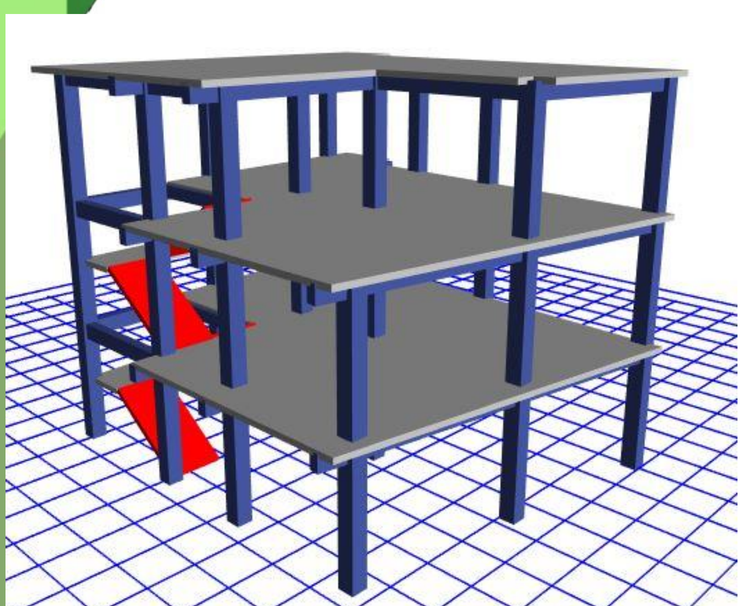
OFFICE OF MUNICIPAL EXECUTIVE
SHANKHARAPUR MUNICIPALITY
Kathmandu District, Bagmati Province, Nepal

Owner/Client	**Mr Padam Bahadur Basnet**
Building type	**Residential Class 'B'**
Location	**Shankharapur-09, Shankharapur Municipality**
Plot Area	**0-3-3-2**
Plot No.	**674**

Structural Analysis and Design Report RCC Residential Building Class "B" USING NBC 105:2020



Submitted by :
Sanam Tajale
BE Civil (NEC REG. 15913 Civil"A")

2024

DECLARATION OF REPORT

The massive data inputs, design analysis, calculations and outputs of the result are computer aided by the Structural and Earthquake Engineering software called ETABS, which is a special purpose computer program developed specifically for building structures by Computers and Structures Inc., Berkeley, CA. It provides the Structural Engineers with all the tools necessary to create, modify, analyse, design, and optimize the structural elements in a building model.

During the design, it is assumed that the client will completely follow the architectural as well as the structural design. If not, the designer would not be responsible for the occurrence of unwanted issues. It is also assumed that the construction will be supervised by a professional engineer.

Er. Sanam Tajale
BE Civil (NEC REG. 15913 Civil”A”)
2024

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CHAPTER 1

INTRODUCTION

1.1.BUILDING DESCRIPTIONS

This document presents the overall methodology and the key results of the structural design of structural components of RC moment resisting frame system.

The parameters followed for the structural analysis and design is as follows.

Technical Information	
Structural System	Special Moment Resisting RCC Frame
Level of Design	Professionally Engineered Building
Plinth area	868.28 Sq ft.
No. of Stories	Three Story
Story Height	2.8448 m (9'-4")
Floor Thickness	125 mm (5")
Parapet wall height	1 m (3'-3")
Earthquake Zone (City)	Kathmandu
Seismic Zone Factor	0.35
Importance factor	1
Ductility factor, R_u	4 (SMRF)
Overstrength Factor, Ω_u	1.5
Building Shape (Column Layout)	Regular in Plan (Rectangular)
Building Dimensions (C/C)	Refer Architectural Drawing
No. of bays	Refer Architectural Drawing
Lateral load resistant elements	350 mm x 350 mm (14"X14") Column Section
	Beams 230 mm x 350 mm (9"X14") with slab
Grade of concrete used	M20 for Column and M20 for Beam and Slab
Type of Foundation	Isolated Foundation, Eccentric Footing
Soil Bearing Capacity	120 KN/m^2 at foundation level
Soil Profile Type	Type D (Very Soft Soil Sites)
Wall Material	Brick Masonry

1.2.ANALYSIS TECHNOLOGY AND METHODOLOGY

After completion of Architectural design, the layout of columns and beams are done without affecting the Architectural functions of building so far. Structure is modelled using finite element method. A three-dimensional beam element having 12 DOF with 6 DOFs at each node were used for modelling beams and columns in the building, while 24 DOFs shell element with 6 DOFs at each node were used to model slab wall.

The structure is analysed by the linear elastic theory to calculate internal actions produced by anticipated design loads. The analysis is carried out using state of art three dimensional structural analysis programs ETABS v2020. 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.

Software Used:

- ETABS ULTIMATE v2020
  For structural modelling of the present building, ETABS software was used. ETABS is a special purpose finite element analysis and design program developed specifically for building systems. With ETABS, models are defined logically floor-by-floor, column-by-column, bay-by-bay and wall-by-wall and not as a stream of non-descript nodes and elements as in general purpose programs. The software has very powerful numerical methods, design procedures and international design codes, all working from a single comprehensive database. At its core, it utilizes the same analysis engine as used by SAP2000. Among others, ETABS can do model generation, seismic and wind load generation, finite element-based linear and non-linear static and dynamic analysis, concrete frame design (column and beam) and shear wall design.
- AUTOCAD V2017
  Based on the final results, the design has been performed and drawings were prepared using AutoCAD v2017.

1.3. NEED FOR STRUCTURAL ANALYSIS

The building to be designed is not within the municipality guidelines (M.R.T) for the normal building. So, for the safety consideration, the building is structurally designed. Structural Analysis is required due to one of the following reasons

- Any of the slab area is greater than 144 Sft.
- Building area is attached to other's property line.
- Wall on cantilever portion.
- Building greater than 3 storey.
- Proposed Building is to be constructed on the sloppy terrain.
- Proposed Building is State of Art Design.

For this project, slab area is greater than 144 Sft.,Span of Critical Beam is greater than permissible & one side of building is attached to other's property line. Hence, structural analysis is essential.

1.4.IDEALIZATION AND ASSUMPTIONS IN ANALYSIS AND DESIGN

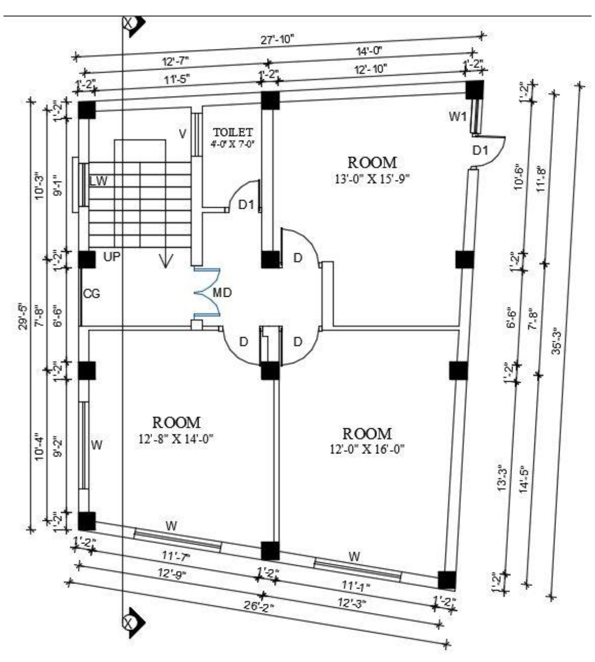
Various assumptions have been made in analysis and design of the structures, for consideration of safety and simplicity, namely:

- Tensile strength of concrete is ignored.
- Shrinkage and temperature strength are negligible.
- Adhesion between concrete and steel is adequate to develop full strength.
- Seismic and wind load don’t occur simultaneously so proposed building is designed for earthquake only.
- Centerlines of beams, columns and shear walls are concurrent everywhere.

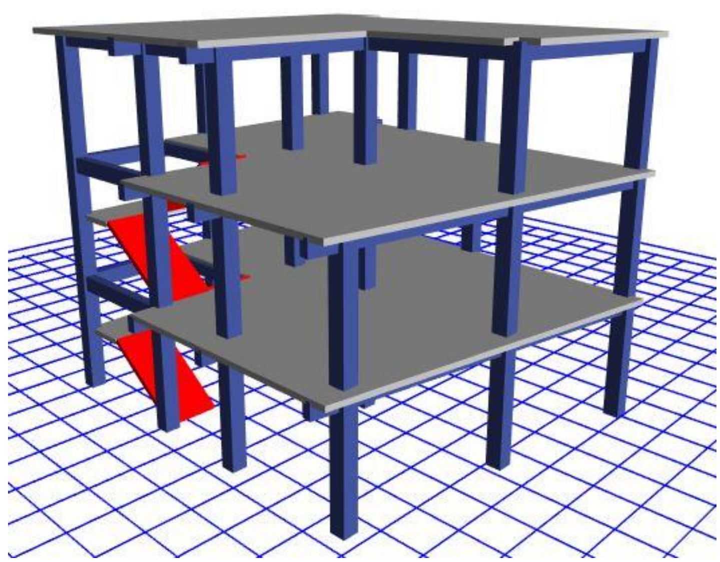
Further assumptions in analysis and design that are not included here if are considered, then they are explained at the assumed section itself.

Earthquakes of magnitude < 5.0 are not expected to cause structural damage
Earthquakes > 5.0 are potentially very damaging
Threshold Magnitude: Normally 5 Richter Scale

1.5.MODELING OF STRUCTURAL SYSTEM



GROUND FLOOR PLAN
FLOOR AREA = 868.28 SQ.FT



Complete, three-dimensional elastic models are created, representing the structure's spatial distribution of the mass and stiffness to an extent that is adequate for the calculation of the significant features of the building's elastic response.

ETABS integrated software is used as analysis tool. The elastic models are used for gravity and DBE level earthquake analysis. Nominal material properties are used in modeling of structural components.

1.6. ANALYSIS PROCEDURES

Analysis procedures used for code-based design are presented in the following sections.

Load cases	Analysis type
Static Analysis	Linear Static Analysis
Dynamic Analysis	None

COMPONENT AND MEMBER DESIGN

The structural components are designed to satisfy the strength and ductility requirements. Strength capacity for different types of actions considered in the design is summarized in the table below.

Structural System	Component	Design Approach/Consideration	Code References
Special moment resisting frame system	Reinforced Concrete (Beams, Slab, Columns)	Axial compression, Shear and flexural	IS 456:2000
	Footings	Bearing capacity of soil	IS 456:2000

1.7. PRELIMINARY DESIGN

Column (Dimensional Limit)
NBC 105:2020 (Clause 4.2.1)

Clause 4.2.1 (a)

Diameter of rebar (d_b)= 16mm (largest dia. of longitudinal rebar in the beam)

$20d_b$= 20*16

320mm

(Clause 4.2.1 (b)

min. dim. of column= 300mm

(Clause 4.2.1 (c)

width to depth ratio >0.45

width to depth ratio= 355.6/355.6

= 1

OK

Column width= 14"

= 14*25.4

= 355.60 mm

Column depth= 14"

= 355.60 mm

Provide Column Size of 14''X14''.

Rebar dia.	numbers	area	no.s X area
20mm	0	314.16 mm2	0
16mm	4	201.06 mm2	804.24772
12mm	4	113.10 mm2	452.38934
10mm	0	78.54 mm2	0
8mm	0	50.27 mm2	0
			1256.6371

PRELIMINARY DESIGN OF BEAM	
Beam(Dimensional Limit) NBC 105:2020	
width of beam=	9"
=	228.60 mm
Depth of beam=	14"
=	431.80 mm
clear span	
ft	inches
13	3
=	4038.40 mm
effective span=	4388.40 mm
Clause 4.1.1 (a)	
width to depth ratio >	0.3
width to depth ratio=	0.64
	OK
Clause 4.1.1 (b)	
min. width of beam=	200 mm
Clause 4.1.1 (c)	
Depth of beam<	1/4th of clear span
1/4th of clear span=	1/4 *4038.40
=	1009.6 mm
	OK
Provide Beam Size of 9''X14''.	

1.8. DESIGN LOAD

The buildings and structures are subjected to number of loads, forces and effects during their service life such as those listed in IS: 456-17, IS: 875-8.1 / NBC. The following loads usually determine the size of structural element:

- Dead load (DL)
- Imposed load (IL)
- Wind load (WL)
- Earthquake load (EL)

The following are the cause which generally causes internally-equilibrated stresses forming cracks in structure, but not collapse.

- Foundation movement,
- Axial elastic shortening,
- Shrinkage,
- Temperature changes, etc.

- **EFFECTIVE STIFNESS OF DIFFERENT STRUCTURAL ELEMENTS**

The deflections shall be obtained by using the effective stiffness properties of the components as given in 3.1.

Table 3.1 Effective stiffness of different components			
S No.	Component	Flexural Stiffness	Shear Stiffness
1	Beam	0.35 Ec Ig	0.40 Ec Aw
2	Columns	0.70 Ec Ig	0.40 Ec Aw
3	Wall—cracked	0.50 Ec Ig	0.40 Ec Aw
4	Wall—uncracked	0.80 Ec Ig	0.40 Ec Aw
For steel structures, the gross stiffness values shall be used.			

1.9.LOAD ASSESSMENT

The proposed building is a RCC framed structure, located in the **Kathmandu**. Thus, wind loads, snow loads, and other special types of loads described by IS: 875 (part 5):1987 can be taken as negligible as compared to the dead, live and seismic loads.

a. Dead Loads:

According to the IS 875:1987(Part I), the dead load in a building shall comprise the weights of all walls, partitions, beam, column, floors and roofs and shall include the weights of all other permanent features in the building.

b. Live Loads:

It means the load assumed or known resulting from the occupancy or use of a building and includes the load on balustrades and loads from movable goods, machinery and plant that are not an integral part of the building. These are to be chosen from codes as IS:875: 1987(Part-2) for various occupancies where required. These codes permit certain modifications in the load intensities where large contributory areas are involved, or when the building consists of many stories.

c. Eccentricity of vertical loads:

When transferring the loads from parapets, partition walls, cladding walls and façade walls etc., to the supporting beams or columns, the eccentricity with these loads should be properly considered in the case of rigid frames of reinforce concrete. Such eccentricities will produce externally-applied joint moments similar to these arising from projecting cantilevers and these should be included in frame design.

d. Seismic Loads:

These are the load resulting from the vibration of the ground underneath the super-structure during an earthquake. The earthquake is an unpredictable natural phenomenon. Nobody knows the exact timing and magnitude of such loads. Seismic loads are to be determined essentially to produce an earthquake resistant design.

Since the probable maximum earthquake occurrence is not frequent, designing building for such earthquake isn't practical as well as economically prudent. Instead, reliance is placed on kinetic dissipation in the structure through plastic deformation of elements and joints and the design forces are reduced accordingly. Thus, the philosophy of seismic design is to obtain a no-collapse structure rather than no-damage structure.

Seismic Design Criteria

Earthquake	Desired Behaviour	Controlling Parameter
Minor	No damage to non-structural components.	Controlling deflection by providing stiffness.
Moderate	No significant structural damage, minor cracks in beams and column should be pre-dominantly elastic.	Avoid yielding of members or permanent damage by providing strength.
Severe Catastrophic	No collapse of system which could cause loss of life.	Allow structure to enter into in-elastic range and absorb energy by providing ductility.

1.9.1. ESTIMATION OF LOADS

It is most important step in structural design. Proper recording of them required for confusion free analysis.

- **DEAD LOADS**

  Dead loads are assumed to be produced by slab, beams, columns, walls, parapet walls, staircase, plasters and mortars, floor finish. The weight of building materials are taken as per IS 875(Part 1)-1987).

- Specific weight of materials [Ref: IS: 875(Part 1)-1987)]

Materials	Unit Weight	Unit
RCC	25.00	(KN/m3)
Brick Masonry	19.20	(KN/m3)
Floor Finish (Cement Punning)	0.91	(KN/m2)
AAC Block (Wet Weight)	10.00	(KN/m3)

- **FLOOR FINISHING**

Materials	Unit Weight (KN/m3)	Thickness (mm)	UDL (KN/m2)
Marble	26.70	20.00	0.53
Screed	22.00	25.00	0.55
Plaster	20.40	12.50	0.26
Total			1.34
Materials	Unit Weight (KN/m3)	Thickness (mm)	UDL (KN/m2)
Screed	22.00	25.00	0.55
Plaster	20.40	12.50	0.26
Punning	20.00	5.00	0.10
Total			0.91

- **WALL LOAD CALCULATION**

WALL LOAD CALCULATION

Full brick wall thickness=	0.23m	
Half brick wall thickness=	0.115m	
Floor to floor height=	2.845m	
Beam depth=	0.356m	
Slab thickness=	0.127m	
Height of wall resting on beam=	2.845-0.356	
=	2.489m	
Height of wall resting on slab=	2.845-0.127	
=	2.718m	
Unit weight of brick masonry=	19.2KN/m³	**IS: 875 (Part 1)-1987,Table-1 Item no. 36**
Parapet wall height=	1.00m	

Wall	WL (without opening) Unit: KN/m		25% opening		Parapet wall load Unit:KN/m
	9"	4.5"	9"	4.5"	4.5"
Resting on beam	=0.23*2.489*19.2	=0.115*2.489*19.2	=0.75*10.996	=0.75*5.53	=1*0.115*19.2
	=10.99	=5.5	=8.243	=4.125	2.208
	≈11	**≈5.5**	**≈8.5**	**≈4.5**	**≈2.5**
Resting on slab	=0.23*2.718*19.2 **=12.00**	=0.115*2.718*19.2 **=6.00**	=0.75*12 **=9.00**	=0.75*6 **=4.50**	
	≈12	**≈6**	**≈9**	**≈4.5**	

AREA LOAD CALCULATION

(i) Floor Finish

Thickness of screeding=	50mm	
Unit weight of screeding/plaster=	20 KN/m^3	**IS: 875 (Part 1)-1987,Table-1 Item no. 42**
Unit weight of flooring=	0.22 KN/m^3	**IS: 875 (Part 1)-1987,Table-2 Item no. 7**
Thickness of plaster on ceiling=	12.50mm	
Flooring=	10.00mm	
Area considered=	1 m^2	
Floor Finish load (screeding)=	20*(50/1000)	
=	1.00	
(ceiling plaster)=	20*(12.5/1000)	
=	0.25	
(flooring)=	0.22*(10/1000)	
=	0.0022	
Total Floor Finish load=	**1.25 KN/m^2**	

(ii) Water Tank Load

slab length=	3.556 m	
slab bredth=	4.267 m	
slab area=	3.556*4.267	
=	15.173 m^2	
Water tank capacity=	2000 Ltr.	
=	20 KN	
Water tank load=	20/15.886	
=	**1.318 KN/m^2**	
	≈1.5	

(iii) Waist slab (due to steps)

Riser (R)=	0.178 m	
Tread (T)=	0.254 m	
Width of stair=	1.067 m	
Unit weight of concrete=	25 KN/m^3	**IS: 875 (Part 1)-1987,Table-1 Item no. 22**

nit weight of concrete

Load on Waist slab=

= (0.178*0.254*25)/{2*sqrt(0.178^2+0.254^2}

= **1.822 KN/m^2**

- **LIVE LOADS**

  Select live load intensity occupancy-wise as applicable for slabs and beams from the code. The reduction of live load intensities for the number of storey in the columns and that for calculating earthquake loads may be considered in the calculations later.

Live Load	UDL (KN/m2)
Bed rooms, Sitting rooms and Kitchen	2.00
Storage and General Store	4.00
Lobby/Corridor/Staircase	3.00
Balconies	3.50
Accessible Roof / Inaccessible Roof	1.50 / 0.75

1.9.2. LOAD COMBINATIONS

The load combinations are based on NBC 105: 2020. The following load combinations are specified for parallel system.

1.2DL + 1.5LL Where, λ = 0.6 for storage facilities

DL + λLL + E = 0.3 for other usage

Name	Type	Is Auto	Load Name
Comb1 (1.2DL + 1.5LL)	Linear Add	No	Comb1 (1.2DL + 1.5LL)
Comb2 (DL + λLL +EQxult)	Linear Add	No	Comb2 (DL + λLL +EQxult)
Comb3 (DL + λLL -EQxult)	Linear Add	No	Comb3 (DL + λLL -EQxult)
Comb4 (DL + λLL +EQyult)	Linear Add	No	Comb4 (DL + λLL +EQyult)
Comb5 (DL + λLL -EQyult)	Linear Add	No	Comb5 (DL + λLL -EQyult)
Comb6 (1.5DL+1.5LL)	Linear Add	No	Comb6 (1.5DL+1.5LL)
Comb7 (DL + λLL +RSx)	Linear Add	No	Comb7 (DL + λLL +RSx)
Comb8 (DL + λLL +RSy)	Linear Add	No	Comb8 (DL + λLL +RSy)
Comb9 (DL + LL)	Linear Add	No	Comb9 (DL +LL)

1.9.3. LOADING ON STRUCTURAL MODEL:

The following considerations are made during the loading on the structural model:

- The loads distributed over the area are imposed on area element and that distributed over length are imposed on line element whenever possible.
- Where such loading is not applicable, equivalent conversion to different loading distribution is carried to load the model near the real case as far as possible.
- The imposed loading of infill walls are considered(as per architectural drwg.) as equivalent UDL with 25% to 30% deductions for openings, but the actual modelling of infill walls as equivalent Struts are not performed. Hence the stiffness of infill walls is not considered.
- The Plinth Tie – Beams are designed as purely tie members for lateral loads only, not designed as flexural members as floor beams.

- Modelling of stair case is performed
- Seismic loads are 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.
- Floor diaphragms are assumed to be rigid.
- Centre-line dimensions are assumed for analysis and design. Preliminary sizes of structural components are assumed as per Architectural Drawing.
- For analysis purpose, the beams are assumed to be rectangular so as to distribute slightly larger moment in columns. In practice a beam that fulfils requirement of flanged section in design, behaves in between a rectangular and a flanged section for moment distribution.

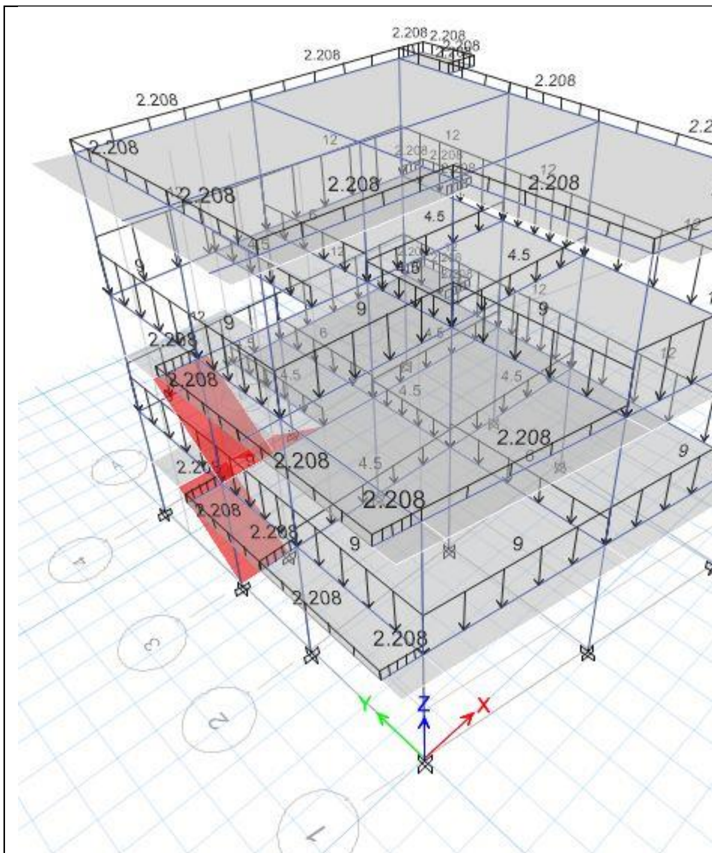


Fig: Wall load and Parapet Wall Load on structure

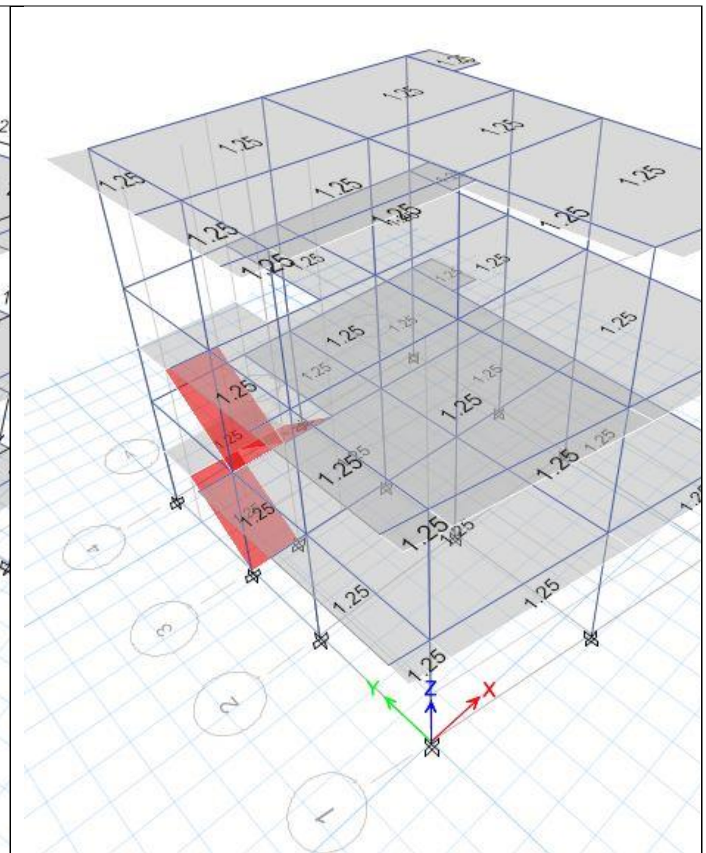


Fig: Floor Finish load imposed on structure

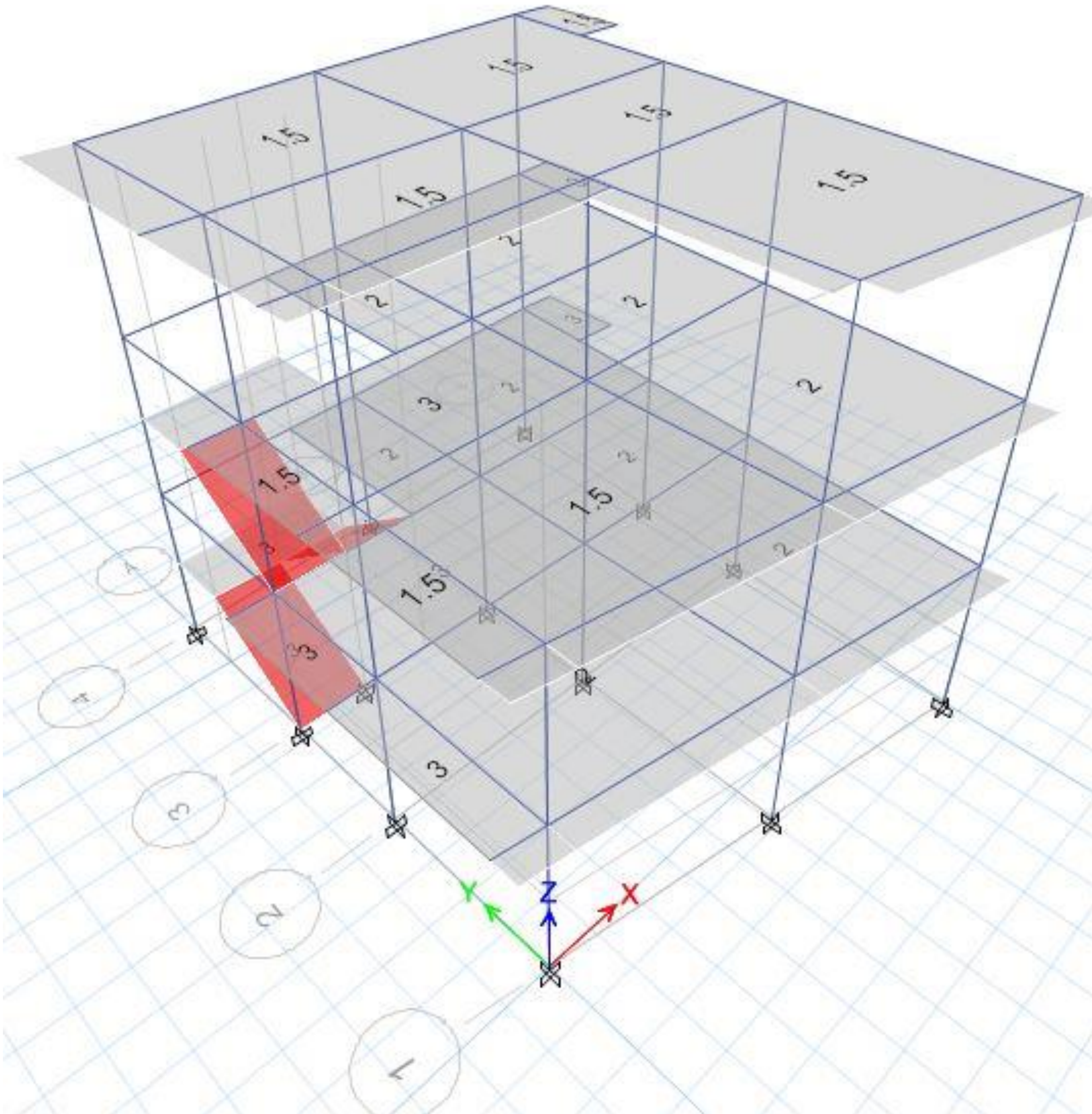


Fig: Live load imposed on structure

1.9.4. BASE SHEAR (AS PER NBC 105:2002)

Base Shear (V_B) = W* C (T)

W = Seismic Weight

C_h (T) = Spectral Shape Factor as per Cl. 4.1.2

The Elastic site spectra for horizontal loading shall be as given by equation 4.1(1).

C (T) = C_h (T) Z I ....4.1(1)

Where,

C_h (T) = Spectral Shape factor as per Cl. 4.1.2

Z = Seismic Zoning factor as per Cl. 4.1.4

I = Importance factor as per Cl. 4.1.5

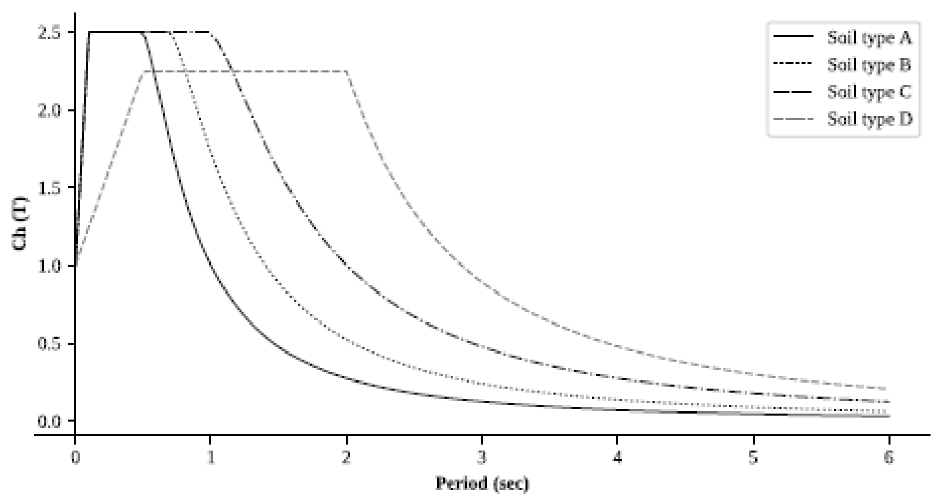


Figure 4-2 Spectral Shape Factor, C_h(T) for Modal Response Spectrum Method, Nonlinear Time History Analysis , Vertical Loading and Parts and Components

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

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

1.9.4. CALCULATION OF SEISMIC COEFFICENTS & BASE SHEAR AS PER NBC 105: 2020

Base Shear Coefficient Calculation using NBC 105:2020 for **Kathmandu**

Residential Building

Zone Factor	Z=	0.35	Clause 4.1.4
Importance Factor	I=	1	Clause 4.1.5
	Soil type:	D	Clause 4.1.3.4
Height of Building	H=	8.534 m	
For Moment Resisting Concrete Frame	K_t=	0.075	Clause 5.1.2
Time Period	$T= 1.25*K_t*H^{0.75}$	0.468 sec	Clause 5.1.2 & 5.1.3
For Equivalent Static Method	Ta=	0	Table 4-1
	Tc=	2	Table 4-1
	α=	2.25	Table 4-1
	K=	0.8	Table 4-1
Spectral Shape Factor	Ch(T)	2.25	Clause 4.1.2
Elastic Site Spectra	C(T)=Ch(T)*Z*I	0.7875	Clause 4.1.1
Elastic Site Spectra for serviceability limit state	Cs(T)=0.2*C(T)	0.1575	Clause 4.2
Horizontal Base Shear Coefficient			
Moment Resisting Frame Systems	**(i) For SLS**		Clause 5.4.2
	Ru=	4	Table 5-2
(Reinforced Concrete Moment Resisting Frame)	Ωu=	1.5	Table 5-2
	Ωs=	1.25	Table 5-2
	Cd(T1)= Cs(T1)/Ωs	**0.1260**	Clause 6.1.2
	(ii) For ULS		Clause 5.4.1
	Ru=	4	Table 5-2
	Ωu=	1.5	Table 5-2
	Ωs=	1.25	Table 5-2
	Cd(T1)= C(T1)/(Ru*Ωu)	**0.1313**	Clause 6.1.1

Building Height exponent	k=	1.00	Clause 6.3
Accidental Eccentricity	e=	0.1	Clause 5.7
Allowable story drift			
	(i) For ULS: 0.025/Ru	0.00625	Clause 8.1.3.1
	(ii) For SLS	0.006	Clause 8.1.3.1
Allowable story displacement			
	(i) For ULS: 0.025*(H/Ru)	53.3400 mm	Clause 5.6.1.1
	(ii) For SLS: 0.006*(H/Rs)	51.2064 mm	Clause 5.6.1.2

CHAPTER 2

ANALYSIS AND DESIGN

2.1. INTRODUCTION

This chapter presents the finite element modelling, analysis and design procedures used in the code-based design.

2.1.1. POSITIONING AND ORIENTATION OF COLUMNS:

Following are some of the building principles, which help in deciding the columns positions.

- Columns should preferably be located at (or) near the corners of a building, and at the intersection of beams/walls.
- Select the position of columns so as to reduce bending moments in beams.
- Avoid larger Centre-to-Centre distance between columns.

2.1.2. POSITIONING OF BEAMS:

- Beams shall normally be provided under the walls or below a heavy concentrated load to avoid punching and shear failures in slab.

- Avoid larger spacing of beams from deflection and cracking criteria. (The deflection varies directly with the cube of the span and inversely with the cube of the depth i.e. L^3/D^3. Consequently, increase in span L which results in greater deflection for larger span.)

2.1.3. SPANNING OF SLABS:

- This is decided by supporting arrangements. When the supports are only on opposite edges or only in one direction, then the slab acts as a one-way slab. When the rectangular slab is supported along its four edges it acts as a one-way slab when $L_y/L_x<2$. The two-way slab action of slab not only depends on the aspect ratio but also on the ratio of reinforcement on the directions. In one-way slab, main steel is provided along with short span only and the load is transferred to two opposite supports. The steel along the long span just acts as the distribution steel and is not designed for transferring the load but to distribute the load and to resist shrinkage and temperature stresses. A slab is made to act as a one-way slab spanning the short span by providing main steel along the short span and only distribution steel along the span.

2.2.ANALYSIS AND DESIGN RESULTS

INTRODUCTION

This chapter presents the analysis and design results of the residential building. The structural components were analysed using both- static and dynamic method. In static analysis, linear static method was adopted whereas for dynamic, Response Spectrum method using Model analysis.

2.2.1. BENDING MOMENT DIAGRAM

As loads were applied obviously the beam and column show their bending nature. After analysing we have to observe the BMD of every beam and columns. We have to check balanced section, under-reinforced and over-reinforced section. This is very important task before designing frames structure. The bending moment diagram is very much essential to design the sections for stability of structures. To get the area of steel, bending moment is essential and without bending moment diagram the design of any structure is not possible.

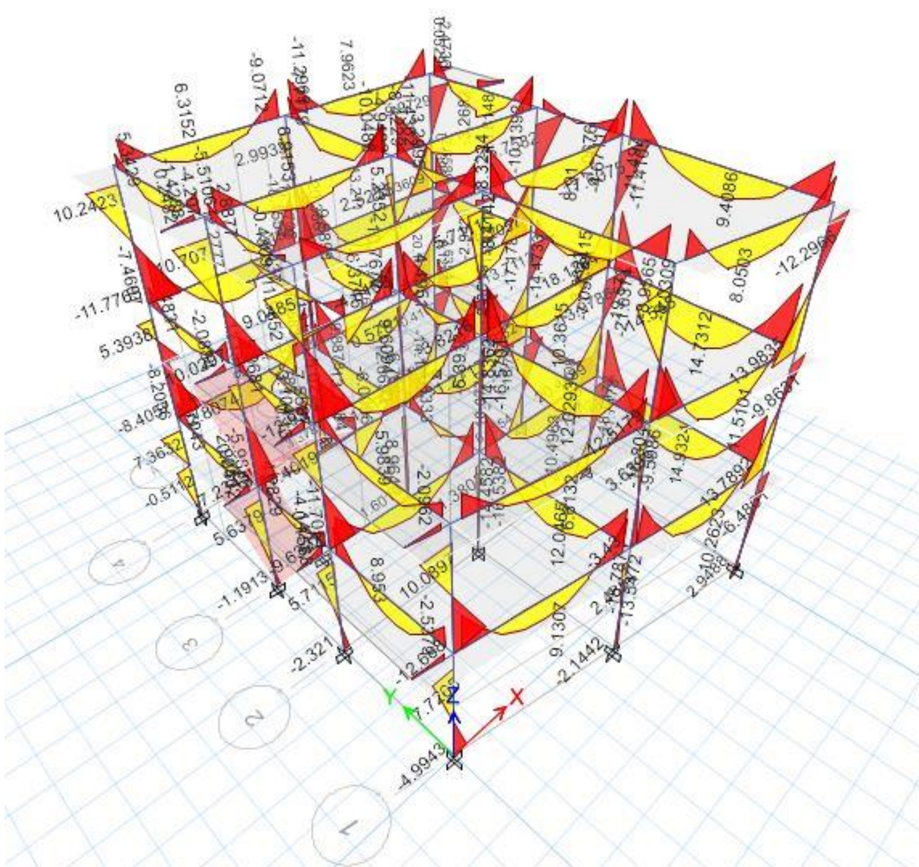


Fig: Moment Diagram 3D View (1.2DL+1.5LL)

This Bending Moment diagram is used to calculate the area of steel by using formula given below,

$$\mathbf{Ast = \frac{0.5fckbd}{fy}\left(1 - \sqrt{\left(1 - \frac{4.6Mu}{fckbd^2}\right)}\right)}$$

Where,

M_u= Bending Moment Obtained from ETABS
F_{ck}=Characteristics Strength of Concrete
F_y= Grade of Steel Used
b= width of section
d= effective depth of section

SHEAR FORCE DIAGRAM

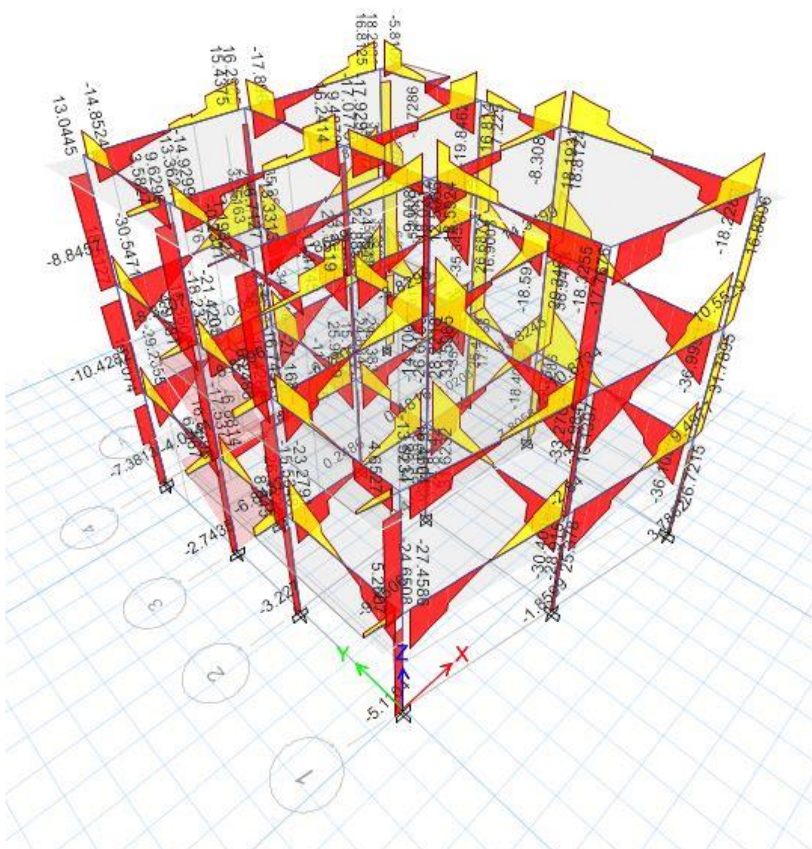


Fig: SFD 3D View (1.2DL+1.5LL)

Shear force diagram is used to calculate or design of stirrups. We noticed that always shear force diagram is maximum at support and less when it moves towards the centre as in figure. Hence the spacing of stirrups at the supports was closely spaced where at the middle it is largely spaced.

AXIAL FORCE DIAGRAM

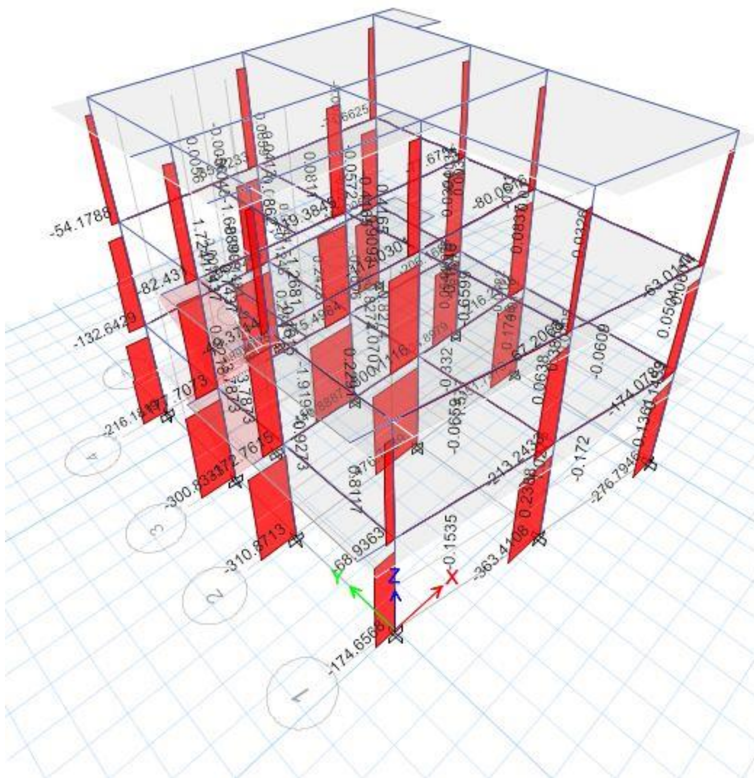


Fig: Axial Force View (1.2 DL+1.5LL)

2.2.3.POST ANALYSIS CHECK AFTER STATIC ANALYSIS OF STRUCTURE

The following are the parameters to check after analysis of model from ETABS.

1. Check For Inter Storey Drift (As per Clause 5.6.3 NBC 105:2020)
2. Maximum Permissible Storey Displacement in both principal directions.
3. Model Participation Factor
4. Check for Torsional Irregularities (As per Clause 5.5.2.1 NBC 105:2020)
5. Center of Mass and Center of Rigidity
6. Support reaction for foundation design
7. Deformed shape of structure
8. Verification of all members passed.
9. Beam Column Capacity Check

2.2.3.1. CHECK FOR INTER STOREY DRIFT (AS PER CLAUSE 5.6.3 NBC 105:2020)

The ratio of the inter-story deflection to the corresponding story height shall not exceed:

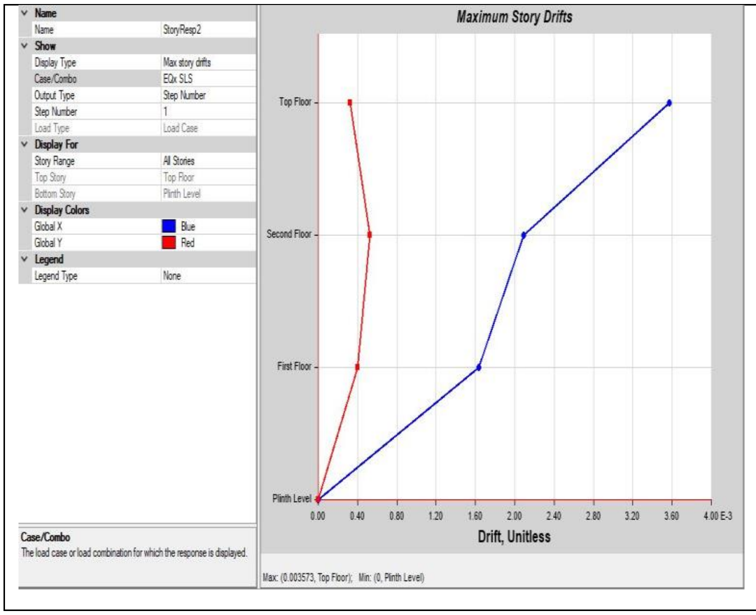
- 0.025 at ultimate limit state
- 0.006 at serviceability limit state

Story Drift along X-Direction and YDirection (EQ)x & (EQY): Serviceability limit state

Story	Output Case	Step Number	Direction	Drift	Remark
Top Floor	EQx SLS	1	X	0.003573	Safe in Drift
Top Floor	EQx SLS	1	Y	0.000326	Safe in Drift
Top Floor	EQx SLS	2	X	0.002985	Safe in Drift
Top Floor	EQx SLS	3	X	0.00416	Safe in Drift
Top Floor	EQx SLS	3	Y	0.00074	Safe in Drift
Top Floor	EQy SLS	1	X	0.001164	Safe in Drift
Top Floor	EQy SLS	1	Y	0.002646	Safe in Drift
Top Floor	EQy SLS	2	X	0.001691	Safe in Drift
Top Floor	EQy SLS	2	Y	0.002275	Safe in Drift
Top Floor	EQy SLS	3	X	0.000638	Safe in Drift
Top Floor	EQy SLS	3	Y	0.003017	Safe in Drift
Second Floor	EQx SLS	1	X	0.002092	Safe in Drift
Second Floor	EQx SLS	1	Y	0.000525	Safe in Drift
Second Floor	EQx SLS	2	X	0.001688	Safe in Drift
Second Floor	EQx SLS	3	X	0.002495	Safe in Drift
Second Floor	EQx SLS	3	Y	0.000853	Safe in Drift
Second Floor	EQy SLS	1	X	0.00082	Safe in Drift
Second Floor	EQy SLS	1	Y	0.002397	Safe in Drift
Second Floor	EQy SLS	2	X	0.001182	Safe in Drift
Second Floor	EQy SLS	2	Y	0.002691	Safe in Drift
Second Floor	EQy SLS	3	X	0.000459	Safe in Drift
Second Floor	EQy SLS	3	Y	0.002102	Safe in Drift
First Floor	EQx SLS	1	X	0.001635	Safe in Drift
First Floor	EQx SLS	1	Y	0.000398	Safe in Drift
First Floor	EQx SLS	2	X	0.00133	Safe in Drift
First Floor	EQx SLS	3	X	0.001941	Safe in Drift
First Floor	EQx SLS	3	Y	0.000627	Safe in Drift
First Floor	EQy SLS	1	X	0.000545	Safe in Drift
First Floor	EQy SLS	1	Y	0.001836	Safe in Drift
First Floor	EQy SLS	2	X	0.000819	Safe in Drift
First Floor	EQy SLS	2	Y	0.002041	Safe in Drift
First Floor	EQy SLS	3	Y	0.001631	Safe in Drift

Story Drift along X-Direction and YDirection (EQ)x & (EQY): Ultimate limit state

Story	Output Case	Step Number	Direction	Drift	Remark
Top Floor	EQx ULS	1	X	0.003723	Safe in Drift
Top Floor	EQx ULS	1	Y	0.00034	Safe in Drift
Top Floor	EQx ULS	2	X	0.003111	Safe in Drift
Top Floor	EQx ULS	3	X	0.004335	Safe in Drift
Top Floor	EQx ULS	3	Y	0.000771	Safe in Drift
Top Floor	EQy ULS	1	X	0.001213	Safe in Drift
Top Floor	EQy ULS	1	Y	0.002758	Safe in Drift
Top Floor	EQy ULS	2	X	0.001762	Safe in Drift
Top Floor	EQy ULS	2	Y	0.002371	Safe in Drift
Top Floor	EQy ULS	3	X	0.000665	Safe in Drift
Top Floor	EQy ULS	3	Y	0.003144	Safe in Drift
Second Floor	EQx ULS	1	X	0.00218	Safe in Drift
Second Floor	EQx ULS	1	Y	0.000547	Safe in Drift
Second Floor	EQx ULS	2	X	0.001759	Safe in Drift
Second Floor	EQx ULS	3	X	0.0026	Safe in Drift
Second Floor	EQx ULS	3	Y	0.000889	Safe in Drift
Second Floor	EQy ULS	1	X	0.000855	Safe in Drift
Second Floor	EQy ULS	1	Y	0.002497	Safe in Drift
Second Floor	EQy ULS	2	X	0.001232	Safe in Drift
Second Floor	EQy ULS	2	Y	0.002804	Safe in Drift
Second Floor	EQy ULS	3	X	0.000478	Safe in Drift
Second Floor	EQy ULS	3	Y	0.002191	Safe in Drift
First Floor	EQx ULS	1	X	0.001704	Safe in Drift
First Floor	EQx ULS	1	Y	0.000415	Safe in Drift
First Floor	EQx ULS	2	X	0.001386	Safe in Drift
First Floor	EQx ULS	3	X	0.002023	Safe in Drift
First Floor	EQx ULS	3	Y	0.000653	Safe in Drift
First Floor	EQy ULS	1	X	0.000568	Safe in Drift
First Floor	EQy ULS	1	Y	0.001913	Safe in Drift
First Floor	EQy ULS	2	X	0.000854	Safe in Drift
First Floor	EQy ULS	2	Y	0.002127	Safe in Drift
First Floor	EQy ULS	3	Y	0.001699	Safe in Drift



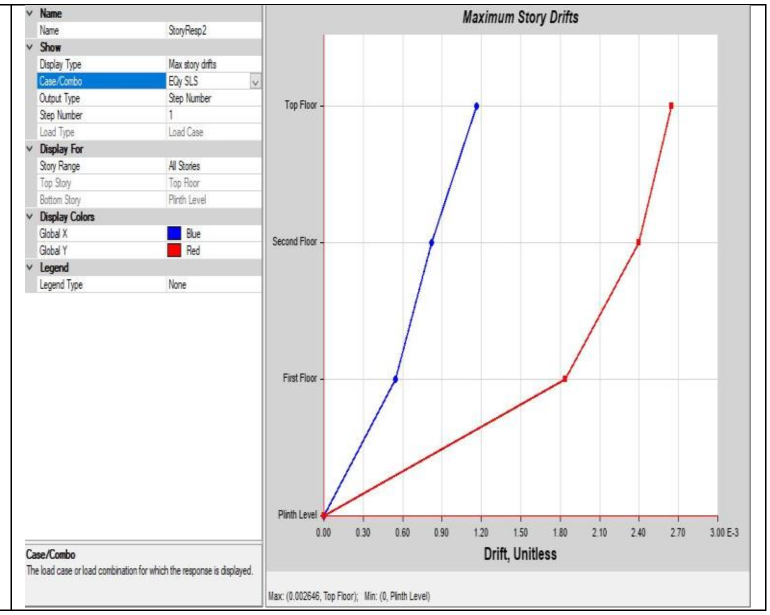


Fig: Maximum Story Drift Along (EQx)service

Fig: Maximum Story Drift Along (EQy)service

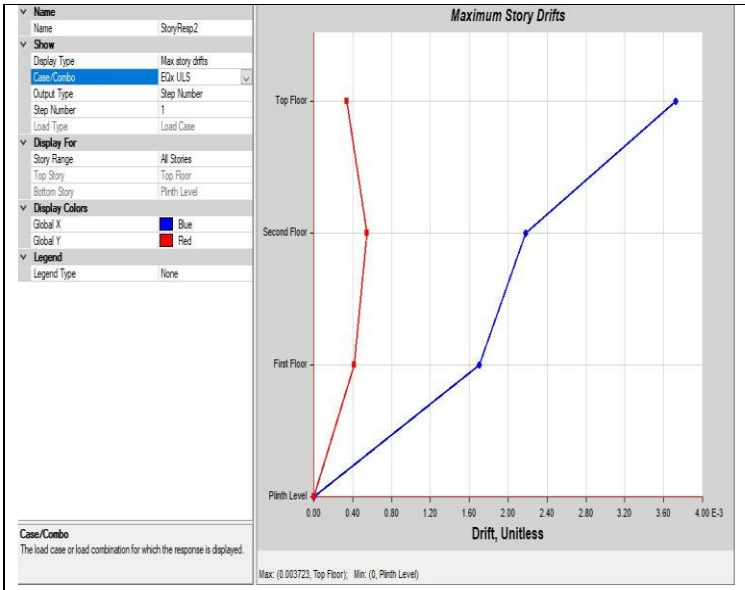


Fig: Maximum Story Drift Along (EQx)ultimate

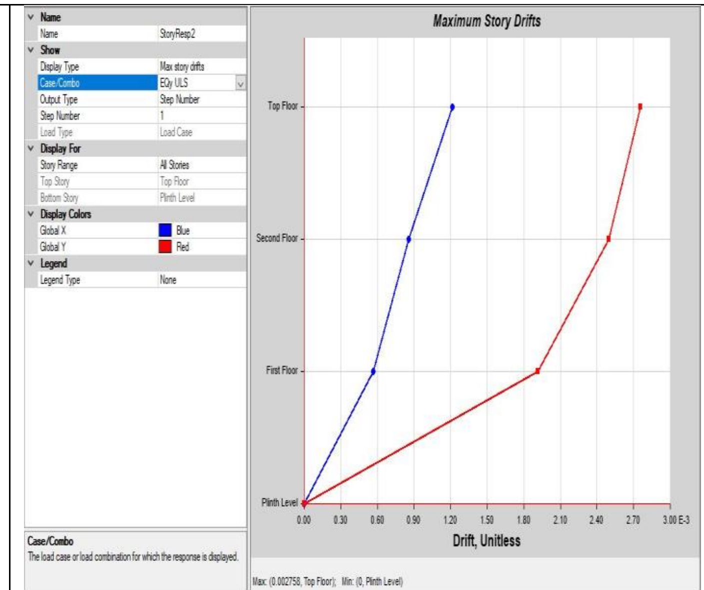


Fig: Maximum Story Drift Along (EQy)ultimate

It is found that story drift ratio for all stories are within permissible limit 0.00625 for ULS & 0.006 for SLS. (OK)

2.2.3.2. MAXIMUM PERMISSIBLE STOREY DISPLACEMENT IN BOTH PRINCIPAL DIRECTIONS

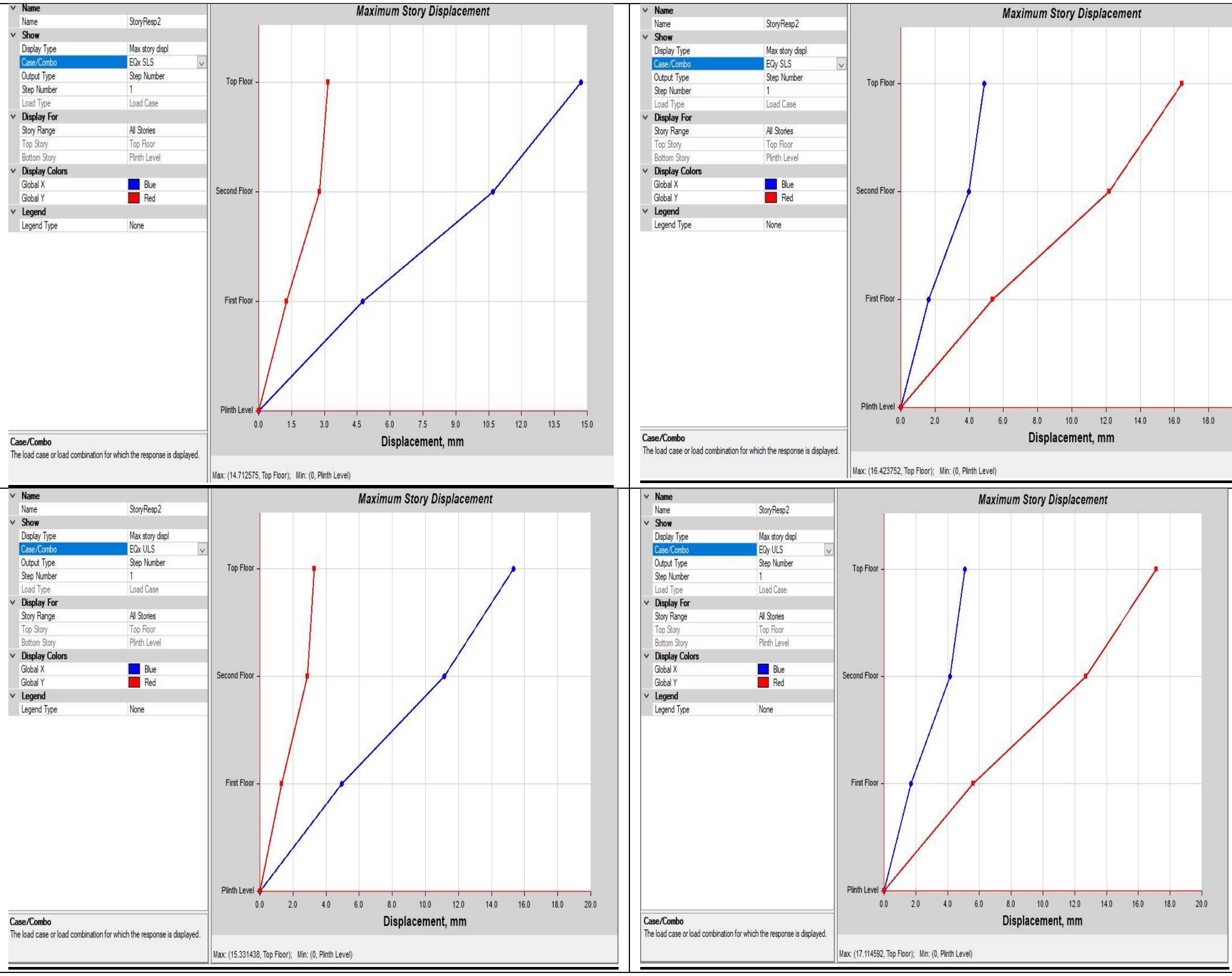


Fig-Maximum Storey Displacement in Eqx and Eqy in Service and Eqx and Eqy in Ultimate

Calculation of Maximum Permissible Displacement

Calculation of Maximum Permissible Displacement

Height of Building	Maximum Permissible Displacement	**Obtained Result for Eqx**	**Obtained Result for Eqy**
8.534 m	53.3400 mm (As per NBC 205:2020) **ULS**	15.33 mm	17.11 mm
8.534 m	51.2064 mm (As per NBC 205:2020) SLS	14.71 mm	16.42 mm

Calculation of Maximum Permissible Displacement as per IS Code and NBC Code

1. Height of Building (H) 8.534 m

2. Maximum Permissible Displacement (ULS)

(As Per NBC 205:2020) $= (0.025*H)/R_u$

Ru= 4

Maximum Permissible Displacement = 53.3400 mm in both

3. Maximum Permissible Displacement (SLS)

(As Per NBC 205:2020) $= (0.006*H)/R_s$

Rs= 1

Maximum Permissible Displacement = 51.2064 mm in both

Hence, Analysis is Okay

2.2.3.3. Model Participation Factor

As per Cl. 7.3, NBC 105:2020,

- A sufficient number of modes shall be included in the analysis to include at least 90% of the total seismic mass in the direction under consideration.
- All modes that are not part of the horizontal load resisting systems shall be ignored in modal combination.
- The modal combination shall be carried out only for modes with natural frequency less than 33 Hz; the effect of modes with natural frequencies more than 33 Hz shall be included by the missing mass correction procedure following established principles of structural dynamics.

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	SumUX	SumUY	RZ	SumRZ
		sec						
Modal	1	0.573	0.1612	0.4296	0.1612	0.4296	0.2681	0.2681
Modal	2	0.472	0.4914	0.316	0.6526	0.7457	0.0264	0.2945
Modal	3	0.424	0.1696	0.1032	0.8222	0.8489	0.5472	0.8417
Modal	4	0.187	0.0485	0.0528	0.8707	0.9017	0.0167	0.8584
Modal	5	0.177	0.0732	0.049	0.944	0.9508	0.0009	0.8594
Modal	6	0.164	0.0082	0.0147	0.9522	0.9654	0.1036	0.963
Modal	7	0.113	0.0137	0.0135	0.9659	0.979	0.0082	0.9712
Modal	8	0.105	0.0236	0.0191	0.9894	0.9981	0.0006	0.9719
Modal	9	0.097	0.0106	0.0019	1	1	0.0281	1
Modal	10	0.006	0	0	1	1	0	1
Modal	11	0.006	0	0	1	1	0	1
Modal	12	0.006	0	0	1	1	0	1

Result:

- **Almost 100 % in of mass has been participated in 12th mode In X and Y directions respectively. (Okay)**

TABLE: Modal Periods and Frequencies

TABLE: Modal Periods And Frequencies					
Case	**Mode**	**Period**	**Frequency**	**CircFreq**	**Eigenvalue**
		sec	cyc/sec	rad/sec	rad^2/sec^2
Modal	1	0.573	1.745	10.9629	120.1848
Modal	2	0.472	2.12	13.3174	177.352
Modal	3	0.424	2.359	14.8208	219.6556
Modal	4	0.187	5.334	33.5143	1123.21
Modal	5	0.177	5.637	35.4174	1254.3915
Modal	6	0.164	6.102	38.3424	1470.1363
Modal	7	0.113	8.813	55.3764	3066.5472
Modal	8	0.105	9.509	59.7498	3570.0356
Modal	9	0.097	10.26	64.4635	4155.5435
Modal	10	0.006	155.299	975.7693	952125.7578
Modal	11	0.006	177.811	1117.2189	1248178.003
Modal	12	0.006	178.379	1120.7862	1256161.686

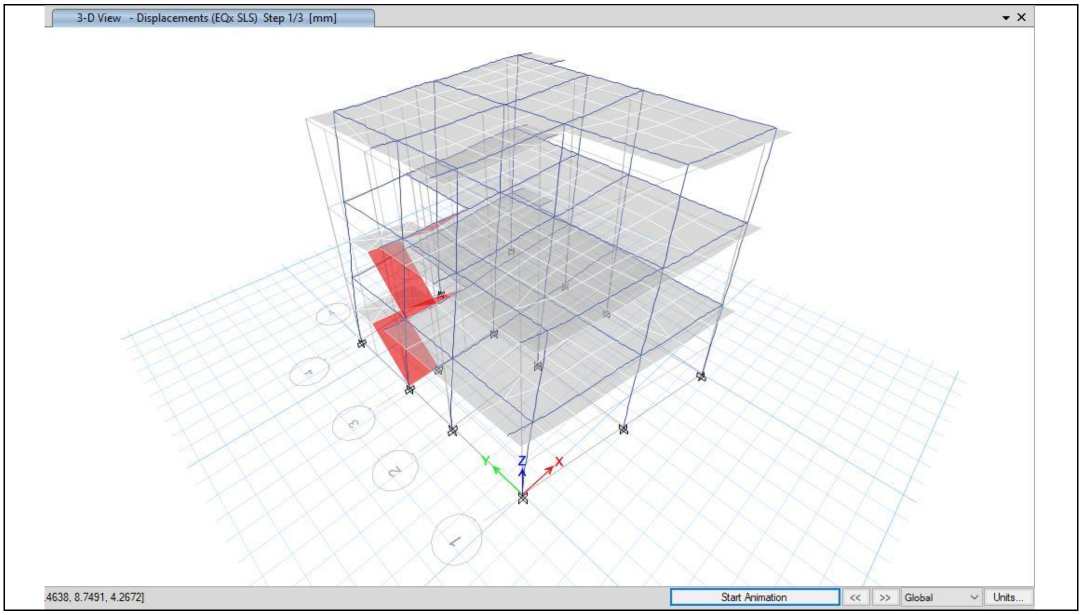
2.2.3.4. Center of Mass and Center of Rigidity

TABLE: Centers Of Mass And Rigidity									
Story	**Diaphragm**	**Mass X**	**Mass Y**	**XCM**	**YCM**	**Cum Mass X**	**Cum Mass Y**	**XCCM**	**YCCM**
		kg	kg	m	m	kg	kg	m	m
First Floor	D2	82986.0	82986.0	4.0	4.4	82986.0	82986.0	4.0	4.4
Second Floor	D3	79664.7	79664.7	4.3	4.5	79664.7	79664.7	4.3	4.5
Top Floor	D4	29222.7	29222.7	4.4	4.7	29222.7	29222.7	4.4	4.7

Criteria : Difference between CCM and CR should not exceed 10% of building width. (NBC 105 : 2020 CL.5.2)

Eccentricity of Building Lies in the Permissible Limit of 10 %. Hence oK

2.2.3.5. DEFORMED SHAPE OF BUILDING



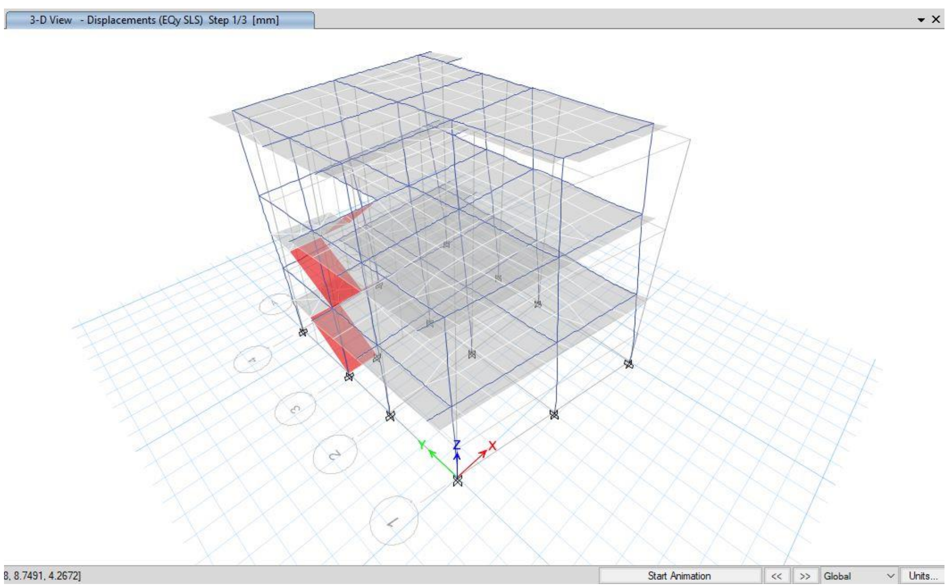
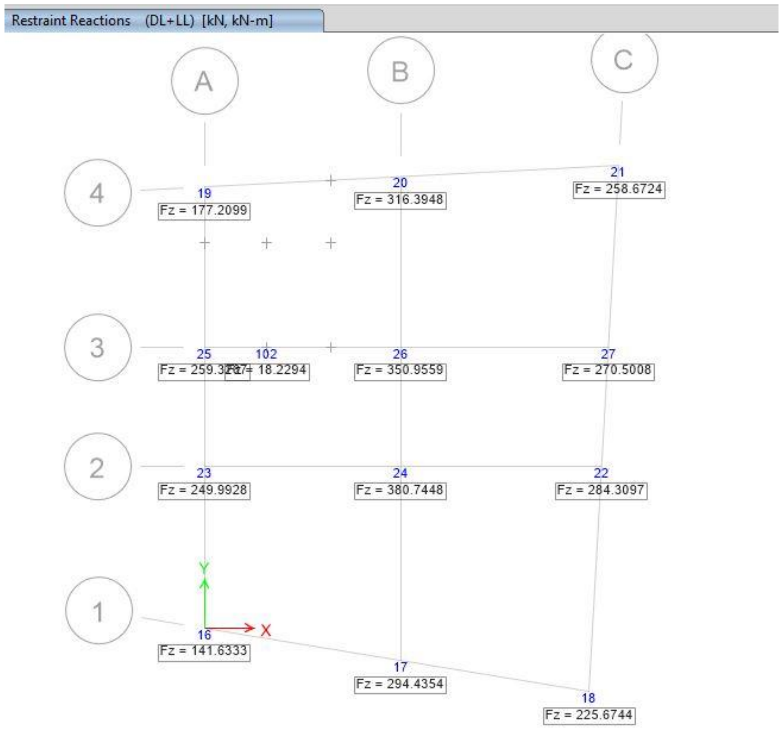


Fig.- Plan View of deformed shaped of building in EQx and EQy direction in Service State.

2.2.3.6. SUPPORT REACTION



The reactions at the support of column for load combination of (DL+LL) are as follows:

We find the area of footing using formula,

Area of footing = $\frac{1.1P}{SBC}$

Where, P = Unfactored load, SBC=Soil bearing capacity

Note: Depth of the footing should be calculated depending upon the size of footing. It should be carried out in fact manually or by Rankine's formula, i.e.,

Minimum depth of foundation formula = $\frac{Qo}{w}\left(\frac{1\text{-}\sin\varphi}{1+\sin\varphi}\right)^2$

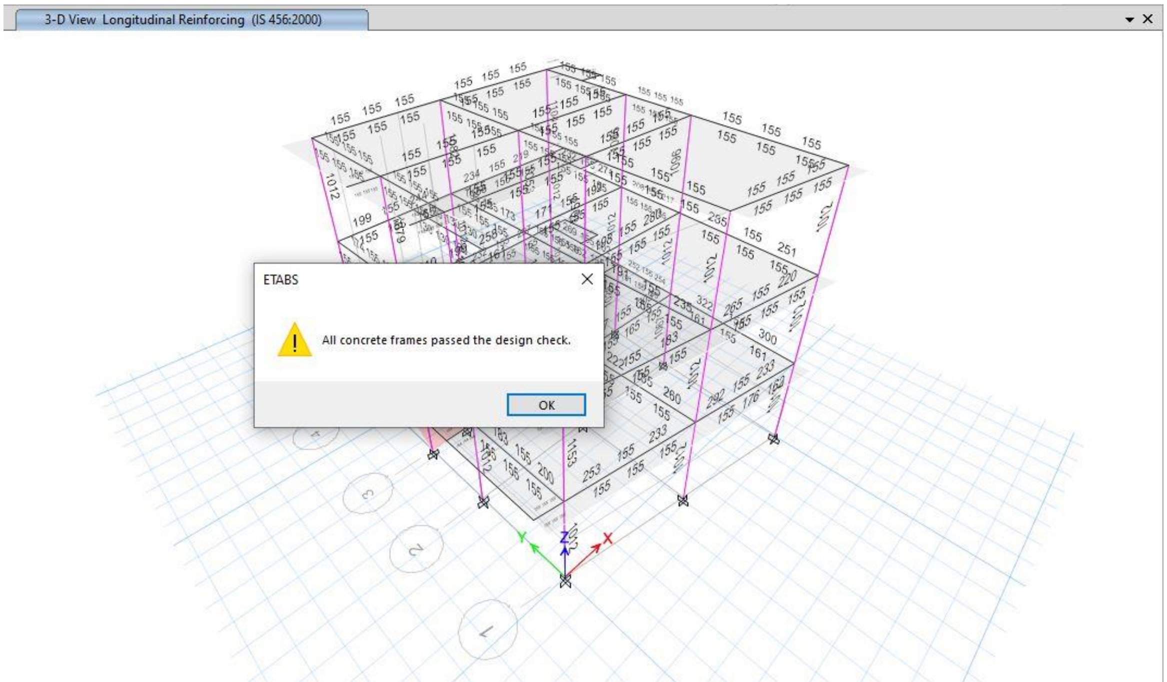
φ =Angle of repose of soil = 30 degree

Qo = Gross bearing capacity of soil = 150 KN/m2

w = Density of soil = 20 KN/m2

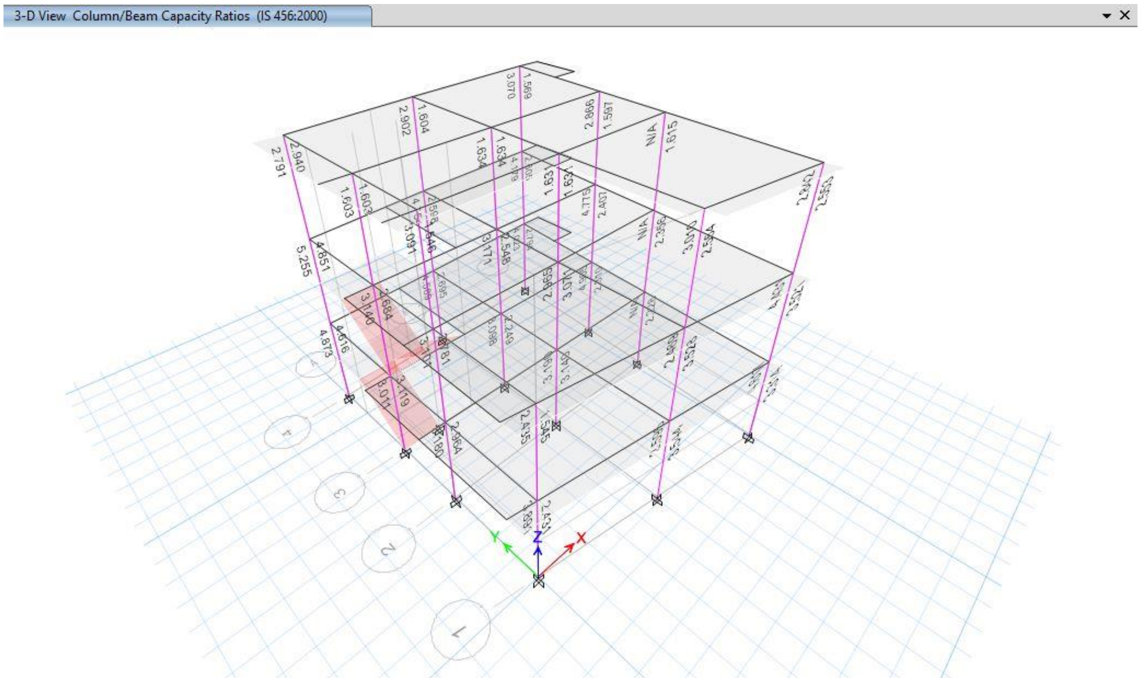
Note: We can neglect Earthquake load for design of footing if base shear coefficient is below 25% (i.e. total value of base shear is less than 25% of that of seismic wt. of the building)

2.2.3.7. VERIFICATION OF ALL MEMBER PASS



All the Sectional Member is passed for the design

2.2.3.8. BEAM COLUMN CAPACITY CHECK



DESIGN PART

User Coefficient Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern EQx ULS 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

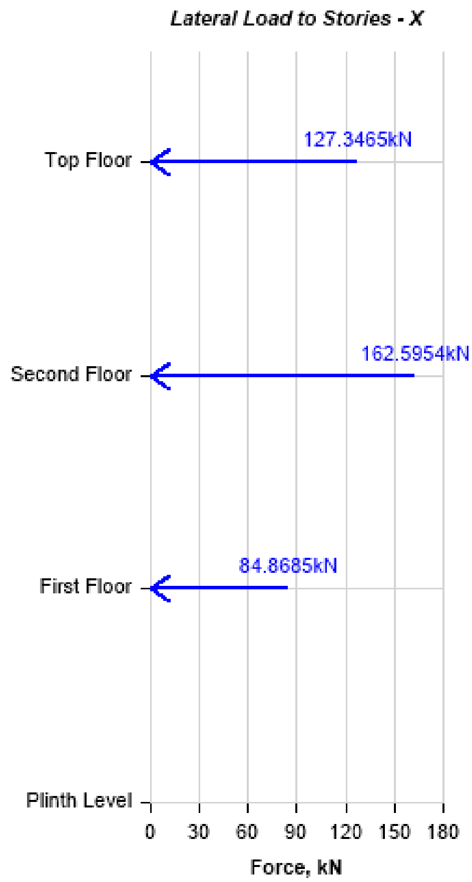
Base Shear Coefficient, C $\quad C = 0.1313$

Base Shear, V $\quad V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
X	0	0	2854.6116	374.8105
X + Ecc. Y	0	0	2854.6116	374.8105
X - Ecc. Y	0	0	2854.6116	374.8105

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Top Floor	8.5344	127.3465	0
Second Floor	5.6896	162.5954	0
First Floor	2.8448	84.8685	0
Plinth Level	0	0	0

User Coefficient Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern EQx SLS 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

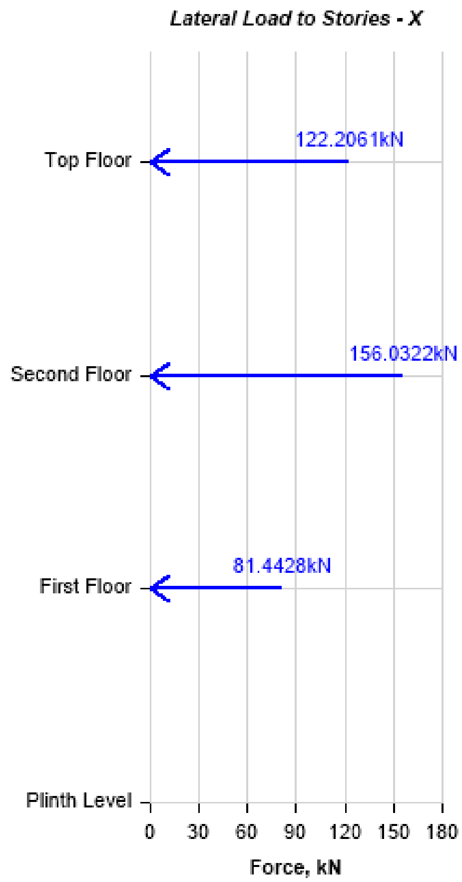
Base Shear Coefficient, C $\mathrm{C} = 0.126$

Base Shear, V $\mathrm{V} = \mathrm{CW}$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
X	0	0	2854.6116	359.6811
X + Ecc. Y	0	0	2854.6116	359.6811
X - Ecc. Y	0	0	2854.6116	359.6811

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Top Floor	8.5344	122.2061	0
Second Floor	5.6896	156.0322	0
First Floor	2.8448	81.4428	0
Plinth Level	0	0	0

User Coefficient Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern EQy ULS 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

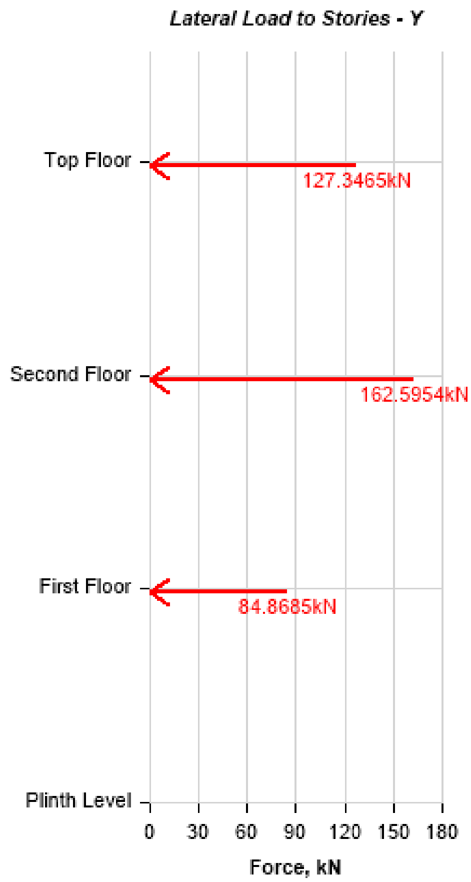
Base Shear Coefficient, C $\mathrm{C} = 0.1313$

Base Shear, V $\mathrm{V} = \mathrm{CW}$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
Y	0	0	2854.6116	374.8105
Y + Ecc. X	0	0	2854.6116	374.8105
Y - Ecc. X	0	0	2854.6116	374.8105

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Top Floor	8.5344	0	127.3465
Second Floor	5.6896	0	162.5954
First Floor	2.8448	0	84.8685
Plinth Level	0	0	0

User Coefficient Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern EQy SLS 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

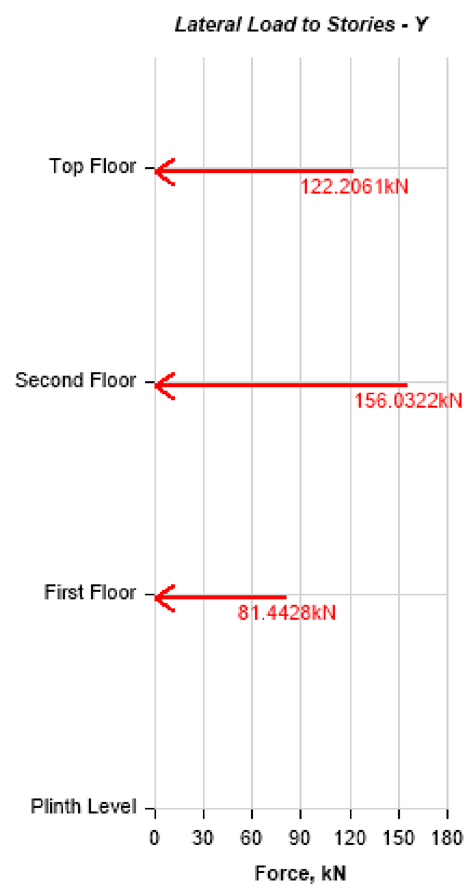
Base Shear Coefficient, C $\quad C = 0.126$

Base Shear, V $\quad V = CW$

Calculated Base Shear

Direction	Period Used (sec)	C	W (kN)	V (kN)
Y	0	0	2854.6116	359.6811
Y + Ecc. X	0	0	2854.6116	359.6811
Y - Ecc. X	0	0	2854.6116	359.6811

Applied Story Forces



Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Top Floor	8.5344	0	122.2061
Second Floor	5.6896	0	156.0322
First Floor	2.8448	0	81.4428
Plinth Level	0	0	0

DESIGN OF COLUMN

ETABS Concrete Frame Design

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

Column Element Details (Envelope)

Level	Element	Unique Name	Section ID	Length (mm)	LLRF	Type
First Floor	C7	25	Column 14"*14"	2844.8	0.772	Ductile Frame

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
355.6	355.6	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

Longitudinal Reinforcement Design for P_u - M_{u2} - M_{u3} Interaction

Column End	Rebar Area mm²	Rebar %
Top	1012	0.8
Bottom	1067	0.84

Design Axial Force & Biaxial Moment for P_u - M_{u2} - M_{u3} Interaction

Column End	Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Station Loc mm	Controlling Combo
Top	279.7274	-46.4674	-17.8792	2490.3	DL+yLL+EQx
Bottom	221.9078	67.5882	15.1424	0	DL+yLL+EQy

Shear Reinforcement for Major Shear, V_{u2}

Column End	Rebar A_{sv} /s mm²/m	Design V_{u2} kN	Station Loc mm	Controlling Combo
Top	394.16	6.1531	2490.3	DL+LL
Bottom	394.16	6.1531	0	DL+LL

Shear Reinforcement for Minor Shear, V_{u3}

Column End	Rebar A_{sv} /s mm²/m	Design V_{u3} kN	Station Loc mm	Controlling Combo
Top	394.16	4.8293	2490.3	DL+LL
Bottom	394.16	4.8293	0	DL+LL

Joint Shear Check/Design

	Joint Shear Ratio	Shear $V_{u,Tot}$ kN	Shear V_c kN	Joint Area mm^2	Controlling Combo
Minor(V_{u3})	0.356	201.4609	565.5077	126451	DL+yLL+EQx

Beam/Column Capacity Ratios

	1.4(B/C) Ratio	Column/Beam Ratio	SumBeam Cap Moments kN-m	SumColCap Moments kN-m	Controlling Combo
$Minor_{22}$	0.628	2.228	53.9994	147.903	DL+yLL+EQy

DESIGN OF BEAM

ETABS Concrete Frame Design

IS 456:2000 Beam Section Design (Envelope)

Beam Element Details

Level	Element	Unique Name	Section ID	Length (mm)	LLRF
First Floor	B14	14	Main Beam 9"*14"	3835.4	1

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	40	40

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

Flexural Reinforcement for Major Axis Moment, M_{u3}

	End-I Rebar Area mm²	End-I Rebar %	Middle Rebar Area mm²	Middle Rebar %	End-J Rebar Area mm²	End-J Rebar %
Top (+2 Axis)	209	0.26	155	0.19	216	0.27
Bot (-2 Axis)	155	0.19	155	0.19	155	0.19

Flexural Design Moment, M_{u3} and Axial Force, P_u

	Station Loc mm	Design M_u kN-m	Design P_u kN	Combo Name
Top (+2 Axis) End-I	177.8	-26.595	0	DL+yLL-EQx
Top (+2 Axis) Middle	2397.1	0	0	DL+yLL-EQy
Top (+2 Axis) End-J	3657.6	-27.3428	0	DL+yLL+EQx
Bot (-2 Axis) End-I	958.9	6.5533	0	DL+LL
Bot (-2 Axis) Middle	2397.1	7.3179	0	DL+LL
Bot (-2 Axis) End-J	3657.6	0	0	DL+LL

Shear Reinforcement for Major Shear, V_{u2}

End-I Rebar A_{sv} /s mm²/m	Middle Rebar A_{sv} /s mm²/m	End-J Rebar A_{sv} /s mm²/m
894.17	347.35	941.08

Design Shear Force for Major Shear, V_{u2}

End-I Design V_u kN	End-I Station Loc mm	Middle Design V_u kN	Middle Station Loc mm	End-J Design V_u kN	End-J Station Loc mm
35.1304	177.8	0.0236	2397.1	36.0568	3657.6
DL+yLL+EQy		DL+yLL-EQy		DL+yLL+EQy	

Torsion Reinforcement
Shear Rebar A_{svt} /s mm^2/m
627.34

Design Torsion Force

Design T_u kN-m	Station Loc mm	Design T_u kN-m	Station Loc mm
10.1618	3657.6	10.1618	3657.6
DL+yLL+EQy		DL+yLL+EQy	

2.3.2. Percentage of steel in frames (Beam and Column)

Maximum percentage of reinforcement varies from member to member in RCC structure. In Indian practice i.e. (As per IS-456):

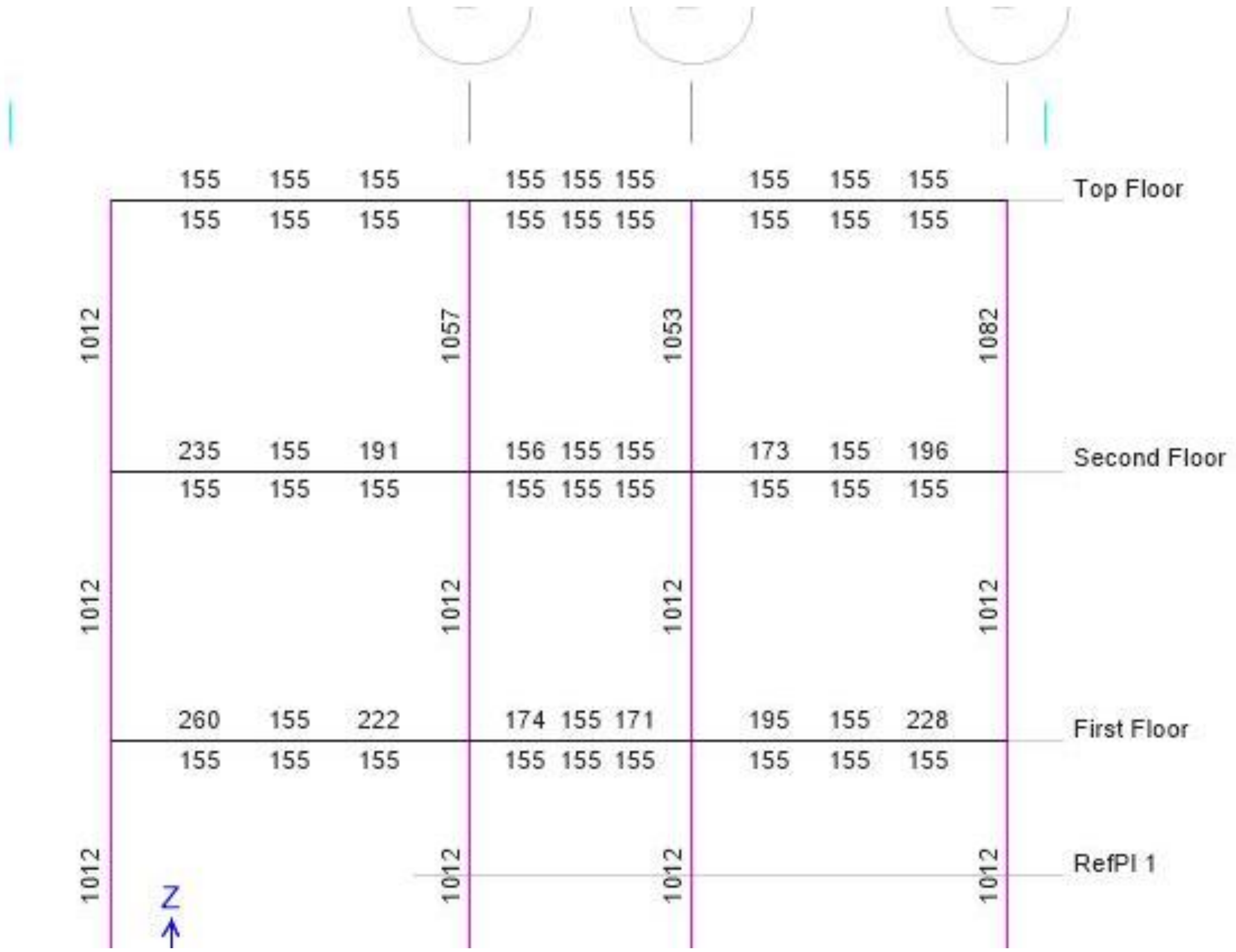
In beam:
1. Max. Area of tension reinforcement shall not exceed 0.04bd (Cl. 26.5.1.1)
2. Max. Area of compression enforcement shall not exceed 0.04bd (Cl. 26.5.1.2)

In column:
The CSA of longitudinal r/f shall not be less than 0.8% no more than 6% of gross cross sectional area of the column (Cl. 26.5.3

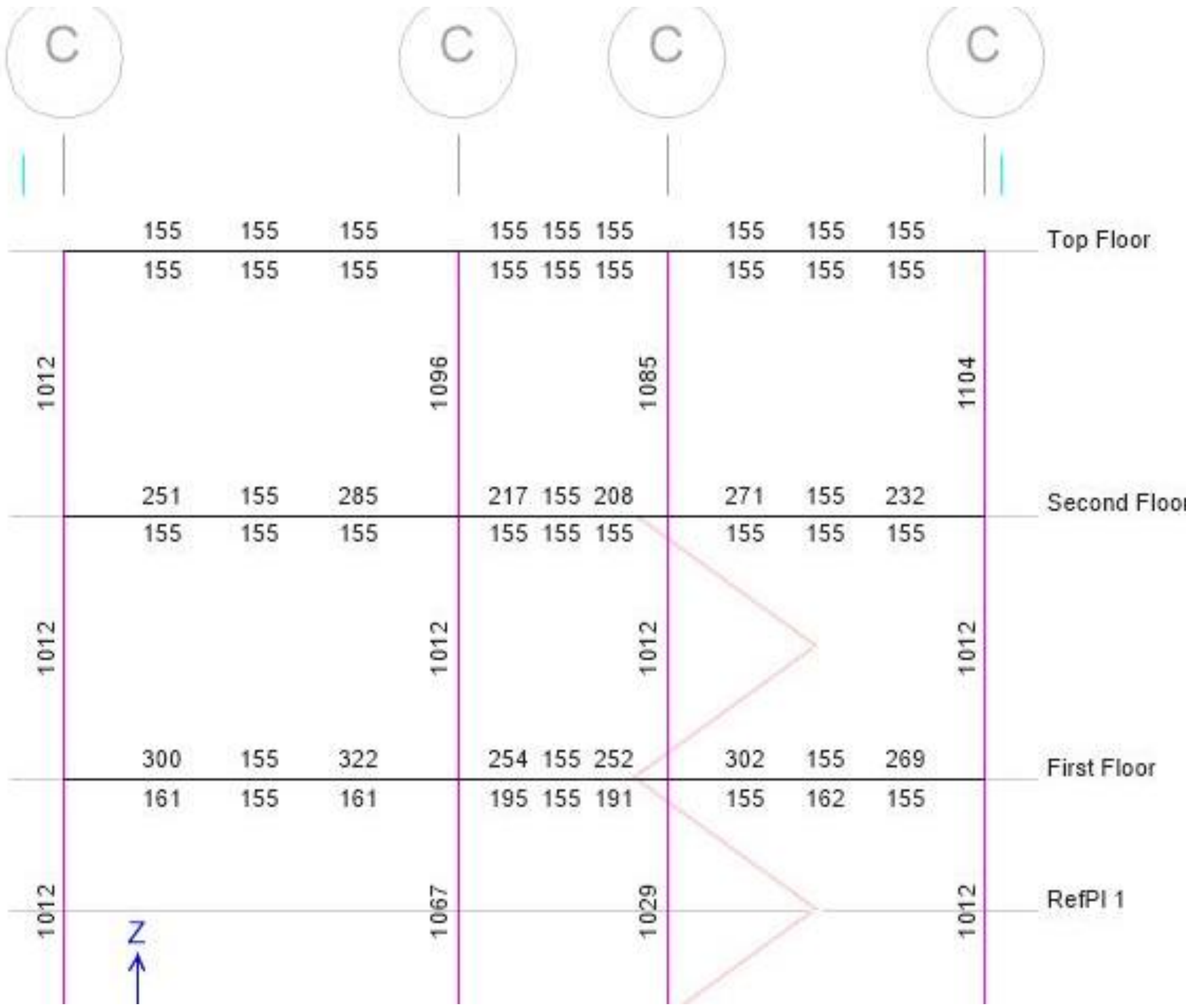
2.3. REINFORCEMENT DETAILS

2.3.1. Longitudinal Reinforcement Details (Area of steel in mm^2 for design of Column Rebar)

Reinforcement detail in Etabs in Grid A

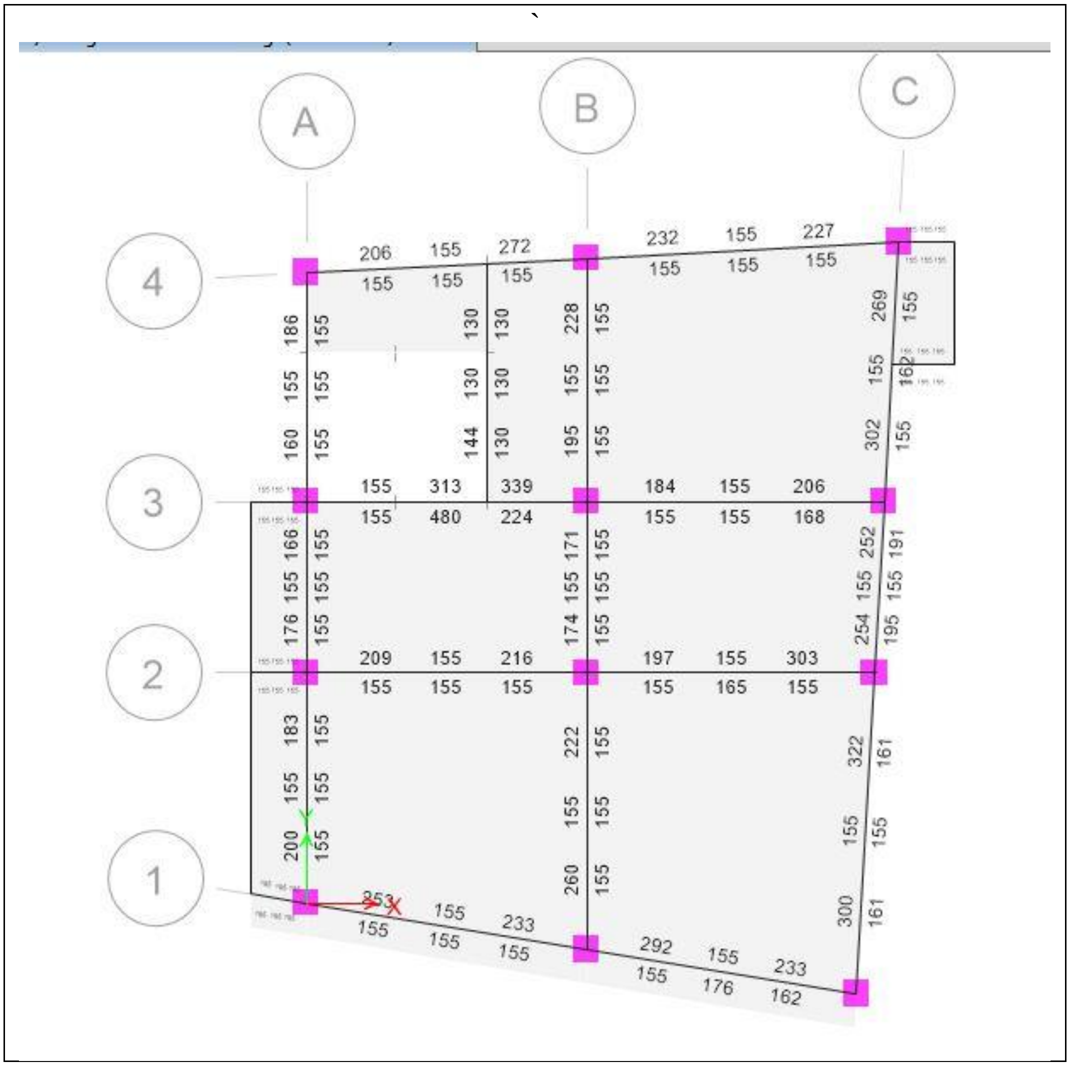


Reinforcement detail in Etabs in Grid B-B

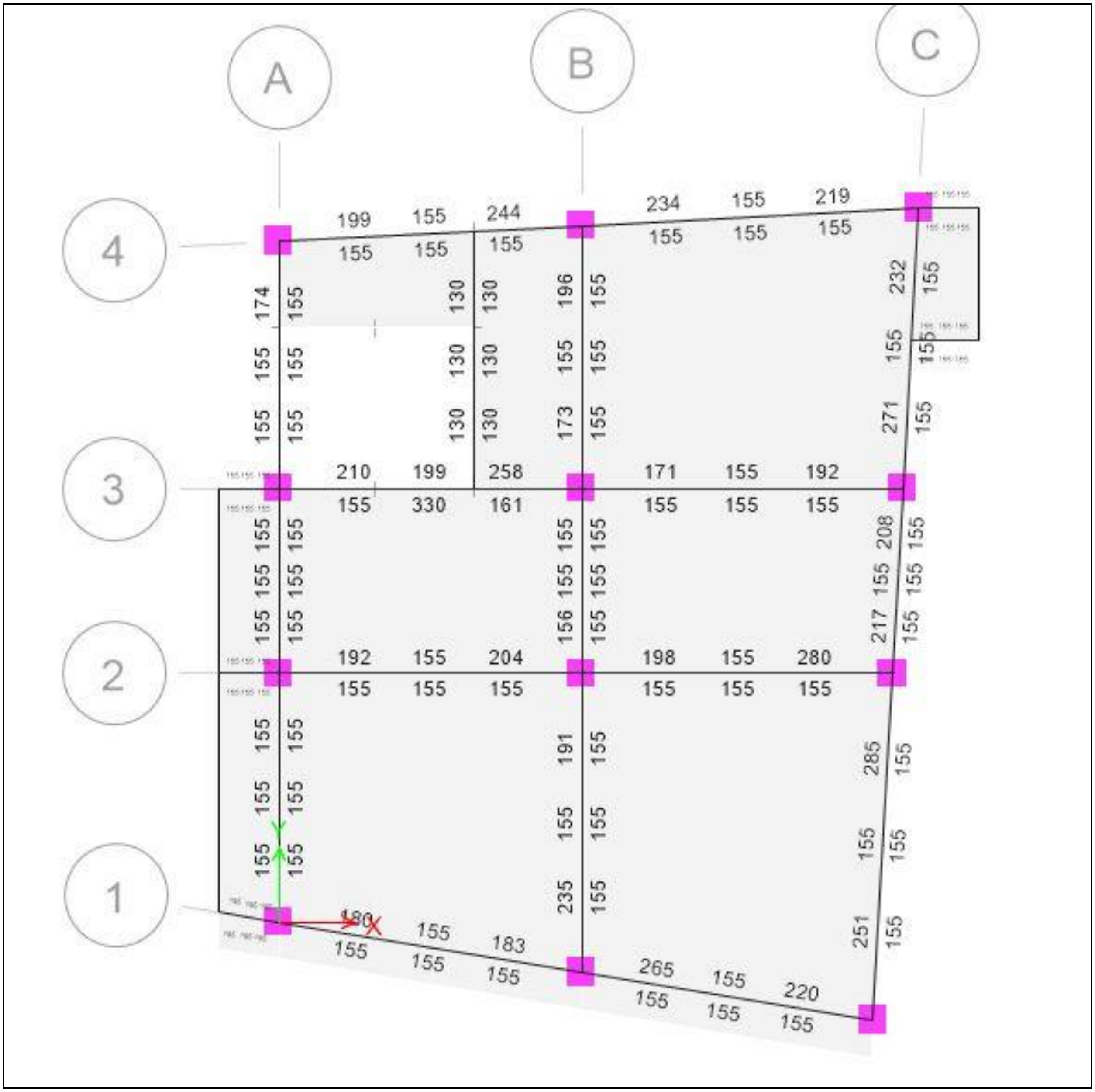


Reinforcement detail in Etabs in Grid C-C

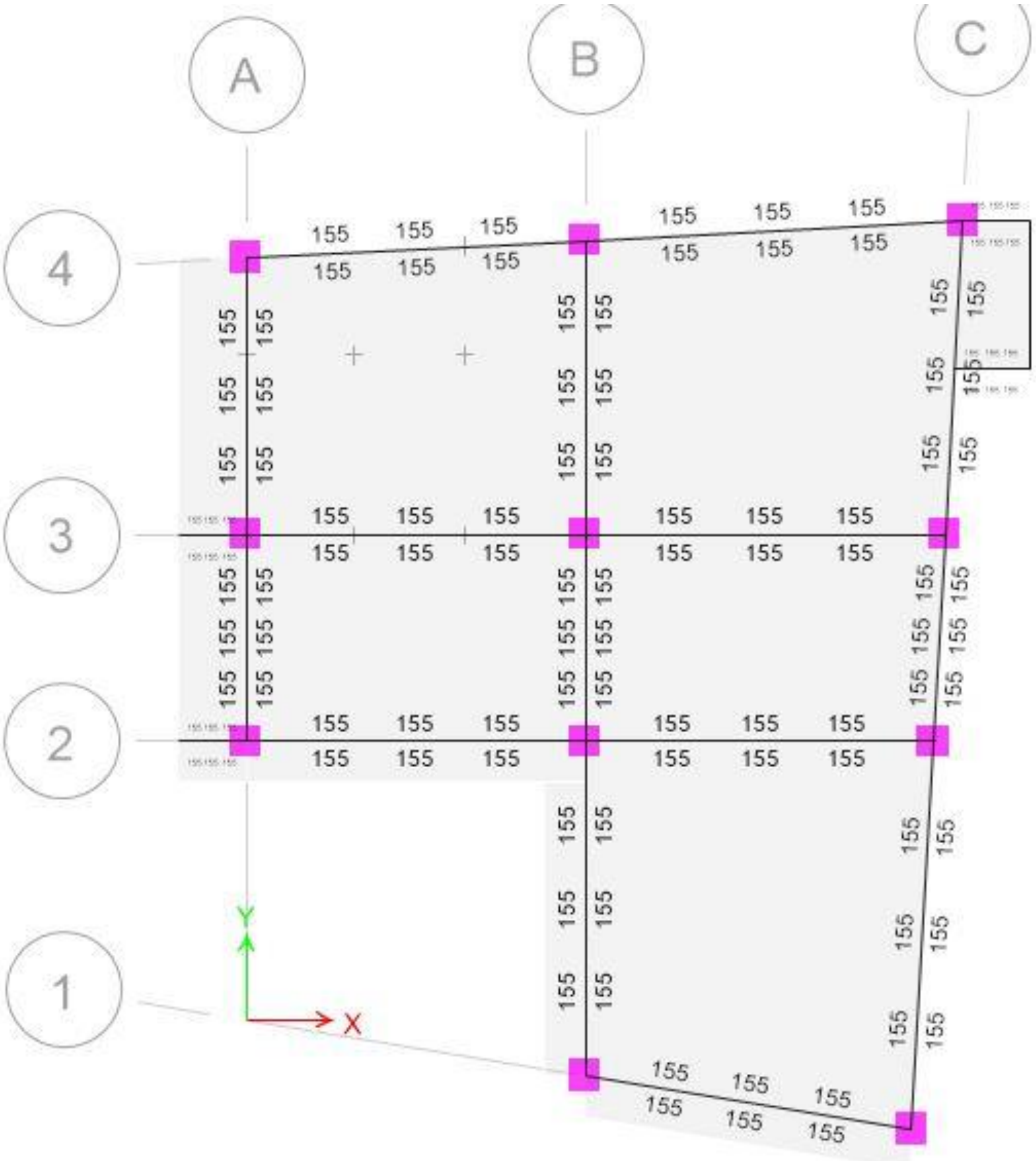
2.3.2. Longitudinal Reinforcement Details (Area of steel in mm^2 for design of Beam Rebar)



Reinforcement detail of First Floor



Reinforcement detail of Second floor



Reinforcement Detail of Top floor beam

ANEX

DESIGN PART

COLUMN REINFORCEMENT

S.N.	GRID	Column ID	SIZE		Reinforcement			Lateral ties
			b (inch)	D (inch)	For Ground Floor	For 1st Floor	For 2nd Floor	
1	A1	C1	14	14	8-Φ16	8-Φ16		8 mm Φ@ 4" c/c
2	A2	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
3	A3	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
4	A4	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
5	B1	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
6	B2	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
7	B3	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
8	B4	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
9	C1	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
10	C2	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
11	C3	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c
12	C4	C2	14	14	8-Φ16	8-Φ16	4-Φ12+4-Φ16	8 mm Φ@ 4" c/c

ANALYSIS & DESIGN OF FOUNDATION SYSTEM USING CSI SAFE

CSI SAFE BASIC PARAMETER (SUPPORT CONDITIONS):

Soil Subgrade Modulus= Soil Bearing Capacity x FOS x 1/Permissible Settlement
Permissible Settlement = 25 mm.
Soil Bearing Capacity = 120 KN/m^2 (Assumed)
Factor of Safety = 3
Soil Subgrade Modulus = 14,400 (compression only)

MAXIMUM SETTLEMENT OF FOUNDATION AS PER SOIL TYPE:

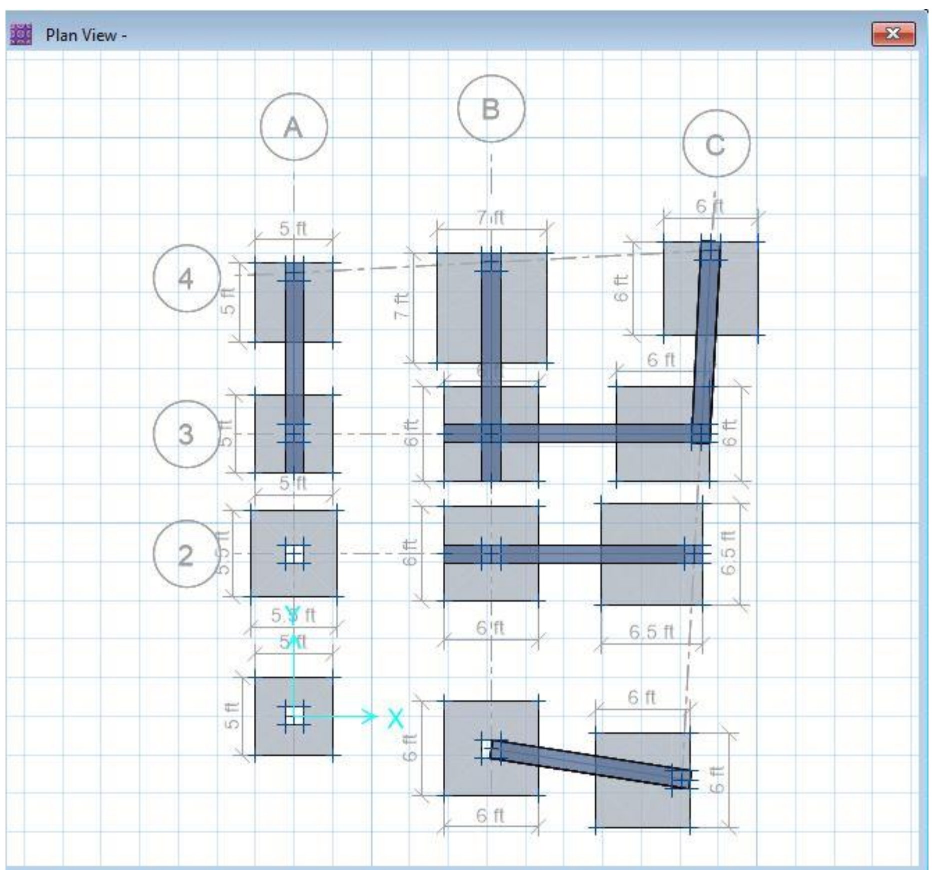
The maximum permissible settlement as per IS-1904 (1966) for isolated foundations is 40mm on sandy soil and 65mm in clayey soils.
The permissible settlement for the raft foundation on clay soil is 65-100 mm and for sandy soil, it is 65 mm.
Differential settlements:
Foundation on Clay soil = 40 mm.
Foundation on Sandy soil = 25 mm.

Dimension of Footing

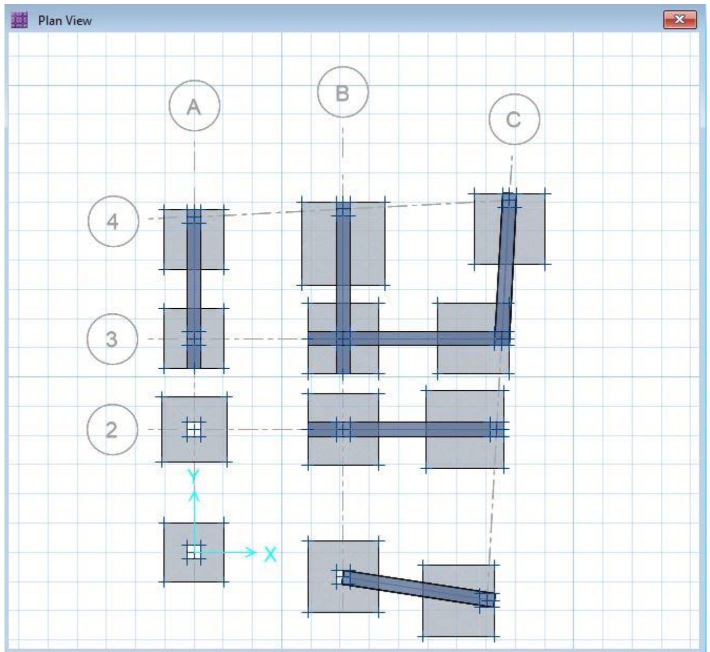
Length of Footing = As per plan

Width of Footing = As per Plan

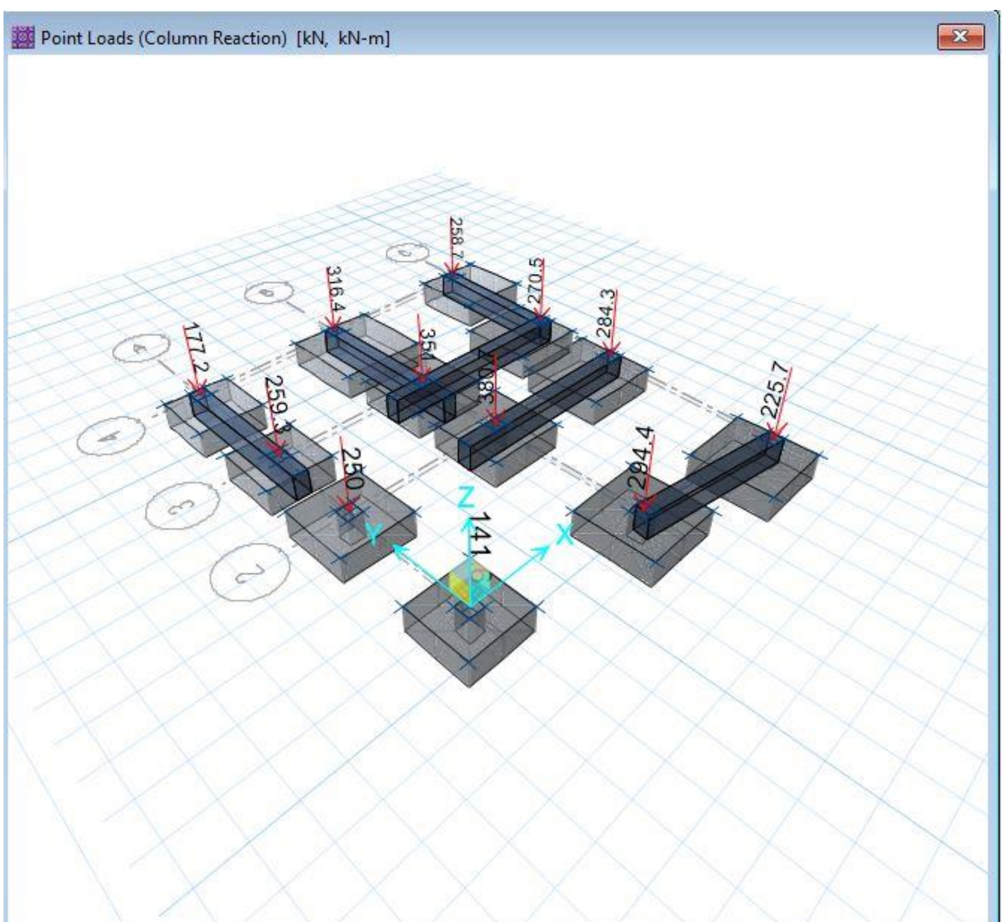
Depth of Footing = 600 mm (24")



Strap Beam Layout Detail

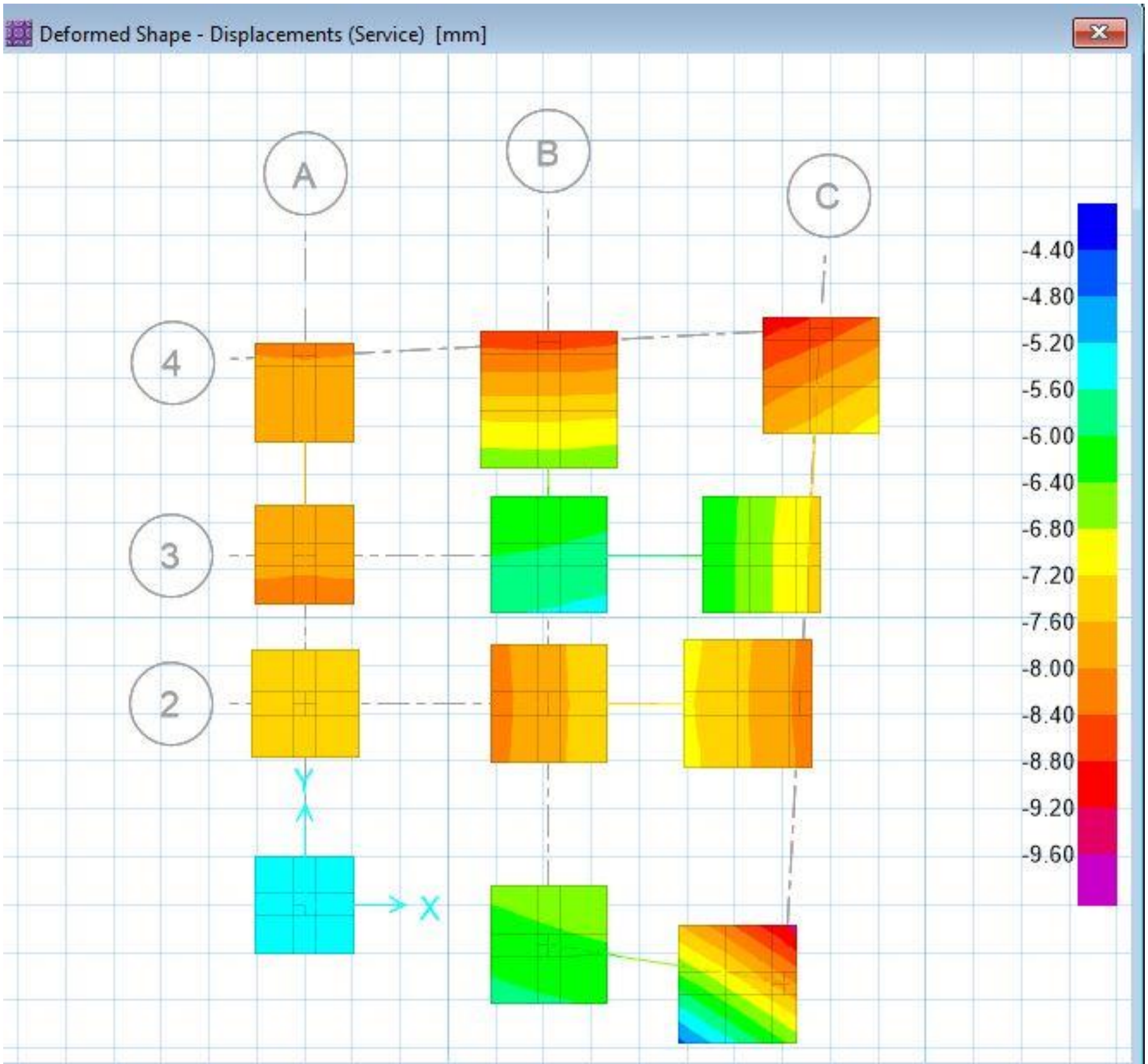


Loading Value in footing (Column Rxn)



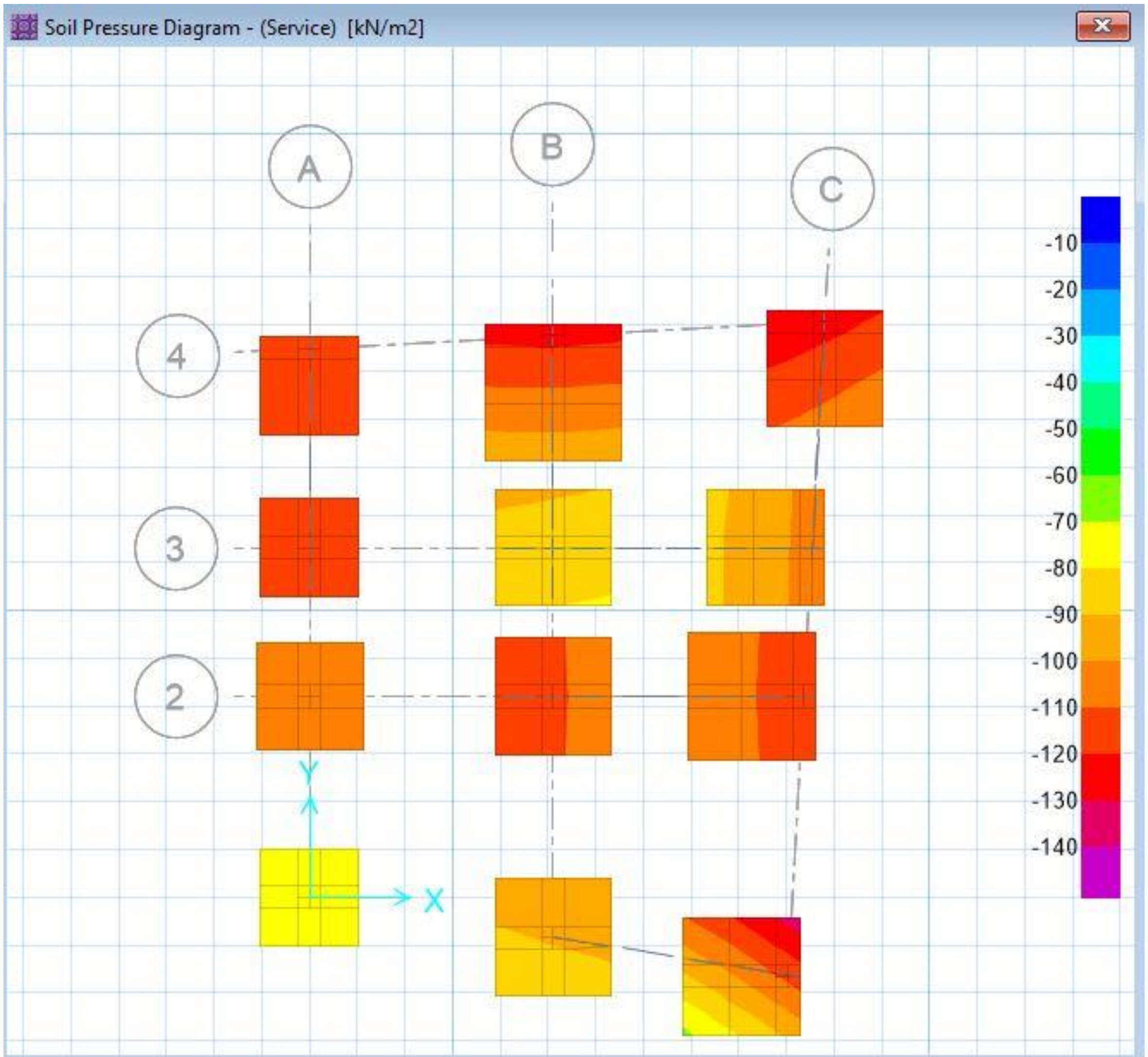
ANALYSIS RESULTS:

1. SETTLEMENT ANALYSIS



(Settlement Values as per CSI SAFE Analysis) Maximum Permissible Settlement =25 mm (OK Safe)

2. BEARING CAPACITY



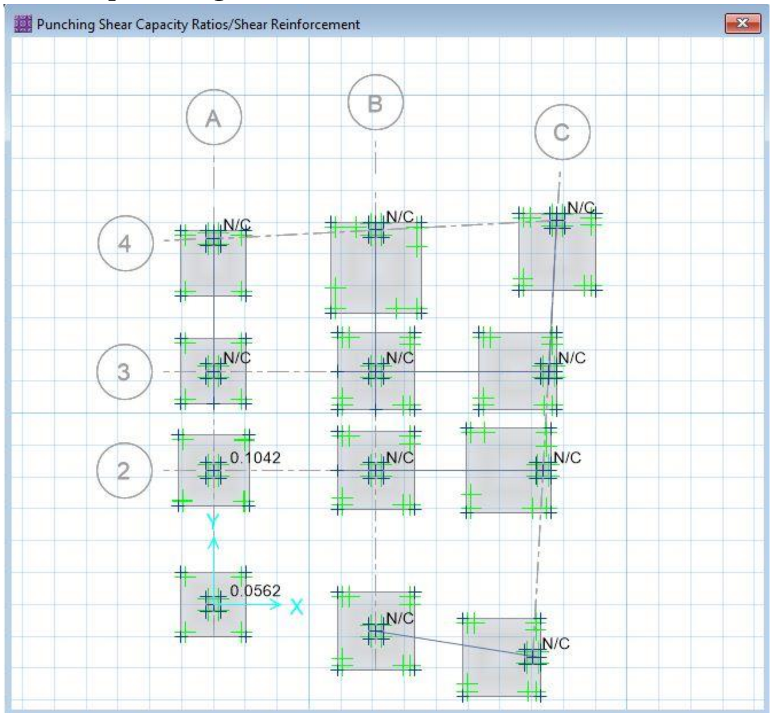
(S.B.C. Values as per SAFE Analysis)

Maximum Permissible S.B.C. = 120 kN/m^2 (OK Safe).

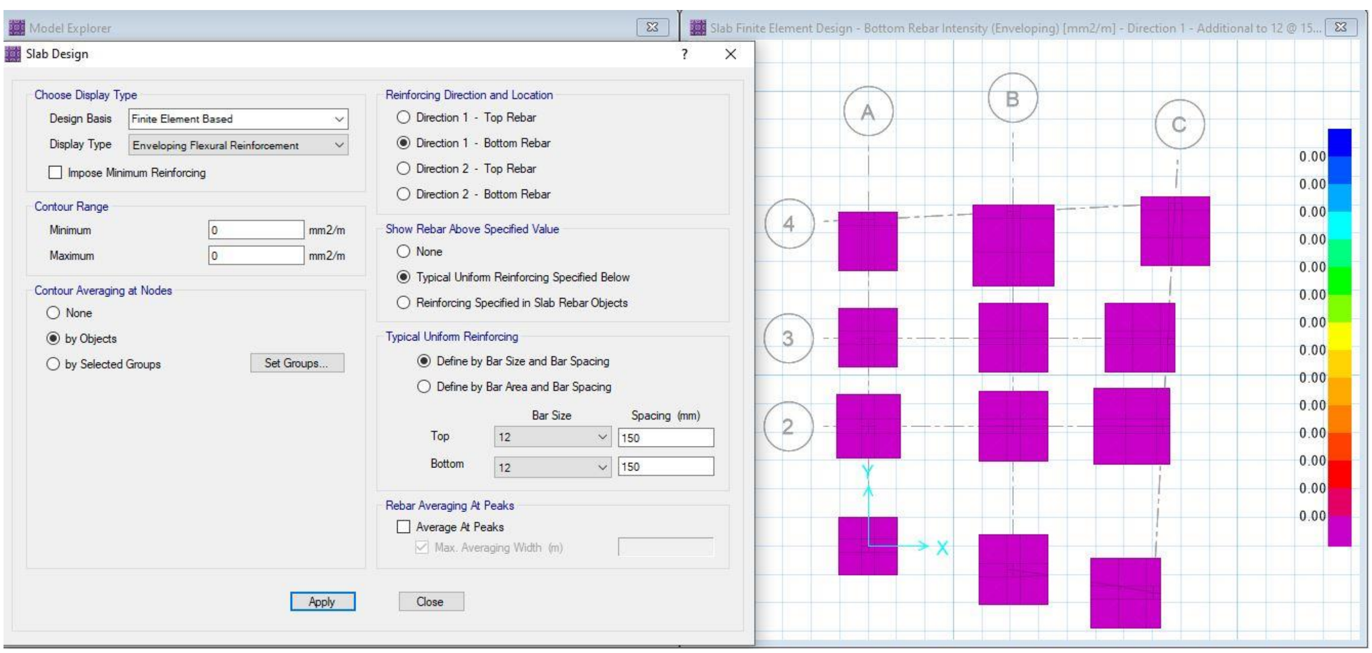
Check for Punching Shear

Punching shear value are less than 1 so safe in punching.

Hence Safe



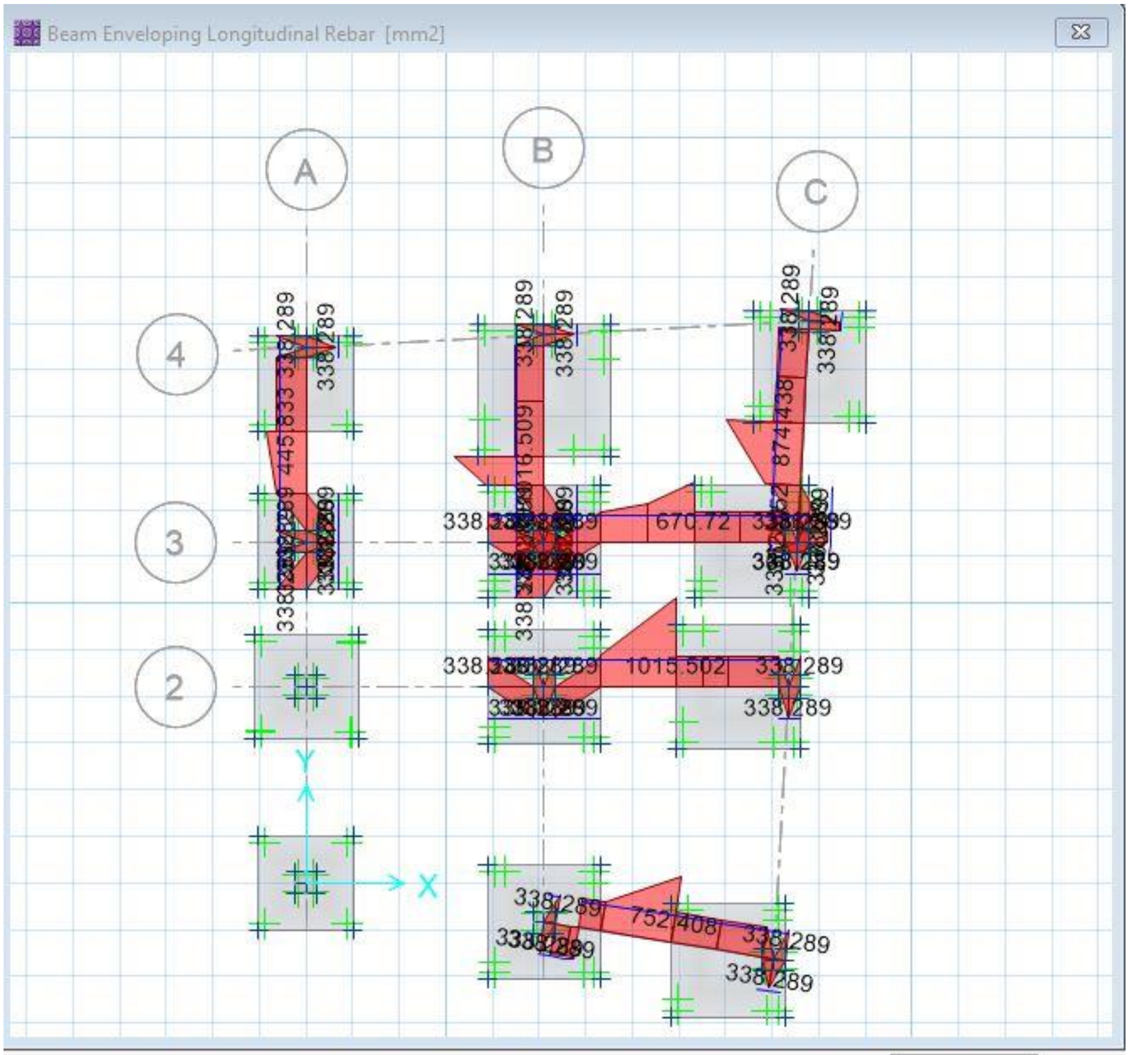
Footing Reinforcement Details



Reinforcement Provided according to Strip force in X and Y Direction

12mmΦ @ 150 mm c/c (Bottom Bar)

Strap Beam Reinforcement Details



FOUNDATION DETAIL									
Unique Name	Load Case	Service load	Size of footing		Area of Reinforcement	D(in)	Size of strap beam	Area of Reinforcement	Remark
		kN	(ft)	B1,B2,B3(ft)			in		
A1	DL+LL	141.6	5	5	12mmØ 6"c/c	24			Isolated footing
A2	DL+LL	250.0	5.5	5.5	12mmØ 6"c/c	24			Isolated footing
A3	DL+LL	259.3	5	5	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
A4	DL+LL	177.2	5	5	12mmØ 6"c/c	24			
B1	DL+LL	294.4	6	6	12mmØ 6"c/c	24			Isolated footing
B2	DL+LL	380.7	6	6	12mmØ 6"c/c	24			Isolated footing
B3	DL+LL	351.0	6	6	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
B4	DL+LL	316.4	7	7	12mmØ 6"c/c	24			
B1	DL+LL	294.4	6	6	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
C1	DL+LL	225.7	6	6	12mmØ 6"c/c	24			
B2	DL+LL	380.7	6	6	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
C2	DL+LL	284.3	6.5	6.5	12mmØ 6"c/c	24			
B3	DL+LL	351.0	6	6	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
C3	DL+LL	270.5	6	6	12mmØ 6"c/c	24			
C3	DL+LL	270.5	6	6	12mmØ 6"c/c	24	14X24	Top=5-16mmØ Bottom=3-16mmØ	Strap footing
C4	DL+LL	258.7	6	6	12mmØ 6"c/c	24			

Beam Design

BEAM REINFORCEMENT SCHEDULE

CONCRETE GRADE: M20

REBAR GRADE: Fe500

Floor	Size	Main Reinforcement		Stirrups	
	(B*D)	Top	Bottom	End	Middle
Plinth Level	9*12	3-12Φ	3-12Φ	8 Φ@4" c/c	8 Φ@6" c/c
First Floor Level	9*14	2-16Φ+1-12Φ	2-16Φ+1-12Φ	8 Φ@4" c/c	8 Φ@6" c/c
Second Floor Level	9*14	2-16Φ+1-12Φ	2-16Φ+1-12Φ	8 Φ@4" c/c	8 Φ@6" c/c
Top Floor level	9*14	3-12Φ	3-12Φ	8 Φ@4" c/c	8 Φ@6" c/c
Secondary Beam	9*12	3-12Φ	3-12Φ	8 Φ@4" c/c	8 Φ@6" c/c

Slab Design

Depth of Slab=125mm: 5"

Slab	Top Bar	Bottom Bar	Distribution Bar
First Floor	8 mm Φ 6" c/c	8 mm Φ 6" c/c	8 mm Φ 6" c/c
Second Floor	8 mm Φ 6" c/c	8 mm Φ 6" c/c	8 mm Φ 6" c/c
Top Floor	8 mm Φ 6" c/c	8 mm Φ 6" c/c	8 mm Φ 6" c/c

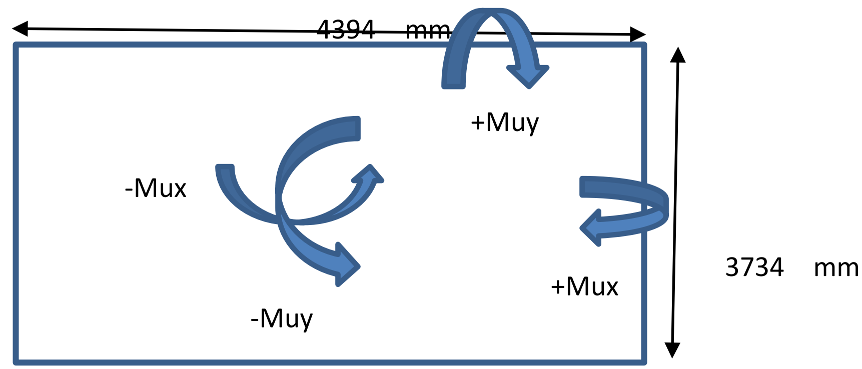
Staircase Reinforcement

Depth of Staircase = 125mm : 5" Depth

Staircase	Main Bar	Distribution Bar
First Floor	12 mm Φ 5" c/c	8 mm Φ 6" c/c
Second Floor	12 mm Φ 5" c/c	8 mm Φ 6" c/c
Top Floor	12 mm Φ 5" c/c	8 mm Φ 6" c/c

Column and Footing Reinforcement as per the table mentioned above.

Slab Design As Per IS456: 2000



Load Calculation

Material	***Thickness(m)***	***Unit Wt(KN/m³)***	***Load(KN)***
Marble	*0.02*	26.7	*0.534*
Screed	*0.025*	22	*0.55*
Slab	*0.125*	25	*3.125*
Plaster	*0.0125*	20.4	*0.255*
Partition			*1*
Live			*2*
		Total	*7.464*
Load Factor			*1.5*
Factored Load			*11.196*

Status

Limiting Reinforcement	***OK***
Deflection	***OK***
Limiting Moment	***OK***
Min. Area of Reinforcement	***OK***

Two adjacent edge Discontinuous

Panel Type	***Short Span Length Lx(mm)***	***Long Span Length Ly (mm)***	***Ly/Lx***	***Basic L/d ratio***	***Modification Factor***	***Permissible L/d***	***Short Span Moment Coefficient(αx)***		***Long Span Moment(αy)***	
							Negative	***Positive***	***Negative***	***Positive***
Two adjacent edge Discontinuous	***3734***	***4394***	*1.177*	*23*	*1.4*	*32.2*	*0.058*	*0.044*	*0.047*	*0.035*
						Moment	*9.11*	*6.84*	*7.34*	*5.46*

f_y N/mm²	***f_{ck} N/mm²***	***b mm***	***D mm***	***cover mm***	***half of bar mm***	***d mm***	***M_u kNm***	***Ast req mm²***	***p_t req %***	
500	*20*	*1000*	*125*	*15*	*4*	*106*	*9.11*	*207.91*	*0.20*	

Bar Φ	Spacing	Provide Spacing	Bar Provided	pt Provided	fs	MF	Actual L/d	Remark
8	241.8	150	8	0.364	156	2.00	46.0	

Limiting Moment of Resistance Values, (KNm)

f_y N/mm²	f_{ck} N/mm²	M_{lim} KNm
500	20	29.88776

Limiting Tensile Reinforcement in Reactangular Sections

f_y N/mm²	f_{ck} N/mm²	X_m/d	P_{lim} %
500	20	0.46	0.76

Minimum Tension Reinforcement

b mm	d mm	f_y N/mm²	A_0 mm²
1000	106	500	180.2

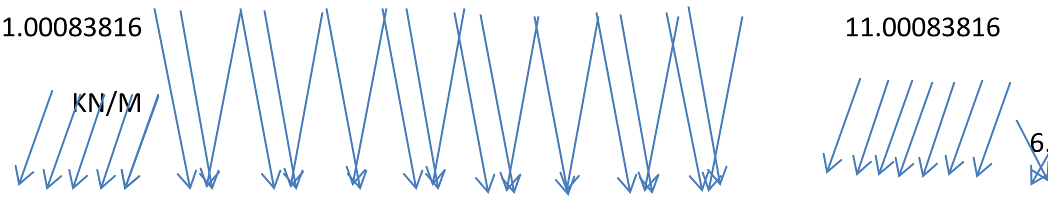
Staircase design

16.44

11.00083816 11.00083816

KN/M

A 6.20047242



0.15 1.75 0.53 0.225

INPUT						B
Conrete grade	20				steel grade	500
No of steps		7	no		LL	3
width of stepin mm		250	mm		main bar	12
total projected length(L2)		1750	mm		flight width	1.0667
height of Riser		175	mm		finish thck	0.03

landing A		Projected	mid span		LANDING B	
(L1)(m)	0.305	Length l2(m)		1.75	(L3)(m)	1.067
Effective landing width =		0.15	m			0.53
let thickness of waist slab		125	mm			
Dead load of flight						

step section	0.022	m^2	hypotenuse of step	
inclined slab	0.038	m^2	305.16	mm
finish	0.01275	m^2		
total area	0.073	m^2		
density of concrete	25.00	KN/m3		

Dl of step section 1m in width		250	mm in plan length			
					1.82	KN/m
	DL per m2 in plan		7.28	KN/m2		note
	LL per m2 in plan		3	KN/m2		
	Total Load		10.28			
	Factored Load		15.42	KN/m2		KN/m
Taking	1.066747943	WIDTH OF SLAB, LOAD=			16	KN/m
						1066.74794

Landing A

Self weight of slab	3.125	KN/m2
finish	0.75	KN/m2
LL	3	KN/m2
Toal Load	6.875	KN/m2
Factored load	10.3125	KN/m2
Taking 1.066747943	11.00083816	KN/m

landingB

same as landing A

Enter Landing width of Flight 2 1.066747943 m

In a distance equal to 150 mm from the wall and a distance equal to 75 mm inside the wall only dead load will be considered.

Hence Total factored load 6.200472417 KN/m

Design of stair flight

REACTION AT SUPPORT B				**fe**		**k**
	R_B	16.23	KN		415	0.138
	R_A	25.96	KN		500	0.133
concrete grade		20			500	0.133
LET point of zero SF occurs at distance x from A						
	X	1.63	m	from A		
		1.48				
MAX BM	21.76	KN/M				
				ok		
Effective depth of slab is given as BM=0.133Fcbd2				Fe		Xm
	d=	87.562	mm		250	0.53
ADOPT EFF. DEPTH =		104	MM		415	0.48
O.DEPTH =		125	MM		500	0.46

Area of tension

BM=0.87sigma y At (d-0.42Xm)

From table on right

we get	Xm =		0.46	d		
Required At=	***596.05***	mm2		required spacing	189.75	mm
USE	**6**	nos 12 bars eq spaced in			1.066747943	m width
provide	**12mm**	spacing		**125**	c/c	**ok**
	provided	(At)		904.32	mm^2	

check for shear:

Tv=	Vu/bd	0.234	N/MM2	
	% of steel=	0.815	%	

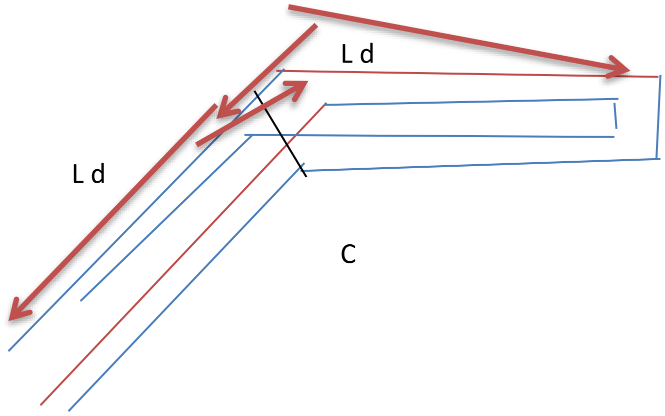
Shear strength of M20 concrete

% Steel ,	Tc	
0.815	0.576	IS 456-pg 73

shear strength of slab					for M		20
Tc'=	kTc		IS 456-pg 72	k		1.3	FOR K
THF Tc'=		0.720	>	Tv	ok		MANUALLY

Check for development length

development length for bar		12	Ld=	717.03	mm
			nearly	720	mm



Ld=
717.03

from point C as shown in fig development length of12mm should be available in either direction to top as well as bottom bars

	M.O.R (M1)=	33.00734721	KNM	
	V	16.23104234		bond stress forM20
let Lo =0	Ld<=	1.3M1/V+Lo		1.3
	Ld=	0.680	m	
	1.3M1/V+Lo=	2.64	m	ok

Temperature reinforcement

provide .12%	1.5	cm2/m	
8	78.5	mm2	
req bar no	2.23	no	
hence r spacing	448.06	mm	
provide	**8**	mm bars	**@150mmc/c**

Design of landing slab A

Effective span	2.88	m
Width=	1.07	
Factored load per m2	10.3125	KN/M2
Total load=	31.70	KN
Reaction from one flight	23.58	KN
Reaction from two flights	47.17	
Maximum BM	28.41	KNM
Maximum SF	39.43	KN
Effective Depth	104.mm	

area of steel is given by BM

BM=0.87sigma y At (d-0.42Xm)

AREA OF TENSION=

BM=0.87sigma y At (d-0.42Xm)

			Fe	Xm
From table on right			250	0.53
we get	Xm =	0.46 d	415	0.48
			500	0.46

At= 778.37 mm2 (required)

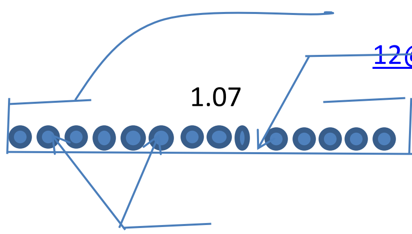
use 12.00 mm dia

USE **12** Nos 12mm bars eq spaced in 1.07 m width

provided (At) 1356.48 mm^2

p.spacing 125 mm c/c

12@ **125mm c/c**



12@ **125mm c/c**

104.mm

12 Nos, **125mm** c/c

Check for deflection

a=	26
beta=	1
delta=	1
lamda=	1

For U

Fs= .58*Fy*Astreq/Ast prov

191.1426063

Pt Ast prov/(b*D)*100 0.678 %

U= 1.3 from graph

permissible deflection= 33.8

provided deflection= 19.49 **ok**