STRUCTURAL ANALYSIS AND DESIGN OF EARTHQUAKE RESISTANT BUILDING

<u>STRUCTURAL REPORT</u>

Owner: Mrs. Sunita Ghatani (B.K)

Submitted to:

Shankharapur Municipality, Kathmandu

Prepared By:

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Table of Contents

1 INTRODUCTION

The purpose of this report is to present general overview on structural analysis & design calculation of the **three-storey** residential Building at Shankharapur, Kathmandu owned by **Mr. [redacted].** This report presents the criteria and methodology that have been used throughout in structural calculation which forms a basis for structural analysis and design regarding the assumption of loadings, follow up of the standards as well as the for relevant methodologies.

2 DESIGN PHILOSOPHY

The past devastating earthquakes have proved the vulnerability of most of the vernacular buildings of Nepal. Enormous life and property were lost due to the collapse of buildings Earthquakes can neither be prevented nor predicted precisely. But large- scale destruction can be minimized by employing seismic-resistant measures in buildings. This can be achieved by the use of existing building materials in appropriate analysis.

The structures of buildings are designed to provide the spatial requirements in accordance with the purpose of the buildings taking into account the aesthetic aspect and provision for various services and systems necessary for the operation of airport. In order to fulfill such requirements, the structural materials and the structural system have been determined taking into account the availability of materials, cost efficiency and structural integrity, i.e. stability, strength and serviceability; the three main factors to be incorporated in the design of all structures.

3 DESIGN CODES AND STANDARDS

The structural design is based primarily on the current National Building Codes and Standards of India, while the relevant British Standards, European Standards or National Building Codes of Nepal are referred to appropriately for the areas/provisions that are addressed in the Indian Standards or as required for the purpose of design.

The main design standards followed for structural design are given below, indicating their area of application.

S.N.	Codes and Standards	Description
1	IS 456: 2000	Plain and Reinforced Concrete - Code of Practice
2	IS 875 (Part 1): 1987	Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures: Part 1 Dead Loads – Unit Weights of Building Material and Stored Materials (Second Revision)
3	IS 875 (Part 2): 1987	Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures
4	IS 875 (Part 3): 1987	Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures
5	SP 34: 1987	Handbook on Concrete Reinforcement and Detailing
6	IS 13920: 1993	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
7	IS 1893: 2016	Criteria for Earthquake Resistant Design of structures
8	IS 383: 1970	Specification for coarse and fine aggregates from natural sources
9	IS 1786: 1985	Specification for high strength deformed steel bars and wires for concrete reinforcement (superseding IS:1139 - 1966)
10	IS 12269: 1987	Specification for 53 Grade Ordinary Portland Cement.
11	IS 1904: 1986	Design and Construction of Foundation in soils: General Requirements.
12	IS 800: 2007	Code of Practice for General Construction in Steel (Third Revision)
13	NBC 104: 1994	Wind Load
14	NBC 105: 2077	Seismic Design of Buildings in Nepal
15	NBC 205: 2024	Ready-To-Use Detailing Guideline for Low Rise Reinforced Concrete Buildings Without Masonry Infill
16	NBC 109: 1994	Masonry: Unreinforced
17	NBC 202: 1994	Mandatory Rules of Thumb Load Bearing Masonry
18	EN 1998 - 1	Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

4 GENERAL DESIGN CRITERIA

4.1 MATERIALS

The materials to be used in structural design are as follows.

Concrete

Cast-in-situ concrete for all structural elements:

For Slabs	-	M20
Columns, Beams	-	M20
For Footings, Lintel/Earthquake Bands	-	M20

Reinforcing Bars

High Strength deformed steel bars: Grade Fe 500 to 1786 (14% minimum elongation)

4.2 SOIL BEARING CAPACITY

In absence of soil test report, the presumed bearing capacity of foundation for the site considering combined footing at 2 m depth is **120 KN/m^2**.

4.3 METHODOLOGY

ETABS version 20 has been used for the linear static and dynamic analysis and design of three- dimensional structures, in which the spatial distribution of the mass and stiffness of the structure is adequate for the calculation of the significant features of structures. The structural elements of reinforced concrete were designed to Limit State Theory, while the structural steel elements have been designed to the Permissible Stress Theory.

The major structural elements were designed using design spreadsheets/software and verified manually too following the design aids SP16, IS 456 and IS 800 for reinforced concrete structures and structural steel elements respectively.

Structures designed and built in seismic regions shall fulfil following fundamental requirements ie. Life safety and damage limitation. For the verification of performance requirements, following limit state shall be checked.

1. Ultimate Limit State(ULS)

   Ultimate limit states are associated with collapse or with other forms of structural failure which might endanger the safety of people. Design for ultimate limit state represents a procedure that ensures the probability of collapse of a structure is at an acceptable level.

2. Serviceability Limit State(SLS)

   Damage limitation states are associated with damage beyond which specified service requirements are no longer met. It represents a level of force within the structure below which there is a high degree of assurance that the structure can continue to be used as originally intended without repair.

Design loads for all structures have been in accordance to the criteria described below.

5 DESIGN LOAD

5.1 DEAD LOAD

Dead Load on the structure comprise the self-weight of the member; weight of the finishes and partition walls. These are usually dependent upon the constructional features and have to be assumed in order to design various structural concrete members. The Loads on the beams due to the slabs were calculated according to clause 23.5 of IS 456 – 2000. The Wall Load is taken for thickness of either 230 mm or 115 mm as per Architectural Drawing and suitable reduction is made for Window and Door Opening.

All loads/forces due to gravity on the components of the building structure including the structures self-weight, roofing, flooring, suspended ceiling, wall/partition, services including machinery, piping, rack with all associated finishing permanently attached thereto are calculated in accordance with IS: 875 (Part 1) - 1987.

As the software, we have used, generates the self-weight of the Structural member by itself, we have not calculated the self-weight.

The structure has been designed considering following ideal loads:

Unit Weight (Material)

a. Density of Concrete = 25 kN/m3
b. Live Load = 0.75 kN/m2 for Not accessible Floor
   = 1.5 kN/m2 for Accessible Floor
   = 3.00 kN/m2 for Staircase and Corridors
   =2.0 kN/m2 for rooms
c. Floor Finishing Load = 1.2 kN/m2
d. Density of Brick Wall =19.2 kN/m^2
e. Soil Bearing Capacity (adopted)= 120 kN/m^2

Dead loads were considered separately as;

Self-weight	=	DL
Wall Load	=	DL
Floor Finishing	=	DL

5.2 IMPOSED LOAD

The load assumed to be produced by the intended use and occupancy of the building, including the loads of movable partition, impact, vibration, but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc., in accordance with IS 875 (Part2) – 1987. The words, "live load", herein or elsewhere shall be read as "imposed load" as synonymous.

Wall Load	**(Assuming 30 % opening)**					
Wall load calculation	B`	Density	H	Without opening	With opening	Unit
9" wall(on grid)	0.23	19.2	2.49	11.02	7.71	KN/m
Plaster 12.5mm	0.013	20.4	2.49	0.64	0.45	KN/m
Total				11.65	8.16	KN/m
Adopted value				**12**	**8.5**	KN/m
4" wall (on grid)	0.115	19.2	2.49	5.51	4.13	KN/m
Plaster 12.5mm	0.013	20.4	2.49	0.64	0.45	KN/m
Total				6.14	4.58	KN/m
Adopted value				**6.3**	**5**	KN/m
Parapet wall						
4" wall (on grid)	0.115	19.2	1.07	2.36		KN/m
Plaster 12.5mm	0.013	20.4	1.07	0.27		KN/m
Total				2.63		KN/m
Adopted value				**2.7**		KN/m

Staircase Load Calculation:

Total staircase area (A)	6.4	m2
Increase 20% for sloped area.		
Hence, A'	7.68	m2
Overall Depth of waist slab (D) =	125	
Dead Load:		
•Self-weight = 25 kN/m3*0.125m*7.68	24	
•Floor-finish = 1.5 kN/m2*7.68 m2	11.52	
Riser	0.18	m
Tread	0.25	m
Stair Width	1.1	m
No. of Steps in a flight	16	no
•Step Dead =25* .5*0.18*0.25*1.1*16	9.9	
•Total Dead Load	45.42	
•Taking half load for staircase	22.71	

•Beam Length	2.36	m
•UDL =	9.622881356	
Adopted value	**10**	taken

Live Load:		
•Live load for staircase=3 kN/m2*7.68	23.04	
•Taking half load for staircase	11.52	
•Beam Length	2.36	
•UDL =	4.881355932	
Adopted value	**5**	taken

5.3 EARTHQUAKE LOAD

Response Spectrum including modal analysis has been used as per the NBC 105:2020 to calculate the earthquake forces on the structure. Base shear was derived from the horizontal seismic base shear (Vb) given by:

$V = C_d(T_1)W$ (NBC 105:2020, Cl. 6.2(1))

Where;

W = Seismic weight of the structure equal to the total dead load plus appropriate amounts of specified imposed load

$C_d(T_1)$ = Horizontal base shear coefficient given by:

a) Ultimate Limit State

$$C_d(T_1) = \frac{C(T_1)}{R\mu \times \Omega u}$$

(NBC 105:2020, Cl. 6.2(1))

Where,

Elastic Site Spectra($C(T1)$) is given by

$C\ (T) = C_h(T)\ Z\ I.$

(NBC 105:2020, Cl. 4.1.1)

Where,

$C_h(T)$ = 2.25 Spectral Shape Factor (NBC 105:2020, Cl. 4.1.2)

I = 1.0 Important factor (NBC 105:2020, Cl. 4.1.5)

Z = 0.35 Seismic Zoning Factor (KATHMANDU) (NBC 105:2020, Cl. 4.1.4)

So, C(T)=2.25*0.35*1.0

=0.7875

R□= The ductility factor=4 (NBC 105:2020, Cl. 5.3.1 table 5-2)

□u=The overstrength factor=1.5 (NBC 105:2020, Cl. 5.4.1 table 5-2)

$C_d(T_1)$ = 0.7875/(4*1.5)
= **0.1313**

b) Serviceability Limit State

$$C_d(T_1) = \frac{Cs(T_1)}{\Omega s} \ldots$$ (NBC 105:2020, Cl. 6.2(2))

Where,

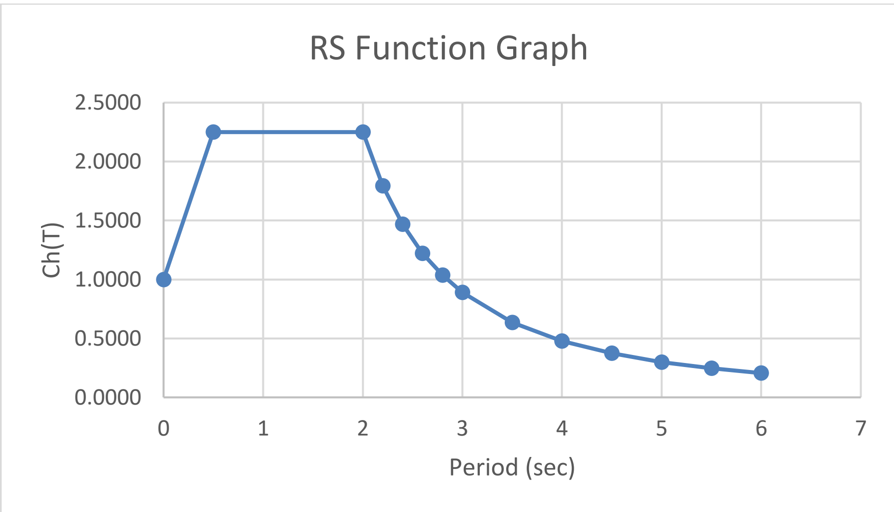
$C_s(T)$ = 0.2C(T) Elastic Site Spectra (NBC 105:2020, Cl. 4.1.2)

= 0.2*0.7875

= 0.1575

□□□□□s= The overstrength factor=1.25 (NBC 105:2020, Cl. 5.4.2 table 5-2)

So,
C_d(T 1)=0.1575/1.25
=**0.126**



Period of vibration
The fundamental translation period shall be determined by the following two methods.

1. Rayleigh Method
2. Emperical Equations

The time period obtained by empirical equations shall be compared with that obtained by Rayleigh Method and the lesser value of the two shall be adopted for the design action.

Emperical Equations

The approximate fundamental natural period of vibration (Ta), in seconds, of a moment resisting frame building without brick infill panels may be estimated by the empirical expression:

Ta = 0.075 $h^{0.75}$ for RC MRF building

= 0.085 $h^{0.75}$ for steel MRF building

Where:

h = Height of building from foundation, in m.

T_1 = 0.075* $8.53^{0.75}$

=0.37 sec.

The approximate fundamental time period as per NBC 105: 2020 CL: 5.1.3 (Page 29)

T_1 = 1.25*0.37

= 0.468 sec

Rayleigh Method

$$T_1 = 2\pi\sqrt{\frac{\sum_{i=1}^{n}(W_i d_i^2)}{g\sum_{i=1}^{n}(F_i d_i)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.1(1)$$

Where

d_i = elastic horizontal displacement of center of mass at level i, ignoring the effects of torsion.

F_i = lateral force acting at level i

g = acceleration due to gravity

i = level under consideration

n = number of levels in the structure

W_i = seismic weight at level i

The seismic weight at each level, W_i, shall be taken as the sum of the dead loads and the factored seismic live loads between the mid-heights of adjacent stories.

The seismic live load shall be determined as given in **Table 5-1**.

***Table 5-1**: Live Load Categories and Factors*

Live Load Category	Factor (λ)
Storage	0.60
For Other Purpose	0.30
Roof	Nil

6 LOAD COMBINATION

For design of reinforced concrete elements, the following load combinations were considered according to NBC 105:2020 CL 3.6.2:

1. 1.2DL+1.5LL
2. DL+0.3LL+SLSEQX+0.3SLSEQY
3. DL+0.3LL+SLSEQX-0.3SLSEQY
4. DL+0.3LL-SLSEQX+0.3SLSEQY
5. DL+0.3LL-SLSEQX-0.3SLSEQY
6. DL+0.3LL+SLSEQY+0.3SLSEQX
7. DL+0.3LL+SLSEQY-0.3SLSEQX
8. DL+0.3LL-SLSEQY+0.3SLSEQX
9. DL+0.3LL-SLSEQY-0.3SLSEQX
10. DL+0.3LL+ULSEQX+0.3ULSEQY
11. DL+0.3LL+ULSEQX-0.3ULSEQY
12. DL+0.3LL-ULSEQX+0.3ULSEQY
13. DL+0.3LL-ULSEQX-0.3ULSEQY
14. DL+0.3LL+ULSEQY+0.3ULSEQX
15. DL+0.3LL+ULSEQY-0.3ULSEQX
16. DL+0.3LL-ULSEQY+0.3ULSEQX
17. DL+0.3LL-ULSEQY-0.3ULSEQX

Where:
DL= Dead Load

LL= Live Load

ULSEQX= Ultimate limit state Earthquake load in X-direction

ULSEQY= Ultimate limit state Earthquake load in Y-direction

SLSEQX= Serviceability limit state Earthquake load in X-direction

SLSEQY= Serviceability limit state Earthquake load in Y-direction

7 STRUCTURAL ANALYSIS USING ETABS

The building was modeled in structural analysis program ETABS Ver. 20 using frame elements. Slabs were modeled using shell elements to distribute loads on frame elements. 3-D Modeling was prepared using this FEM modeling based software considering beams and columns as FRAME element, and Slab as shell element wherever possible.

Equivalent Static Method(ESM) was carried out for its analysis in lateral loading due to earthquake.

8 DESIGN METHODS OF STRUCTURAL ELEMENTS

We have followed Indian Standard Code of Practice for Plain and Reinforced Concrete IS: 456-2000 for design of Structural Elements. This incorporates the two methods of Structural Design of RC structures specified as:

a. Working Stress Method based on the Working loads in conjunction with permissible stresses in the materials.
b. Limit State Method based on safety and serviceability requirements associated with the design loads and design strengths of the materials. These design loads and design strengths are obtained by applying partial safety factors for characteristic loads and strengths of the materials concrete and steel.

We have followed the limit state method which is incorporated in IS:456-2000. It is consistent with the new philosophy of design termed limit state approach which was incorporated in the Russian Code – 1954, the British code BS 8110 – 1985 and the American Code ACI 318 – 1989.

9 LIMIT STATE METHOD

- **Limit States**

The Limit State method of design covers the various forms of failure. There are several limit state at which the structure ceases to function, the most important among them being,

a. The limit state of collapse or total failure of structure.

It corresponds to the maximum load carrying capacity. Violation of collapse implies failure. This limit state corresponds to Flexure, Compression, Shear and Torsion.

b. The limit state of serviceability which includes excessive deflection and excessive local damage. Excessive deflection adversely affects the finishes and excessive local damage results in cracking of concrete, which impairs the efficiency, or appearance of the structure.

- Design Equations in Limit State Method :
  a) Singly Reinforced Sections:

The depth of Neutral Axis xu is

obtained as $X u = [(0.87A_{st}$

$fy / 0.36 f_{ck} b)]$

For under Reinforced Sections, the neutral Axis depth Xu is limited to a value of X_u max < 0.48 d for steel of $f_y = 415\ N/mm^2$

If the neutral axis depth is less than these limiting values, the ultimate moment is computed

By the equation:

$M_u = 0.87\ f_y A_{st}\ d\ [\ 1 - \{\ f_y A_{st}\ /\ b\ d\ f_{ck}\ \}\ ]$

If the Neutral Depth is equal to the limiting values, then the section is balanced or limiting and the moment capacity is evaluated by the equation.

$M_{u,lim} = 0.36\ X_{u,\ max} / d\ [\ 1 - 0.42\ X_{u,max}\ /\ d\ ]\ b\ d^2\ f_{ck}$

$M_{u,lim} = 0.138\ f_{ck}\ b\ d^2$ (for HYSD bars with $f_y = 415\ N/mm^2$) Area of steel in a balanced section is given by:

$A_{st} = [\ 0.36\ f_{ck}\ b\ X_{u,max}\ /\ 0.87\ f_y\ ]$

b) Doubly Reinforced Sections:

The ultimate moment resistance of sections with compression reinforcement (doubly reinforced Section) is computed by the equation.

$[\ M_u - M_{u,lim}\ ] = f_{sc}\ A_{sc}\ (\ d - d'\ )$

Where, M_u = Moment of Resistance of the doubly reinforced sections

$M_{u,lim}$ = Limiting moment of Resistance of a section without Compression reinforcement

d d' = Effective Depth

= Depth of Compression Reinforcement from compression face

f_{sc} = Design stress in compression reinforcement

The total Area of Tension Reinforcement is obtained as $A_{st} = A_{st1} + A_{st2}$ Where,

A_{st1} = Total Area of Tensile Reinforcement

A_{st2} = Area of Tensile Reinforcement for a singly Reinforced Section for $M_{u,kim}$

A_{sc} = $A_{sc}\ f_{sc}\ /\ 0.87\ f_y$

The nominal shear stress Tv in beams of uniform depth is obtained as

$T_v = V_u / b\ d$

Where, Vu = Ultimate shear Force due to design loads

B = Breadth of member

d = effective depth

The permissible shear stress T_c in beam depends upon the percentage of longitudinal reinforcement. Where $Tc < Tv$, minimum shear Reinforcement is given by

$Asv / bSv >= 0.4 / fy$

If Tv exceeds Tc, but is less than Tc max, then Shear Reinforcements are designed to take up the balanced shear $Vu – Tc\ bd$

The Strength of Shear Reinforcement Vus is calculated as $Vus = 0.87\ fi\ Asv\ d / Sv$

10 ANALYSIS AND DESIGN OF THE STRUCTURAL ELEMENTS:

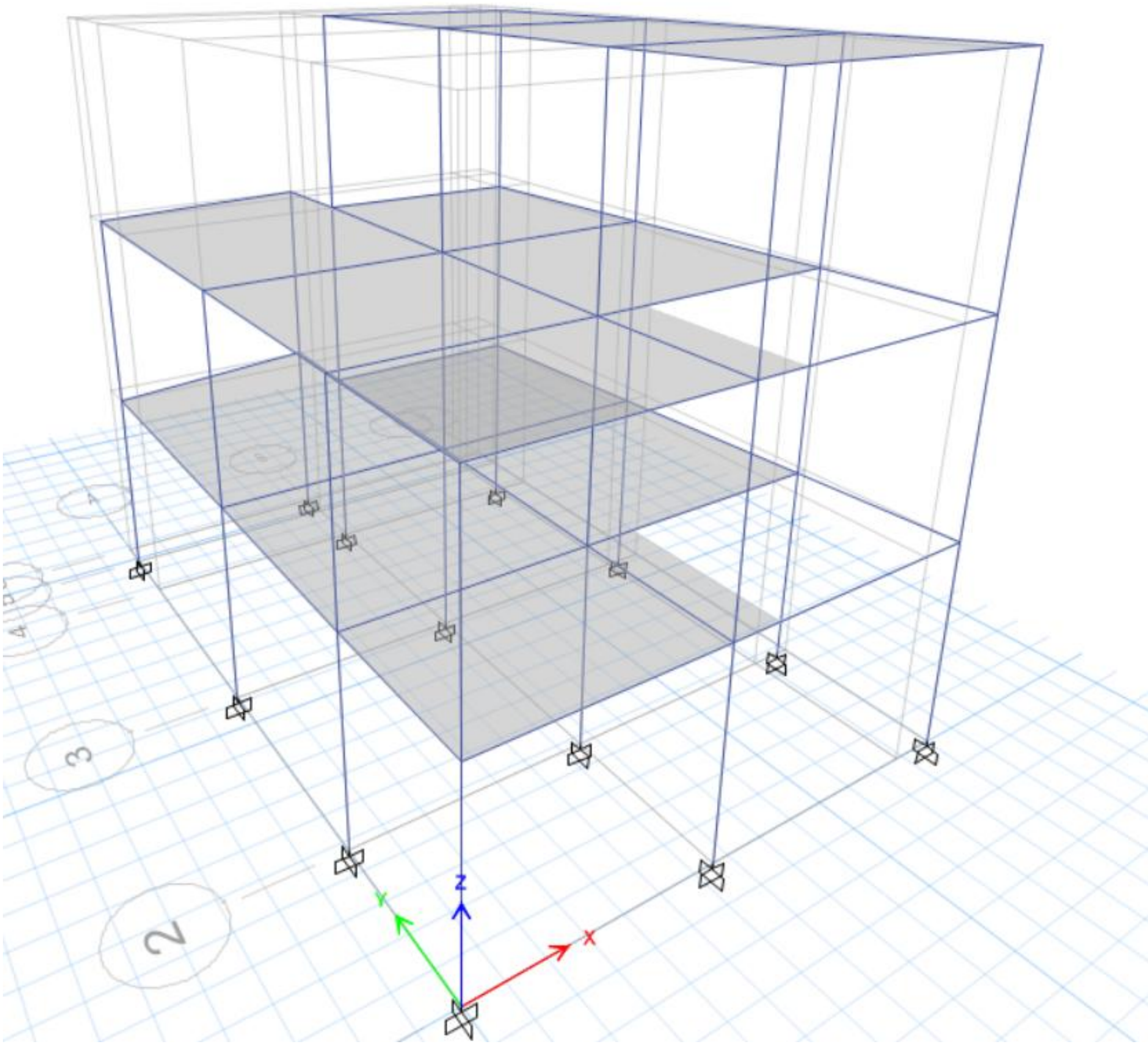
The Structure is analyzed and designed by standard software ETABS Vr.20. It is the World's most popular and widely used structural Engineering Software. It is equipped with the powerful analysis, design, graphics, and visualization capabilities.

General Information on Structural Elements of the Building

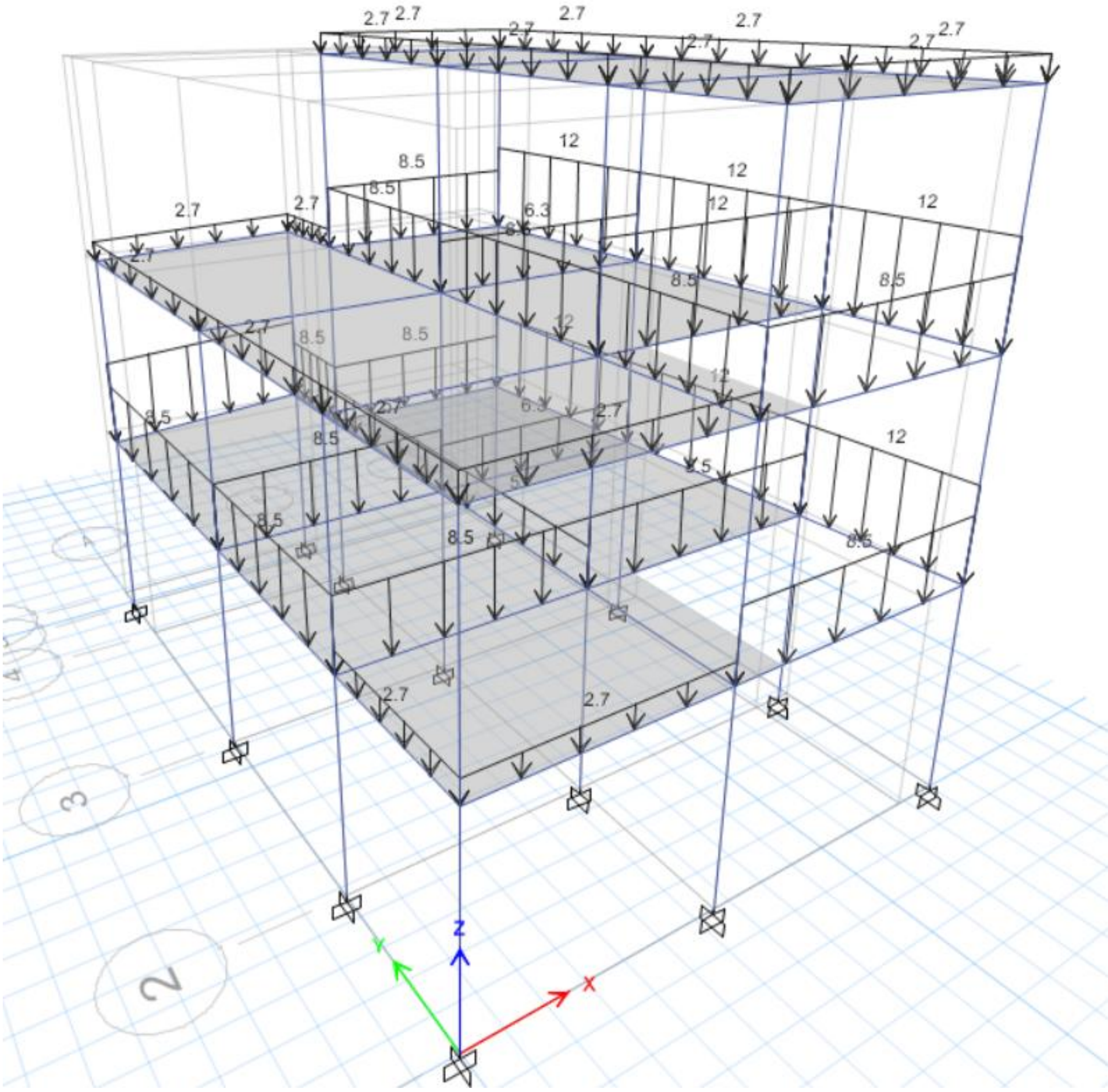
Element	Description	Grade of Concrete	Remarks
Column	350 mm X 350 mm	M20	
Main Beam	350 mm X 230 mm	M20	
Slab	125 mm	M20	
Waist Slab	125 mm	M20	
Foundation	Isolated, Combined and Strap Footing	M20	Soil Bearing Capacity is assumed to be 120 kN/m^2

11 DETAILING OF THE STRUCTURAL ELEMENTS:

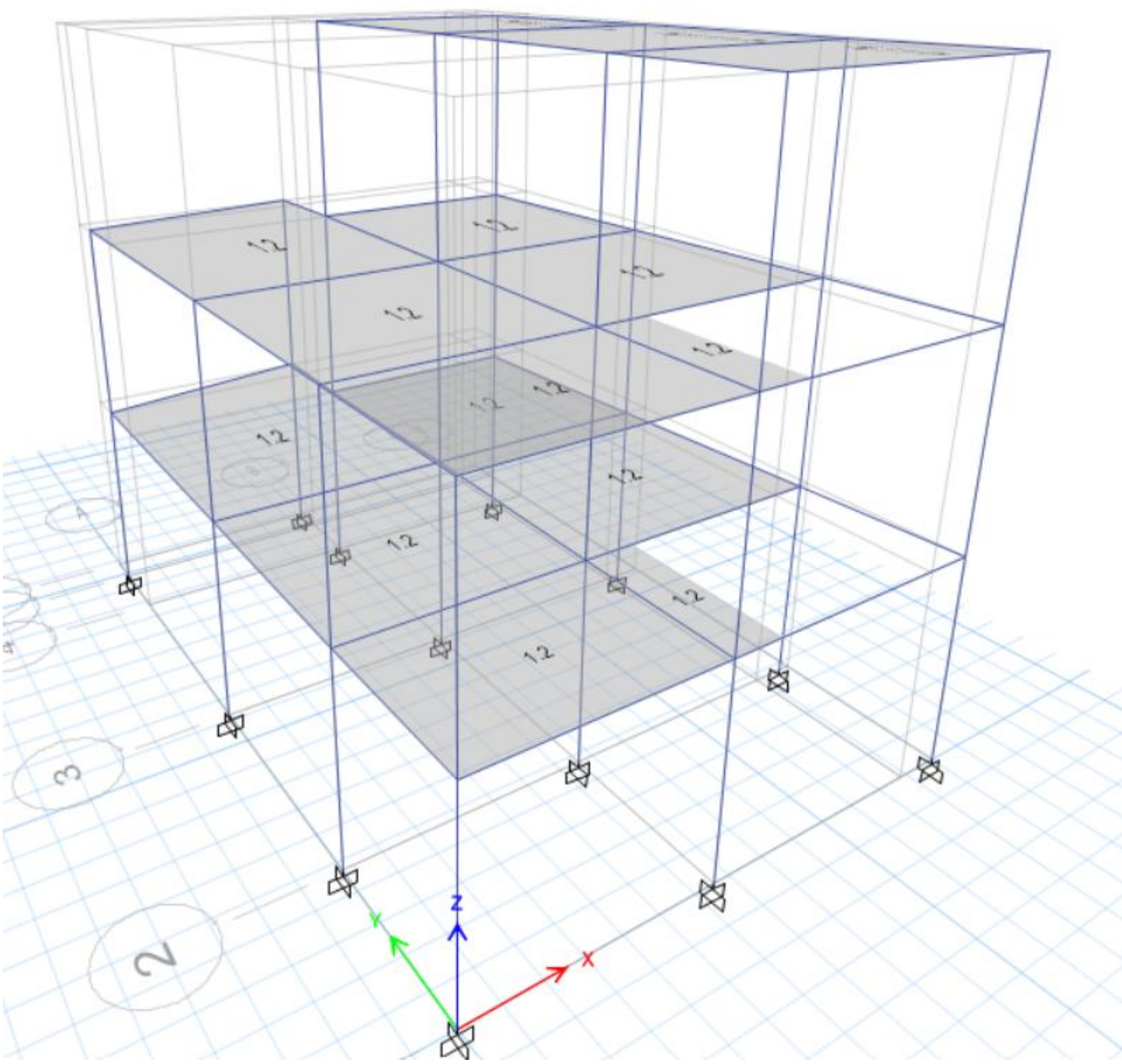
The Reinforcement detailing of most of the important structural components have been shown in drawing. They confirm with the relevant sections of the IS Codes IS 456-2000, IS 1893-1984, SP-16, and SP –34 –1987.



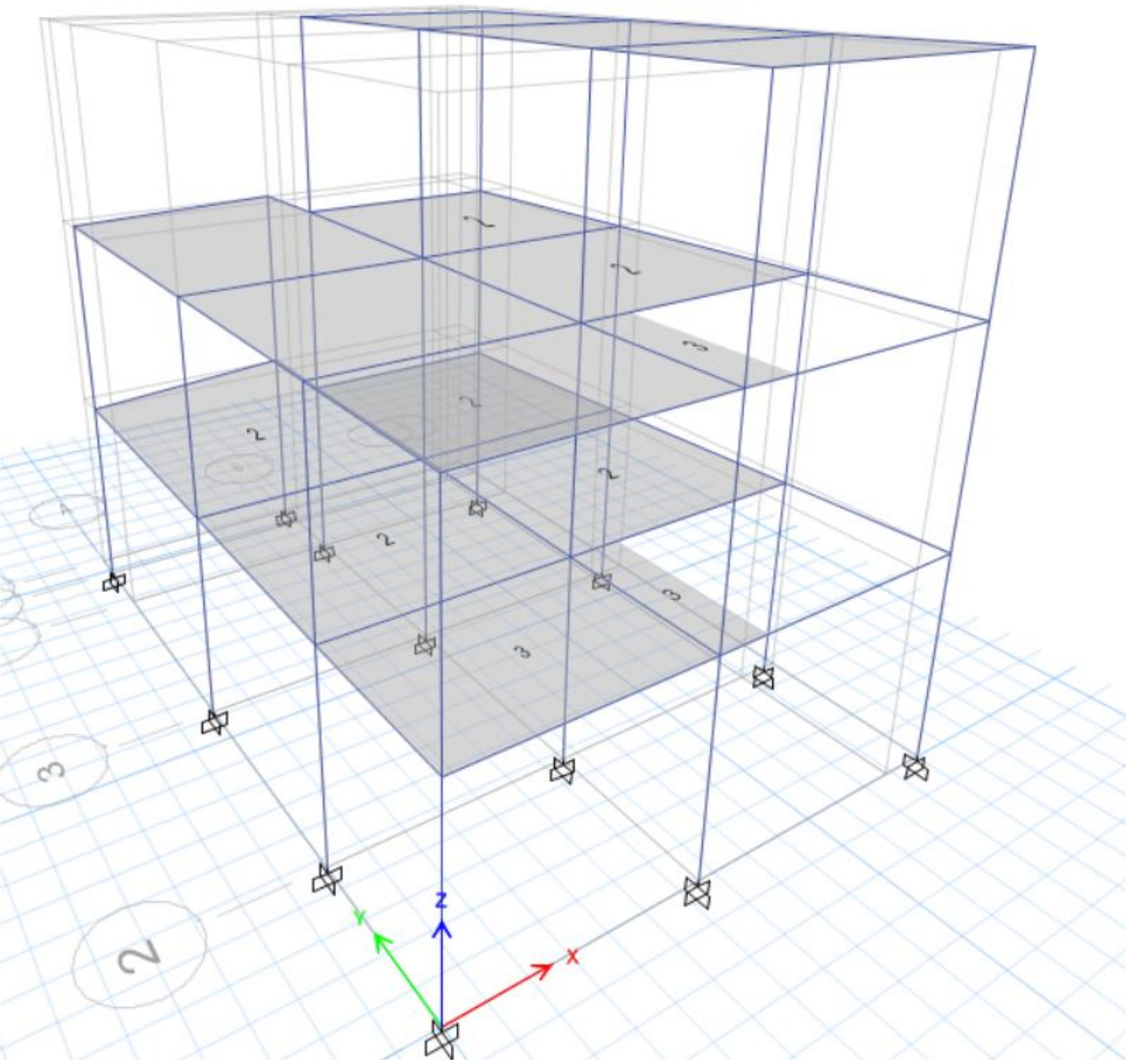
Frame Structure and Element



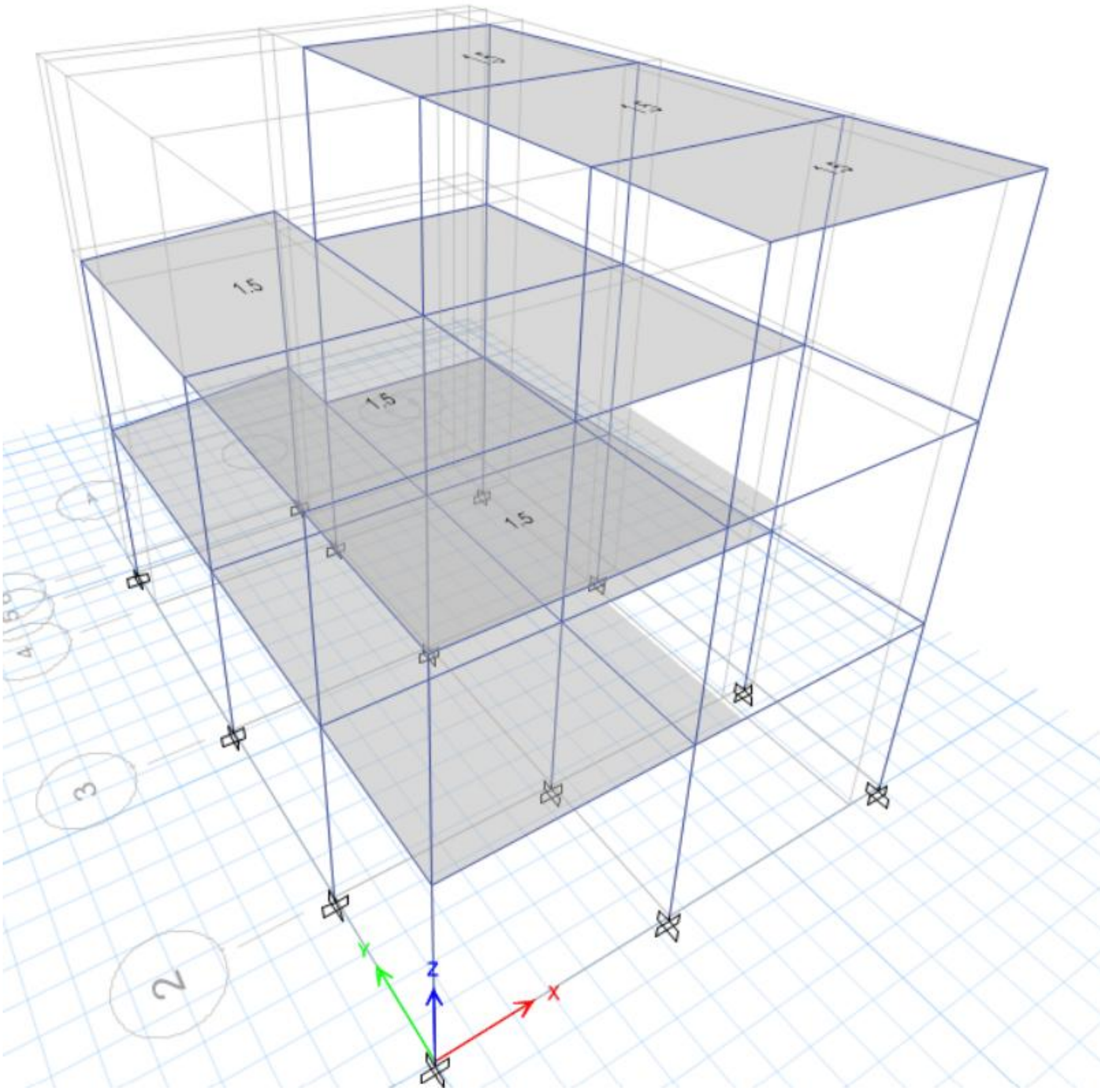
Wall Dead Load Frames (KN/m)



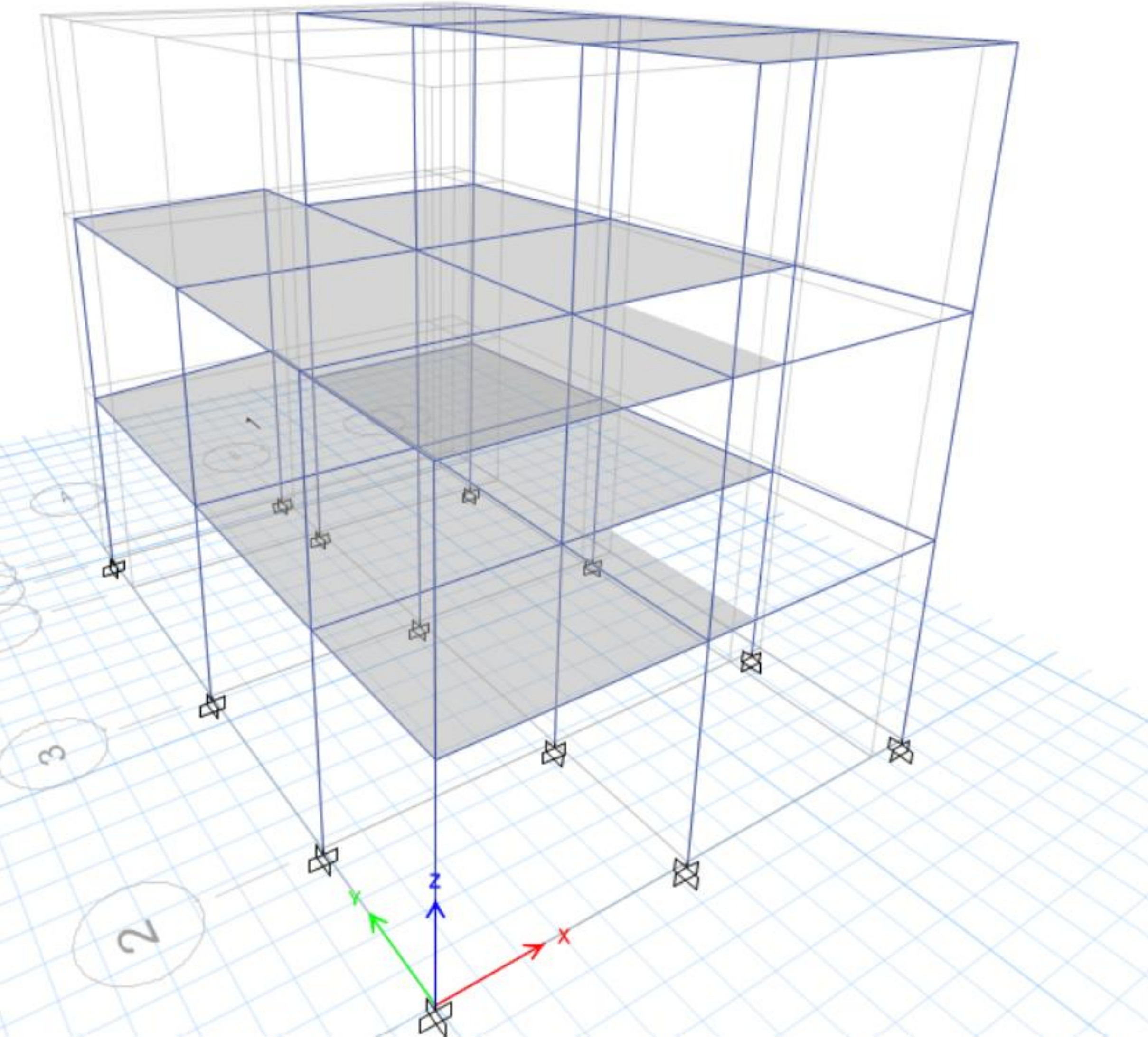
Floor Finish (KN/m^2)



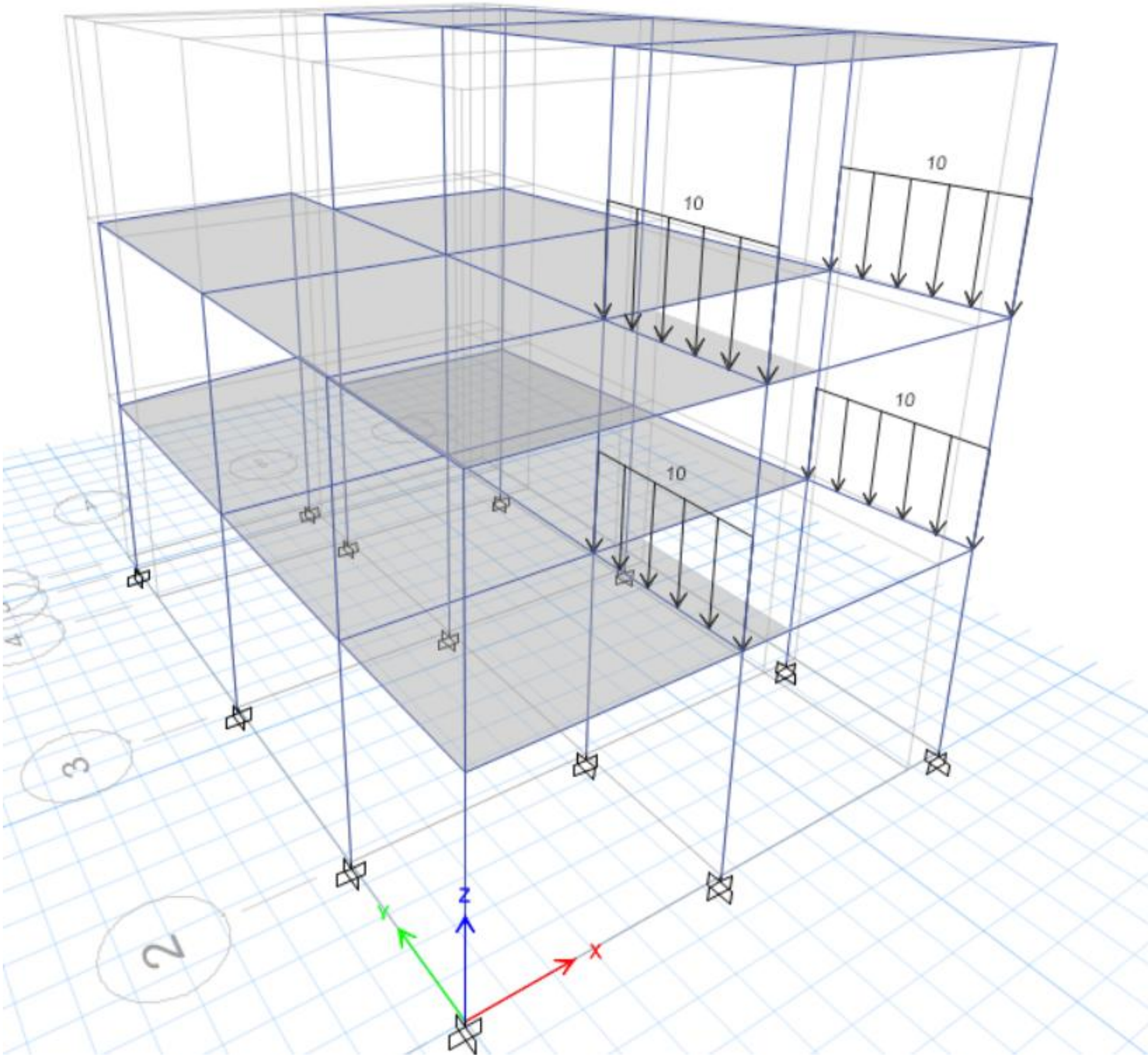
Live Load (KN/m²)



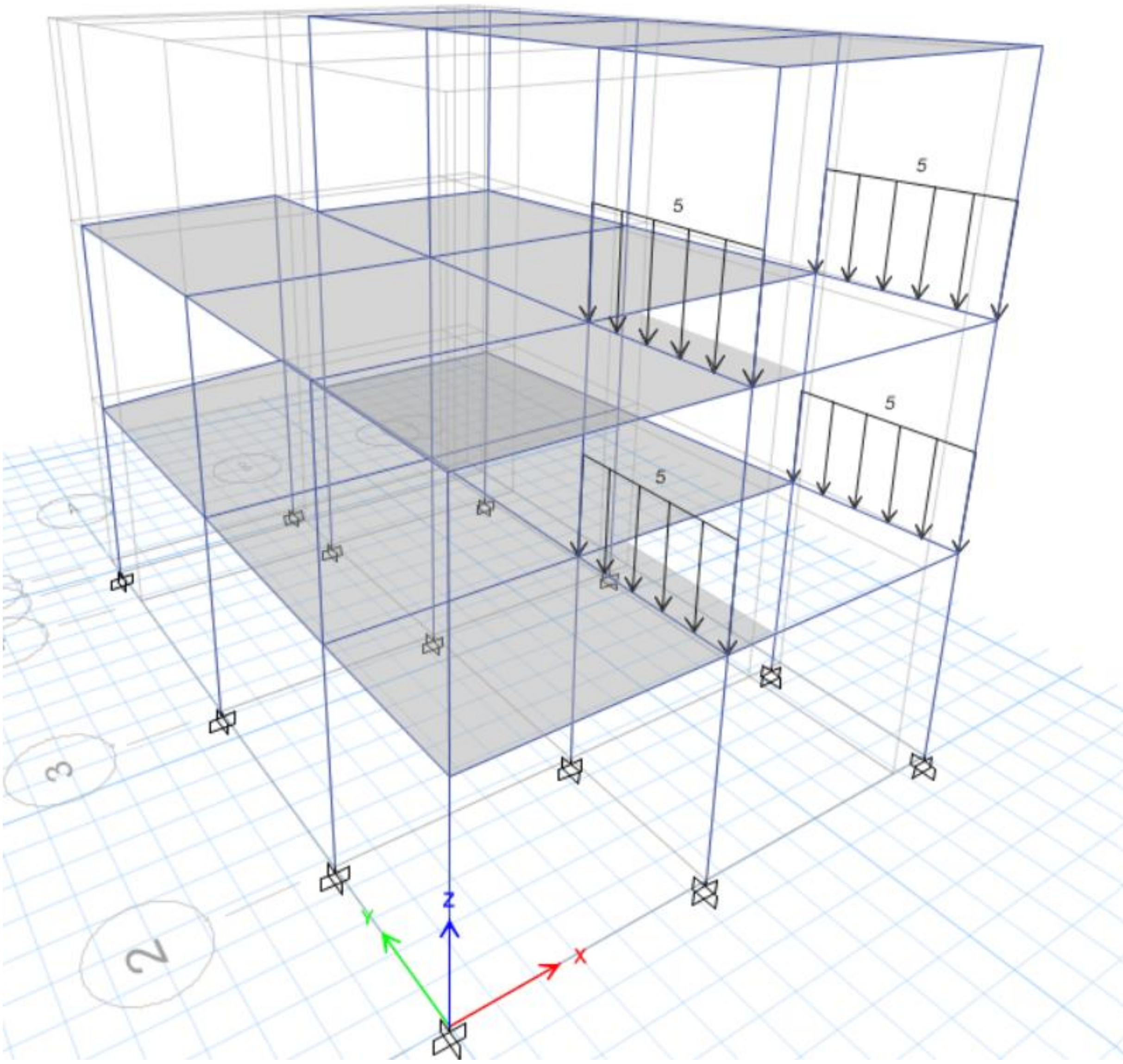
Roof Live (KN/m²)



Wall Load (KN/m²)



Stair Dead (KN/m)



Stair Live (KN/m)

Longitudinal Reinforcements (X - Z Axis) (mm^2)

Grid 1-1

2
A
2
B
2
C
2
C'
Story3
Story2
Story1
Base
154 154 154
154 154 154
1095
1090
167 154 179
216 154 250
154 154 154
154 154 154
1110
1012
1012
256 154 240
235 154 277
154 154 154
154 154 154
1012
1012
1012
Z
X

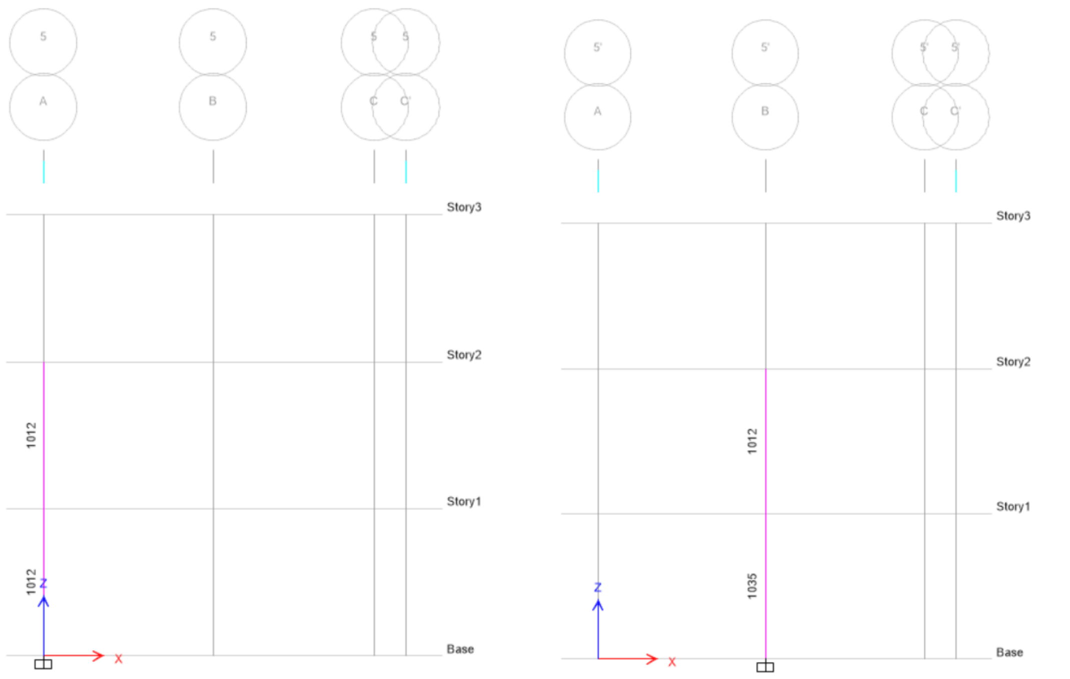
Grid 2-2


3
3
3
3
A
B
C
C'
154 154 154
154 154 154
1086
1085
Story3
159 154 156
190 154 206
154 154 154
154 154 154
Story2
1114
1012
1012
254 154 215
219 154 238
154 154 154
154 154 154
Story1
1012
1012
1012
Z
X
Base

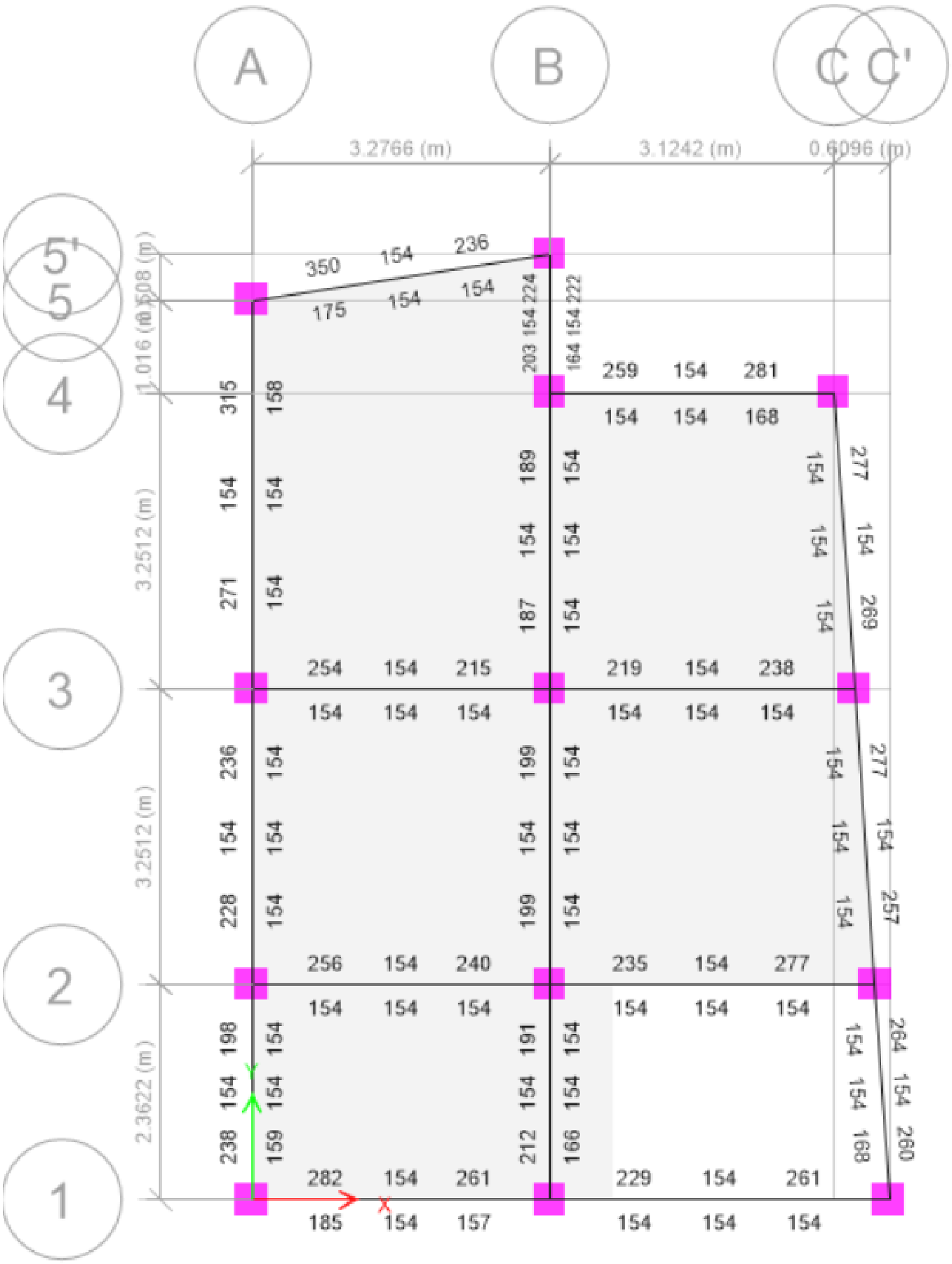
Grid 3-3


4
4
4
4
A
B
C
C'
154 154 154
154 154 154
Story3
1012
1012
218 154 238
154 154 154
Story2
1012
1012
259 154 281
154 154 168
Story1
1012
1012
Z
X
Base

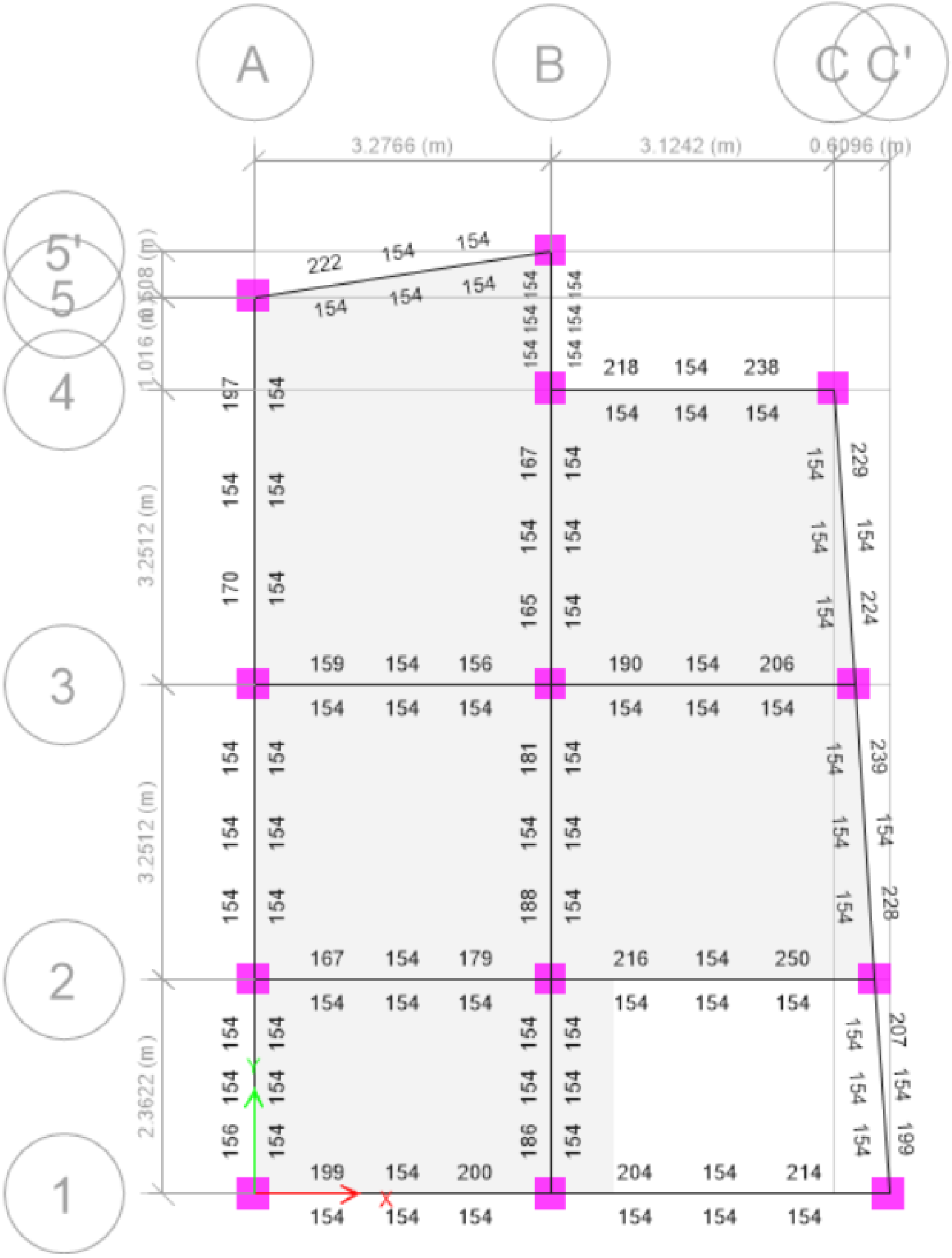
Grid 4-4


5
5
5
5
A
B
C
C'
Story3
Story2
Story1
Base
1012
1012
Z
X
5'
5'
5'
5'
A
B
C
C'
Story3
Story2
Story1
Base
1012
1035
Z
X

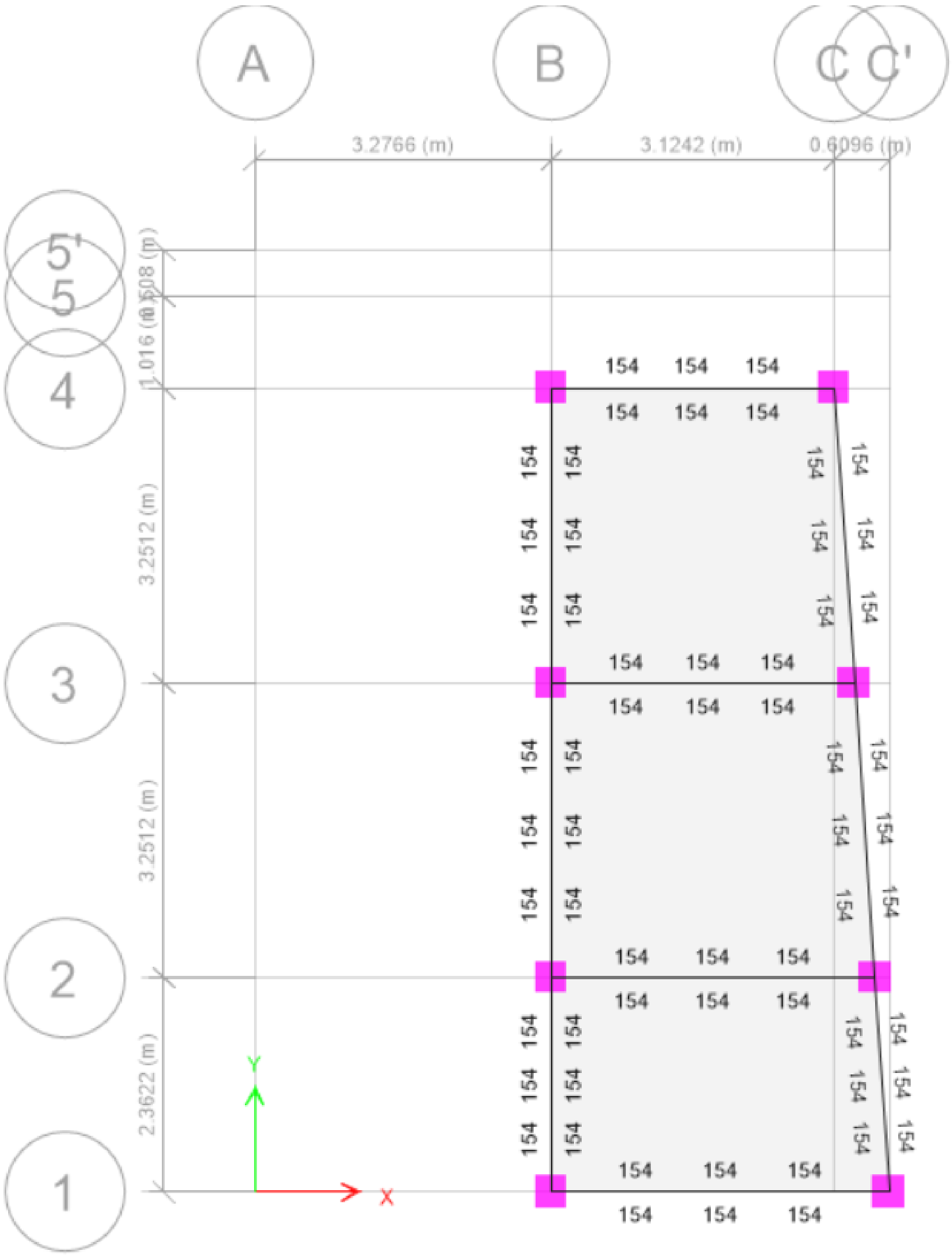
Grid 5-5



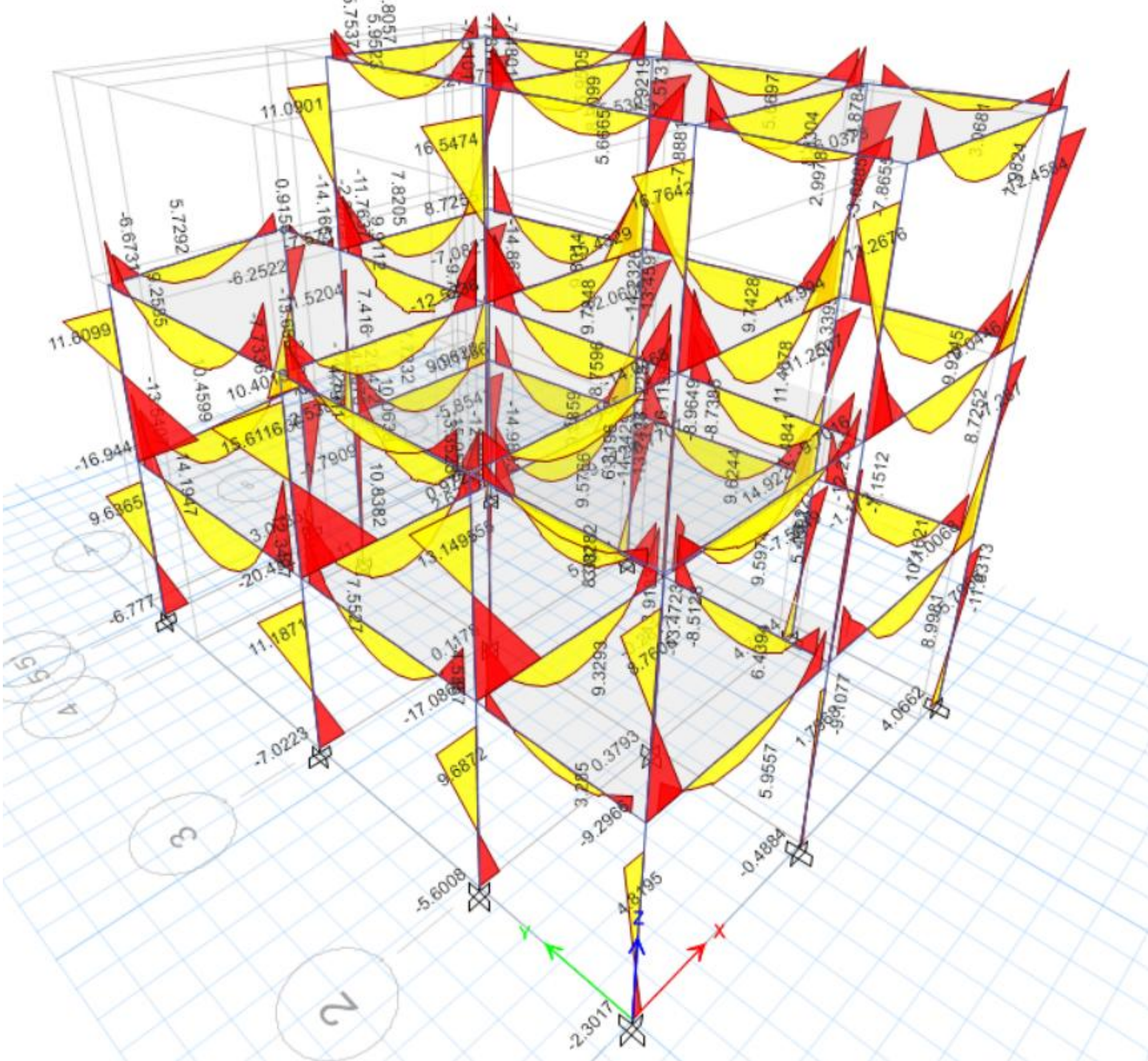
Beam Reinforcements (X -Y Axis) First Floor Beam



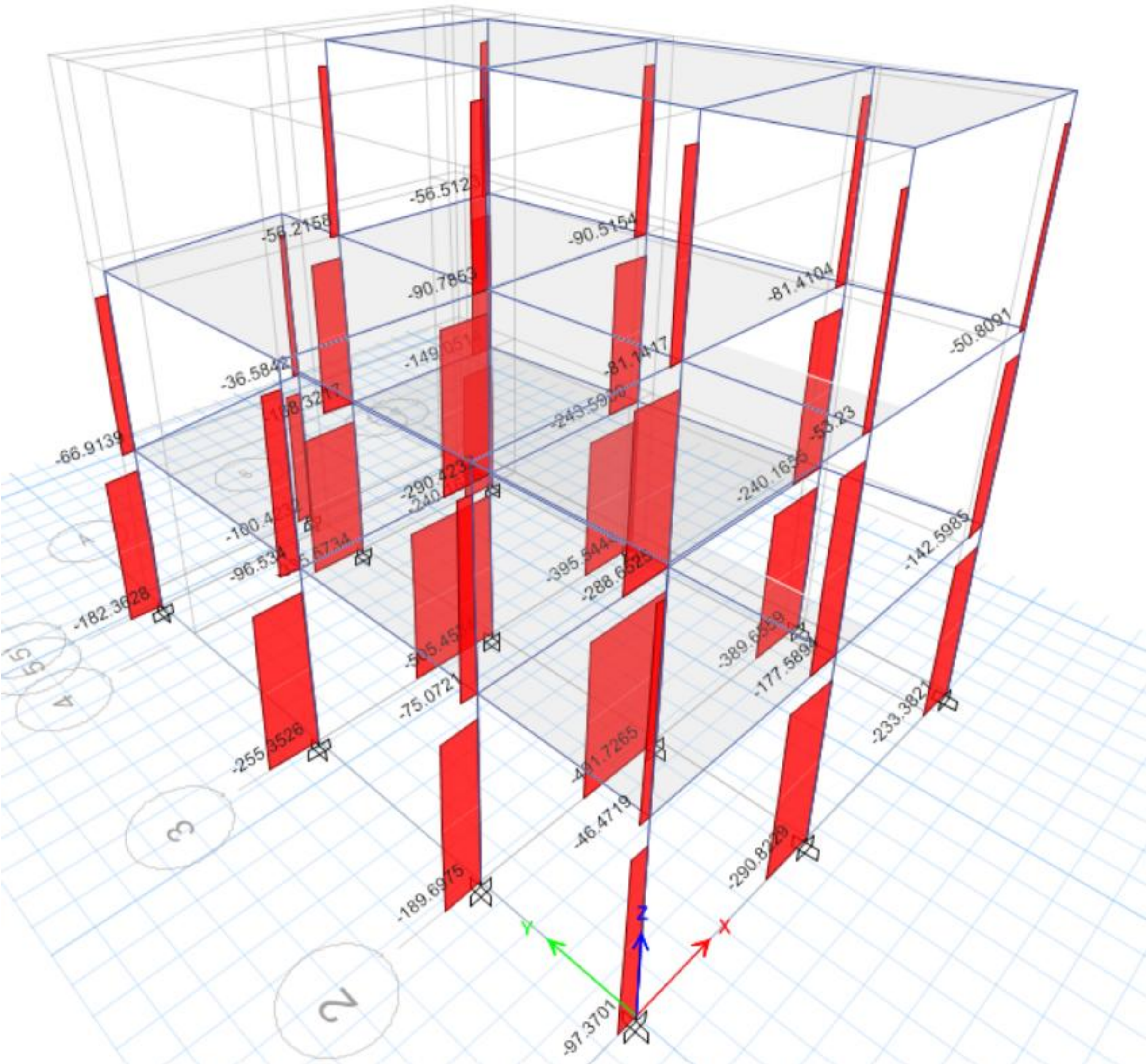
Beam Reinforcements (X -Y Axis) Second Floor Beam



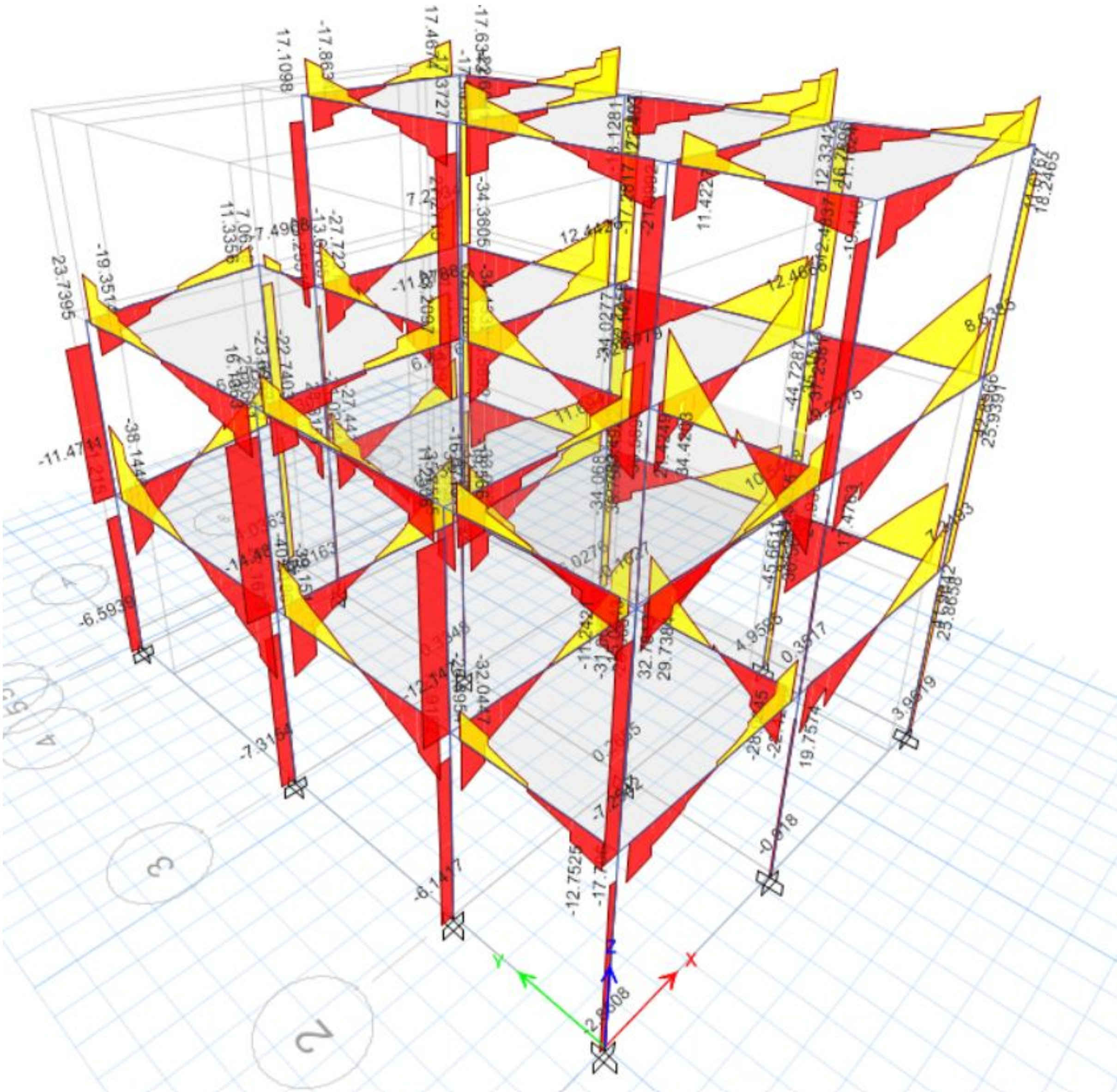
Beam Reinforcements (X -Y Axis) Third Floor Beam



Bending Moment Diagram



Axial Force Diagram



<u>**Shear Force Diagram**</u>

Seismic Load

Horizontal Base shear coefficient

a) Ultimate Limit State
$C_d(T_1)$ = 0.7875/(4*1.5)
= 0.1313

b) Serviceability Limit State
C_d(T 1) = 0.1575/1.25
=0.126

Seismic Weight of the Structure= 2164.93 KN

Horizontal Seismic Base shear

V= $C_d(T_1)$*W
Where $C_d(T_1)$=Horizontal Base shear coefficient
W=Seismic Weight of the Structure

a) Ultimate Limit State Base Shear
V=0.1313*2164.93
=284.25 KN

b) Serviceability Limit State Base Shear
V=0.126*2164.93
=272.78 KN

TABLE: Auto Sesmic Load

TABLE: Load Pattern Definitions - Auto Seismic - User Coefficient							
Name	**Ecc Ratio**	**Top Story**	**Bottom Story**	**C**	**K**	**Weight Used**	**Base Shear**
						kN	kN
EQX SLS	0.1	Story3	Base	0.1313	1		
EQX SLS(1/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQX SLS(2/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQX SLS(3/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQX ULS	0.1	Story3	Base	0.126	1		
EQX ULS(1/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811
EQX ULS(2/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811
EQX ULS(3/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811
EQY SLS	0.1	Story3	Base	0.1313	1		
EQY SLS(1/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQY SLS(2/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQY SLS(3/3)	0.1	Story3	Base	0.1313	1	2164.9294	284.2552
EQY ULS	0.1	Story3	Base	0.126	1		
EQY ULS(1/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811
EQY ULS(2/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811
EQY ULS(3/3)	0.1	Story3	Base	0.126	1	2164.9294	272.7811

TABLE: Modal Participating Mass Ratios								
Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ
		sec						
Modal	1	0.498	0.5563	0.1785	0	0.5563	0.1785	0
Modal	2	0.474	0.2674	0.5038	0	0.8237	0.6824	0
Modal	3	0.373	0.0161	0.1727	0	0.8398	0.855	0
Modal	4	0.172	0.1117	0.0003	0	0.9515	0.8553	0
Modal	5	0.163	0.0006	0.1018	0	0.952	0.9572	0
Modal	6	0.147	0.0005	0.0011	0	0.9525	0.9583	0
Modal	7	0.107	0.0474	0.0001	0	0.9999	0.9583	0
Modal	8	0.105	0.0001	0.0415	0	1	0.9998	0
Modal	9	0.095	1.775E-05	0.0002	0	1	1	0
Modal	10	0.006	0	0	0	1	1	0
Modal	11	0.005	0	0	0	1	1	0
Modal	12	0.005	0	0	0	1	1	0
Modal	13	0.498	0.5563	0.1785	0	0.5563	0.1785	0
Modal	14	0.474	0.2674	0.5038	0	0.8237	0.6824	0
Modal	15	0.373	0.0161	0.1727	0	0.8398	0.855	0

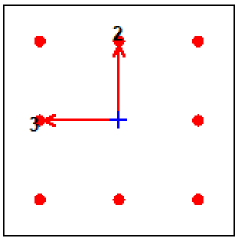
12 DESIGN

12.1 COLUMN DESIGN

Ground Floor=B5

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
Story1	C9	27	Column 14" X 14"	dl+0.3ll-slseqy+0.3slseqx	0	2844.8	1	Ductile Frame

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
355.6	355.6	56	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 Area mm²	Rebar % %
-10.3774	-38.8123	26.6489	0.2075	0.2075	1035	0.82

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)	0.666343	2489.2	12.9149	0	0.2075
Minor Bend(M2)	0.640032	2489.2	-18.8303	0	0.2075

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}	14.8273	50.407	42.6146	14.8273	394.16
Minor, V_{u3}	20.0687	50.407	42.6146	16.5626	394.16

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
1264.5	10.3	1526.1603	458.0498	-10.3774	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	0.875	355.6	4.664	12	No	0
Minor Bending (M_2)	Yes	0.875	355.6	4.48	12	No	0

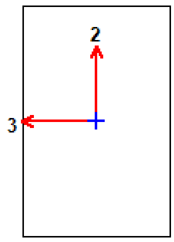
Notes:
N/A: Not Applicable
N/C: Not Calculated
N/N: Not Needed

12.2 BEAM DESIGN

Ground Floor-A5-B5

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
Story1	B6	57	Beam 9"x14"	dl+0.3ll-slseqx+.3slseqy	177.8	3315.7	1	Ductile Frame

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
228.6	355.6	228.6	0	41	41

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
-31.1688	7.1554	46.5956	0.7287

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-31.1688	10.7565	0	-41.9252

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)	-41.9252		350	0	350	154
Bottom (-2 Axis)		0	175	0	0	175

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
54.0532	0	104.1347	30.3826	917.25

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
7.1554	46.5956	166.6	293.6	581.28

12.3 SLAB DESIGN

Design of Two way Slab by Limit State Method

(As per IS 456:2000)

1	**Data**			
	Longer span of slab, ly	4.724	m	
	Shorter span of slab, lx	3.277	m	
	Materials used			
	Concrete	M20	20	N/mm2
	Steel	Fe500	500	N/mm2
2	**Effective span**			
	Longer span of slab, ly	4.548	m	
	Shorter span of slab, lx	3.101	m	
	ly/lx	1.467		
	type of slab	<2 two way slab		
	Support Condition :			
	One Short Edge Discontinuous			
3	**Calculation of loads**			
	i) Dead load			
i	Slab thickness	127	mm	
	Self weight of concrete	25	KN/ m3	
	Dead load of slab = 25 * 0.125	3.175	KN/ m2	
ii	Screeding thickness	30	mm	
	Self weight of screeding	20.4	KN/ m3	
	Dead load of screeding = 20.4 * 0.03	0.612	KN/ m2	
iii	marble flooring thickness	19	mm	
	Self weight of marble	27	KN/ m3	
	Dead load of marble = 27 * 0.019	0.513	KN/ m2	
iv	Cement plaster thickness	12.5	mm	
	Self weight of plaster	20.4	KN/ m3	
	Dead load of plaster = 20.4 * 0.0125	0.255	KN/ m2	

Total dead load on slab	**4.555**	**KN/ m2**
ii) Live load		
For Residential Building	2	KN/ m2
Total design load (DL+LL)	**6.555**	**KN/ m2**
Factored load = 1.5 * design load	9.8325	KN/ m2

4 Calculation of moments

As per code,

Shorter Direction		Longer Direction	
Support, αx1	0.056	Support, αy1	0.037
mid, αx2	0.043	mid, αy2	0.028

-ve moment at support

+ve moment at mid

Along shorter span,

Mx = αx1*wu*lx	5.991	KNm
My = αy1*wu*lx	3.935	KNm

Along longer span,

Mx = αx2*wu*lx	4.573	KNm
My = αy2*wu*lx	2.978	KNm

5 Depth Calculation

Minimum depth of slab is calculated considering maximum bending moment

Maxm bending moment	5.991	
Depth required, d=sqrt(Mu/(0.36*xumax/d)*(1-0.42*xumax/d)*b*fck)		
overall depth, D=d+φ/2+clear cover)		mm
For safe design, adopting depth of slab	125	mm
Effective depth	96	mm

6 Reinforcement Calculation

	Main Bar	Dist. Bar	
provide the reinforcement of dia	10	8	mm

S. No.	Description	Shorter Direction		Longer Direction	
		Support	mid	Support	mid
1	αx & αy	0.056	0.043	0.037	0.028
2	BM	5.99	4.57	3.93	2.98
3	Ast required	132.83	100.61	86.28	64.96
4	Ast min	152.40	152.40	152.40	152.40

5	Spacing reqd	515.56	515.56	329.96	329.96
6	Spacing prov.	150.00	150.00	150.00	150.00
7	Ast provided	523.81	523.81	335.24	335.24
8	% of steel provided	0.41	0.41	0.26	0.26

7 Check

7.1 Minimum reinforcement

Min Ast = 0.12% bD 150 mm2 < Ast provided in all sections

7.2 Check for deflection

From deflection control criteria

lx/d < (l/d)basic*αβγ where

lx/d 28.9766355

α = modification factor for tension reinforcement fig 4

β = modification factor for compression reinf. 1 fig 5

γ = reduction factor for ratios of span to eff. depth in flanged beam 1 fig 6 of IS 456

(l/d)basic = 23

For α,

fs = 0.58*fy*(Ast required/Ast provided) 84.374 N/mm2

% of tensional reinforcement 0.412

α 2

now, (l/d)basic*αβγ 46 OK Safe

Since, lx/d < (l/d)basic*αβγ SAFE

7.3 Check for Shear

Shear is checked along short span.

Maximum shear force, Vumax = w*lx/2 17.150 KN

Normal shear stress, τv = V/bd 0.160 N/mm2

% of steel provided = 100*Ast provided/bD 0.245

Shear capacity of section without reinforcement

From table 19,

τc 0.356 N/mm2

Shear strength, τ'c = k*τc

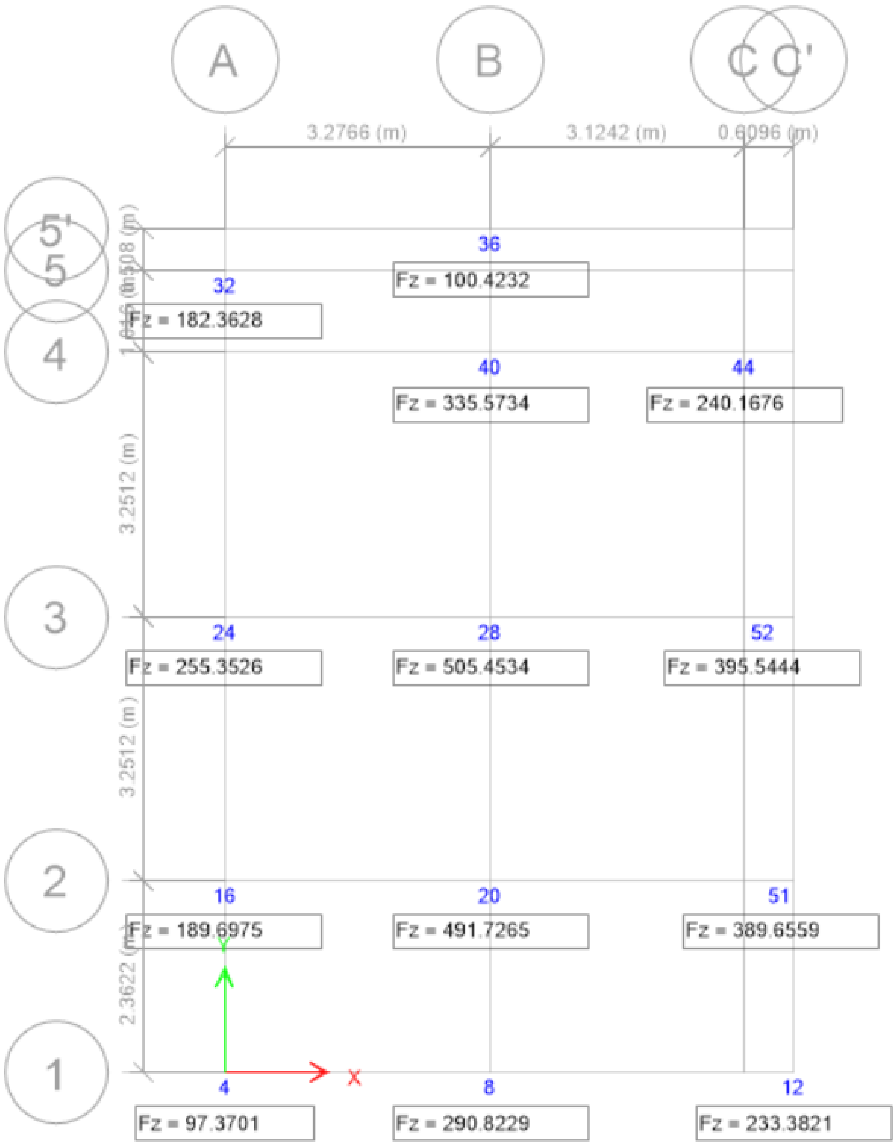
For slab thickness 125mm, k 1.3

Shear strength, τ'c	0.463	N/mm2
Since, τ'c > τv	OK Safe	

8 Results

Overall depth of slab =	125	mm
Main bar along short span at support	10mm ø @ 150mm c/c	
Main bar along short span at mid	10mm ø @ 150mm c/c	
Distribution Bar along long span at support	8mm ø @ 150mm c/c	
Distribution bar along long span at mid	8mm ø @ 150mm c/c	

12.4 FOUNDATION DESIGN



Joint Reaction1.5(DL+LL)

Isolated Footing Design

Foundation Type : F1

Required Data

size of colunm=

l =	0.35	m		
b =	0.35	m		
Bearing Capacity of Soil=	120	KN/m²		
Strength of Steel (fy)=	500	N/mm²		
Strength of Concrete (fck)=	20	N/mm²	(M 20)	
Factor Load=	505.45			
Axial Load =	336.97	KN		
Approximate area of footing=	2.81	m²		
Weight of footing including earth=	84.24			
Axial Load =	336.97	KN		
Total weight on soil=	**421.21**	KN		
Actual Area=	3.51	m²		
Size of Square Footing =	1.874			6.14516

Adopted size=

L =	1.98	m	6.49
B =	1.98	m	
Actual area of footing =	3.9204	m²	
Net Pressure acting upwads =	128.93	KN/m²	

B. M. at the face of column about an axis = 84.78 KN-m

The effective depth required is given by

BM= 0.138 fck*bd^2

d= 124.56 mm

Adopt d = 2 to 3 Times of calculated value of d for Shear considerations.

Adop. d= 350 mm

D= 400 mm

Check for one-way Shear action

The critical section is taken at distance d away from the face of column

Shear force Vu= 118.70 KN

Nominal shear stress (Tv) = Vu/b*d = 0.17 N/mm²

Allowable Shear Stress of Concrete for pt% of Steel < = 0.15 & (M 20) 0.28

For

0.165% Tc = 0.292 N/sq.mm (From IS 456: 2000, table 19)

Hence, **OK**

Tc should be equal to or greater than Tv

Check for two-way Shear action

The critical section is taken at a distance of 0.5d away from the face of column ,

Shear force Vu= 442.28 KN

Nominal Shear Stress(Tv) = Vu/b'd (Where b' is the periphery of critical section)

and b' = 2800 mm

So, Nominal Shear Stress(Tv) = 0.45 N/mm²

Shear Strength of concrete is

Tc = 1.12 N/sq.mm

T'c = Ks*Tc Where Ks=(0.5+Bc)

Bc=length of shorter side of column/length of longer side of column

Bc= 1

Ks= 1.5 should not be greater than 1

Take(Ks)= 1

T'c= 1.12 N/mm²

Hence, **OK** T'c should be greater than Tv

Area of Steel Calculation,

Area of Steel is given by formula, BM = 0.87* fy* At*{d-fy*At/(fck*b)}

Then,

Ast = 568.52 sq.mm > Ast min = 0.12% of b * d

Ast per m = 287.13 420 mm²

Req. Area of steel = 420.00 mm²

% of steel= 0.082

Steel requied as 12 mm bar @ 269.28 mm c/c distance.

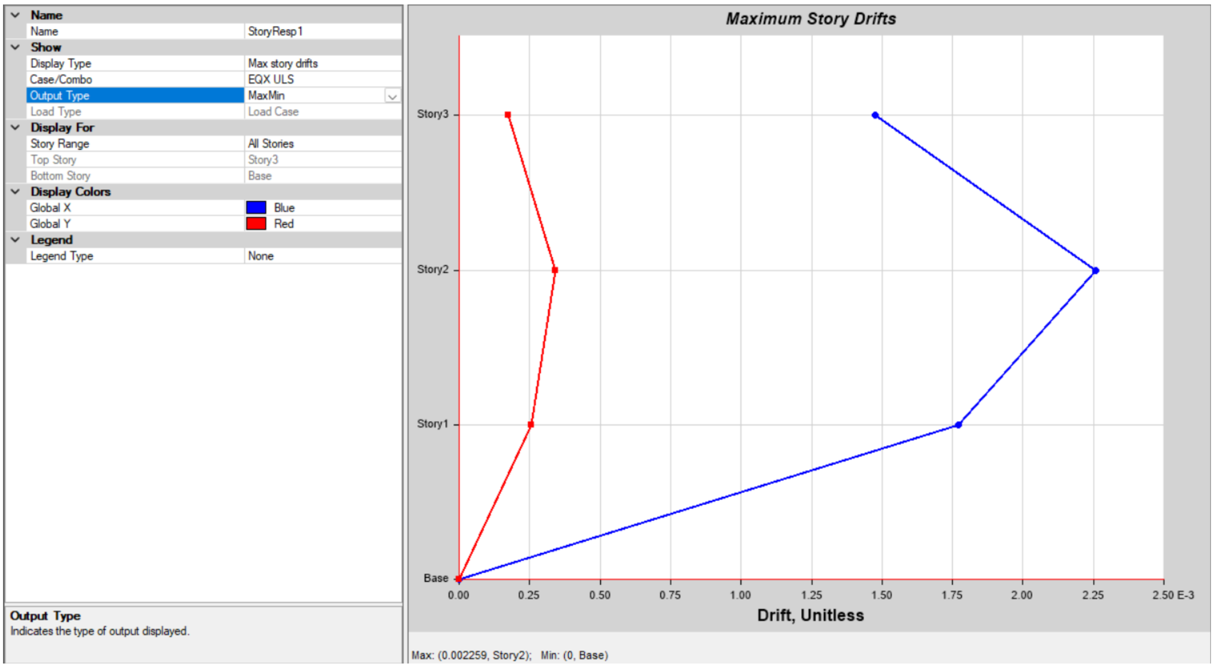
Provide Steel as = 12 mm bar @ 150 mm c/c distance.

Provided steel = 753.98 mm²

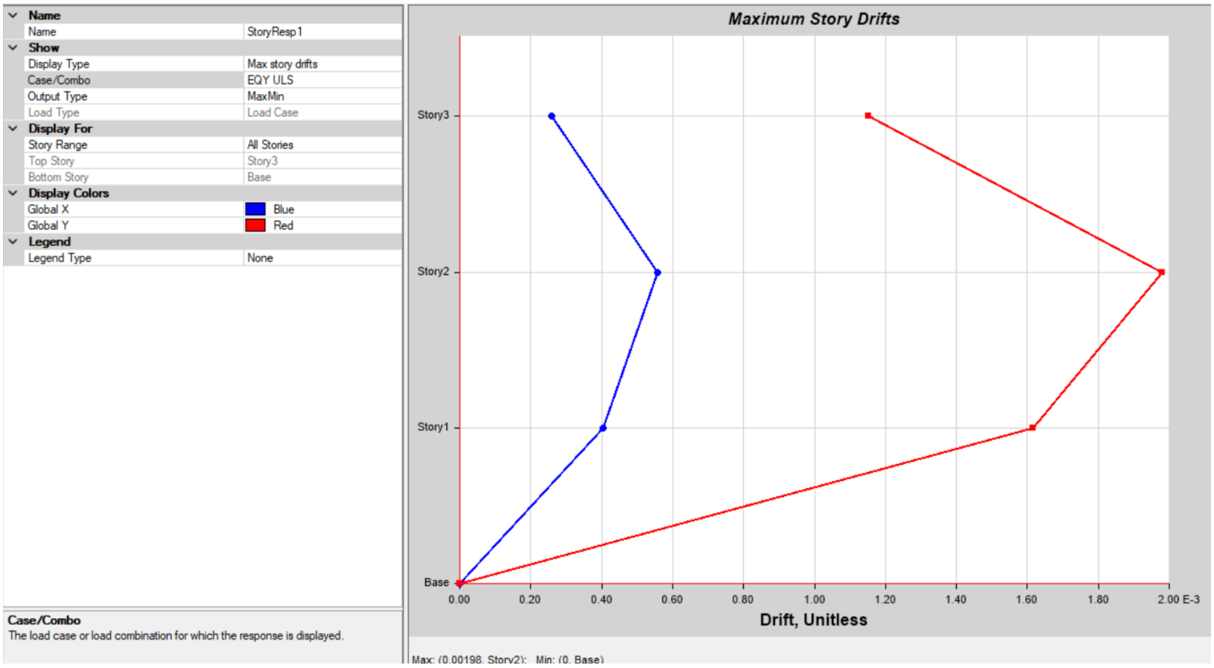
Hence Ok.

13 ACCEPTABILITY CRITERIA

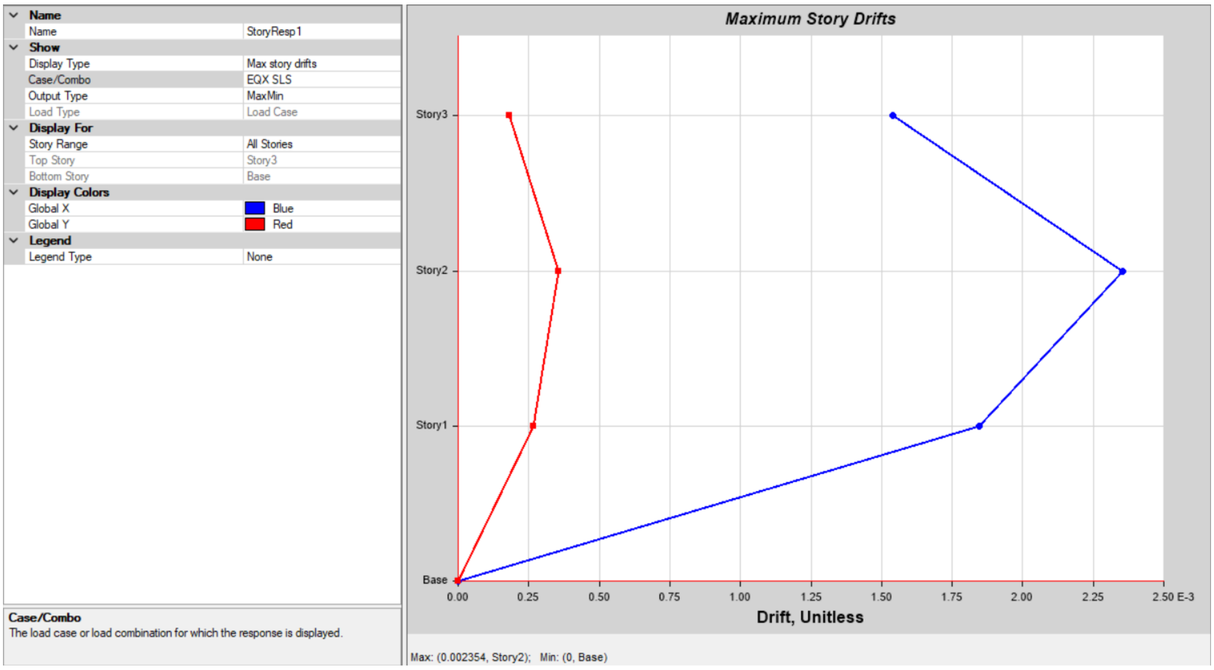
13.1 STORY DRIFT



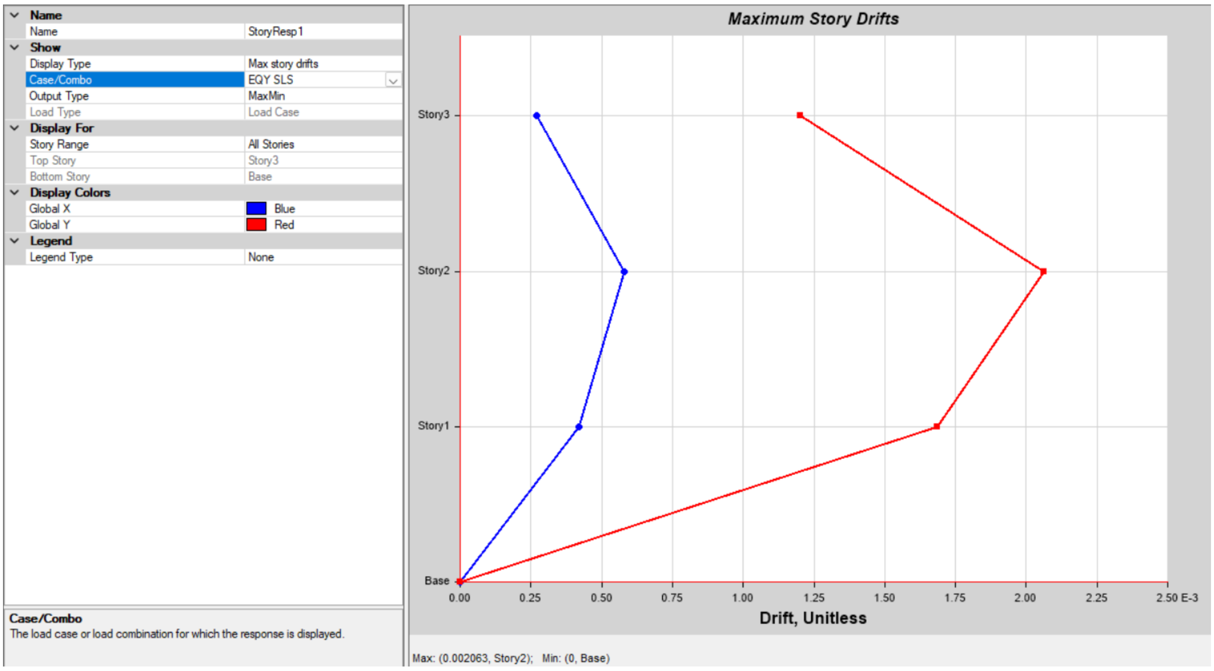
Inter-storey Drift(Load case:ULSx)



Inter-storey Drift(Load case:ULSy)



Inter-storey Drift(Load case:SLSx)

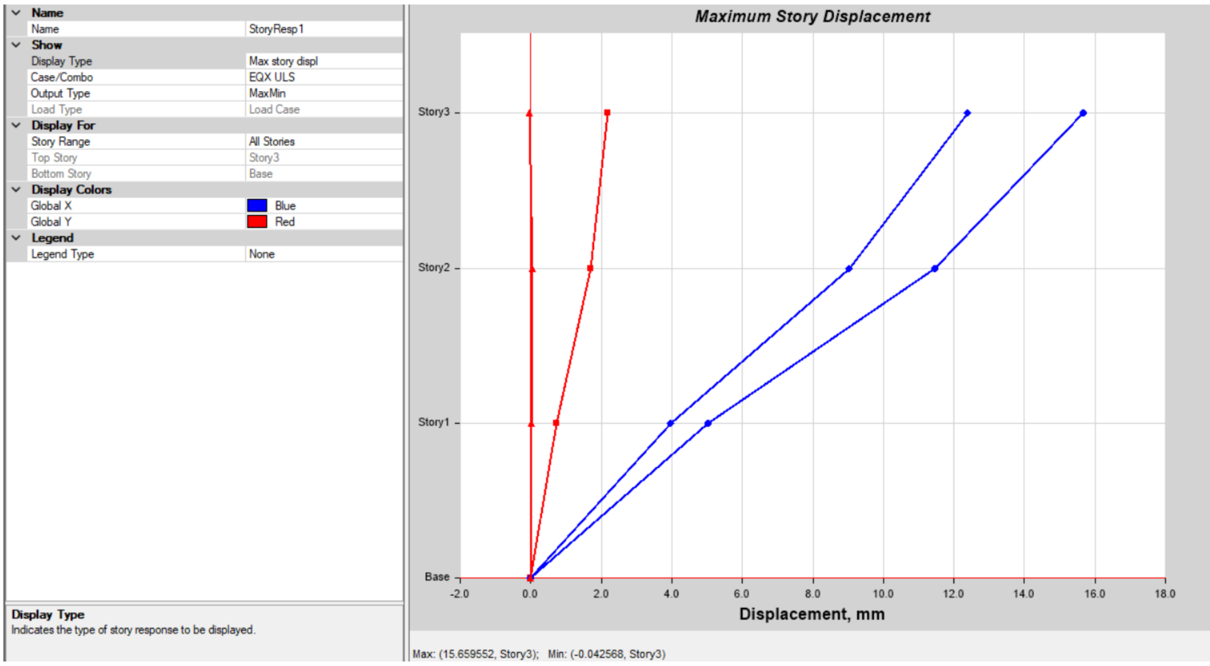


Inter-storey Drift(Load case:SLSy)

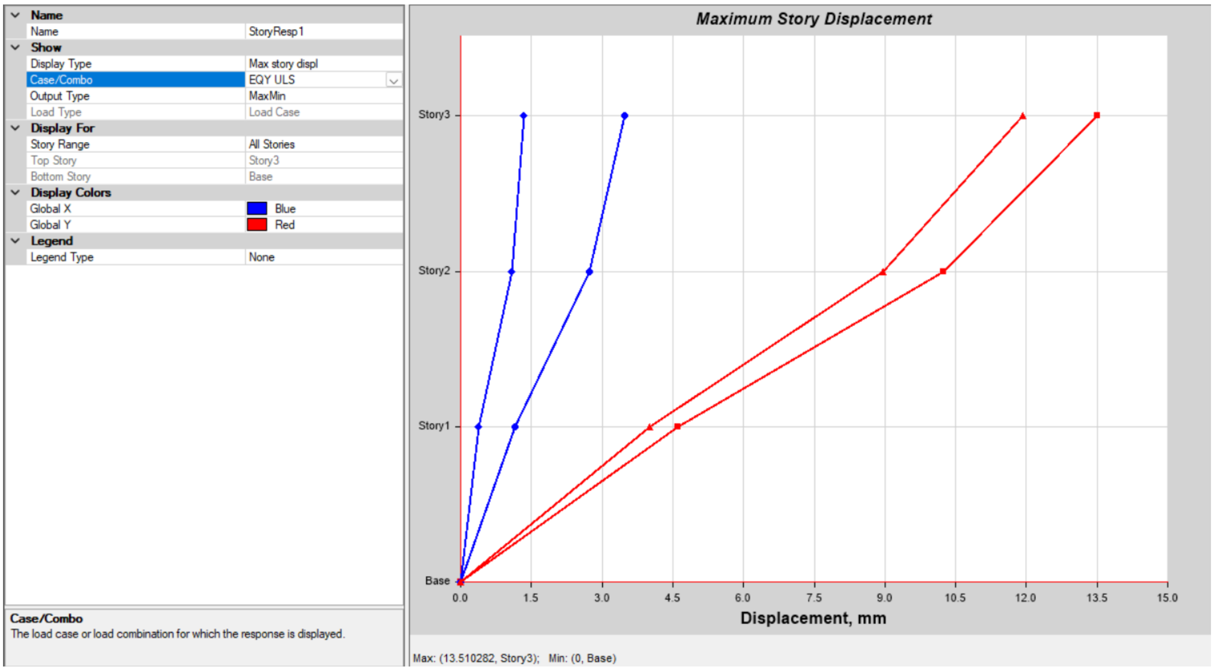
To control overall deflection, the criteria given in clause 5.6.1 of NBC 105:2020 is applied. The maximum design horizontal deflection in any story due to the design lateral force shall be determined by multiplying the horizontal deflection found from Equivalent Static Method or Modal Response Spectrum Method by the Ductility factor (Rμ). For ultimate limit state and for serviceability limit state it shall be taken as equal to the horizontal deflections calculated either by Equivalent Static Method or Modal Response Spectrum Methods.

Furthermore, the drift shall not exceed maximum drift in the model. The maximum drift for ultimate limit state is 0.002259*4=0.009 which is less than 0.025. The maximum drift for serviceability limit state is 0.002354 which is less than 0.006.

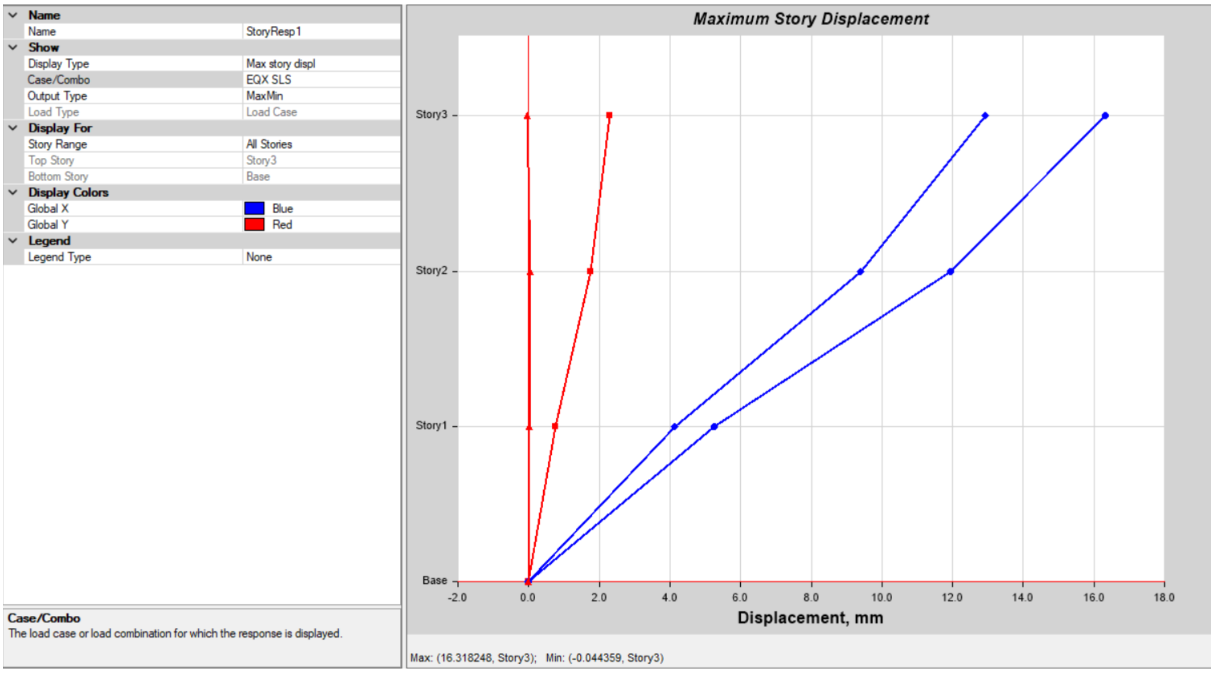
13.2 STORY DISPLACEMENT



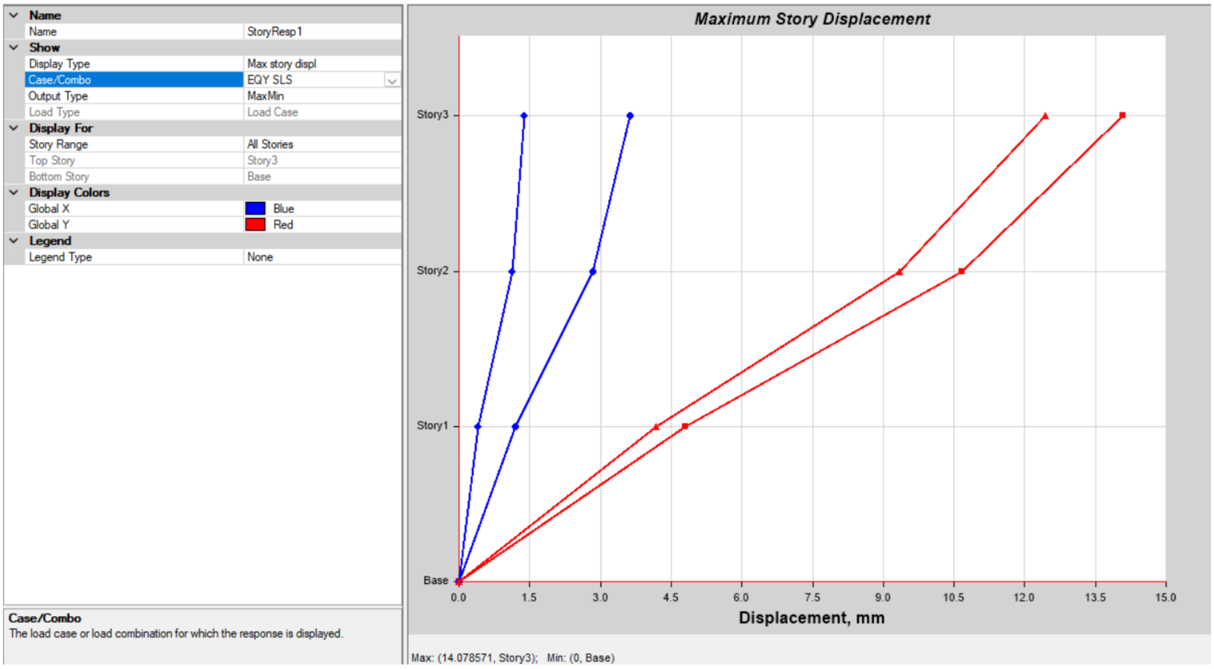
Storey Displacement:ULSx



Storey Displacement:ULSy



Storey Displacement:SLSx



Storey Displacement:SLSy

TORSIONAL IRREGULARITY CHECK

ULSEQX			
Displacement at upper end(A)	=	10.111	
Displacement at upper end(B)	=	8.419	
A/B	=	1.20097	<1.5(OK)
SLSEQX			
Displacement at upper end(A)	=	10.537	
Displacement at upper end(B)	=	8.773	
A/B	=	1.20107	<1.5(OK)
ULSEQY			
Displacement at upper end(A)	=	9.595	
Displacement at upper end(B)	=	6.892	
A/B	=	1.39219	<1.5(OK)
SLSEQY			
Displacement at upper end(A)	=	9.999	
Displacement at upper end(B)	=	7.182	
A/B	=	1.39223	<1.5(OK)

The structure pass in torsion

14 DESIGN INPUT IN MUNICIPALITY FORMAT

A. Geometrical Configuration of Structure:
(i) No. of Blocks:- 1
(ii) No. of Storey:-3
(iii) Total Height of the Structure:- 8.53 m

B. Structural Analysis and Design:
(i) Structural Analysis Software:- ETABS 2020
(ii) Structural System: - RC buildings with Special Moment Resisting Frame SMRF.
(iii) Foundation System:- Isolated, Combined and Strap Footing
(iv) Loading Parameters:
a) Dead Load:- As per IS875:1987 Part I
b) Live Load:- As per IS875:1987 Part II
c) Seismic Load (As per NBC 105:2020):-
- Horizontal Base Shear Coefficient
  Ultimate Limit State=0.1313
  Serviceability Limit State=0.126
- Seismic Weight:- 2164.93 kN
- Base Shear
  Ultimate Limit State =284.25 kN
  Serviceability Limit State=272.78 kN

(v) Maximum Deflection of the Building:-

Maximum Deflection(mm)	Allowable(mm)	Check
15.66 16.318	53.3(ultimate) 51.18(serviceability)	OK

(vi) Maximum Drift in the Building:-

Maximum Drift	Drift should be less	Check
0.009 0.002354	0.025(ultimate) 0.006(serviceability)	OK

(vii) Load Combination Considered:- NBC 105:2020
(viii) Concrete Design code Referred:- IS 456:2000
(ix) Ductile Detailing code Referred:- IS13920:2016
(x) Concrete Grade Used:
Beam – M20
Slab – M20
Column – M20
Foundation – M20
(xi) Reinforcement Grade Used: - Fe500