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Seismic Resistant Multi Storey RCC Frame Residential Building

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Abstract: *Increasing population growth increased the size of the building thus increasing the risk of collapse for traditional building. Rapid urbanization gradually increased the necessities of multi storey buildings. Besides considering the scarcity of land, earthquake is one of the dominant constraints while designing the multi storey RCC frame buildings in the earthquake prone zone like Kathmandu, Nepal. Recent earthquake of 2015 has shown the serious problem with the traditional building design. This paper discusses the design of the building using ETABS software and relevant Indian Standard codes used for design of various building elements such as slabs, beams, columns, foundations and staircase and seismic analysis of building and researches the differences and similarities between seismic design code of Nepal and India.*

Keywords: *ETABS, Limit State, Seismic analysis, Base shear, Lateral load, Storey drift, etc.*

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I. Introduction

The occurrence of seismic hazard events and simultaneously, the increasing population is creating relevant implications for seismic resistant multistorey building. Knowledge regarding the occurrence of seismic events and its level of exposure to seismic damage are crucial factors for the assessment of seismic hazards. The geographical risk might be reduced if there is an improvement in seismic vulnerability in the built environment; this is critical solution for mitigating the consequences of earthquakes.

Countries over the world has made their own code for designing the building according to the suitability of their country topography, weather, geology and seismic activities. Since, Nepal and India are neighboring countries having borders in three directions with relevant reference as well as similar topography, weather and geology and thus, the design response spectrum and the diversity of soil type incorporated in Indian seismic design code IS 1893:2016. Therefore, Nepal followed Indian building design code to design buildings. In 1994, Nepal developed its own building code as NBC 105:1994 which was updated as NBC 105:2019 and finally NBC 105:2020 was implemented. Even though there is introduction of NBC, there is no restrictions on the of IS code on any policy level of Nepal.

Engineers should understand the major changes incorporated in IS 1893:2016 and NBC 105:2020. Hence, an attempt is done to compare the both codes and the study is performed with a RCC building model having 5 storey and the analysis of model is done using ETABS software.

II. OBJECTIVES OF THE STUDY

The objective of this study is to design and analyze the RC frame building using both Nepal Building Code and Indian Building Code in ETABS software. The objectives can be summarized as:

➢ To investigate the design capacities for both the design codes.
➢ To compare the drift value, displacement value and base shear of both codes.[1]

III. LITERATURE REVIEW

Devendra Shah and Shakshi (2022) [1]: -Compared the RC frame building with NBC 105:2020 and IS 1893:2002. They analyzed RCC building model having G+8 stories with regular plan using equivalent static model in ETABS software. They concluded that Nepal Building Code has higher value in displacement, drift, storey shear and base shear in comparison with IS code.

Muhaned Abass Mohammed (2020) [2]: -Evaluated the Indian and African building layout regulations. He did the design and seismic analysis of the structure by ETABS using IS code of India and BS

code of Africa and concluded that the base reaction, center of mass and rigidity, shear force, frequency and eigen values are higher in Is code than in BS code. Whereas, center of mass displacement and diaphragm acceleration values are higher in BS code.
Er. Aashish Aryal and Er. Sarams Dhungana (2020)
[3]:-
Investigated enough proof to out rule a general explanation that Indian seismic codes are more moderate than Nepali seismic code and compared the analysis of NBC code with IS code for RC structure. They concluded that the seismic interest as processed utilizing IS 1893 is constantly higher than the NBC 105.
Tabish Izhar, Samreen Bano and Neha Mumtaz (2019) [4]:-Analyzed and designed reinforced concrete building under seismic forces for different codal guidelines. They presented comparative study for four codal guidelines (IS 1893:2002, code 8, Japan-2007 and ASCE: 7-10) using Staad Pro. The comparison includes building base shear, bending moment, shear force, percentage of steel, required area, displacement and story-drift.
Ahmed M. EI-Kholy, Hoda Sayed, Ayman A.
Saheen (2018) [5]: -Compared seismic provisions of four building codes (Egyptian code for loads ECL 2012, Eurocode 8-2013, IBC 2015 and UBC 1997) to the prevailing multistorey residential reinforced concrete buildings comprising shear walls (SW) and located in Cairo-Fayoum zone. They concluded that structural engineers have to raise their confidence level in ECL results and expand its use instead of conservative UBC or other codes.
Yassser E. Ibrahim (2018) [6]:-Presented analytical fragility curves for typical mid-rise plane reinforced concrete moment resisting frames in Kingdom of Saudi Arabia, KSA, which is considered low seismicity area. They combined the result obtained in their research with the result obtained before for similar structures in the same cities to provide sets of analytical fragility curves considering OP,DC and CP performance levels.
H. Chaulagain, H. Rodrigues, J. Jara, E. Spacone, H.Varum (2013) [7]:- Investigated the seismic response of the current reinforced concrete buildings in Nepal. Three dimensional analytical models of buildings were developed and studied under nonlinear static pushover analysis and dynamic analysis.

IV. Design

The following materials are adopted for the design of the elements:

- Concrete Grade:M20 for Beam, slab, columns &footing.
- Reinforcement Steel –Fe 500 for longitudinal as well as for lateral bar

Limit state method is used for the design of RC elements. The design is based on IS: 456-2000, SP16, NBC 105: 2020 are extensively used in the progress of design. Also, comparison is done for NBC 105:2020 with IS 1893:2016.
The design moments, shear forces, axial forces are taken as computed by computer software program "ETABS 2017" for the worst possible combination and a number of hand calculations are done so as to verify the reliability of the design results suggested by the software.

V. METHODOLOGY

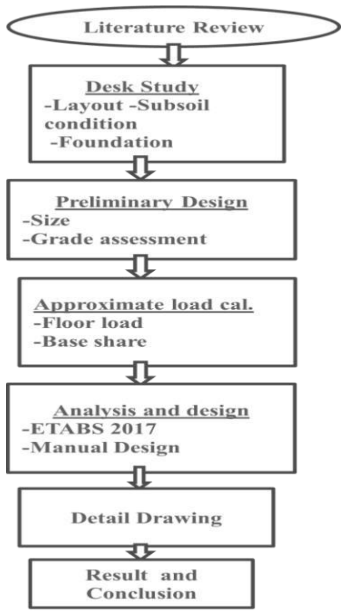
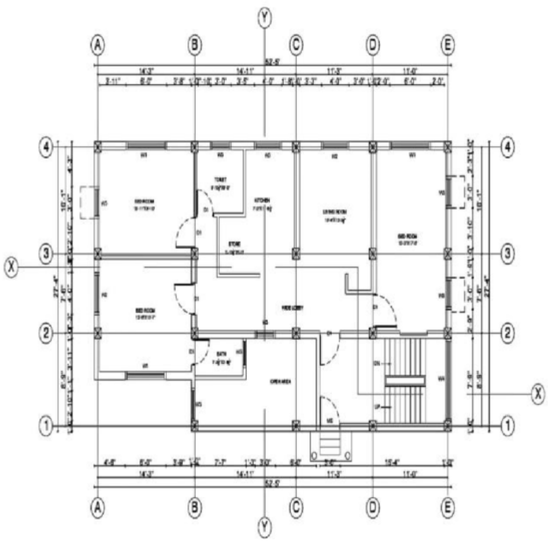


Fig: Methodology

5.1 Building Descriptions

Building Type: Residential Multi-Storied Building Foundation: Isolated Footing and Combined Footing Floor finishing: (Screening, punning 25mm)+ plaster 12mm = 37mm
No. of storey: 5
Plinth area cover: 1427. 583sq.ft
Structural System: RCC Framed structure
Slab thickness: 150mm
Soil type: Medium Soil
Storey height: 2.94 m (1st floor – 4thfloor)
Staircase: Doglegged
Total No of column: 84
Total no of beam:166 Total Height:15.24



GROUND FLOOR
AREA: 1427.583 SQ. FT.

5.2 Guidelines for Preliminary Design

The following guidelines will be helpful in design of building:

5.5.1 Functional Design

Provide happy environment inside as well as outside.
Proper arrangements of room/halls.

5.5.2 Structural Design

Structural design is an art and science of understanding the behavior of structural members subjected to loads and designing them with economy and elegance to give a safe, serviceable and durable structure.

5.5.3 Positioning of Columns

Located at or near the corners of building.
Located at intersection of beams/walls.
Selecting the position of columns so as to reduce bending moments in beams.
Avoid larger spans of beams.
Avoid larger center to center distance between columns.
Avoid the projection of column outside the wall.
Orient the column so that the depth of column is contained in the major plane of the bending or is perpendicular to the major axis of bending.
Orient the column in grid pattern to resist the lateral force as per stiffness.

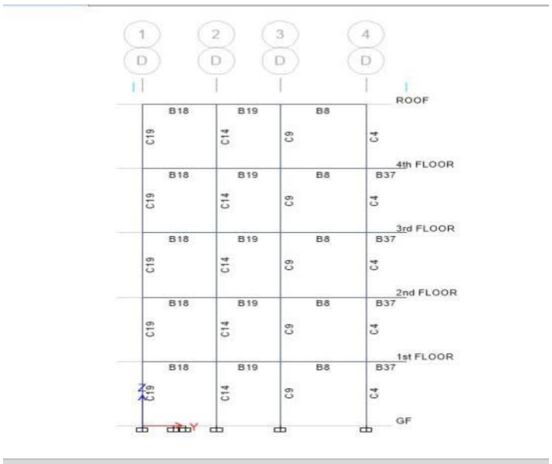


Fig: Column Leveling

5.5.4 Positioning of Beams

Normally provided under walls.

Below a heavy concentrated load to avoid these loads directly coming on slabs.

Avoid the larger spacing of beams from deflection and cracking criteria.

In building with live load less than 5KN/m^2, the maximum spacing of beams may be limited to the value of maximum spans of slabs.

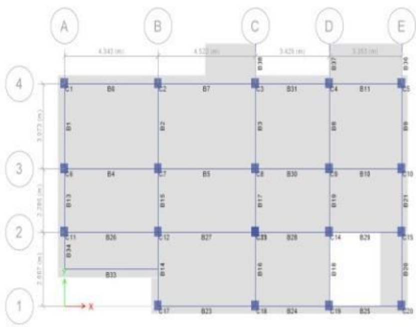


Fig: Beam Leveling

5.5.5 Spanning of Slabs

A slab normally acts as a one way slab when the aspect ratio $L_y/L_x>2$.

A two-way slab having aspect ratio $L_y/L_x<2$ is generally economical compared to one-way slab because steel along both the spans acts as main steel and transfers the load to all its four corners.

Spanning of slab is decided by the necessity of continuity to adjacent slab.

a. Decide the type of slab.
b. Canopy or Porch.
c. Corner Balconies.

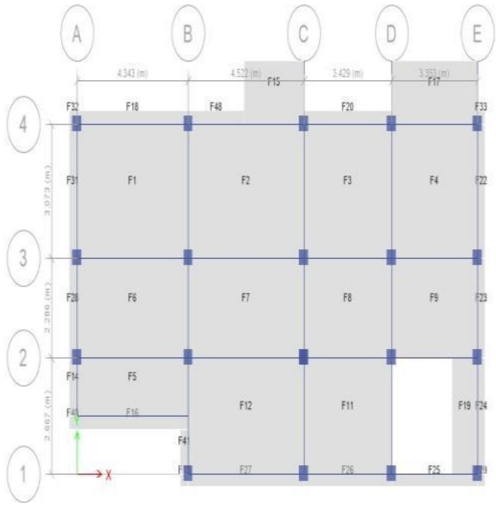


Fig: Slab Leveling

5.5.6 Layout of Stairs

The rise R should not be more than 200mm and trade T not less than200mm.

For residential building the riser (R) may be between 150mm to 180mm and tread (T) between 220mm to250mm.

For public building the riser (R) may be kept between 120mm to 150mm and tread (T) between 250mm to300mm.

The sum of tread plus twice the rise (T+2R) should be between 500mm to 650mm.

The width of stairs for residential building = 0.8m to1m.

The width of stairs for public building =1.8m to2m.

The width of landing should not be less than width of stairs.

For comfortable ascend on stairs, the arrangement of steps in each flight should not be greater than 38degree.

The head room measured vertically above any step or below mid-landing shall not be less than2.1m

At the preliminary design stage, calculation of reinforcement may be excessive, but it will be good to know the maximum steel required to check that it lies within a reasonable percentage of the concrete section and can be located in it without congestion.

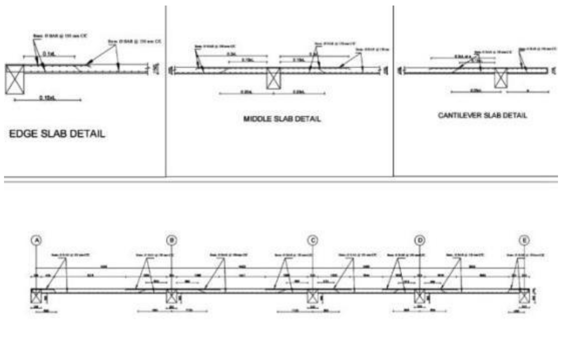


Fig: Staircase Leveling

VI. ANALYSIS OF BUILDING IN ETABS

The design size after preliminary analysis and design will be used for creating the model in ETABS. The loading, however will be applied in slightly different approach as required for plateframe analysis using Static Method for seismic analysis.

6.1 Method

For Plate from model of building following builders will be made for

a) Elements
b) Loading of gravity loads
c) Loading of seismic loads
d) Combination of response for the design using Limit State Design

e) Checking Limit State of Serviceability

6.2 Beam
Type: Line element
Length: C/C distance of column
Width: Horizontal dimension in section
Depth: Vertical dimension inspection

6.3 Column
Type: Line element
Length: Floor height
Width: dimension parallel to Y-axis
Depth: dimension parallel to X-axis

6.4 Slab
Type: Area element
Thickness (D): as defined by user

6.5 Support
For analysis of super-structure, columns are support and are fixed to the Raft. Further analyses are carried out using combined behavior of Raft and Super- structure using Soil Spring Model for foundation material.

6.6 Materials
The material property definitions are used in defining the structural objects .i.e. Frame sections, cable sections, tendon sections, area sections, solid properties, etc. During modeling of building we defined concrete and rebar. Concrete as defined by IS456:2000 by grade 'M', property for concrete specified are concrete compressive strength, weight per unit volume, Modulus of
Elasticity and Poisson's ratio.
For Columns(all floors): M20
For Slabs and Beams (all floors):M20

6.7 Defining Section Property
- Defined primary beam and column.
- Assigned dimension of the section and concrete reinforcement requirement.

6.8 Drawing Structural Element • Grid lines were fixed first according to the required dimension. • Structural elements were drawn according to the color defined during defining section property.
- The model was prepared with slab. • The support were assigned as fix support and assigned at basement level.

6.9 Load cases
Each different analysis performed is called Load Case. A label is assigned to each Load Case as part of the definition. These labels can be used to create additional combinations and to control output.
Static Load Dead and Imposed load Earthquake load: Generated based on
Modal Analysis and Static Analysis

6.10 Load Pattern
In load pattern self-weight multiplier is taken as 1 for self-weight and for others (live and dead load) self-weight multiplier is taken as zero.

6.11 Load Combination
Default design combination is taken which consists of fourteen combinations.

Combo 1	= DL
Combo 2	= LL
Combo 3	= 1.2DL + 1.5 LL
Combo 4	= DL + XLL + EQxSLS

Combo 5	= DL + XLL - EQxSLS
Combo 6	= DL + XLL + EQySLS
Combo 7	= DL + XLL - EQySLS
Combo 8	= DL + XLL + EQxULS
Combo 9	= DL + XLL - EQxULS
Combo 10	= DL + XLL + EQyULS
Combo 10	= DL + XLL - EQyULS

6.12 Mass Source

Mass system is defined from loading and selfweight of structure as 100% for seismic mass and live load as 50% as imposed load exceeds 3KN/m^2.

VII. ANALYSIS RESULT

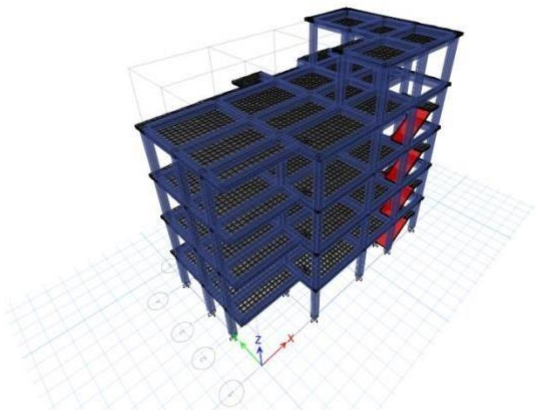


Fig: 3D modeling of Building

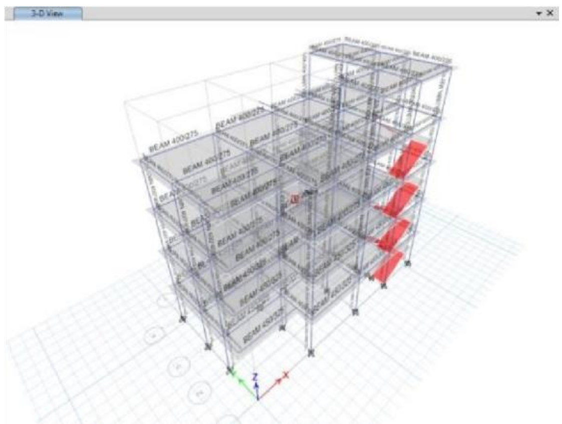


Fig: Frame Section Assignment

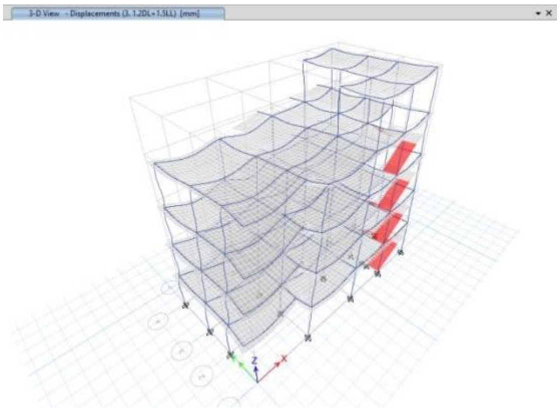


Fig: Displacement (1.2DL+1.5LL)

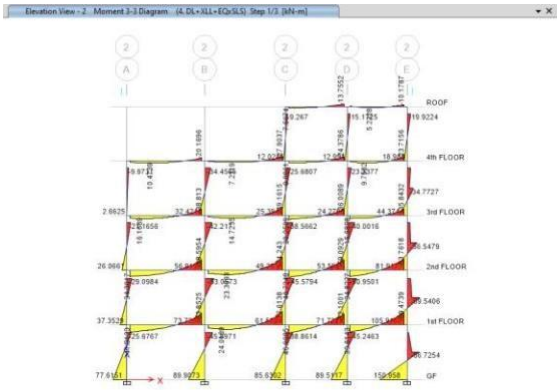


Fig: BM Diagram

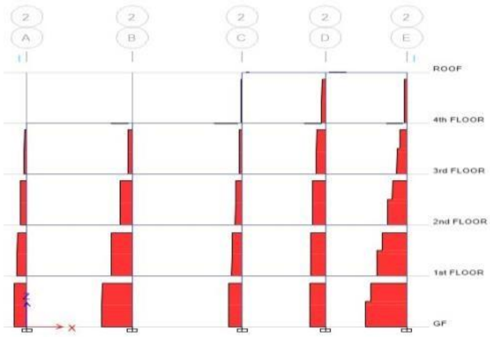


Fig: Axial Force Diagram

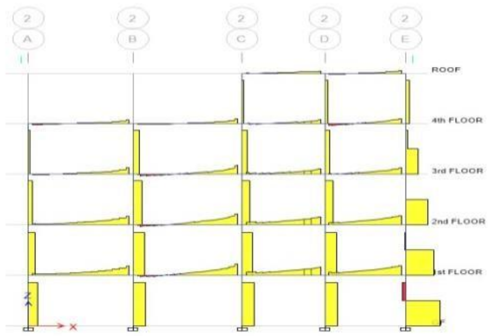


Fig: Shear Force Diagram

TABLE FOR LATERAL LOAD CALCULATION

FLOOR	HEIGHT (m)	STOREY LOAD Wi (KN)	Wi* hi^2	(Wi*hi2)/(∑Wi*hi2)	Qi (KN)	Vi (KN)
First Floor	3.048	1636.538	15203.936	0.02763937	24.901969	900.96
Second Floor	6.096	1636.538	60815.742	0.11055749	99.607875	876.058
Third Floor	9.144	1550.298	129624.66	0.23564584	212.30747	776.4502
Fourth Floor	12.192	1550.298	230443.84	0.41892594	377.43551	564.1427
Roof	15.24	490.81	113994.35	0.20723137	186.70717	186.7072
		∑	550082.52		900.96	

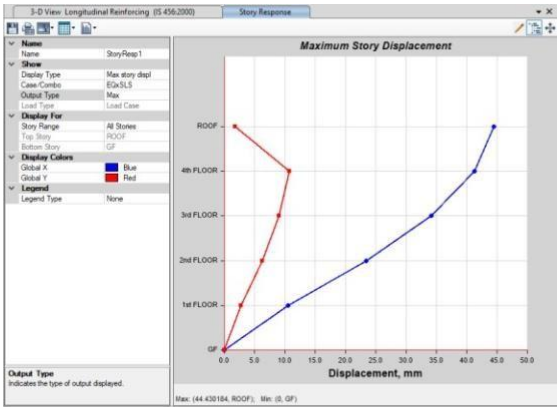


Fig: Maximum Storey Displacement (EQxSLS)
NOTE: Allowable Max displacement (0.006*15240= 91.44mm) NBC 105

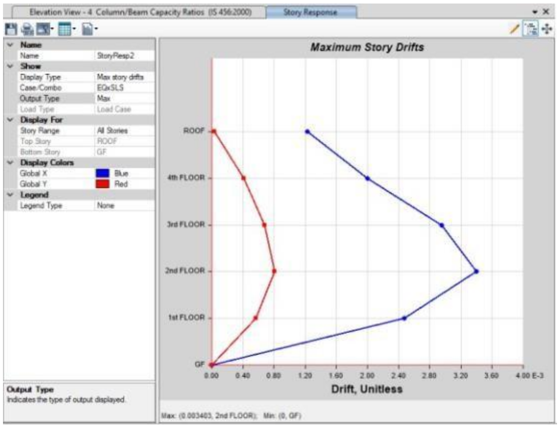
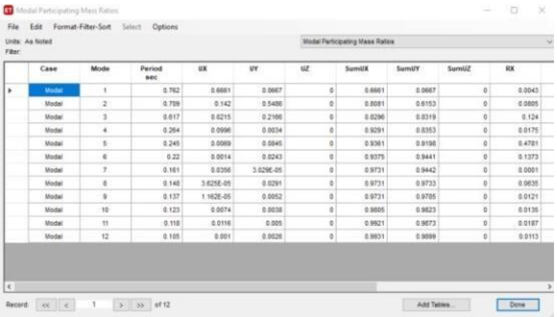


Fig: Maximum Storey Drift (EQySLS)
NOTE: Maximum Storey drift limit;
As per NBC 105;2020 is 0.0062



Case	Mode	Period sec	UX	UY	UZ	SumUX	SumUY	SumUZ	RX
Modal	1	0.762	0.6661	0.0667	0	0.6661	0.0667	0	0.0043
Modal	2	0.709	0.142	0.5486	0	0.8081	0.6153	0	0.0805
Modal	3	0.617	0.0215	0.2166	0	0.8296	0.8319	0	0.124
Modal	4	0.264	0.0996	0.0034	0	0.9291	0.8353	0	0.0175
Modal	5	0.245	0.0069	0.0845	0	0.9361	0.9198	0	0.4781
Modal	6	0.22	0.0014	0.0243	0	0.9375	0.9441	0	0.1373
Modal	7	0.161	0.0356	3.029E-05	0	0.9731	0.9442	0	0.0001
Modal	8	0.148	3.625E-05	0.0291	0	0.9731	0.9733	0	0.0635
Modal	9	0.137	1.162E-05	0.0052	0	0.9731	0.9785	0	0.0121
Modal	10	0.123	0.0074	0.0038	0	0.9805	0.9823	0	0.0136
Modal	11	0.118	0.0116	0.005	0	0.9921	0.9873	0	0.0187
Modal	12	0.105	0.001	0.0026	0	0.9931	0.9899	0	0.0113

Fig: Modal Mass Participation Mass Ratio

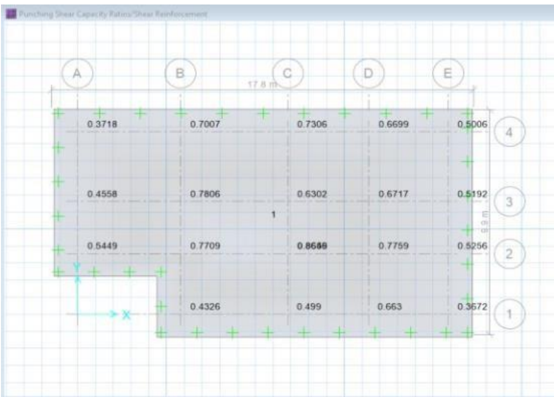


Fig: Punching Shear Capacity (< 1 ok)

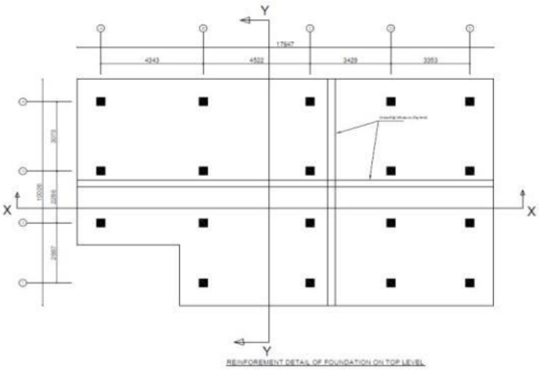


Fig: Reinforcement detail of foundation top level

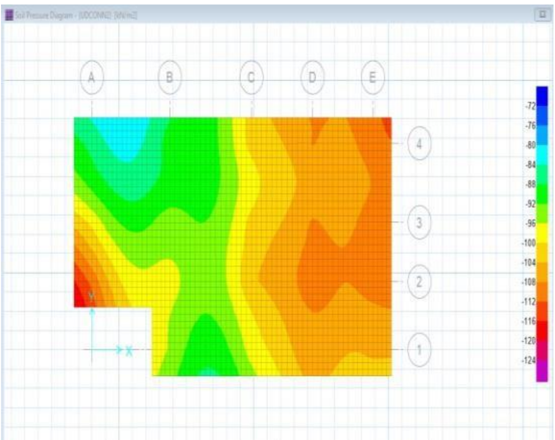


Fig: Soil Pressure Diagram

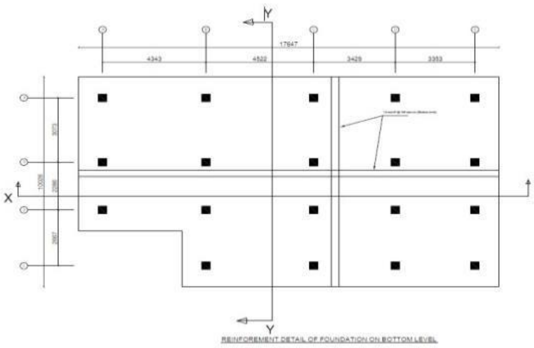


Fig: Reinforcement detail of foundation

VIII. CONCLUSION

[1]. All the structural elements are designed and got in suitable size. (beam, column, slab, footing, staircase).
[2]. Design is based on IS 456:2000 and NBC 105: 2020.
[3]. Analysis & Modeling is done by the computer aided application ETABS software and foundation is designed by SAFE software, also AUTOCAD is used to design the plan of the building.
[4]. Sample elements are designed manually.
[5]. Storey drift and displacement are within permissible.
[6]. Base shear is distributed from base to top of building.
[7]. All the checking is within limit.
[8]. Detailing is as per IS 13920 (Ductile Detailing).

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