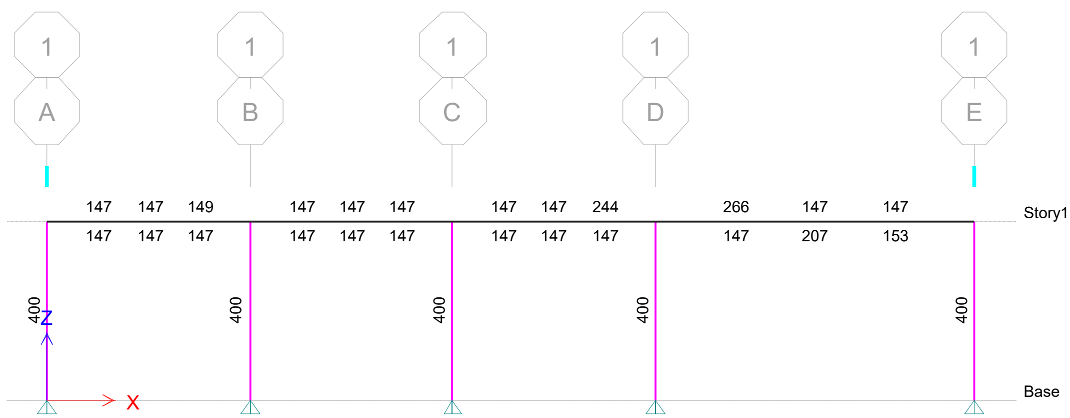
Block-J Staff Rest Room.EDB Elevation View - C Longitudinal Reinforcing (Eurocode 2-2004)



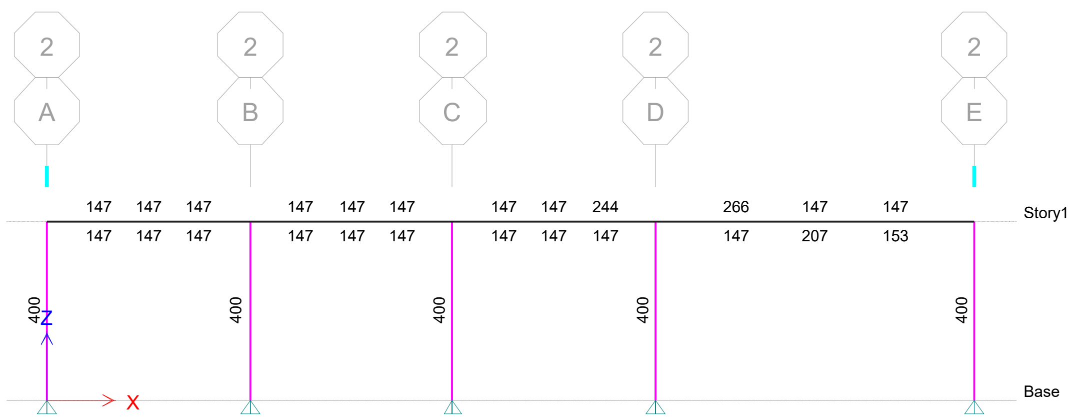
Block-J Staff Rest Room.EDB Elevation View - D Longitudinal Reinforcing (Eurocode 2-2004)



Block-J Walkway.EDB Plan View - Story1 - Z = 3.4 (m) Longitudinal Reinforcing (Eurocode 2-2004)



Block-J Walkway.EDB Elevation View - 1 Longitudinal Reinforcing (Eurocode 2-2004)


2
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Story1
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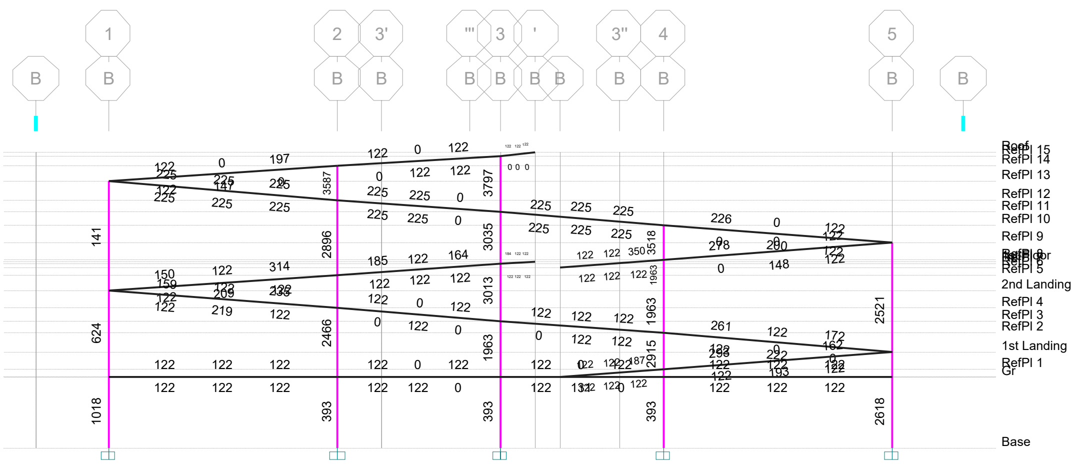
400
Z
X
Base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3
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3''
4
5
B
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RefPl 15
RefPl 14
RefPl 13
RefPl 12
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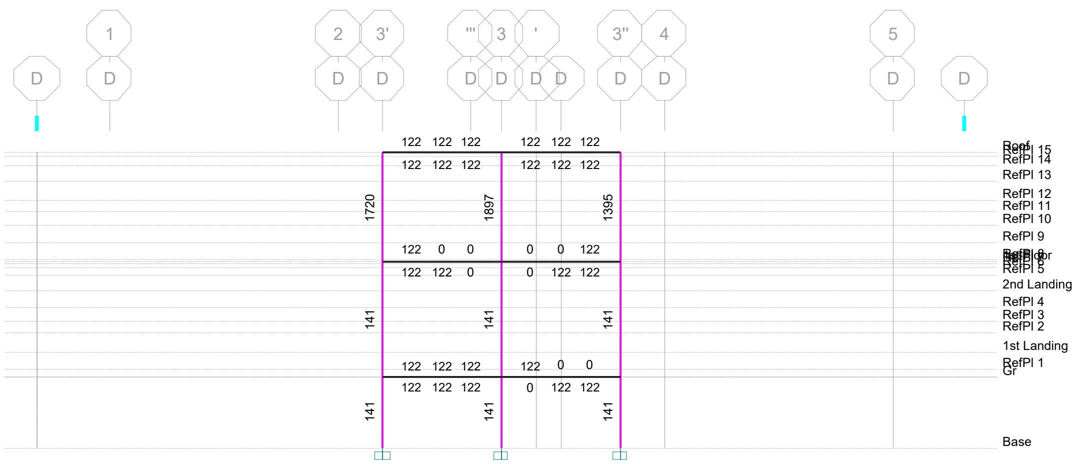
RefPl 9
RefPl 5
2nd Landing
RefPl 4
RefPl 3
RefPl 2
1st Landing
RefPl 1
Gr
Base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122 122 122
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1720
1897
1395
141
Roof
RefPl 15
RefPl 14
RefPl 13
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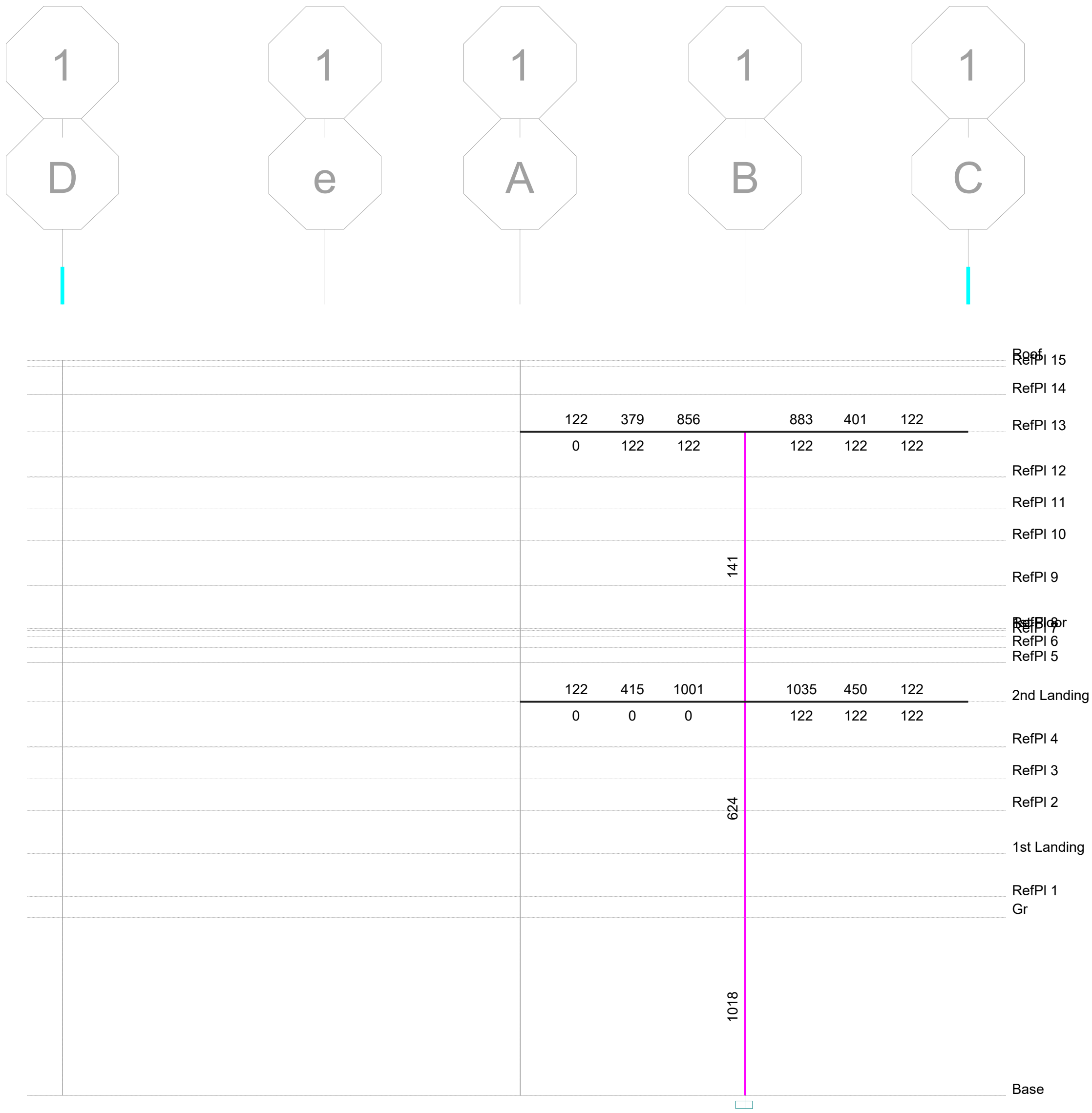
RefPl 2
1st Landing
RefPl 1
Gr
Base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RefPl 12
RefPl 11
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141
RefPl 9
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RefPl 7
RefPl 6
RefPl 5
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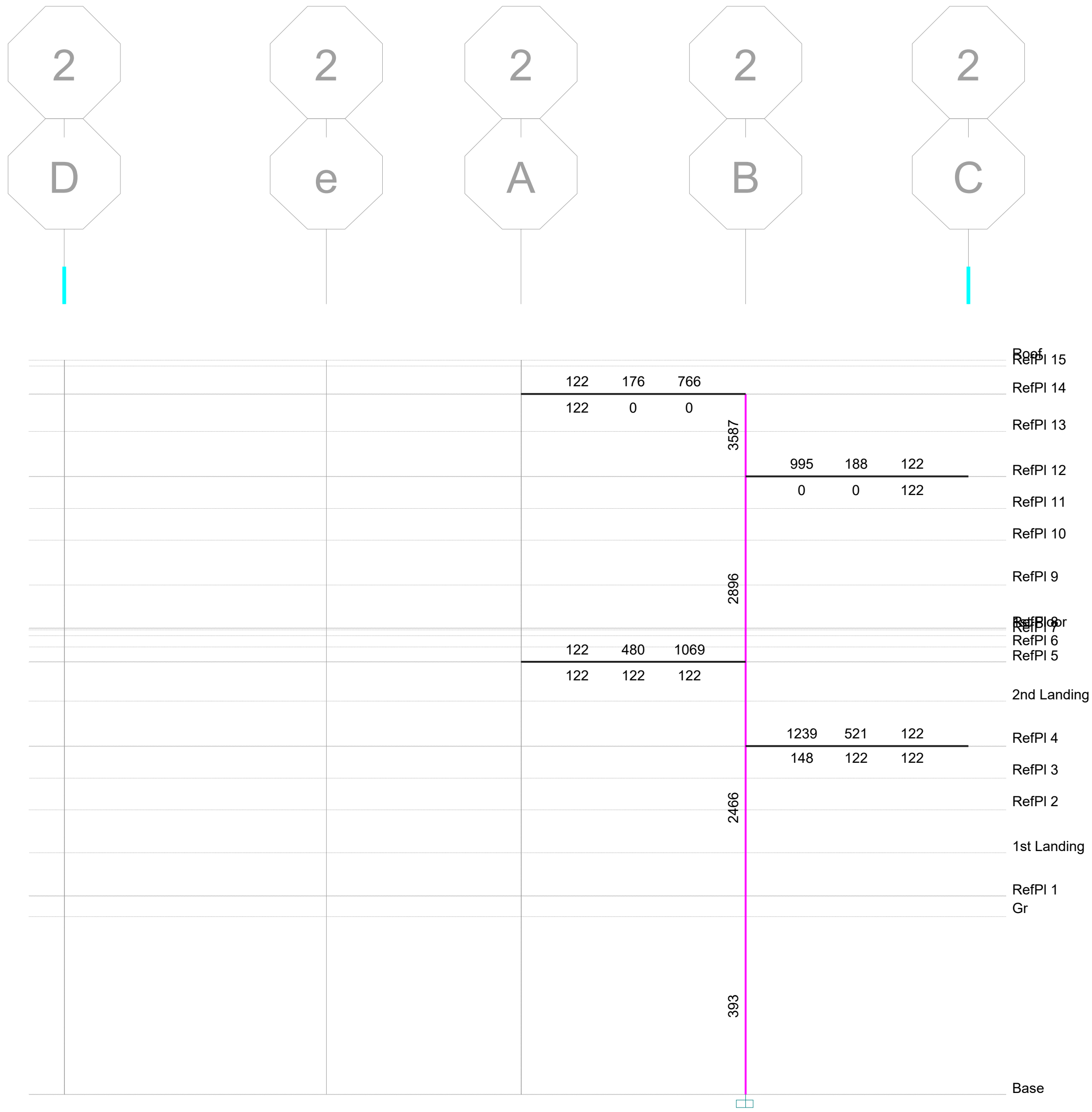
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2 A
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2 C
Roof
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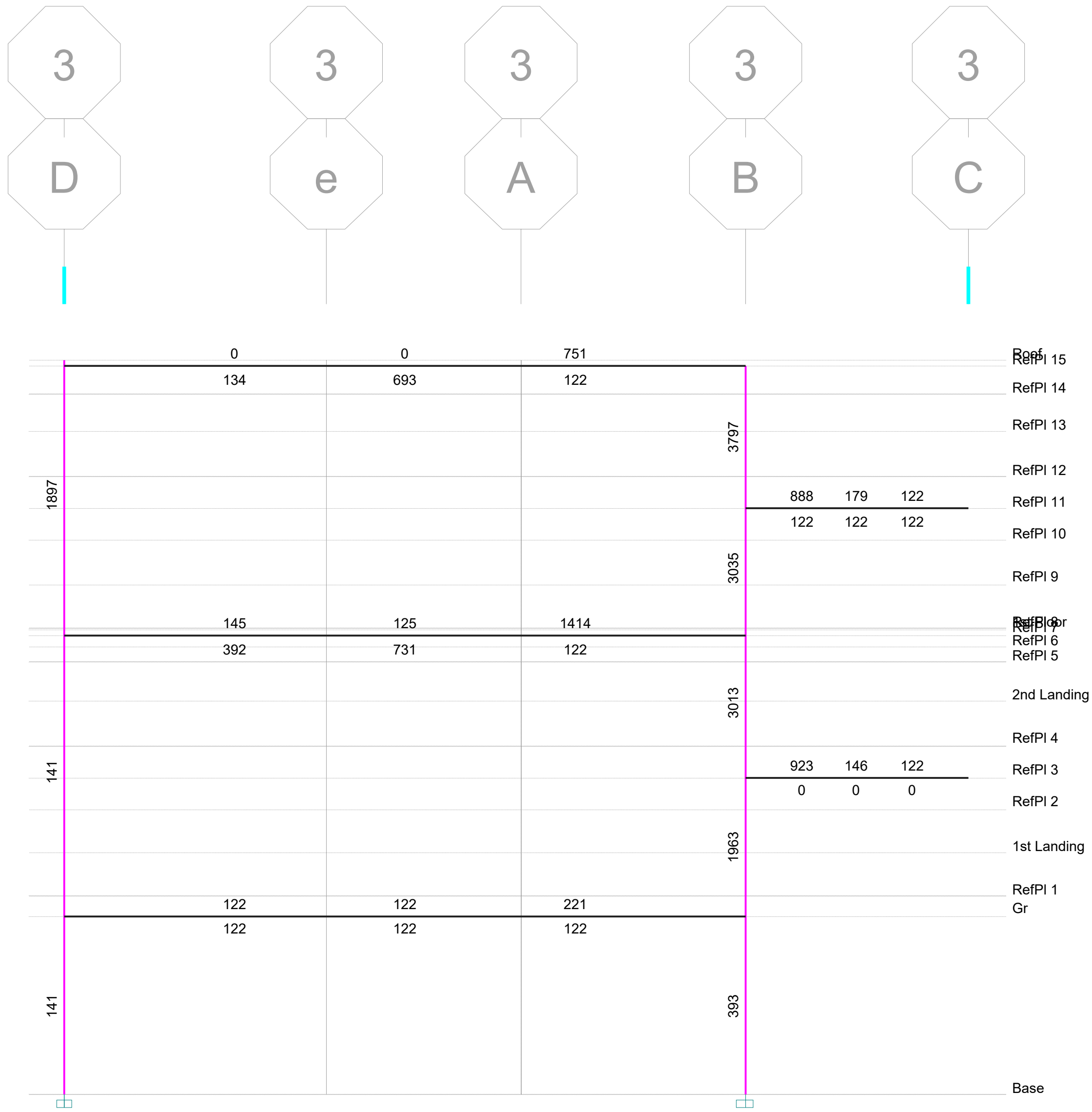
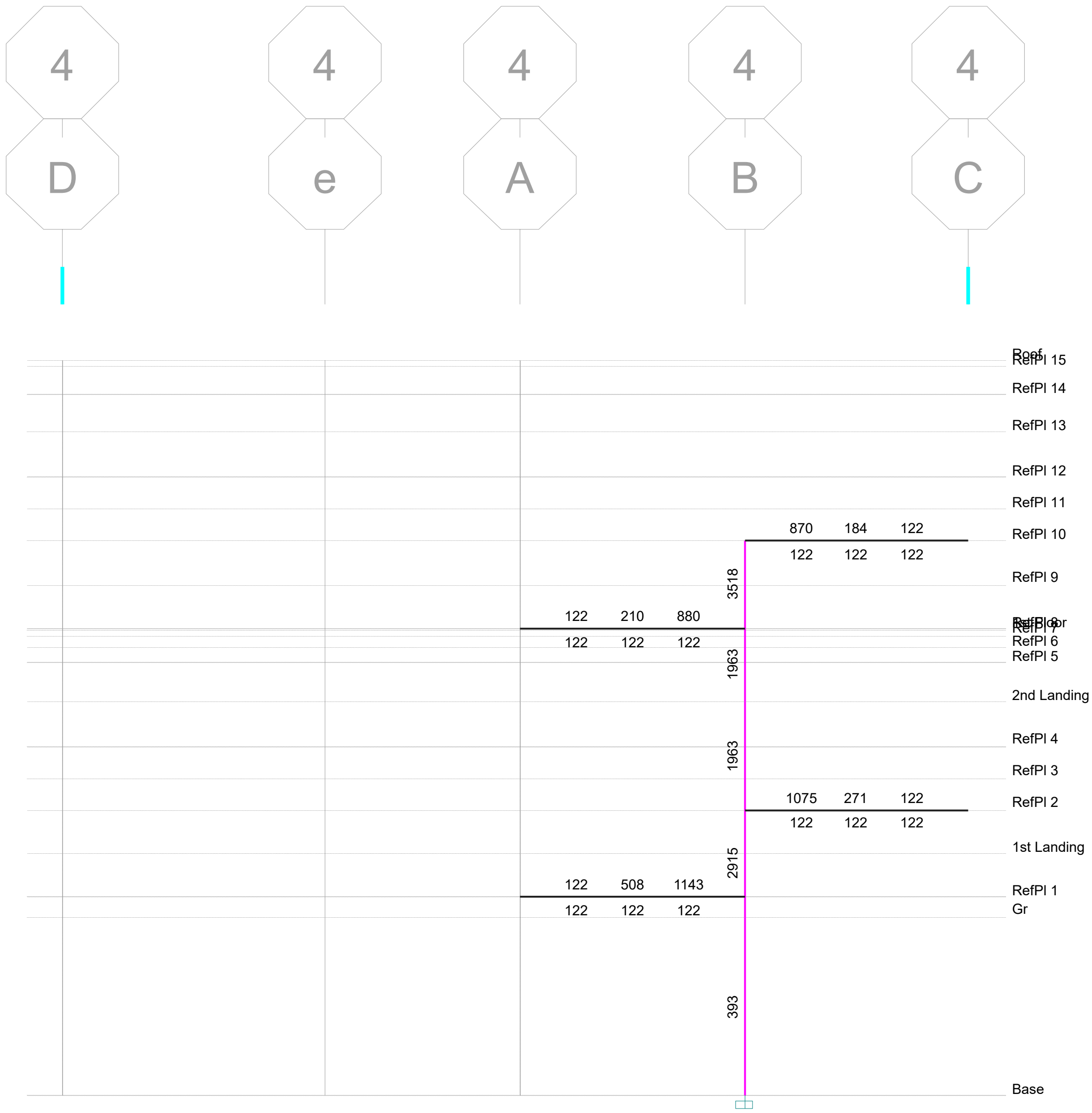
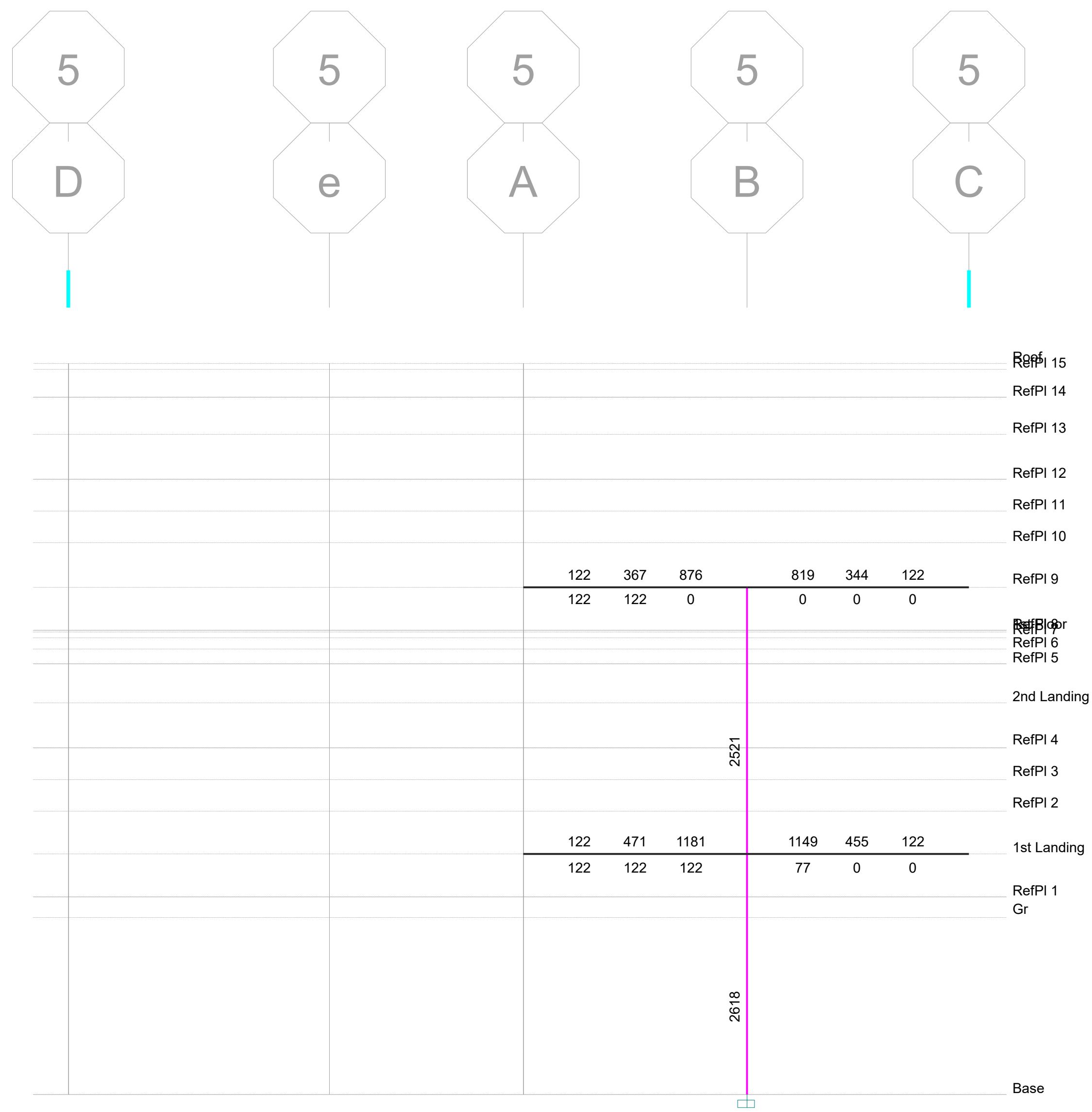
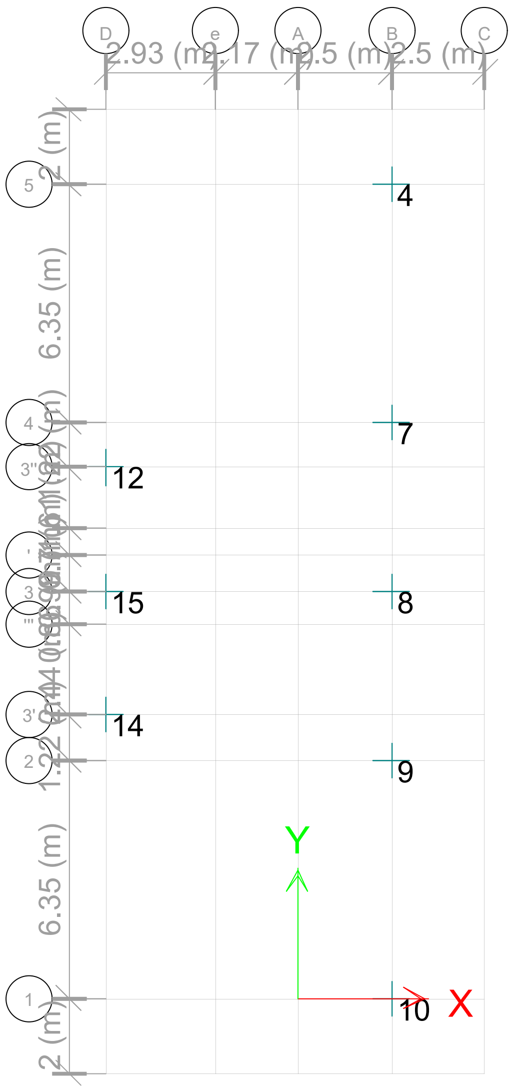
RefPl 9
RefPl 8
RefPl 7
RefPl 6
RefPl 5
2nd Landing
RefPl 4
RefPl 3
RefPl 2
1st Landing
RefPl 1
Gr
Base
122 176 766
122 0 0
3587
995 188 122
0 0 122
2896
122 480 1069
122 122 122
1239 521 122
148 122 122
2466
393


3
D
3
e
3
A
3
B
3
C
0 0 751
134 693 122
3797
1897
888 179 122
122 122 122
3035
145 125 1414
392 731 122
3013
141
923 146 122
0 0 0
1963
122 122 221
122 122 122
141
393
Roof
RefPl 15
RefPl 14
RefPl 13
RefPl 12
RefPl 11
RefPl 10
RefPl 9
RefPl 8
RefPl 7
RefPl 6
RefPl 5
2nd Landing
RefPl 4
RefPl 3
RefPl 2
1st Landing
RefPl 1
Gr
Base


4
D
4
e
4
A
4
B
4
C
Roof
RefPl 15
RefPl 14
RefPl 13
RefPl 12
RefPl 11
RefPl 10
RefPl 9
RefPl 8
Floor
RefPl 7
RefPl 6
RefPl 5
2nd Landing
RefPl 4
RefPl 3
RefPl 2
1st Landing
RefPl 1
Gr
Base
870 184 122
122 122 122
3518
122 210 880
122 122 122
1963
1963
1075 271 122
122 122 122
2915
122 508 1143
122 122 122
393


5
D
5
e
5
A
5
B
5
C
Roof
RefPl 15
RefPl 14
RefPl 13
RefPl 12
RefPl 11
RefPl 10
122 367 876 819 344 122
RefPl 9
122 122 0 0 0 0
RefFloor
RefPl 7
RefPl 6
RefPl 5
2nd Landing
RefPl 4
2521
RefPl 3
RefPl 2
122 471 1181 1149 455 122
1st Landing
122 122 122 77 0 0
RefPl 1
Gr
2618
Base

SECTION-6: DESIGN OF FOUNDATIONS


D
e
A
B
C
2.93 (m)
2.17 (m)
2.5 (m)
2.5 (m)
2 (m)
6.35 (m)
6.35 (m)
2 (m)
5
4
3"
3
3'
2
1
4
7
12
15
8
14
9
10
Y
X

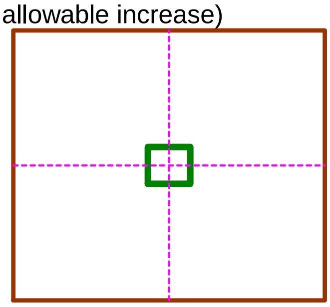
Project	Kassala Health Citadel, Sudan		REINFORCED CONCRETE COUNCIL
Client	UNOPS	Made by: RMW	Date: 30-Sep-20	Page: 113
Location	Footing - F1	Single column base	
	PAD FOUNDATION DESIGN to BS 8110:1997	Checked: chg	Revision: -	Job No: R68
	Originated from RCC81.xls on CD	© 1999 BCA for RCC	

MATERIALS

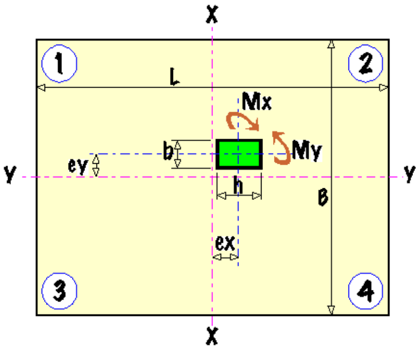
fcu	25	N/mm²	h agg	20	mm	γc	1.5	concrete
fy	400	N/mm²	cover	50	mm	γs	1.05	steel
Densities - Concrete	23.6	kN/m³	Soil	18	kN/m³			
Bearing pressure	200	kN/m² (net allowable increase)						

DIMENSIONS mm

BASE		COLUMN	
L =	2200	h =	300
B =	2200	b =	300
depth H =	350		
ex =	0	ey =	0



Plot (to scale)

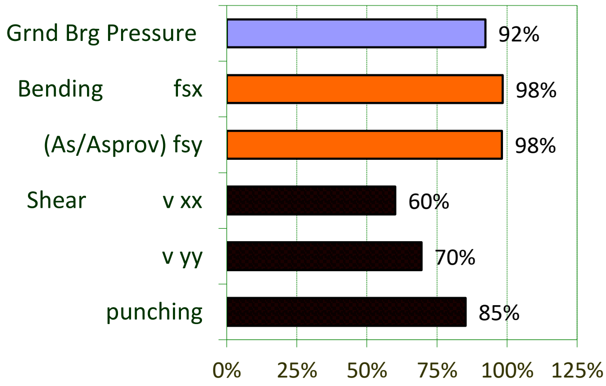


Key

COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	624.7	146.3	80.0
Mx (kNm)	1.3	0.3	
My (kNm)	-23.7	-6.7	
Hx (kN)	-25.9	-6.7	
Hy (kN)	-0.6	0.1	

STATUS VALID DESIGN



Efficiency

BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	149.0	139.1	184.6	172.4
with wind	165.6	155.5	201.1	189.0

REINFORCEMENT

Detail to 3.11.3.2			Detail to 3.11.3.2		
Mxx =	223.2	kNm	Myy =	235.2	kNm
b =	2200	mm	b =	2200	mm
d =	294	mm	d =	282	mm
As =	2110	mm²	As =	2338	mm²
Asmin=	2110	mm²	Asmin =	2338	mm²
PROVIDE	19 R12 @ 150 B1		PROVIDE	21 R12 @ 150 B2	
As prov =	2149	mm²	As prov =	2375	mm²

BEAM SHEAR

Vxx =	326.3	kN at d from col face	Vyy =	353.6	kN at d from col face
v =	0.505	N/mm²	v =	0.570	N/mm²
or Vxx =	183.8	kN at 2d from col face	or Vyy =	215.9	kN at 2d from col face
v =	0.284	N/mm²	v =	0.348	N/mm²
vc =	0.473	N/mm²	vc =	0.501	N/mm²

PUNCHING SHEAR

d ave =	288	mm	u crit =	4400	mm
As prov =	0.358	%	v max =	3.171	N/mm² at col face
v =	0.415	N/mm²	vc =	0.487	N/mm²

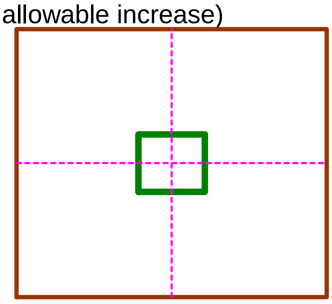
Project	Kassala Health Citadel, Sudan	REINFORCED CONCRETE COUNCIL	
Client	UNOPS	Made by / Date / Page	RMW / 30-Sep-20 / 113
Location	Footing - F2	Single column base	
	PAD FOUNDATION DESIGN to BS 8110:1997	Checked / Revision / Job No	chg / - / R68
	Originated from RCC81.xls on CD	© 1999 BCA for RCC	

MATERIALS

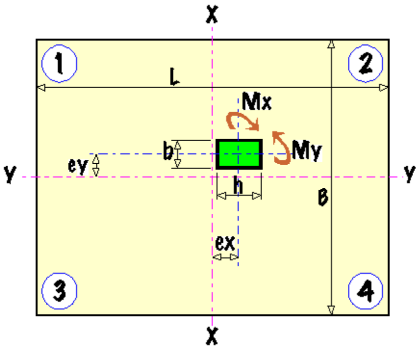
	fcu	25	N/mm²	h agg	20	mm	γc 1.5	concrete
	fy	400	N/mm²	cover	50	mm	γs 1.05	steel
Densities - Concrete		23.6	kN/m³	Soil	18	kN/m³		
Bearing pressure		200	kN/m² (net allowable increase)					

DIMENSIONS mm

BASE		COLUMN	
L =	1400	h =	300
B =	1400	b =	300
depth H =	350		
ex =	0	ey =	0



Plot (to scale)

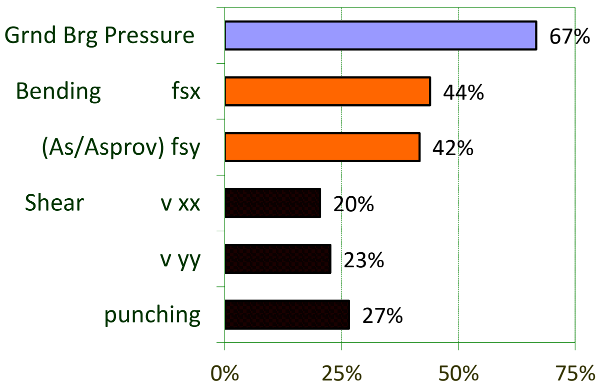


Key

COLUMN REACTIONS kN, kNm *characteristic*

	DEAD	IMPOSED	WIND
Axial (kN)	183.5	41.3	80.0
Mx (kNm)	-1.0	-0.2	
My (kNm)	-1.7	-1.3	
Hx (kN)	0.2	-1.2	
Hy (kN)	0.9	0.2	

STATUS VALID DESIGN



Efficiency

BEARING PRESSURES kN/m² *characteristic*

CORNER	1	2	3	4
no wind	114.2	107.7	125.9	118.8
with wind	155.0	148.5	166.7	159.7

REINFORCEMENT

Mxx =	40.2	kNm	Myy =	40.6	kNm
b =	1400	mm	b =	1400	mm
d =	294	mm	d =	282	mm
As =	377	mm²	As =	398	mm²
Asmin=	818	mm²	Asmin =	818	mm²

PROVIDE 8 R12 @ 150 B1 PROVIDE 8 R12 @ 150 B2

As prov =	905	mm²	As prov =	905	mm²

BEAM SHEAR

Vxx =	69.1	kN at d from col face	Vyy =	75.3	kN at d from col face
v =	0.168	N/mm²	v =	0.191	N/mm²
or Vxx =	0.0	kN at 2d from col face	or Vyy =	2.7	kN at 2d from col face
v =	0.000	N/mm²	v =	0.007	N/mm²
vc =	0.412	N/mm²	vc =	0.422	N/mm²

PUNCHING SHEAR

d ave =	288	mm	u crit =	2800	mm
As prov =	0.224	%	v max =	1.063	N/mm² at col face
v =	0.081	N/mm²	vc =	0.417	N/mm²

STRIP MASONRY FOUNDATION - OFFICE BUILDING

Loading from Structure (Critical Loads):

i) Block-A Extension (Axis 4/D)
DL = 155.27 KN
LL = 8.7 KN

ii) Block-J – Staff Rest Room (Axis 4/D)
DL= 177.6 KN
LL = 10.7 KN

iii) Block-J Walkway (Axis 2/D)
DL= 97.79 KN
LL = 6.5 KN

Foundation Type: Strip Foundation - 500 mm thick stone masonry foundation

Loading on Masonry Foundation:

Dead load:

- From structure = 177.6/4 = 44.4 KN/m
- Block wall = 14*3.5*0.22 = 10.8 KN/m
- Grade Beam = 0.5*0.2*25 = 2.5 KN/m
- Stone Masonry = 27*2.0*0.5 = 27 KN/m

G = 84.7 KN/m

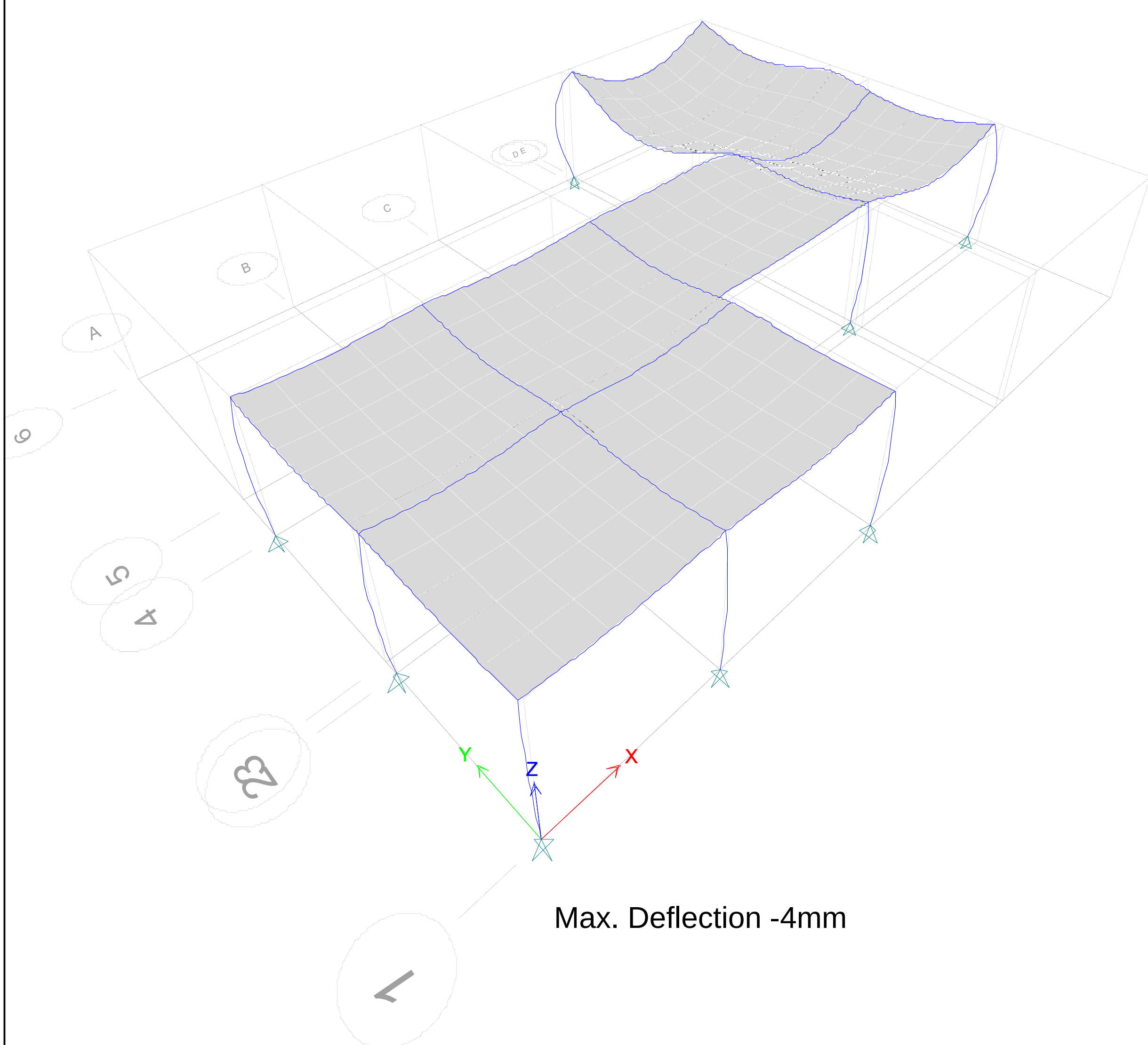
Live load:

- Live load from structure = 10.7/4 = 2.7 KN/m

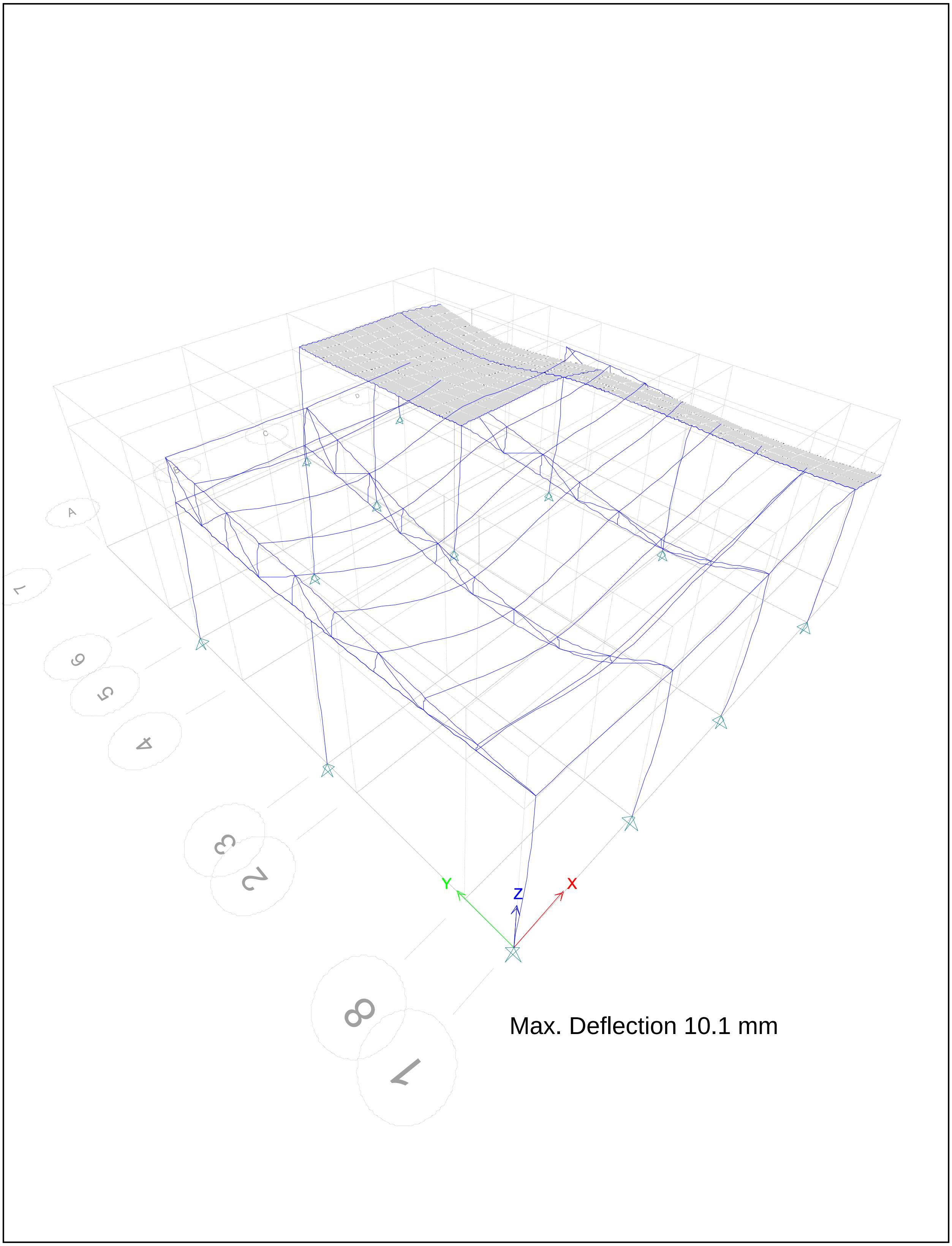
W = 87.4 KN/m

Contact Pressure (δ) = 87.4 /0.5 = 174.8 KN/m^2 < 200 KPa .... Okay

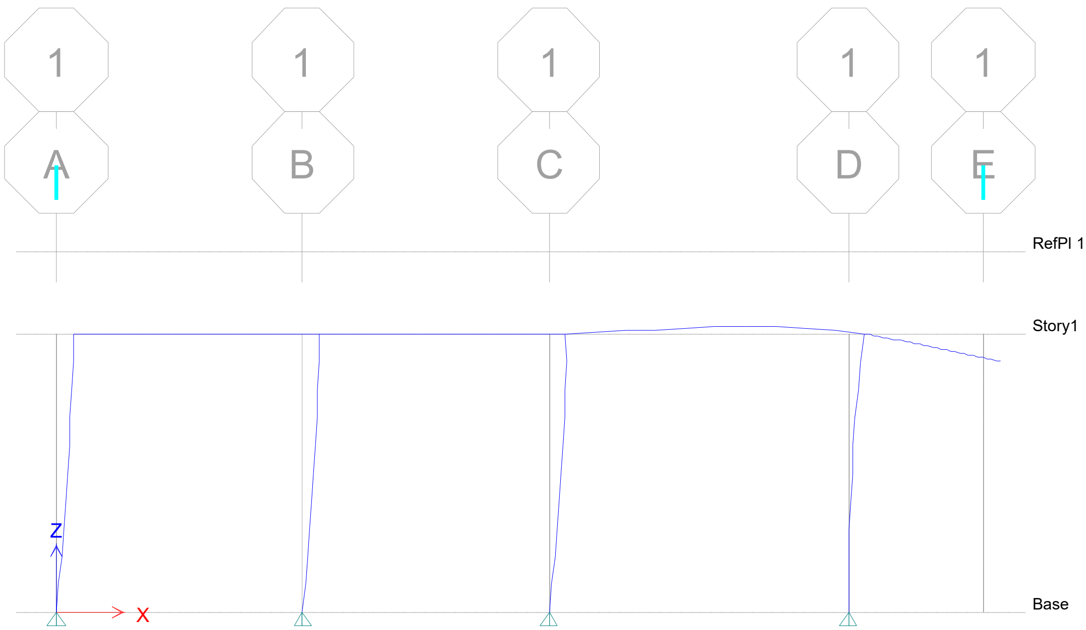
SECTION-7: FRAME OUTPUT



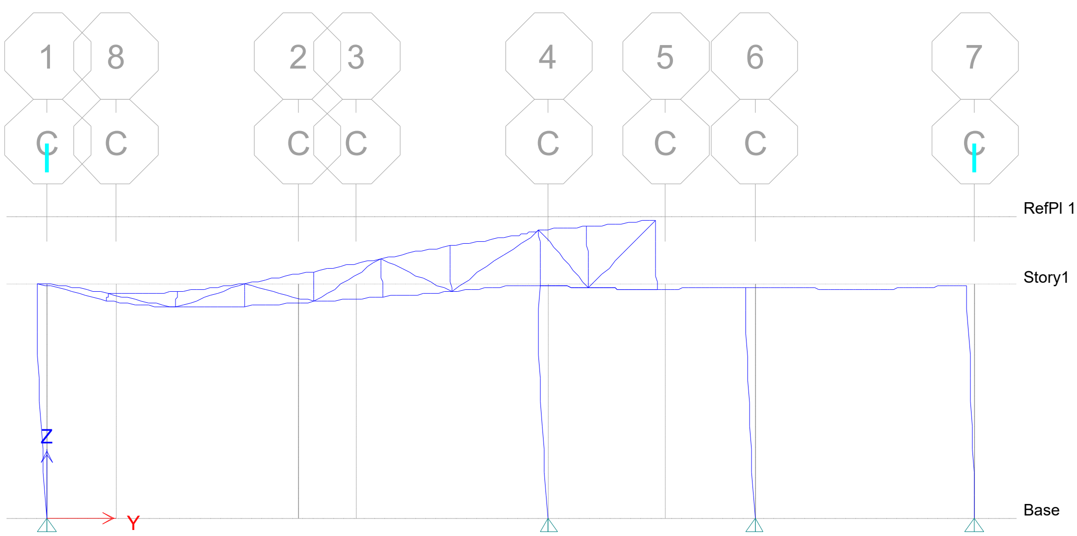
Max. Deflection -4mm



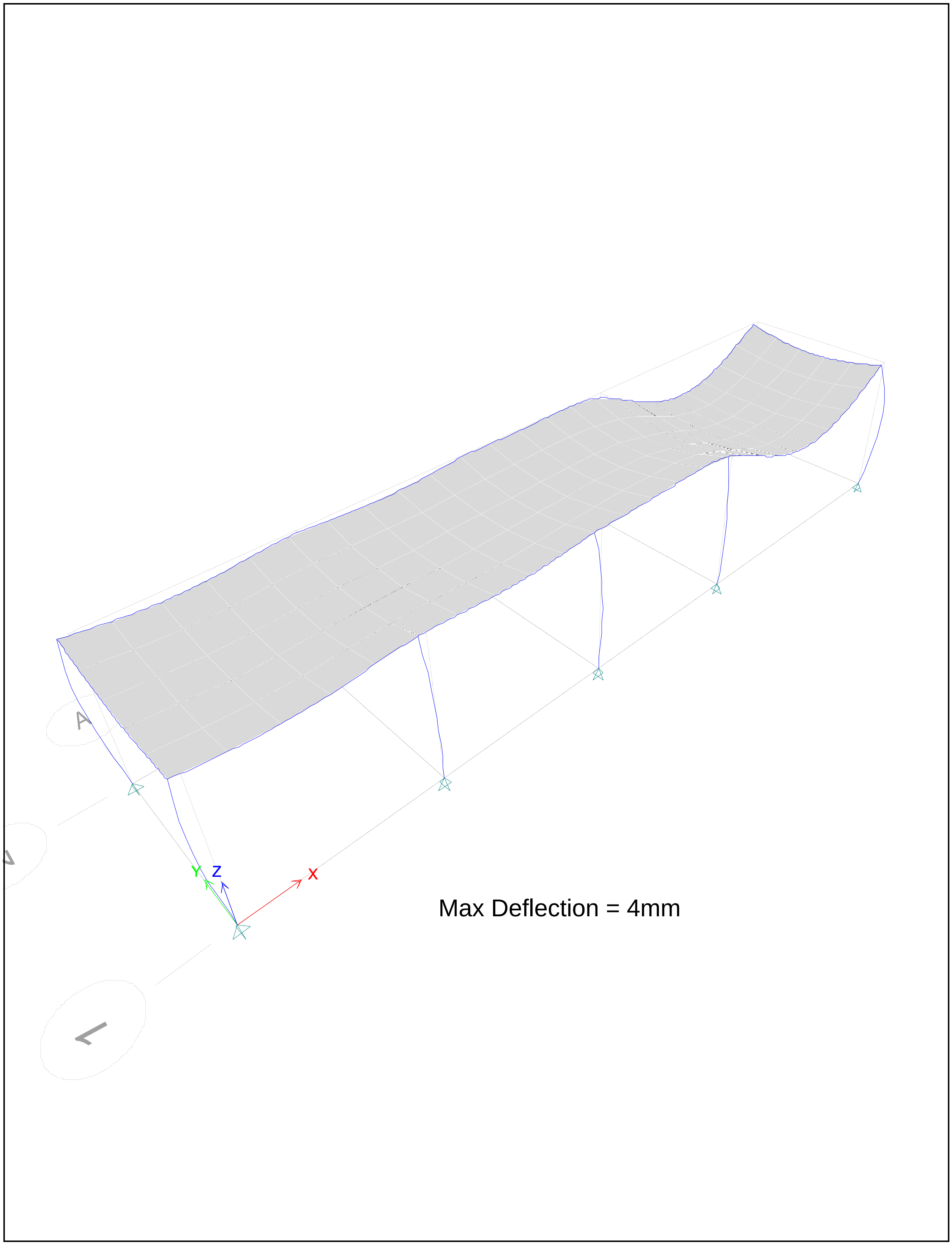
Block-J Staff Rest Rooms.EDB3-D View - Displacements (SERVE) [mm]



Max. Drift 3.4mm



Max Drift - 3.2mm


Y
Z
X
A
Max Deflection = 4mm