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.

- Analysis of structure.
- Member design.
- Drawing, detailing and preparation of structures.

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

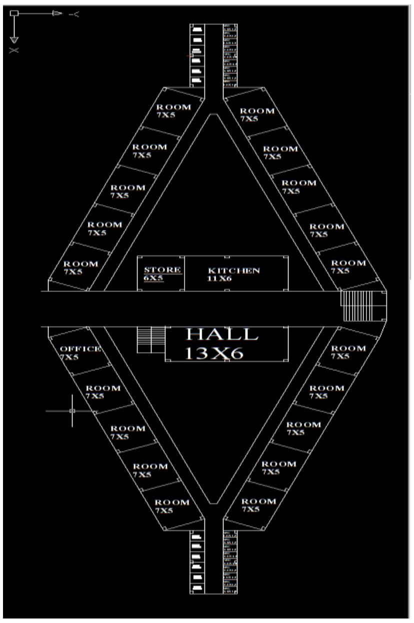
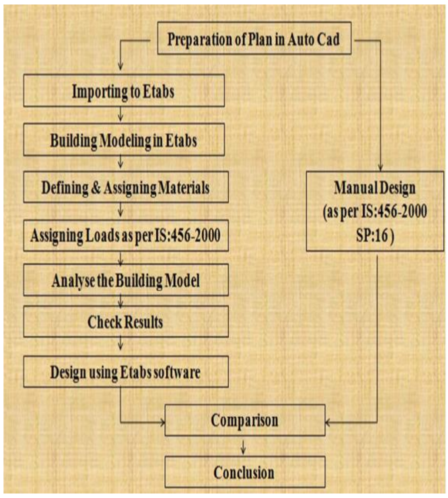


Fig 1: Ground floor plan

Table -1: Ground Floor Details

Sl. No.	ROOMS	SIZE(mxm)	No's
1	HALL	13X6	1
2	KITCHEN	11X6	1
3	STORE ROOM	5X6	1
4	LIVING ROOM	7X5	15
5	W/C	1.5X1.2	18
6	BATH	1.5X1.8	12

5. METHODOLOGY



6. ANALYSIS RESULT

Table 2:Results considered for design of columns

Sl. No.	Column	No. of Column	P_u (KN)	M_{ux} (KN-m)	M_{uy} (KN-m)
1	C1	6	873	-67.51	-19.24
2	C2	13	1104	29.99	-81.88
3	C3	10	1987	43.43	65.68
4	C4	19	2304	-40.98	-101.4
5	C5	5	2992	-30.68	4.01
6	C6	22	3423	34.11	-152.89

7. DESIGN DETAILS

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.
$\alpha_x = 0.047$, $\alpha y = 0.028$
$M_x = \alpha_x w l_x^2 = 0.047 \text{ X } 12.51 \text{ X } 5^2 = 14.69$ kN-m
$M_y = \alpha_y w l_x^2 = 0.028\text{X } 12.51\text{X } 5^2 = 8.75$ kN-m

Check for Depth of Slab;

$Mu_{lim} = 0.133 f_{ck} b d^2$
$14.69 x10^6 = 0.133x25x1000xd^2$
d= 66.46 mm < provided (130 mm)
∴ Slab is safe against moment.

Calculation of Ast:

$Mu_{lim} = 0.87 f_y A_{st}$ d $\{1-(A_{st} f_y / bdf_{ck})\}$
$14.69x10_6=0.87x500xA_{st}x130\{1-(A_{st}x500)/1000x130x25)\}$
$8.7A_{st}^2-56550A_{st}+14.69x10^6$
A_{st} = 271mm²
Ast required = 271mm²
A_{st} = 0.12% of gross area= (0.12/100) x (1000x150) =180mm
Assume 10mm dia bars,
No of bars= total area/area of 1 bar = 271/78.53= 3 no,s

Spacing

Providing 10# bars
Ast = (Px10²) = 78.53mm²
a)Main bars: Spacing of 10 # = (78.53 x1000)/271
=289.77 mm c/c
=300 mm c/c
Spacing should be minimum of 3d = 3x130= 390mm
Provide 10mm dia bars @ 300mm c/c
(b)Distribution bars = 8# @ 0.012 X A_{St}
Spacing of 8 # = (50.26 x1000)/271=185.46 mm c/c≅ 180mm c/c
Provide 8 # @ 180mm c/c

Check for shear;

$V_u = (w_u \text{ x } l_x)/2$= (12.15x5)/2=30.37 KN
Nominal shear stress τ_v= Vu/bd = 30.37x10³/1000x130 =0.23N/mm²
Permissible Shear Stress, Pt = (100Ast)/bd = (100 x 271)/(1000 x 130) = 0.20
Table no. 19 of IS 456 2000;
τ_c= 0.325 N/mm²
$\tau_c > \tau_v$
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_{ck}=25 N/mm2
F_y= 500 n/mm2
Effective depth= span/15
=7000/15=466.7=500 mm
Adopt d=500 mm
D=520 mm
B=230 mm
Effective span=clear span+effective depth
=7+0.5=7.5 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 KN/m
Ultimate moment and shear forces
M_u = 0.125xwuxL²
= 0.125x78.7x7.5²
=551.25 KN-m
V_u = $0.5xw_uxL$
= 0.5X29.77X7.5
= 295.12 KN
M_{ulim}= $0.133xf_{ck}xbxd^2$
=0.133x25x230x500²
=191.18 KN-m
Since $M_u > M_{ulim}$, section is over reinforced
$M_u - M_{u\,lim} = f_{sc} x A_{sc}(d-d^1)$
$F_{sc} = (0.0035(x_{umax}-d^1)/x_{u\,max})xE_s$
= (0.0035(230-20)/230)x2x10⁵
= 639.13 N/mm² not greater than 0.87x f_y=435 N/mm²
$A_{sc} = [(M_u - M_{ulim})/f_{sc}(d-d^1)]$
= [(551.25-191.18)x10⁶/435(500-20)]
= 1724.4 mm²

Provide 2 bars of 12 mm diameter (A_{sc}=226 mm2)
$A_{st2} = (A_{sc}xf_{sc}/0.87f_y)$=(1724.4x435/0.87x500)
=1724.4 mm²
$A_{st1} = (0.36xf_{ck}bx_{u\,lim}/0.87xf_y)$
= (0.36x25x230x0.46x500/0.87x500)
= 1094.48 mm²
$A_{st} = A_{st1}+A_{st2}$
A_{st} = 2818.8 mm²
Provide 3 numbers of 25 mm diameter (Ast=1473 mm2)
Shear reinforcement
$\tau_v = v_u/bd$
= 295.125x10³/230x500
= 2.5 N/mm2
$p_t = (100\ A_{st})/bd$
= (100x1473)/(230x500)
= 1.28
τ_c = 0.704 < 2.5
Hence shear reinforcement are required
$V_{us} = (Vu-(\tau_c bd))$
V_{us} = (295.12-(0.704x230x500)x10⁻³)=214.16 KN
Using 8 mm diameter 2-legged stirrups
$S_v=(0.87xfyxAsvxd/V_{us})$=(0.87x500x100X500/214.16)

S_v=102.09 mm
S_v> 0.75d=375 mm
Adopt spacing of 100 mm near support ,gradually increasing to 300 mm towards the centre of span.
Check for deflecion
$(L/d)_{act}$ = (7500/500)=15
$(L/d)_{max}$ = $[(L/d)_{basic} x K_c x K_t x K_f]$
$(L/d)_{max}$= 15x1.03x0.98x1 = 15.14
$(L/d)_{act} < (L/d)_{max}$
Hence deflection control is satisfied.

6.3 DESIGN OF FOOTING

b = 230 mm
d = 750 mm
f_{ck}= 25 N/mm^2
f_y = 500 N/mm
P_u = 3423 kN
SBC of soil = 140 KN/m^2
Factored SBC = 1.5 x 140 = 210 kN/m^2
Add 10% of load as self-weight of footing =3423 +10 % (3423) = 3765.3 kN
P_u = 3765.3 kN

1) Size of Footing:

Area (A) = $Load/SBC$ = 3765.3/ 210 = 17.93 m2
Proportion the footing area in the same proportion as the sides of the column.
Hence (2.3 x) X (7.5 x) = 17.93
x= 1.03
Short side of footing = (0.23x 1.03) = 2.36 m
Long side of footing = (7.5 x 1.03) =7.72 m
Provide size of footing as (2.5m x 7.75m)
Soil Pressure (P_o) = $P/Area$ = 3423/(2.5x7.75) = 176.6 kN/m^2< 210 kN/m^2

2) Bending Moment Calculation:

Cantilever projection from the short side face of the column = 0.5(7.75-0.75) = 3.5m
Cantilever projection from the long side face of the column = 0.5(2.5-0.23)

Bending moment at long side face of column is ($0.5p_oL^2$) = 0.5x176x3.5^2 =1078 KN-m
Bending moment at short side face of column is ($0.5p_oL^2$) = 0.5x176x1.13^{2}N-m

3) Calculation for Depth of Footing:

From moment consideration,
Depth(d)=$\sqrt{M_u/(0.138 f_{ck} \times B)}$
=$\sqrt{1078x10^6/(0.138x25x1000)}$ =558.9 mm
From shear consideration,
From IS-456:2000

Vu = P_o x (1620 - d) = 176 x (1695-d)
Assuming shear stress τ_c = 0.36 N/ mm2 for M40 grade Pt = 0.25
τ_c = Vu/bd
0.36 = 176×(1695-d)/1000 ×d
d = 556.56mm.
Provide d = 560 mm

4) Area of Reinforcement:

Longer Direction,

Mr = 0.87 x f_yx A_{st}x d (1 - A_{ts} f_y/(bdf_{ck}))
1078x10^6= 0.87 x 500 x A_{st}x560(1-A_{st}x500/(1000x560x25))
A_{st} = 5509.30mm^2
Using 25mm dia bars @ 100mm spacing (A_{st}=5399.6 mm^2)

Shorter Direction,

Mr = 0.87 x f_yx A_{st}x d (1 - A_{ts} f_y/(bdf_{ck}))
112.36x10^6= 0.87x500xA_{st}x560 {1-A_{st}x500/(1000x560x25)}
A_{st} = 469.10 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_o x d = 176 x 0.56
Vu = 98.56kN
P_t = 100A_{st}/bd=(100x5399.6)/1000x560)=0.96
From Table No. 19 of IS 456:2000
τ_c = 0.64 N/ mm^2
τ_v = Vu/bd = 98.56x10^3/(1000x560)=0.176 N/mm^2
$\tau_c > \tau_v$
Hence safe.

6.4 DESIGN OF COLUMN

Size of column (230x450) mm
P_u =1104KN
M_{ux} = 35.64KN-m
M_{uy} = 64.48KN-m
F_{ck} = 25N/mm^2
F_y = 500N/mm^2

Selecting trial reinforcement:

Pu/f_{ck}bD =1104x10^3/25x230x450=0.426
Uniaxial m_u= 1.15 $\sqrt{(m_{ux}^2+m_{uy}^2)}$
= 1.15 $\sqrt{(35.64^2+64.45^2)}$
=84.69KN-m
$M_u/f_{ck}bD^2$= 84.69x10^6/25x230x450^2=0.072
d^1/D= 50/450=0.11
referring to chart 48 in SP-16

$P/f_{ck}= 0.04$
$P= 0.04x25=1$
$A_{sc}= pbD/ 100= 1X230X450/100$
$A_{sc}= 1035mm^2$
Provide 4 bars of 20mm diameter.
Area provided = $1256.63mm^2$
Actual p= 1256.63/230x450=1.21
$P/f_{ck}= 1.21/25=0.04$

To find m_{ux1};

$P/f_{ck} =0.04$, $P_u/f_{ck}bD = 0.426$, $d/D = 0.11$
from chart 48
$m_{ux1}/f_{ck}bD2 = 0.07$
$m_{ux1}= 0.07x25x230x450$
=81.5KN-m

To find m_{uy1};

Since $P_u/f_{ck}bd$, p/f_{ck} , $mu/f_{ck}bd^2$ are same as above
Here also muy1= 81.5KN-m
To find $p_{u2}= 0.45xf_{ck}xA_c+0.75f_yA_{sc}$
$A_c= 230x450-1256.63=102243.37mm^2$
$A_{sc}= 1256.63mm^2$
$P_{u2}=0.45x25x102243.37+0.75x500x1256.63$
=1621.47KN

To find αn;

$P_u/p_{u2}= 1104/1621.47=0.68$
This between 0.2 and 0.8
$\alpha_n=1+(0.68-0.2)/0.6=1.8$
Checking interaction formula;
$(M_{ux}/m_{ux1})^{\alpha n} + (m_{uy}/m_{uy1})^{\alpha n}$
$(35.64/81.5)^{1.8}+ (64.48/81.5)^{1.8}$
=0.88<1
Interaction formula is satisfied

Design of ties;

Use 8mm diameter tie
Maximum pitch

a) Least lateral dimension = 230mm
b) 16xϕ= 16x20=320mm
c) 300mm

Hence provide 8mm@ 230mm 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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