

# ANALYSIS, DESIGN AND ESTIMATION OF BASEMENT+G+2 RESIDENTIAL BUILDING

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**Abstract** - Structural analysis is a branch which involves determination of behavior of structures in order to predict the responses of real structures such as buildings, bridges, trusses etc, with economy, elegance, serviceability and durability of structure. Structural engineers are facing the challenge of striving for the most efficient and economical design with accuracy in solution, while ensuring that the final design of a building must be serviceable for its intended function over its design lifetime. This project attempts to understand the structural behavior of various components in the multi-storied building. Analysis, designing and estimation of multi-storied building has been taken up for Basement+G+2 Building, thereby depending on the suitability of plan, layout of beams and positions of columns are fixed. Dead loads are calculated based on material properties and live loads are considered according to the code IS875-part 2, footings are designed based on safe bearing capacity of soil. For the design of columns and beams frame analysis is done by limit state method to know the moments they are acted upon. Slab designing is done depending upon the type of slab (one way or two way), end conditions and the loading. From the slabs the loads are transferred to the beams, thereafter the loads from the beams are taken up by the columns and then to footing finally the section is checked for the components manually and using ETABS 15.0.0 software for the post analysis of structure, maximum shear force, bending moment and maximum storey displacement are computed. The quantitative estimation has been worked out.

**Key Words:** NBC, ETABS, Multi-storied Building, Isolated Footing, Open Newel Quarter Turn Staircase, Estimation.

## 1. INTRODUCTION

Structural analysis means determination of the general shape and all the specific dimensions of a particular structure so that it will perform the function for which it is created and will safely withstand the influences which will act on it throughout its useful life.

Due to concentration and increase of population into urban cities, there is a need to accommodate the influx in urban cities. However, due to rapid increase of land cost and limited availability of land, constructions of Multi-storied buildings is taking part in our daily life. A multi-storied is a building that has multiple floors above ground in the building. Multi-storied buildings aim to increase the floor

area of the building without increasing the area of the land, the building is built on and hence saving land and in most cases money (depending on material used and land prices in the area). The design process of multi storied building requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering<sup>[1]</sup>. In the present study Basement+G+2 building is considered for the analysis of building using ETABS software 15.0.0.

The project deals with the planning and designing of building of reinforced concrete framed structure using IS 456:2000 code. IS 456:2000 is the basic code for general construction in concrete structures, hence all the structural members are designed using limit state method in accordance with the IS 456:2000 code. The planning of any building in India will recognized by national building code (NBC)<sup>[1]</sup>. Hence the building is planned in accordance with the NBC.

Load consideration is in accordance with IS 875-part2. Modeling of the building is done in ETABS and is analyzed to get the deformation, bending moment, shear force and area of steel requirement. Structural members like slab, beam, column and footing are designed manually based on the values of bending moment and shear force obtained.

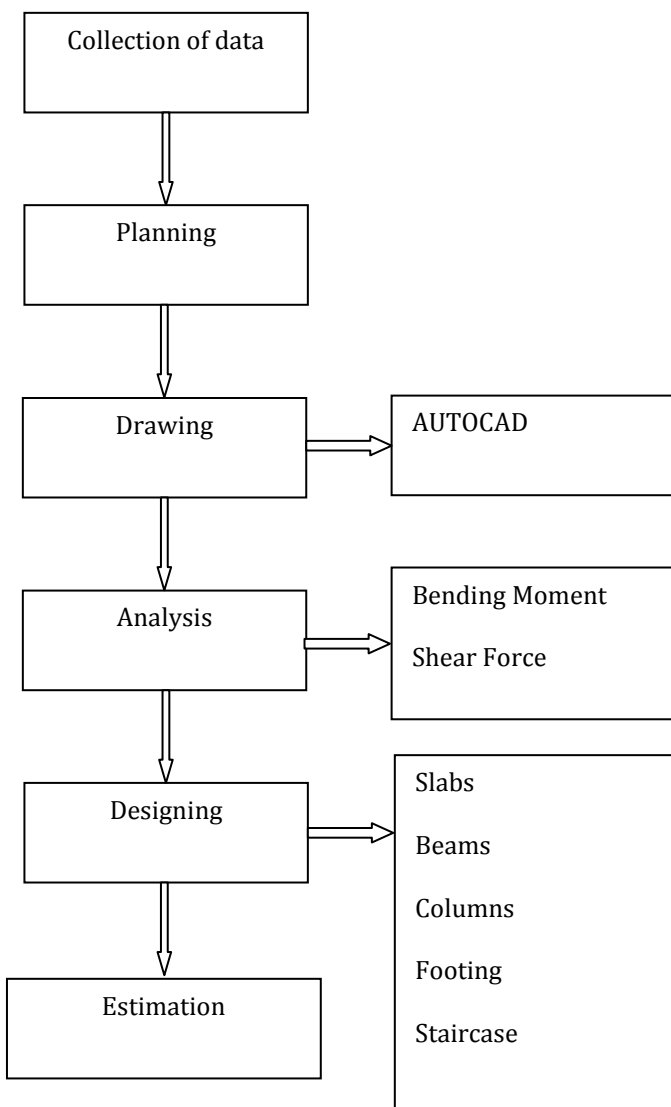
## 2. LITERATURE REVIEW

**M. Mallikarjun, Dr P V Surya Prakash (2016):** Carried study on analysis and design of a multi-storied residential building of ung-2+G+10 by using most economical column method and the dead load and live load was applied on the various structural component like slabs, beams and found that as the study is carried using most economical column method this was achieved by reducing the size of columns at top floors as load was more at the bottom floor. The economizing was done by means of column orientation in longer span in longer direction as it will reduce the amount of bending and the area of steel was also reduced<sup>[3]</sup>.

**P.P. Chandurkar et al (2013):** Had presented study of G+9 building having three meters height for each storey. The whole building design had carried out according to IS code for seismic resistant design and the building had considered fixed at base. Structural element for design had assumed as square or rectangular in section. They had done modeling of building using ETAB software in that four different models were studied with different positioning of shear walls<sup>[5]</sup>.

**Ismail Sab, Prof .S.M. Hashmi (2014):** Generated 3D analytical model of twelve storied buildings for different buildings Models and analyzed using structural analysis tool ETABS. To study the effect of infill, ground soft, bare frame and models with ground soft having concrete core wall and shear walls and concrete bracings at different positions during earthquake; seismic analysis using both linear static, linear dynamic (response spectrum method) has been performed. The analytical model of the building includes all important components that influence the mass, strength, stiffness and deformability of the structure [7].

### 3. METHODOLOGY



### 4. BUILDING DATA FOR ANALYSIS

#### Salient Features

- Utility of Building : Residential Building
- Area of the site: 70 X 60 (ft)
- Building Height: 47 ft
- Number of Storey: (BASEMENT+G+2)
- Type of construction : R.C.C Framed Structure
- Shape of Building :Rectangular
- Number of staircase: one
- Number of Lift: One
- Type of Walls : Brick Wall

• Dimensions Of Beams	B <sub>1</sub> 230x300 mm B <sub>2</sub> 230x380 mm
• Dimensions of Column	C <sub>1</sub> 230x380 mm C <sub>2</sub> 230x460 mm C <sub>3</sub> 230x600 mm
• Thickness of Slab	4.5" (140mm)
• Thickness of External Wall	9" (230mm)
• Thickness of Internal Wall	5" (120mm) (as per IS:875 part2)
• Live Load	1.5kN/m <sup>2</sup>
• Floor Finish	
• All rooms and Kitchen	2kN/m <sup>2</sup>
• Toilet and Bathroom	2kN/m <sup>2</sup>
• Corridor, Staircase and Balcony	3N/m <sup>2</sup>

## 5. ANALYSIS AND DESIGN OF BASEMENT + G + 2 BUILDING USING ETABS

### Step - 1: Step by Step procedure for ETABS Analysis

The procedure carried out for Modeling and analyzing the structure involves the following flow chart.

### Step - 2: Creation of Grid points & Generation of structure

After getting opened with ETABS we select a new model and a window appears where we had entered the grid dimensions and story dimensions of our building. Here itself we had generated our 3D structure by specifying the building details in the following window.

### Step - 3: Defining of property

Here we had first defined the material property by selecting define menu, material properties. We add new material for our structural components (beams, columns, slabs) by giving the specified details in defining. After that we define section size by selecting frame sections as shown below & added the required section for beams, columns etc.

### Step - 4: Assigning of Property

After defining the property we draw the structural components using command menu

Draw line for beam for beams and create columns in region for columns by which property assigning is completed for beams and columns.

### Step - 5: Assigning of Supports

By keeping the selection at the base of the structure and selecting all the columns we assigned supports by going to assign menu, joint\frame, Restraints (supports), fixed.

### Step - 6: Defining of loads

The loads in ETABS are defined as using static load cases command in define menu

### Step - 7: Assigning of Dead loads

After defining all the loads dead loads are assigned for external walls, internal walls

### Step - 8: Assigning of Live loads

Live loads are assigned for the entire structure including floor finishing.

### Step - 11: Assigning of load combinations

Load combinations is based on IS 875 1987 PART 5 using load combinations command in define menu

### Step - 12: Analysis

After the completion of all the above steps we have performed the analysis and checked for errors.

### Step - 13: Design

After the completion of analysis we had performed concrete design on the structure as per IS 456:2000.

For this go to Design menu, concrete design, select design combo. After this again goes to design menu, concrete frame design, start design \ check of structure then ETABS performs the design for every structural element.

## 5.1 Plan of the Building

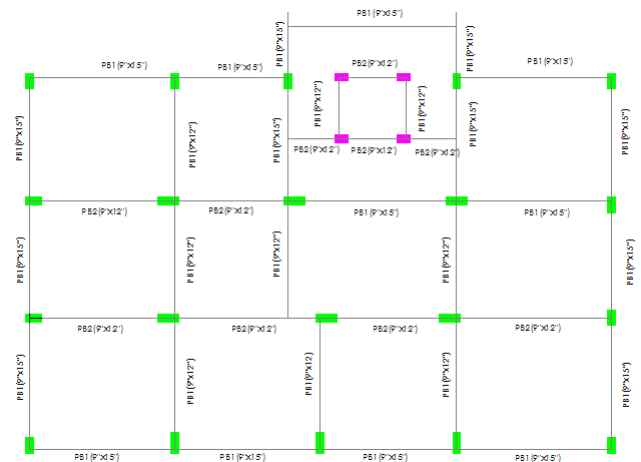


Fig-1: Plan of the building

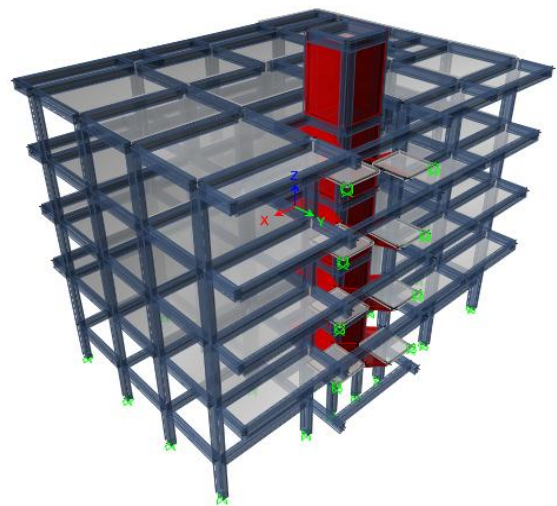


Fig-2: 3-D View of Frames and Slabs

## 5.2 Design of Structural components

### 5.2.1 Slabs

Slab is plate elements forming floor and roofs of buildings carrying distributed loads primarily by flexure. A concrete slab is common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 4 and 20 inches (100 and 500 mm) thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving.

Slabs may be classified into 2 types depending on ratio of larger side to shorter side, its recommended in IS 456 to design slabs having (ly/lx) ratio greater than 2 as one way slab and slabs having (ly/lx) less than 2 as two way slab.

### Design of Slabs

#### Step 1:

Assume thickness of slab = 0.14m=140mm

(Providing clear cover of 20mm) effective depth = 0.12m =120mm

Density of concrete = 25KN/m<sup>3</sup>

#### Step 2:

#### Effective span

Lx = 1.51m

Width = 1.0m

#### Step 3

#### Load calculation

Dead load = 3kN/m

Live load = 2kN/m

Floor finish = 1.5kN/m

Total factored load = 1.5\*(3+2+1.5) = (9.75kN/m)

#### Step 4

#### Design moment for cantilever beam

$$M_u = \frac{wl^2}{2} = \frac{9.75 \cdot 1.51^2}{2} = 12.83 \text{ kN} - \text{m}$$

#### Step 5

#### Main steel reinforcement

$$A_{st}(\text{req}) = \frac{0.5 \times f_{ck}}{f_y} * \left( 1 - \text{sqrt} \left( 1 - \left( \frac{M_u \cdot 10^6}{f_{ck} \cdot b \cdot d^2} \right) \right) \right) (b * d)$$

$$= \frac{0.5 \cdot 20}{415} * \left( 1 - \text{sqrt} \left( 1 - \left( \frac{12.83 \cdot 10^6}{20 \cdot 1000 \cdot 120^2} \right) \right) \right) (1000 * 120)$$

$$A_{st}(\text{req}) = 313.13 \text{ mm}^2$$

$$A_{st}(\text{min}) = \frac{0.12 \cdot b \cdot d}{100} = \frac{0.12 \cdot 1000 \cdot 140}{100} = 168 \text{ mm}^2$$

Consider 10mm dia bar Area = 78.53mm<sup>2</sup>

$$S_v(\text{req}) = \frac{78.53 \cdot 1000}{313.33} = 250.85 \text{ mm}$$

Providing spacing of 230mm

$$A_{st}(\text{pro}) = \frac{78.53 \cdot 1000}{230} = 341.52 \text{ mm}^2$$

Therefore provide 10mm dia @230mmc/c

#### Step 6

#### Distribution steel reinforcement

Provide minimum reinforcement of 168.0mm<sup>2</sup>

Consider 8mm dia bar for distribution bar

$$\text{Spacing required} = S_v = \frac{50.26 \cdot 1000}{168} = 299 \text{ mm}$$

Spacing provided = 280mm

#### Step 7

#### Check for deflection

$$P_t = \frac{100 \cdot A_{st}(\text{pro})}{b \cdot d} = \frac{100 \cdot 341.53}{1000 \cdot 120} = 0.28$$

$$f_s = \frac{0.58 \cdot f_y \cdot A_{st}(\text{req})}{A_{st}(\text{pro})} = \frac{0.58 \cdot 250 \cdot 313.3}{341.52} = 132.94 \text{ N/mm}^2$$

Kt = 2.00

$$\left( \frac{l}{d} \right)_{\text{max}} = 7 * Kt = 7 * 2.00 = 14.00$$

$$\left( \frac{l}{d} \right)_{\text{pro}} = \left( \frac{1.51 \cdot 1000}{120} \right) = 12.583$$

$$\left( \frac{l}{d} \right)_{\text{max}} > \left( \frac{l}{d} \right)_{\text{pro}} \text{ Hence safe}$$

#### Step 8

#### Check for shear

$$V_u = \frac{w \cdot l}{2} = \frac{9.75 \cdot 1.51}{2} = 8.49 \text{ kN}$$

$$\tau_v = \frac{V_u}{b \cdot d} = \frac{8.49}{1000 \cdot 120} = 0.071$$

$\tau_c = 0.40$

Since  $\tau_v < \tau_c$  no shear reinforcement required

#### Step 9

#### Torsion reinforcement

$$\text{Mesh size} = \frac{l_x}{5} = 0.302 \text{ m}$$

$$A = \frac{3}{4} * Ast = \frac{3}{4} * 341.52 = 256.14mm^2$$

Area of 8mm dia = 50.4mm<sup>2</sup>

$$Sv = \frac{1000 * 50.4}{256.14} = 196.79mm$$

Sv(pro) = 190mm

Therefore provide torsion reinforcement of 8mm mesh bar @190mm/c

### 5.2.2 Beams

Beams shall normally be provided under the wall or bellow a heavy concentrated load. Beams transfer load from slabs to columns, beams are designed for bending. In general we have two types of beam: single and double. Similar to columns geometry and perimeters of the beams are assigned.

There are three types of reinforced concrete beams

1. Single reinforced beams
2. Double reinforced concrete
3. Flanged beams

#### Design of Beam

##### Step 1

Beam size 230\*380

Span =4.20m

Breadth b =230mm

Depth D=380mm

$$\text{Effective depth} = 380 - 25 - \frac{12}{2} = 349mm$$

BM (Muy) (left) = 28.4kN-m

SF = 66.2kN-m

fck=20N/mm<sup>2</sup>

fy=415N/mm<sup>2</sup>

##### Step 2

$$Mulim = 0.138 * fcb * b * d^2$$

$$= 0.138 * 20 * 0.23 * (0.349)^2$$

$$= 77.32kN-m$$

Mu < Mulim

Therefore design the beam as singly reinforced beam.

##### Step 3

#### Area of steel reinforcement

$$Ast(REQ) = \frac{0.5 * 20}{415} \left( 1 - \sqrt{1 - \left( \frac{28.4 * 10^6}{20 * 230 * 349^2} \right)} \right) (230 * 349)$$

$$= 240.44mm^2$$

$$Ast(min) = \frac{0.12 * 230 * 380}{100} = 104.88mm^2$$

Consider 12mm dia bar

$$\text{Number of bars required} = \frac{240.44}{\left(\frac{\pi}{4} * 12\right)^2} = 2.12$$

Number of bars provided = 3 bars

$$Ast \text{ provided} = 3 * \left(\frac{\pi}{4} * 12\right)^2 = 339.3mm^2$$

##### Step 4

#### Check for deflection

$$\text{Percentage of steel (Pt)} = \frac{100 * Ast(pro)}{b * d} = \frac{100 * 339.3}{230 * 349} = 0.39\%$$

$$fs = 0.58 * fy * \frac{Ast(REQ)}{Ast(pro)}$$

$$fs = 0.58 * 250 * \frac{240.44}{339.3} = 102.74N/mm^2$$

Kt = 2.00

$$\left(\frac{l}{d}\right)_{max} = 26 * Kt$$

$$= 26 * 2$$

$$= 52$$

$$\left(\frac{l}{d}\right)_{pro} = \left(\frac{4.20 * 1000}{249}\right) = 12.04$$

$$\left(\frac{l}{d}\right)_{pro} < \left(\frac{l}{d}\right)_{max}$$

Hence safe against deflection

##### Step 5

#### Design of shear reinforcement

$$\tau_v = \frac{Vu}{b * d} = \frac{66.2 * 10^3}{230 * 349} = 0.82$$

$$\tau_v = 0.82$$

$$\tau_c = 0.42$$

Since  $\tau_v > \tau_c$  shear reinforcement is required

For shear design consider 2 legged stirrups of 8mm dia

$$V_{us} = V_u - \tau_c * b * d$$

$$= 66.2 * 10^3 - 0.42 * 230 * 349 = 32487 \text{ N}$$

$$A_{sv} = 2 * \frac{\pi}{4} * 8^2 = 100.54 \text{ mm}^2$$

$$S_v = \frac{0.87 * A_{sv} * f_y * d}{V_{us}} = \frac{0.87 * 100.54 * 250 * 349}{32487}$$

$$S_v = 234.19 \text{ mm say } 230 \text{ mm}$$

### Step 6

#### Minimum shear reinforcement

$$S_v = \frac{0.87 * f_y * A_{sv}}{0.4 * b} = \frac{0.87 * 250 * 100.54}{0.4 * 230}$$

$$S_v = 237.70 \text{ mm say } = 230 \text{ mm}$$

### Step 7

#### Reinforcement

Provide 3#12mm dia @ mid span

5#12mm dia @ sides

2 legged 8mm dia @ 230mm/c.

### 5.2.3 Column

A column or strut is a compression member, which is used primarily to support axial compressive loads and with a height of at least three it is least lateral dimension. A reinforced concrete column is said to be subjected to axially load when line of the resultant thrust of loads supported by column is coincident with the line of C.G of the column in the longitudinal direction.

#### Design of Column

##### Step 1

Column size 230\*460

Breadth = b = 230mm

Depth = D = 460mm

$$P_u = 1316.4 \text{ kN}$$

$$M_{ux} = 6.6 \text{ kN-m}$$

$$M_{uy} = 1.3 \text{ kN-m}$$

$$f_{ck} = 25 \text{ N/mm}^2$$

$$f_y = 415 \text{ N/mm}^2$$

$$d' = 40$$

##### Step 2

$$\frac{P_u}{(f_{ck} * b * d)} = \frac{1316.4 * 10^3}{25 * 230 * 460} = 0.497$$

$$M_u = 1.15 * \text{sqrt}(M_{ux}^2 + M_{uy}^2)$$

$$= 1.15 * \text{sqrt}(6.6^2 + 1.3^2)$$

$$= 7.74 \text{ kN-m}$$

$$\frac{M_u}{f_{ck} * b * d^2} = \frac{7.74 * 10^6}{25 * 230 * 460^2} = 0.00636$$

$$d'/D = 0.11$$

Using sp-16 chart -45

$$p/f_{ck} = 0.02$$

$$P = 0.02 * f_{ck} = 0.02 * 25$$

$$= 0.5$$

$$A_{sc} = \frac{p * b * d}{100} = \frac{0.5 * 230 * 460}{100}$$

$$A_{sc} = 529 \text{ mm}^2$$

Provide 6 bars of 12mm dia

$$A_{sc \text{ pro}} = 678.67 \text{ mm}^2$$

$$\text{Actual } p = \frac{(A_{sc \text{ pro}} * 100)}{b * d} = \frac{678.67 * 100}{230 * 460}$$

$$\text{Actual } p = 0.641$$

$$p/f_{ck} = \frac{0.641}{25} = 0.0257$$

##### Step 3

#### To find $M_{ux1}$

$$p/f_{ck} = 0.0257$$

$$P_u / (f_{ck} * b * d) = 0.02$$

$$d'/D = 0.11$$

from chart 46

$$\frac{M_{ux1}}{f_{ck} * b * d^2} = 0.0157$$

$$M_{ux1} = 0.015 * 25 * 230 * 460^2$$

= 19.102kN-m

**Step 4**

**To find  $M_{uy1}$**

Since  $p/fck, \frac{pu}{fck \cdot b \cdot d}, d'/D$  are same  $\frac{M_u}{fck \cdot b \cdot d}$  are also same therefore

$M_{uy1} = 19.102kN-m$

**Step 5**

**To find  $P_{uz}$**

$P_{uz} = 0.45 \cdot f_{ck} \cdot A_c + 0.75 \cdot f_y \cdot A_{sc}$

$A_c = b \cdot D - A_{sc}(pro)$

=  $230 \cdot 460 - 678.87$

=  $105121mm^2$

$P_{uz} = 0.45 \cdot 25 \cdot 105121 + 0.75 \cdot 415 \cdot 678.87$

= 1393.9

**Step 6**

**To find  $\alpha_n$**

$$\frac{p_u}{p_{uz}} = \frac{1316.4}{1393.9} = 0.944$$

This is exceeding value of 0.8

Therefore  $\alpha_n = 2$

$$\left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha_n} + \left(\frac{M_{uy}}{M_{uy1}}\right)^{\alpha_n}$$

$$= \left(\frac{6.6}{19.102}\right)^2 + \left(\frac{1.3}{19.102}\right)^2$$

=  $0.124 < 1$

Hence safe

**Step 7**

**Design of Ties**

Consider diameter of Ties = 8mm

Maximum spacing

- 1) b or D = 230mm
- 2)  $16 \cdot 12 = 190mm$
- 3) 300mm (therefore provide 8mm dia bar @190mm/c)

**5.2.4 Isolated Footing**

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

**Design of Footing**

**Step 1**

Column size  $230 \cdot 460$

Factored load on footing =  $p_u = 1316.4kN$

Working load on footing =  $\frac{1316.4}{1.5} = 877.61kN$

Assume self weight of footing =  $\frac{10}{100} \cdot p = \frac{10}{100} \cdot 877.61 = 87.76kN$

Total load  $w = p + 0.1p$

=  $877.61 + 87.76$

=  $965.37kN$

**Step 2**

Area of footing required  $A = \frac{w}{SBC}$

Consider SBC of soil =  $200kN/m^2$

Area =  $\frac{965.37}{200} = 4.83m^2$

For rectangular footing

Consider length of the footing (L) =  $3.20m$

Therefore the breadth (B) =  $\frac{4.83}{3.20} = 1.60$

Area provided =  $3.20 \cdot 1.60$

=  $5.12m$

**Step 3**

**Upward factored soil reaction ( $w_u$ )**

$$W_u = \frac{p_u}{A} = \frac{1316.4}{5.12} = 257.11kN/m^2$$

**Step 4**

a) Bending moment about axis x-x passing through face of column as

$$M_{ux} = w_u * B * \left(\frac{l-d}{2}\right)^2 * 0.5$$

$$M_{ux} = 0.5 * 257.11 * 1.60 * \left(\frac{3.20 - 0.460}{2}\right)^2$$

$$= 386.1 \text{ kN-m}$$

b) Bending moment about axis y-y passing through face of the column

$$M_{uy} = 0.5 * w_u * L * \left(\frac{B-b}{2}\right)^2$$

$$M_{uy} = 0.5 * 257.11 * 3.20 * \left(\frac{1.60 - 0.23}{2}\right)^2$$

$$M_{uy} = 193.0 \text{ kN-m}$$

### Step 5

Effective depth required

$$d_{req} = \sqrt{\frac{M_{ux}}{0.138 * f_{ck} * b}}$$

$$= \sqrt{\frac{386.1 * 10^6}{0.138 * 20 * 1600}}$$

$$= 295.7 \text{ mm}$$

Increase depth 1.75 to 2 times due to shear considerations

$$\text{Depth provided} = 2 * d_{pro} = 2 * 295.7 = 591.3 \text{ mm}$$

$$\text{Effective depth provided} = 600 \text{ mm}$$

### Step 6

#### Area of reinforcement along x-direction

$$a) \quad A_{stx} = \frac{0.5 * 20}{415} \left( 1 - \sqrt{1 - \frac{4.6 * 386.1 * 10^6}{20 * 1600 * 600^2}} \right) (1600 * 600)$$

$$A_{stx} = 1857.60 \text{ mm}^2$$

Consider 16mm dia bar

$$\text{Number of bars} = \frac{1857.60}{\frac{\pi}{4} * 16^2} = 9.23 \text{ say } 10 \text{ bars}$$

Provide 10 bars of 16mm dia along x-axis

$$b) \quad A_{sty} = \frac{0.5 * f_{ck}}{415} \left( 1 - \sqrt{1 - \frac{4.6 * M_{uy}}{f_{ck} * b * d^2}} \right) * b * d$$

$$= \frac{0.5 * 20}{415} \left( 1 - \sqrt{1 - \frac{4.6 * 193 * 10^6}{20 * 1600 * 600^2}} \right) * 1600 * 600$$

$$= 909.38 \text{ mm}^2$$

Consider 16mm dia bar

$$\text{No. of bars} = \frac{909.38}{\frac{\pi}{4} * 16^2} = 4.52 \text{ say } 5 \text{ bars}$$

Therefore provide 5 bars of 16mm dia along y- axis

### Step 7

#### Check for one way shear

$$V_u = w * B * \left(\frac{l-d}{2} - d\right)$$

$$= 257.11 * 1.60 * \left(\frac{3.20 - 0.460}{2} - 0.6\right)$$

$$V_u = 316.8 \text{ kN}$$

$$\tau_v = \frac{V_u}{b * d} = \frac{316.8 * 10^3}{1600 * 600} = 0.330$$

$$P_t = \frac{100 * A_{stx}(pro)}{b * d} = \frac{100 * 10 * \frac{\pi}{4} * 16^2}{1600 * 600}$$

$$P_t = 0.209$$

Refer table no.19 IS 456-2000 for  $\tau_c$  value

$$\tau_c = 0.327$$

Since  $\tau_v < \tau_c$  safe for one way shear

### Step 8

#### Check for two way shear

$$V_u = w_u * (A - ((D+d) * (B+b)))$$

$$= 257.1 * ((320 * 1.60) - (0.46 * 0.60) * (0.23 * 0.6))$$

$$V_u = 1090.2 \text{ kN}$$

$$b_o = \text{perimeter} = 2 * (D+d) + 2 * (b+d)$$

$$= 2 * (0.46 + 0.6) + 2 * (0.23 + 0.6)$$

$$b_o = 3.78 \text{ m}$$

$$\text{Nominal stress } \tau_v = \frac{V_u}{b_d} = \frac{1090.2 * 10^3}{3780 * 600}$$

$$\tau_v = 0.48$$

$$\tau_c = 0.25 * \sqrt{f_{ck}}$$

$$= 0.25 * \sqrt{20}$$

$$= 1.118$$

$$K = 0.5 + \beta$$



Where  $\beta = \frac{B}{D} = \frac{0.23}{0.46}$

$K = 0.5 + 0.5 = 1.0$

Therefore  $\tau c' = k * \tau c$

$\tau c' = 1 * 1.118$

Therefore = 1.118

Since  $\tau c' > \tau v$  The design is safe against two way shear.

**5.2.4 Open Newel Quarter Turn Staircase**

The type of stair and its layout is governed essentially by the available size of staircase room and the positions of the beams and columns along the boundary of the staircase. The slabs, in general, are heavy compared to floor slab-because of Greater live load on stairs than that on floors. Therefore, longer spans for the flights are avoided as far as possible.

Stair flight shall preferably be supported on beams or walls. Supporting the flight on landing slab should be avoided as far as possible. Wherever possible, landing beams may be provided at this end of flight to reduce the span.

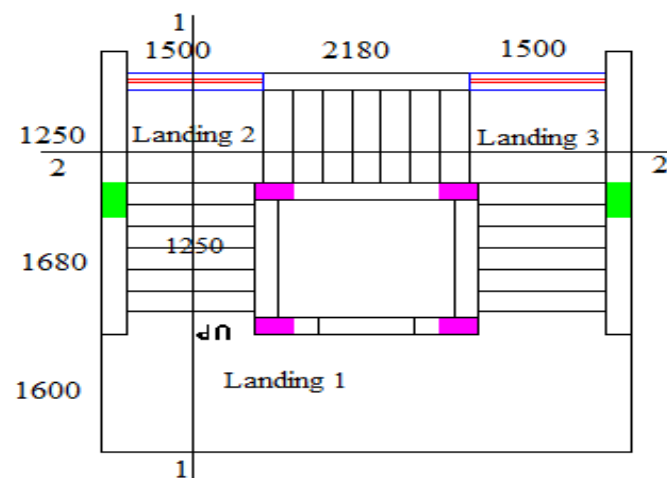


Fig-3: Staircase Plan

**Design of Staircase**

Floor height = 3m

$f_{ck} = 25N/mm^2$

$f_y = 500N/mm^2$

**Step 1**

Consider flight of 1m each

Assume riser of 125mm

Number of riser = 8

Number of treads = 7

Treads = 240mm

Total going = 7\*240=1680mm

Width of each landing 2 and 3 = 1500mm

The landing slab is spanning longitudinally along section 1-1. Landing slab 2 is common to spans of 1-1 and 2-2. Crossing at right angles clause (33.2 of IS 456). The effective span of sec 1-1 shall be from centre line of edge beam to centre line of bridge wall. While the effective span for section 2-2 shall be from centre line of landing slab 2 to centre line of landing slab 3( CI 33.1 b of IS 456).

**Design of landing slab 1 and going**

**Step 2**

**Effective span and depth of slab.**

Effective span =  $150 + 1600 + 1680 + \frac{1250}{2} = 4055mm$ .

Depth of waist slab is assumed as  $= \frac{4055}{20} = 202.75 = D = 200mm$

The effective depth  $d = 175mm$

The landing slab is also assumed to have total depth of 200mm and effective depth of 175mm

**Step 3**

**Calculations of loads**

1) loads on going (on projected plan area)

a) Self weight of waist slab =  $D * \text{sqrt}(1 + \text{riser}^2 / \text{tread}^2) * 25$

=  $0.2 * \text{sqrt}(1 + \frac{125^2}{240^2}) * 25$

=  $0.20 * 1.1275 * 25$

=  $5.63kN/m^2$

b) Self weight of steps =  $25 * (\text{riser})$

=  $\frac{1}{2} * 25 * (0.125)$

=  $1.5625kN/m^2$

c) Finish load =  $1.0kN/m^2$

d) Live load =  $35.0kN/m^2$

Total load =  $11.193kN/m^2$

Factored load =  $1.5 \times 11.193 = 16.78 \text{ kN/m}^2$

$K = 1.20$

2) Landing slab 1

$$\tau_c = 1.2 \times (0.28) = 0.336$$

Self weight of slab =  $250 \times 0.20 = 5 \text{ kN-m}$

Finish load =  $1.00 \text{ kN/m}^2$

Live load =  $3.00 \text{ kN/m}^2$

Total =  $9 \text{ kN/m}^2$

Factored load =  $13.5 \text{ kN/m}^2$

$\tau_{cmax} = \tau_v < \tau_c < \tau_{max}$  The design is safe.

**Step 6**

**Determination of areas of steel reinforcement**

3) Landing slab 2 = 50% of load n landing slab 1 =  $6.75 \text{ kN/m}^2$

$$A_{st} = \frac{0.5 \times 20}{415} \times \left( 1 - \text{sqrt} \left( 1 - \left( \frac{4.6 \times 37.67 \times 10^6}{20 \times 1000 \times 175^2} \right) \right) \right) \times 1000 \times 175$$

$$= 645.97 \text{ mm}^2$$

The total loads of 1, 2 and 3

Total loads (1) going =  $16.78 \times 1.68 \times 1.25$

=  $35.23 \text{ kN}$

Total loads (2) landing slab (1) =  $13.5 \times 1.6 \times 1.25$

=  $27.00 \text{ kN}$

Total loads (3) landing slab (2) =  $6.75 \times 0.625 \times 1.25$

=  $5.27 \text{ kN}$

Total =  $67.50 \text{ kN}$

Use 12mm dia bars

$$S_v = \frac{\pi \times 12^2}{4} \times 1000 = 175.08 \text{ mm}$$

Use 12mm dia bars @ 170mm c/c

Distribution steel reinforcement

**Step 4**

Bending moment and shear force width = 1.250mm

$$A_{st} = \frac{0.12 \times 1000 \times 200}{100} = 240 \text{ mm}^2$$

$V_p = (27(4.055 - 0.875) + 35.23(4.055 - 2.59) + 5.27(0.3125)) / 4.055$

$$S_v = \frac{\pi \times 8^2}{4} \times 1000 = 200 \text{ mm}$$

$$V_p = \frac{39.11}{4.055}$$

Use 8mm dia @ 200mm c/c

$$V_p = 34.30 \text{ kN}$$

**Design of landing slabs 2 and 3**

$$V_j = 67.5 - 34.30$$

**Step 1**

$$V_j = 33.20 \text{ kN}$$

Effective span and depth of slab

The distance x where shear force is zero is obtained

The effective span from the centre line of landing slab 2 to the centre line of landing of 3 =  $750 + 1680 + 750$

$$34.30 - 27 - 16.78 \times (1.25) \times (X - 1.75) = 0$$

$$X = 2.098 \text{ m}$$

The depth of the waist slab and landing is maintained as 200mm

$$= 34.30(2.098) - 27(1.223) - 16.78(1.25)(0.348 \times 0.348) \times 0.5$$

**Step 2**

$$= 37.67 \text{ kN-m}$$

**Calculation of loads**

**Step 5**

**Check for depth**

$$d = \text{sqrt} \left( \frac{37.67 \times 10^6}{1250 \times 2.76} \right) = 104.49 \text{ mm}$$

$$104.9 < 175 \text{ mm}$$

- (1) Load on going ( step 2(1) of A ) =  $16.78 \text{ kN/m}^2$
- (2) Loads on landing slab 2 (step 2(3)) =  $6.75 \text{ kN/m}^2$
- (3) Loads on landing slab 3 (step 2(3)) =  $6.78 \text{ kN/m}^2$

Total factored load

$$\text{For maximum shear force } \tau_v = \frac{39.11 \times 10^3}{1250 \times 175} = 0.178 \text{ N/mm}^2$$

- 1) Going =  $16.78(1.68) \times (1.25) = 35.23 \text{ kN}$ .
- 2) Landing slab A =  $6.75 \times 0.875(1.25) = 7.3 \text{ kN}$
- 3) Landing slab B =  $6.75(0.625)(1.25) = 5.27 \text{ kN}$ .

Total =  $47.88 \text{ kN}$ .

For depth of slab as 200 (C.I.402.1.1 OF IS456)

**Step 3**

**Bending moment and shear force (width =1.25m)**

- 1) The total load is 47.88kN/m<sup>2</sup> and symmetrically placed to give Vg=Vh= 23.94kN.
- 2) The maximum bending moment at x = 1.59m(centre line of span 3.18m= 23.94\*1.95-7.38(1.59-0.4375)-16.78\*1.25\*(0.715)(0.715\*(0.5)  
 Moment = 20.96nN-m  
 Shear force = 23.94kN

(Since the maximum bending moment and shear force are less than those of other section, maximum moment = 37.67 and shear force = 34.30kN)

The depth of 200mm here is ok . Accordingly the amount reinforcing is determined.

$$A_{st} = 346mm^2$$

Providing 12mm dia bars

$$\frac{\pi * 12^2}{4} * 1000 = 300mm$$

Distribution bars are of 8mm dia @200mmc/c.

**6. ESTIMATION**

Estimating is the technique of calculating or computing the various quantities and the expected expenditure to be incurred on a particular work or project.

Following requirement are necessary for preparing an estimate

- a. Drawings like plan, elevation and section of important parts.
- b. Detailed specifications about workmanship and properties of materials etc.
- c. Standard schedule of rates of the current year.

Before taking up any work for its execution, the owner or builder should have a thorough knowledge of work that can be completed within the limits of his funds or the probable cost that may be required to complete the proposed work.

It is therefore necessary to prepare the probable cost or estimate for the proposed work from its plan and specifications. Otherwise, it may so happen that the work has to be stopped before it is complete due to shortage of funds or of materials. Besides the above, an estimate for any public construction work is required to be prepared and submitted beforehand so that section of necessary funds may be obtained from the authority concerned.

Estimation is Done by	Centre Line Method
Estimation is Done Using	Microsoft Excel

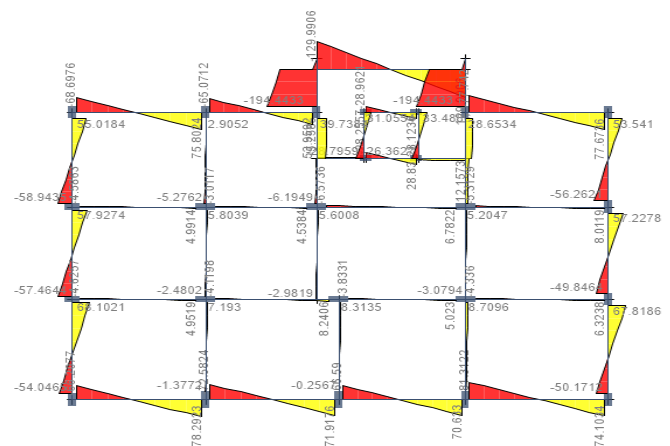
STOREY	INR (Rs)
BASEMENT FLOOR =	28,50,000.00
GROUND FLOOR =	30,90,000.00
FIRST FLOOR =	34,40,000.00
SECOND FLOOR =	36,11,000.00
GRAND TOTAL=	129,91,000.00
RUPEES ONE CRORE TWENTY NINE LAKHS NINETY ONE THOUSAND ONLY.	

**Table-1:** Estimation of the Building

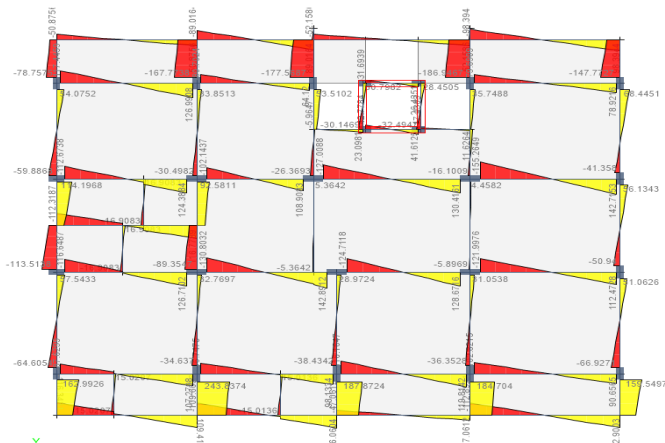
**7. ETABS OUTPUT**

**7.1 Shear Force**

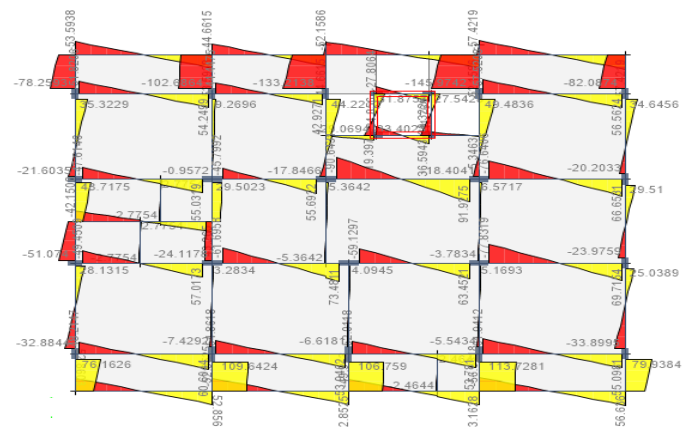
Basement



**Fig-4:** Shear Force Values of Basement Floor Ground Floor



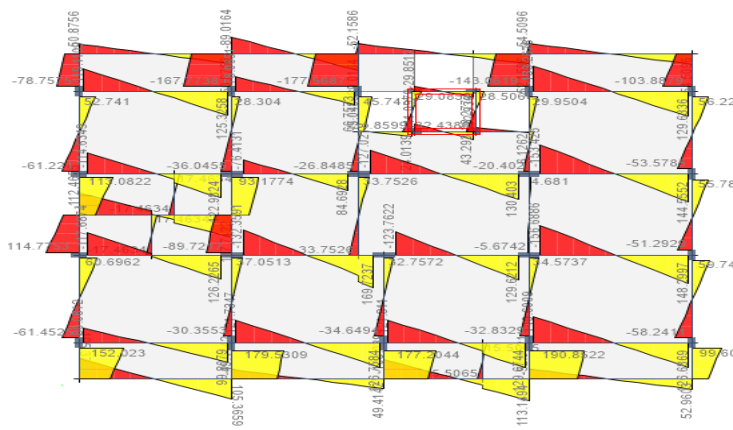
**Fig-5:** Shear Force Values of Ground Floor First Floor



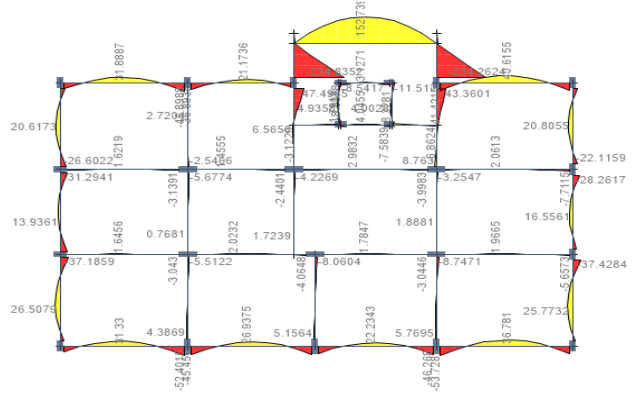
**Fig-8:** Shear Force Values of Terrace

**7.2 Bending Moment**

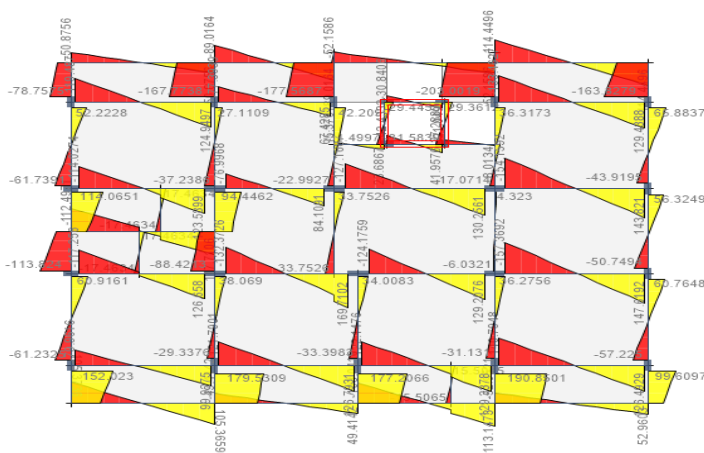
**Basement**



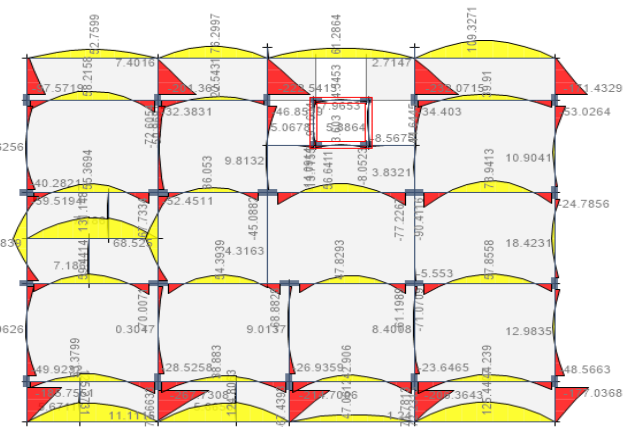
**Fig-6:** Shear Force Values of First Floor Second Floor



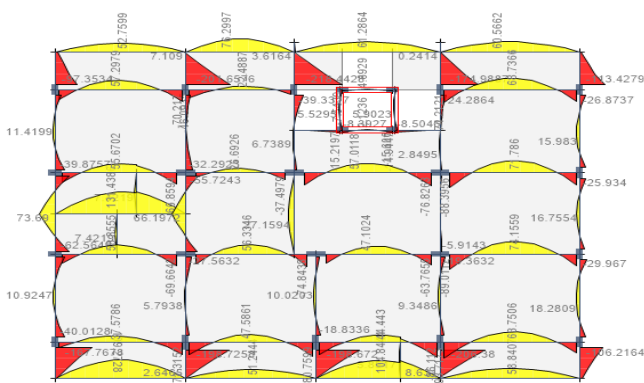
**Fig-9:** Bending Moment Values of Basement Ground Floor



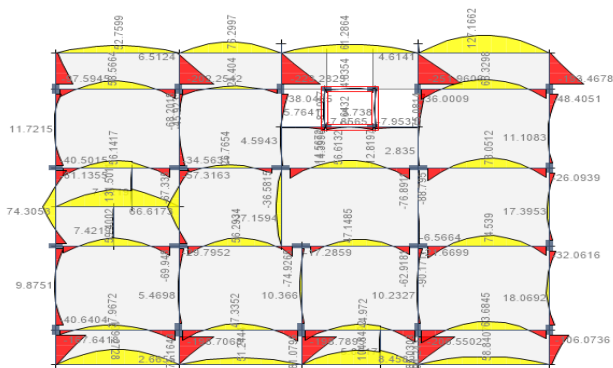
**Fig-7:** Shear Force Values of Second Floor Terrace



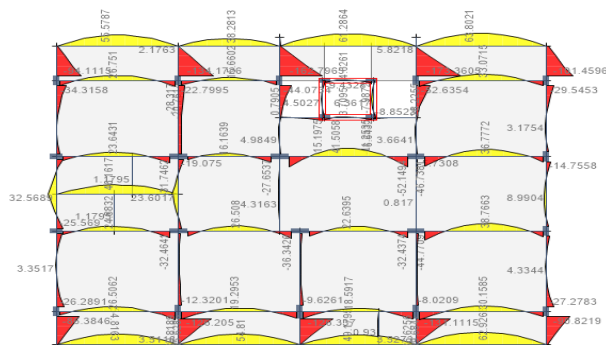
**Fig-10:** Bending Moment Values of Ground Floor First Floor



**Fig-11:-** Bending Moment Values of First Floor  
Second Floor



**Fig-12:-** Bending Moment Values of Second Floor  
Terrace



**Fig-13:-** Bending Moment Values of Terrace

## 8. CONCLUSIONS

- From the analysis and design of the slabs and beams it was found that the check for deflection and shear was safe.
- The Columns were designed using SP-16 and was checked for interaction formula and was found to be safe.
- The footing were designed and checked for one way shear and two way shear was found to be safe and

the load was found to be less the safe bearing capacity of the soil.

- In the present scenario, a structural engineer cannot afford to generate the results manually as it involves tedious procedures and complicated calculations, which requires considerable time and patience. Thus there is always a need of a simpler alternative like the use of various; Computer Aided Software's which would offer great flexibility and efficiency.
- In this project, analysis and design of structure was done with the aid of software called ETABS which is quiet feasible in using and offers more efficient designs and flexibility.
- Using software's helps to get faster results and simultaneously designing can also be done for that members.
- Different load combination can be applied easily.
- Load combination can be altered easily.
- Time is saved for structural design work, so that work can start very quickly.
- We can conclude that there is a difference between the theoretical and practical work done as the scope of understanding will be much more when practical work is done as we get more knowledge in such a situation where we have great experience doing the practical work.
- ETABS gives more economical and convenient results than manual design results.

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