Analysis and design of Multi storey Structure Using ETABS


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Abstract - Most buildings are of straight forward geometry with horizontal beams and vertical columns. Although any building configuration is possible with ETABS version 2009, in most cases, a simple grid system defined by horizontal floors and vertical column lines can establish building geometry with minimum effort. Many of the floor level in buildings are similar. This commonality can be used to dramatically reduce modelling and design time.

The present work deals with the analysis and design of a multi storied residential building of (G+2) by using most economical beam to column method. The dead load & live loads are applied and the design for beams, columns, footing is obtained from etabs with its new features surpassed its predecessors with its data sharing.

Our main aim is to complete a multi-storey building and to ensure that the structure is safe and economical against gravity loading conditions and to fulfil the function for which the structures have been built for. For the design of the structure, the dead load and live load are considered. The analysis and design of the structure done by using a software package ETABS. In this project multi-storeyed construction, we have adopted limit state method of analysis. The design is in confirmation with IS 456-2000.

The results of analysis are used to verify the fitness of structure for use. Computer software's are also being used for the calculation of forces, bending moment, stress, strain & deformation or deflection for a complex structural system. The principle objective of this project is to compare the design and analysis of multi-storeyed building (G+2) by ETABS 2009 with manual calculations.

Key Words: Gravity load, Hostel, building, Etabs, Design.

1. INTRODUCTION

As our country is the fastest growing country across the globe so the need of shelter for highly populated cities where the cost of land is high and further horizontal expansion is not possible due to unavailability of space, so the only solution is vertical expansion. Structural design is the primary aspect of civil engineering. The foremost basics in structure is the design of simple basic components and members of a building like slabs, beams, columns, and footings. In order to design them it is important to first obtain the plan of the particular building. Thereby depending on the suitability plan layout of beams and the position of columns are fixed. Thereafter, the vertical loads are calculated namely the dead load and live load.

Once the loads are obtained, the component takes the load first i.e. the slabs can be designed. Designing of slabs depends upon whether it is a one-way or a two-way slab, the end condition and the loading. From the slabs, the loads are transferred to the beam. The loads coming from the slabs onto the beam may be trapezoidal or triangular. Depending on this, the beam may be designed. There after, the loads (mainly shear) from the beams are taken by the columns. For designing columns, it is necessary to know the moments they are subjected to for this purpose, frame analysis is done by Kanis method. After this the designing of column is taken up depending on end conditions, moments, eccentricity and if it is a short or slender column. Finally, the footings are designed based on the loading from the column and also the soil bearing capacity value for that particular area. Most importantly, the sections must be checked for all the components with regard to strength and serviceability.

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS Version 9.7.4 features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, and design procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineers in the building industry.

1.1 DESIGN PHILOSOPHIES

There are three philosophies for the design of reinforced concrete namely:

1) Working stress method
2) Ultimate load method
3) Limit state method

1.2 STAGES IN STRUCTURAL DESIGN

The process of structural design involves the following stages

- Structural planning.
- Estimation of loads.
2 OBJECTIVE

Following are the objectives

1. Modeling the building using the software ETABS V.9.7.4
2. Applying gravity loads and different load combinations as per Indian codal provision.
3. Analysing and designing of hostel building for worst case of load combination.

4. PLAN OF HOSTEL BUILDING

Fig 1: Ground floor plan

Table -1: Ground Floor Details

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>ROOMS</th>
<th>SIZE(mxm)</th>
<th>No's</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HALL</td>
<td>13x6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>KITCHEN</td>
<td>11x6</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>STORE ROOM</td>
<td>5x6</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>LIVING ROOM</td>
<td>7x5</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>W/C</td>
<td>1.5x1.2</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>BATH</td>
<td>1.5x1.8</td>
<td>12</td>
</tr>
</tbody>
</table>

5. METHODOLOGY

6. ANALYSIS RESULT

Table 2: Results considered for design of columns

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Column</th>
<th>No. of Column</th>
<th>P_u (KN)</th>
<th>M_max (KN-m)</th>
<th>M_min (KN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>6</td>
<td>873</td>
<td>-67.51</td>
<td>-19.24</td>
</tr>
<tr>
<td>2</td>
<td>C2</td>
<td>13</td>
<td>1104</td>
<td>29.99</td>
<td>-81.88</td>
</tr>
<tr>
<td>3</td>
<td>C3</td>
<td>10</td>
<td>1987</td>
<td>43.43</td>
<td>65.68</td>
</tr>
<tr>
<td>4</td>
<td>C4</td>
<td>19</td>
<td>2304</td>
<td>-40.98</td>
<td>-101.4</td>
</tr>
<tr>
<td>5</td>
<td>C5</td>
<td>5</td>
<td>2992</td>
<td>-30.68</td>
<td>4.01</td>
</tr>
<tr>
<td>6</td>
<td>C6</td>
<td>22</td>
<td>3423</td>
<td>34.11</td>
<td>-152.89</td>
</tr>
</tbody>
</table>

6.1 DESIGN OF SLAB: (one long edge discontinuous)

Size of the slab = (7x5) m
L_y = 7 m  L_x = 5 m
L_y/L_x = 7/5 = 1.4 < 2
Therefore, design the slab as 2-way slab
Assume overall depth of the slab as 150 mm
Assume effective cover = 20mm
Effective depth (d) = 150-20 = 130mm

Calculation of load:
Self-weight of slab = 0.15x1x24 = 3.6 kN/m
Live load = 3 kN/m
Floor finish load = 1.5 kN/m
Total load = 8.1 kN/m
Factored load = 1.5x8.1 = 12.15 kN/m
### Calculation of Ultimate Moments;

From table 12 of IS456-2000 for interior panels.  
\[ \alpha_s = 0.047, \quad \gamma = 0.028 \]
\[ M_u = \alpha_s W L^2 = 0.047 \times 12.51 \times 5^2 = 14.69 \text{ kN-m} \]
\[ M_p = \alpha_p W L^2 = 0.028 \times 12.51 \times 5^2 = 8.75 \text{ kN-m} \]

**Check for Depth of Slab;**

\[ M_{ulim} = 0.133 f_{ck} b d^2 \]
\[ = 14.69 \times 10^6 = 0.133 \times 25 \times 1000 \text{ kN} \cdot \text{m}^2 \]
\[ d = 66.46 \text{ mm} \text{ < provided (130 mm)} \]

\[ \therefore \text{ Slab is safe against moment.} \]

### Calculation of Ast:

\[ M_{ulim} = 0.87 f_{ck} A_{st} \{ 1 - (A_{sf} / b d f_u) \} \]
\[ = 14.69 \times 10^6 = 0.87 \times 500 \times 130 \{ 1 - (A_{sf} / 500 \times 130) \} \]
\[ A_{sf} = 271 \text{ mm}^2 \]
\[ A_{st} = 0.12 \% \text{ of gross area} = 0.12 / 100 \times (1000 \times 150) \]
\[ = 180 \text{ mm}^2 \]

**Assume 10 mm dia bars,**

**No of bars** = total area / area of 1 bar = 271 / 78.53 = 3 nos

#### Spacing

**Providing 10# bars**

\[ A_{st} = (P / x^2) = 78.53 \text{ mm}^2 \]
\[ a) \text{Main bars: Spacing of 10# = (78.53 x 1000) / 271} \]
\[ = 289.77 \text{ mm c/c} \]
\[ = 300 \text{ mm c/c} \]

**Spacing should be minimum of 3d = 3 x 130 = 390 mm**

**Provide 10mm dia bars @ 300 mm c/c**

**b) Distribution bars = 8# @ 0.012 X A_{st}**

**Spacing of 8# = (50.26 x 1000) / 271 = 185.46 mm c/c = 180 mm c/c**

**Provide 8# @ 180 mm c/c**

**Check for shear;**

\[ V_u = (w \times l_e) / 2 = (12.15 \times 5) / 2 = 30.37 \text{ KN} \]

Nominal shear stress \( \tau_v = V_u / b d = 30.37 \times 10^3 / 1000 \times 130 \]
\[ = 0.23 \text{ N/mm}^2 \]

Permissible shear stress, \( P_t = \{ (100 A_{st}) / b d \} = (100 \times 271) / (1000 \times 130) = 0.20 \]

Table no. 19 of IS 456 2000;

\[ \tau_v = 0.325 \text{ N/mm}^2 \]

\[ \tau > \tau_v \]

Hence shear reinforcement is not required.

### 6.2 DESIGN OF BEAM

Clear span=7 m
Width of support =230 mm
Service load=3 KN/m
Materials: M25 grade concrete
Fe500
\( F_{d1} = 25 \text{ N/mm}^2 \)
\( F_{d2} = 500 \text{ N/mm}^2 \)
Effective depth= span / 15
\[ = 7000 / 15 = 466.7 = 500 \text{ mm} \]

**Adopt d=500 mm**

D=520 mm
B=230 mm
Effective span=clear span+effective depth
\[ = 7 + 0.5 = 7.5 \text{ m} \]

Center to center of support=7.23 m
Hence L=7.5 m
Load= w= 52.5 KN/m
Design ultimate load= \( W_u = 78.75 \text{ KN/m} \)

Ultimate moment and shear forces

\[ M_u = 0.125 x w u \cdot d \]
\[ = 0.125 \times 78.75 \times 7.5 \]
\[ = 551.25 \text{ KN-m} \]

\[ V_u = 0.5 x w d x L \]
\[ = 0.5 \times 29.77 \times 7.5 \]
\[ = 295.12 \text{ KN} \]

\[ M_{ulim} = 0.133 x f_{ck} b x b d x \]
\[ = 0.133 \times 25 \times 250 \times 500 \]
\[ = 191.18 \text{ KN-m} \]

Since \( M_u > M_{ulim}, \text{ section is over reinforced} \)

\[ M_u - M_{ulim} = f_{ck} x A_{st} (d - d') \]

\[ f_{ck} = (0.0035 (x_{max} - d') / x_{max}) x E_s \]
\[ = 0.0035 (230 - 20) / 230 x 2 \times 10^5 \]
\[ = 639.13 \text{ N/mm}^2 \text{ not greater than 0.87x f}_{p} = 435 \text{ N/mm}^2 \]

\[ A_{st} = [(M_u - M_{ulim}) / f_{ck} (d - d')] \]
\[ = [(551.25 - 191.18) x 10^3 / 435(500 - 20)] \]
\[ = 1724.4 \text{ mm}^2 \]

Provide 2 bars of 12 mm diameter (\( A_{st}=226 \text{ mm}^2 \))

\[ A_{st2} = (A_{st} / 0.87) = (1724.4 x 435 / 0.87 x 500) \]
\[ = 1724.4 \text{ mm}^2 \]

\[ A_{st1} = (0.36 x f_{ck} b x_{lim} / 0.87 x f_{p}) \]
\[ = (0.36 x 25 x 230 x 0.46 x 500 / 0.87 x 500) \]
\[ = 1094.48 \text{ mm}^2 \]

\[ A_{st} = A_{st1} + A_{st2} \]

\[ A_{st} = 2818.8 \text{ mm}^2 \]

Provide 3 numbers of 25 mm diameter (\( A_{st}=1473 \text{ mm}^2 \))

**Shear reinforcement**

\[ \tau_u = V_u / (b d) \]

\[ V_u = (295.12 - 0.704 x 230 x 500 x 10^{-3}) = 214.16 \text{ KN} \]

**Using 8 mm diameter 2-legged stirrups**

\[ S_r = (0.87 x f_{ck} A_{svx} / V_u) = (0.87 x 500 x 100 x 500 / 214.16) \]
From shear consideration, 
\[ Vu = P \times (1620 - d) = 176 \times (1695 - d) \]
Assuming shear stress \( \tau_c = 0.36 \text{ N/mm}^2 \) for M40 grade Pt = 0.25
\[ \tau_c = Vu/bd \]
\[ 0.36 = 176 \times (1695 - d) / 1000 \times d \]
\[ d = 556.56 \text{ mm} \]
Provide \( d = 560 \text{ mm} \)

### 4) Area of Reinforcement:

**Longer Direction,**

\[ Mr = 0.87 \times f_y \times A_{st} \times d \left( 1 - A_{st} / (b_d f_y) \right) \]
\[ 1078 \times 10^3 \times 0.87 \times 500 \times A_{st} \times 560 \left( 1 - A_{st} / (1000 \times 560) \right) \]
\[ A_{st} = 5509.30 \text{ mm}^2 \]
Using 25mm dia bars @ 100mm spacing \( A_{st} = 5399.6 \text{ mm}^2 \)

**Shorter Direction,**

\[ Mr = 0.87 \times f_y \times A_{st} \times d \left( 1 - A_{st} / (b_d f_y) \right) \]
\[ 112.36 \times 10^3 \times 0.87 \times 500 \times A_{st} \times 560 \left( 1 - A_{st} / (1000 \times 560) \right) \]
\[ A_{st} = 469.10 \text{ mm}^2 \]

### 4) Check for Shear:

The critical section for one way shear is located at a distance 'd' from the face of the column.

Ultimate shear force per metre width in the longer direction is:

\[ Vu = P \times d = 176 \times 0.56 \]
\[ Vu = 98.56 \text{ kN} \]
\[ P_t = 100A_{st} / bd = 100 \times (5399.6 / 1000 \times 560) = 0.96 \]
From Table No. 19 of IS 456:2000
\[ \tau_s = 0.64 \text{ N/mm}^2 \]
\[ \tau_v = Vu / bd = 98.56 \times 10^3 / (1000 \times 560) = 0.176 \text{ N/mm}^2 \]
\[ \tau_c > \tau_v \]
Hence safe.

### 6.4 DESIGN OF COLUMN

Size of column \( (230 \times 450) \text{ mm} \)
\[ P_u = 1104 \text{ KN} \]
\[ M_u = 35.64 \text{ KN} \cdot \text{m} \]
\[ M_{up} = 64.48 \text{ KN} \cdot \text{m} \]
\[ F_{ck} = 25 \text{ N/mm}^2 \]
\[ F_y = 500 \text{ N/mm}^2 \]

Selecting trial reinforcement:

\[ Pu / f_y bD = 1104 \times 10^3 / 25 \times 230 \times 450 = 0.426 \]
Uniaxial \( m_u = 1.15 \sqrt{(m_{u,c}^2 + m_{u,v}^2)} \)
\[ = 1.15 \sqrt{(35.64^2 + 64.45^2)} \]
\[ = 84.69 \text{ KN} \cdot \text{m} \]
\[ M_{u} / f_y bD^2 = 84.69 \times 10^3 / 25 \times 230 \times 450^2 = 0.072 \]
\[ d / D = 50 / 450 = 0.11 \]
referring to chart 48 in SP-16
To find \( m_{ux} \):

\[
P/u = 0.4 \times f_u b_d = 0.426, \quad d/D = 0.11
\]

from chart 48

\[
m_{ux} = 0.07 \times 25 \times 230 \times 450
\]

= 81.5 KN

To find \( m_{uy} \):

Since \( P/u = 0.45 \times f_u b_d \), \( p/u = f_u b_d u \)

Also \( u_{y} = 81.5 \text{ KN} \)

To find \( u_{y} \):

\[
A = 230 \times 450 - 1256.63 = 102243.37 \text{ mm}^2
\]

\[
A = 1256.63 \text{ mm}^2
\]

\[
P/u = 0.45 \times 25 \times 102243.37 + 0.75 \times 500 \times 1256.63
\]

= 1621.47 KN

To find \( n \):

\[
P/u = 1104/1621.47 = 0.68
\]

This between 0.2 and 0.8

\[
\alpha = 1 + (0.68-0.2)/0.6 = 1.8
\]

Checking interaction formula;

\[
(M_{ux}/m_{ux})^u + (m_{uy}/m_{uy})^u
\]

(35.64/81.5)\(^u\) + (64.48/81.5)\(^u\)

= 0.88 < 1

Interaction formula is satisfied

Design of ties:

Use 8 mm diameter tie

- Maximum pitch
  - Least lateral dimension = 230 mm
  - 16x\( \phi \) = 16x20 = 320 mm
  - 300 mm

Hence provide 8 mm @ 230 mm c/c.

7. CONCLUSIONS

1. The preparation of the project has provided an excellent opportunity to emerge ourselves in planning and designing of multi-storeyed hostel building.
2. This project has given an opportunity to re-collect and co-ordinate the various methods of designing and engineering principles which we have learnt in our lower classes.
3. Design was done by using ETABS software and successfully verified manually as per IS 456-2000.
4. By using ETABS, the analysis and design work can be completed within the stipulated time.
5. The analysis and design results obtained from software are safe when compared with manual calculations and design.

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