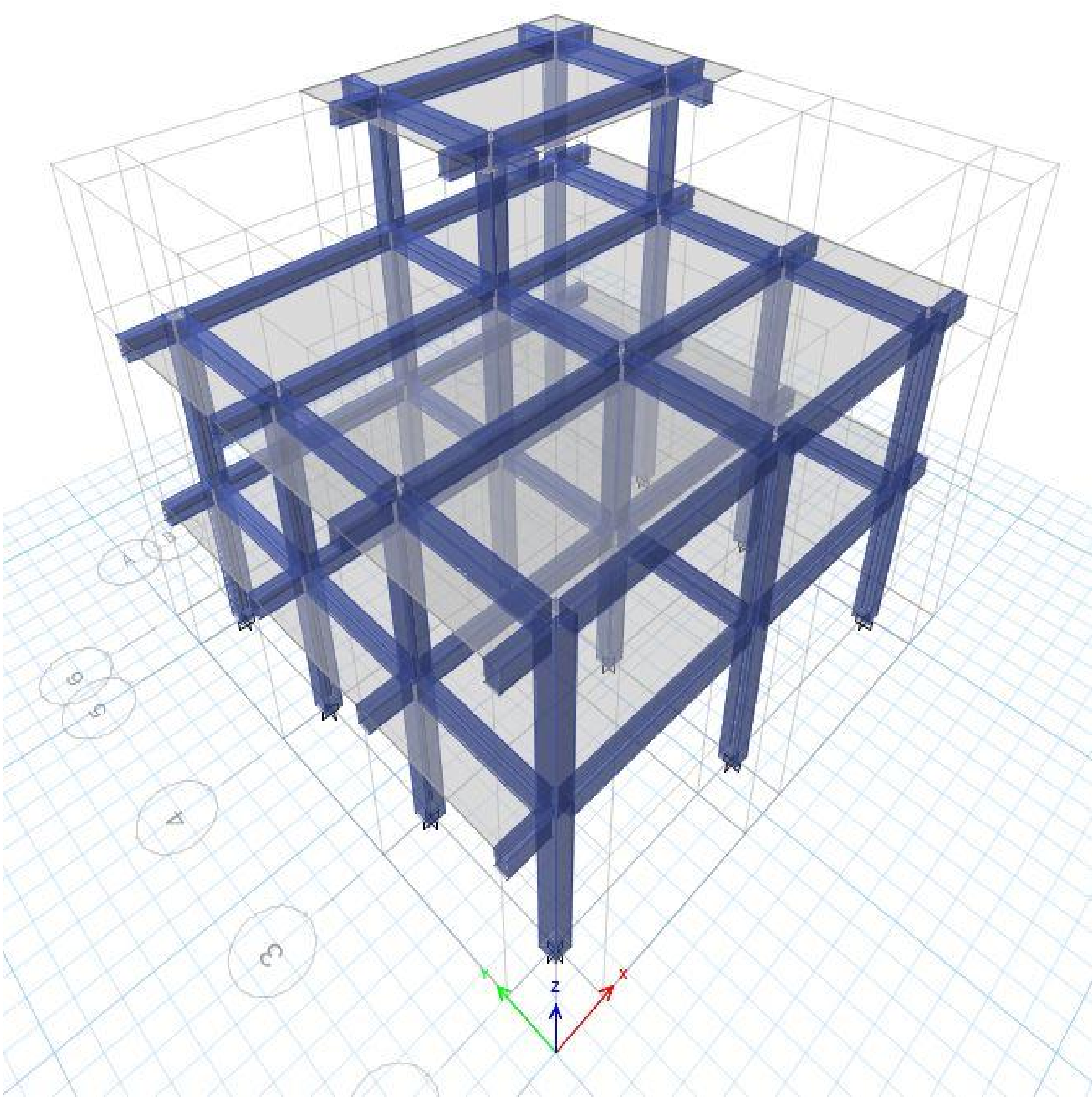
Structural report of Residence
AT
Babarmahal , Kathmandu

Structural Analysis and Design Report



Structural Design Consultant:
Laligurans Design and Consultant
Satdobato, Lalitpur

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GENERAL INFORMATION:

S.N.	General Information:	
1	Name of the Building Owner:	Mr. Ram Nepal
2	Address:	Babarmahal, Kathmandu
3	Occupancy Type of the Building as per byelaws:	Residential
4	Name of the Structural Designer	Mr. Sachin KC
5	NEC Registration no. of the Structural Designer:	131xx"Civil A"
6	Contact Number of the Structural Designer:	9841xxxxxxx
7	Name of the Consulting Firm (if applicable):	Laligurans Design and Consultants
8	Municipality Registration No./ Application No. :	xxxx
9	Date of Application in Municipality :	2023/06/23

A. Features of the Building

A.1 General Information of the Building

The building is intended for residential purpose.

Design Details:
The building has three floors made of reinforced concrete frames and filled with brick walls. Each floor has a height of 3.2 meters. The building is laid out in a rectangular grid pattern, with a maximum span of 11 meters horizontally (X-direction) and 9 meters vertically (Y-direction) between columns.

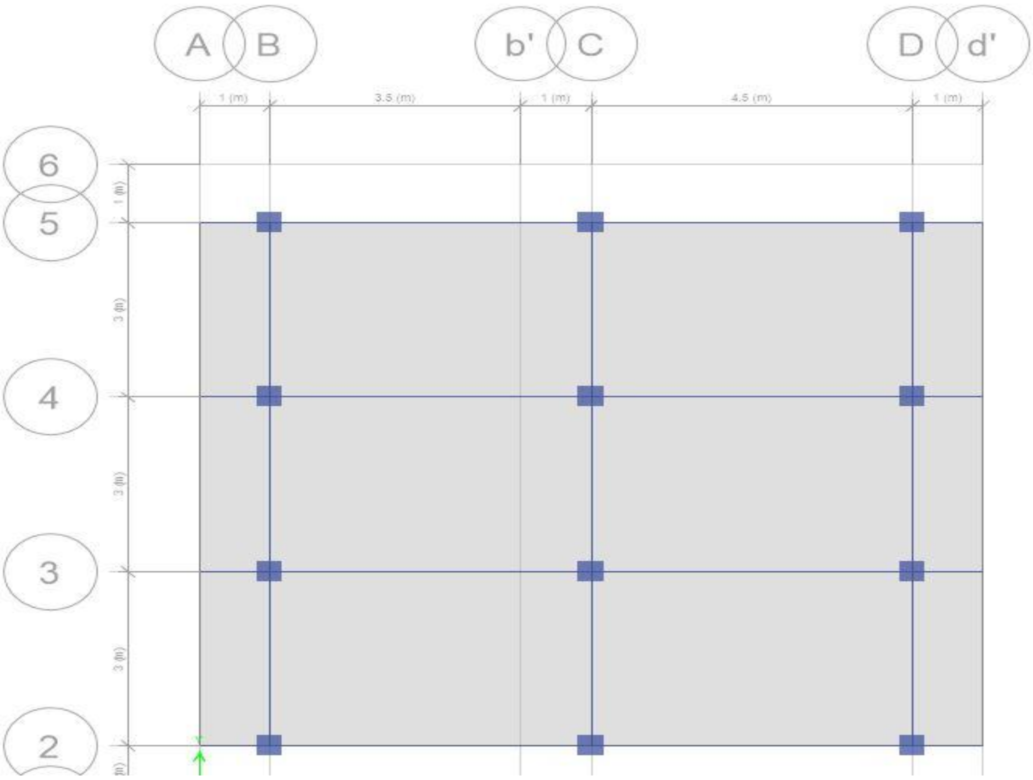

Figure 1: Plan of Building

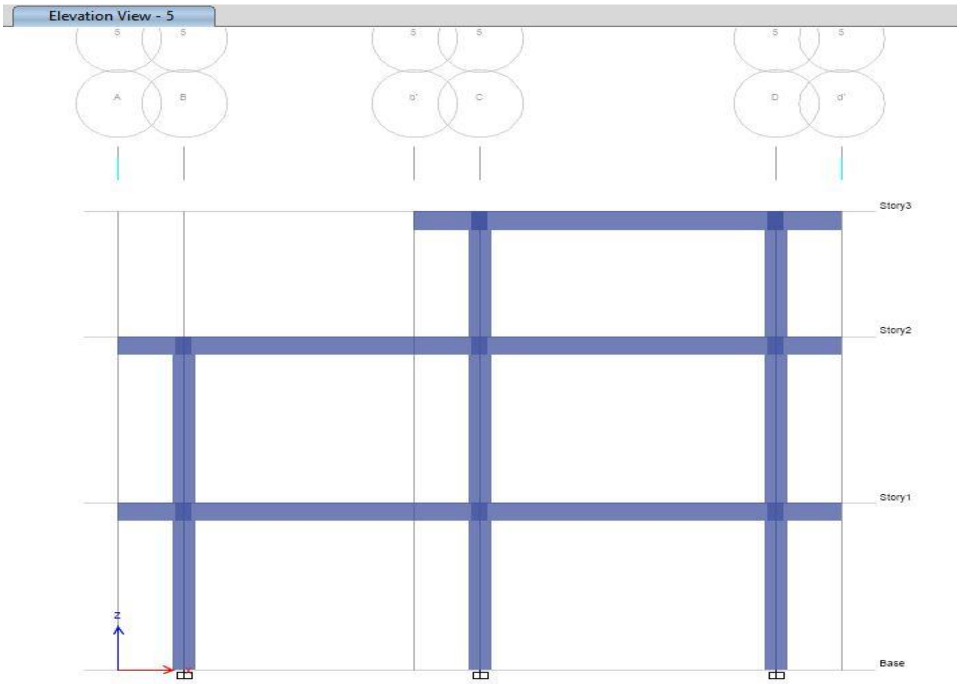

Figure 2: Section of Building

Table 1: General Information of the Building

A.1-01	Location of Building	Kathmandu
A.1-02	Number of Storeys proposed for Building Permit	3
A.1-03	Number of Storeys considered in the Design	3
A.1-04	Number of Basements	0
A.1-05	Height of Ground Floor	3.2 meters
A.1-06	Height of Typical Floor	3.2 meters
A.1-07	Total Height of the Building	9.6 meters
A.1-08	Height considered for Fundamental Time Period	9.6 meters
A.1-09	Occupancy Type of the Building according to the Building Code	Residential Building

Table 2: General Information on Structural Elements of the Building

Element	Description	Grade of Concrete	Remarks
Column	350 mm X 350 mm	M20	
Main Beam	250 mm X 355 mm	M20	
Staircase Slab	175 mm	M20	
Slab	125 mm	M20	
Foundation	Isolated Footing	M20	Soil Bearing Capacity is taken as 100 kN/m^2

A2. Element sizes

Element sizes of column, beam and slab can be derived from the table below:

A.3 Structural System and Foundation:

The chosen structural system for the building is a reinforced concrete (RC) building with a Special Moment Resisting Frame (SMRF). The columns and beams are carefully laid out in coordination with the architectural and services planning. This arrangement ensures that the structure can effectively support and transmit forces from earthquake motions, gravity, and live loads to the ground. The significance of this system increases as the building height increases. Hence, the key requirements for the structural systems are sufficient strength to prevent failure, adequate lateral stiffness, and efficient performance over the building's lifespan.

The selection and arrangement of major structural elements to efficiently resist gravity and horizontal loads are essential in determining the building's structural form. Several factors influence the choice of structural form, including internal planning, construction materials and methods, external architectural treatment, placement and routing of service systems, magnitude and nature of horizontal loading, as well as the building's height and proportions.

All loads from the building's superstructure are transferred to the ground. If the foundation design is inadequate, all efforts put into designing the superstructure would be futile. Therefore, meticulous care must be taken in the design of foundations. The foundation design process begins with detailed field and soil investigation. Understanding the soil's geotechnical properties, including soil chemistry, is crucial to ensure the foundation performs reliably.

Table 3: **Structural System & Foundation**		
A.3-01	Type of Structural System	Moment Resisting Frames
A.3-02	Type of Foundation	Isolated Footing
A.3-03	Type of Slab used	Conventional

B. Modeling of the Building

B.1 Material Properties (Concrete, Re-bar, Structural Steel)

CONCRETE
According to NBC105:2020, The material should be taken as per Cl.2.1.
Minimum grade of structural concrete shall be M20, but M25 for buildings more than 12 m in height.
As the building is less than 12 m in height, M20 concrete has been taken for all the structural components.

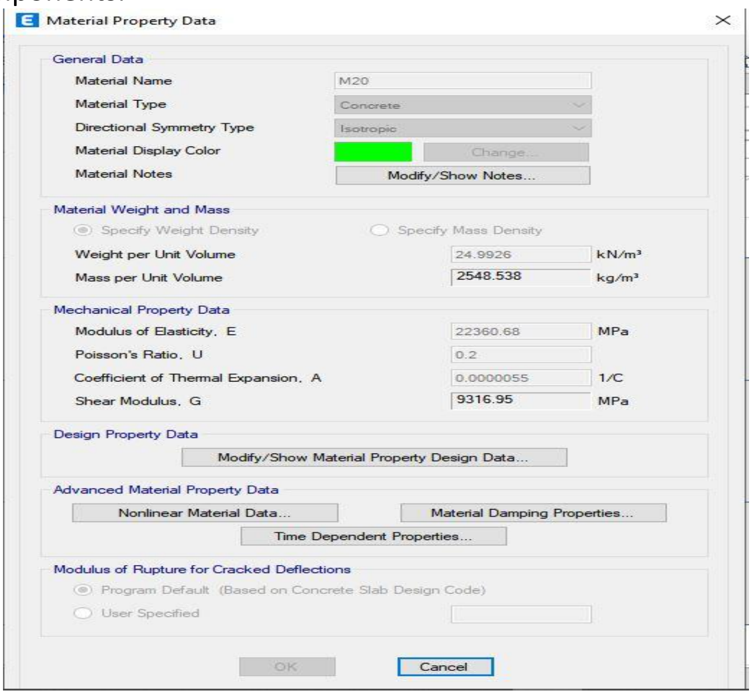

Figure 3: Material Property (Concrete)

STEEL
Steel reinforcement used shall be of,
a) Grade Fe 415 or less; or
b) High strength deformed steel bars produced by thermo-mechanical treatment process having elongation capacity of more than 15 percent; e.g. Grade Fe 500 and Fe 550.

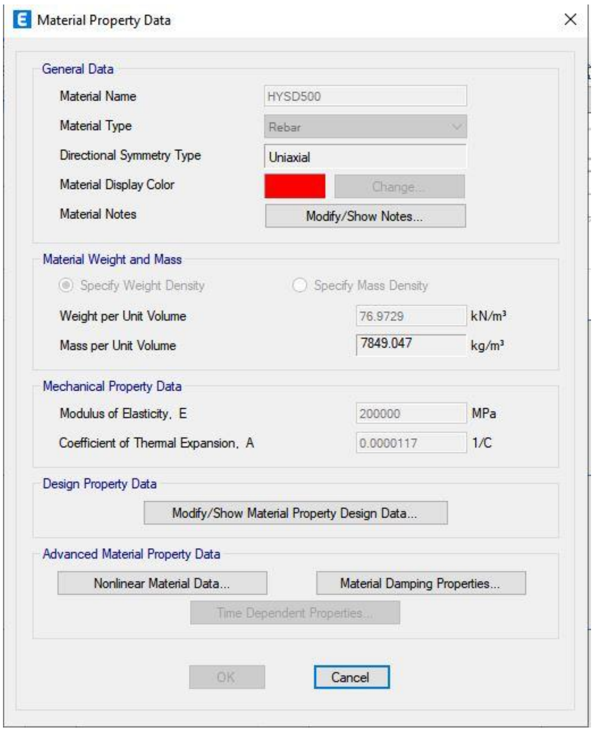

Figure 4: Material Property (Rebar)

Steel Grade of Fe500 has been used in the longitudinal and transverse reinforcement.

B.2 Stiffness Modifiers

Table 4: Effective stiffness of different components

S No.	Component	Flexural Stiffness	Shear Stiffness
1	Beam	$0.35\ E_c\ I_g$	$0.40\ E_c\ A_w$
2	Columns	$0.70\ E_c\ I_g$	$0.40\ E_c\ A_w$
3	Wall—cracked	$0.50\ E_c\ I_g$	$0.40\ E_c\ A_w$
4	Wall—uncracked	$0.80\ E_c\ I_g$	$0.40\ E_c\ A_w$

For steel structures, the gross stiffness values shall be used.

Regarding the shear stiffness modifier,

Since, $G=E/(2*(1+\mu))=0.4*E$. Thus for shear stiffness, full shear stiffness of the section is to be used. Hence, while giving input in software such as ETABS, stiffness modifier for shear area shall be given as 1 and not as 0.4 as the design software considers the value of shear stiffness in terms of G.

B.3 Slab and Diaphragm

The column exhibits high rigidity in the vertical direction, while the floor system is assumed to have significantly higher stiffness in resisting horizontal loads, primarily due to the presence of the floor slab. The floor slab contributes to the overall in-plane rigidity, causing the columns, walls, and braces connected to that plane to behave as a cohesive unit when subjected to lateral forces. This system is commonly referred to as a rigid floor diaphragm, where the beam is seamlessly connected to the slab, resulting in minimal bending in the vertical plane. Conventional slab with rigid diaphragm has been assumed.

B.4 Accidental Eccentricity

Due to the eccentricity arising between the centre of mass and the centre of rigidity at each floor level of the building, code requires increase in shear forces on the lateral force resisting elements caused by the twisting about the vertical axis of the building. Hence design codes prescribe that the actual centre of mass shall be shifted by a stipulated value to consider accidental torsional force in the lateral force resisting elements, i.e. columns and shear walls. In this part of the checklist, accidental eccentricity to be considered in x-direction as per the clause 5.7 of NBC 105:2020 is to be listed. As per the clause, the value of accidental eccentricity shall be $\pm 0.1*b_y$ where b_y is the floor lateral dimension of the building perpendicular to the direction of lateral force EQ_x. Thus the design eccentricity at floor level i, $e_{di,y}$ will be equal to $e_{si,y} \pm 0.10*b_y$ where $e_{si,y}$ is the actual static eccentricity in y-direction.

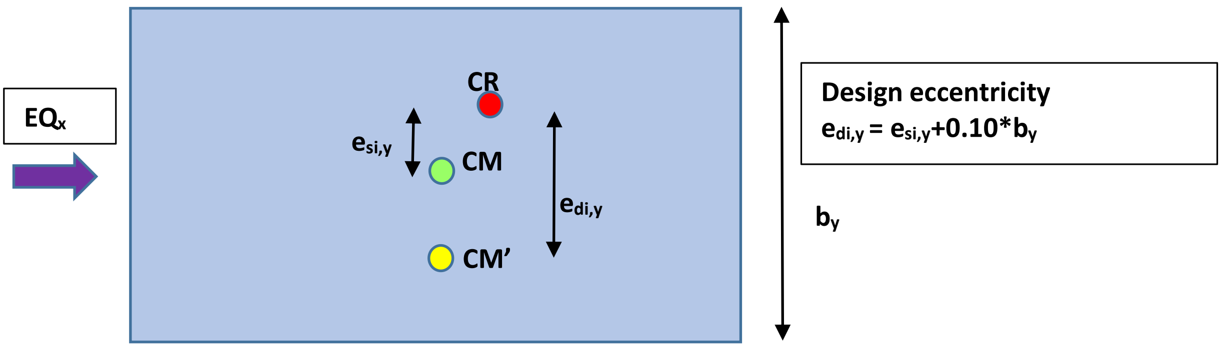

Figure 5: Accidental Eccentricity

B.5 Support Condition

If the building is supported by a pile or mat foundation, or an isolated footing on firm soil, the support condition is considered to be fixed. However, if the soil is less firm and the foundation type is isolated, the support condition will be closer to a hinge support. Therefore, it is necessary for the designer to specify the appropriate type of support used in the building model in this section of the checklist. For this design, the foundation is assumed to be fixed.

B.6 Structural Analysis Software Used

The building was modeled using the ETABS 20.3.0 software. ETABS 20.3.0 is a specialized program designed specifically for the analysis and design of building systems. It offers a user-friendly interface and advanced features, making it both sophisticated and easy to use. The software provides intuitive modeling capabilities, powerful analytical tools, efficient design procedures, robust numerical methods, and supports various international design codes. With its ability to handle complex structures and nonlinear behaviors, ETABS 20.3.0 is widely preferred by structural engineers in the building industry. However, finite element software like SAP2000,

Staad.Pro, RISA3D, etc. are also present.
For the design of foundation, manual calculation was done. However, other softwares like SAFE, Staad.Foundation, RISAFoundation , etc may also be used.

C. Adequacy of Actions to the Buildings

C.1 Load Patterns considered

Load calculations are performed using the NBC 102:1994 as a reference. The first step is to select the type of material and determine the unit weight values from the aforementioned code. The thickness of the material is chosen based on the design requirements. With the knowledge of the area, thickness, and unit weight of the materials, the loads on each section are determined.

Dead Loads:
Wall Load:
The brick masonry is constructed with careful adherence to standard practices, including pre-soaking the bricks in water, ensuring level bedding with full mortar coverage, breaking vertical joints from course to course, and filling them with mortar completely.
Bricks: Standard rectangular bricks are used, which are well burnt, hand-formed or machine-made, and possess a crushing strength of at least 3.5 N/mm². The preferred brick size is 230 x 115 x 57 mm, with 10 mm thick horizontal and vertical mortar joints.
Tolerances: For thick walls, acceptable tolerances are -10 mm on length, -5 mm on width, and ±3 mm on thickness.
Wall Thickness: The minimum thickness is half-brick, while the maximum thickness is one brick.
Mortar: Cement-sand mixes of 1:6 and 1:4 are adopted for one-brick and half-brick thick walls, respectively. Adding a small amount of freshly hydrated lime, in a ratio of ¼ to ½ of the cement, enhances the mortar's plasticity without compromising its strength. Therefore, adding lime within these limits is encouraged.
Plaster: All plasters should have a cement-sand mix with a minimum ratio of 1:6 and a cube crushing strength of at least 3 N/mm² after 28 days.
Wall Thicknesses: Internal walls have a thickness of up to 115 mm for brick walls or equivalent materials, while external walls have a thickness of up to 230 mm for brick walls or equivalent materials.

Load Assessment for Structural Analysis

1	**Unit Weights of materials**		
	Brick masonry	**19.50**	kN/m^3
	Screed	**21.00**	kN/m^3

	Mosaic	**23.10**	kN/m^3
	Marble	**26.70**	kN/m^3
	Reinforced Concrete	**25.00**	kN/m^3
	Cement plaster	**20.40**	kN/m^3

2	**Heights of Beams, Walls & Parapet Walls**		
	Depth of Beam	**0.38**	m
	Height of Building	**3.20**	m
	Height of Parapet Wall	**0.90**	m
	Wall thickness	**0.23**	m
	Plaster thickness (both interior and exterior)	**0.03**	m

3	**Dead Loads of Walls**		
a)	Dead load of 230 mm thick wall with 10% opening	12.29	kN/m
	Dead load of 230 mm thick wall with 30% opening	9.56	kN/m
b)	Dead load of 115 mm thick wall	6.15	kN/m
c)	Dead load of parapet wall	2.4	kN/m

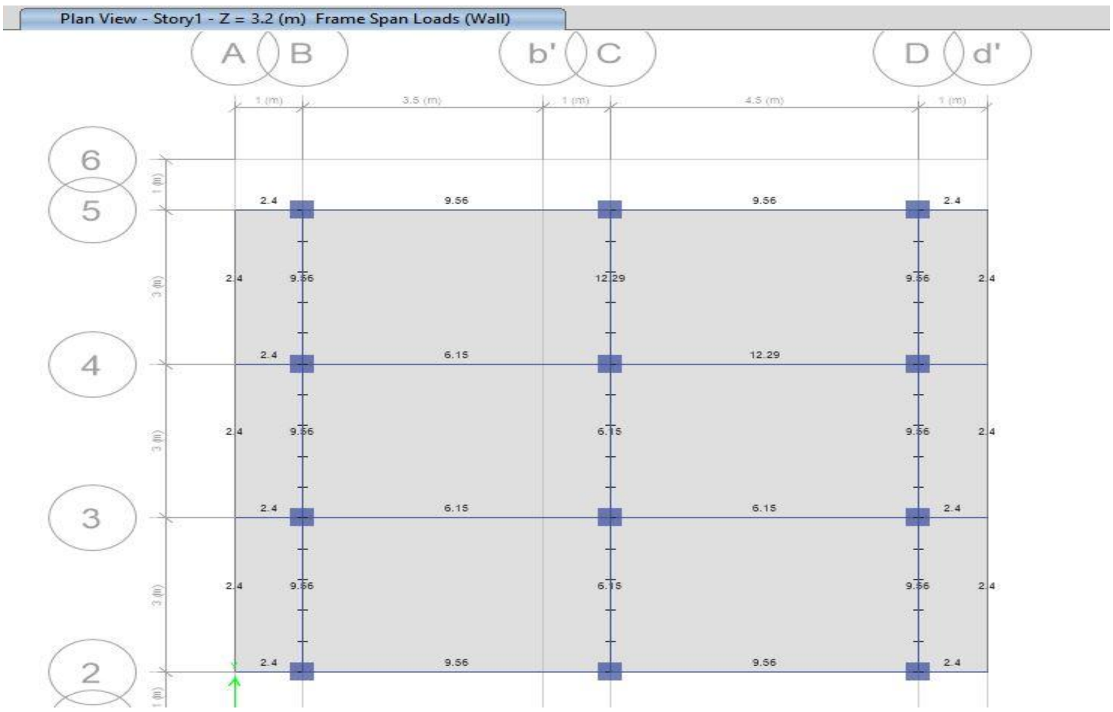

Figure 6: Wall Load(First Floor in kN/m)

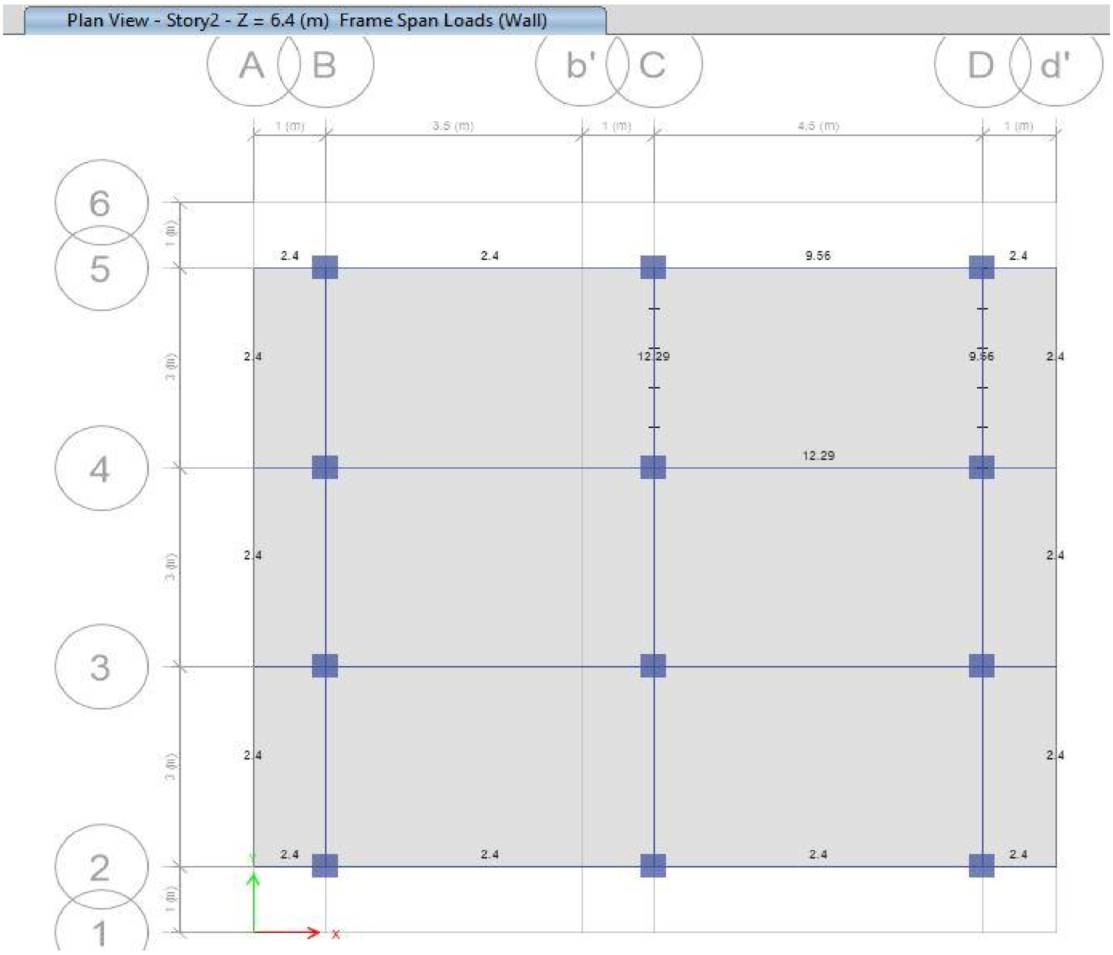

Figure 7: Wall Load(Second Floor in kN/m)

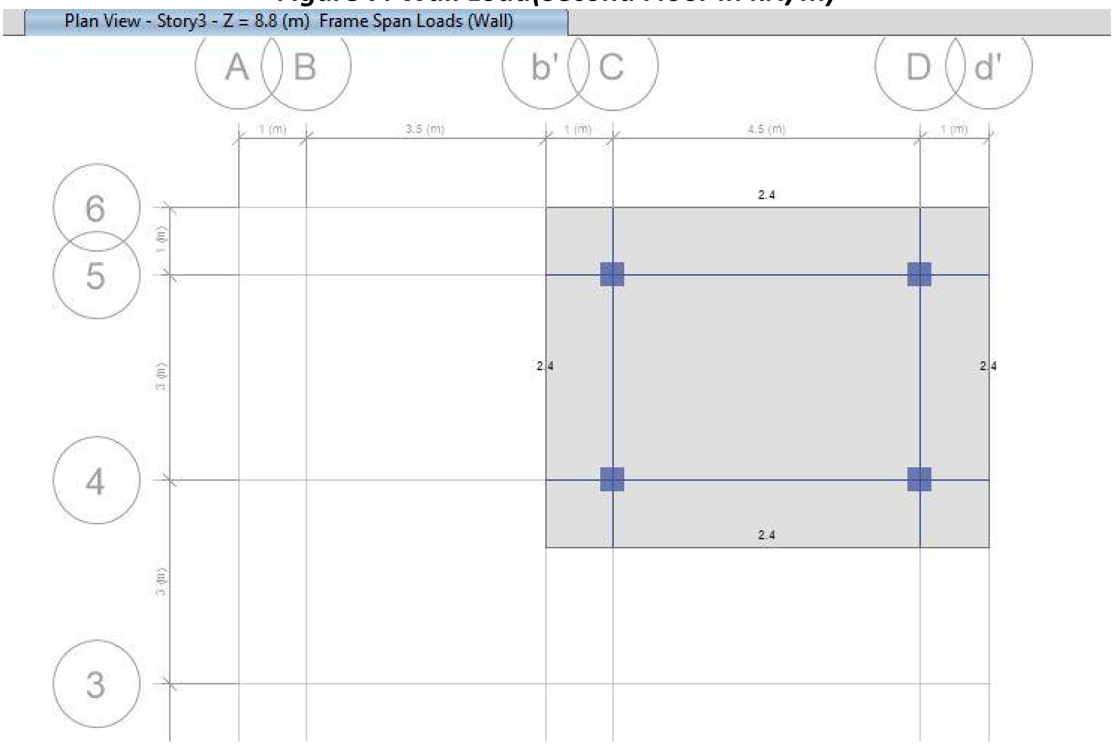

Figure 8: Wall Load(Third Floor in kN/m)

FLOOR FINISH

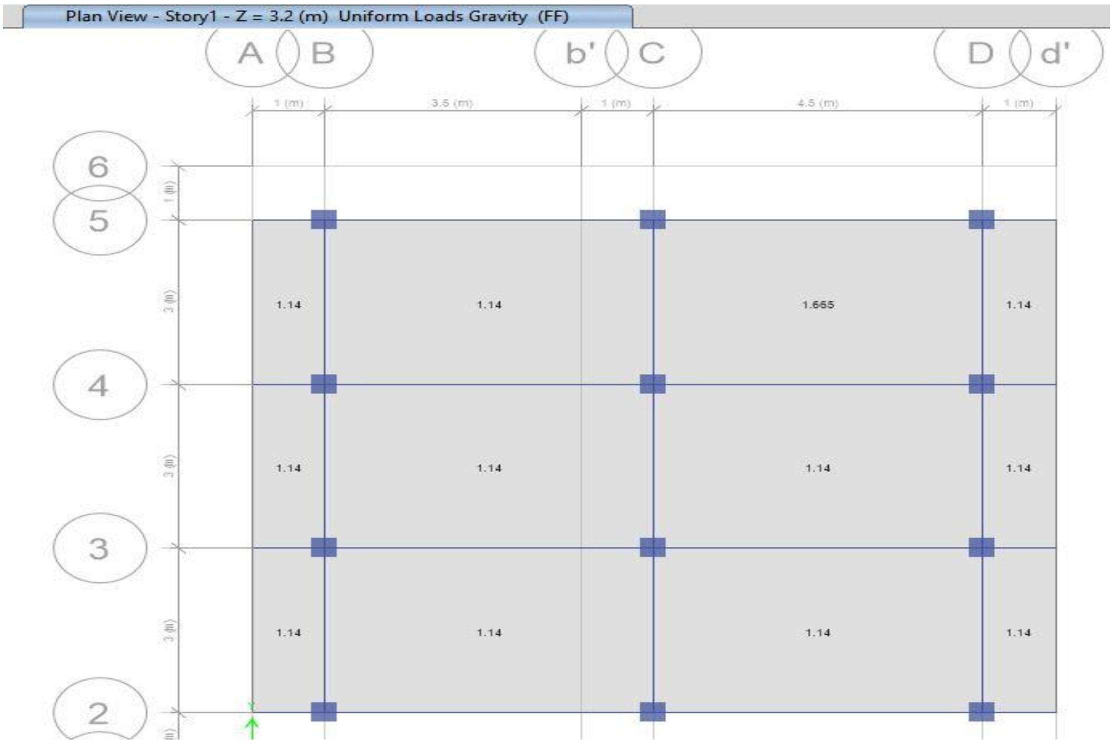

Figure 9: Floor Finish (First Floor in kN/m²)

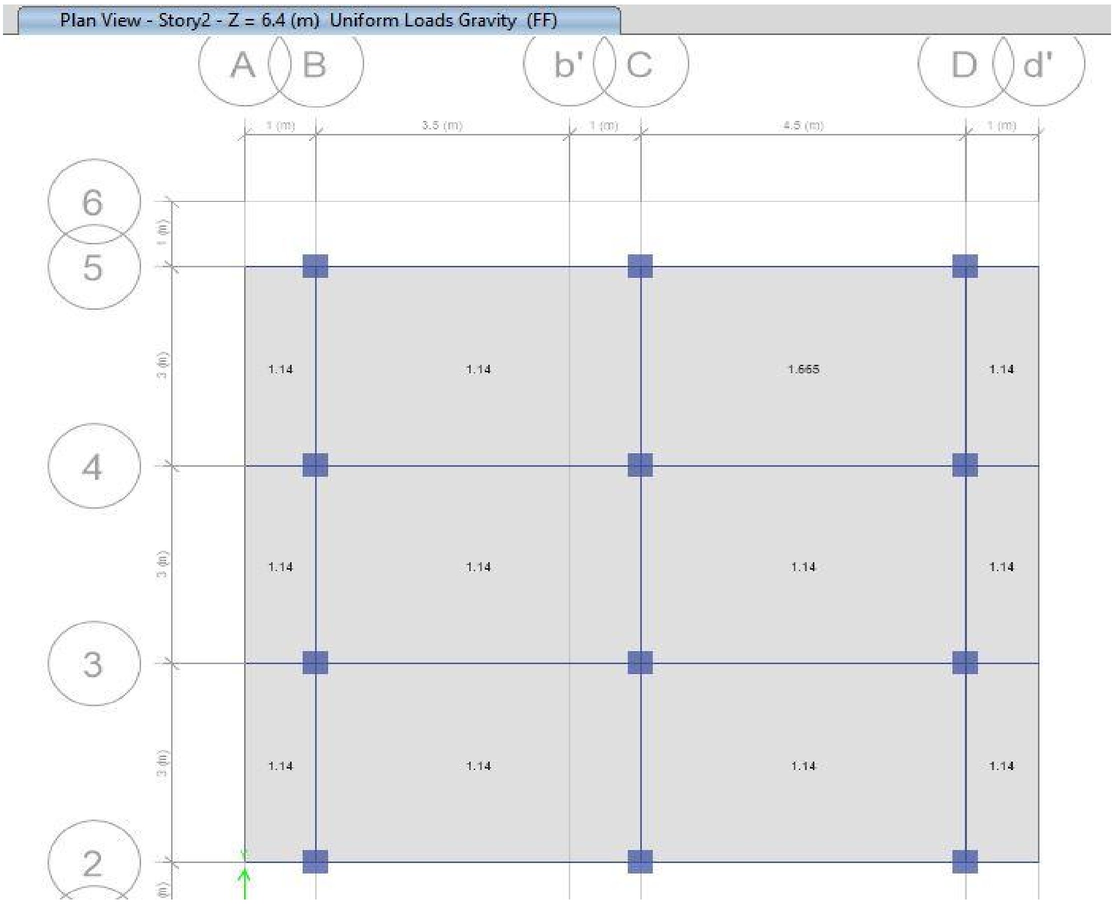

Figure 10: Floor Finish (Second Floor in kN/m²)

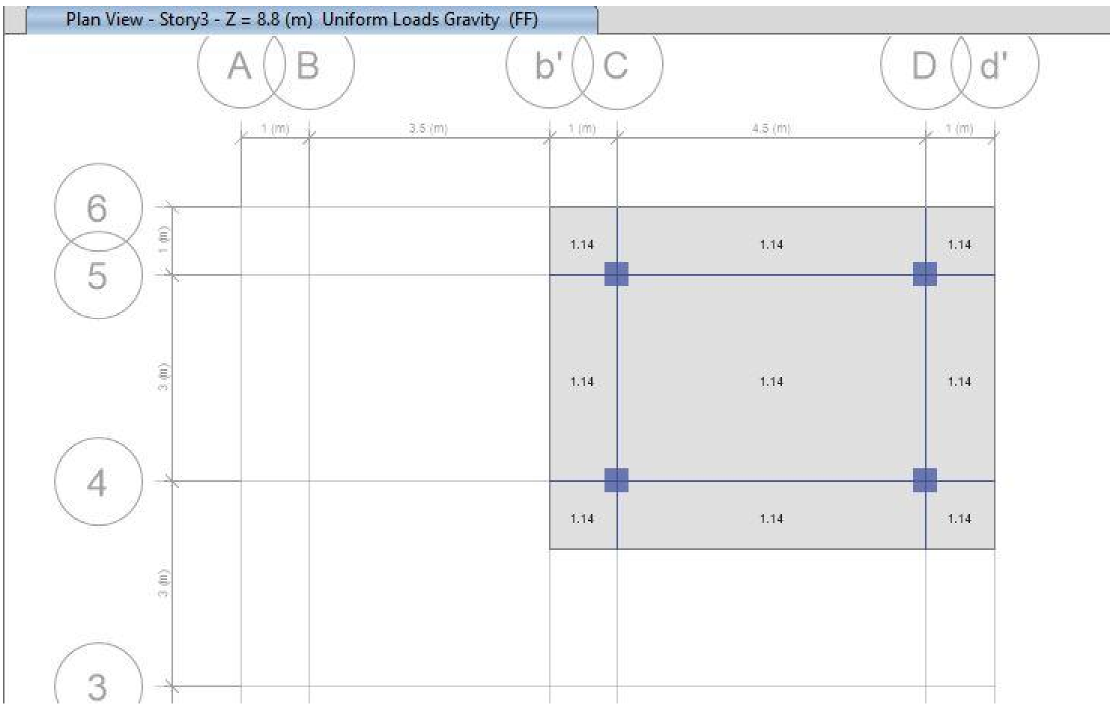

Figure 11: Floor Finish (Top Floorin kN/m²)

LIVE LOADS

The live loads for the floor and roof are determined using IS 875 part 2, as referenced by the National Building Code. For residential buildings, the appropriate live load values specified in Table 1 of IS 875 Part 2 are considered. Since the building is intended for residential use, the loading intensity for dwelling houses under the residential category is taken into account.

Table 5: Live load intensity in different rooms

S.N	OCCUPANCY CLASSIFICATION	Uniformly distributed load
	Dwelling houses:	
1)	All rooms and kitchens	2.0 kN/m^2
2)	Toilet and bath rooms	2.0 kN/m^2
3)	Corridors, passages, staircases including tire escapes and store rooms	3.0 kN/m^2
4)	Balconies	3.0 kN/m^2
	Flat, sloping or curved roof with slopes up to and including 10 degrees	
	Access provided	1.5 KN/m^2
	Access not provided except for maintenance	0.75 KN/m^2

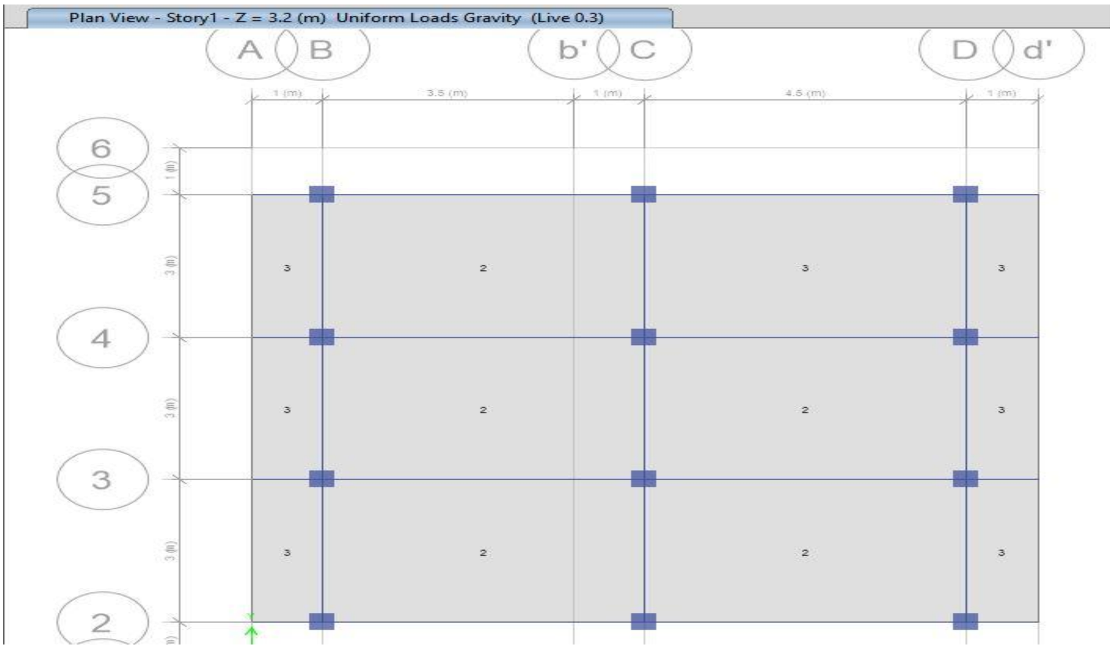

Figure 12: Live Load (First Floorin kN/m^2)

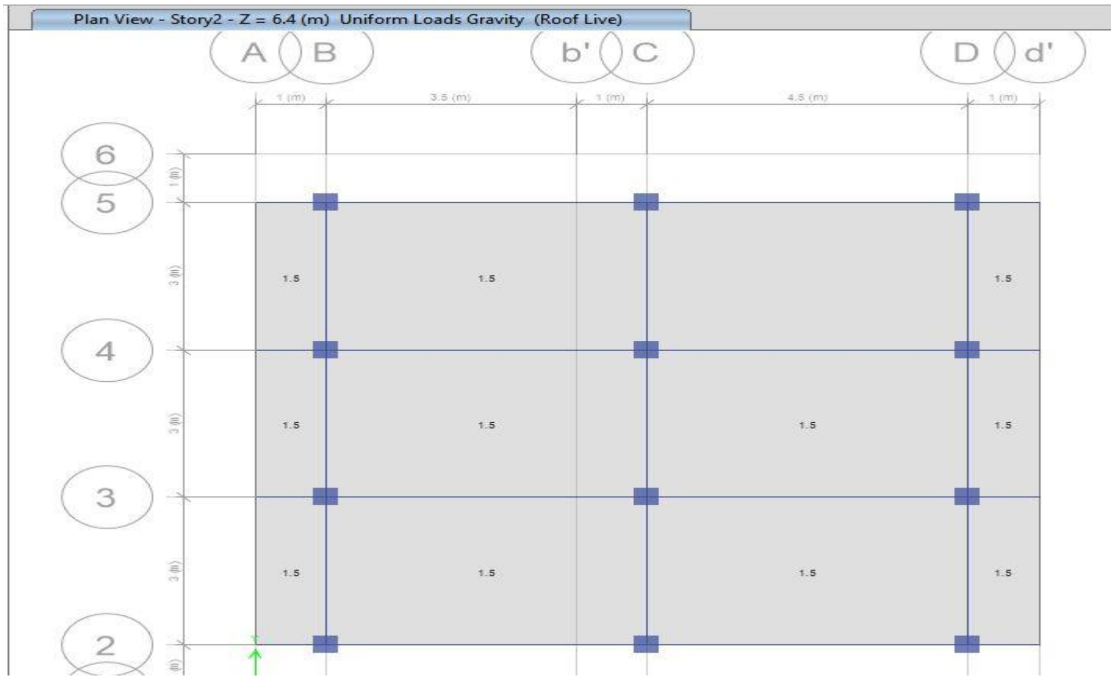

Figure 13: Roof Live Load(Second Floor in kN/m^2)

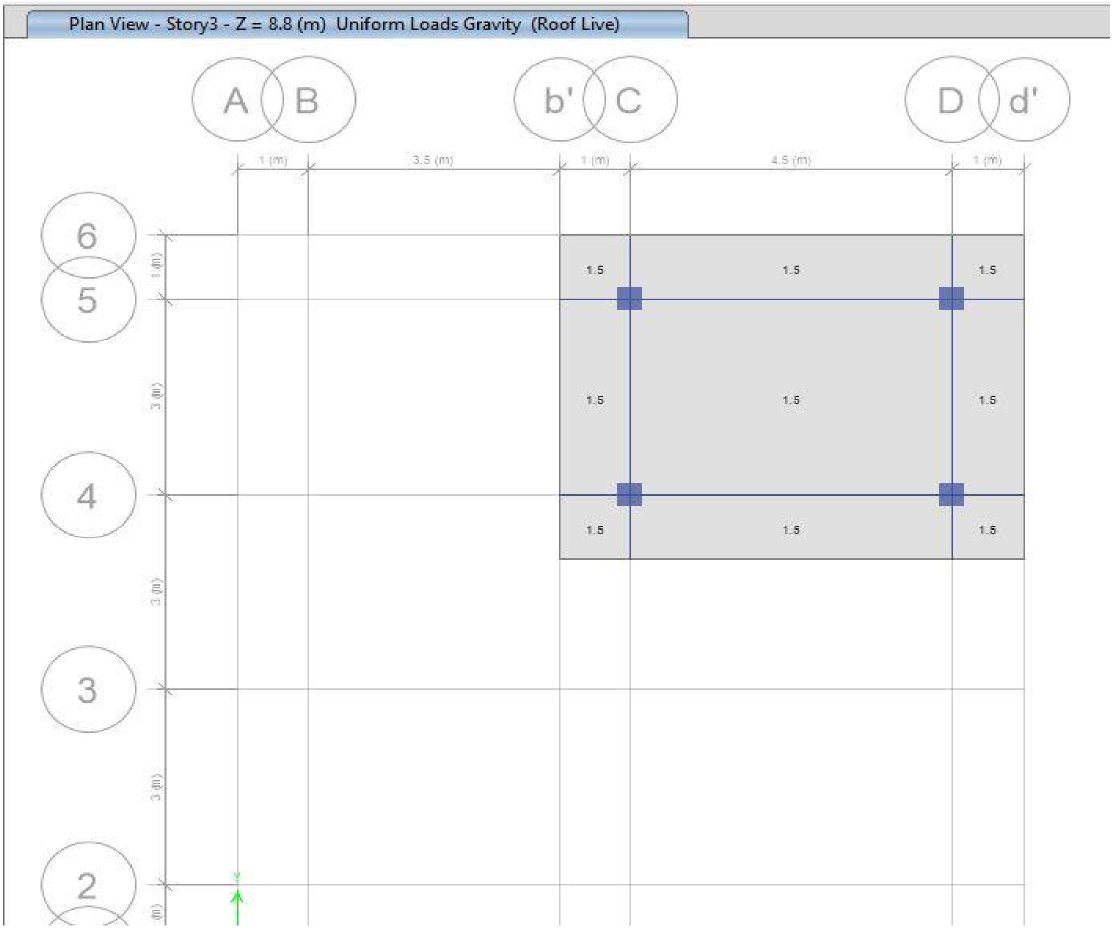

Figure 14: Roof live (Top Floor in kN/m^2)

C.2 Load Cases Considered for Response Spectrum Analysis (if applicable)

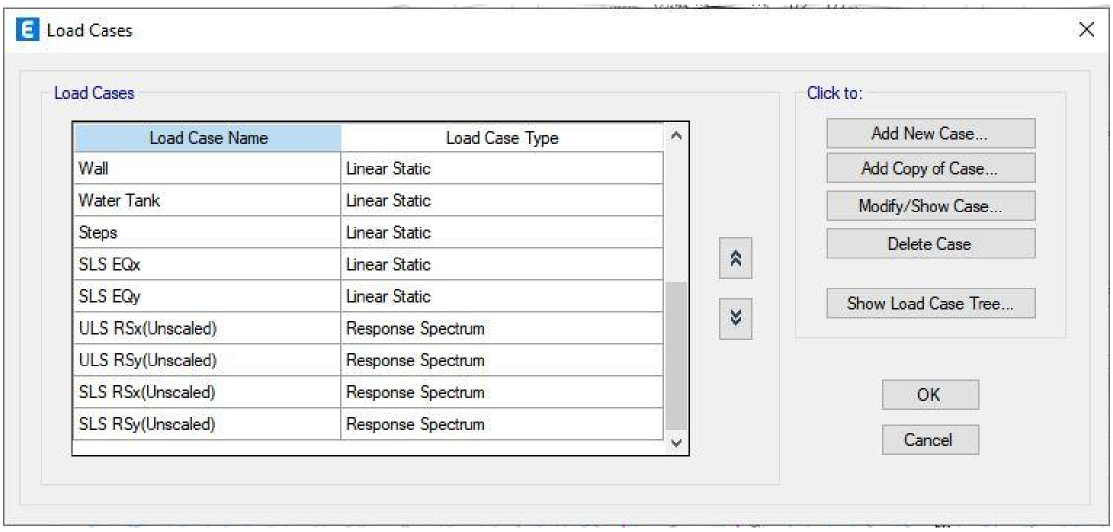

Figure 15: Load Cases considered in the software

C.3 Mass Source Considered for Seismic Weight

Table 6: Mass Source

Load	Multiplier
LIVE	0.3
WALL	1
STAIRCASE DEAD	1
STAIRCASE LIVE	1
FINISHING	1
PARTITION	1
WATER TANK LOAD	1
DEAD	1

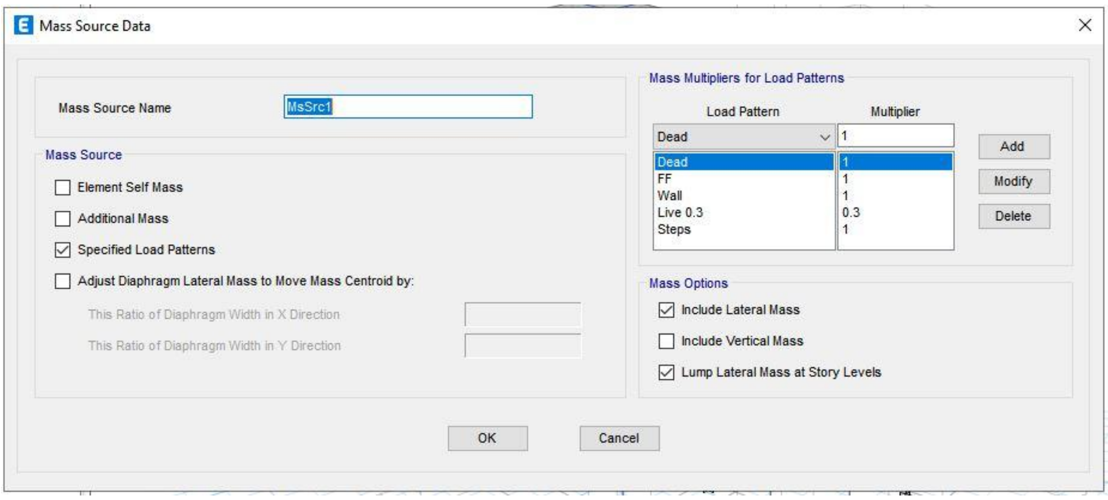

Figure 16: Mass sources considered

C.4 Detailed Load Calculations

Details of the calculations of dead and live load have been provided above.

C.5 Seismic Load Calculation Parameters

C.5.1 Base Shear Calculation from Equivalent Static Method

Fundamental Time Period Based on Empirical Formula

Height of building from foundation or from top of rigid basement (H)	9.6	m
Type of lateral resisting System	Moment Resisting Concrete Frame	
Time Coefficient (kt)	0.075	
Approximate fundamental time period based on Empirical Formula	0.409	Sec
Amplification of Approximate fundamental time period by 1.25		
Amplified Approximate Fundamental time period	0.511	Sec

Rayleigh method

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

Base shear from ETABS 344.4459

Exponent related to the structural period 1

Level	Wi (kg)	Elevation hi(m)	hi^k	Wihi^k	ULS Fi	Shear Force(kN)
Story3	25827.75	9.6	9.60	2429.87	60.0858	60.09
Story2	93844.6	6.4	6.40	5885.93	158.7786	218.86
Story1	148447.55	3.2	3.20	4655.32	125.5815	344.45
Base	5994.16	0	0.00	0.00	0	344.45
Total	274114.06			12971.12		

Level	Wi (kN)	di(mm)	di(m)	di2	ULS Fi	Fidi	Widi2
Story3	253.11195	23.662	0.023662	0.00055989	60.09	1.42	0.142
Story2	919.67708	19.129	0.019129	0.000365919	158.78	3.04	0.337
Story1	1454.78599	8.879	0.008879	7.88366E-05	125.58	1.12	0.115
Base	58.742768	0	0	0	0.00	0.00	0.000
	Total					5.57	0.593
	Rayleigh time period		0.654277449				

As Empirical time period(0.511 sec) is lesser than than the Rayleigh time period (0.654 sec), use empirical time period for the calculation.

Elastic Site Spectra for horizontal loading is given by C(t)=Ch(t)*Z*I

Where,

Ch(t)=Spectral Shape factor as per cl.4.1.2

Z= Seismic Zoning Factor as per 4.1.4

I=Importance factor as per 4.1.5

Fundamental Time Period =		0.511	Sec
Spectral Shape Factor			
Site Soil Category =		Very Soft Soil	
Ta =	0.5	Tc =	2
Soil Type =		D	
α =	2.25	k =	0.8
Spectral Shape Factor Ch(t)=		2.250	
Location=	kathmandu	PGA (Z)=	0.35
Structural Types =		Ordinary Structures	
Importance Factor =		1	
Elastic Site Spectra for Horizontal loading C(t) =			0.788
Elastic Site Spectra for Serviceability limit state, Cs=			0.158
Horizontal Seismic Coefficient			
Structural System =			Reinforced Concrete Moment Resisting Frame
Ductility Factor =			4

Over strength Factor Ultimate limit State =	1.5
Over strength Factor Serviceability limit State =	1.25
For Ultimate Limit State =	0.131
For Serviceability State =	0.126

C.5.2 Base Shear from Modal Response Spectrum

C.5.2.1 Response Spectrum Function [Ch(T) vs T]

The response spectrum has been input manually.

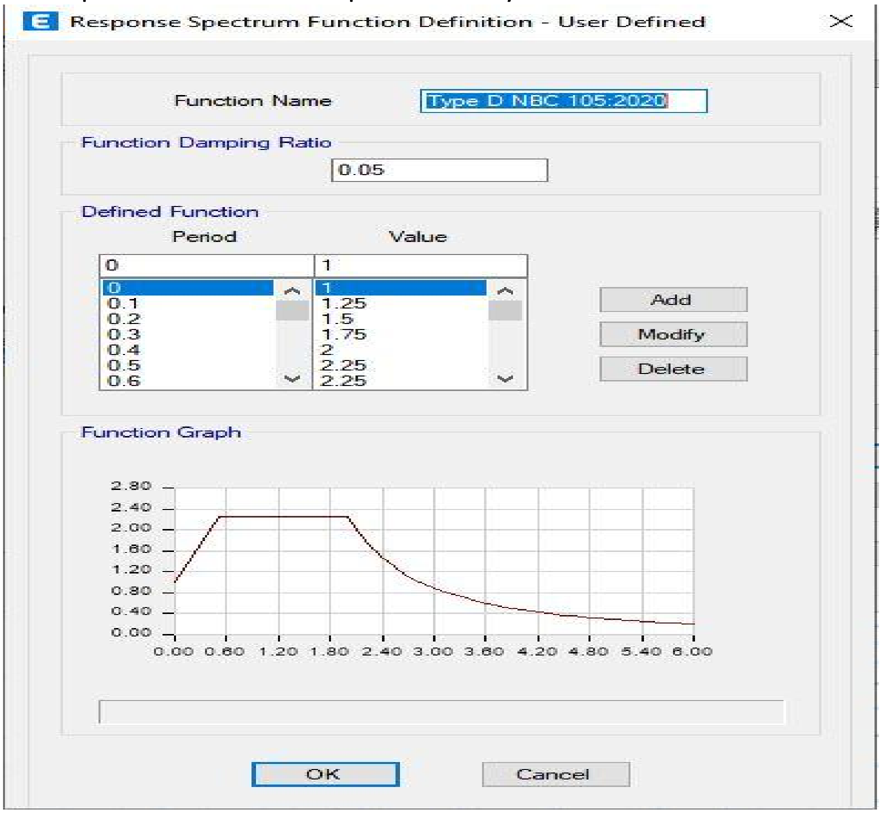

Figure 17: Definition of Response Spectrum (Manual)

C.5.2.2 Scaling of Base Shear in MRSM

Initial Scale Factor (for ULS) = (Z x I x g) / (R_u x Ω_u) = 0.35*1*9810/ (1.5*4)= 572.25

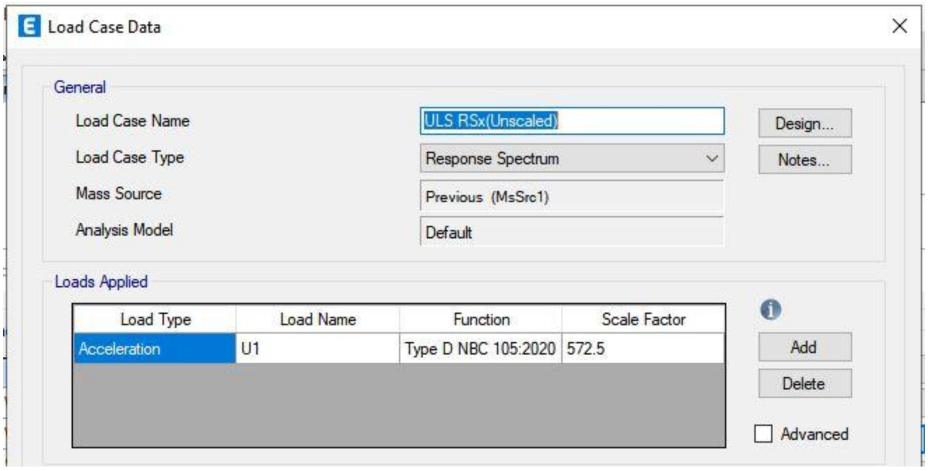

Figure 18: Load case for MRSM(ULS)

Initial Scale Factor (for SLS): (0.2 x Z x I x g) / (Ω_s) = 0.2*0.35*1*9810/ 1.25 = 549.35

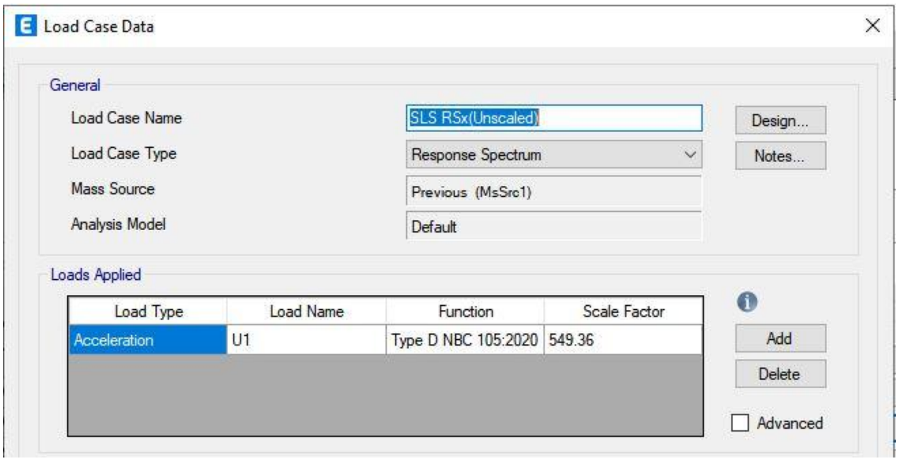

Figure 19: Load case for MRSM(SLS)

Scaling of the Base Shear :

Perform Scaling as per Clause 7.5 of NBC 105:2020

When the design base shear (VR) obtained by combining the modal base shear forces is less than the base shear (V) calculated using Equivalent Static Method; the member forces, story shear forces & base reactions obtained from the MRS method shall be multiplied by V/VR.

Where, V = Base Shear determined from Equivalent Static Method

VR = Base Shear determined from Modal Combination

C.5.2.3 Horizontal Base Shear from RSM (before scaling):

Base Reactions

File Edit Format-Filter-Sort Select Options

Units: As Noted Hidden Columns: No Sort: None Base Reactions

Filter: None

Output Case	Case Type	Step Type	Step Number	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m	X m
ULS EQx	LinStatic	Step By Step	1	-344.4459	0	0	0	-1946.7989	2184.7382	
ULS EQx	LinStatic	Step By Step	2	-344.4459	0	0	0	-1946.7989	2357.4747	
ULS EQx	LinStatic	Step By Step	3	-344.4459	0	0	0	-1946.7989	2012.0017	
ULS EQy	LinStatic	Step By Step	1	0	-344.4459	0	1946.7989	0	-2111.7721	
ULS EQy	LinStatic	Step By Step	2	0	-344.4459	0	1946.7989	0	-2324.3215	
ULS EQy	LinStatic	Step By Step	3	0	-344.4459	0	1946.7989	0	-1899.2227	
SLS EQx	LinStatic	Step By Step	1	-331.2991	0	0	0	-1872.4936	2101.3512	
SLS EQx	LinStatic	Step By Step	2	-331.2991	0	0	0	-1872.4936	2267.4947	
SLS EQx	LinStatic	Step By Step	3	-331.2991	0	0	0	-1872.4936	1935.2077	
SLS EQy	LinStatic	Step By Step	1	0	-331.2991	0	1872.4936	0	-2031.1701	
SLS EQy	LinStatic	Step By Step	2	0	-331.2991	0	1872.4936	0	-2235.6069	
SLS EQy	LinStatic	Step By Step	3	0	-331.2991	0	1872.4936	0	-1826.7333	
ULS RSx(Uns...	LinRespSpec	Max		295.5904	94.2785	0	534.9322	1687.5864	2565.9112	
ULS RSy(Uns...	LinRespSpec	Max		94.2785	301.4647	0	1689.2449	497.4157	1953.7868	
SLS RSx(Uns...	LinRespSpec	Max		283.7668	90.5074	0	513.5349	1620.083	2463.2747	
SLS RSy(Uns...	LinRespSpec	Max		90.5074	289.4061	0	1621.6751	477.519	1875.6353	

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Figure 20: Scaling of Base Shear

C.5.2.4 Final Scale Factor (When VR<V in ULS & SLS)

The scale factor thus obtained shall be multiplied to the initial scale factor to obtain the final scale factor.

<u>For ULS</u>

Final Scale Factor for X = (EQx -ULS / RSx ULS–Initial Scale Factor)*572.25
= (344.4459/295.5904)*572.25 = 666.8321

Final Scale Factor for Y = (EQy -ULS / RSy ULS– Initial Scale Factor)*572.25
= (344.4459/301.4647)*572.25 = 653.8383

<u>For SLS</u>

Final Scale Factor for X = (EQx -SLS / RSx SLS–Initial Scale Factor)*549.36
= (331.2991/283.7668)*549.36 = 641.3804

Final Scale Factor for Y = (EQy -SLS / RSy SLS– Initial Scale Factor)*549.36
= (331.2991/289.4061)*549.36 = 628.8826

After Scaling, the base shear obtained from RSx shall not be less than that of ESM.

C.6 Load Combination

When lateral load resisting elements are oriented along mutually orthogonal horizontal directions, the structure system is considered to be parallel and load combinations as specified in clause 3.6.1 of NBC 105:2020 is used for design.

<u>For Parallel System (Cl. 3.6.1)</u>

1.2DL + 1.5LL

DL + λLL ± E ....

Where, λ = 0.6 for storage facilities

= 0.3 for other usage

D. Analysis of Building

D.1 Modal Analysis Results

NBC105:2020 clause 7.3 states that 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 of the structure. The analysis was carried out for 12 modes so that the mass participation satisfies this criterion in both orthogonal directions. The table shows time period and mass participation ratio for all modes.

Table 7: Time period and mass participation ratio

Case	Mode	Period	UX	UY	Sum UX	Sum UY
		sec				
Modal	1	0.638	0.6978	0.0278	0.6978	0.0278
Modal	2	0.558	0.0846	0.7049	0.7824	0.7327
Modal	3	0.464	0.0805	0.1492	0.8629	0.8819
Modal	4	0.217	0.1084	0.0002	0.9713	0.8821
Modal	5	0.204	0.0004	0.0984	0.9717	0.9805
Modal	6	0.189	0.0037	0.0032	0.9754	0.9837
Modal	7	0.154	0.0189	0.0035	0.9943	0.9872
Modal	8	0.141	0.0047	0.0103	0.999	0.9975
Modal	9	0.13	0.001	0.0025	1	1
Modal	10	0.007	0	0	1	1
Modal	11	0.006	0	0	1	1
Modal	12	0.006	0	0	1	1

E. Adequacy of Member Design

E.1 Check for All Members Passed (for Element Design through Software)

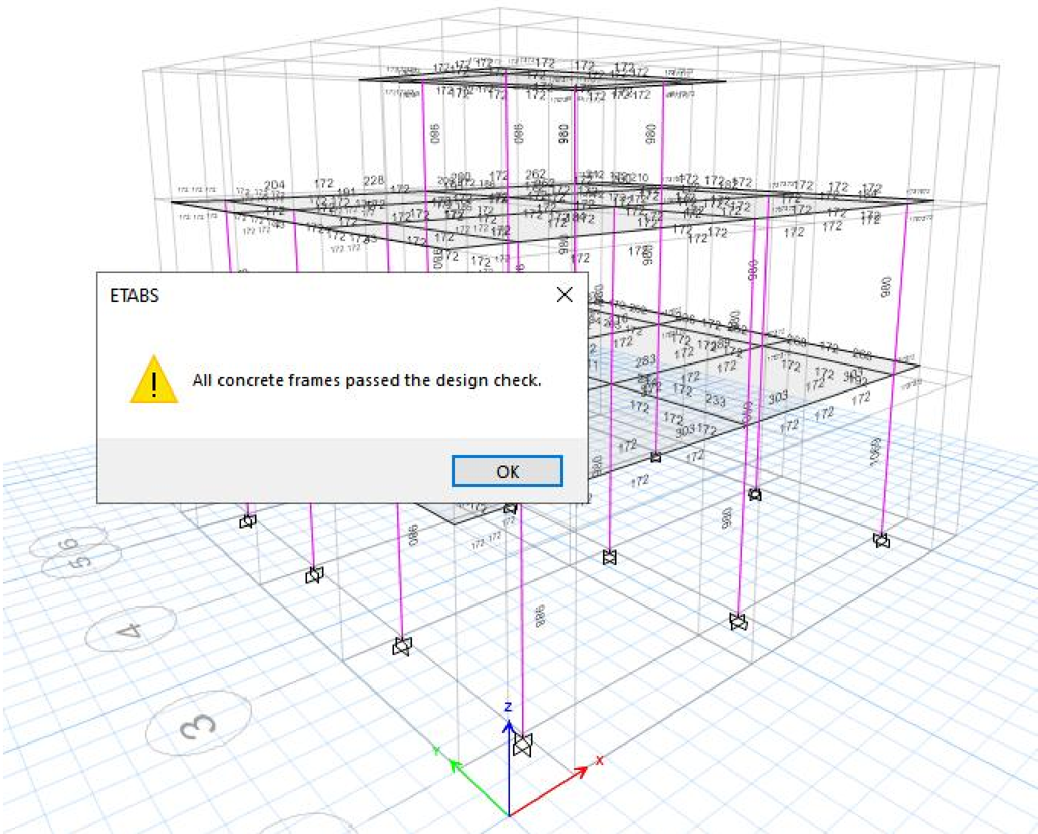


Figure 21: Design check for frames

E.2 Check for Column-Beam (C/B) Capacity Ratio

To prevent the progressive collapse of a structure caused by the failure of columns at lower levels, the design follows the principle of Strong-Column-Weak Beam Design. This design approach ensures that the columns are designed to be stronger than the beams. This helps the structure effectively absorb and dissipate seismic energy, reducing the risk of complete collapse. By allowing plastic hinges to form in the beams, the structure gains increased ductility, enabling it to undergo significant lateral displacements while maintaining its integrity. This design strategy enhances the structure's ability to withstand seismic forces and mitigate potential damage.
Sample check :

Column Beam Moment Capacity Check (Column E2 Ground First)

1) Moment calculation for the column

Grade of concrete(fck)	=	20	N/mm2
Grade of steel(fy)	=	500	N/mm2

Width of column(b)	=	350	mm
Width of column(D)	=	350	mm
Effective cover(d')	=	52	=clear cover+dia of shear bar+dia of main bar/2
Upper Column			
Pu	=	85.21	kN
Therefore, percentage reinforcement(pt)	=	1.03	%
Area of steel provided (Ast)	=	1256.63	mm2
d'/D	=	0.15	
P/fck	=	0.05	
Pu/fck/bD	=	0.03	
From SP-16 chart,			
Mu/ fckbD2	=	0.07	
Mu	=	60.025	kN-m
Lower column			
Pu	=	304.198	kN
Therefore, percentage reinforcement(pt)	=	1.0258	%
Area of steel provided (Ast)	=	1256.63	mm2
d'/D	=	0.15	
Pt/fck	=	0.05	
Pu/fckbD	=	0.12	
From SP-16 chart,			
Mu/ fckbD2	=	0.1	
Mu	=	85.75	kN-m
TOTAL MOMENT(MC)		145.775	kN-m

2) Moment capacity calculation for beam

Grade of concrete(fck)	=	20	N/mm2
Grade of steel(fy)	=	500	N/mm2

Width of beam(bw)	=	250	mm
Overall depth(D)	=	355	mm
Effective cover(d')	=	43	mm
Effective depth(d)	=	312	mm
Ast,top	=	339.292	For hogging
Ast,bottom	=	339.292	For sagging
Left beam (Sagging Moment)			
Depth of neutral axis(xu)	=	81.9955	xu/d=(0.87fyAst)/0.36fck bd) IS 456:2000, Annex g, Cl G 1.1a
Saggging moment at left(MBL)	=	40.97	
Right beam (Hogging moment)			
Limiting depth of neutral axis (xu,max)	=	143.52	=0.46 d for Fe500
Moment due to balanced section(Mu1)	=	64.73	Mu,lim = 0.133 fckbd2 for Fe500)
Area of steel due to balanced section(Ast)	=	591.18	
Area of compresion steel(Asc)	=	0	
Moment due to Asc(Mu2)	=	0	Mu=Mu,lim= fscAsc(d-d')
Hogging moment at right(MBR)	=	64.73	=MU1+MU2
TOTAL MOMENT(MB)	=	105.70	=MBL+MBR
3) Check for strong column weak beam			
MC	**=**	**145.775**	**kN/m**
MB	**=**	**105.70**	**kN/m**
Check for BC capacity		**1.38**	**>1.2, ok**

E.3 Check for Max. & Min. Percentage of Reinforcement Provided

Maximum Percentage of Rebars provided in columns
= Maximum longitudinal reinforcement area/ Cross sectional area of Column
= 1256.637/ (350*350)*100% =1.026% <4% (Ok)

Minimum Percentage of Rebars provided in columns
= 1.026% > 1% (Ok)

Maximum Percentage of Rebars provided in beams
= 678.584/ (250*355) = 0.764% <2.5% (Ok)

Minimum Percentage of Rebars provided in beams
= 0.764% >0.26 % (Ok)

E.4 Design of Slabs

1.General information:

Concrete Grade=	M	20
Steel Grade=	Fe	500
As per IS 456:2000,		
Case No.=	4	
Type of panel=	Two Adjacent Edges Discontinuous	

2.Thickness of slab and durability consideration:

Short Span, lx =	3000	mm
Long Span,ly =	4500	mm
Adopting, overall depth(D)=	125	mm
Assuming, clear cover=	20	mm
and diameter of bar=	8	mm
Effective depth of slab(d)=	101	mm
Effective short span (Lx)=	3101	mm
Effective long span (Ly)=	4601	mm
Ly/Lx=	1.48	
Hence, it is a two way slab.		

3.Calculation of Design Load:

Self weight	=	3.125	kN/m^2
Finishing &Partition	=	2.14	kN/m^2
Live Load	=	2	kN/m^2
Total Load	=	7.265	kN/m^2
Factored load	=	10.90	kN/m^2
Considering unit width of Slab,			
w=		10.90	kN/m

4.Moment and Reinforcement Calculation:

Moments considered		Coefficient(α)	Moment (kN.m)
Shorter Span	Support (-ve)	0.074	7.290
	mid span(+ve)	0.056	5.829
Longer Span	Support (-ve)	0.047	4.611
	mid span(+ve)	0.035	3.434

Hence,

the moment to be considered (Mu)= 7.290 kN.m

Solving, Mu=0.87*fy*Ast*d*(1-Ast*fy/bd.fck)

Ast= 190.5 mm^2/m

Also, Minimum Ast(0.25%)= 252.5 mm^2/m

Hence, Limiting Ast= 252.5 mm^2/m

Providing 8 dia bars @150c/c

Ast provided= 352 mm^2/m

Provided Ast is sufficient

5. Check for Deflection:

shorter span of critical slab=	3101	mm
spacing of bars=	150	mm

overall depth of slab=	125	mm
eff depth of slab=	101	mm
% Tension reinforcement=	0.348%	
fs=	209	
From graph Fig 4 IS 456-2000,		
Modification factor =	1.6	
Basic L/d=	23.000	
Permissible L/d ratio=	36.8	
Provided L/d ratio=	30.70	

E.5 Design of Beams

<u>Check for Deflection for beam:</u>

Boundary condition of beam	Continuous	
Effective span=	4500	mm
Effective depth of beam=	316	mm
Basic (L/d) ratio, $(L/d)_{basic}$=	14.24	mm
% Tension $reinforcement_{required}$=	0.32%	
% Tension $reinforcement_{required}$=	0.415%	
From graph Fig 4 IS 456-2000,		
Steel stress of service, fs	197.6	
Modification factor =	1.3	
Basic L/d=	23.000	
Permissible L/d ratio=	29.9	
Provided L/d ratio=	14.24	

E.6 Design of Columns

Determine whether the storey in which the critical column is located is of type “Sway” or “Non-sway” for bending in X-X and Y-Y plane. This is determined on the basis of the value of the Stability Index Q as per the clause 25.2 & Clause E.2 of the

Annex-E of IS 456:2000.

Q = (ΣPu*Δu)/(Hu*hs)
where, ΣPu = sum of axial loads on all columns in the storey
Δu= elastically computed first order lateral deflection
Hu= total lateral force acting within the storey, and
hs= height of the storey.
For the Pu, take the gravity loads only.
The Hu/ Δu is given by lateral stiffness k in each direction.
Therefore, the stability can be given as :
Q = (ΣPu)/(k*hs)

					X direction		Y direction	
Story	kx	ky	hs	Pu	Qx	Check	Qy	check
3rd	13599.2	18791.69	3.2	412.8442	0.009487	sway	0.006865	sway
2nd	24739.73	33870.67	3.2	1808.655	0.022846	sway	0.016687	sway
1st	44025.32	53057.06	3.2	3817.213	0.027095	sway	0.022483	sway

For bending in X and Y plane, the column is of type sway.
Size of the critical column = 350 mm* 350 mm

Effective length factor of the column:
β1 & β2 represent the degree of rotation at top and bottom of a column.

For sway column,

$$\beta_1 = \frac{k+ku}{k+ku+\Sigma(kbt*1.5)}$$

$$\beta_2 = \frac{k+kcb}{k+kcb+\Sigma(kbb*1.5)}$$

where,
ku= stiffness of the upper column
kcb= stiffness of the bottom column
kbt= Stiffness of the beams at the top
kbb= Stiffness of the beams at bottom

As all the columns are of same size,
k= ku= kcb = $(bD^3)/12L$

As all the beams are the same in X direction,
Effective length factor of the column for bending in X-X plane, ke,xx = 1.8
Effective length factor of the column for bending in Y-Y plane, ke,yy = 2.1
Unsupported length of column for bending in X-X Plane, Lxx = 3.2-0.355
=2.845 m

Unsupported length of column for bending in Y-Y Plane, Lyy = 3.2-0.355
=2.845 m

Slenderness ratio for bending in X-X Plane, Le,xx/D=ke,xx*Lxx/D = 1.8*2.845/.350
= 14.63
Slenderness ratio for bending in Y-Y Plane, Le,yy/b==ke,yy*Lyy/b= 2.1*2.845/.350
= 17.07
Type of Column for Bending in X-X Plane = Slender
Type of Column for Bending in Y-Y Plane = Slender
Column designed as Short/Slender Column in X-X Plane = Slender
Column designed as Short/Slender Column in Y-Y Plane = Slender

E.7 Check for Ductile Detailing

E.7.1 Detailing of members

Refer to the structural drawing to verify whether proper ductile detailing has been done in the beam, column, joints etc. Verify the other requirements and also the ductile detailing requirements of the building as per Annex A of the code.

E.7.2 Anchorage of Beam Longitudinal Reinforcement

The value of l_{dh} is given by,

$$l_{dh} = \frac{f_y d_b}{4.85\sqrt{f_{ck}}} \quad \text{.........4.4.2(a)}$$

but ,

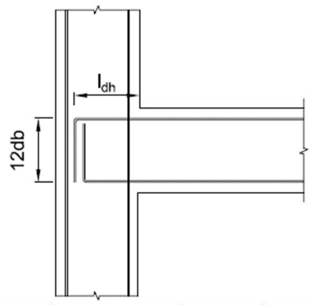
$$l_{dh} \nless D_c - Concrete\ Cover \quad \text{.........4.4.2(b)}$$

Where

d_b = diameter of largest longitudinal bar in beam in mm

f_y = Yield strength of steel

f_{ck} = Characteristic compressive strength of concrete



For FE 500 and M20				
db of bar (mm)	Ldh (mm)	concrete cover (mm)	Required Dc- column size (mm)	Provided Dc- column size (mm)
8.00	184.42	40	224.42	**300**
10.00	230.52	40	270.52	**300**
12.00	276.63	40	316.63	**325**
16.00	368.84	40	408.84	**425**
20.00	461.04	40	501.04	**525**
25.00	576.31	40	616.31	**625**
28.00	645.46	40	685.46	**700**
32.00	737.67	40	777.67	**800**

E.8 Design of Foundations

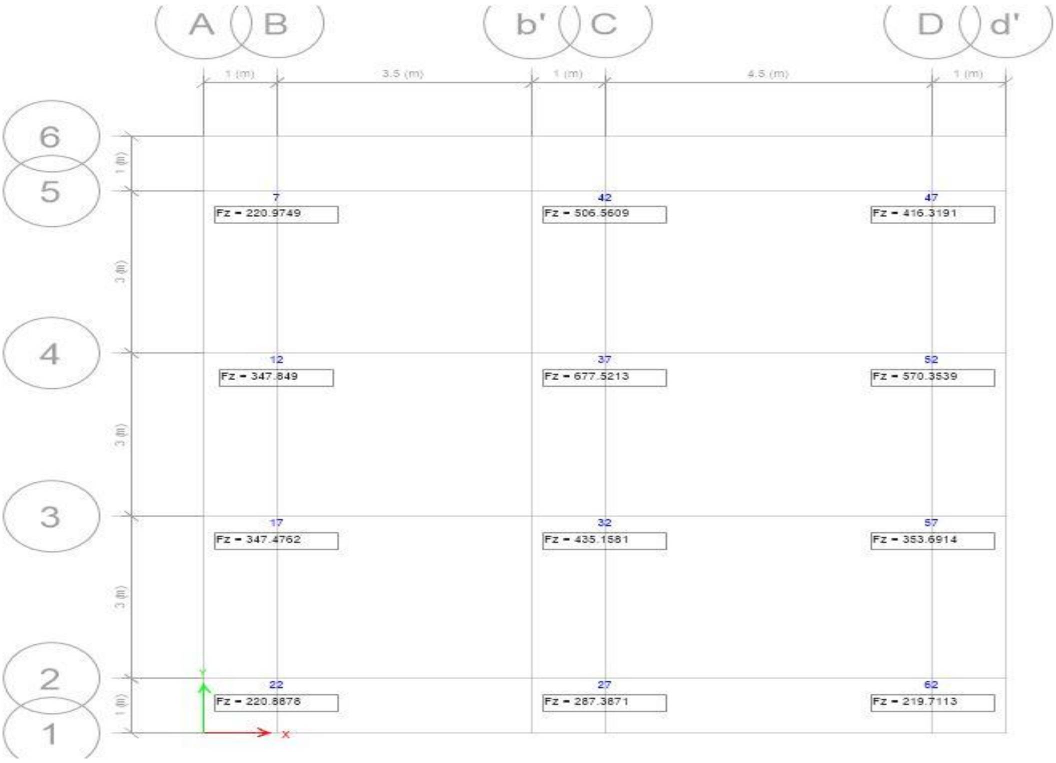


Figure 22: Foundation reaction(1.5DL+1.5LL)

Design of Corner Isolated Foundation:

A) Given Data

Size of column			
Bc	=	350	mm
Dc	=	350	mm
Column Load (V)	=	147	KN
Bearing Capacity (qa)	=	100	KN/m2
Grade of Concrete (fck)	=	20	Mpa
Grade of Steel (fy)	=	500	Mpa

B) Calculation of size of footing

wt. of foundation	=	14.72585333	KN
Total Load (P)	=	161.9843867	KN
Area of footing	=	1.620	m2

*Note:Taking the ratio of width and length of footing same as that of column dimensions

Size of footing			
L	=	1.273	m
B	=	1.273	m
Provided (L)	=	1.500	m
Provided (B)	=	1.500	m
Upward reaction (q')	=	98.172	KN/m
Max'm B.M.	=	16.229	KN-m

C) Calculation for depth of footing

B.M.	=	0.134	fckbd2
depth (d)	=	78	mm
Provided depth (d)	=	300	mm

D) Check for Shear

Per. Shear Strength (τc) = 0.25√fck =1.118 N/mm2

a) Punching shear

depth (d)	=	250	mm
Punching shear(τ'V)	=	0.368	N/mm2
Ok			
Provided depth (d)	=	250	mm
Overall Depth (D)	=	300	mm
Punching shear(τ'V)	=	0.368	N/mm2
Ok			

b) One way Shear (Calculation for no shear reinforcement)

depth (d)	=	250	mm
Max'm S.F.	=	31.906	KN
One way Shear (τv)	=	0.128	N/mm2
Provided Ast	=	0.2	%
β	=	11.61	
Concrete Shear strength (τc)	=	0.326	N/mm2
Ok			
Ast	=	500	mm2

E) Calculation for reinforcement

Ast	=	152	mm2
Ast required	=	500	mm2
Provided, Size	=	12	mm dia
Spacing	=	150	mm c/c
Ast Provided	=	754	mm2
Ok			
Area of Steel Along width			
B.M.	=	16.229	KN-m
Ast	=	500	mm2
Provided Size	=	12	mm dia
Spacing	=	150	mm c/c
Ast Provided	=	754	mm2
Ok			

F) Development Length

Bond stress(τbd)	=	1.920	N/mm2
Development length (Ld)	=	680	mm
Available Ld along length	=	525	mm
Provide Hook			

G) Load Transfer from Column to Footing

Nominal bearing stress in column	=	1.803	N/mm2
Allowable bearing stress	=	0.45*fck	
9.000 N/mm2			
Now Excess load	=	0.000	kN
Area of steel required As	=	0	mm2
Minimum Ast	=	0.5% of column area	
	=	612.5	mm2
Thus, area of steel for dowel bars	=	613	mm2

Now

Bar extended

Nos	dia	Ast
8	16	1608
0	12	0

Available Ast for load transfer = 1608 mm2

Thus no additional dowel bars are required to transfer load

Additional Ast = No dowel bars are needed

Table 8: Foundation details

(Soil Bearing Capacity= 100 kN/m²)

Column Type	Foundation Plan, L=B (m)	Foundation Thickness, tm (mm)	Reinforcement Each Way
Corner	1.5	300	12Ø @ 150mm c-c spacing
Face	1.75	300	12Ø @ 150 mm c-c spacing
Interior	1.75	300	12Ø @ 150 mm c-c spacing
Staircase	2.25	300	12Ø @ 100 mm c-c spacing

E.9 Design of Staircases

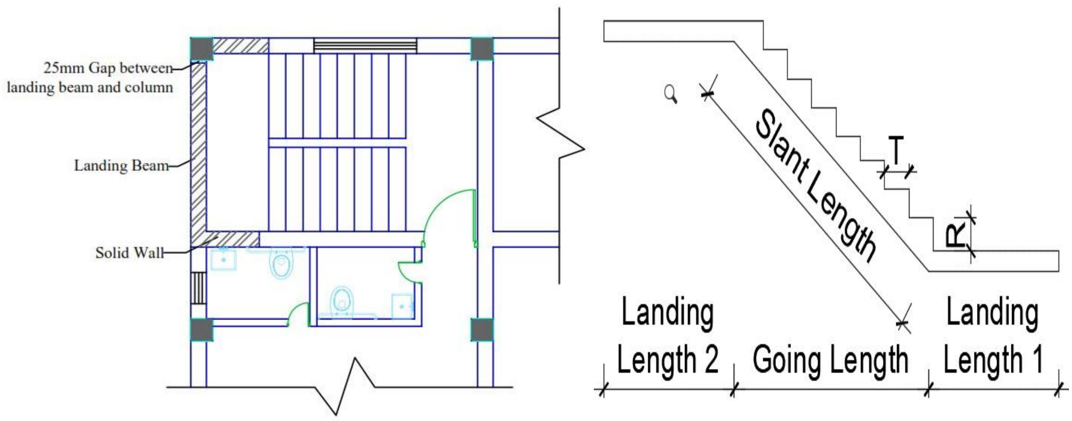


Figure 23: Plan Of staircase

Input Data

Height of the Floor	=	3.2	m
Landing Length 1 (L1)	=	1.4625	m
Number of Steps per Flight	=	9	Nos
Going Length (Horizontal)	=	2.475	m
Slant Length	=	2.9	m
Landing Length 2 (L2)	=	1.4625	m
Density of the concrete	=	25	KN/m3
Riser	=	177.8	mm
Tread	=	275	mm
Waist Slab Thickness	=	175	mm
Clear cover	=	15	mm
Effective depth of the waist slab	=	152	mm
Live for the staircase considered	=	2	KN/m2
Floor Finish for the staircase considered	=	1.665	KN/m2

Material Properties

Grade of the steel	=	Fe500	
Yield Strength of the steel, fy	=	500	Mpa
Modulus of elasticity of Steel, E	=	200000	Mpa
Grade of the concrete	=	M20	
Compressive Strength of the concrete, fc	=	20	Mpa
xu/d	=	0.48	
0.36*fck*xu*(1-0.42*xu)	=	2.76	

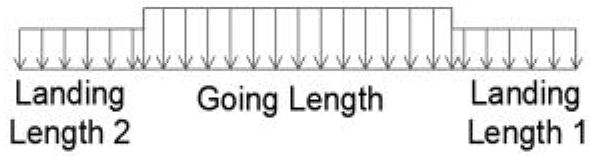
Loads on the Staircase (Going and Landings)

Considering 1m width of the Staircase		Going	
Self Weight of the Slab	=	5.21	KN/m
Self Weight of the Steps	=	2.22	KN/m
Weight of the floor finish	=	1.665	KN/m
Live Load Weight	=	2	KN/m

Loads on the Going = 11.095 KN/m

Loads on the Landings = 8.045 KN/m

8.045 11.095 8.045 KN/m



B

1.4625 2.475 1.4625

Analysis of the Staircase

Reaction at A = 25.5 KN

Reaction at B = 25.5 KN

Maximum moment arises at the center of the span (assuming simply supported stairs)

Bending Moment = 60.94 KN-m

Shear Force Max = 25.5 KN

R value for the considered concrete and Steel Grade

R = 2.76

Check For the effective depth

d = 148.61 mm

Safe Remarks

Design of the Reinforcement

Ast Required = 1133.4 mm2 Main Reinforcement

Dia.	Area/bar	Spacings(Required) mm	Spacing to be provided(mm)
12	113.10	99.79	150
12	113.10	99.79	150

Distribution Reinforcement

Ast min. = 210 mm2 0.12% of the gross area of the concrete

Dia. Used = 8 mm

Area/bar	=	50.27	mm2	
Spacings	=	239.36	mm	Required
		150	mm	Provided
		Safe	Remarks	
Shear Force resisted by Concrete				
K	=	1.3	For the depth of slab less than or equal to 150	
Tc	=	0.36	N/mm2	For M20 concrete and 0.25% of the reinforcement
Shear force Resisted		=	81.9	KN
Max. Shear Force		=	25.5	KN
			Safe	Remarks

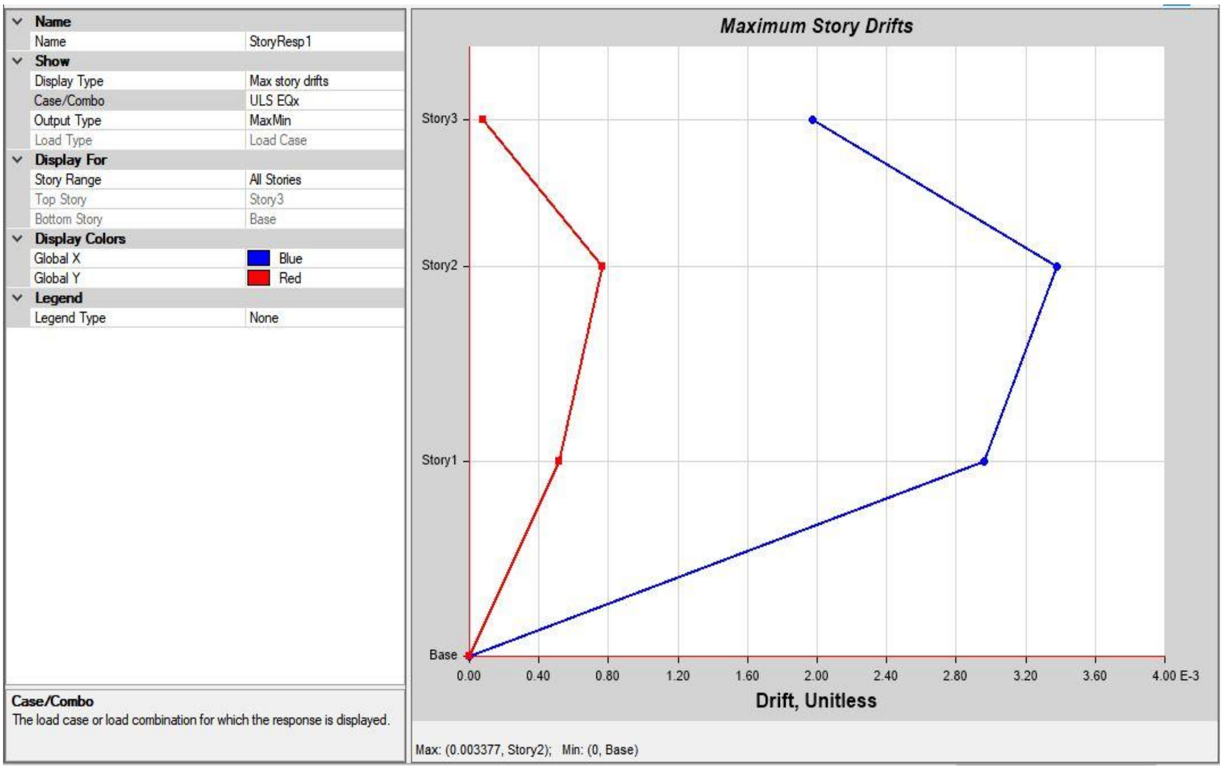
E.10 Design of other members

F. Performance of Building

F.1 Storey Drift Ratio, Storey Displacement and Separation between blocks:

In order to control deflection of structural elements, the criteria given in the Clause 5.6.3 of NBC 105:2077 is proposed to be used.
To control overall deformation due to earthquake load, the criteria given in Clause 5.6.3 of NBC 105:2077 is applied. The maximum deflection in any story due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.006 times the story height. Furthermore, the drift shall not exceed 0.006 in Serviceability Limit State and 0.025 in Ultimate Limit State case.

DRIFT CHECK FOR ULS



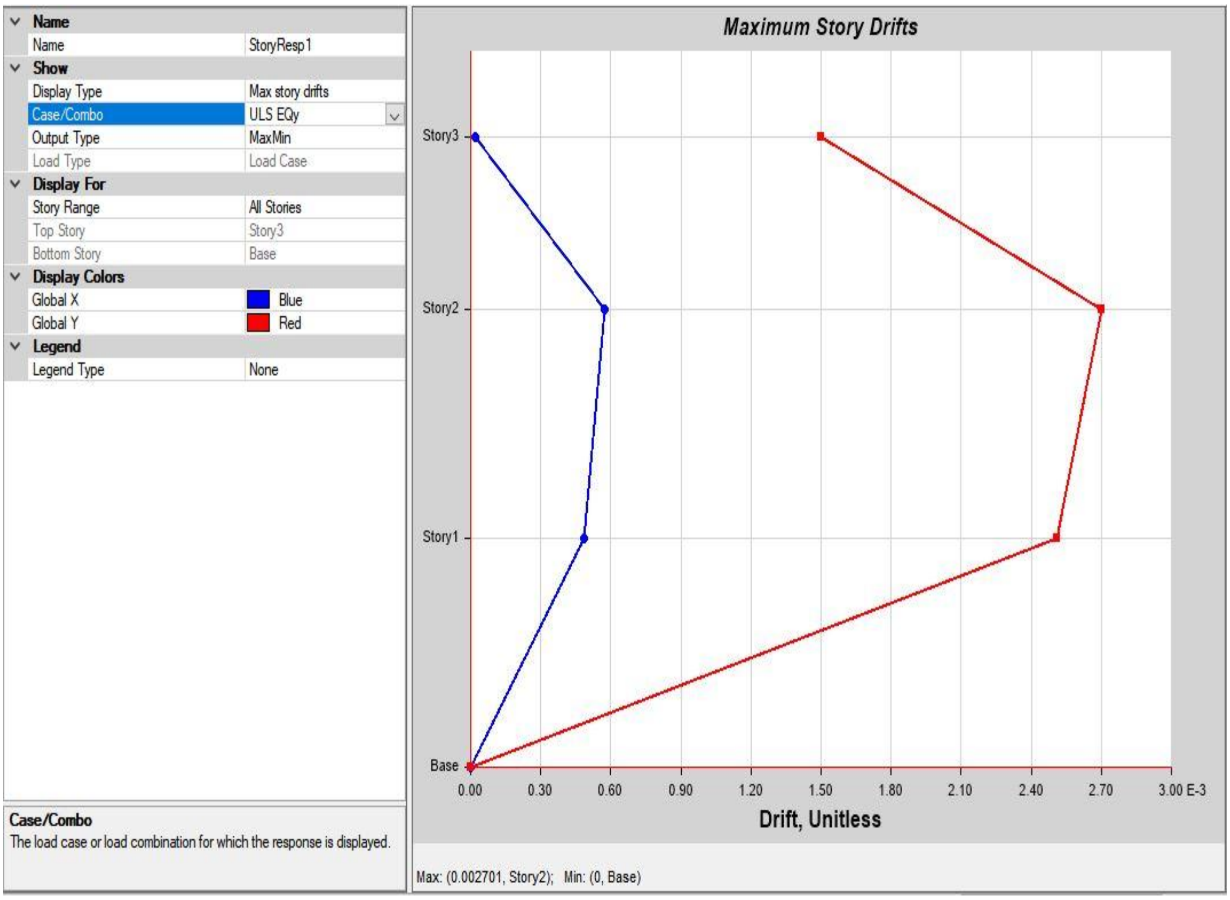


Figure 24: Maximum drift of ULS due to EQX and EQY

Design horizontal Inter-Story Drift = 0.003377 x 4 = 0.0135 < 0.025, OK

DRIFT CHECK FOR SLS

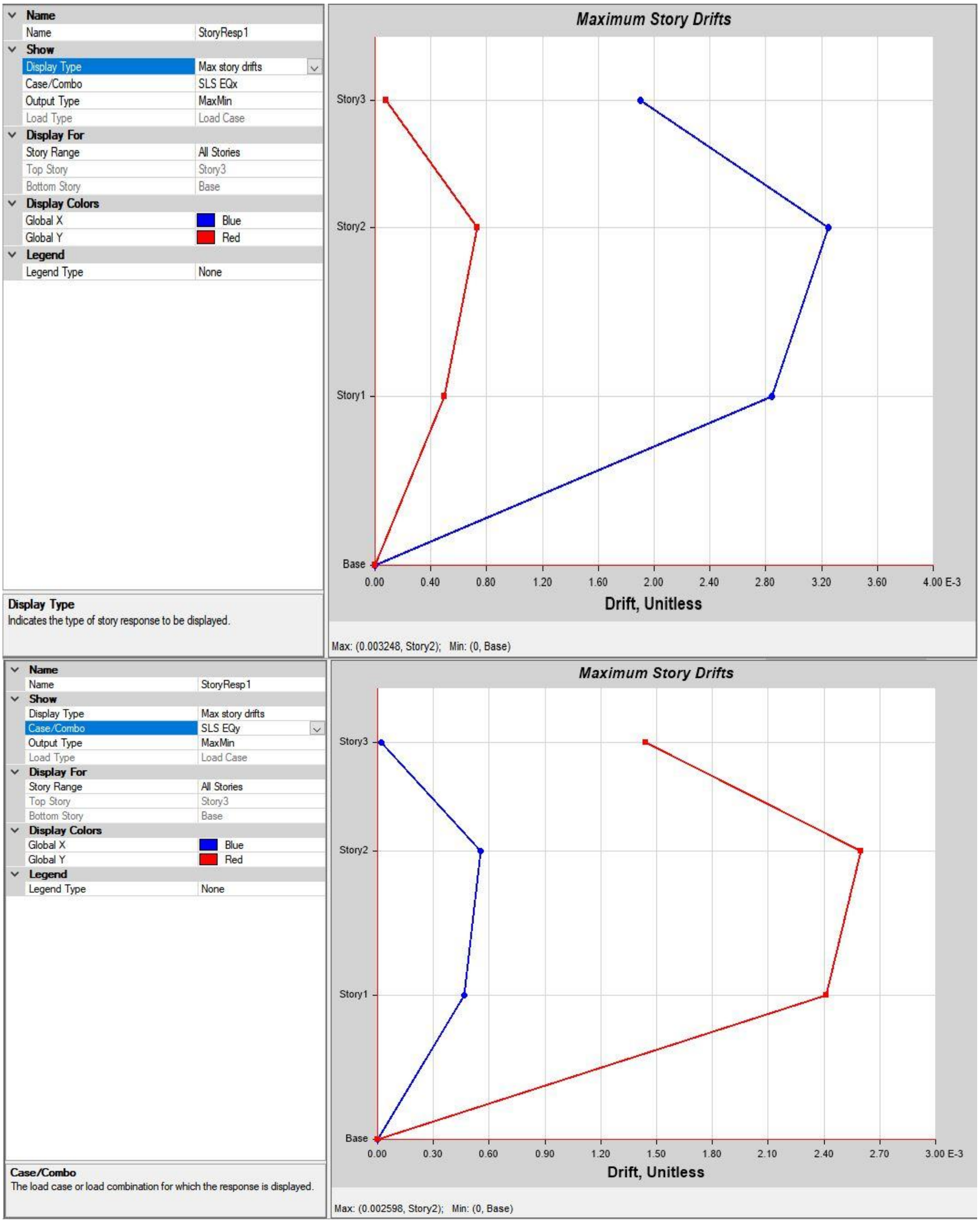


Figure 25: Maximum drift of ULS due to EQX and EQY

Design horizontal Inter-Story Drift = 0.003248 < 0.006, OK (For SLS)

F.2 Check for Structural Irregularity

One of the basic virtue of earthquake resistant design of structures is that the structure shall be regular as much as possible. It is observed that the structures with simple and regular configurations suffer much less damage during a large earthquake in comparison to the structures with irregular configurations. At the planning stage itself, the Designer should try to make the structure as regular as possible. Clause 5.5 of NBC 105:2020 has given provisions to check the structural irregularity of structures.

F.2.1 Torsional Irregularity

As per the clause 5.5.2.1 of NBC 105:2020, torsion irregularity is considered to exist when the maximum horizontal displacement of any floor in the direction of the lateral force, applied at the centre of mass, at one end of the storey is more than 1.5 times its minimum horizontal displacement at the far end of the same storey in that direction.

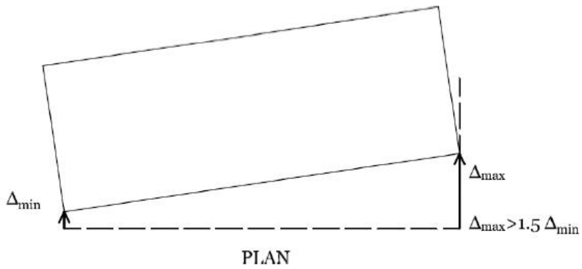


Figure 26: Torsional Irregularity

For EQx

Floor	Maximum Displacement	Minimum Displacement	Ratio	Check
3	24.285	21.171	1.147	OK
2	19.129	14.212	1.346	OK
1	8.879	6.769	1.312	OK

For EQY

Floor	Maximum Displacement	Minimum Displacement	Ratio	Check
3	7.479	5.505	1.359	OK
2	15.265	10.642	1.434	OK
1	18.589	15.559	1.195	OK

As all the ratio of the maximum displacement to the minimum displacement is less than 1.5, no torsion irregularity is seen.

F 2.2 Soft Storey

As per the clause 5.5.1.2, a soft storey is the one whose stiffness of the lateral force resisting system is less than 70% of the lateral force resisting system stiffness in an adjacent storey above or below, or less than 80% of the average lateral force resisting system stiffness of the three storeys above or below.

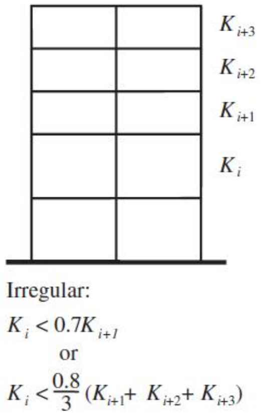


Figure 27: Soft storey check

No soft storey is observed in the building.

F 2.3 In-plane Discontinuity

As per the clause 5.5.1.4 of NBC 105:2020, if there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on supporting structural elements, then there will be in-plane discontinuity in vertical lateral force resisting element type of irregularity.

No in-plane discontinuity is present in the structure.

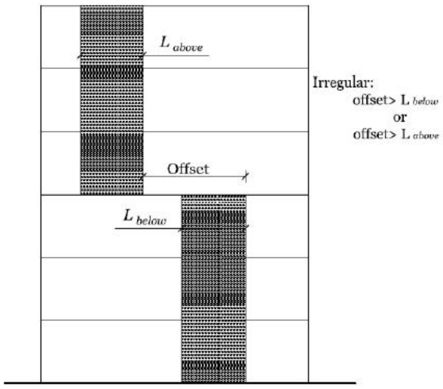


Figure 28: In-Plane Discontinuity

F 2.4 Mass Irregularity

If there is a difference of more than 50% between the effective masses of two consecutive storeys, then there will be the existence of mass irregularity in the structural system of the building as per the clause 5.5.1.5 of NBC 105:2020. However, for such checks, light roofs, penthouse and mezzanine floors are not to be considered. The Designer is required to carry out the check for mass irregularity in the structural

system and present the same in tabular form in the structural design report.
No mass irregularity is seen as the stories are nearly identical.

F 2.5 Re-entrant Corner

As per the clause 5.5.2.2 of NBC 105:2020, a structure is said to have re-entrant corner irregularity in a direction if its structural configuration has a projection of greater than 15% of its overall dimensions in that direction.
The building is rectangular in shape with no re-entrant corners.

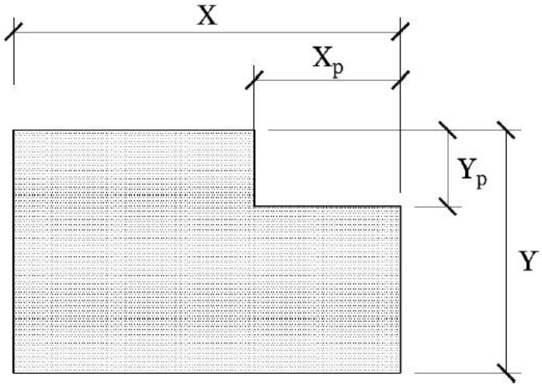


Figure 29: Re-entrant corners

F 2.6 Diaphragm Discontinuity

If the diaphragm of a building has a cutout or open area greater than 50% of the gross enclosed diaphragm area or if the effective diaphragm stiffness changes more than 50% from one storey to the next, then as per the clause 5.5.2.3 of NBC 105:2020, the building is said to have diaphragm discontinuity irregularity. The Designer is required to check the existence of such irregularity in the building and provide the details in the structural design report.
No cut-outs larger to cause diaphragm discontinuity can be observed.

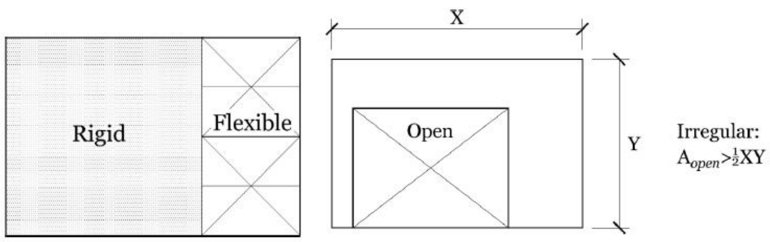


Figure 30: Diaphram Discontinuity

F 2.7 Out-of-plane Offset

If there is a discontinuity in a lateral force resisting path such as an out-of-plane of at least one vertical element in the structural system of the building, then as per the clause 5.5.2.4 of NBC 105:2020, the building is said to have out of plane irregularity.
No out-of-plane offset can be seen as per the drawings.

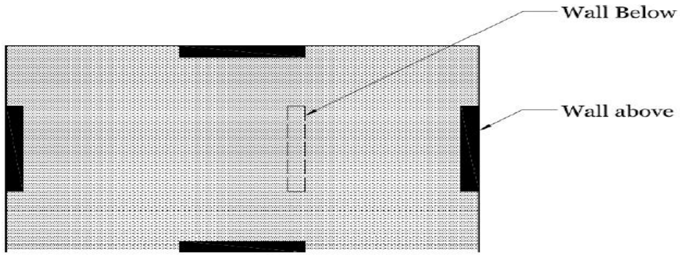


Figure 31: Out of plane offset