Design and Analysis of Residential Building using E-TABS

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Abstract - ETABS stands for Extended Three Dimensional Analysis of Building Systems. The main purpose of this software is to design multi-storeyed building in a systematic process. The effective design and construction of an earthquake resistant structures have great importance all over the world. This project presents multi-storeyed residential building analysed and designed with lateral loading effect of earthquake using ETABS. This project is designed as per INDIAN CODES- IS 1893-part2:2002, IS 456:2000.

Every structural engineer should design a building with most efficient planning and also be economical. They should ensure that it is serviceable, habitable in healthy environment for its occupants and have longer design period. Structurally robust and aesthetically pleasing building are being constructed by combining the best properties of any construction material and at the same time meeting specific requirements like type of building and its loads, soil condition, time, flexibility and economy. In the view of above, the high rise buildings are best suited solution. This paper discusses the analysis of a commercial building (G+1) located at Hyderabad under effect of Seismic forces. Shear forces and bending moments of beams and columns are observed and concluded that larger span have more shear forces and bending moment.

Key Words: Structural design, ETABS, Shear forces, Bending moments.

1. INTRODUCTION

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building system. ETABS version 9.0 features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, and design procedures, all inte-grated 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 tool of choice for structural engineers in the building industry.

Dating back more than 30 years to the original development of ETABS, the predecessor of ETABS, it was clearly recognized that buildings constituted very special class structures. Early releases of ETABS provide input, output and numerical solution techniques that took into consideration and characteristics unique to building type structure, providing a tool that offered significant savings in time and increased accuracy, over general purpose programs.

As computers and computer interfaces evolved, ETABS added computationally complex analytical options such as dynamic nonlinear behavior, and powerful CAD-like drawing tools in a graphical and object based interface.

Most building is of straightforward geometry with horizontal and vertical beams and vertical columns. Although any building configuration is possible with ETABS, in most cases, simple grid system defined by horizontal floors and vertical column lines can establish building geometry with minimal effort.

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

1) Drawing Study
2) Load Combinations
3) Analysis Of Structures
4) Structural design

2 OBJECTIVE

Following are the objectives

1. Modeling the building using the software ETABS V.9
2. Applying gravity loads and different load combinations as per Indian codal provision.
3. Analysing and designing of Residential building(G+1) for worst case of load combination
3. Plan of Residential Building

![Plan of Residential Building](image)

Table -1: SILENT FEATURE OF PROPOSED BUILDING:

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LOCATION</td>
<td>BANGLORE</td>
</tr>
<tr>
<td>2</td>
<td>TYPE OF BUILDING</td>
<td>G+1</td>
</tr>
<tr>
<td>3</td>
<td>STRUCTURE</td>
<td>R.C.C FRAME</td>
</tr>
<tr>
<td>4</td>
<td>BUILT UP AREA</td>
<td>140 m²</td>
</tr>
<tr>
<td>5</td>
<td>HEIGHT B/W THE FLOOR</td>
<td>3.1 m</td>
</tr>
<tr>
<td>6</td>
<td>DEPTH OF FOUNDATION BELOW G.L.</td>
<td>1.5 m</td>
</tr>
<tr>
<td>7</td>
<td>PRIMARY AND SECONDARY WALL THICKNESS</td>
<td>230, 115 m m</td>
</tr>
</tbody>
</table>

4. Analysis Methods

Etab is the premier FEM analysis and design tool for any type of project including towers, culverts, plants, bridges, stadiums, and marine structures. With an array of advanced analysis capabilities including linear static, response spectra, time history, cable, and pushover and nonlinear analyses, Etab provides good compatibility with a scalable solution that will meet the demands of project every time.

5. ANALYSIS RESULT

![3D MODEL](image)
6. DESIGN DETAILS

**Design of slab 1**

L_x = 2.40 m  
L_y = 4.37 m  
L_y/L_x = 1.80 < 2 (Hence slab designed as two way)  
Total load on slab = 9.35 kN/m^2  
Factored moment = 10 Kn-m  
Assuming depth of slab = 150 mm  
Design of the as under reinforced  
Slab cover = 25 mm  
Bend the alternative bars@ a distance of L/7 from the face of the wall = 2.40 / 7 = 0.342 m  
Assuming dia 8mm 150 c/c (main reinforcement)  
Distribution reinforcement  
A_{kB} as distribution reinforcement = 0.12 % * b^2 * D  
= 0.12 % * 1000 * 150  
= 180 mm^2  
Sapcing of 10 mm dia = (π * 10^2 * 100) / 180 = 200 mm

Provide 8 mm dia @ 150 mm c/c  
Check for deflection:  
Assuming span to depth ratio = L/d < 20  
= 2.4 / 125 < 20  
= 19.2 < 20, Hence safe.

**Design of Slab 2:**

L_y = 4.7 m  
L_x = 4.0 m  
Aspect ratio (l_y/ l_x) = 4.7/4 = 1.17 < 2 (hence two way slab)  
two edges discontinuous, two edge continuous

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>M_x = x * w*L_x^2</th>
<th>Dia spacing x</th>
<th>Dia spacing y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ve reinforcement</td>
<td>0.084</td>
<td>-</td>
<td>12.56 kN.m</td>
<td>8 dia @200 mm c/c</td>
</tr>
<tr>
<td>+ve reinforcement</td>
<td>0.064</td>
<td>0.043</td>
<td>9.57 kN.m</td>
<td>8 dia @150 mm c/c</td>
</tr>
</tbody>
</table>

**Design of slab 3:**

L_y = 3.9 m  
L_x = 3.5 m  
Aspect ratio (l_y/ l_x) = 3.9/3.5 = 1.11 < 2 (hence two way slab)  
One short edge discontinuous.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>M_y = y * w*L_x^2</th>
<th>Dia spacing x</th>
<th>Dia spacing y</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ve reinforcement</td>
<td>0.048</td>
<td>0.037</td>
<td>5.5 kN.m</td>
<td>10 dia @180 mm c/c</td>
</tr>
<tr>
<td>+ve reinforcement</td>
<td>0.036</td>
<td>0.028</td>
<td>4.2 kN.m</td>
<td>8 dia @180 mm c/c</td>
</tr>
</tbody>
</table>

**Slab 6:** L_x = 2.4, L_y = 5.0, aspect ratio (L_y/ L_x) = 2.1 > 2, one way slab

Total load on slab = 9.35 kN/m^2  
M_x = w *L_x^2 / 8 = (9.35 * 2.4^2 / 8) = 6.73 kN.m  
Factored moment = 1.5 * 6.73 = 10 kN.m  
Assuming 8 dia @ 270 mm c/c (main reinforcement)  
Distribution reinforcement  
A_{Kb} as distribution reinforcement = 0.12 % * 1000 * 150  
= 180 mm^2  
Spacing of 6 mm dia = 3.142 * 6^2 * 1000 / (4 * 180)  
= 150 mm  
So, provide 8 mm dia @ 150 c/c.

**Check for deflection:**

Assuming span to depth ratio = L/d < 20  
= 2.4 / 125 < 20  
= 19.2 < 20, Hence safe
7. DESIGN OF BEAM

Data, Grid beam no 1-A

Characteristic compressive strength of concrete = $f_{ck} = 20$ N/mm²

Characteristic strength of steel = $f_y = 500$ N/mm²

Adopted $d = 400$ mm

D = 450 mm

b = 230 mm

Length = $L = 7.6$ m

From Etab results,

Negative moment at interior support, $M_u = 55$ kN-m

Positive moment at center of span, $M_u = 43$ kN-m

Maximum shear force at support section, $V_u = 50$ kN

Main reinforcement

For -ve B.M.

$M_u = 0.87 f_{ck} A_d [1 - A_s f_y / b d_f]$

$55 x 10^4 = 0.87 x 500 x A_d x 450 x [1 - A_s x 500 / 230 x 450 x 20]$

$A_d = 350.63$ mm²

Provide 2 bars of 12 mm dia and 2 bars of 10 mm dia $(A_u = 380$ mm²) @ top tension face near supports

For +ve B.M.

$M_u = 0.87 f_{ck} A_d [1 - A_s f_y / b d_f]$

$43 x 10^4 = 0.87 x 500 x A_d x 450 x [1 - A_s x 500 / 230 x 450 x 20]$

$A_d = 300$ mm²

Provide 3 bars of 12 mm dia $(350$ mm²) at bottom tension face at centre of span section.

Shear reinforcement,

$\tau_c = \frac{V_u}{b d} = 50 x 10^3 / 230 x 450$

= 0.48 N/mm²

$P_t = 100 x A_s / b d = 100 x 350 / 230 x 450$

= 0.33 %

Refer table 19 (IS 456) read out,

$\tau_c \geq 0.42$ N/mm²

Hence shear reinforcement is required.

$V_{un} = V_u - \frac{b d}{50} - \frac{(0.42 x 230 x 450) 10^3}{10.16}$

= 10.16 kN

Use 8 mm dia two legged stirrups, the spacing is,

$S_v = (0.87 f_{ck} A_d d) / V_{un}$

= $(0.87 x 500 x 50 x 450) / 10.16 x 1000$

$S_v = 250$ mm

Adopt 8 mm dia two legged stirrups @ 220 mm c/c

Check for deflection,

At centre of span:

$P_t = 100 A_u / b d = 100 x 350 / 230 x 450$

= 0.33 %

From fig. 4 of IS 456, $K_v = 1.2$, $K_v = 1$, $K_v = 1$

$(L/d)_{max} = (L/d)_{basic} x K_v x K_v$

= $26 x 1.2 x 1$

= 31.2

$(L/d)_{actual} = 7600 / 450 = 16.88$

$(L/d)_{actual} < (L/d)_{max}$

Hence deflection control is satisfied

8. DESIGN OF COLUMNS

Data,

Characteristic compressive strength of concrete = $f_{ck} = 20$ N/mm²

Characteristic strength of steel = $f_y = 500$ N/mm²

$P_u = 250$ kN (taken from Etab)

D = 350 mm

Length = $L = 3100$ mm

Longitudinal reinforcement = $P_u = 0.4 * f_{ck} A_e + 0.67 * f_y A_{sc}$

= $0.4 * f_{ck} A_e + (0.67 * 415 - 0.4 * 20) A_{sc}$

$= 250 x 10^4 = 0.4 * 20 * 230 * 350 + (0.67 * 500 - 0.4 * 20) A_{st}$

$A_{st} = 1200$ mm²

So,

$P_{min} = 0.8$

$A_{st} = 699.2$ mm²

Provide 4 bars of 16 mm diameter

Design of lateral ties

Tie diameter

So, provide lateral reinforcement 8 mm ties

Tie spacing $S_t$

So, provide tie spacing at 8 mm @ 230 mm c/c

Design of uniaxial column

$P_u = 164$ kN

$M_{tu} = 10$ kN.m

Width $b = 230$ mm

Depth $d = 350$ mm

$d / D = 0.15$

$P_u / (f_{ck} b D) = 164 x 10^3 / (20 x 230 x 350) = 0.101$

$M_{tu} / (f_{ck} b D^2) = 10 x 10^5 / (20 x 230 x 350) = 0.017$

$A_{ST_{min}} = 0.8$ (from SP 16 code)

$P / f_{ck} = 0.06$ (minimum)

$P = 0.06 x 20 = 1.2$

Area of steel = $(1.2 x 230 x 350) / 100$

= 966 mm²

= 9.66 cm²

So, provide 4 bars of 20 mm diameter

Design for lateral ties

Tie diameter =

So, provide 8 mm lateral ties

Design tie spacing $S_t$

So, provide tie spacing 230 mm
18 DESIGN OF FOOTING

Isolated Footing

Unfactored Load = 266 kN
Factored Load = 398 kN
Moment about X-axis, Mux = 9 kN-m
Moment about Y-axis, Muy = 3 kN-m
S.B.C. of Soil = 180 kN/m²
Grade of Concrete = M 20
Grade of Steel = Fe-500

- Proportioning of footing size:
  \[ A_g = \frac{1.1P}{SBC} = \frac{1.1 \times 266}{180} = 1.63 \text{m}^2 \]
Assume, L = B = 1.3 m
Let provide footing size 1.3 m × 1.3 m
Provide A = 1.7 m²
\[ e = \frac{M}{P} = \frac{266}{216.24} = 1.18 \text{m} \]
Minimum cover required for footing = 50 mm
Assuming diameter of bar in footing = 16 mm
Minimum cover required for footing = 50 mm
Therefore, effective depth \( d = 300 - 58 = 242 \text{ mm} \)

CONCLUSION

Finally concluded that I have my satisfaction with my internship in that particular company, further procedure of Dynamic analysis of the multi-story buildings I will keep my internship with the company and I hope am learned what they gives design works with period of internship. The Internship gave ample exposure to the field practice in the modeling, analysis and design of the multi storied buildings and various construction techniques used in the industry. The analysis was done using the software package ETAB and drawing details in AutoCAD and REVIT. The structural components were designed manually in addition to the software design. This training helped to understand and analyze the structural problem faced by the construction industry. Site visits also gave an exposure to the industry. It provide help us to apply theoretical knowledge in industrial application, acquire knowledge of various stages of construction, project management and team-work, practice ethical and professional work culture, provide opportunity for students to work with industrial practitioners.

In next eight weeks I am going to learn SAFE software to design foundation and study the dynamic analysis of some more multistory buildings in ETAB.

REFERENCES

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