Design of G+10 Storey Residential Building using STAAD.PRO

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Abstract – *The main aim of structural engineer is to design the structure for a safe, serviceable, durable and economical. The entire process of structural planning and design is required imaginations and sound knowledge. Analysis and design of G+10 storey residential building structure as per IS Code method. Analysis and design of entire structure have been completed by manual design and verifies using STAAD.PRO Software. All the drafting and detailing was done by using AutoCAD. In this project, the design of beam, column, slab, staircase, shear wall is calculated by "Limit State Method" using IS: 456-2000 code book. Different load active on the member are consider according to IS: 875-1987 (part 1, part 2) & IS: 1893-2005 for seismic load. Hence residential building is properly planned in accordance with Indian Standard Code of India.*

Key Words: Analysis, Design, AutoCAD, STAAD.PRO, Residential building, Dynamic load, Static load.

1.INTRODUCTION

India is a developing country; huge construction projects are yet to come as undeveloped cities are needed to develop since so many years. In current century, many projects all over the world are going on, time delay takes place which in turn affects the growth of the construction of huge projects. To avoid time delay and thereby the growth, economic construction methodology should be adopted. To economize the structure, structural optimization techniques should be used. Many metropolitan cities are facing vast growth of infrastructure whether it may be in terms of horizontal development or vertical development. In high rise buildings, we should concern about all the forces that act on building, its weight as well as the soil behavior. For loose soil, we preferred deep foundation(pile). Calculation for high rise construction manually then it will take extra time in addition to human individual errors possibly will occurred. The software's used in this project are.

- AutoCAD
- STAAD.PRO

1.1 AutoCAD

AutoCAD is a drafting software which is used for developing 2-Dimensional and 3-Dimensional structures, developed and sold by Autodesk Inc. It is a vector graphics drawing program. AutoCAD's native file format DWG and to a lesser extent, its interchange file format, DXF.

1.2 STAAD.PRO

STAAD.PRO is user friendly software which is used for analysing and designing of structures by structural engineers. STAAD.PRO provides a lot of precise and correct results than manual techniques.STAAD.PRO software is used for both static and dynamic analysis for structures such as bridges, low rise or high-rise buildings, stadiums, steel structures etc. First step in STAAD.PRO is to specify the geometry of the structures and then the properties of the members are mentioned, then the supports are generated and loadings are specified on the structure. Finally, the structure is analysed.

2. LITERATURE REVIEW

Ibrahim, et al (April 2019): Design and Analysis of Residential Building(G+4):

After analyzing the G+4 storey residential building structure, conducted that the structure is rate in loading like dead load, live load, wind load and seismic loads. Member dimensions are assigned by calculating the load type and its quantity applied on it. Auto CAD gives detailed information at the structural members length, height, depth, size and numbers etc. STAAD.PRO has a capability to calculate the program contains number of parameters which are designed as per IS:456-2000. Beams were designed for flexure, shear and tension and it gives the detail number, position and spacing brief.

Devi Krishna Chaitanya, et al (January 2017): Analysis and Design of a (G+6) Multi storey Building using STAAD.PRO:

They used static Indeterminacy methods to calculate numbers of unknown forces. Distributing known fixed end moments, the condition of compatibility by iteration method, Kani's method was used to distribute moments at successor joints in frame and continues beam for stability of members of building structure. They used to design software STAAD.PRO which reduced a lot of time in design, gives accuracy.

R. D. Deshpande, et al (June 2017): Analysis, Design and Estimation of B+G+2 Residential Building:

They found that check for deflection was safe. They carried design and analysis of G+2 residential building by using Etabs software with the estimation of building by methods of center line. They safely designed column using SP-16 checked with interaction formula.

3. Building Description:

Purpose of Building	Residential
Shape of the Building	Regular (Rectangular)
No. of Stories	(G+10) Storey
Height of Stories	3 m (Similar)
Type of Wall	Brick Wall
Depth of Foundation	1.5 m
Area of Building	241 m^2
Area	Delhi NCR
Zone	IV
Zone Factor	0.24

Table.1

4. Floor Plan of building:

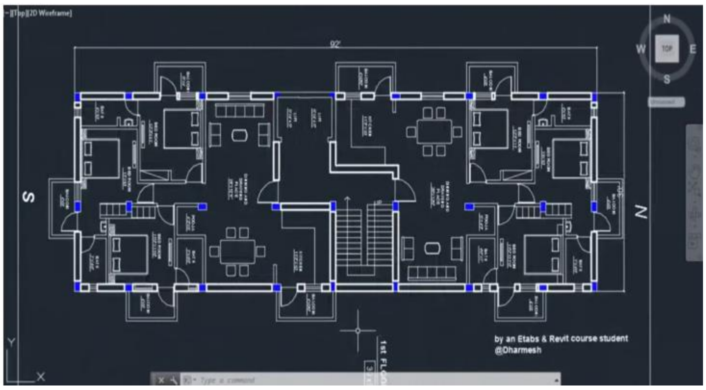

Fig.1: floor plan of building

5.Flow chart diagram:

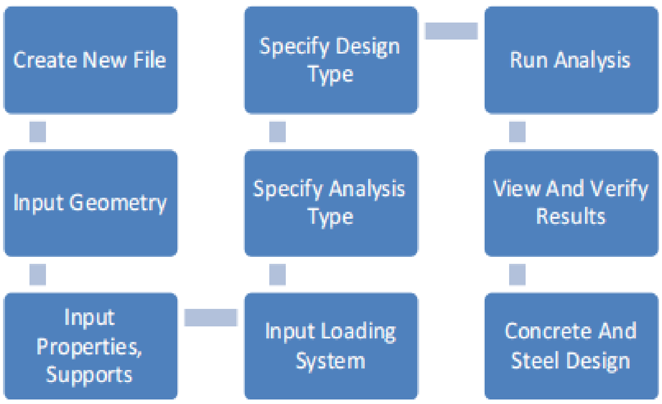

Fig.2: flow chart diagram

6.Methodology:

6.1. Modelling of Structure:

- ✓ B+G+10 Residential

6.2. Loads Assigning:

- ✓ Seismic load
- ✓ Dead load
- ✓ Live load
- ✓ Combination of loads
  - D.L + L.L
  - 1.5 (D.L + L.L)
  - 1.2 (D.L + L.L ± EQ)
  - 1.5 (D.L ±EQ)
  - 0.9D.L ± 1.5EQ

6.3. Analysis & interpret the result:

- ✓ Analysis of RCC framed structure
- ✓ Shear force, Bending moment and Axial force
- ✓ Design of this structure as per guidelines of IS:456-2000(Limit state design)

6.4. Design:

- ✓ Design of Slab
- ✓ Design of Beam
- ✓ Design of Column
- ✓ Shear Wall: 6' X 4'5" (1.825m X 3.04m) & Staircase
- ✓ Footing

6.5. Input data:

- ✓ Slab =150mm
- ✓ Beam =400mm X 400mm
- ✓ Column =550mm X 400mm
- ✓ Thickness of outer wall = 230mm
- ✓ Thickness of inner wall = 127mm
- ✓ Height of parapet wall =1 m

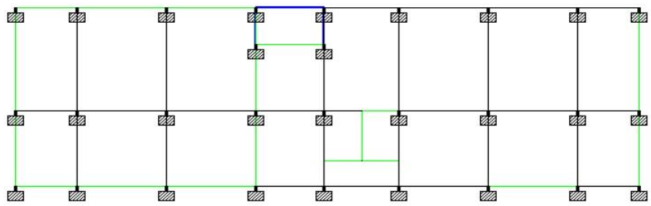

fig.3: Top View Model

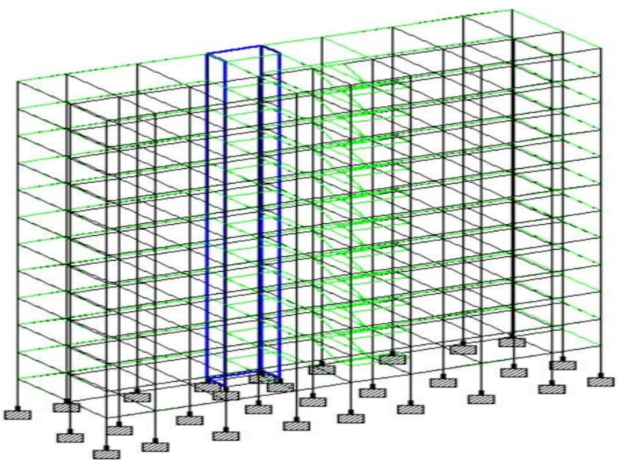

fig.4: 3-D View Model

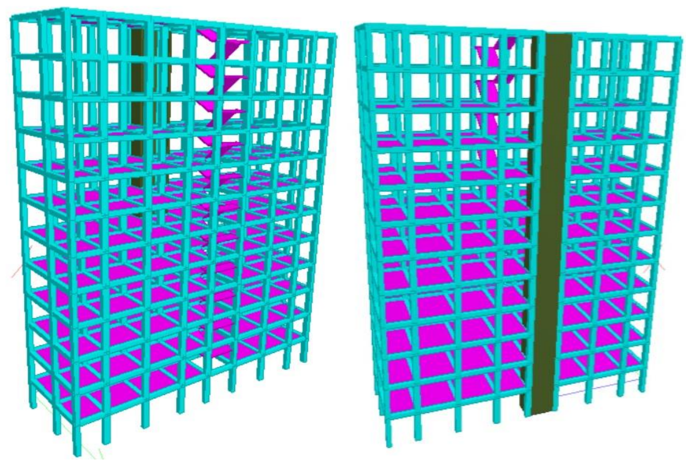

fig.5: 3-D Rendered View

7. Assigning of Loads:

7.1. Seismic load:(IS: 1893-2002/2005)

Zone: IV
Zone factor: 0.24
Damping ratio: 0.05
Period in X direction: 0.58 seconds
Period in Z direction: 1.05 seconds
Response reduction factor: 5
Soil type: 2(medium)

- ✓ Unit weight of concrete= 25
- ✓ Unit weight of mortar= 18
- ✓ Init weight of brick masonry= 20

7.2. Dead load: (IS:875(PART 1)**)**

7.2.1. Due to self-weight of slab:

Thickness of slab= 150mm
Slab load per m =thickness X unit weight
=0.150 X 25 = 3.75 KN/m^2
Floor finished load per m = 1.5 KN/m^2

7.2.2. Due to outer-wall:

- ✓ Thickness of outer wall =230mm (9 inch)

Outer wall load = Thickness X unit weight X (height of typical storey – depth of beam)
=0.230 X 20 X (3-0.450)
=11.73 KN/m^2
(Plaster of two faces=2[0.02 X (3-0.45) X 18] =2 KN/m^2)
Outer wall load=11.73+2=13.73 KN/m^2

7.2.3. Due to inner wall:

- ✓ Thickness of inner wall= 127mm (5 inch)

Inner wall load= 0.127 X 20 X (3-0.45)
=6.47 KN/m^2 +2 KN/m^2 = 8.47KN/ m^2

7.2.4. Due to parapet wall:

- ✓ Thickness of parapet wall= 127mm (5 inch)

Parapet wall load= 0.127 X 20 X 1= 2.54KN/m^2

7.3. Live load: (IS:875(PART 2)**)**

Area	**Live load (KN/m^2)**
Bedroom & Kitchen	2
Toilet & Bathroom	2
Dining &Drawing Place	2
Staircase	3
Lift	4

Table.2

Live load= 4 KN/m^2
Roof live load= 2 KN/m^2

7.4. Load combinations:

For Superstructure	**For Substructure**
1.5(D. L+L.L)	D.L+L.L
1.2(D. L+L.L±EQ (X, Z))	D.L+0.5L. L±EQ (X, Z)
1.5(D. L±EQ (X, Z))	D.L±EQ (X, Z)
0.9D. L±1.5EQ (X, Z)	

Table.3

8.Analysis & interpret the result:

8.1. Interpreting the displacement

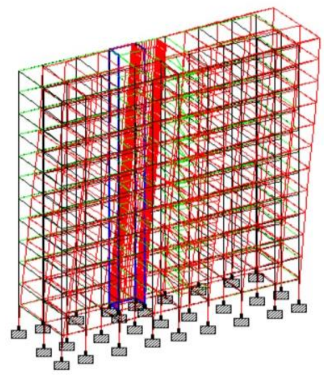

fig.6: due to EQ in X-dir^n

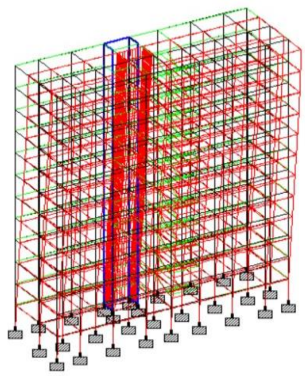

fig.7: due to EQ in Z-dir^n

8.2. Interpreting the Bending Moment

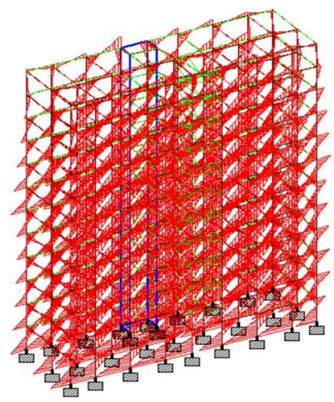

fig.8: due to EQ in X-dir^n

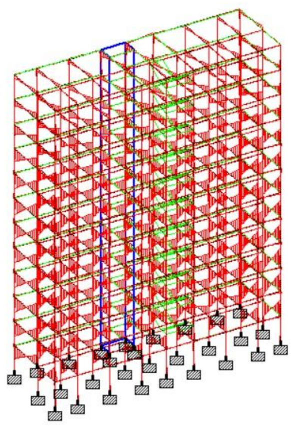

fig.9: due to EQ in Z-dir^n

8.3. Interpreting the Shera Force

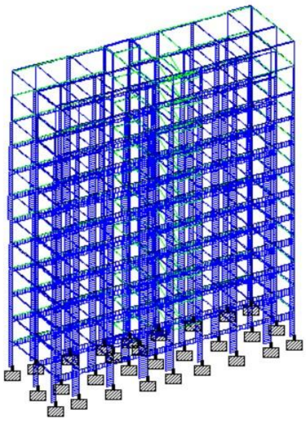
fig.10: due to EQ in X-dir^n

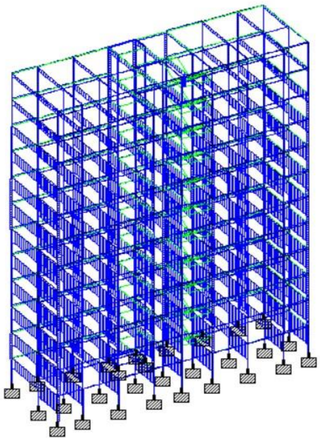
fig.11: due to EQ in Z-dir^n

8.4. Interpreting the Axial Force

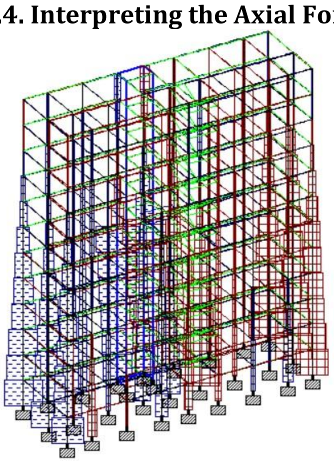
fig.12: due to EQ in X- dir^n

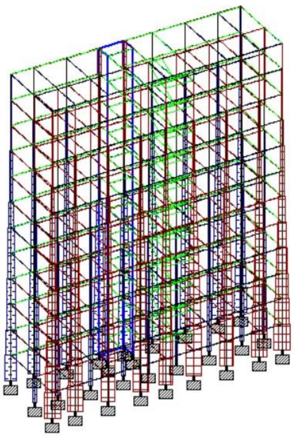
fig.13: due to EQ in Z-dir^n

9. Design of the structure:

- ✓ Design of Slab
- ✓ Design of Beam
- ✓ Design of Column
- ✓ Design of Shear wall
- ✓ Design of Foundation

9.1. Design of Slab

Slabs are most widely used structural elements forming floor and roof of building. Slab supports mainly transverse load and transfer them to supports by bending actions in both the directions. On the basis of spanning direction, it is of two types.

- One-way Slab
- Two-way Slab

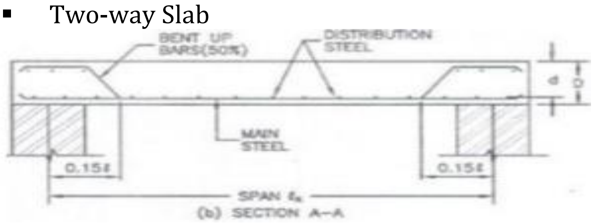

Fig.14: Slab reinforcement

Material Specification

Grade of Concrete, M30	30 N/mm^2
Grade of Steel, Fe415	415 N/mm^2
Clear Cover of Slab, Beam	25 mm
Clear Cover of Column	40 mm

Table.4

9.2. Design of Beam

- Singly reinforced beam
- Doubly reinforced beam

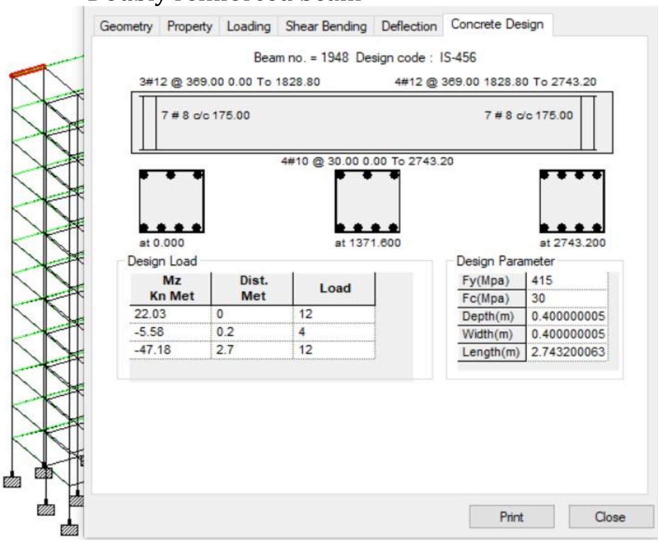

fig.15: Beam design

IS-456 LIMIT STATE DESIGN
BEAM NO. 1948 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 2743.2 mm SIZE: 400.0 mm X 400.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	685.8 mm	1371.6 mm	2057.4 mm	2743.2 mm
TOP REINF.	303.13 (Sq. mm)	303.13 (Sq. mm)	303.13 (Sq. mm)	303.13 (Sq. mm)	402.41 (Sq. mm)
BOTTOM REINF.	303.13 (Sq. mm)	303.13 (Sq. mm)	303.13 (Sq. mm)	303.13 (Sq. mm)	303.13 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	685.8 mm	1371.6 mm	2057.4 mm	2743.2 mm
TOP REINF.	3-12í 1 layer(s)	3-12í 1 layer(s)	3-12í 1 layer(s)	3-12í 1 layer(s)	4-12í 1 layer(s)
BOTTOM REINF.	4-10í 1 layer(s)	4-10í 1 layer(s)	4-10í 1 layer(s)	4-10í 1 layer(s)	4-10í 1 layer(s)
SHEAR REINF.	2 legged 8í @ 175 mm c/c	2 legged 8í @ 175 mm c/c	2 legged 8í @ 175 mm c/c	2 legged 8í @ 175 mm c/c	2 legged 8í @ 175 mm c/c

Fig.16: Detailing of beam

9.3. Design of Column

A column may be defined as an element used primary to support axial compressive loads and with a height of a least three times its lateral dimension. The strength of column depends upon the strength of materials, shape, size of cross section, length and degree of proportional and dedicational restraints at its ends.

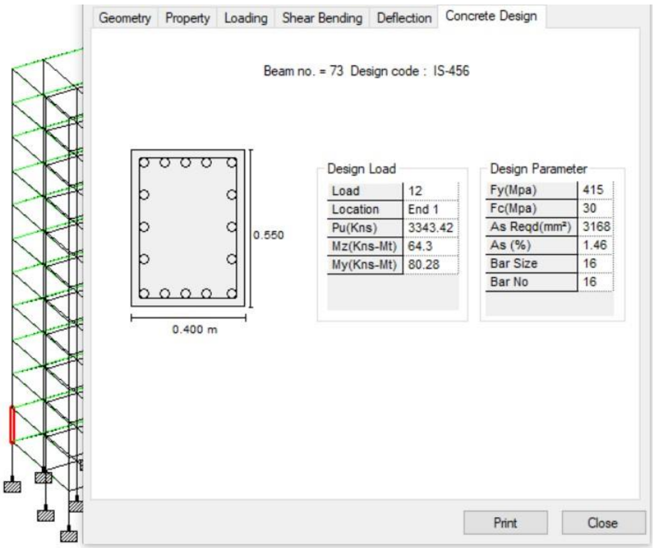

fig.17: Column design

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        IS-456   L I M I T   S T A T E   D E S I G N
      C O L U M N  N O.   73  D E S I G N  R E S U L T S

    M30                  Fe415 (Main)              Fe415 (Sec.)

LENGTH:  3000.0 mm   CROSS SECTION:  550.0 mm X  400.0 mm  COVER: 40.0 mm

** GUIDING LOAD CASE:   12 END JOINT:    10  SHORT COLUMN


REQD. STEEL AREA    :     3168.00 Sq.mm.
REQD. CONCRETE AREA:    216832.00 Sq.mm.
MAIN REINFORCEMENT : Provide  16 - 16 dia. (1.46%,   3216.99 Sq.mm.)
                     (Equally distributed)
TIE REINFORCEMENT  : Provide  8 mm dia. rectangular ties @ 255 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)
----------------------------------------------------------
Puz :   3913.27   Muz1 :     91.46   Muy1 :     130.84

INTERACTION RATIO: 0.92 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)
----------------------------------------------------------
WORST LOAD CASE:    12
END JOINT:     10 Puz :    3927.86   Muz :     93.84   Muy :     134.45   IR: 0.87
```

fig.18: Detailing of column

9.4. Design of Shear wall:

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-----------------------------------------------------------------------------

PANEL  NO.   1 OF SHEARWALL     19  DESIGN PER IS 456-2000


WIDTH :        3.05 M               FC :              30.00 MPA
HEIGHT :     36.00 M                FY :             415.00 MPA
THICKNESS : 200.00 MM               CONC. COVER :   25.000 MM

REINFORCING SUMMARY (REBAR SPACING/AREA UNITS: MM/MM^2)
-----------------------------------------------------------------------------
```

fig.19: Detailing of Shear wall

9.5. Design of Foundations:

Foundations are structural elements that transfer the loads from the building or individual column to the earth. Foundations must be designed to prevent excessive settlement or rotation, to minimize differential settlement and to provide adequate safety against sliding and overturning.

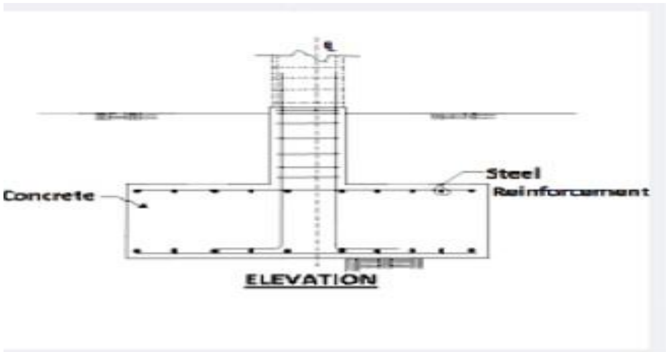

fig.20: Elevation of footing

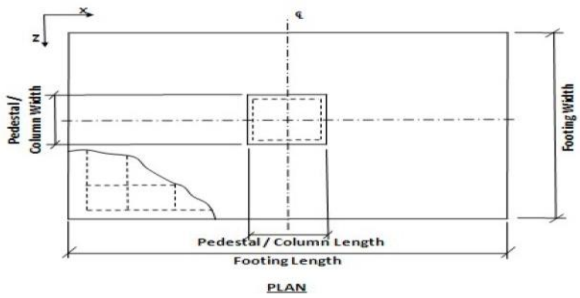

fig.21: Plan of footing

9.5.1. Footing Geometry:

Design Type	Calculated Dimension
Footing Thickness (Ft)	305.00 mm
Footing – X (Fl)	1000.00 mm
Footing -Z (F w)	1000.00 mm

Table.5

9.5.2. Column Dimension:

Column Shape	Rectangular
Column length -X (Pl)	0.400 m
Column Width -X (Pw)	0.550 m

Table.6

9.5.3. Design Parameters:

Unit weight of Concrete	25 KN/m³
Strength of Concrete	25 N/mm²
Yield Strength of Steel	415 N/mm²
Minimum Bar Size	10 mm
Maximum Bar Size	32 mm
Minimum Bar Spacing	50 mm

Maximum Bar Spacing	500 mm
Pedestal Clear Cover (P, Cl)	50 mm
Pedestal Clear Cover (F, Cl)	50 mm

Table.7

9.5.4. Soil Properties:

Soil type	Drained
Unit weight	22 KN/m^3
Soil Bearing Capacity	150 KN/m^2

Table.8

9.5.5. Results of Footing:

Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
868	1	4.400 m	4.400 m	0.605 m
869	2	3.950 m	3.950 m	0.605 m
870	3	3.900 m	3.900 m	0.605 m
871	4	6.050 m	6.050 m	0.757 m
872	5	5.850 m	5.850 m	0.707 m
873	6	4.550 m	4.550 m	0.655 m
874	7	4.100 m	4.100 m	0.605 m
875	8	3.950 m	3.950 m	0.605 m
876	9	4.250 m	4.250 m	0.605 m
877	10	4.000 m	4.000 m	0.605 m
878	11	4.250 m	4.250 m	0.605 m
879	12	4.500 m	4.500 m	0.655 m
880	13	4.250 m	4.250 m	0.605 m
881	14	4.400 m	4.400 m	0.655 m
882	15	4.650 m	4.650 m	0.655 m
883	16	4.550 m	4.550 m	0.655 m
884	17	4.250 m	4.250 m	0.605 m
885	18	4.000 m	4.000 m	0.605 m
886	19	4.000 m	4.000 m	0.555 m
887	20	3.750 m	3.750 m	0.555 m
888	21	3.900 m	3.900 m	0.605 m
889	22	4.600 m	4.600 m	0.655 m
890	23	4.450 m	4.450 m	0.655 m
891	24	4.550 m	4.550 m	0.605 m
892	25	3.950 m	3.950 m	0.605 m
893	26	3.800 m	3.800 m	0.555 m
894	27	4.000 m	4.000 m	0.605 m
910	28	7.350 m	7.350 m	0.755 m
911	29	7.450 m	7.450 m	0.755 m

fig.22: Geometry of footing

Footing No.	Footing Reinforcement			
-	Bottom Reinforcement(M_z)	Bottom Reinforcement(M_x)	Top Reinforcement(M_z)	Top Reinforcement(M_x)
868	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 105 mm c/c
869	Ø10 @ 75 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 75 mm c/c	Ø10 @ 115 mm c/c
870	Ø10 @ 75 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 75 mm c/c	Ø10 @ 110 mm c/c
871	Ø12 @ 60 mm c/c	Ø12 @ 55 mm c/c	Ø10 @ 50 mm c/c	Ø10 @ 85 mm c/c
872	Ø12 @ 55 mm c/c	Ø12 @ 55 mm c/c	Ø10 @ 50 mm c/c	Ø10 @ 90 mm c/c
873	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 95 mm c/c
874	Ø10 @ 70 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 115 mm c/c
875	Ø10 @ 70 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 115 mm c/c
876	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 115 mm c/c
877	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 140 mm c/c
878	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 105 mm c/c
879	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 75 mm c/c	Ø10 @ 95 mm c/c
880	Ø10 @ 55 mm c/c	Ø10 @ 50 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 115 mm c/c
881	Ø10 @ 55 mm c/c	Ø10 @ 50 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 115 mm c/c
882	Ø10 @ 50 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 50 mm c/c	Ø10 @ 115 mm c/c
883	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 75 mm c/c	Ø10 @ 95 mm c/c
884	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 105 mm c/c
885	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 140 mm c/c
886	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 140 mm c/c
887	Ø10 @ 70 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 75 mm c/c	Ø10 @ 155 mm c/c
888	Ø10 @ 65 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 155 mm c/c
889	Ø10 @ 60 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 115 mm c/c
890	Ø10 @ 65 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 85 mm c/c	Ø10 @ 95 mm c/c
891	Ø10 @ 50 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 105 mm c/c
892	Ø10 @ 65 mm c/c	Ø10 @ 55 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 160 mm c/c
893	Ø10 @ 70 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 70 mm c/c	Ø10 @ 160 mm c/c
894	Ø10 @ 55 mm c/c	Ø10 @ 60 mm c/c	Ø10 @ 65 mm c/c	Ø10 @ 140 mm c/c
910	Ø10 @ 85 mm c/c	Ø10 @ 85 mm c/c	Ø10 @ 210 mm c/c	Ø10 @ 115 mm c/c
911	Ø10 @ 85 mm c/c	Ø10 @ 85 mm c/c	Ø10 @ 215 mm c/c	Ø10 @ 110 mm c/c

fig.23: Detailing of footing

9.5.6. Layout of Foundation:

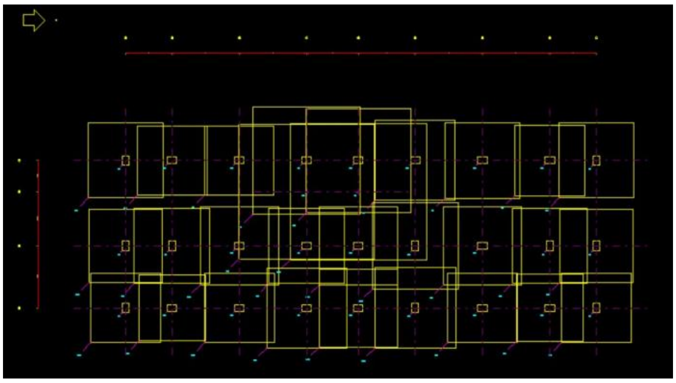

fig.24: Layout of Foundation

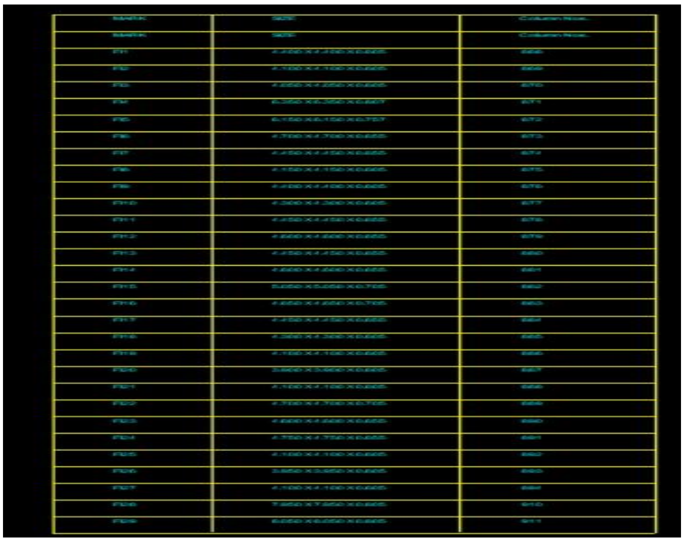

fig.25: Layout of footing

9.5.7. Reinforcement details of column is shown:

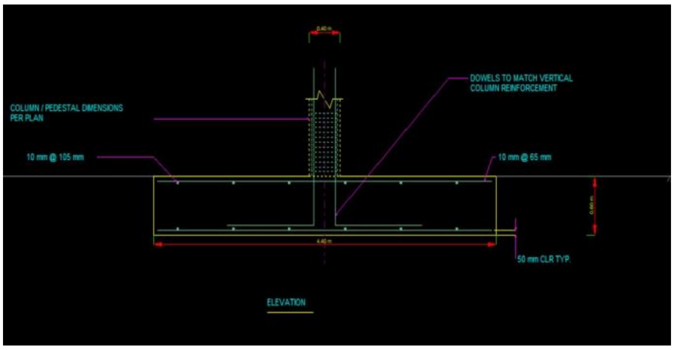

fig.26: Reinforcement details of footing

9.5.8. Plan of reinforcement:

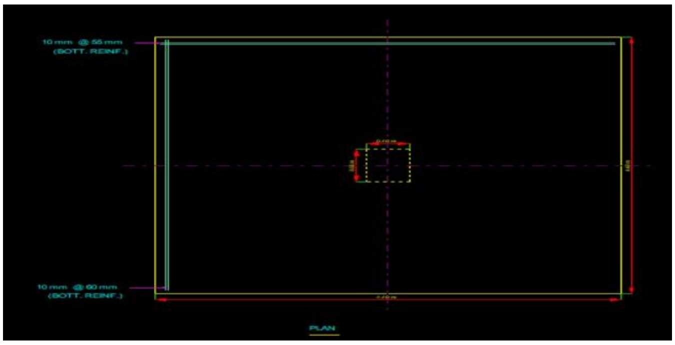

fig.26: Plan of reinforcement

10. CONCLUSIONS

On the following work carried out, we conclude that: -

1. This project has given an opportunity to re-collect and coordinate the various methods of designing and engineering principles which we have learnt.
2. Analysis and designing were done by using STAAD.PRO software and successfully verified manually as per IS: 456-2000.
3. Calculation by both manually as well as software analysis, gives almost same result.
4. Percentage of steel required in column is 0.82 to 3.14.
5. Displacement Increases as the storey height increases.
6. Maximum deflection in Horizontal (X-direction) is **49.756 mm**.
7. Maximum deflection in Horizontal (Z-direction) is **45.349** mm.
8. Maximum deflection in Vertical (Y-direction) is 5.702 mm.
9. Maximum rotation in X, Y, Z- directions are 0.005 rad, 0.001 rad, 0.003 rad respectively.
10. Maximum & Minimum Bending Moment in Z-direction are **277.68 KN-m** & **-228.45** KN-m.
11. Maximum & Minimum Shear Force in Y-direction are **198.77 KN** & **-157.74 KN**.
12. Maximum & Minimum Axial Force in X-direction are 4694.68 KN & -654.92 KN.

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