Design of Residential Building and Analysis with STAAD Pro
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Abstract—The construction these days have been far than the
reach due to developing status that our country India holds.
With development of country, development of residential
buildings takes place. In this paper the design of residential
building is done with limit state analysis. Limit state method
is a good way to attain strength of structure with low cost
when compare to other design synopsis. The plan, section and
elevation are generated in AUTOCAD software as per
required area of 200 sq m. Then the design follows with
different types of loading conditions with different cases of
rooms and position of rooms. After plotting the design,
analysis is made with the help of STAAD Pro software and
the results found out to be same.

Key words: STAAD Pro, Residential Building, AUTOCAD

I. INTRODUCTION

The basic requirements of human presences are food, apparet's and shelter. From times immemorial man has been
attempting endeavors in enhancing their way of life. The
purpose of his endeavors has been to give a monetary and
productive sanctuary. The ownership of safe house other than
being a fundamental, utilized, gives a sentiment security,
obligation and demonstrated the societal position of man.

Each individual has an inborn enjoying for a quiet
domain required for his charming living, this item is
accomplished by having a position of living arranged at the
safe and advantageous area, such a spot for agreeable and
wonderful living requires considered and kept in perspective.

- A Peaceful domain
- Security from all normal source and atmosphere
conditions
- General facilities for group of his neighborhood

The basic requirement for a man is to reduce the cost of
construction. The limit state method is use

II. EXPERIMENTAL SETUP

The main aim of this project is to design a residential building
with appropriate reinforcement as per Indian standards with
limit state analysis. The design of residential building takes
generation of plan which is done with the help of AUTOCAD
software. Before going through this software the respective
plan for ground floor and first floor which are
drafted in AUTOCAD software are shown as individually as
the plan section and elevation of residential building which
are drafted in AUTOCAD software in 2007 version and is
shown below.

A. Arrangements of Rooms

1) Aspects

Aspect means particular arrangement of doors and windows
in external walls of residential building while environment to
pass through it. The important aspect in panning is not only
providing the sunshine but also hygiene and eco-friendly
environment. The room is based upon the allowance of air
and light and referred to such particular aspect. As per the
plan the different arrangements of room are shown below.

<table>
<thead>
<tr>
<th>Room (In both floors)</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance</td>
<td>North</td>
</tr>
<tr>
<td>Kitchen</td>
<td>East</td>
</tr>
<tr>
<td>Dining hall</td>
<td>South</td>
</tr>
<tr>
<td>Living room</td>
<td>South East</td>
</tr>
<tr>
<td>Prayer Room</td>
<td>East</td>
</tr>
<tr>
<td>Master Bedroom</td>
<td>South West</td>
</tr>
<tr>
<td>Bed room</td>
<td>West</td>
</tr>
<tr>
<td>Staircase</td>
<td>North</td>
</tr>
<tr>
<td>Verandah</td>
<td>West or South West</td>
</tr>
<tr>
<td>Utensils</td>
<td>West near to bedrooms</td>
</tr>
</tbody>
</table>

Table 1

2) Size

The total area of residential building is 200 sq m. The area is
divided into number of rooms as per requirement. In keeping
the view of health and ventilation, The sizes of room are
provided keeping in view of National Building code, the
different dimensions of rooms are provided as.

<table>
<thead>
<tr>
<th>Room</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Floor</td>
<td></td>
</tr>
<tr>
<td>Kitchen</td>
<td>3x2.5 m</td>
</tr>
<tr>
<td>Dining hall</td>
<td>3x2.5 m</td>
</tr>
<tr>
<td>Master Bedroom</td>
<td>4x3.5 m</td>
</tr>
<tr>
<td>Bedroom</td>
<td>3.5x3 m</td>
</tr>
<tr>
<td>Living room</td>
<td>5x3 m</td>
</tr>
<tr>
<td>Prayer Room</td>
<td>1x1.5 m</td>
</tr>
<tr>
<td>Utensils</td>
<td>2x1.5 m</td>
</tr>
<tr>
<td>Second Floor</td>
<td></td>
</tr>
<tr>
<td>Kitchen</td>
<td>3x2.5 m</td>
</tr>
<tr>
<td>Dining hall</td>
<td>3x2.5 m</td>
</tr>
<tr>
<td>Master Bedroom</td>
<td>4x3.5 m</td>
</tr>
<tr>
<td>Bedroom</td>
<td>3.5x3 m</td>
</tr>
<tr>
<td>Prayer Room</td>
<td>1.5x2 m</td>
</tr>
<tr>
<td>Utensils</td>
<td>1.8x2 m</td>
</tr>
</tbody>
</table>

Table 2
III. DESIGN OF RESIDENTIAL BUILDING

The design of residential building is carried out as per Limit state analysis. The codes used in the design are IS:456 2000 and IS:875 1980

IV. DESIGN OF SLAB

The foremost important point in design of slab is analysis of loads. The loads are directly taken as provided in Indian Standard IS: 875 1980 (Part 1 for dead load; Part 2 for live load; Part 3 for wind load)

As per IS: 875–1980 part II, the live loads for different types of rooms rested on ground floor is selected as:

<table>
<thead>
<tr>
<th>Room</th>
<th>Loads as per IS: 875 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>3 KN/m²</td>
</tr>
<tr>
<td>Dining hall</td>
<td>4 KN/m²</td>
</tr>
<tr>
<td>Master Bedroom</td>
<td>3 KN/m²</td>
</tr>
<tr>
<td>Bedroom</td>
<td>2 KN/m²</td>
</tr>
<tr>
<td>Living Room</td>
<td>2 KN/m²</td>
</tr>
<tr>
<td>Prayer Room</td>
<td>2 KN/m²</td>
</tr>
<tr>
<td>Utensils</td>
<td>2 KN/m²</td>
</tr>
</tbody>
</table>

Table: 3

A. Kitchen

The dimensions of kitchen room are 3x2.5 m (as we discussed earlier)

1) Type of Slab

The type of slab is decided based upon ratio of longer span to shorter span

Longer span/shorter span = 3/2.5 = 1.2

If this ratio is less than 2 then two way slab (If more than 2 one way slab)

As per our dimensions of kitchen the design goes with two way slab

The super imposed load for kitchen is taken as 3 KN/m²

2) Depth of slab

Based upon the stiffness, selected l/d ratio as 28

d = 89.28 mm (approx. 90 mm)

Provide 30 mm effective cover

Over all depth of slab = 120 mm

3) Loads per meter

Dead load = 25x1x0.12 = 3 KN/m
Super imposed load = 3 KN/m
Total load = 6 KN/m
Factored load = 1.5x6=9 KN/m
4) Effective span
As per IS: 456 2000 clause 22.2
The effective span is given as leff=90+2500=2590 mm
5) Moments
As per IS: 456 2000 table 27
Mx=αx Wleff2
Mx=0.084x9x2.59x2.59=5.07 KNm
My=αy Wleff2
My=0.059x9x2.59x2.59=3.56 KNm
6) Check for depth
M=0.138fckbd2
5.07x106=0.138x20x1000xd2
D=42.85 mm (HENCE SAFE)
7) Reinforcement
8) Longer span
Mx=0.87fyAstd(1-fyAst/fckb)
The area of reinforcement for shorter span is obtained as
Ast=112.47 mm2
9) Spacing
Provide 12 mmØ diameter bars
Spacing, S= ast/Ast x1000
=3d=270 mm
=300 mm
Whichever is less
Provide 12 mm Ø bars @ 270 mm c/c
10) Shorter span
My=0.87fyAstd(1-fyAst/fckb)
The area of reinforcement for shorter span is obtained as
Ast=162.08 mm2
11) Spacing
Provide 12 mm Ø diameter bars
Spacing, S= ast/Ast x1000
=3d=270 mm
=300 mm
Provide 12 mm Ø bars @ 270 mm c/c
12) Edge Strip
As per IS: 456, Clause 26.5.1.2.1
Ast= 0.12 % of gross area = 0.12 x1000x120 /100=144 mm2
13) Spacing
Provide 8 mm Ø diameter bars
Spacing, S= ast/Ast x1000
=5d=450 mm
=450 mm
Provide 8 mm Ø bars @ 350 mm c/c
14) Check for deflection
L/d=20
Fs=0.58 fyAst(req)/Ast (pro)
As per IS: 456 2000, Clause 23.2.1
Modification factor = 2
l/d(req)=40
l/d(get)=2590/90 = 28.78 (HENCE SAFE)
B. Design of Beam
D=300mm
d=250mm
d'=50mm
b=125mm
fck=20N/mm2
fy=415N/mm2
1) Loads per meter
Dead load=25x0.25x0.125=0.781KN/M
Super imposed load=2KN/M
Live load=10.78KN/M
Total load=13.56KN/M
Factor load=1.5x13.56
Wu=20.34KN/M
Bending moment=wul2/8
=20.34x3.52/8
Mu=30.14KNM
Check for depth:-
Mu=0.138fckbd2
d=295.59mm
Depth is failed (So provide double reinforcement)
2) Reinforcement
3) Ast in compression
0.87fyAst1=0.36fckbxumax
Ast1=0.36x20x125x120/0.87x415
Ast1=299.12mm2
(From sp 16 charts ) Fsc=342.4N/mm2
Mu limit=0.138fckbd2
Mu limit=21.56KNM
Mu2=8.585KNM
Mu2=fsc Asc(d-d')
8.58x106=342.4xAscx (250-50)
Asc=125.36mm2
4) Additional tensile steel (Ast2)
0.87fyAst2=fscAsc
Ast2=fscAsc/0.87fy
Ast2=118.88mm2
5) Total tensile steel
Ast=Ast1+Ast2
Ast=418mm2
6) No. of bars (in tension)
Ast=418,ф=18mm
=418/π/4x182
=2bars
7) In compression
Ф=12mm
=125.36/π/4x122
=2bars
Provide 2-18mm bars in tension
Provide 2-12mm bars in compression
8) Column (Axial)
Height=2.75m
Factor load=1100KN
Let Assume the Gross area % of steel
\[ A_{sc} = 1\% A_{g} = 0.01 A_{g} \]
Area of concrete, \[ A_{c} = A_{g} - A_{sc} \]
Ag = 0.01Ag = 0.99 Ag

Axially load column:
\[ P_u = 0.4 f_{ck} A_{sc} + 0.67 f_{y} A_{sc} \]
\[ 1100 \times 103 = 0.4 \times 20 \times 0.99 A_{g} + 0.67 \times 415 \times 0.01 A_{g} \]
\[ A_{g} = 102798.93 \text{mm}^2 \]
\[ S^2 = 102798.9 \]
\[ S = 320 \times 320 \text{mm} \]

Provide 4 bars of 18mm diameter

9) Lateral reinforcement

From IS:456-2000, clause 26.5.3.2
10) Ties

Adopt 6mm φ bars

11) Pitch

320mm (or)
16xφ = 16x18 = 288mm (or)
300mm

Provide 6mm lateral ties @ 288mm/c

C. Design of Footing

Axial load = 1100KN
Size of column = 320x320mm

Soil bearing capacity = 200KN/M2

Fck = 20N/MM2, Fy = 415N/MM2

1) Size of footings

Assume dead load 10%
Dead load = 1.1x733.33/200
Area = 4m2

2) Upward soil pressure

\[ P_u = 733.33 \times 1.5 \]
\[ P_u = 1100 \text{KN} \]

3) Moment

\[ M_u = q_u x B \times (B - b)/2 \]
\[ M_u = 957,440 \text{KN} \]

4) Depth

\[ d = 190 \text{mm} \]

5) Reinforcement

\[ M_u = 0.87 f_{y} A_{std} (1 - f_{y} A_{std}/f_{ck} d) \]
\[ A_{st} = 139.3 \text{mm}^2 \]

6) Spacing

From IS:456-2000, Clause 26.3.3

φ = 12mm

S = ast/Ast x B
S = 162.26mm

Provide 12mmφ @ 160mm/c

One-way shear:

\[ V_u = q_u B (B-b)/2 - d \]
\[ V_u = 242,000 \text{KN} \]

7) Nominal shear stress

\[ \tau_1 = V_u / b \]
\[ \tau_1 = 0.3025 \text{KN/MM}^2 \]

From IS:456-2000, Table-19

D. Design of Stair Case

1) Proportioning of Stairs

Dimension of stair hall = 2.5x4.5m
Height of floor = 3.3m

Rise R = 225mm
Tread T = 150mm

2) Effective span

From IS:456-2000, Clause 22.2
le = 4.73m

3) Loads

Weight of waist slab = D√(1+(R/T))2x25
= 6.61KN/m

Weight of steps = (1/2RT)/TX25 = 1.875KN/m2

Floor finish = 0.6KN/m2

Total load = 3KN/m2

Live load = 12.1KN/m2

Factor load (wu) = 1.5x1.2 = 18.15KN/m2

Bending moment \( M_u = wu/2 \)

Mu = 50.76KNM

4) Depth

\[ d = 190 \text{mm} \]

Provide 12mmφ bars @ 130mm/c
7) Distribution steel
Ast=0.12% of gross area
=0.12x1000x220/100=264mm²
Using 8mm bars, spacing
S=π/4x8²=190.4mm
Hence provide 8mm bars @ 190mm c/c
8) Reinforcement details
a) Beams
Provide 2-18mm bars in tension
Provide 2-12mm bars in compression
b) Column
Provide 4 bars of 18mm diameter
Provide 6mm lateral ties @ 288mm c/c
c) Footing
Provide 12mmф @ 160mm c/c
Provide 2legged-6mmф @ 300mm c/c
d) Slab
Provide 12mmф @ 270mm c/c
Provide 12mmф @ 280mm c/c
Provide 8mmф @ 350mm c/c
9) Reinforcement sketches
10) Slab
11) Kitchen room

12) Other Rooms

13) Columns

14) Footings

15) Staircases

16) Results
The results shown are based on analysis of designed model in STAAD Pro software. The model generated in STAAD Pro is shown in figure below as position of beams and column. The STAAD Pro generate diagram shows the dimension of beam and columns.
17) **Forces**
The analysis of buildings start with analysis of forces in each member in their respective axis, then moments, stresses and at last deflection. First of all the forces are found in X, Y and Z- direction and there diagram are shown below.

18) **Axial Forces in X- direction**

19) **Axial Forces in Y-direction**

20) **Axial Forces in Z-direction**

22) **The Moment in Y-direction**

23) **The Moment in Z-direction**

24) **Stresses**

25) **Deflection**

26) **Final static report**
The final static report is given as
Hence all the loads and displacements are resisted by structure itself

V. CONCLUSION

The method used is limit state analysis, the factor of safety for concrete is 1.5 and steel is 1.1 it means 50% more concrete and 10% more steel is consider. Where as in working state method which is widely followed in our country has factor of safety of 3 for concrete and 1.7 for steel it means 200% more concrete and 70% more steel. As amount of more concrete and steel, bigger areas can be seen in working stress method. As we can reduce out area by following limit state method and hence also proved as economical.

The design follow the study of AUTO CAD and analysis with STAAD pro and found out the structure is safe in deflections, stresses, loads and moments. The aspects and prospects are made according to NBC of India, which gives various advantages over random arrangements.

REFERENCES