ANALYSIS AND DESIGN OF MULTI - STOREY BUILDING UNDER LOAD COMBINATION

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ABSTRACT: *To design and evaluate the Reinforced Concrete (RC) building structures for precise results with various loads is a wide and complex problem. Proper design of structure and valid results leads to better life and performance of structure, under various load combinations. It is necessary to carry out the most realistic definition of the structural capacity, in terms of strength and deformability of the system under the effect of multiple loads. For this purpose, it is necessary to adopt a clear and concise procedure with specified load combinations that will enable quick and simple methods to reduce defects. In this study, the G+5 storey RC building has been analyzed and designed with load combinations under seismic considerations, which is considered for very high seismic prone area zone - V and also, virtually considered for heavy snow fall. Comparison between manual and software design has been analyzed, which leads to increase the design quality and accuracy. Structural members under lateral and seismic forces have been designed for torsion and ductility.*

Keywords: - Structural load, load combination, Snow load, Comparison

1. INTRODUCTION

The main aim of the project is to design a multi - storey building (G+5) for residential purpose, taking different load combinations into consideration. The design process of multi - storey building require not only imagination and conceptual thinking but also a knowledge in structural engineering and practical aspects such as recent design codes, bye laws, backed up with sample experience. The purpose of standards is to ensure and enhance the safety with vigilance balance between beams, columns, footings, slabs etc., This study has been carried out for the analysis of G+5 multi - storey residential building against to sustain natural calamities like Earthquake and snow loads as per Indian standard codes of 1893(part1) - 2002(in some cases IS13920 also used) and IS 875(part4) - 1987. The member forces have been calculated for load combinations by using limit state method given in IS 456: 2002 and designed for the most critical member forces among them. The snow, wind (IS 875 part3) and seismic loads which are acting on the building have been calculated for seismic zone - V in Himachal Pradesh, (kangra). In most cases, dead and live loads are considered using the codes IS 875 - part1 and IS 875 - part2, whereas for load combinations IS 875 -part 5 is used.

1.1 Building elements
1.2 Loads
1.3 Load combination
1.4 Basics of design

1.1 Building Elements

a) Foundation
b) Beams
c) Column
d) Staircase

1.2 Loads

a) Dead load
b) Live load
c) Seismic load
d) Wind load
e) Snow load
f) Other loads

1.3 Load Combination

Load combinations provide the basic set of building load conditions that should be considered by the designer.

i) 1.5(DL+LL)
ii) 1.2(DL+LL+EQX)
iii) 1.2(DL+LL+EQZ)
iv) 1.5(DL+EQX)
v) 1.5(DL+EQZ)
vi) 1.5(DL + WLX)
vii) 1.5(DL + WL Z)
viii) 0.9DL+1.5EQX
ix) 0.9DL+1.5EQZ
x) 0.8DL +0.9 SL
xi) 1.5 DL + 1.2 LL+1.2 SL
xii) 1.2 DL + 1.2 LL +1.2 WL

xii) 1.2 DL + 1.2 LL +1.2 WL+1.2 SL

2. PLAN AND LAY OUT

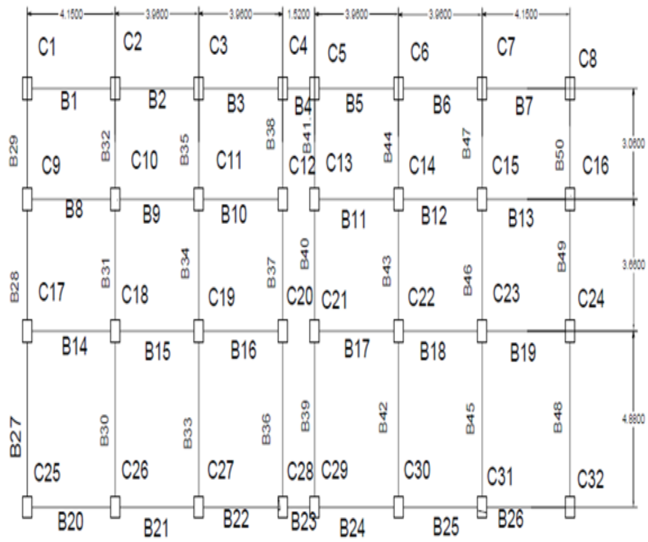
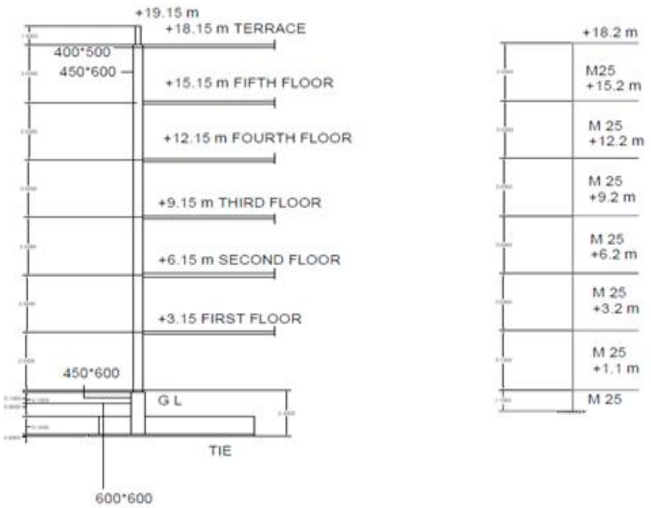


Figure 2.1 Typical Floor Layout Plan



(a) (b)

Figure 2.2 (a) Part Section (b) Part Frame Section

2.1 MODELING OF BUILDING

2.1.1 Details of Building

i) Length of Building = 25.66m

ii) Width of Building = 11.6 m

iii) Height of Building = 18 m

iv) Dimensions of column = (0.60m x 0.45m)

v) Dimensions of beam = (0.40m x 0.50m)

vi) Thickness of Slab = 0.18m

vii) Dead Load on Building for 0.23m thick wall = 14KN/m

viii) Live Load on Building =2.0 KN/m2

ix) Seismic load as per Zone factor

a) Earthquake load in X- Direction

b) Earthquake load in Z- Direction

x) Wind load

a) Wind load in X - Direction

b) Wind load in Z - Direction

xi) Snow load

a) Snow load in Y - Direction

2.2 Salient Features

Utility of building	= Residential Building
No of stories	= 5
No of stair cases	= 1
No of flats	= 10
No of lifts	= 1
Type of structure	= RCC framed structure
Type of walls	= brick wall

2.3 Geometric Details

Ground floor	= 3 m
Floor to floor height	= 3 m
Height of plinth	= 0.6 m
Depth of foundation	= 2 m

2.4 Materials Used

Concrete grade	= M25
All steel grades	= Fe 415 steel
Bearing capacity of soil	= 250 KN/m^2

3. METHODOLOGY

3.1 Design:

To design a structure with less anomalies and errors, it is very necessary to choose a suitable design method. A structure is embedded with no of elements and components hence any error in design can lead to failure of the entire structure. There are two design methods available as given below:

i) Working stress method
ii) Limit state design method

3.1.1 Working Stress Method

i) This method is based on the condition that the stresses caused by service loads without load factors are not to exceed the allowable stresses which are taken as a fraction of the ultimate stresses of the materials, *fc'* for concrete and *'fy'* for steel.

ii) It deals only with elastic behavior of member perfectly elastic at all stages of loading; Stress-strain relations obey hooks law (linear).

iii) Factor of safely for yield stress, allowable stresses are less than 'f_y'

iv) Since, the specifications set limit on the stress, it became working stress method.

v) Working Stress method does not give reasonable measure of strength, which is more fundamental measure of resistance than is allowable stress.

vi) Another, drawback in working stress method is that safety is applied only to stress level. Loads are considered to be deterministic (without variation). For example, Permissible bending & direct compression are as fraction of crushing strength.

3.1.2 Limit State Method

Limit state is a method in which a structure or structural components ceases to fulfil the functions for which it is designed. The above structural elements are designed based on limit state method which considers the variability not only in resistance but also in the effects of load. Concept of separate partial safety factors of loads of different combinations in the two limit state methods.In this method all relevant states must be considered in design to ensure a degree of safety. By adopting this method the structure leads to better and accurate results.

3.2 Analysis

Analysis deals with the study of strength and behavior of the members for working loads in which frames can be analyzed by various methods. However, the method of analysis which is adopted depends on the type of frame with its configuration on multi - storey buildings and the resulting degree of indeterminacy.

3.2.1 Analysis Methods

The methods used for Analysis are:

i) Flexibility coefficient method
ii) Slope displacement method
iii) Iterative methods

a. Moment distribution method (by Hardy cross in 1930's).

b. Kani's method (by Gasper kani in 1940's)

iv) Approximate methods

a. Substitute frame method

b. Portal method
c. Cantilever method

4. DESIGN FOR SEISMIC FORCES

4.1 Seismic Weight Calculations

Table No 4.1 Seismic weight of storey VI (terrace)

Details	Dimensions	D.L +L.L
From Slab	11.5 * 12.8	3680+2
Parapet	1*11.5	287.5+2
Walls	1* 11.5	230+2
Beams	0.40 * 0.500	5+2
Columns	0.45 * 0.600	6.75+2
Total		**4219.5 KN**

Table No 4.2 Seismic weight of storey V, IV, III

Details	Dimensions	D.L + L.L
Slab	11.5 * 12.8	3680 + 2
Walls	1 *11.5	287.5 + 2
Beams	0.400*0.500	5 + 2
Columns	0.450* 0.600	6.75 +2
Total		**3987.25 KN**

Table No 4.3 Seismic weight of storey II

Details	Dimensions	D.L + L.L
Slab	11.5 * 12.8	3680+2
Walls	1 * 11.5	230 + 2
Beams	0.40 * 0.5	5 + 2
Columns	0.45 * 0.6	6.75 +2
Total		**3929.75 KN**

Table No 4.4 Seismic weight of storey I(Plinth)

Details	Dimensions	D.L + L.L
Walls	1 * 11.5	230 + 2
Beams	0.4 * 0.5	5 + 2
Columns	0.45 * 0.6	6.75 + 2
Total		**247.75 KN**

Seismic weight of the entire building

= 4219.25+3987.25+3929.25+247.75

= 12384 KN

4.2 Design Seismic Load

$T_a = 0.075\ h^{(0.75)}$

$= 0.075\ (18)^{(0.75)}$

$= 0.65$ sec

Zone factor, z = 0.36(zone V)

From [IS: 1893 (part 1); 2002, table 2]

Importance factor, I = 2

S_a/g = $1/T_a$

= 1/0.65

= 1.538

[IS: 1893 (part 1): 2002]

Table No 4.5 Distribution of Total Horizontal Load to Different Floor Level

= 180 mm

Storey	W_i(Kn)	H_i (M)	$W_i h_i^2 * 10^{(-3)}$	Q_i	V_i
VI	4219.25	18	1367.03	563.45	563.45
V	3987.25	15	897.13	369.77	933.25
IV	3987.25	12	574.16	236.65	1169.87
III	3987.25	9	322.96	131.11	1302.98
II	3929.75	6	141.47	58.31	1361.29
I	247.75	3	2.22	0.919	1362.20
Total			**3304.97**	**1362.20**	

A_h = (z/2) * (i/r) *(s_a/g)

= (0.36/2) * (2/5) * (1/0.65)

= 0.110

4.2.1 Base Shear

V_b = A_h * W

= 0.110 * 12384

= 1362.24 KN

4.2.2 Accidental Eccentricity

E_{di} = 1.5 e_{si} + 0.05 b_i

(Or)

= E_{si} – 0.05 b_i

0.05 b_i = 0.05 * 12.07

= 0.603 m

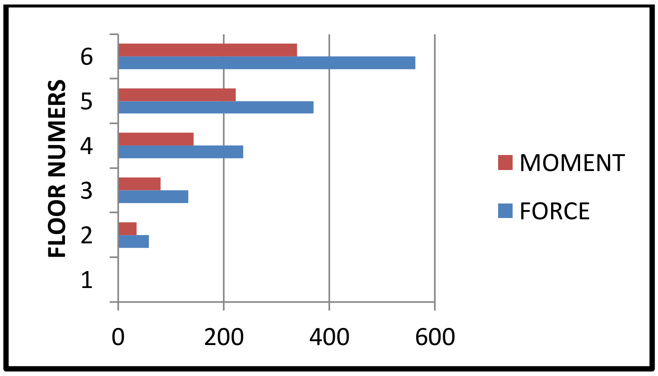


Figure 4.1 Accidental Eccentricity Including Torsion in the building

5. DESIGN OF SLAB

Dimensions = 4.15 * 4.88 m

I_Y/I_x = 4.88/4.15

= 1.176 < 2

Hence, it is two way slab.

Thickness = 150 + 30

Total load = 17.5 KN/m² Factored load = 26.25 KN/m²

M_{ux} = 0.057 x 26.25 x 4.152

= 25.77 KN-m

M_{uy} = 0.047x 26.25 x 4.152

= 21.25 KN-m

$V_u = W_u l/ 2$ = (16.25 x 4.15)/2

= 54.47 KN

5.1 Reinforced Details

5.1.1 Along X Direction

Ast_x (req) = 504.04mm²

*Hence provide 10 mm bars at 220 mm c/c

5.1.2 Along Y Direction

$A_{st\,(req)}$ = 443.74 mm²

*Provide 4bars of 12mm diameter bars of 250mm c/c.

5.2 Edge Strips

Hence, provide 8mm bars at 230mm c/c

6. DESIGN OF BEAM AND COLUMNS

6.1 Manual Analysis for Load Combination by Substitute Frame Method

Assumed dimensions

Beam = 400 * 500 mm

Column = 450 * 600 mm

6.1.1 Cases Considered

I) Max – Min – Max 160 KN – 110 KN – 160 KN
II) Min – Max – Min 110 KN – 160 KN – 110 KN
III) Max – Max – Max 160 KN – 160 KN – 160 KN

Table 6.1 Cases for Fixed End Moments

Cases	M_{1-2}	M_{2-1}	M_{2-3}	M3-2	$M_{3-4'}$	M_{4-3}
I	-317.52	317.52	-122.79	122.79	-124.03	124.03
II	-218.29	218.29	-178.60	178.60	-85.27	85.27
III	-317.52	317.52	-178.60	178.60	-124.03	124.03

Table 6.2 Distribution Factor Table

Joint	Member	R S F	SUM	D.F
1	1-2	0.85	3.55	0.25
	1-5	2.7		0.75
2	2-1	0.85	4.68	0.18
	2-6	2.7		0.57
	2-3	1.13		0.24
3	3-2	1.13	5.19	0.21
	3-7	2.7		0.52
	3-4	1.36		0.26
4	4-3	1.36	4.06	0.33
	4-8	2.7		0.66

Table No 6.3 Substitute Frame Moments

Cases	1			2				3				4	
	col	1-2	Span mmt	2-1	Col	2-3	Span mmt	3-2	Col	3-4	Span mmt	4-3	col
D.F	0.75	0.25		0.18	0.58	0.24		0.21	0.53	0.26		0.33	0.67
I	119.07	-238.14	457.83	283.65	40.68	-169.28	222.52	123.05	-0.295	-123.711	429.06	83.10	-41.55
II	81.85	-163.72	306.56	211.15	8.35	-188.13	454.28	159	21.68	-109.53	265.91	57.14	-28.57
III	119.07	-238.14	452.22	292.55	29.12	-211.94	440.73	167.16	12.83	-138.21	411.58	83.11	-41.55
max	119.07	-238.14	457.83	292.53	40.68	-211.94	454.28	167.16	21.68	-138.21	429.06	83.11	-41.55

Table No 6.4 Substitute Frame Shear Forces

Cases	1	2		3		4
I	381.28	399.52	213.95	188.69	257.31	230.69
II	258.69	278.11	300.75	284.85	184.92	150.58
III	379.26	401.54	305.03	280.57	262.06	225.94
Max	381.28	401.54	305.03	284.85	262.06	230.69
	381.28	706.57		546.91		230.69

*From the above tables

Maximum bending moment = 457.83 KN m

Maximum shear force = 706.57 KN

6.2. Beam Design

Assume beam dimensions = 400 * 500

d = 450 mm

d' = 50 mm

f_{ck} = 25 N/mm²

f_y = 415 N/mm²

L = 4.15 m

Total load = 58 KN/m

Ultimate design load = 87 KN/m

6.2.1 Reinforcement Details

A_{st} = 2153.71 + 1235.13 = 3388 mm²

Provide 6 bars of 28mm diameter (Ast = 3694.51mm²)

6.2.2 Shear Reinforcement

*Provide8 mm diameter bars spacing of stirrups 250mm.

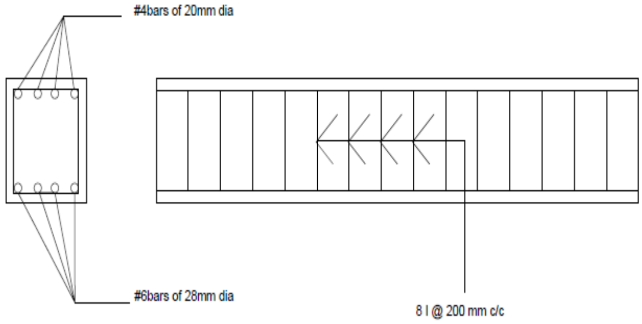


Figure 6.1 Reinforcement Details of Beam

6.3 Column Design

M_{ux} = 119.04 KN-m

M_{uy} = 46.73 KN-m

Data

B = 450 mm

D = 600 mm

p_u = 4219.25 KN

fck = 25 N/mm²

fy = 415 N/mm²

d' = 60 mm

d/D = 0.1

6.3.1 Reinforcement

A_s = pbD/100

= 3 * 450 * 600/100 = 8100 mm^2

Using 18 bars of 25mm diameter distributed 3 on each face

A_s =8835.72 mm^2

M_{ux1} =486 KN-m

,M_{uy} =364.5 KN-m

p_{uz} =5688.21 KN

*provide 8mm diameter lateral ties at 300mm centers will contours to the weld requirements.

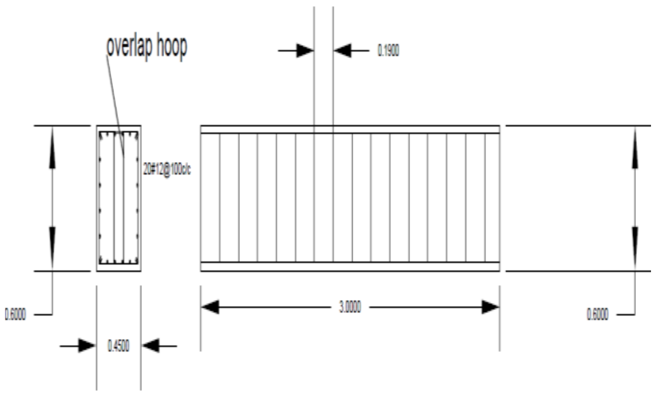


Figure 6.2 Reinforcement Details of Column

7. SOFTWARE DESIGN

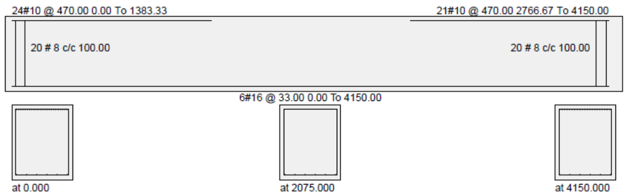
7.1 Beam Design

Dist.m	Fy(kN)	Mz(kNm)
0.000000	-51.5448	-111.5926
0.345833	-51.5448	-93.7667
0.691667	-51.5448	-75.9408
1.037500	-51.5448	-58.1149
1.383333	-51.5448	-40.2890
1.729167	-51.5448	-22.4631
2.075000	-51.5448	-4.6372
2.420833	-51.5448	13.1887
2.766667	-51.5448	31.0146
3.112500	-51.5448	48.8405
3.458333	-51.5448	66.6664
3.804167	-51.5448	84.4922
4.150000	-51.5448	102.3181

Figure 7.1 Shear Force and Bending Moment Details of Beam

Dist.m	Fz(kN)	My(kNm)
0.000000	-3.1335	-4.5961
0.250000	-3.1335	-3.8128
0.500000	-3.1335	-3.0294
0.750000	-3.1335	-2.2460
1.000000	-3.1335	-1.4626
1.250000	-3.1335	-0.6792
1.500000	-3.1335	0.1042
1.750000	-3.1335	0.8875
2.000000	-3.1335	1.6709
2.250000	-3.1335	2.4543
2.500000	-3.1335	3.2377
2.750000	-3.1335	4.0211
3.000000	-3.1335	4.8045

Figure 7.2 Deflection of Beam



Design Load

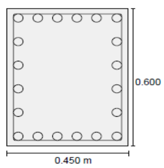
Mz(Kn Met)	Dist.et	Load
176.740005	0.000000	44
-249.490005	0.000000	17
-222.539993	4.200000	12

Design Parameter

Fy(Mpa)	415.000000
Fc(Mpa)	25.000000
Depth(m)	0.500000
Width(m)	0.400000
Length(m)	4.150000

Figure 7.3 Reinforcement details of Beam

7.2 Design of column



Design Load

Load	1
Location	End 1
Pu(Kns)	-236.750000
Mz(Kns-Mt)	88.989998
My(Kns-Mt)	4.600000

Design Results

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm^2)	2160.000000
As (%)	0.838000
Bar Size	12
Bar No	20

Figure 7.4 Reinforcement Details of Column

Dist.m	Fz(kN)	My(kNm)
0.000000	-3.1335	-4.5961
0.250000	-3.1335	-3.8128
0.500000	-3.1335	-3.0294
0.750000	-3.1335	-2.2460
1.000000	-3.1335	-1.4626
1.250000	-3.1335	-0.6792
1.500000	-3.1335	0.1042
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2.250000	-3.1335	2.4543
2.500000	-3.1335	3.2377
2.750000	-3.1335	4.0211
3.000000	-3.1335	4.8045

Figure 7.5 Column Shear Force

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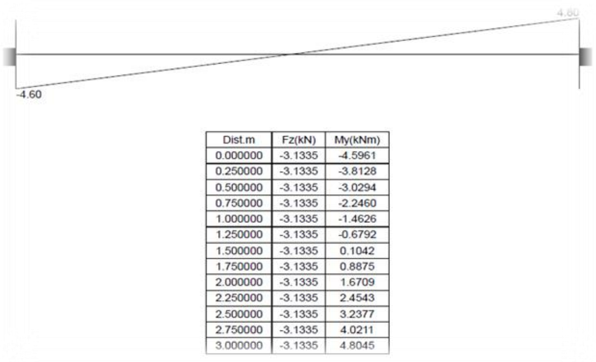

Dist.m	Fz(kN)	My(kNm)
0.000000	-3.1335	-4.5961
0.250000	-3.1335	-3.8128
0.500000	-3.1335	-3.0294
0.750000	-3.1335	-2.2460
1.000000	-3.1335	-1.4626
1.250000	-3.1335	-0.6792
1.500000	-3.1335	0.1042
1.750000	-3.1335	0.8875
2.000000	-3.1335	1.6709
2.250000	-3.1335	2.4543
2.500000	-3.1335	3.2377
2.750000	-3.1335	4.0211
3.000000	-3.1335	4.8045

Figure 7.6 Column Deflection

8. DESIGN OF FOOTING

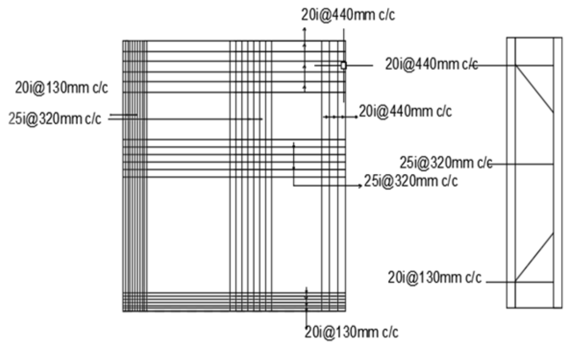

Figure 8.1 Reinforcement Details of Mat Footing

Table No 8.1 Punch Shear Report

Column	Load Case	Allow. Stress (kN/m²)	Corner 1 (kN/m²)	Corner 2 (kN/m²)	Corner 3 (kN/m²)	Corner 4 (kN/m²)	Status
1	201	1250.000	-1067.441	-1092.306	-1063.078	-1038.212	Pass
2	201	1250.000	-1032.819	-1032.895	-1008.033	-1007.956	Pass
3	201	1250.000	-1013.329	-1012.088	-987.375	-988.616	Pass
4	201	1250.000	-1062.438	-1040.540	-1011.418	-1033.316	Pass
29	201	1250.000	-1029.883	-1053.398	-1061.174	-1037.659	Pass
30	201	1250.000	-874.222	-874.311	-881.958	-881.869	Pass
31	201	1250.000	-858.274	-856.805	-864.390	-865.858	Pass
32	201	1250.000	-1025.887	-1004.999	-1012.708	-1033.596	Pass
57	201	1250.000	-839.989	-862.041	-865.471	-843.419	Pass
58	201	1250.000	-719.125	-718.876	-722.457	-722.707	Pass
59	201	1250.000	-705.684	-704.739	-708.261	-709.206	Pass
60	201	1250.000	-838.787	-819.206	-822.574	-842.155	Pass
85	201	1250.000	-795.071	-819.705	-829.867	-805.233	Pass
86	201	1250.000	-788.030	-787.763	-796.435	-796.703	Pass
87	201	1250.000	-772.255	-771.508	-780.116	-780.862	Pass
88	201	1250.000	-795.085	-773.259	-783.382	-805.208	Pass

Table 8.2 Longitudinal Direction - Top Zone Reinforcement Summary

Zone	Moment(KN-m/m)	Load Case	X(m)	Z(m)	Area Req. (mm²/m)	Area Provided (mm²/m)	Bar Detail
1.	136.150	201	11.462	3.985	722.390	722.390	20@ 440" c/c
2.	279.475	201	10.576	9.751	1521.521	1521.709	25@ 320" c/c
3.	413.857	201	1.937	- 0.500	2312.835	2324.778	20@ 130" c/c

9 DESIGN OF STAIR CASE

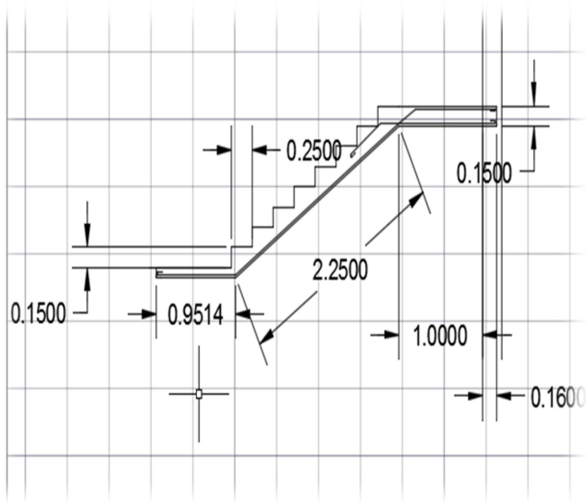

Figure 9.1 Details of Stair Case

10. IS CODES

i) IS 456-2000 (Design of RCC structural elements)
ii) IS 875-Part 1 (Dead Load)
iii) IS 875-Part 2 (Live Load)
iv) IS 875- Part 3 (Wind Load)
v) IS 875- Part 4 (Snow Load)
vi) IS 875- Part 5 (Load Combination)
vii) IS 1893-part 1 (Seismic Forces)
viii) IS 13920 (ductile details)
ix) SP-16 (Depth and Percentage of Reinforcement)

11. CONCLUSION

i) The design of slab, beam, column, rectangular footing and staircase has been done in limit state method which is safe at, control of safer comparatively deflection and in all meticulous aspects.

ii) The structure has been designed by using staad.pro considering IS codes for safer results.

iii) By comparing the manual and the numerical model design the area of AST required for the beam, column, footing and slab are comparatively similar to that requirement.

iv) Structural members like columns and beams have been designed for ductility, hence the lateral forces at member joints will effect minimum and also resist for torsion.

The consideration of various load combinations was a challenging part for design of G+5 building in high seismic prone areas. Hence, in seismic design of forces as referred earlier, it's important to design structures for earthquake resistant as well as for ductility.

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