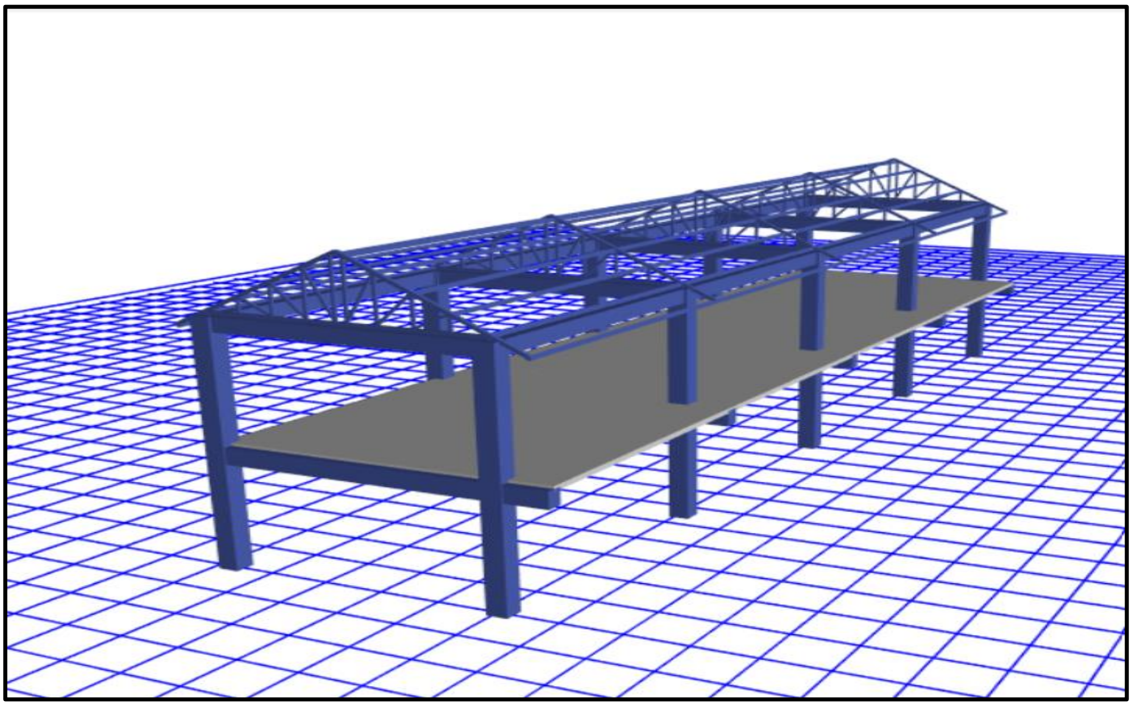
STRUCTURAL REPORT



GANESH SECONDARY SCHOOL BUILDING

CONSULTANT:

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1.0. INTRODUCTION

1.1. EXECUTIVE SUMMARY

This report has been prepared as a part of the structural engineering analysis and design of the **Kavre District** as a partial requirement of application for permit to construct building. This Report describes in brief the Structural Aspects and Design Report of the proposed building. The analysis and design have been carried out using finite element software **ETABS 2021.0.0**. This software provides the Structural Engineer with all the tools necessary to create, modify, analyze, design, and optimize the structural elements in a building model. The structure design is intended to be based primarily on the current National Building Code of Practice of India taking account of relevant British Codes for the provisions not covered in this and is generally in conformance with NBC of Nepal.

General Features:	
Project: -	Detailed Project Report of Ganesh Secondary School
Location: -	Kavre District
Area: -	111.817 sq. m.
Architectural features:	
Type of Building: -	Institutional Building
Height of Storey: -	3.0m
Total Height of the Building: -	7.710 m from plinth to truss structure ridge
Wall and Partition: -	Brick Masonary Wall
Structural features	
Structural System: -	Special Moment Resisting Frame
Foundation Type: -	Isolated, Combined footing
Columns: -	350x350 mm
Beams: -	Main Beam Rectangular :300mmx400mm ,250x350mm
Slab: -	Floor Slab of 125mm thick
Geotechnical features	*(refer geo-tech report)*
Soil Type: -	Medium Soil (Soil type – II)
Seismic Zone: -	Beni (as per NBC 105:2020,)

Allowable bearing capacity: -	120 KN/m2 at depth 1.8 m from GS
Foundation Thickness: -	350 mmm
Materials	
Grade of concrete: -	M20 (slab, beam, Column,) M20 (Footing)
Grade of steel: -	Fe-500 (elongation >14.5%)
Unit weight of concrete: -	25 kN/m3
Young's Modulus of Elasticity, Ec :-	5000 √fck
Modulus of elasticity for Steel, Es: -	200 KN/mm2
Poisson's Ratio: -	0.20 for concrete and 0.3 for rebar
Cover to Reinforcement	
Footings (Bottom, and Top)	50mm
Footing (Sides)	75mm
Columns	40mm
Beams	25mm or bar diameter whichever is greater
Slabs	20mm or bar diameter whichever is greater
Stairs (Waist Slab/Folded)	-15mm
Water Tank walls and Slab	-15mm

1.2. STRUCTURAL MODELLING

ETABS Software, produced by CSI, has made structural analysis of this building California Berkeley and the Foundation System has been made by the SAFE Software, produced by CSI California Berkeley. 3-Dimensional models have been prepared for each part with the dimension shown in the drawings. Concrete grade M20 has been used for Column, Footing, Beam and Slab. Centre-line dimensions are followed for analysis and design. Preliminary sizes of structural components are assumed by experience. For analysis purpose, the beams are assumed to be rectangular so as to distribute slightly larger moment in columns and also to consider the reversibility of seismic load. Seismic loads will be considered acting in the horizontal direction (along either of the two principal directions) and not along the vertical direction, since it is not considered to be significant. The design seismic force has been applied and automatically distributed by the software at various floor level Analysis of the structure were adhered to Indian Standard

456:2000. Specifically, Static and Dynamic Linear Analysis Method (Response Spectrum) was performed to understand the lateral load response of the building with use of ETABS 2021.0.0. The design loads considered as per the relevant codes of practice comprise dead load due to permanent structures, live load due to occupancy of the structure and seismic load due to anticipated earthquake possible at the proposed location. A number of load combinations are considered to obtain the maximum values of design stresses.

1.3. STRUCTURAL SYSTEM OF THE BUILDING

The structural system chosen is **Building with SMRFs**. Columns and beams have been laid out in plan in coordination with architectural and services planning that acts jointly support and transmit to the ground those forces arising from earthquake motions, gravity and live load. Its role becomes increasingly important with the increase in building height. Thus, the vital criteria for structural systems are an adequate reserve of strength against failure, adequate lateral stiffness, and an efficient performance during the service life of the building. The determination of the structural forms of a building involves the selection and arrangement of the major structural elements to resist most efficiently the various combinations of gravity and horizontal loadings. The choice of structural form is strongly influenced by the internal planning, the material and method of construction, the external architectural treatment, the location and routing of service systems, the nature and magnitude of the horizontal loading, and the height and proportion of the building.

2.0. GENERAL DATA FOR STRUCTURAL ANALYSIS

Grade of Concrete and Cover to the Reinforcement is provided according to the provisions of the Indian Code. The appropriate grade of concrete and nominal cover to reinforcement is governed by the following main considerations:

i. Durability of Concrete include Fire resistance rating
ii. Corrosion Protection of the Reinforcement
iii. Bar Size
iv. Nominal maximum aggregate size

2.1. GRADE OF CONCRETE

The Indian Code IS: 456-2000, permits a minimum grade of concrete for reinforced concrete members as M20 and the following concrete grades shall be used for "normal" conditions, But, the Grade of Concrete considered for this Building is given below:

Foundation: M20
Column: M20
Beam: M20
Secondary Beam: M20
Slab: M20
Plinth Beam: M20

Table 1 Concrete Material Properties

Material Properties	
Grade f_{ck}, [MPa]	20
Youngs Modulus E, [Mpa]	2236000
Co-efficient of thermal expansion	0.0000117 per ^{0}C
Basic shrinkage strain	Refer IS 456:200
Basic Creep Factor	Refer IS 456:200
Poisson's Ratio	0.3
Density	24 KN/m^3 (plain concrete) 25 KN/m^3 (reinforced concrete)

2.2. REINFORCEMENT STEEL

All reinforcing steel to be used in the structural elements shall have a yield stress of 500 MPa, (Thermo-Mechanically Treated bars), conforming to IS: 1786-1985.

Table 2 Reinforcement Properties

Bar	Elastic Modulus [MPa]	Yield Strength, fy [MPa]
Stirrups and Ties	200,000	500
Longitudinal Bars	200,000	500

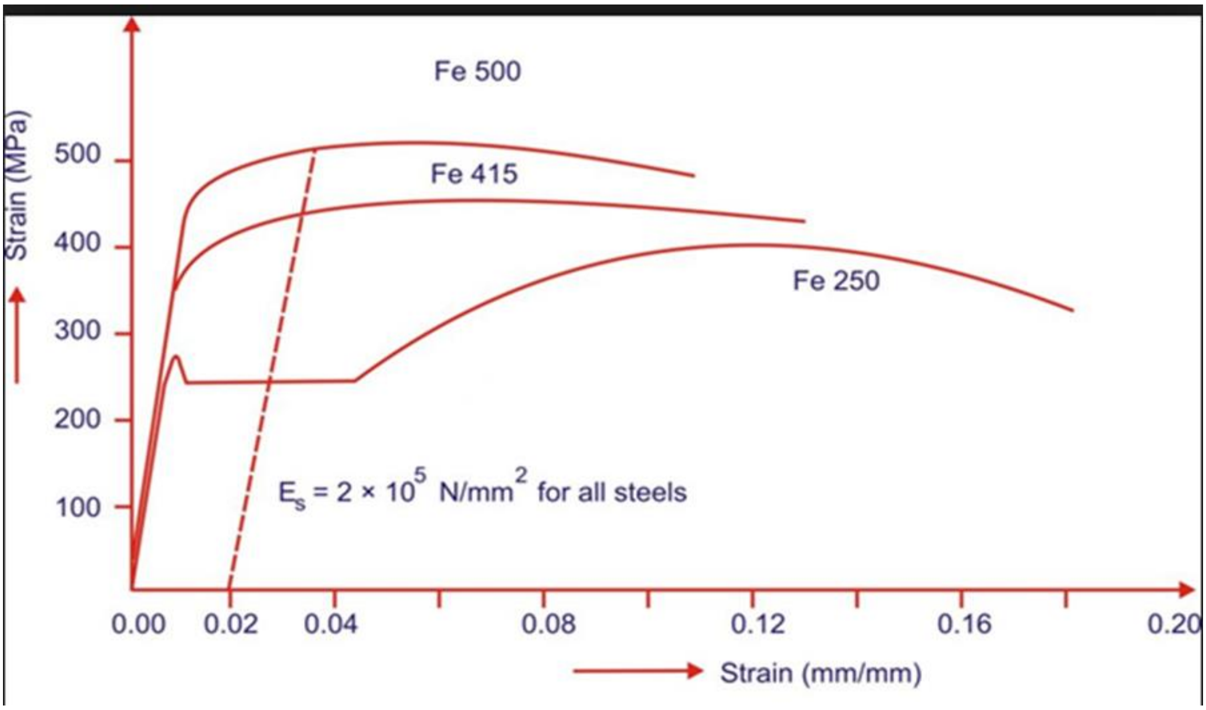


Figure 1 Hook's Law

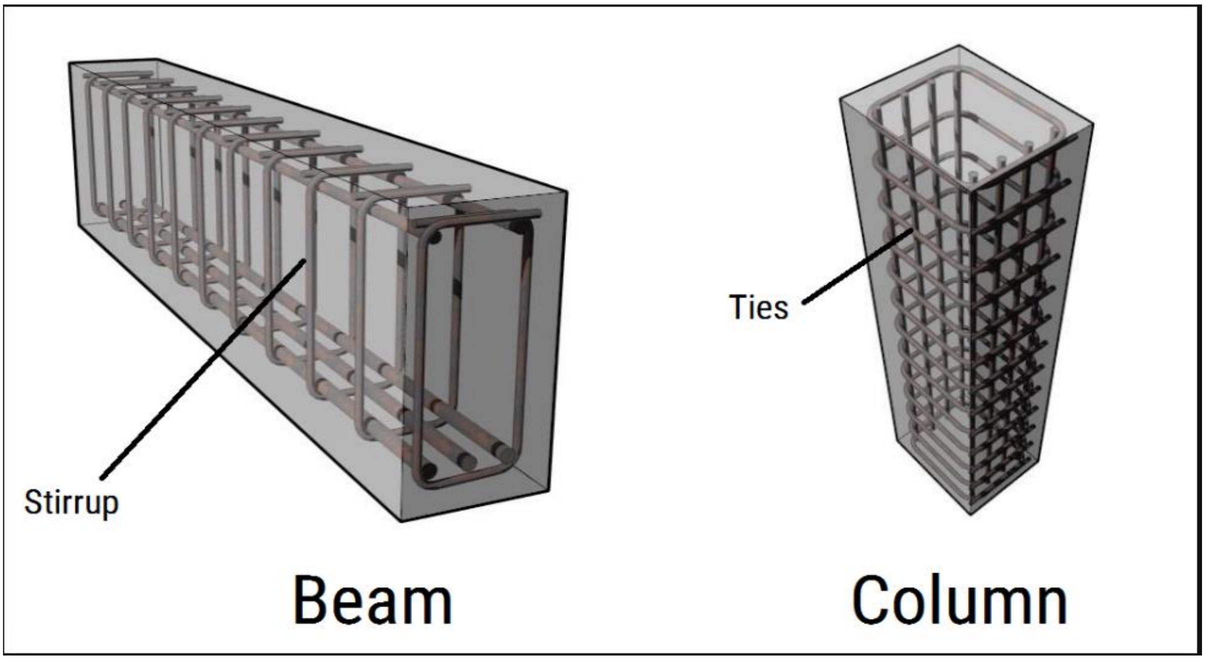


Figure 2 Beam and Column Sections

2.3. CLEAR COVER

Clear cover to the main reinforcement in the various structural elements shall be as follows:

a. Footings (Bottom): 50 mm
b. Footings (Top and Sides): 50 mm
c. Secondary Beam: 25 mm
d. Columns: 40 mm
e. Beams: 25 mm or bar diameter whichever is greater
f. Slabs: 20 mm or bar diameter whichever is greater

2.4. REFERENCE CODES

Many international standard codes of practices were adopted for the creation of mathematical model, its analysis and design. As per the requirement, National Building Code was used for the load combination in order to check for the worse case during analysis.

Some of the codes used are enlisted below:

A. Loading

Code	Description
IS 875: 1987 Part I	Dead Loads
IS 875: 1987 Part II	Imposed Loads
IS 875: 1987 Part V	Special Loads and Combinations

B. Design of Earthquake Resistance

Code	Description
NBC 105:2020	Nepal National Building code – Seismic Design of Building in Nepal
IS 1893:2016	Criteria for earthquake resistant design of structures
IS 4326:2013	Code of practice for earthquake resistant design and construction of buildings

C. Design of Concrete Elements

Code	Description
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed in 2016)
IS 1786:2008	Specification for high strength deformed steel bars and wires for concrete reinforcement

SP-16	Design aids for reinforced concrete
SP-34	Handbook on concrete reinforcement and detailing

D. Design of Foundations

Code	Description
IS 1904	Indian Standard code of practice for design and construction of foundations in soil - General requirements
IS 2950	Indian Standard code of practice for design and construction of raft foundation (Part - I)
IS 2911	Indian Standard code of practice for design and construction of pile foundations
IS 2974	Code of practice for design and construction of machine foundation

E. Detailing of Structures

Code	Description
NBC 105:2020	Nepal National Building code – Seismic Design of Building in Nepal
IS 13920:2016	Ductile Design and Detailing of Reinforced Concrete structures subjected to lateral forces (Reaffirmed in 2017)

2.5. GENERAL BUILDING LAYOUT:

The proposed building consists of G + 1 Story. The Architectural Plan is as shown:

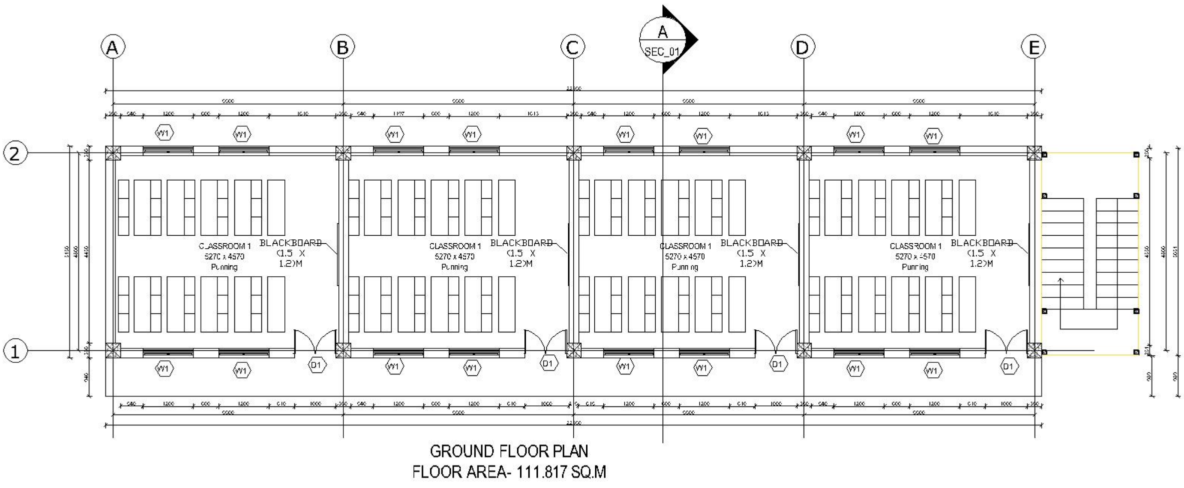


Figure 3 General Layout of the Proposed Building (Ground Floor Plan)

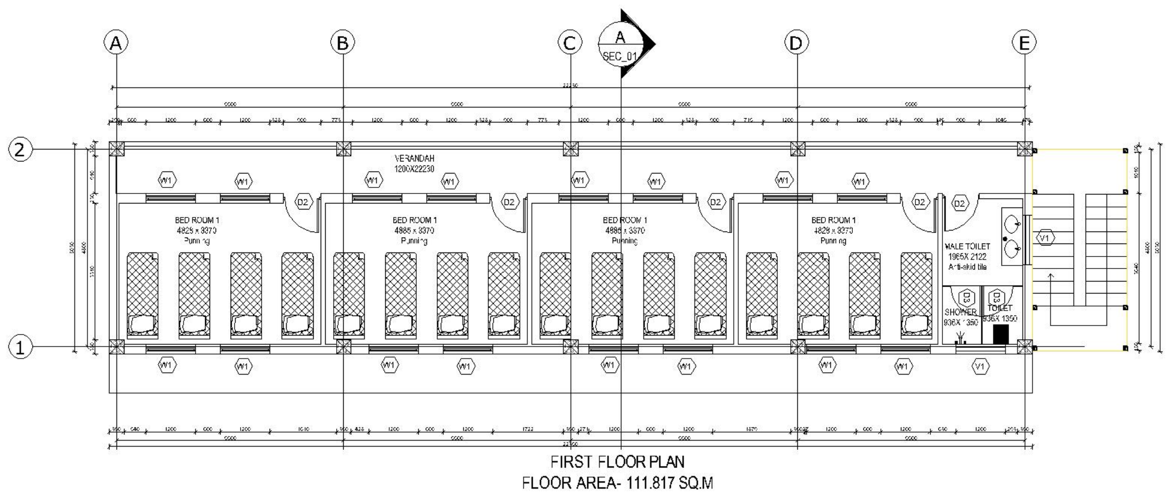


Figure 4 General Layout of the Proposed Building (First Floor Plan)

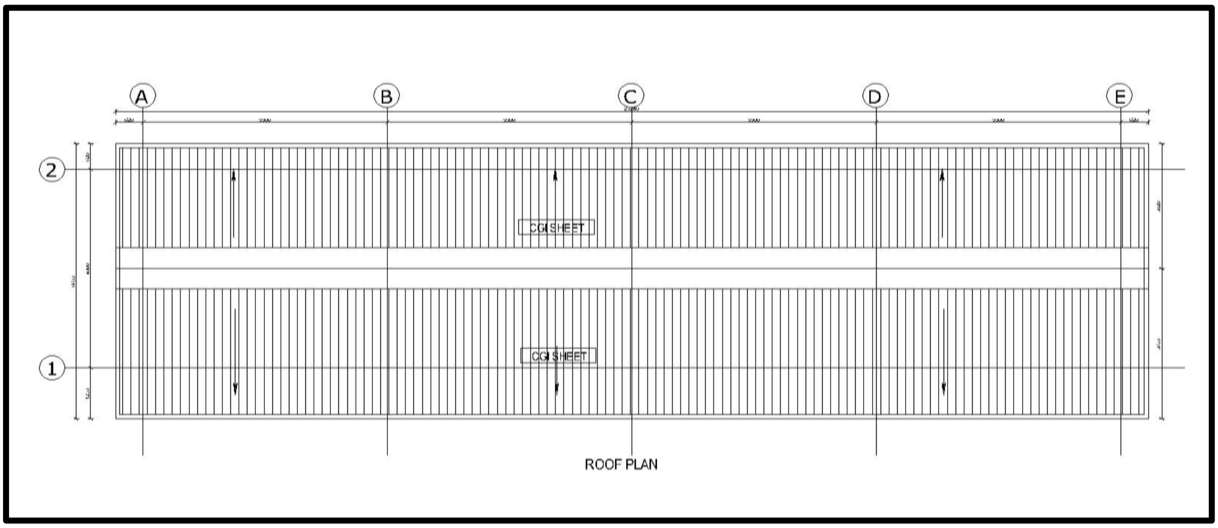
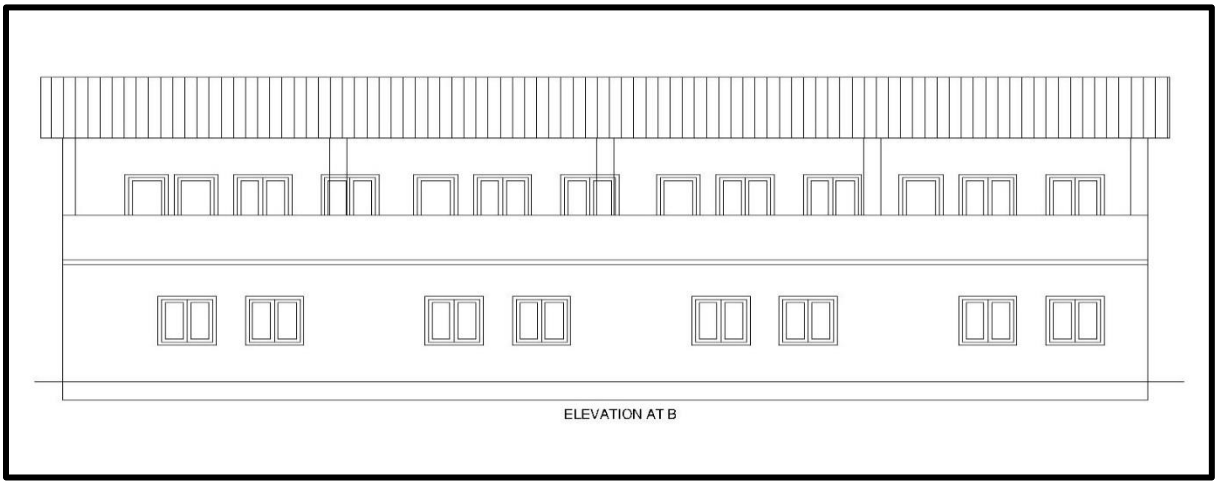


Figure 5 General Layout Plan of the Proposed Building (Roof Floor Plan)



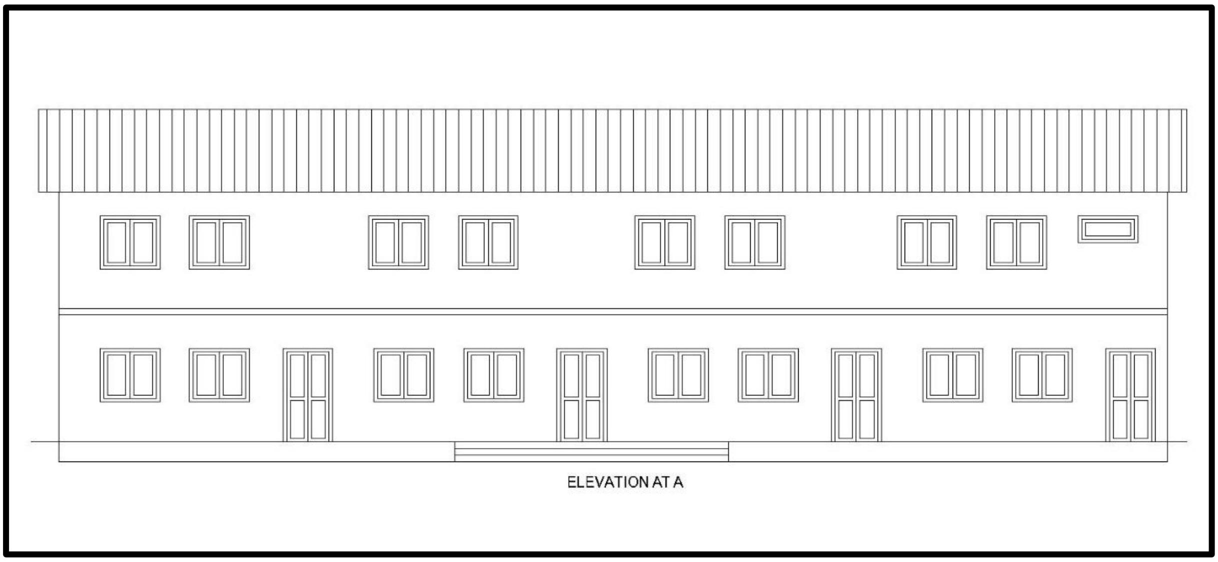


Figure 6 Elevation of the proposed Building

2.6. LOAD CALCULATIONS

2.6.1. Gravity Loads

Gravity loading is primarily due to the self-weight of the structure, superimposed dead load and occupancy of the building. Following loads have been considered for the analysis and design of the building based on the relevant Indian Standards.

2.6.2. Live Loads

The Live Load for building has been adopted as given **IS 875 - Part II** Section I Loads for Institutional buildings.

The following value has been adopted:

SN	Load Set	Load Pattern	Load
			KN/m^2
1	Balcony, passage	Live	4
2	Classroom	Live	4
3	Stair	Live	4
4	Office Room	Live	3
5	Accessible Roof	Live	1.5
6	Toilet Bathroom	Live	2
7	Inaccessible Roof	Live	0.75

2.6.3. Dead Load

The following densities of materials have been assumed:

Density of materials assumed:			
Concrete:	25	N/m^3	IS 875: Part I
Stone Masonry:	22	N/m^3	IS 875: Part I
Mortar Screed:	0.21	N/m^2	IS 875: Part I
Floor finishes:	0.5	N/m^2	IS 875: Part I
½ inch Plaster:	0.225	N/m^2	IS 875: Part I
Maximum finishing load consideration			
Floor finish	1.2,1.5	N/m^2	

Wall Load Calculation

S.No.	Thickness (m)	Height(m)	Beam Depth(m)	Opening (%)	Wall Load (KN/m)	Wall load ETABS(KN/m)
1	0.3	3.0	0.4	0	17.16	17.2
2	0.3	3.0	0.4	30	12.2	12.2
3	0.3	1	(Parapet Wall)			6.6

2.6.4. Seismic Load

2.6.4.1. Seismic Coefficient Method

The basic seismic input shall be determined from NBC 105:2020 based earthquake is used as Design Basis Earthquake in code-based design.

Inertial loads due to earthquake will be applied at the mass centres of each level. These forces would be either calculated manually or auto generated by using the Auto Seismic Loads function of the software ETABS version 2021.0.0 and used for analysis. For all structures, the seismic base will be considered at foundation level.

The Lateral loads for the all building would be resisted by special moment resisting frames.

Equivalent Seismic coefficient method shall be used depending on the building height and geometric configuration as specified in clause 3.2.1 of NBC 105:2020. Appropriate actions would be taken as recommended by NBC code for Structural irregularities. Appropriate percentage of imposed load will be considered in seismic weight calculations as per clause 5.2 of NBC 105:2020.

2.6.4.1.1. Seismic Zoning Factor (Z)

The country is subdivided into different seismic zones based on local seismic hazard. The seismic hazard within zone is assumed to be constant. The value of Z can be obtained from the **table 4-5 (NBC105:2020)** for selected Municipalities.

2.6.4.1.2. Importance classes and Importance Factor (I)

Structure are categorised into three classes depending on the consequences of their loss of function. The importance classes are characterized by an importance factor I which is given in **Table 4-6 (NBC105:2020)**

2.6.4.1.3. The Ductility factor

The ductility factor (R_μ) shall be chosen to be consistent with the structural system and the structural member connection detailing. The value of R_μ for various type of structures are taken from Table **5-2 (NBC105:2020, Cl- 5.3.1)**

2.6.4.1.4. Over strength Factor

The over-strength factor Ω for Ultimate limit state is adopted from Table 5-2 for appropriate structural system. Similarly, the over –strength factor Ω for Serviceability Limit State is also taken from Table 5-2 NBC105:2020(Cl-5.4.1, 5.4.2)

Table 3 Seismic Loading Parameter

Parameter	Value
Zone factor, Z	0.35 (Dhulikhel)
Importance factor	1.25
Soil type	B
Ductility factor	4 (SMRF)
Over strength factor	1.5

2.6.4.2. Base Shear Calculation using NBC 105:2020

2.6.4.2.1. Ultimate limit state (ULS)

SCHOOL STRUCTURE			
BASE SHEAR COEFFICIENT CALCULATION	**DATA**	**UNIT**	**CLAUSE**
Equivalent Static Method for ULS:		**NBC**	**105:2020**
Height of Building (H)	6.00	m	
Location of a Building	Dhulikhel		
Seismic Zoning Factor (Z)	0.35	g	
Type of Building	Schools		
Importance Factor (I)	1.25		
(For Moment Resisting Concrete Frame)			
K_t	0.085		
Aprox Fundamenral Period of Vibration (T)	0.33	sec	
Amplification Factor	1.25		**Clause 5.1.3**
Amplified Period of Vibration (Ta)	0.41	sec	
Fundamental Period of Vibration (Ti)	**0.41**	sec	
Soil Type	C		
Spectral Shape Facter C_h (T)			
For above soil type	C		
Ta	0.10		
Tc	1.00		
Alpha (á)	2.50		
K	1.80		
Hence, Spectral Shape Facter C_h (T)	**2.50**		
Elastic Site Spectra C(T)	**1.09**		**Clause 4.1.1**
Ductility Factor R_μ	4.00		**Clause 5.3**
Over strength Factor Ω_u	1.50		**Clause 5.4**
Horizantal Base Shear Coefficient C_d(T1)	**0.1823**		**Clause 6.1.1**
Seismic Weight of Structure ,W	1837.47	kN	
Horizontal Seismic Base Shear , V	**334.97**	**kN**	**Clause 6.2**
Exponent Related to the structural Peroid, K	**0.95**		**Clause 6.3**

2.6.4.2.2. Serviceability limit state

BASE SHEAR COEFFICIENT CALCULATION	DATA	UNIT	CLAUSE
Equivalent Static Method for SLS:		**NBC**	**105:2020**
Height of Building (H)	6.00	m	
Location of a Building	**Dhulikhel**		
Seismic Zoning Factor (Z)	0.35	g	
Type of Building	**Schools**		
Importance Factor (I)	1.25		
(For Moment Resisting Concrete Frame)			
K_t	0.085		
Aprox Fundamental Period of Vibration (T)	0.33	sec	
Amplification Factor	1.25		**Clause 5.1.3**
Amplified Period of Vibration (Ta)	0.41	sec	
Fundamental Period of Vibration (Ti)	**0.41**	sec	
Soil Type	**C**		
Spectral Shape Facter C_h (T)			
For above soil type	C		
Ta	0.10		
Tc	1.00		
Alpha (á)	2.50		
K	1.80		
Hence,Spectral Shape Facter C_h (T)	**2.50**		
Elastic Site Spectra Cs(T)	**0.22**		**Clause 4.1.1**
Ductility Factor R_u	4.00		**Clause 5.3**
Over strength Factor Ω_u	1.25		**Clause 5.4**
Horizantal Base Shear Coefficient C_d(T1)	**0.1752**		**Clause 6.1.1**
Seismic Weight of Structure ,W	1837.47	kN	
Horizontal Seismic Base Shear , V	**321.92**	**kN**	**Clause 6.2**
Exponent Related to the structural Peroid, K	**0.95**		**Clause 6.3**

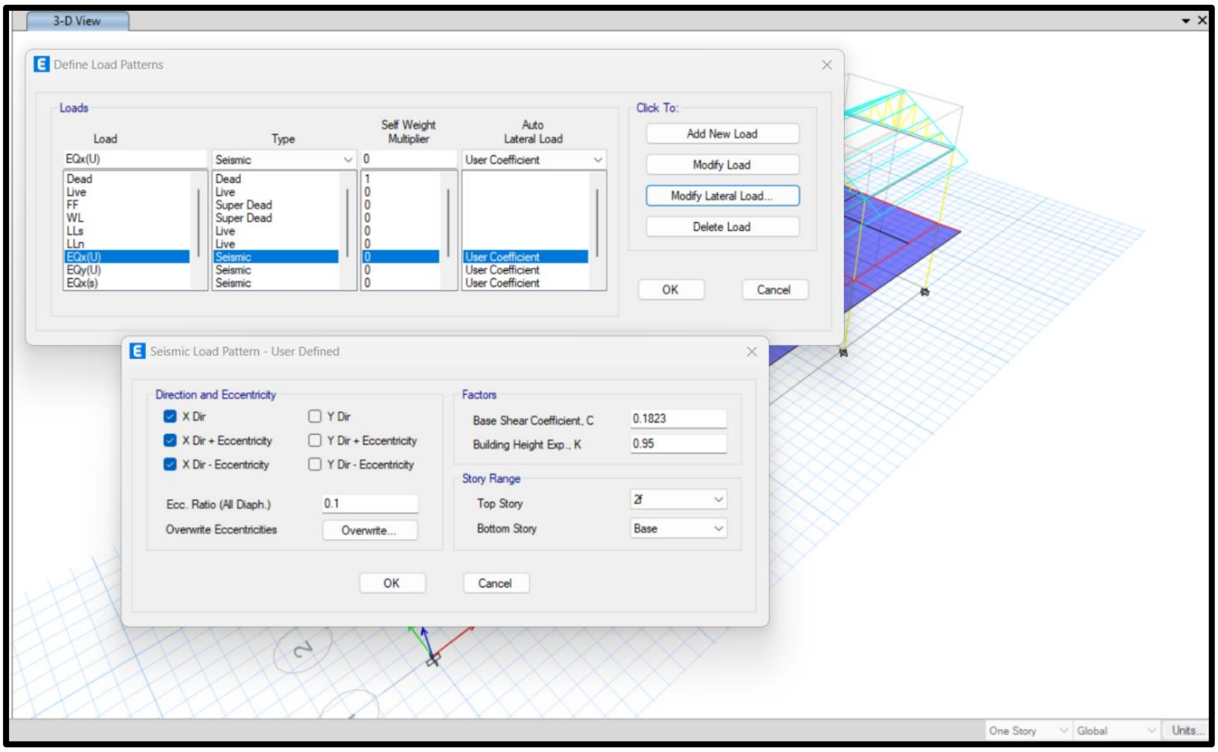


Figure 7 Static Loading Condition (Ultimate Limit state)

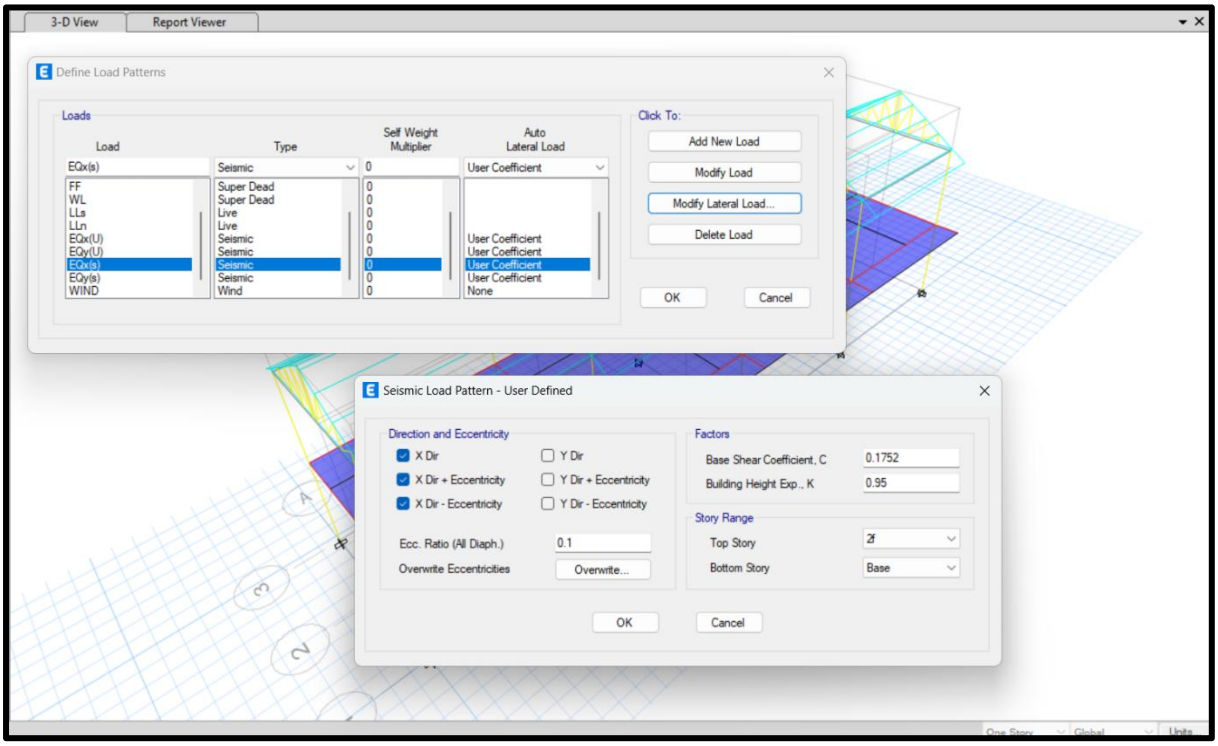


Figure 8 Static Loading Condition (Serviceability Limit state)

2.6.4.3. Dynamic Analysis:

Linear dynamic analysis was performed to obtain the design later force i.e. design seismic base shear and its distribution to different levels along the height of the building, and to various lateral load resisting elements by response spectrum method with use of design acceleration spectrum specified. The spectral shape factor for relevant soil type is obtain from the Figure- 4-2. And equation given in Cl-4.1(2).

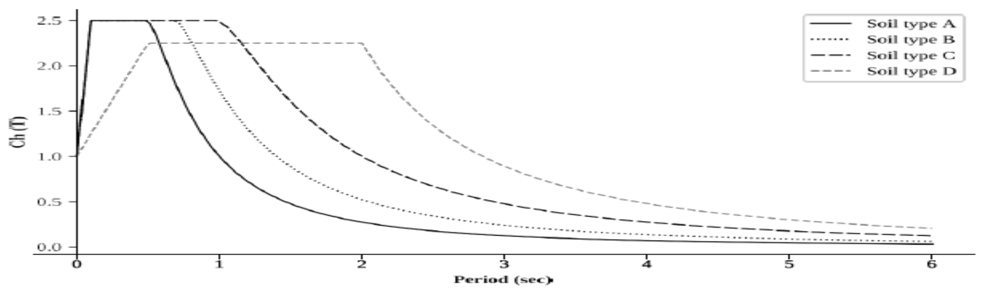


Figure 4-2 Spectral Shape Factor, $C_h(T)$ for Modal Response Spectrum Method, Nonlinear Time History Analysis , Vertical Loading and Parts and Components

$$C_h(T) = \begin{cases} 1 + (\alpha - 1) \times \frac{T}{T_a} \; if \; T < T_a \\ \alpha \; if \; T_a \le T \le T_c \\ \alpha \left[K + (1-K)\left(\frac{T_c}{T}\right)^2\right]\left(\frac{T_c}{T}\right)^2 \; if \; T_c \le T \le 6 \end{cases} \quad ...4.1(2)$$

Where,

α - peak spectral acceleration normalized by PGA

T_a and T_c - the lower and upper periods of the flat part of the spectrum

K – Coefficient that controls the descending branch of the spectrum

Figure 9 Spectral Shape Factor, C_h (T) for Model Response Spectrum Method

2.6.5. Wind Loads

Wind load has only applied on roof truss member which is calculated as follow:

Wind Loads act on the Roof of the structure.

Calculation of Wind Load is as follows:
We have,
Span = 4.8 m
Pitch = Rise/Span = 1.5/4.8= 0.3125
Height = 7.7 m
Building is situated in Nepal.

We have,
Design wind force on roof (F) = (Cpe-Cpi)*Pd*A
And, Design wind Pressure (F/A) = (Cpe-Cpi)*Pd
where,

Cpe = External Pressure Coefficient
Cpi = Internal Pressure Coefficient
= 0.6 $(Vz)^2$ N/m^2

where,

Vz = Design wind velocity in m/sec = $K_1*K_2*K_3*Vb$

From Table B-10 of Appendix B (IS 875-Part III)

Vb = 47 m/sec (For Nepal), and

K_1 = Risk coefficient

K_2 = Terrain, height and structure size factor

K_3 = Topography factor

(i) Taking the probable life of the structure as 100 years and for Vb = 47 m/sec, we have $K_1 = 1.07$ (Clause 5.3.1, IS 875-Part III)

(ii) Since, the surrounding has well scattered obstructions having height generally between 1.5 m to 10 m; it belongs to Category 2 structure.
The maximum dimension of the building is 13.716 m, it belongs to Class B.
From Table 2, $K_2 = 0.98$ (Clause 5.3.2, IS 875-Part III)

(iii) Since the terrain is considerably flat,
We have, $K_3 = 1$ (Clause 5.3.3, IS 875-Part III)

Hence, $K_1*K_2*K_3 = 1.07*0.98*1 = 1.0486$

$\therefore Vz = 1.0486*47$ m/s = 49.28 m/sec

$\therefore Pd = 0.6\ (Vz)^2 = 1457.11 N/m^2$

Roof angle or slope of roof = $\tan^{-1}(Rise/(span/2)) = \tan^{-}1(1.5/2.4) \approx 32^0$

And h/w = 6/4.8 = 1.25

Here, we have to find the design wind pressure on the sloping roof for two conditions

Condition 1: When wind direction is normal to the ridge ($\theta = 0^0$)

For windward side (EF) (Front side)

From Table 5 of IS 875-Part III,

For $0.5 \leq h/w \leq 1.5$ and wind angle $\theta = 0^0$

At, Roof angle $\alpha = 30^0$, Cpe = -0.2

Roof angle $\alpha = 45^0$, Cpe = 0.2

$\therefore$ Roof angle $\alpha = 32^0$, Cpe = -0.1467

For medium permeability,

Wall opening = 5-20% of wall area

$\therefore$ From IS 875-Part III, Clause 6.2.3.2, Internal pressure coefficient = ±0.5

$\therefore$ Design wind pressure = (Cpe-Cpi)*Pd = (-0.1467-0.5)* 1457.11= -942.31 N/m^2

And Design wind pressure = (Cpe-Cpi)*Pd = (-0.1467+0.5)* 1457.11= -514.79 N/m^2

For leeward side (GH) (Back side)

From Table 5 of IS 875-Part III,

For $0.5 \leq h/w \leq 1.5$ and wind angle $\theta = 0^0$

At, Roof angle $\alpha = 30^0$, Cpe = -0.6

Roof angle $\alpha = 45^0$, Cpe = -0.6

$\therefore$ Roof angle $\alpha = 32^0$, Cpe = -0.6

For medium permeability,

Wall opening = 5-20% of wall area
∴ From IS 875-Part III, Clause 6.2.3.2, Internal pressure coefficient = ±0.5

∴Design wind pressure = (Cpe-Cpi)*Pd = (-0.6-0.5)*1457.11 = -1602.82 N/m^2
And Design wind pressure = (Cpe-Cpi)*Pd = (-0.6+0.5)*1457.11 = -145.711 N/m^2

Condition 2: When wind direction is parallel to the ridge ($\theta = 90^0$)
For windward side (EG) (Front side)
From Table 5 of IS 875-Part III,
For $0.5 \leq h/w \leq 1.5$ and wind angle $\theta = 90^0$
At, Roof angle $\alpha = 30^0$, Cpe = -0.8
Roof angle $\alpha = 45^0$, Cpe = -0.8
∴ Roof angle $\alpha = 32^0$, Cpe = -0.8

For medium permeability,
Wall opening = 5-20% of wall area
∴ From IS 875-Part III, Clause 6.2.3.2, Internal pressure coefficient = ±0.5

∴Design wind pressure = (Cpe-Cpi)*Pd = (-0.8-0.5)*1457.11 = -1894.24 N/m^2
And Design wind pressure = (Cpe-Cpi)*Pd = (-0.8+0.5)*1457.11 = -437.133 N/m^2

For leeward side (FH) (Back side)
From Table 5 of IS 875-Part III,
For $0.5 \leq h/w \leq 1.5$ and wind angle $\theta = 90^0$
At, Roof angle $\alpha = 30^0$, Cpe = -0.8
Roof angle $\alpha = 45^0$, Cpe = -0.8
∴ Roof angle $\alpha = 32^0$, Cpe = -0.8

For medium permeability,
Wall opening = 5-20% of wall area
∴ From IS 875-Part III, Clause 6.2.3.2, Internal pressure coefficient = ±0.5

∴Design wind pressure = (Cpe-Cpi)*Pd = (-0.8-0.5)*1457.11 = -1894.24 N/m^2
And Design wind pressure = (Cpe-Cpi)*Pd = (-0.8+0.5)*1457.11 = -437.133 N/m^2

Hence, Design wind pressure for uplift = Maximum value of negative pressure
= -1894.24 N/mm^2
And, Design wind pressure for downward = -145.711 N/mm^2

Here, Maximum spacing of purlin = 0.680 m
Hence, load to be applied on purlin = (1894.24 - 437.133) * 0.680 N/m
= 990.83 N/m = 0.99083 kN/m (uplift).

2.7. Soft Storey

A soft storey can be detected by comparing the stiffness of adjacent storeys.

Soft storeys are present in buildings with open fronts on the ground floor or tall storeys.

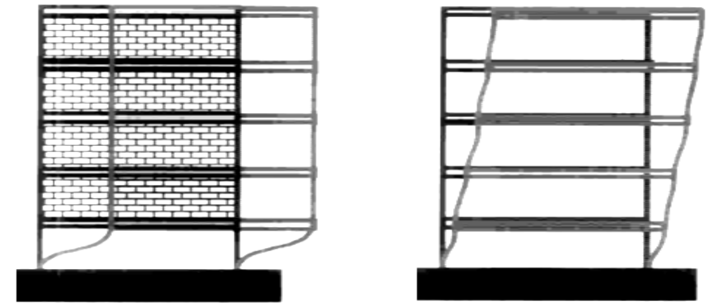


Figure 10 Open Ground Storey and Bare Frame

There is no soft storey in the proposed building since no storey level has change in mass and stiffness in considerate amount.

2.8. LOAD COMBINATIONS

When Seismic load effect is combined with other load effects, the following load combination are adopted. (Cl_3.6.1, NBC105:2020)

2.8.1. Static load combination for Limit State Method

The static load condition according to NBC 105:2020 clause 3.6 are given below:

- 1.2DL+1.5LL
- DL + λLL ± EQx
- DL + λLL ± EQy

Where,

DL: Dead Load, LL: Live Load
EQX: Earthquake Load along X-axis
EQY: Earthquake Load along Y-axis
λ= 0.6 for storage facilities
=0.3 for other facilities

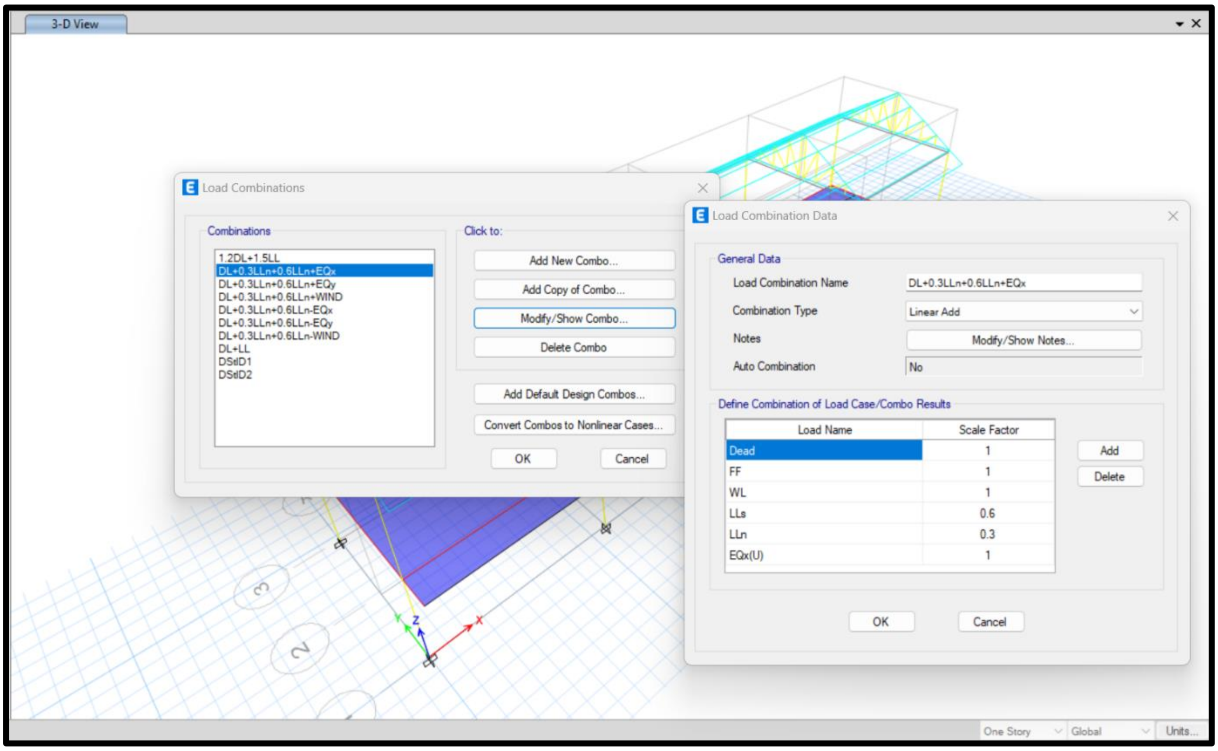


Figure 11 Various Static Load Combination

2.8.2. Dynamic Load Combination

The dynamic Load conditions is not considered in this building.

The number of modes to be used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90 Percent of the total seismic mass and missing mass correction beyond 33 Percent.

Percentage of live load (storage type) to be taken for calculating seismic weight =60% for live load intensity and live Load for other purpose is taken as 30%for live load intensity [Table 5.1, NBC 105:2020

The live load on roof need not be considered for calculating the seismic weight of the building.

For the purpose of analysis, seismic forces are applied in the model of the building in ETABS. Hence, the manual calculations of seismic weight, base shear and the seismic forces have not been shown. However, the ETABS output for the Seismic Weight and Base Shear is shown.

3.0. ANALYSIS AND DESIGN PROCEDURE

Space frame analysis using **ETABS 2021.0.0** software has been undertaken to obtain refined results for all load combinations in accordance with Indian Standards

The RCC design shall be based on IS: 456-2000 Code of practice for plain and reinforced concrete, following Limit state philosophy. Structural design for typical members has been done for the combination of loads that produces maximum stress in the structural elements, and in turn requires maximum reinforcing steel provisions.

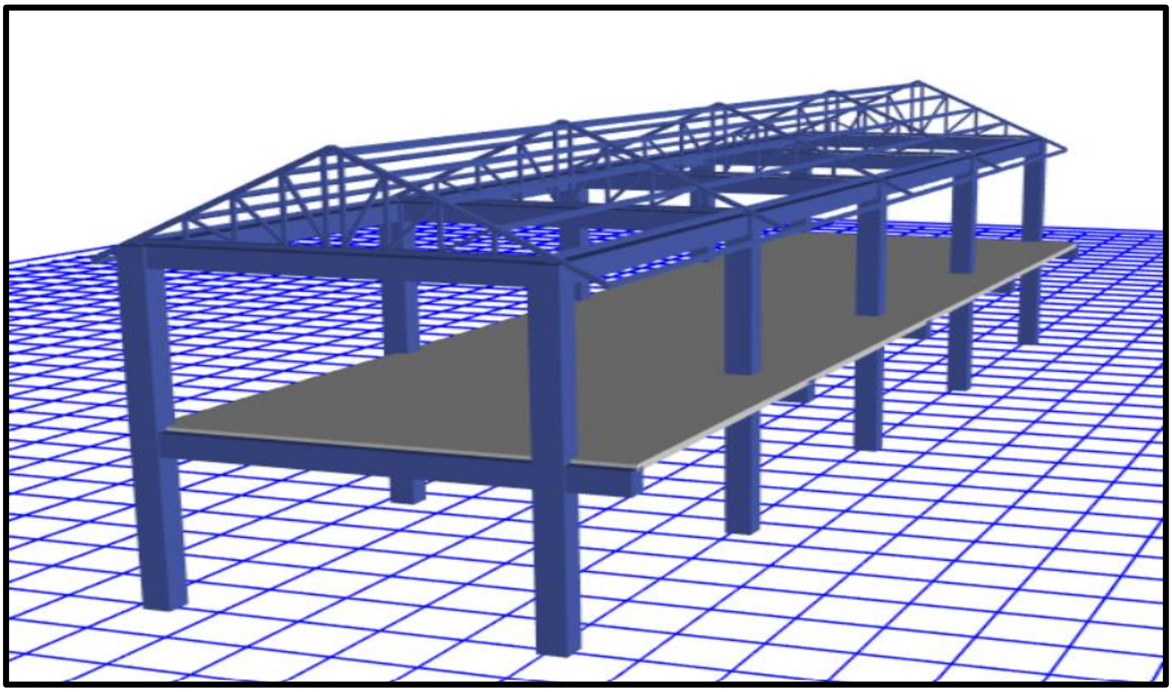
The design of Columns and Beams is done directly using **ETABS 2021.0.0**design software, foundation is designed by Worksheets. The design of Slab is done by Worksheets in Excel. The size of columns and beams are provided as per requirement.

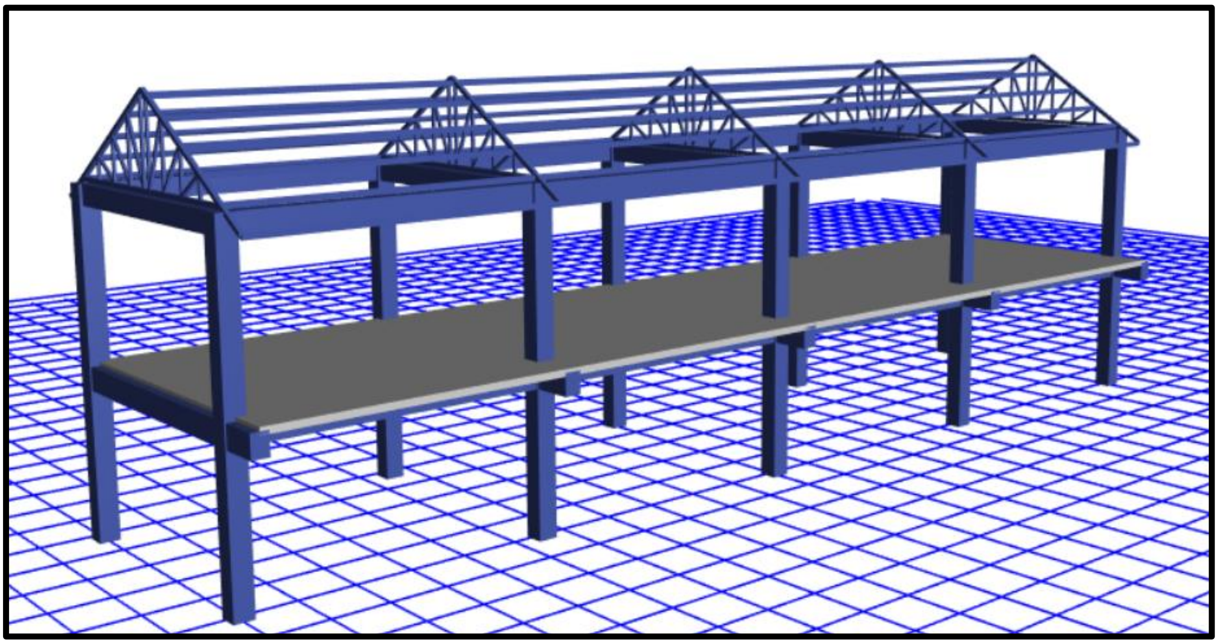
General Information on Structural Elements of the Building:

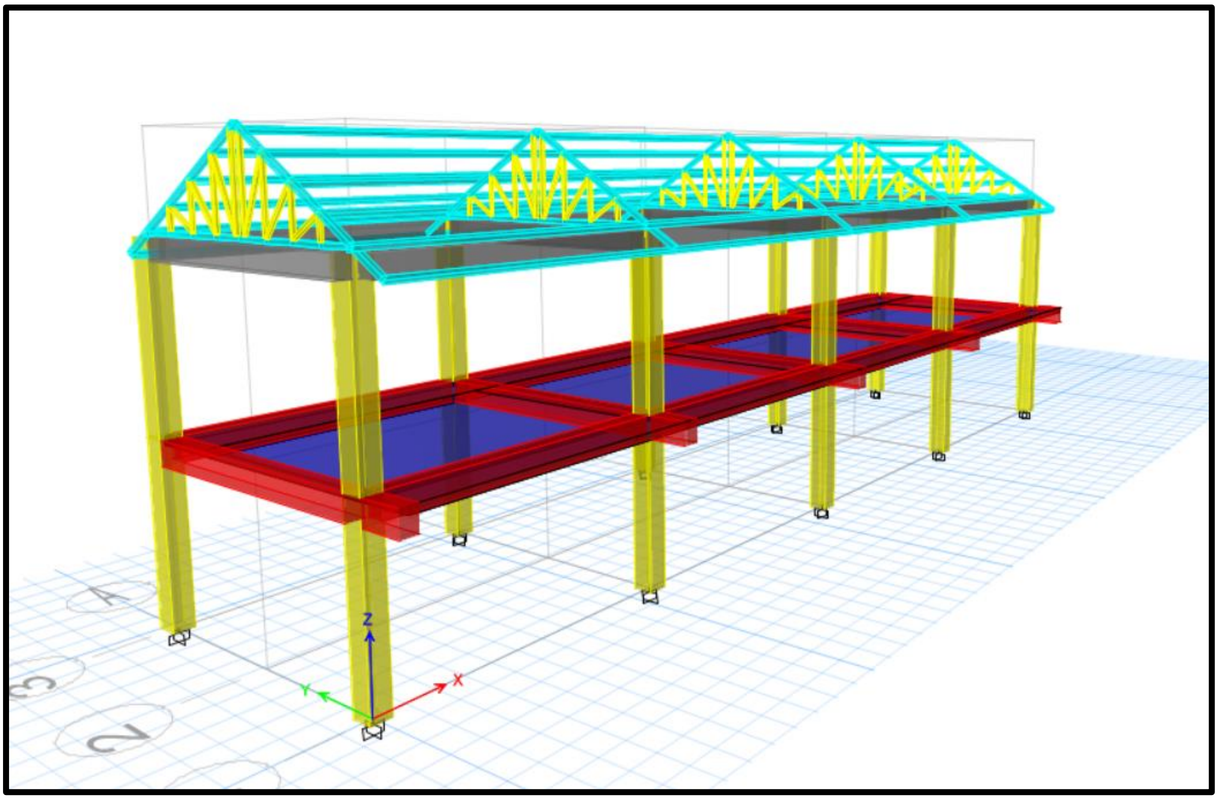
Elements	Description	Grade of Concrete	Remarks
Column	350x350 mm	M20	
Main Beam	300x400 mm	M20	
Plinth Beam	250 mm X 300 mm	M20	
Main Slab Waist Slab	125 mm	M20 M20	
Foundation	Isolated and Combined Footing	M20	From Soil test Report, Bearing Capacity of Soil = 120 KN/m2 & Settlement =25 mm.

4.0. MODELING IN ETABS 2021.0.0

4.1. 3D VIEW OF THE BUILDING







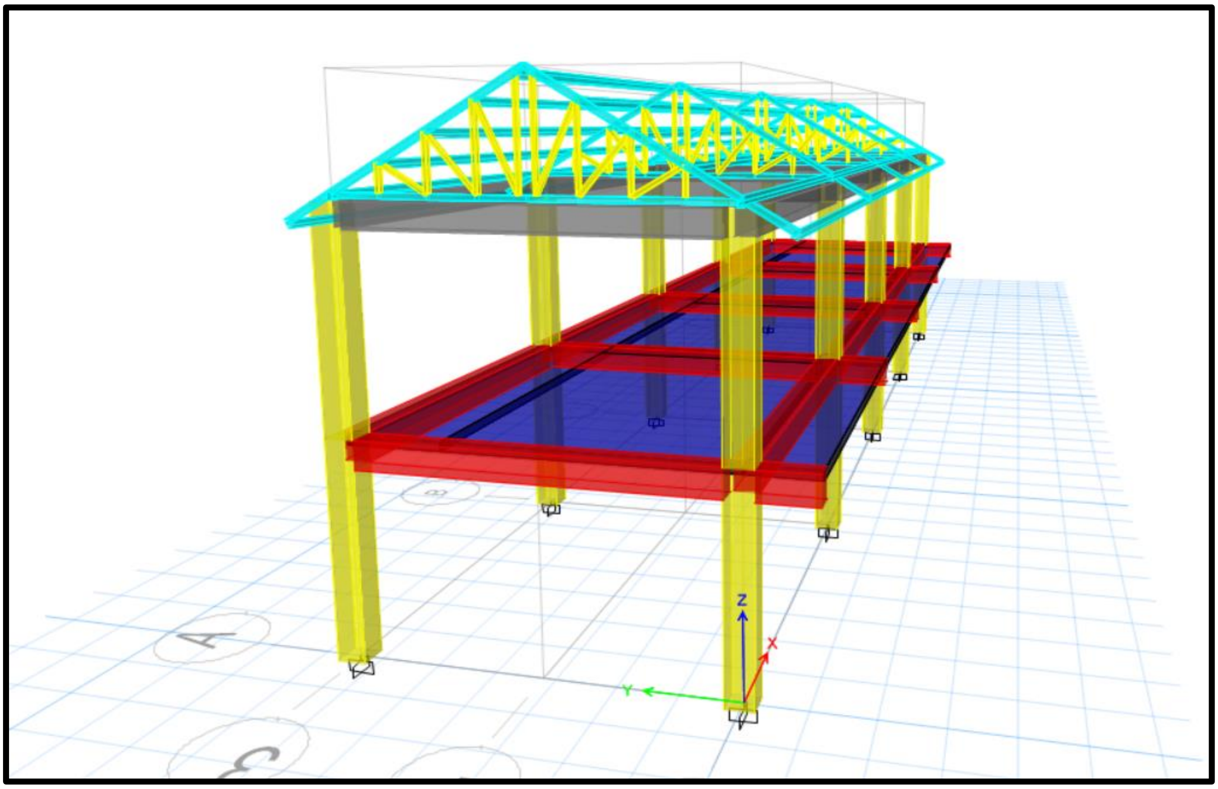


Figure 12 3D Rendered View of the Building

4.2. LOAD APPLICATION

4.2.1. Floor Finish

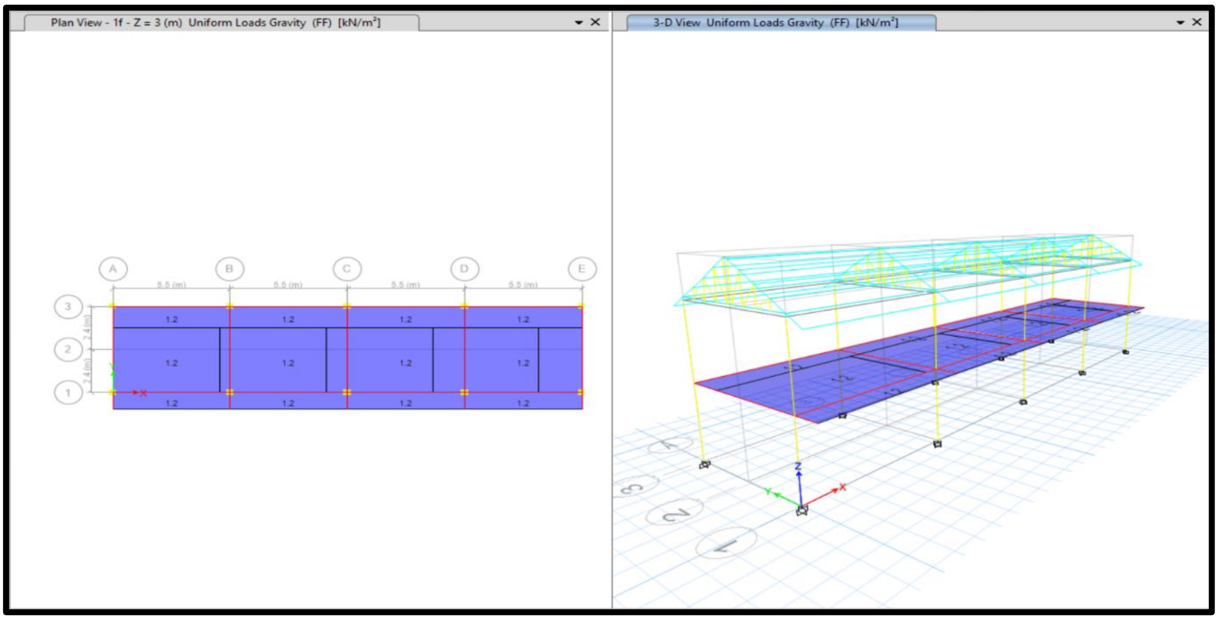


Figure 13 Floor Finish Load in the Building

4.2.2. Live load

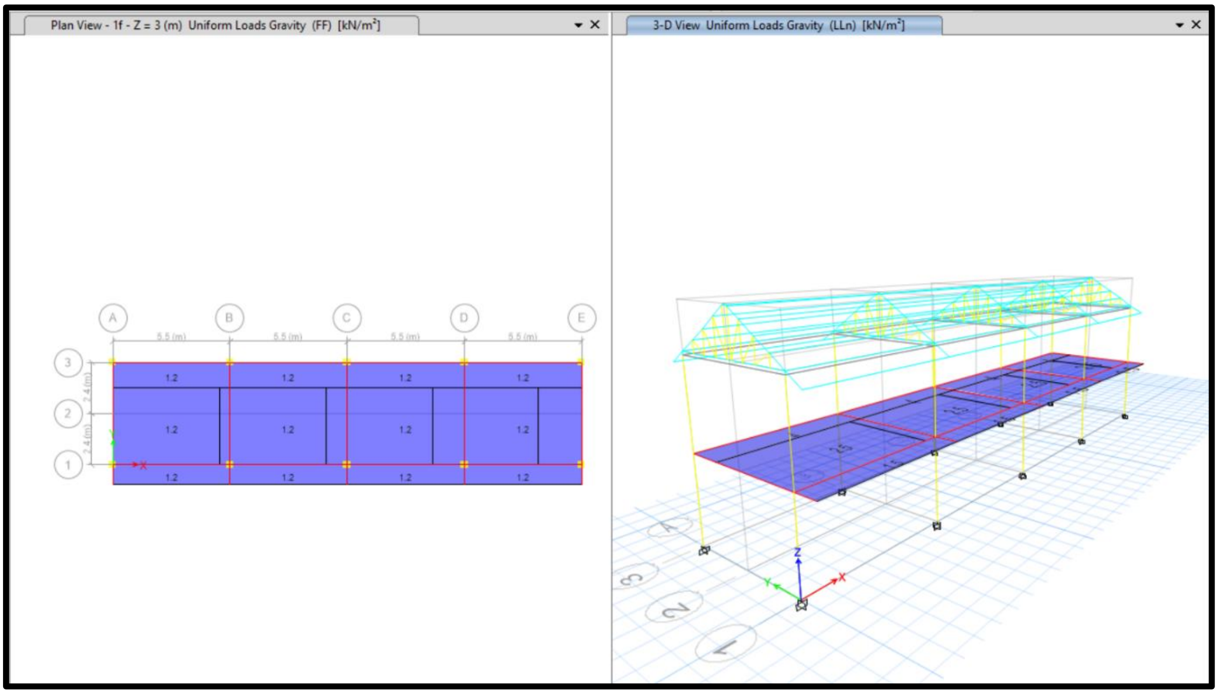


Figure 14 Live Load (LLn) in the Building

4.2.3. Wall Load

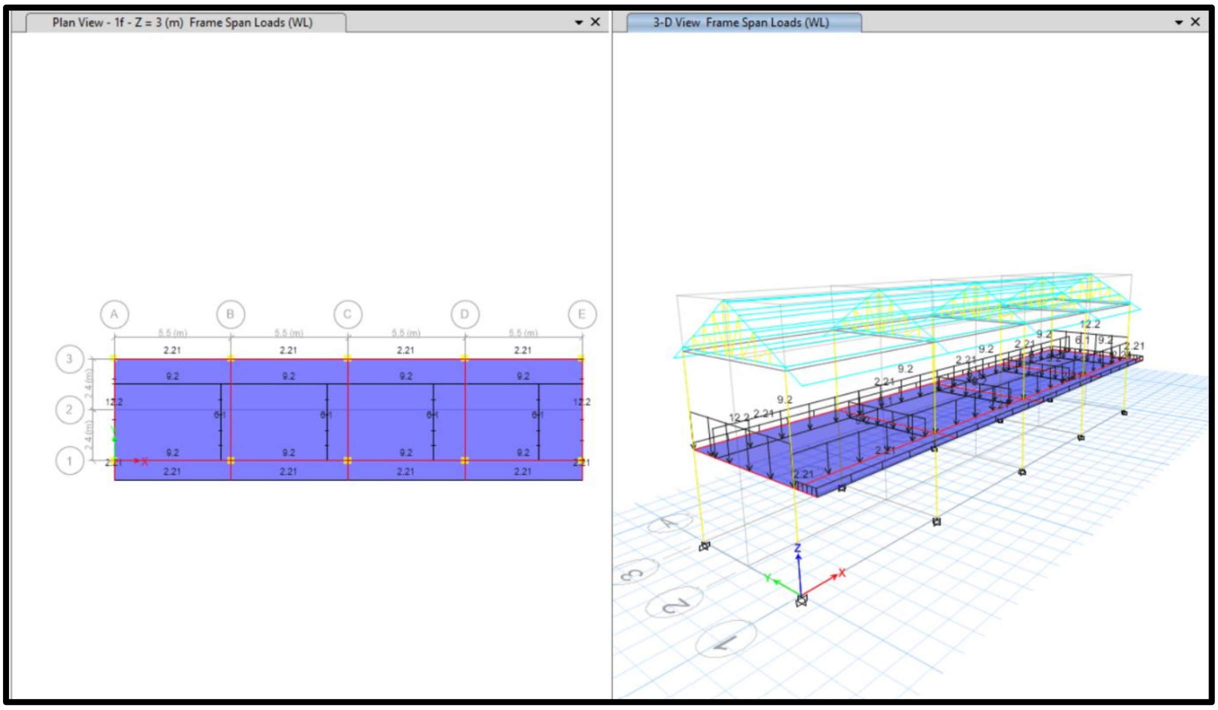


Figure 15 Wall Load in the Building

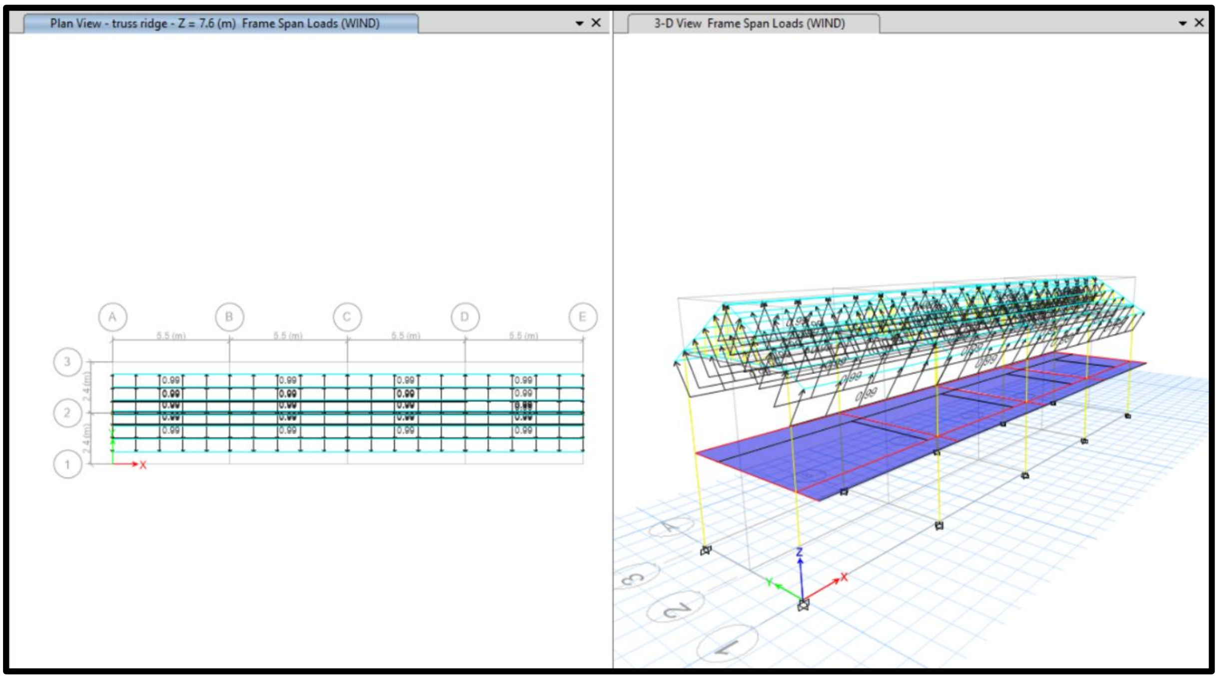


Figure 16 Wind Load in the Building

5.0. DESIGN OUTPUT AND STRUCTURAL CHECKS

5.1. AUTO SESMIC LOAD

5.1.1. Auto seismic load along x-x direction

5.1.1.1. Ultimate Limit State

This calculation presents the automatically generated lateral seismic loads for load pattern EQx(U) using the user input coefficients, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 10% for all diaphragms

Factors and Coefficients

Equivalent Lateral Forces

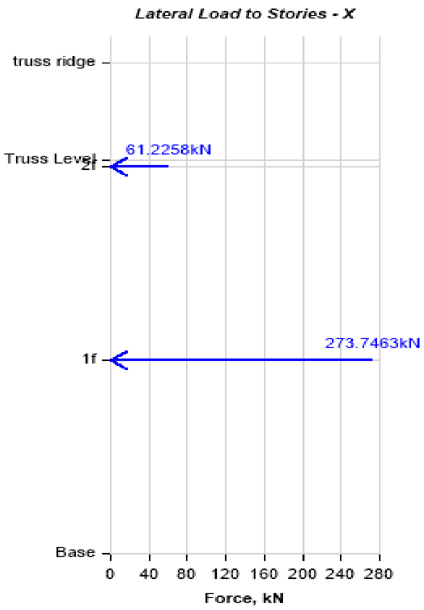
Base Shear Coefficient, C $C = 0.1823$

Base Shear, V $V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
X	0	0	1837.4771	334.9721
X + Ecc. Y	0	0	1837.4771	334.9721
X - Ecc. Y	0	0	1837.4771	334.9721

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
truss ridge	7.6	0	0
Truss Level	6.1	0	0
2f	6	61.2258	0
1f	3	273.7463	0
Base	0	0	0

5.1.1.2. Serviceability Limit State

This calculation presents the automatically generated lateral seismic loads for load pattern EQx(s) using the user input coefficients, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 10% for all diaphragms

Factors and Coefficients

Equivalent Lateral Forces

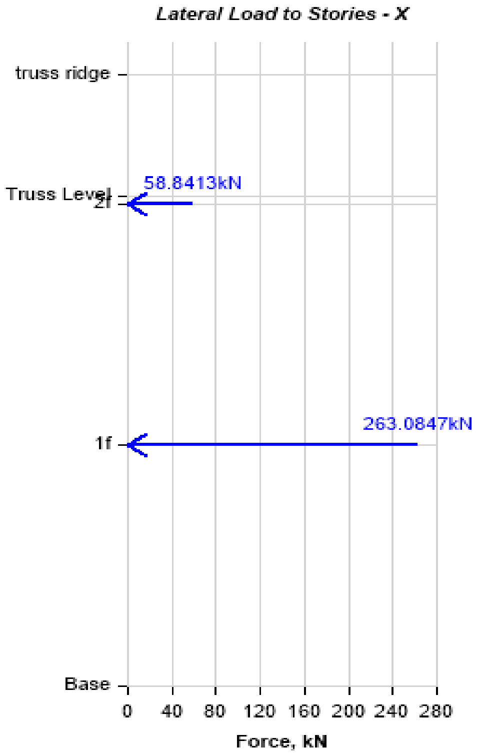
Base Shear Coefficient, C $C = 0.1752$

Base Shear, V $V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
X	0	0	1837.4771	321.926
X + Ecc. Y	0	0	1837.4771	321.926
X - Ecc. Y	0	0	1837.4771	321.926

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
truss ridge	7.6	0	0
Truss Level	6.1	0	0
2f	6	58.8413	0
1f	3	263.0847	0
Base	0	0	0

5.1.2. Auto seismic load along Y-Y direction

5.1.2.1. Ultimate Limit State

This calculation presents the automatically generated lateral seismic loads for load pattern EQy(U) using the user input coefficients, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 10% for all diaphragms

Factors and Coefficients

Equivalent Lateral Forces

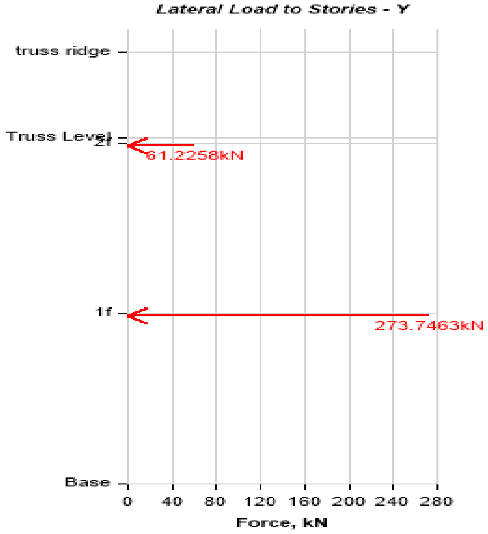
Base Shear Coefficient, C $\quad C = 0.1823$

Base Shear, V $\quad V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
Y	0	0	1837.4771	334.9721
Y + Ecc. X	0	0	1837.4771	334.9721
Y - Ecc. X	0	0	1837.4771	334.9721

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
truss ridge	7.6	0	0
Truss Level	6.1	0	0
2f	6	0	61.2258
1f	3	0	273.7463
Base	0	0	0

5.1.2.2. Serviceability Limit State

This calculation presents the automatically generated lateral seismic loads for load pattern EQy(s) using the user input coefficients, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 10% for all diaphragms

Factors and Coefficients

Equivalent Lateral Forces

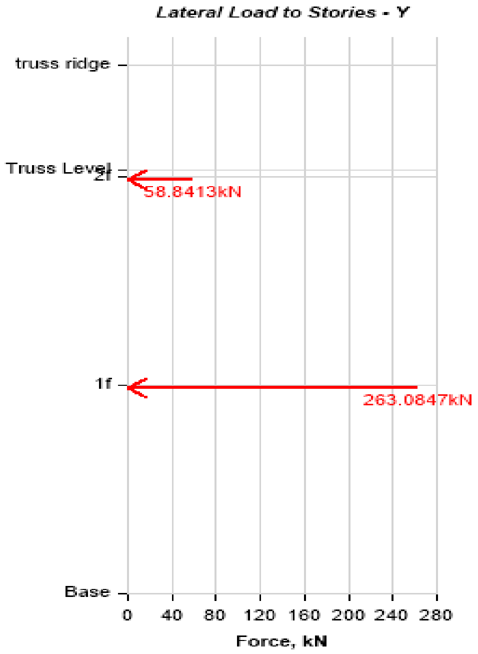
Base Shear Coefficient, C $C = 0.1752$

Base Shear, V $V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
Y	0	0	1837.4771	321.926
Y + Ecc. X	0	0	1837.4771	321.926
Y - Ecc. X	0	0	1837.4771	321.926

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
truss ridge	7.6	0	0
Truss Level	6.1	0	0
2f	6	0	58.8413
1f	3	0	263.0847
Base	0	0	0

5.2. AXIAL FORCE DIAGRAM

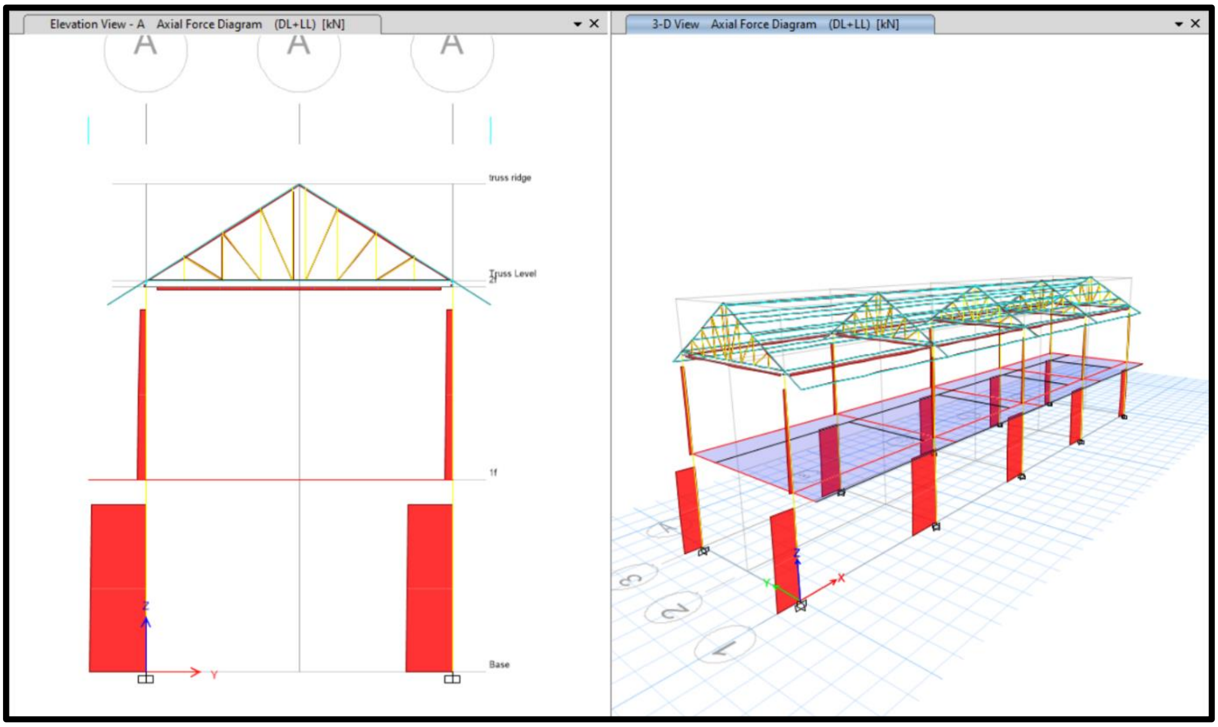


Figure 17 Axial Force Diagram

5.3. SHEAR FORCE DIAGRAM

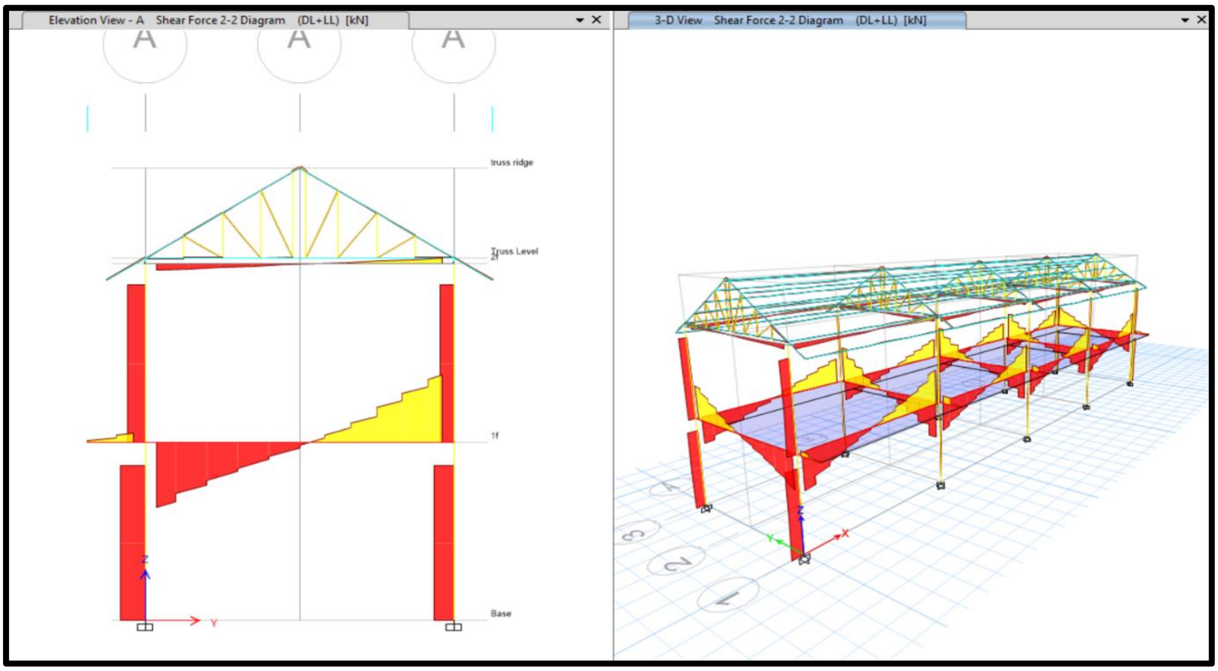


Figure 18 Shear Force Diagram

5.4. BENDING MOMENT DIAGRAM

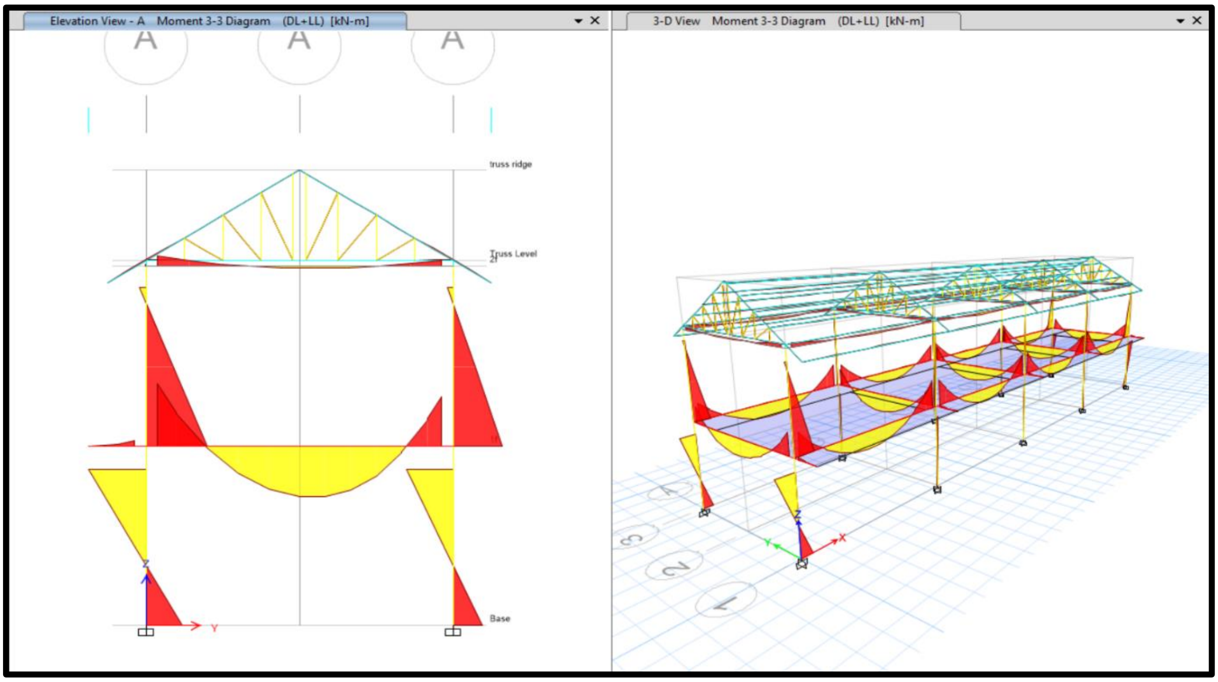


Figure 19 Bending Moment Diagram

5.5. MODEL MASS PARTICIPATION RATIO

A sufficient number of modes shall be included in the analysis at least 90% of the total seismic weight in the direction of lateral force.

TABLE: Modal Participating Mass Ratios									
Case	Mode	Period	UX	UY	SumUX	SumUY	SumRX	SumRY	SumRZ
		sec							
Modal	1	0.406	0.7251	0.0002	0.7251	0.0002	0.00001892	0.1949	0.0061
Modal	2	0.398	0.0002	0.9428	0.7253	0.9431	0.0953	0.195	0.0071
Modal	3	0.362	0.0002	0.001	0.7255	0.9441	0.0955	0.2032	0.931
Modal	4	0.328	0.2371	0.000002005	0.9626	0.9441	0.0955	0.2808	0.9411
Modal	5	0.165	0	0.0189	0.9626	0.963	0.3791	0.2808	0.9411
Modal	6	0.161	0.00002241	6.245E-07	0.9626	0.963	0.3791	0.2814	0.9544
Modal	7	0.154	0	0.0152	0.9626	0.9782	0.62	0.2814	0.9544
Modal	8	0.14	0.00001668	0.0218	0.9626	1	0.9816	0.2817	0.9544
Modal	9	0.14	0.0316	0.0000206	0.9943	1	0.9819	0.8786	0.9548
Modal	10	0.139	0.0049	0.000003944	0.9991	1	0.9819	0.9814	0.9564
Modal	11	0.132	0.0005	0.0000128	0.9996	1	0.9821	0.9866	1
Modal	12	0.093	0.0004	0	1	1	0.9821	0.9999	1

Figure 20 Model Mass Participation Ratio

90% mode participation in exactly 04 modes
Corresponding Time period (T) = 0.328 secs
Corresponding frequency (f) = 1/T = 3.049Hz
As per NBC 105:2020 Clause 7.3, f<33 Hz, which is OK

5.6. TORSONAL IRREGULARITY CHECK

Torsion irregularity is considered to exist where the maximum horizontal displacement of any floor in the direction of the lateral force (applied at the center of mass) at one end of the story is more than 1.5 times its minimum horizontal displacement at the far end of the same story in that direction.

Table 4 Torsional Irregularity Check

TABLE: Story Max Over Avg Displacements								
Story	**Output Case**	**Case Type**	**Step Type**	**Step Number**	**Maximum**	**Average**	**Ratio**	**Check**
					mm	mm		<1.5
1f	EQx(U)	LinStatic	Step By Step	1	6.13	6.076	1.009	OK
1f	EQx(U)	LinStatic	Step By Step	2	6.085	6.078	1.001	OK
1f	EQx(U)	LinStatic	Step By Step	3	6.19	6.075	1.019	OK
1f	EQy(U)	LinStatic	Step By Step	1	6.403	6.34	1.01	OK
1f	EQy(U)	LinStatic	Step By Step	2	7.488	6.34	1.181	OK
1f	EQy(U)	LinStatic	Step By Step	3	7.362	6.34	1.161	OK

TABLE: Story Max Over Avg Displacements								
Story	**Output Case**	**Case Type**	**Step Type**	**Step Number**	**Maximum**	**Average**	**Ratio**	**Check**
					mm	mm		<1.5
1f	EQx(s)	LinStatic	Step By Step	1	5.892	5.84	1.009	OK
1f	EQx(s)	LinStatic	Step By Step	2	5.848	5.841	1.001	OK
1f	EQx(s)	LinStatic	Step By Step	3	5.949	5.839	1.019	OK
1f	EQy(s)	LinStatic	Step By Step	1	6.154	6.093	1.01	OK
1f	EQy(s)	LinStatic	Step By Step	2	7.196	6.093	1.181	OK
1f	EQy(s)	LinStatic	Step By Step	3	7.076	6.093	1.161	OK

5.7. MAXIMUM STOREY DISPLACEMENT

5.7.1. Ultimate Limit state

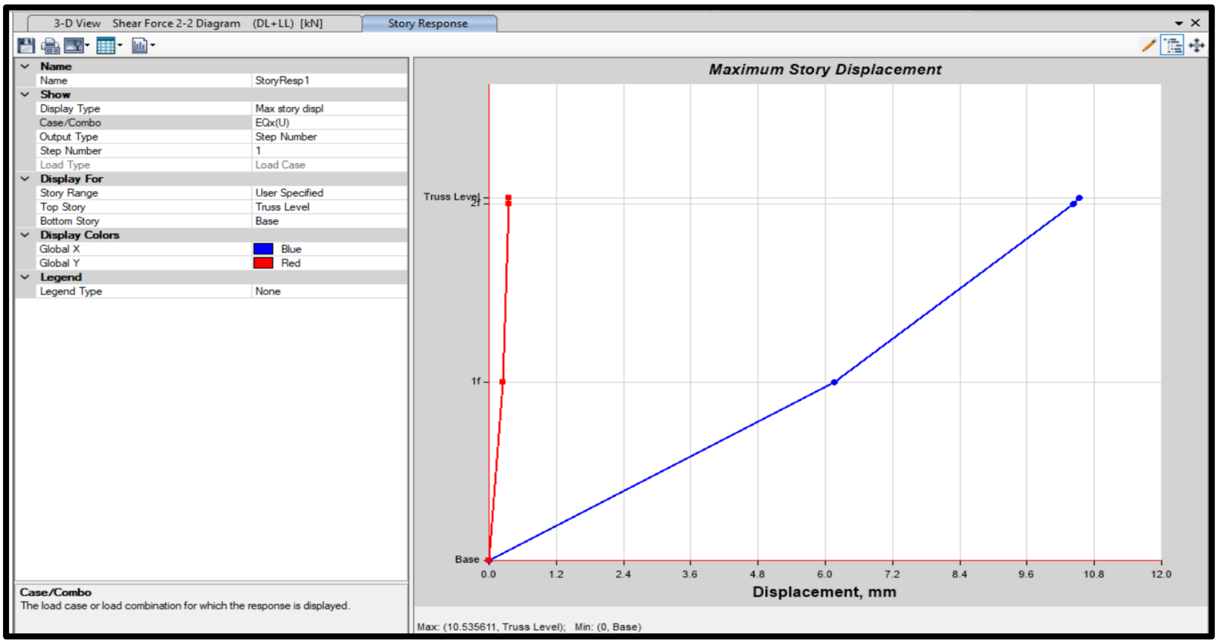


Figure 21 Response Plot showing Maximum Storey Displacement due to EQX(u)

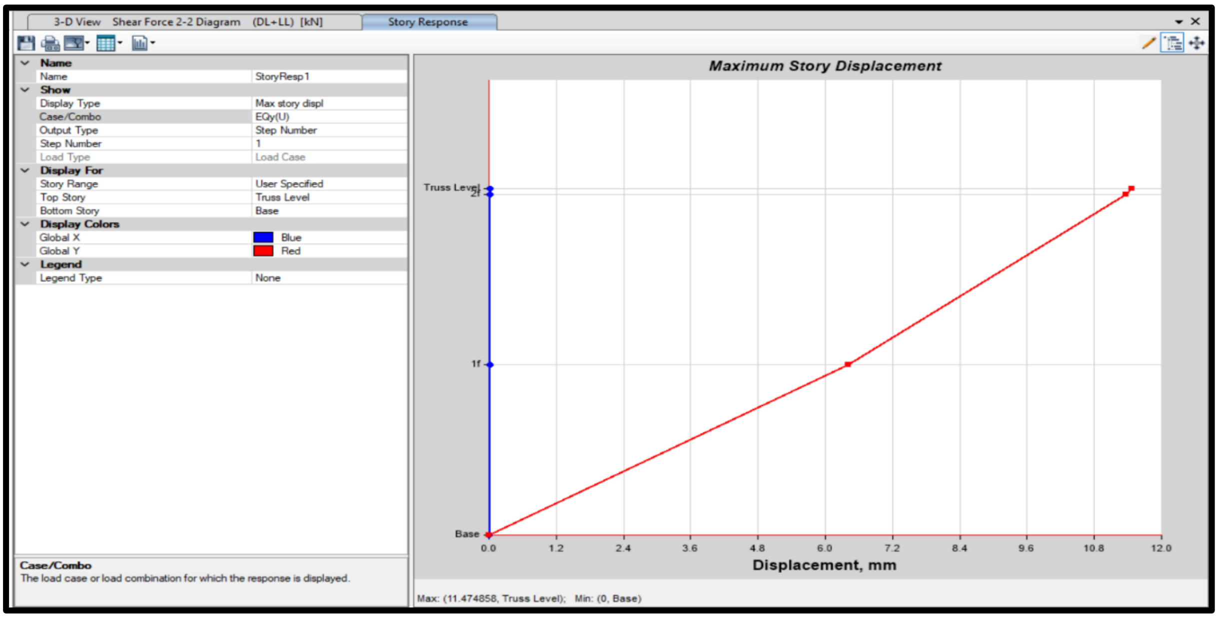


Figure 22Response Plot showing Maximum Storey Displacement due to EQY(u)

Permissible displacement = 0.025 /4 X 6.0 X 1000 = **37.5mm**
Actual maximum displacement = **11.47 mm**
Permissible displacement > Actual displacement **Hence Safe**

5.7.2. Serviceability Limit State

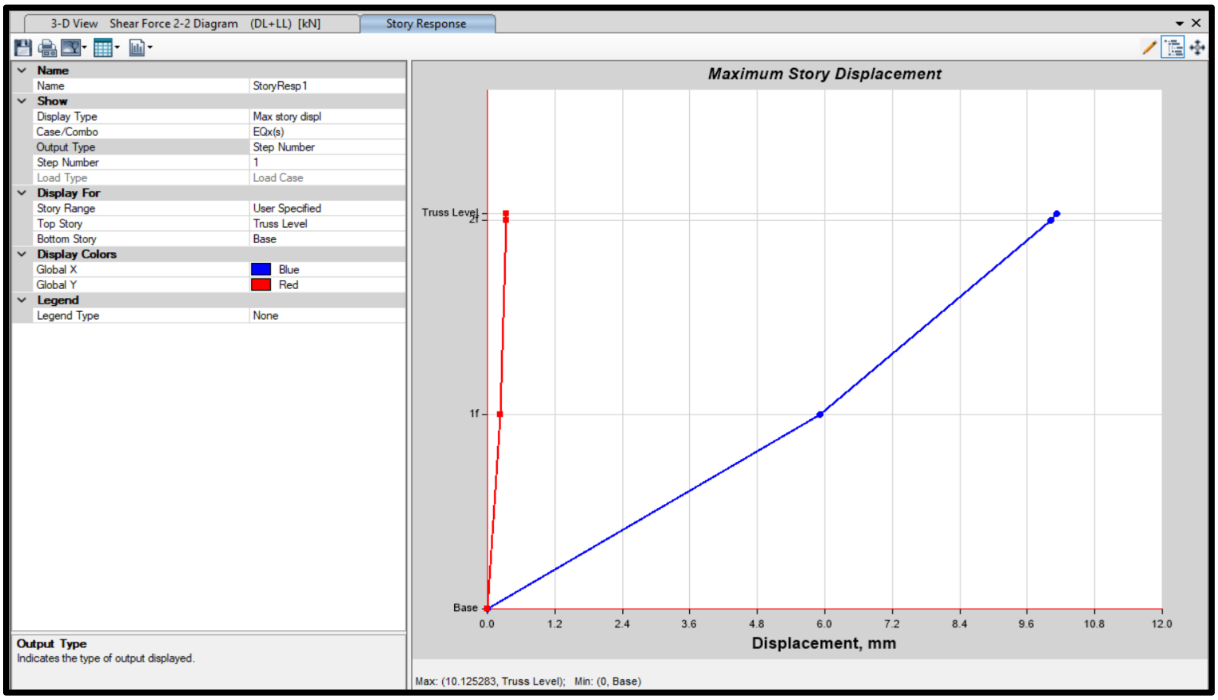


Figure 23 Response Plot showing Maximum Storey Displacement due to EQX(s)

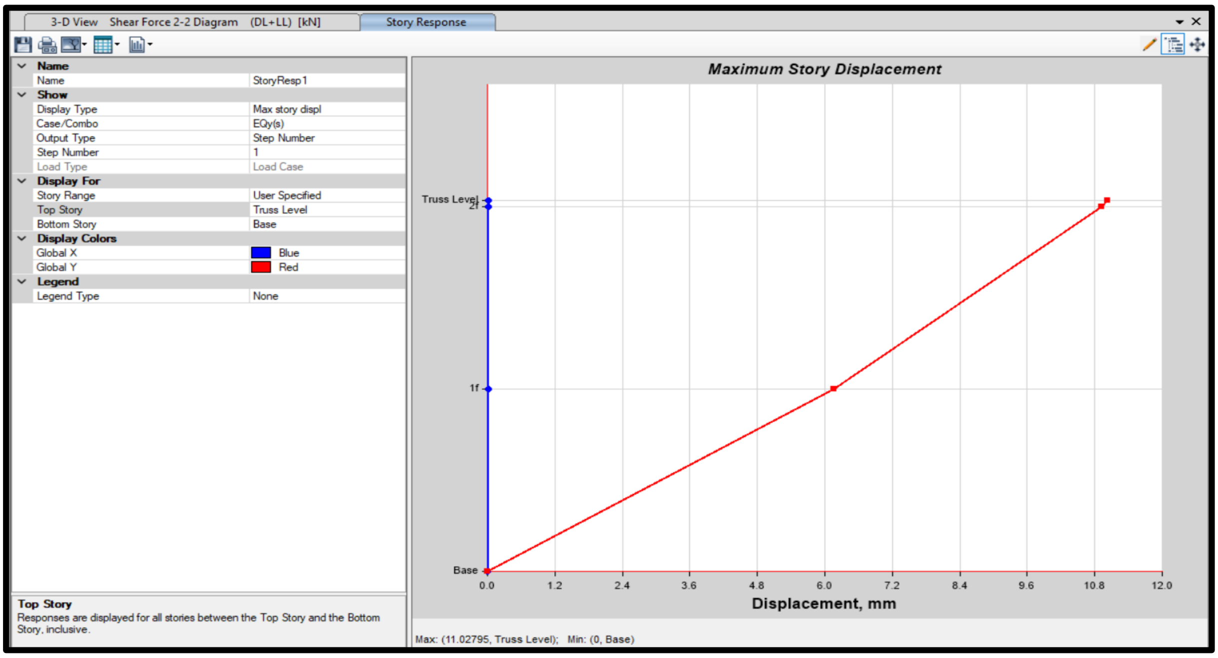


Figure 24Response Plot showing Maximum Storey Displacement due to EQY(s)

Permissible displacement = 0.006 X 6.0 X 1000 =36 **mm**
Actual maximum displacement = **11.027 mm**
Permissible displacement > Actual displacement **Hence Safe.**

5.8. MAXIMUM STOREY DRIFT

5.8.1. Ultimate Limit State

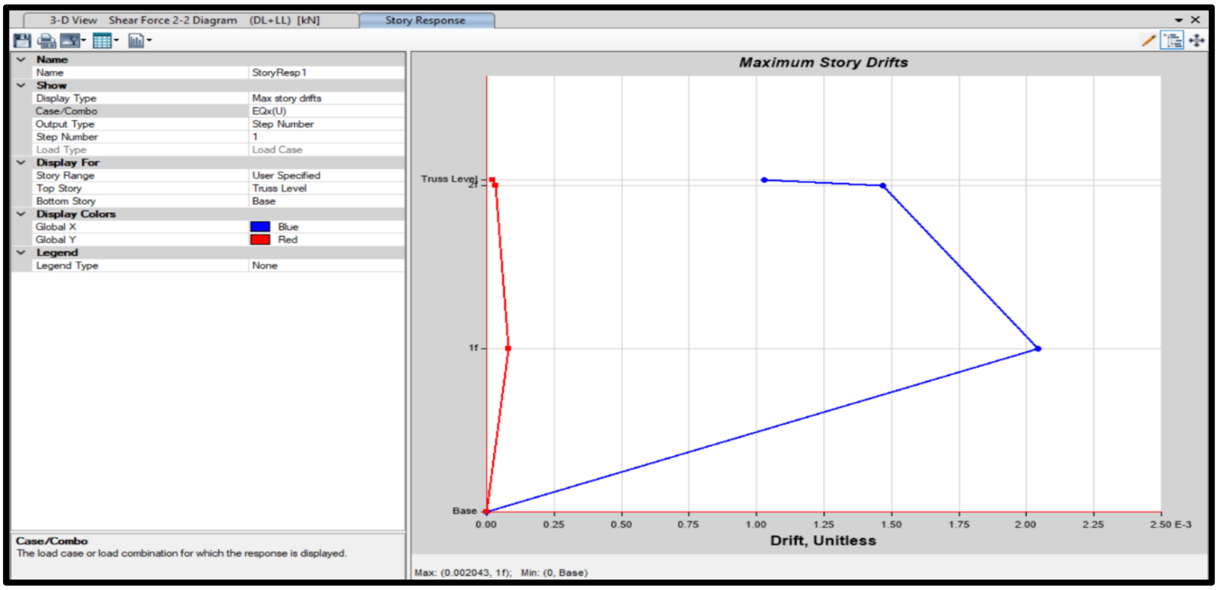


Figure 25 Response plot showing maximum storey drift due to EQX (u)

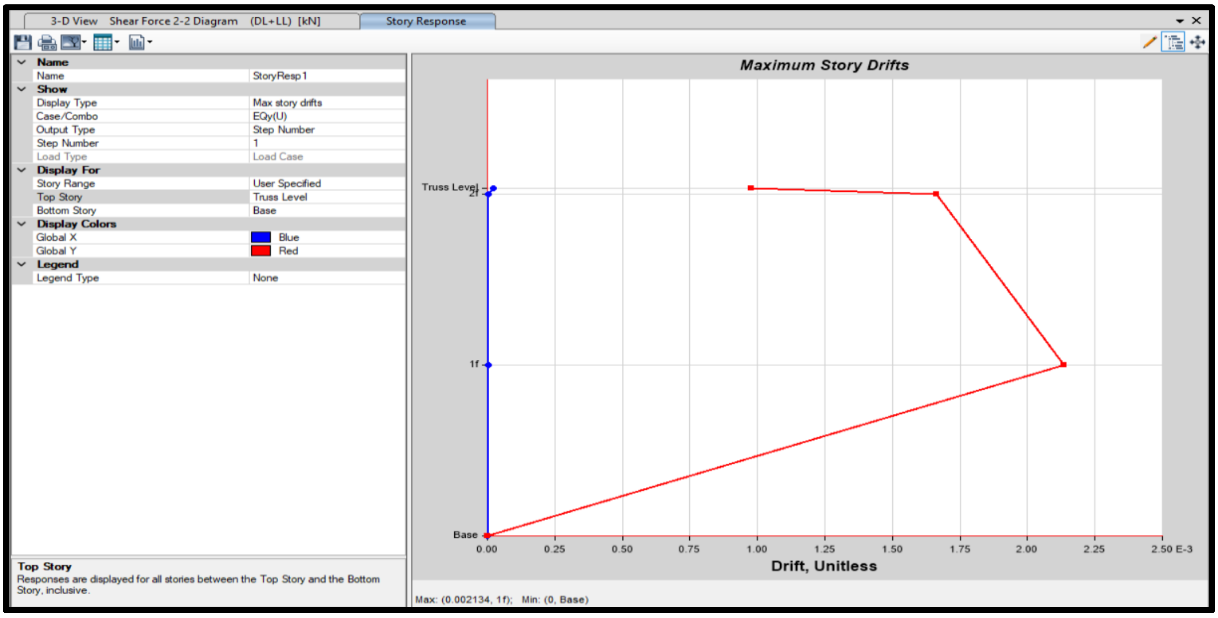


Figure 26Response plot showing maximum storey drift due to EQY (u)

Maximum story drift limit based on NBC 105: 2020 is **0.025/4=0.00625** (Clause 5.6.3) for Ultimate Limit State whereas the maximum story drift of building is **0.002134**

Maximum drift ratio = **0.001165**

Permissible drift > Actual drift **Hence Safe**

5.8.1. Serviceability Limit State

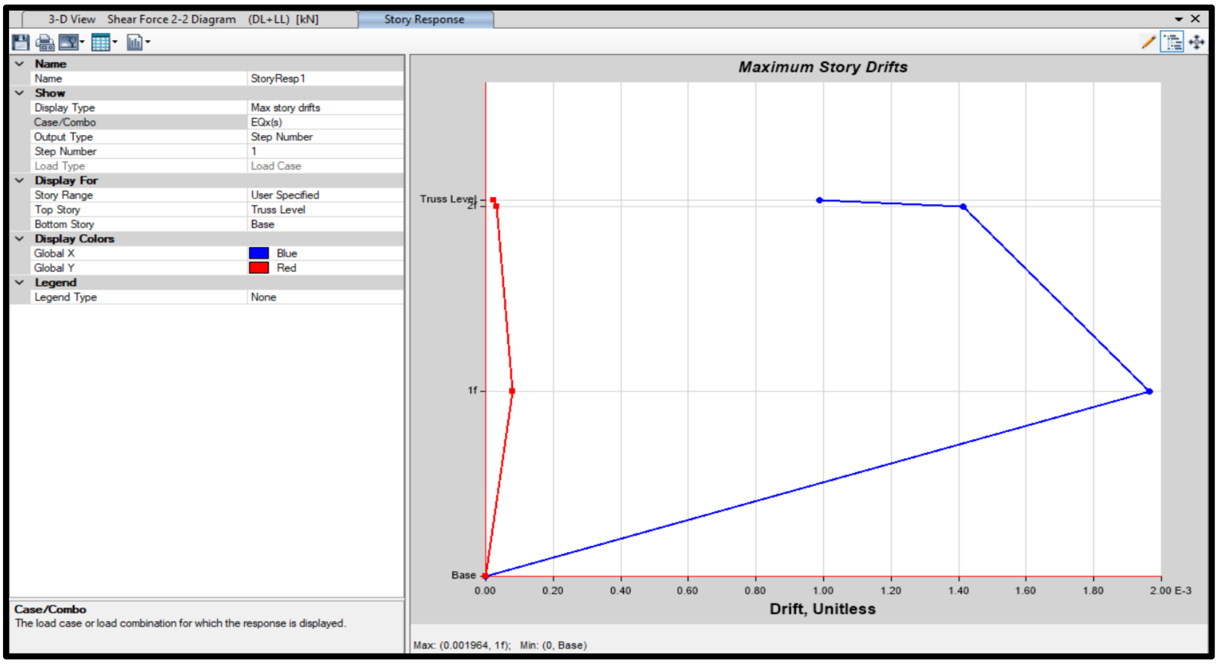


Figure 27 Response plot showing maximum storey drift due to EQX(s)

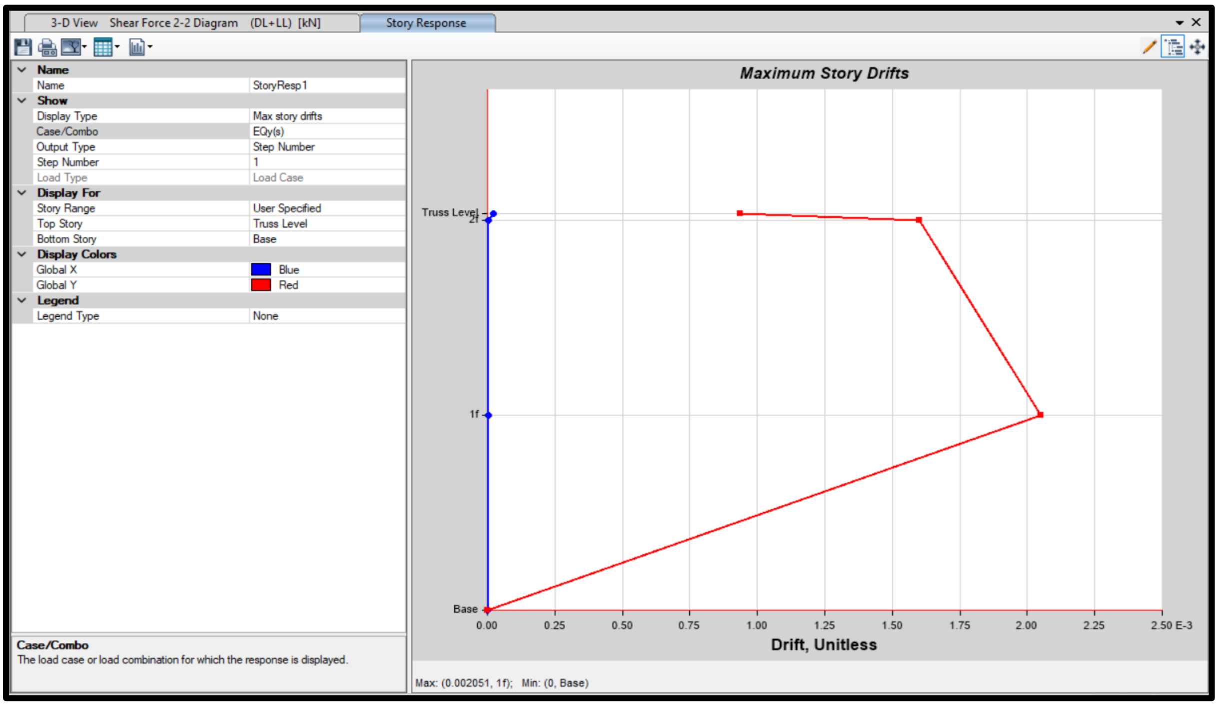


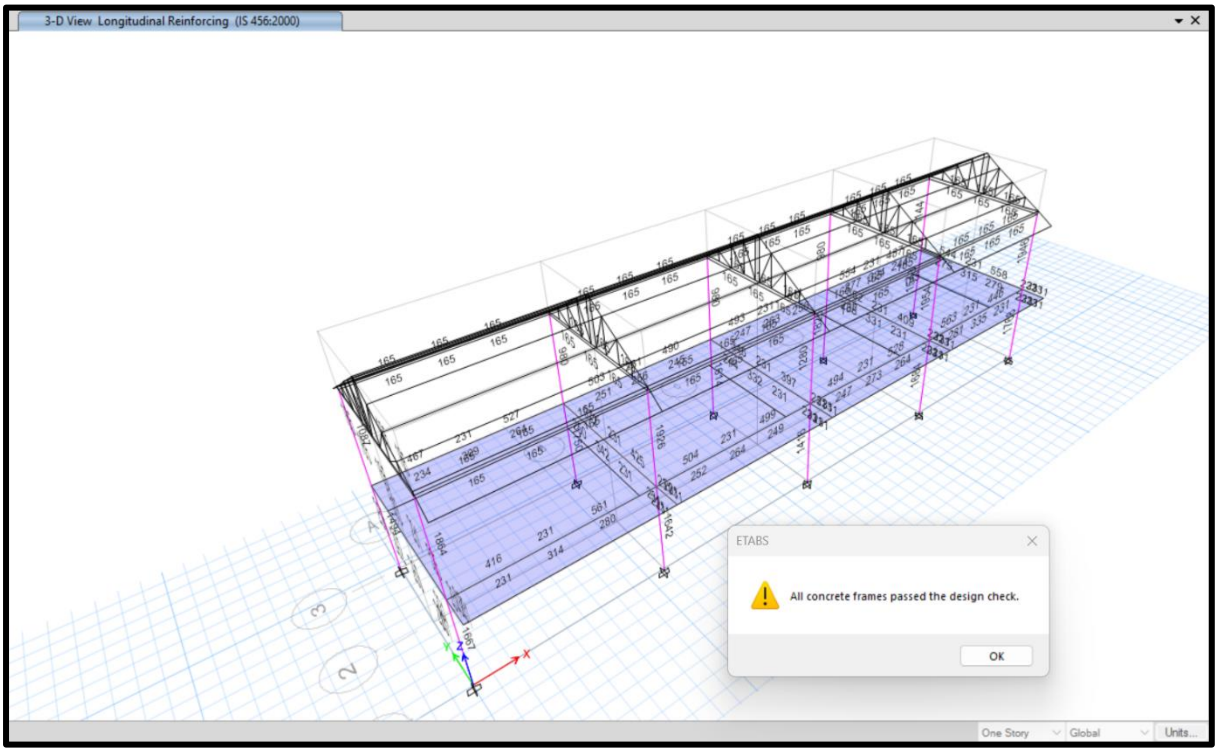
Figure 28Response plot showing maximum storey drift due to EQY(s)

Maximum story drift limit based on NBC 105: 2020 is **0.006**(Clause 5.6.3) Serviceability Limit State whereas the maximum story drift of building is **0.002051**

Maximum drift ratio = **0.002051**

Permissible drift > Actual drift **Hence Safe**

5.9. SECTION VERIFICATION



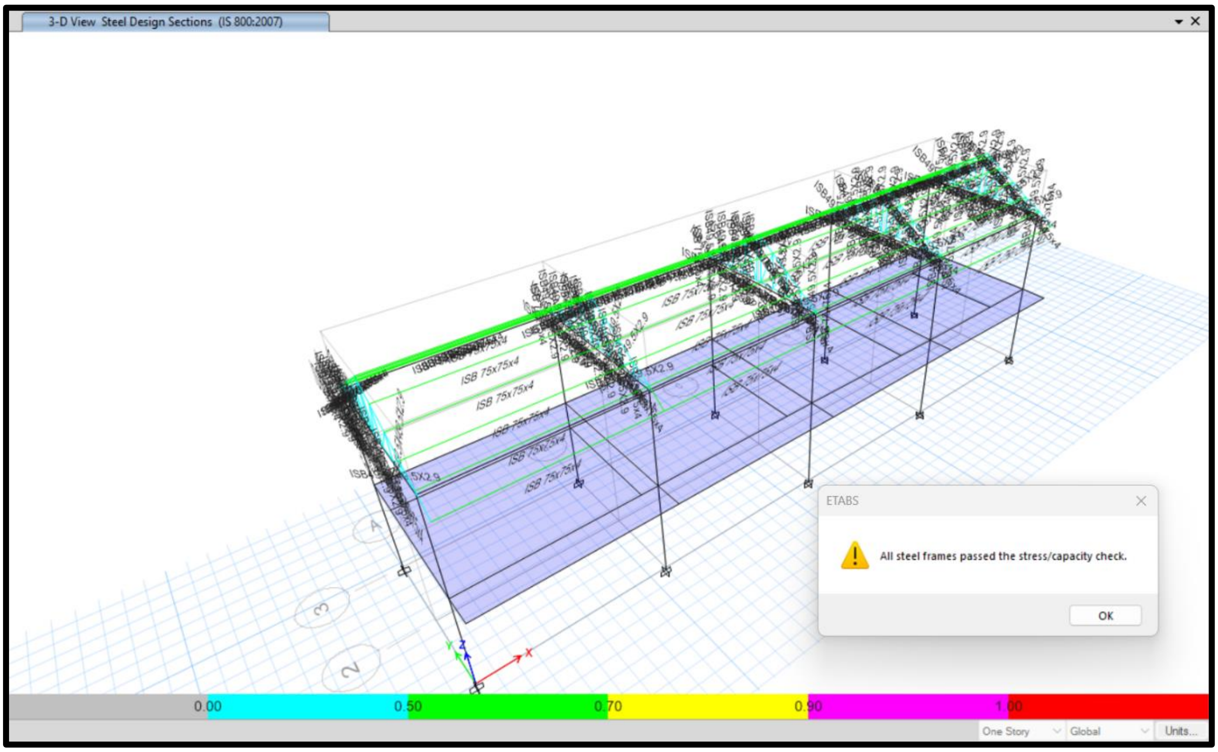


Figure 29 Section Verification

5.10. SUPPORT REACTION

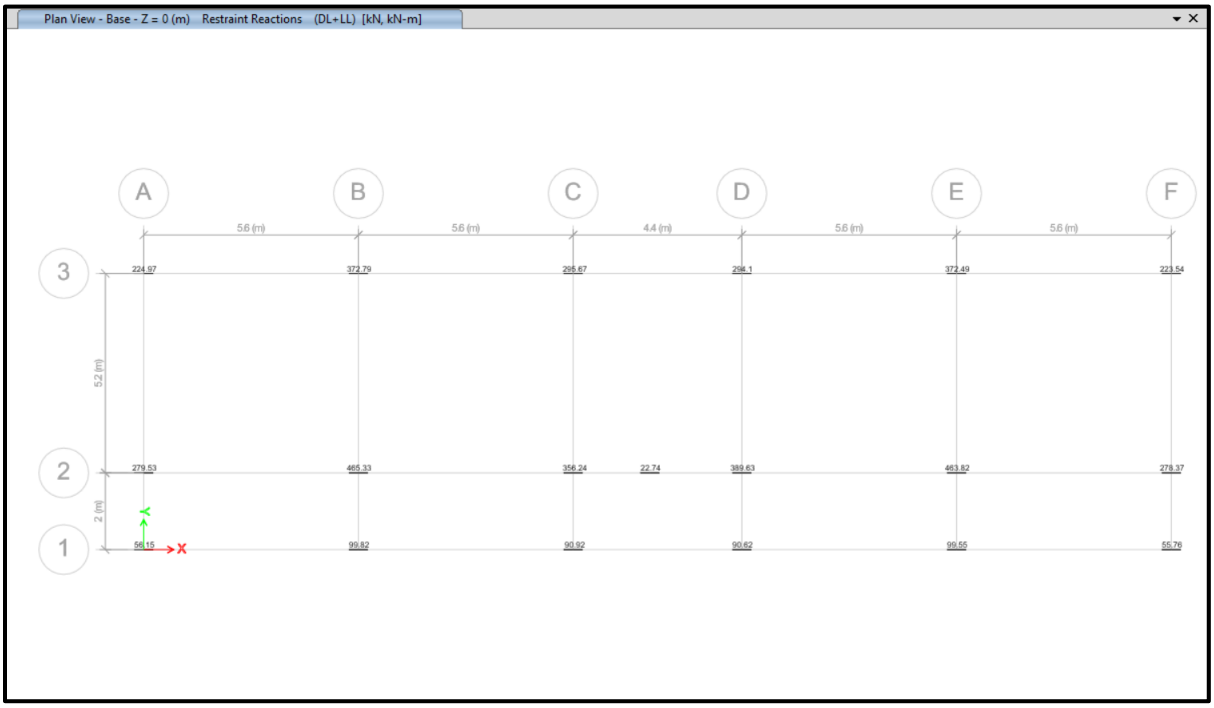


Figure 30 Support Reaction for DL+LL Combination

6.0. DESIGN OF STRUCTURAL ELEMENTS

6.1. DESIGN OF COLUMN

6.1.1. Etabs Definition

Section of columns & SECTION Details of size 350x350mm

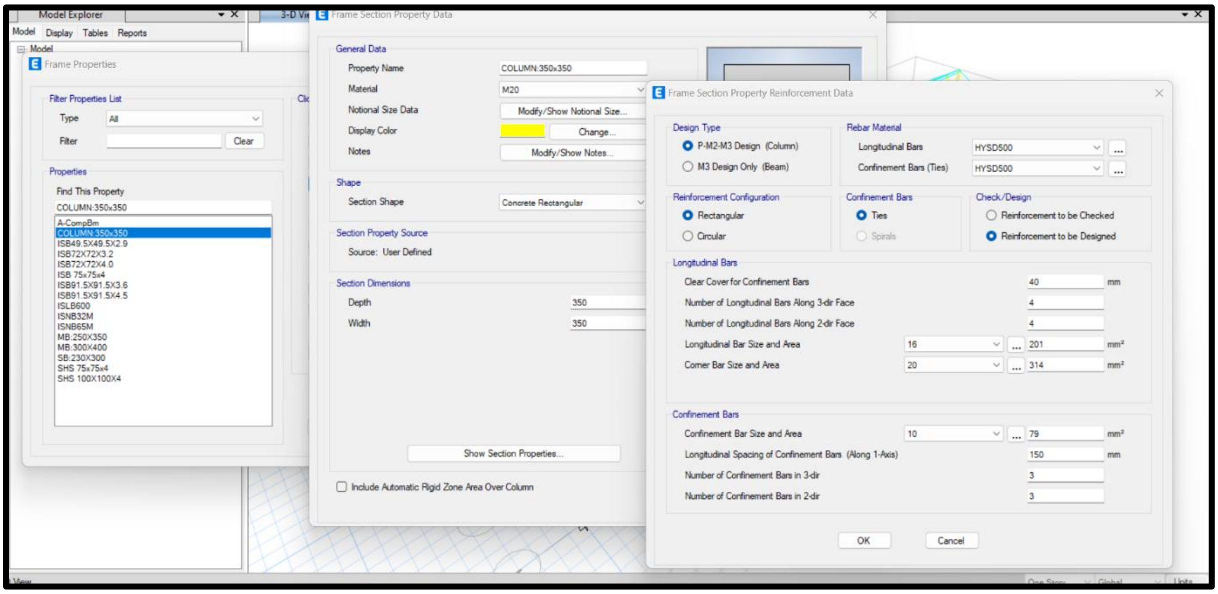


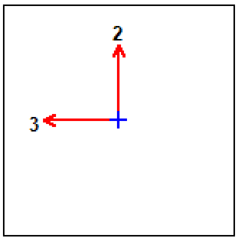
Figure 31 Column section in ETABS

6.1.2. Design summary of column

GRID: C2

ETABS Concrete Frame Design

IS 456:2000 + IS 13920:2016 Column Section Design (Summary)



Column Element Details

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
1f	C4	4	COLUMN:350x350	DL+0.3LLn+0.6LLn+EQy	0	3000	0.879	Ductile Frame

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
350	350	58	30

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
22360.68	20	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar % %	Capacity Ratio Unitless
219.5979	80.7571	4.392	4.392	4.392	1.97	0.648

Axial Force and Biaxial Moment Factors

	K Factor Unitless	Length mm	Initial Moment kN-m	Additional Moment kN-m	Minimum Moment kN-m
Major Bend(M3)	0.634232	2600	-1.4127	0	4.392
Minor Bend(M2)	0.655106	2600	32.3029	0	4.392

Shear Design for V_{u2} , V_{u3}

	Shear V_u kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm²/m
Major, V_{u2}	52.6681	84.9392	40.8802	52.6681	387.95
Minor, V_{u3}	54.1074	85.0874	40.8802	25.4669	387.95

Joint Shear Check/Design

	Joint Shear Force kN	Shear V_{Top} kN	Shear $V_{u,Tot}$ kN	Shear V_c kN	Joint Area cm²	Shear Ratio Unitless
Major Shear, V_{u2}	N/N	N/N	N/N	N/N	N/N	N/N
Minor Shear, V_{u3}	N/N	N/N	N/N	N/N	N/N	N/N

(1.4) Beam/Column Capacity Ratio

Major Ratio	Minor Ratio
N/N	N/N

Additional Moment Reduction Factor k (IS 39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	k Unitless
1225	24.1	2007.45	450.7589	219.5979	1

Additional Moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	0.867	350	4.711	12	No	0
Minor Bending (M_2)	Yes	0.867	350	4.867	12	No	0

- Ast(required) = 1377 mm^2
- Provide 4-20 φ +8-16mmφ bars
- Ast (provided) = 2865.13mm^2
- Here, Ast(provided) >Ast(required) **OK**

For lateral ties (IS 456:2000) Clause 26.5.3.2(c):

- Spacing shall be less than the least of:
  - i. Least lateral dimension = 400 mm
  - ii. 16 φ = 16 x 20 = 320 mm
  - iii. 300 mm
- Provide lateral ties 10φ @100mm c/c at edges and 8φ @150mm c/c at mid-span.

All the columns are designed in a similar way. Please Refer Structural Drawings for further details.

6.1.3. Longitudinal reinforcement of column

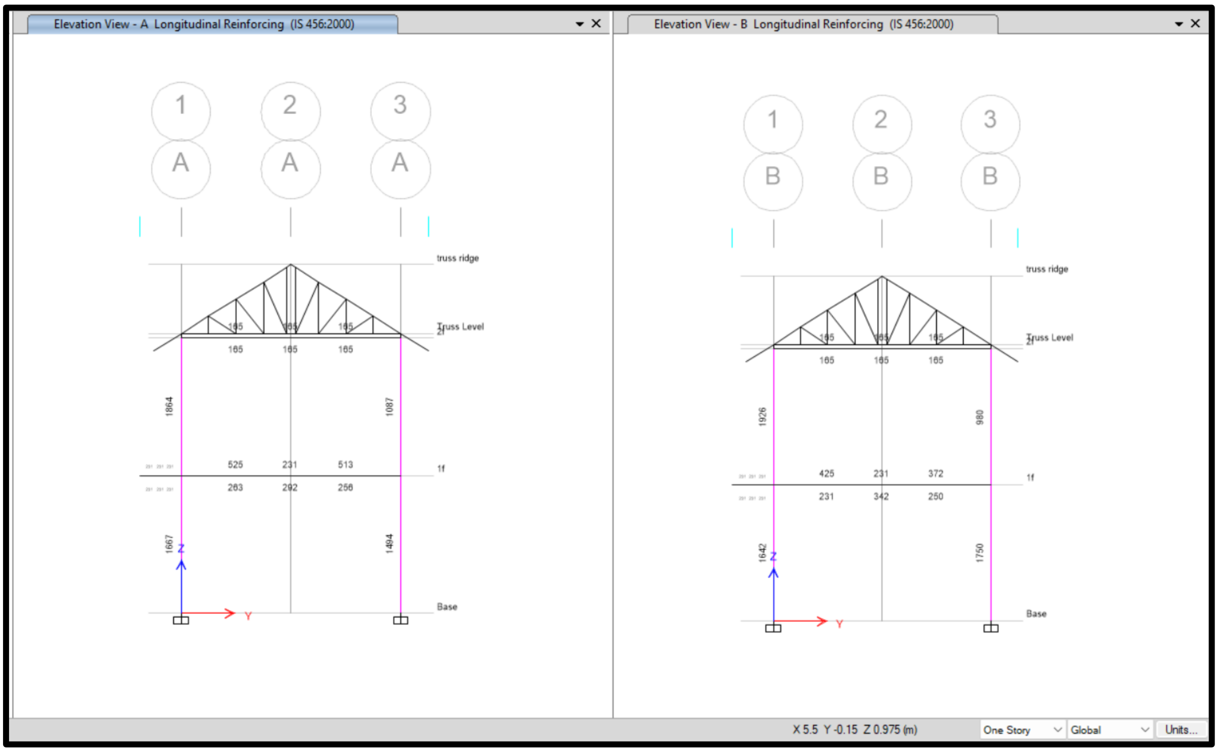


Figure 32 Typical longitudinal reinforcement of column in grid A and B

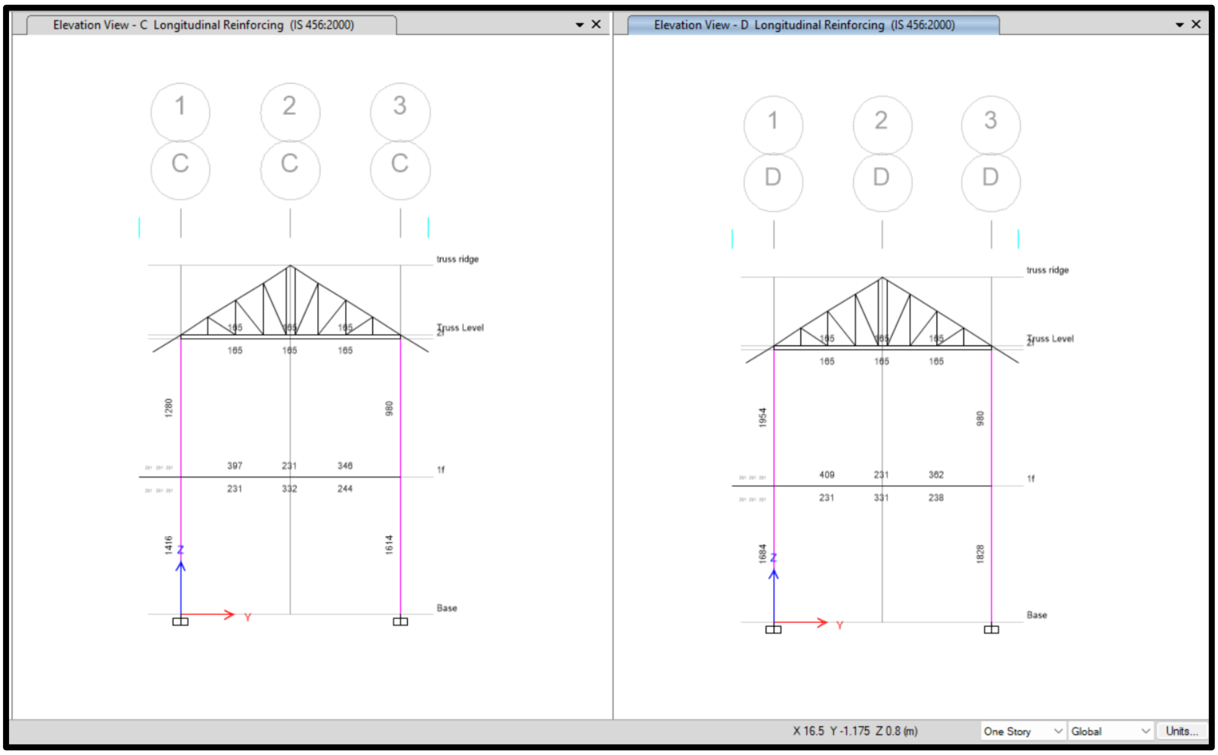


Figure 33 Typical longitudinal reinforcement of column in Grid C & D

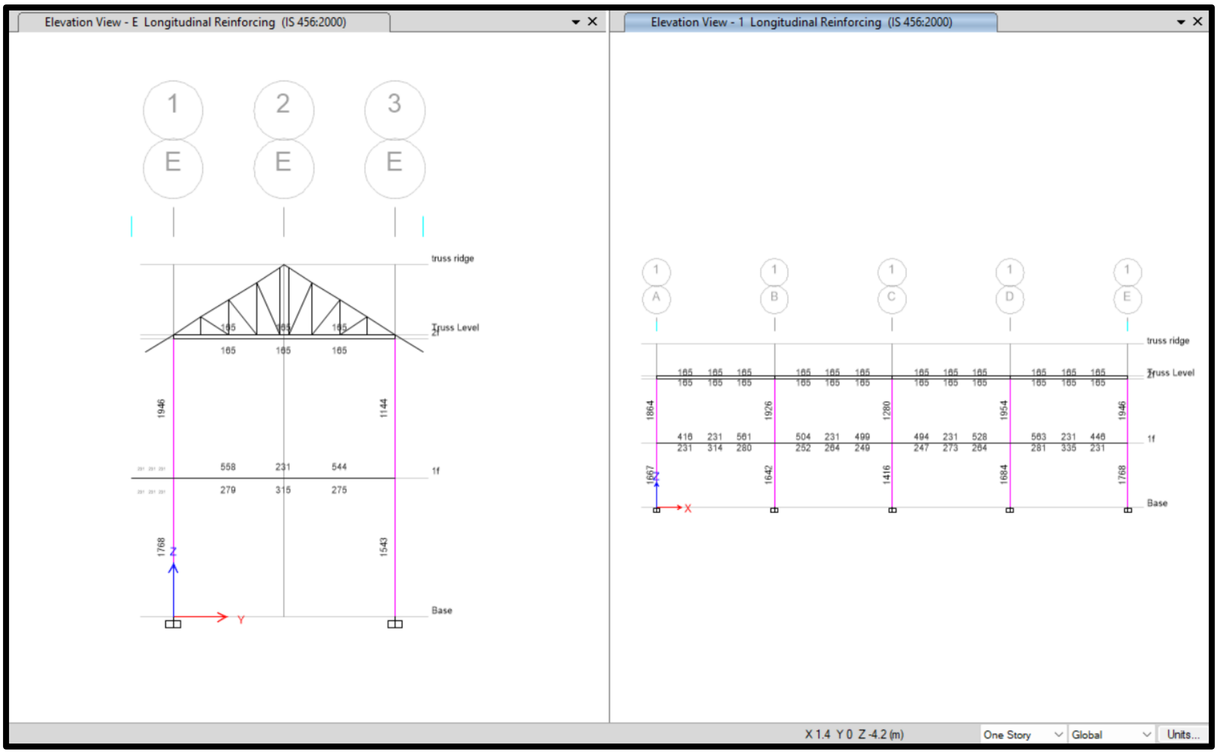


Figure 34 Typical longitudinal reinforcement of column in Grid E

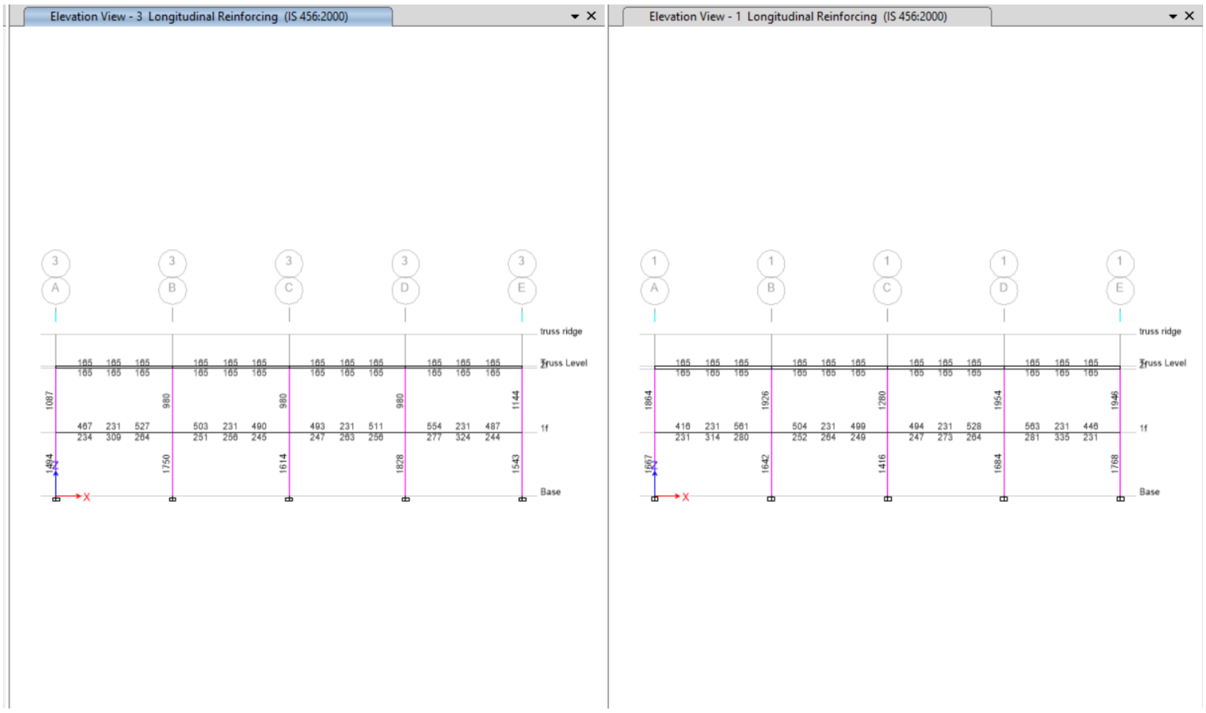


Figure 35 Typical longitudinal reinforcement of column in Grid 1 & 2

6.2. DESIGN OF BEAM

6.2.1. Etabs Definition

Main Beam :300x400 mm

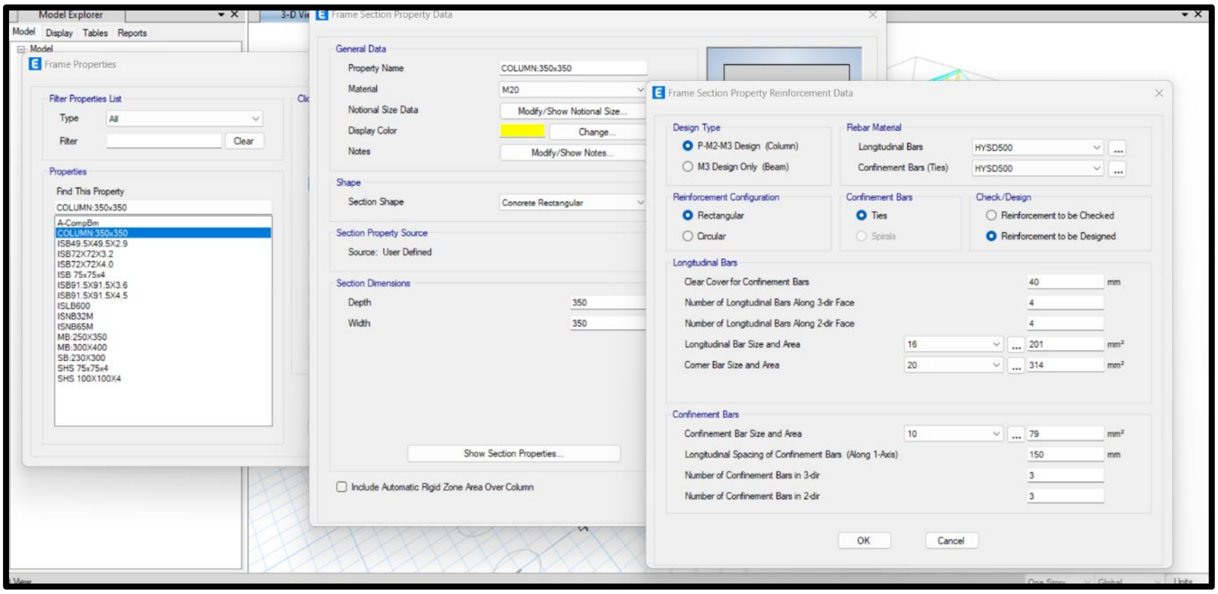


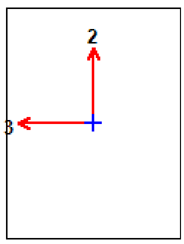
Figure 36 Beam size in ETABS

6.2.2. Design Summary of Beam

Sample Beam: A1-A3

ETABS Concrete Frame Design

IS 456:2000 + IS 13920:2016 Beam Section Design (Summary)



Beam Element Details

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
1f	B1	21	MB:300X400	DL+0.3LLn+0.6LLn-EQy	175	4800	1	Ductile Frame

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
300	400	300	0	42	42

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
22360.68	20	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Factored Forces and Moments

Factored M_{u3} kN-m	Factored T_u kN-m	Factored V_{u2} kN	Factored P_u kN
-60.0453	11.1708	66.2331	2.544

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-60.0453	15.3325	0	-75.3778

Design Moment and Flexural Reinforcement for Moment, M_{u3} & T_u

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	-75.3778		525	0	525	231
Bottom (-2 Axis)		0	263	0	0	263

Shear Force and Reinforcement for Shear, V_{u2} & T_u

Shear V_e kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm²/m
84.6825	0	146.3063	35.6551	1132.48

Torsion Force and Torsion Reinforcement for Torsion, T_u & V_{U2}

T_u kN-m	V_u kN	Core b_1 mm	Core d_1 mm	Rebar A_{svt} /s mm²/m
11.1708	66.2331	236	336	608.87

Ast (required)	Top Reinf. Bar Area	Left	525	mm^2
		Middle	231	mm^2
		Right	513	mm^2
	Bottom Reinf. Bar Area	Left	263	mm^2
		Middle	292	mm^2
		Right	256	mm^2
Provide	Top Bars: 2-16φ(TH.)+ 2-12φ(TH.) + 2-12φ(EX.)			
Provide	Bottom Bars: 2-16φ(TH.)+ 2-12φ(TH.)			
Ast(provided)	Top Reinf. Bar Area	Left	854.51	mm^2
		Middle	628.32	mm^2
		Right	854.51	mm^2
	Bottom Reinf. Bar Area	Left	628.32	mm^2
		Middle	628.32	mm^2
		Right	628.32	mm^2

All the beams are designed in a similar way. The design results are summarized and tabulated in the adjacent tables.

- Provide lateral ties 8φ (4L) @100mm c/c at both edges and 8φ (4L) @150mm c/c at mid-span.

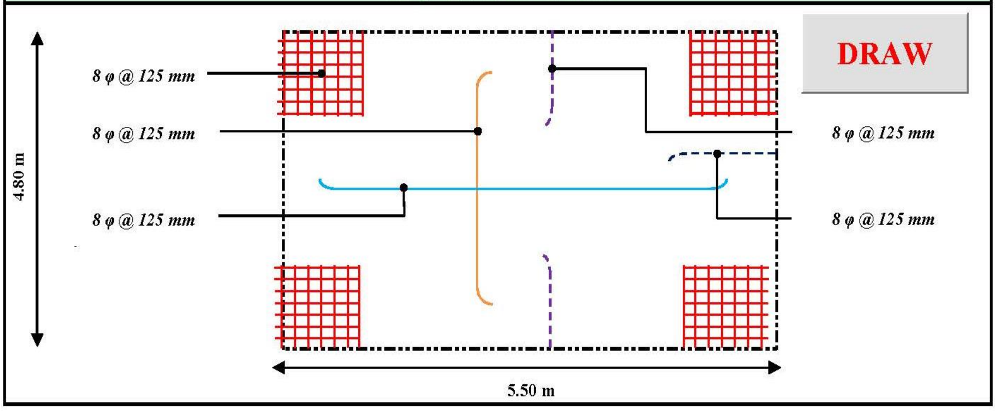
6.3. DESIGN OF BEAM COLUMN CAPACITY (NBC105:2020 CLAUSE 4.4.4)

At every beam column junction in a frame, the summation of the moment capacities of the column end sections shall be greater than 1.2 times the summation of the beam end moment capacities.

BEAM-COLUMN CAPACITY (BCC) RATIO	-	CALCULATION	UNIT	IS CODE AND NBC105:2020 (REMARKS)
1. Moment Calculation for Column:				
Concrete Grade, Fck	=	20	MPa	
Steel Grade, Fy	=	500	MPa	
Width of Column, b	=	350	mm	
Depth of Column, D	=	350	mm	Consider Greater Dim. Of Column as D
Effective Cover, d'	=	56		*Clear Cover+Dia. of Shear Bar+Main Bar/2*
For Upper Column:				
Pu	=	42.254	kN	From Etabs
Therefore,				
Percentage Reinforcement, pt	=	1.97	%	From Etabs
Area of Steel Provided, Ast	=	2413.25	sq.mm	From Etabs
d'/D	=	0.16		
pt/Fck	=	0.10		
Pu/(Fck.b.D)	=	0.00		
From Sp-16 Chart:				
Mu/(Fck.b.b.D)	=	0.14		(For Rec. Col., consider Mu about the weaker
Mu	=	120.05	kN	axis value i.e axis along with less moment of
				inertia (b*D^3/12). For greater D, consider Mu
				along y-axis.)
For Lower Column:				
Pu	=	219.598	kN	
Therefore,				
Percentage Reinforcement, pt	=	1.97	%	From Etabs
Area of Steel Provided, Ast	=	2413.25	sq.mm	From Etabs
d'/D	=	0.16		
pt/Fck	=	0.10		
Pu/(Fck.b.D)	=	0.00		
From Sp-16 Chart:				
Mu/(Fck.b.b.D)	=	0.14		(For Rec. Col., consider Mu about the weaker
Mu	=	120.05	kN	axis value i.e axis along with less moment of
				inertia (b*D^3/12). For greater D, consider Mu
				along y-axis.)
Total Moment (Sum Mc)	=	240.10	kN-m	*Mu(T) + Mu(L)*
2. Moment Calculation for Beam:				
Concrete Grade, Fck	=	20	Mpa	
Steel Grade, Fy	=	500	MPa	
Width of Beam, bw	=	300	mm	
Overall Depth of Beawm, D	=	400	mm	
Effective Cover, d'	=	41	mm	*Clear Cover+Dia. Of Shear Bar+Main Bar/2*
Effective Depth, d	=	359	mm	
Ast (Top)	=	527	sq.mm	For Hogging (Right Top Area)-Etabs
Ast (Bottom)	=	264	sq.mm	For Sagging (Left Bottom Area)-Etabs
Left Beam (Sagging Moment - Positive):				
Depth of Neutral Axis, xu	=	53.17	mm	*xu/d = (0.87*Fy*Ast)/(0.36*Fck*b*d)*
Sagging Moment at Left, M(BL)	=	38.66	kN-m	*(IS456:2000, Annex G, Cl. G.1.1.a)*
Right Beam (Hogging Moment - Negative):				
Limiting Depth of Neutral Axis, Xu(max)	=	165.14	mm	*(0.46*d for Fe500)*
Moment due to Balanced Section, Mu1	=	102.85	kN-m	*Mu,lim = 0.133*Fck*b*d*d (for Fe500)*
Area of Steel due to Balanced Section, Ast	=	816.29	sq.mm	
Area of Compression Steel, Asc	=	0.00	sq.mm	
Moment due to Asc, Mu2	=	0.00	kN-m	*Mu-Mu,lim = Fsc*Asc*(d-d')*
Hogging Moment at Right, M(BR)	=	102.85	kN-m	*Mu1 + Mu2*
Total Moment (Sum Mb)	=	141.51	kN-m	*M(BL) + M(BR)*
3. Check for Strong Column-Weak Beam:				
Total Moment (Sum Mc)	=	240.10	kN-m	(Sum of the design moment of resistance of the
				column above and below.)
Total Moment (Sum Mb)	=	141.51	kN-m	(Sum of the design moment of resistance of
				beams)
(Sum Mc/Sum Mb):	=	1.70	Okay	
BCC Ratio Check	=	Okay		*Must be greater than 1.2*

6.4. DESIGN OF SLAB

SLAB DESIGN					
Input	Calculation	Output	Date : 26 October 2024		
Slab Mark	Label-F6	Storey1	Floor Finish (w_{sdl})	1.50	kN/m^2
Overall Depth (D)	125 mm		Live Load (w_{ll})	3.00	kN/m^2
Effective Cover (d')	25 mm		Other Loads (w_{vl})	1.50	kN/m^2
Grade of Concrete (f_{ck})	M20		Self Weight (w_{dl})	3.13	kN/m^2
Grade of Steel (f_y)	Fe 500		Total Load (w)	9.13	kN/m^2
Clear Span in Shorter Direction (l_x)	4.80 m		Factored Total Load (w_u)	13.69	kN/m^2
Clear Span in Longer Direction (l_y)	5.50 m		Edge Support Condition	Two Adjacent Edges Discontinuous	
Reinforcement Details					
Diameter of Bars along Shorter Direction at Mid-span ($\varphi_{x\text{-mid}}$)	8 mm		Diameter of Bars along Shorter Direction at Support ($\varphi_{x\text{-sup}}$)	8 mm	
Diameter of Bars along Longer Direction at Mid-span ($\varphi_{y\text{-mid}}$)	8 mm		Diameter of Bars along Longer Direction at Support ($\varphi_{y\text{-sup}}$)	8 mm	
Spacing for Bars along Shorter Direction at Mid-span ($s_{x\text{-mid}}$)	100 mm		Spacing for Bars along Shorter Direction at Support ($s_{x\text{-sup}}$)	75 mm	
Provided Spacing for Bars along Shorter Direction at Mid-span	125 mm		Provided Spacing for Bars along Shorter Direction at Support	125 mm	
Spacing for Bars along Longer Direction at Mid-span ($s_{y\text{-mid}}$)	100 mm		Spacing for Bars along Longer Direction at Support ($s_{y\text{-sup}}$)	75 mm	
Provided Spacing for Bars along Longer Direction at Mid-span	125 mm		Provided Spacing for Bars along Longer Direction at Support	125 mm	
Revision Needed					
Corners Lift-up?	No		$A_{st,\ torsion}$	301.59	mm^2
Diameter of Bars in Mesh (φ_t)	8 mm		Spacing of Bars in Mesh (s_t)	125 mm	
Provide 8 mm φ @ 125 mm c/c both ways at top and bottom at each corner over an area 960 mm × 960 mm					
Strength Criteria					
$p_{t,lim}$	0.76 %		$p_{t,provided}$	0.44 %	
Design is Safe for Strength Criteria					
Deflection Criteria					
				Middle	Support
Shorter Direction			$(l/d)_{max}$	N/A	N/A
			$(l/d)_{provided}$	N/A	N/A
Longer Direction			$(l/d)_{max}$	N/A	N/A
			$(l/d)_{provided}$	N/A	N/A
Design is Safe for Deflection Criteria					
Shear Criteria					
Design is Safe for Shear Criteria					



6.5. DESIGN OF FOOTING

6.5.1. Soil Subgrade Modulus

a) Concrete Grade = 20 MPa

b) Rebar Grade = 500 MPa

c) Footing thickness provided =350MM

d) Footing Settlement: 25 mm (ISOLATED)

e) Modulus of Subgrade Reaction:

Based on Bowles, “FOUNDATION ANALYSIS AND DESIGN” Chapter 10.5

Modulus of Subgrade Reaction = Allowable Bearing Capacity

*Factor of Safety/Deflection

= 120*3/(25/1000) = 14400 kN/m^3

Footing thickness provided is 350 mm

6.5.2. Analysis output

6.5.2.1. Soil Pressure diagram for DL+LL combination

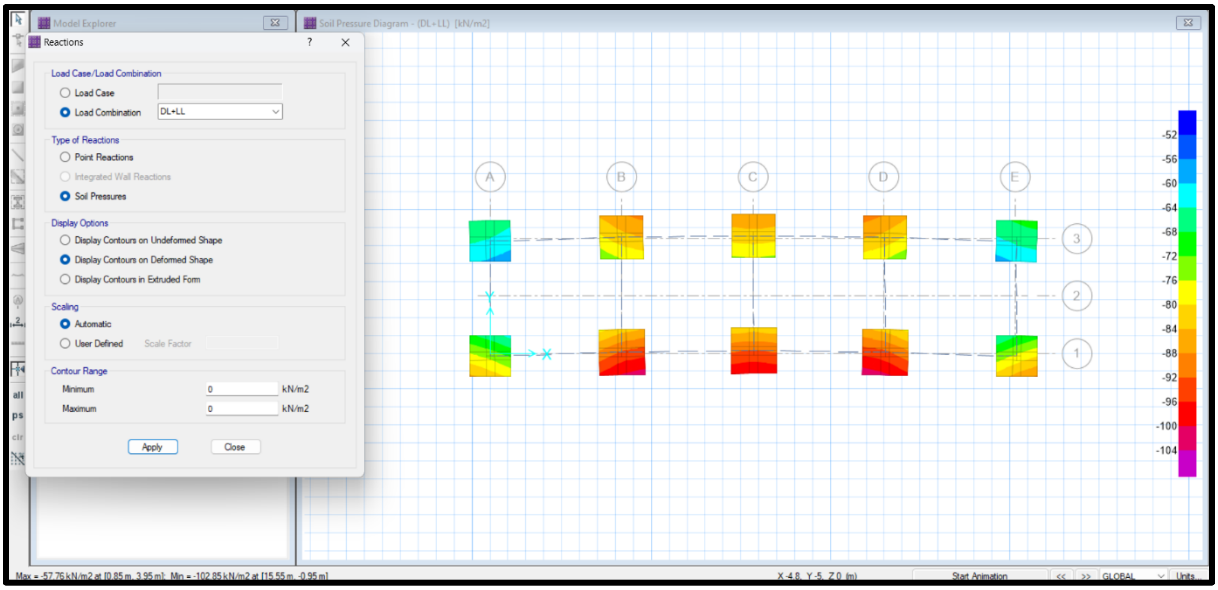


Figure 37 Soil Pressure for DL+LL Combination

Maximum Soil Pressure obtained is 102.85 KN/m^2 which is lower than Soil bearing capacity (120 KN/m^2). Hence, soil pressure is satisfied for DL+LL load combination.

6.5.2.2. Deflection Check

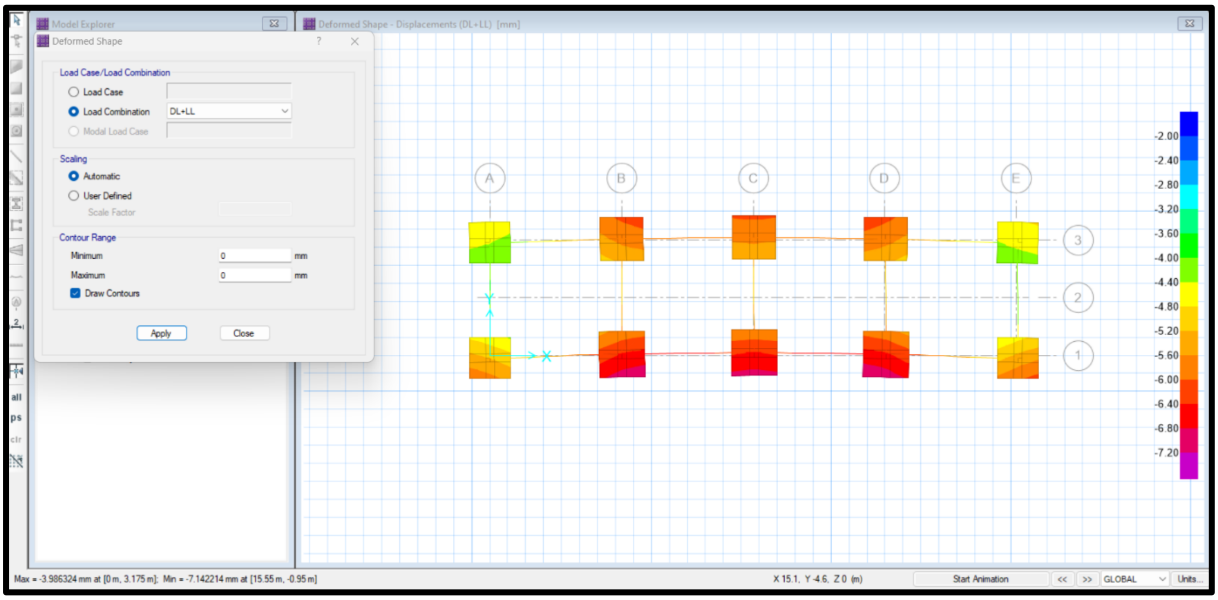


Figure 38 Deflection Diagram for DL+LL combination

Maximum Deflection obtained is 7.142 mm which is lower than Isolated Foundation Deflection (25 mm). Hence, Deflection is satisfied for DL+LL load combination.

6.5.2.3. **Punching Shear Check**

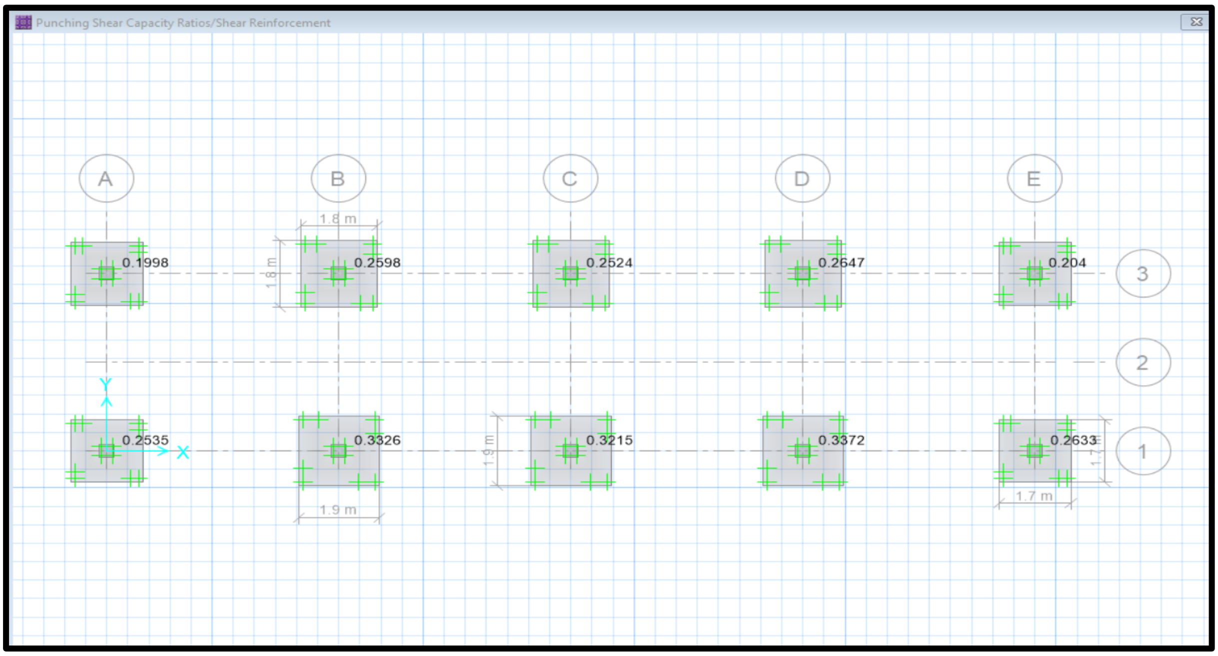


Figure 39Punching Shear Capacity Ratio

Maximum Punching Shear obtained is lower than 1. Hence, Punching Shear is satisfied.

6.5.2.4. Design of Footing Slab:

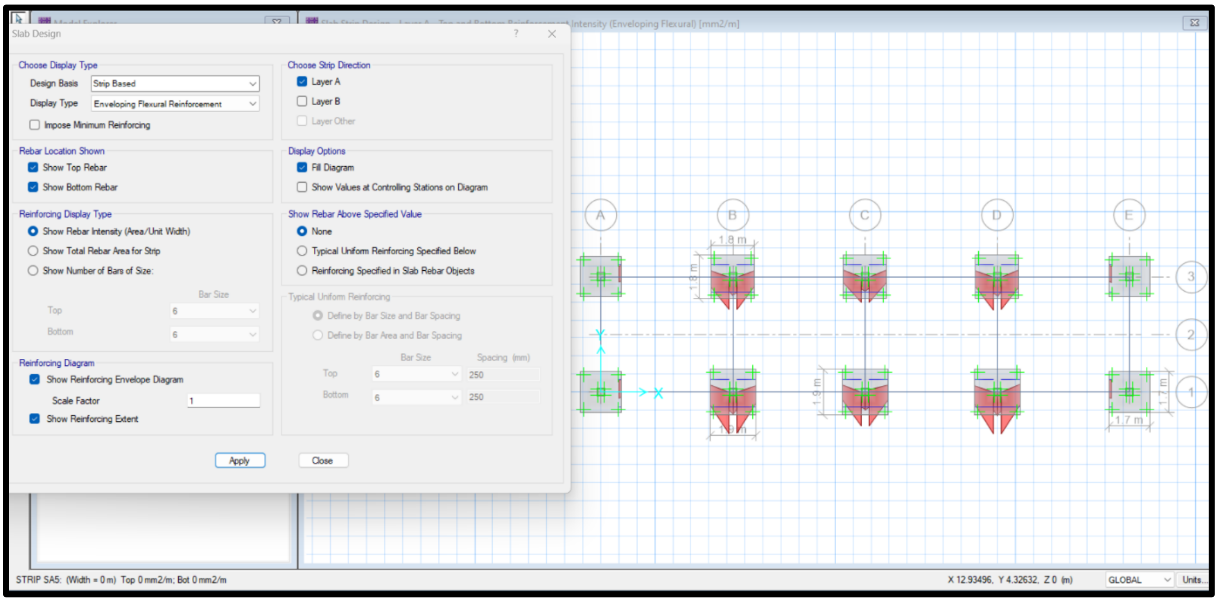


Figure 40: Reinforcement Intensity in X & direction

Please refer structural Drawing for further details.

6.5.2.5. Reinforcement provided in Foundation

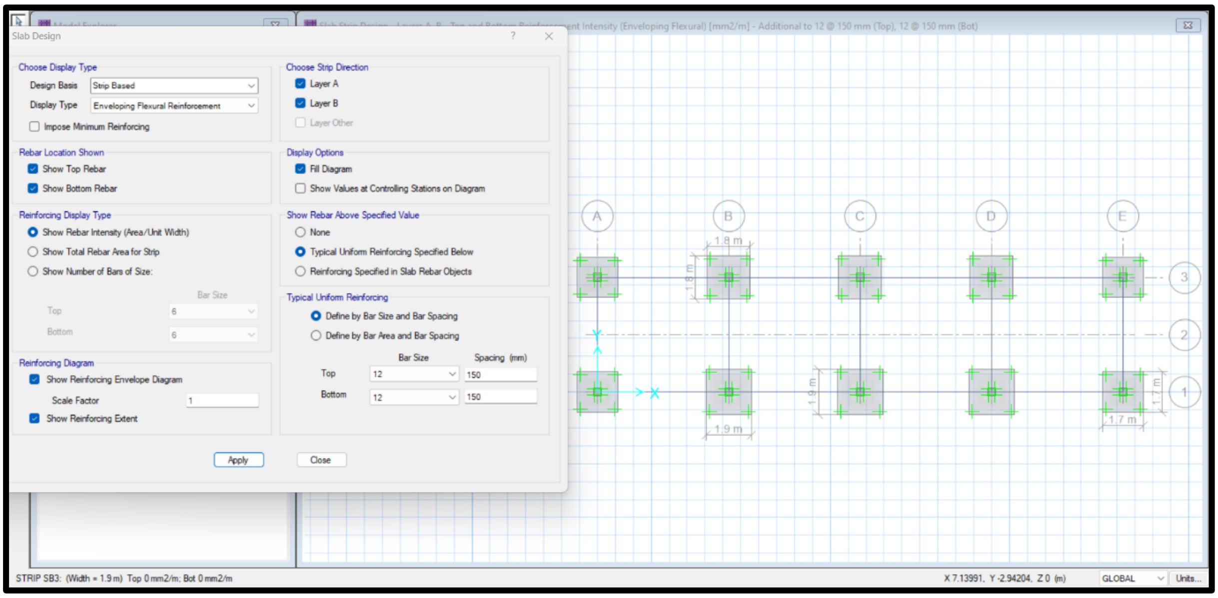


Figure 41 Reinforcement provide in Pad Foundation