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Analysis and Design of Multi-Storey Building Subjected to Lateral Forces

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Abstract: This work involves the analysis and design of irregular 3-D frames of (basement + ground + 5) storeys using a software tool STAAD Pro. Using the analysis results various members of the structure are designed i.e. beams, columns, slabs. After the design of beam, column and slabs the design of retaining wall and raft foundation is done. Slab, retaining wall and raft foundation are designed manually. In addition to this the detailed study of seismic and wind forces were undertaken.

Keywords: Raft foundation; Seismic zone; Basic wind speed; Beam; Column; Slab; Retaining wall; Critical stresses

I. INTRODUCTION

In this thesis work a residential building which consists of basement + ground floor + 5 storeys is taken whose height is 21.00 m, length is 36m and width is 30m. The heights of different levels are as follows:

Basement height = 4m

Ground floor to 5th floor = 3.5m

The building is of irregular shape and consists of multiple bays. The modelling of the building is done in the STADD Pro software. The overall plan dimensions are 36m x 30m. The height of different floor levels is stated previously. A solid slab of 150mm has been considered for all storeys. Live load intensity on floor is taken as 3KN/m^2 for all over the floor area and 0.75KN/m^2 for the roof in which access not provided except for maintenance as per IS 875 (part-2):1987. Dead load of beams, columns, slabs and masonry wall are taken as per IS 875 (part-1):1987. Wind load calculations are done as per IS 875 (part-3):1987. Seismic load calculation is done as per IS 1893 (part-1): 2002. And the building has been designed as per IS 456:2000. The other details are tabulated in Table 1.

No. of stories	**Basement + ground + 5**
Seismic zone	V, Darbhanga, (Bihar)
Soil type	Soft soil
Basic wind speed	55 m/sec, Darbhanga, (Bihar)
Grade of concrete	M25
Grade of steel	Fe500 d, Fe415

Table 1: Description of Building.

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II. METHODOLOGY

The building components are analyzed for different load combination and the load combinations as per IS 875 (part 5):1987. And the load combinations are given in Table 2.

DL	LL	WLX	WLZ	SLX	SLZ
1.5	1.5	-	-	-	-
1.2	1.2	1.2	-	-	-
1.2	1.2	-	1.2	-	-
1.2	1.2	-	-	1.2	-
1.2	1.2	-	-	-	1.2
0.9	-	1.5	-	-	-
0.9	-	-	1.5	-	-
0.9	-	-	-	1.5	-
0.9	-	-	-	-	1.5

Table 2: Load Combination For RCC Structures.

Where,
DL = Dead load.
LL = Live load.
WLX = Wind load in X direction.
WLZ = Wind load in Y direction.
SLX = Seismic load X direction.
SLZ = Seismic load Y direction.

Once the building is analyzed for above load combinations different components of the building i.e. beams, columns, slabs, foundations, retaining wall etc will be designed as per IS 456:2000 recommendations.STADD Pro modeling is shown in Figure 1 and Figure 2. After the application of loads and load combination; beam, column and slab are dimensions.

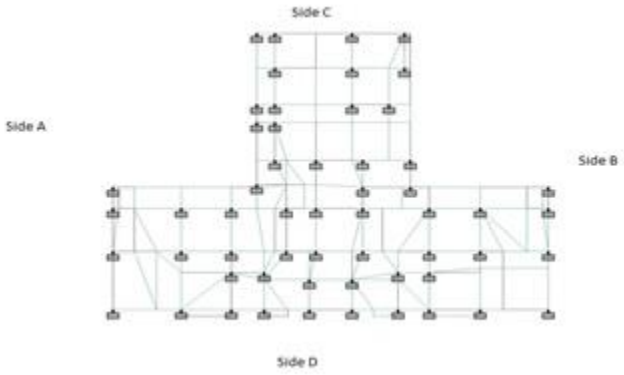

Figure 1: STADD pro modeled plan of building.

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III. LOAD CALCULATION

Dead Load Calculation

1. **Self-weight of Building frame:**
   Self-weight of building frame, i.e. Column, Beam & Slab have modelled in staad.
   This load shall be calculated by staad-pro itself by giving command "SELFWEIHT"

2. **Brick Wall Load:**
   Thickness of Brick Wall = 0.23m
   Height of wall = 3.5m
   Density of Brick = 18 kN/m^3
   Thickness of Plaster outside the wall = 20 mm
   Thickness of Plaster inside the wall = 15 mm
   Density of Plaster Masonry = 20 kN/m^3
   Total Weight per running meter = 16.94 kN/m^3

Live Load Calculation

1. As per IS 875 Part -2, live load on residential building has been recommended as 3.0 kN/Sq metre. The same magnitude has been applied on building as Floor Load in Stadd model.
2. Live load on roof has been applied as 0.75 kN/Sq meter, considering rarely accessibly.
3. Since a water tank is coming on the roof of the building, therefore an additional live load of 1.5 kN/Sq m have been applied on water tank area for tank maintenance.

Wind load calculation

Wind load shall applied as per IS 875Part III.
Basic Wind Speed 'Vb' = 55 m/sec
Probabilility Factor 'K1' = 1.0 (As per IS 875 -III Clause 5.3.1 (Table 1))
Terrain, Height & structure size factor 'K2' = Terrain Category 2, Class B 0 (As per IS 875 -III Clause 5.3.2 (Table 2))
Topography Factor 'K3' = 1.0 (As per IS 875 -III Clause 5.3.3)
Design Wind Speed 'Vz' = Vb*K1*K2*K3 (As per IS 875 -III Clause 5.3)
Design Wind Pressure 'Pz' = $0.6Vz^2$ (As per IS 875 -III Clause 5.4)
As per IS 875 -III Clause 5.3.2 (Table 2), K2 value shall be calculated

h	K2	K1	K3	Vz (m/sec)	Pz (kN)
10	0.98	1	1	53.9	1.74
15	1.02	1	1	56.1	1.89
20	1.05	1	1	57.75	2
30	1.1	1	1	60.5	2.2
50	1.15	1	1	63.25	2.4

Table 3: Design wind pressure values.

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External Pressure Co-efficient

h/w	l/w	Angle (in Degree)	A	B	C	D
0.7	1.2	0	0.7	-0.25	-0.6	-0.6
		90	-0.6	-0.6	0.7	-0.25

Table 4: External pressure co-efficient.

CASE-1							
Force Co-efficient	(Cpe-Cpi)	A	B	C	D	Angle (in Degree)	
		0.2	-0.75	-1.1	-1.1	0	X Direction
		-1.1	-1.1	0.2	-0.75	90	Z Direction
CASE-2							
Force Co-efficient	(Cpe-Cpi)	A	B	C	D	Angle (in Degree)	
		1.2	0.25	-0.1	-0.1	0	X Direction
		-0.1	-0.1	1.2	1.2	90	Z Direction

Table 5: Force co-efficient factors.

Seismic force calculation

Seismic force is calculated by doing mass lumping and finding out the reaction on the joint and then applying same reaction in x, y and z direction and then applying spectrum method to it directly in the software.

The algorithm automatically generates mask image without user interaction that contains only text regions to be inpainted.

IV. DESIGN OF STRUCTURAL ELEMENT

Step 1- Assume square size of column and beam.
Step 2- Apply dead load and live load on it.
Step 3- Analyse the structure and then see the bending moment diagram
Step 4- According to BM diagram size and orientation of beam and column are decided.
Step 5- According to the stresses that are coming to ground through column raft foundation is designed for the most critical load combination.

Design of raft foundation and retaining wall is shown in fig-3, critical cases stress diagram is shown in Figure 4 (A,B,C)

RESULTS

1. Size of beam is 0.375m x 0.600m
2. Size of column is 0.900m x 0.600m; 0.600m x 0.900m; 0.600m x 0.600m
3. Size of retaining wall is: thickness is 0.200m and height is 4m.
4. Thickness of raft footing is: under column is 1.5m and other places 0.600m.

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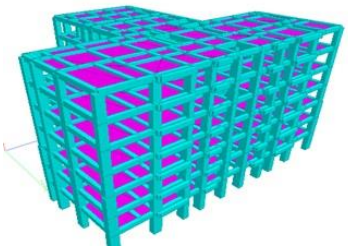

Figure 2: STADD pro 3D modelled view.

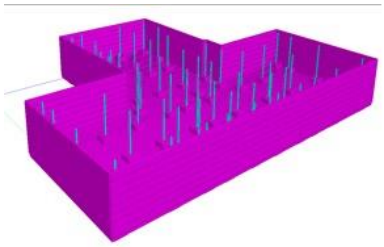

Figure 3: STADD pro 3D modeled view of raft foundation and retaining wall.

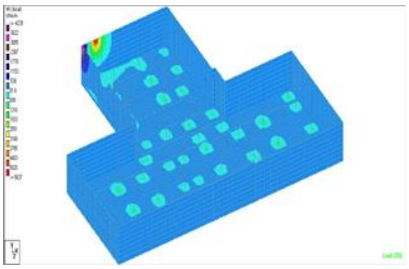

Figure 4 (a): STADD pro 3D modeled view of critical stress for raft foundation and retaining wall.

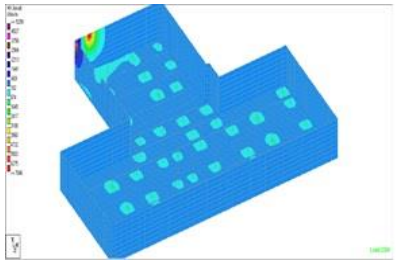

Figure 4 (b): STADD pro 3D modeled view of critical stress for raft foundation and retaining wall.

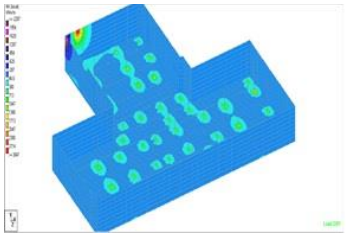

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Figure 4 (c): STADD pro 3D modeled view of critical stress for raft foundation and retaining wall.

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V. CONCLUSION

1. For the building in seismic Zone V and basic wind speed 55m/sec the depth of foundation is more.
2. One way shear and two way shear are large, so the depth of foundation below column is increased.
3. The lateral force that is governing on the building is seismic force.

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