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Design of Earthquake Resistant Multistoried Building On A Sloping Ground

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Abstract

In this paper is studied the structural analysis software 'STAAD Pro v8i' is used to study the effect of sloping ground on multistoried building performance during earthquake. The purpose of the paper is to perform linear static analysis of medium height RC buildings and investigate the changes in structural behavior due to consideration of sloping ground. This project report comprises of seismic analysis and design of a R.C. building with symmetrical plan. The structure should withstand the moderate earthquakes, which may be expected to occur during the service life of structure with damage within acceptable limits. Such earthquakes are characterized as Design Basis Earthquakes (DBE). The building is modeled as a 3D space frame with six degrees of freedom at each node using the software STAAD- PRO. Building (G+15) is analyzed using Response Spectrum method on 0°, 7.5°, 15°, 22° slope ground. The Response Spectrum as per IS 1893 (Part 1):2002 for medium soil is used. Comparison of results for (G+15) building is done for different slope and same soil condition. Analysis is performed for various load cases and combinations and the worst case is considered for the design of beams and columns. Reinforced concrete design is carried out as Per IS 456: 2000 and ductile detailing is done as per IS 13920: 1993. Various static checks are applied on the results.

1 Description of the Building

The typical framing plan of G+15storey building is shown in figure a) the building is square in plan. Length and width of the building is considered as 36m. Each storey height is considered as 3m. Spacing of frame along length and width is 4m. Material grades of M30 & Fe415 were used for the design.

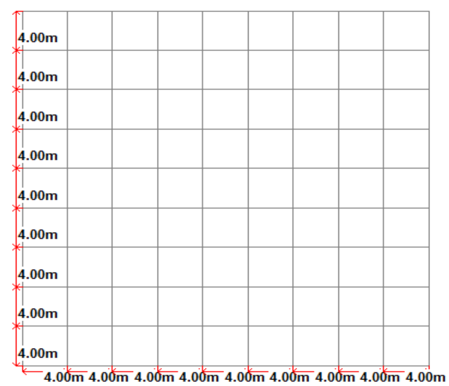

Fig.a) Plan of building

1.1) Structural properties of Building

Total depth of slab	0.125 m
Floor finish load	1 KN/m^2
External wall thickness	0.23 m
Internal wall thickness	0.23 m
Size of external column	0.5 X 0.5m
Size of internal column	0.5 X 0.5 m
Size of beam in longitudinal and transverse direction	0.23 x 0.5m

Earthquake load (As Per IS 1893-PART 1:2002):

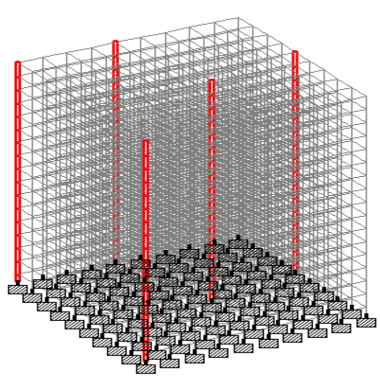

Fig. c) 3-D view of position of column

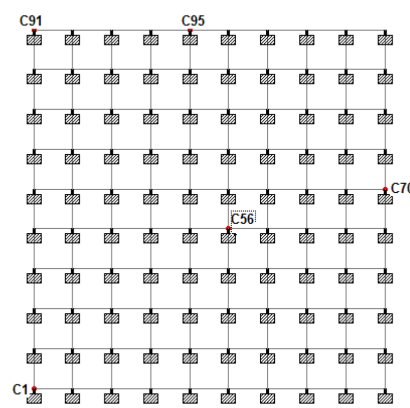

Fig b) Different position of column in plan

ISSN 2348 – 7968

2) ANALYSIS AND MODELING

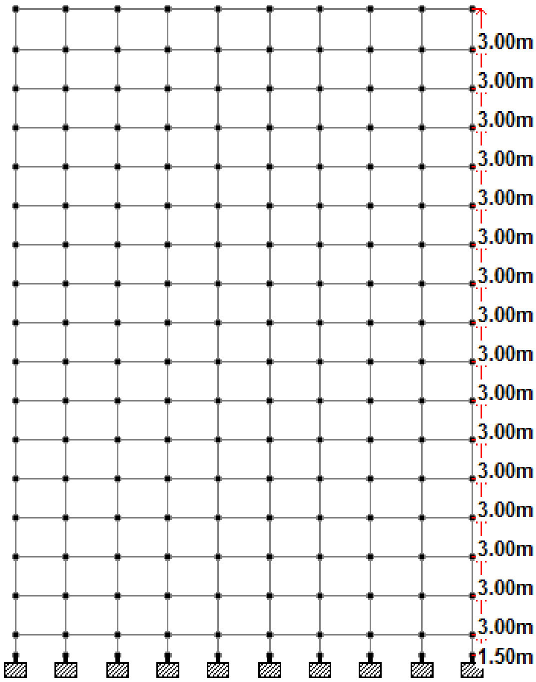

Fig. 2.1) Elevation on plane ground

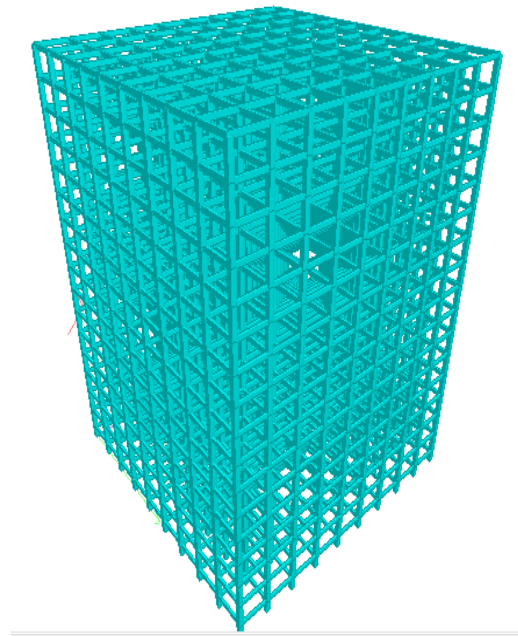

Fig. 2.1.1) 3D view on plane ground

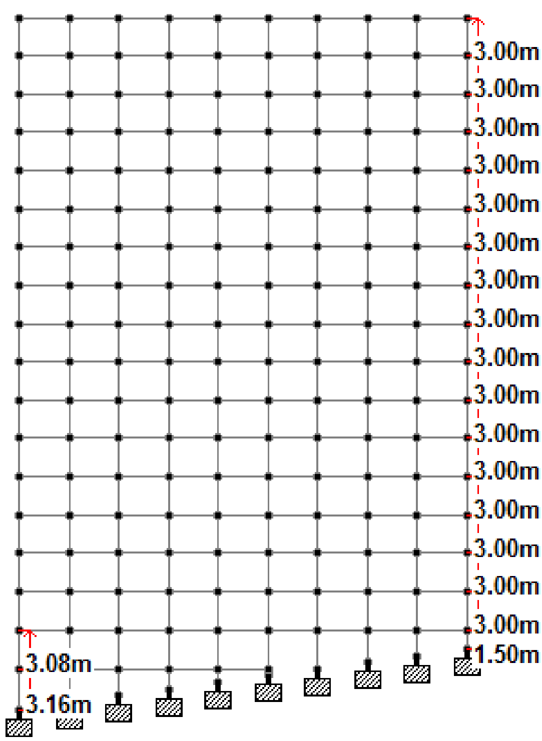

Fig. 2.2) Elevation 7.5°slope ground

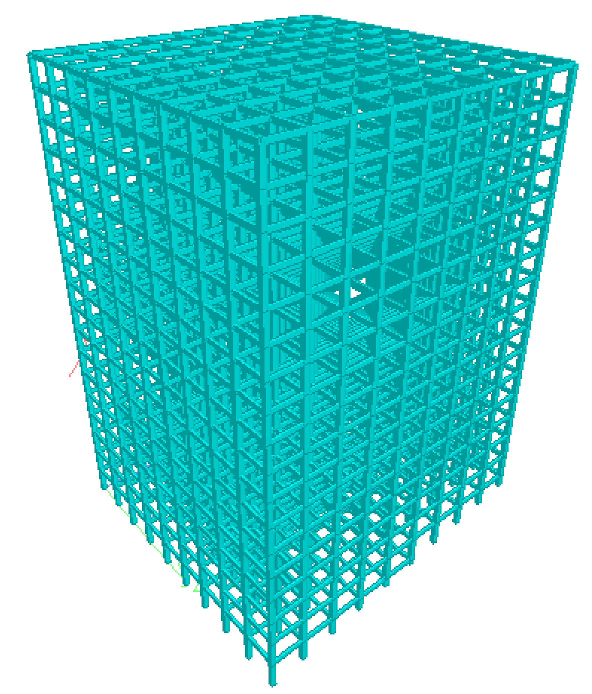

fig. 2.2.1) 3D view on 7.5°slope ground

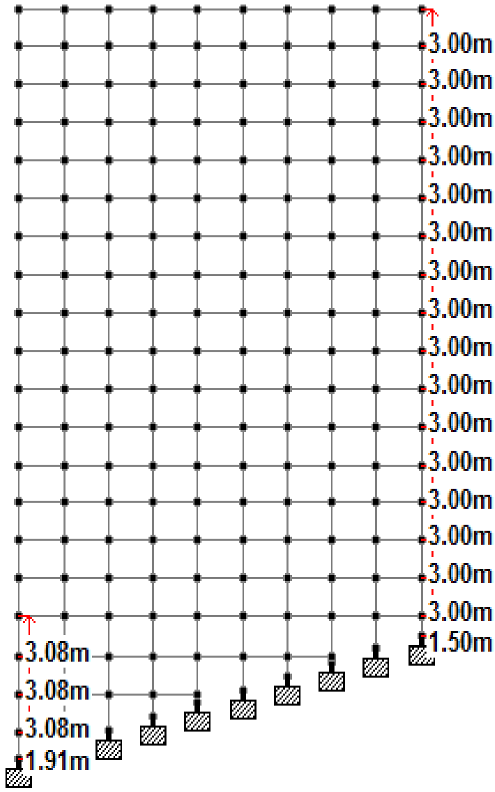

Fig. 2.3) Elevation on 15°slope ground

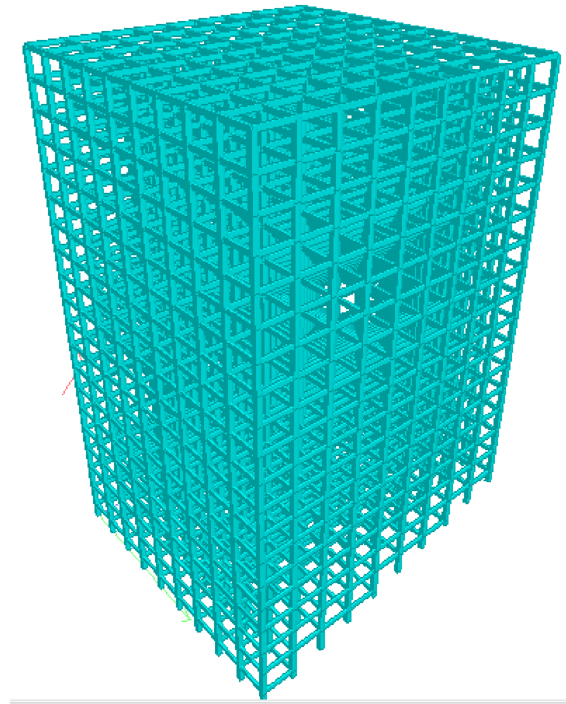

Fig. 2.3.1) 3D view on 15°slope ground

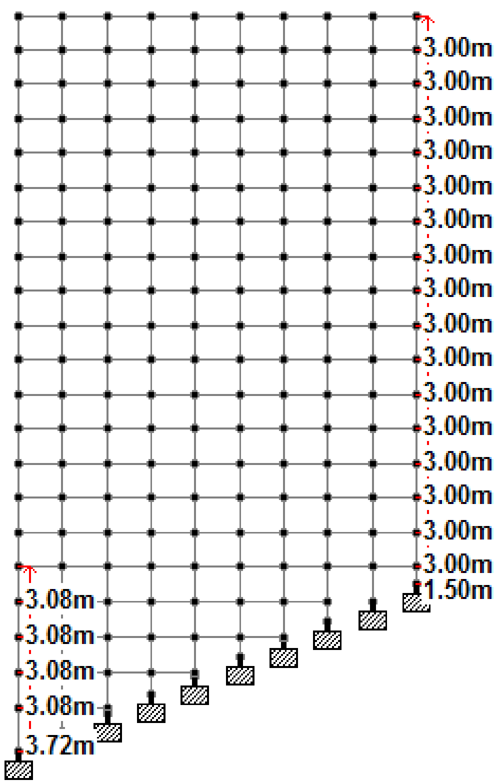

Fig. 2.4) Elevation on 22°slope ground

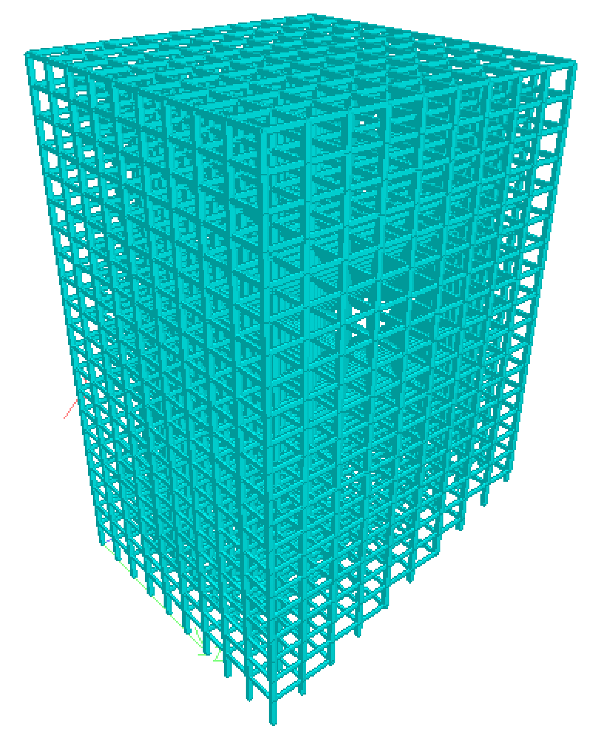

fig. 2.4.1) 3D view on 22°slope ground

ISSN 2348 – 7968

3) Mode shapes

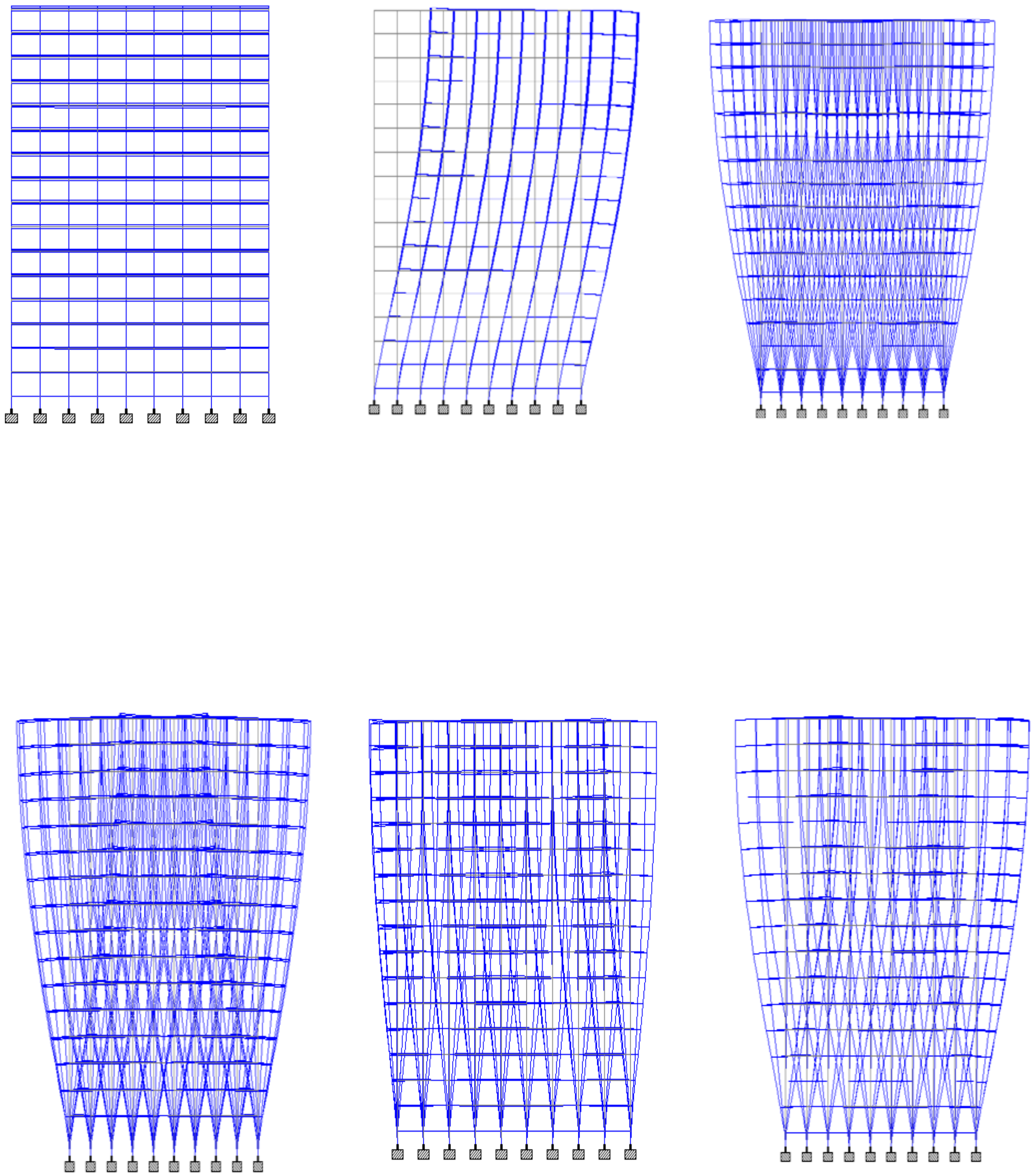

fig. 3.1 Mode shapes for plane ground

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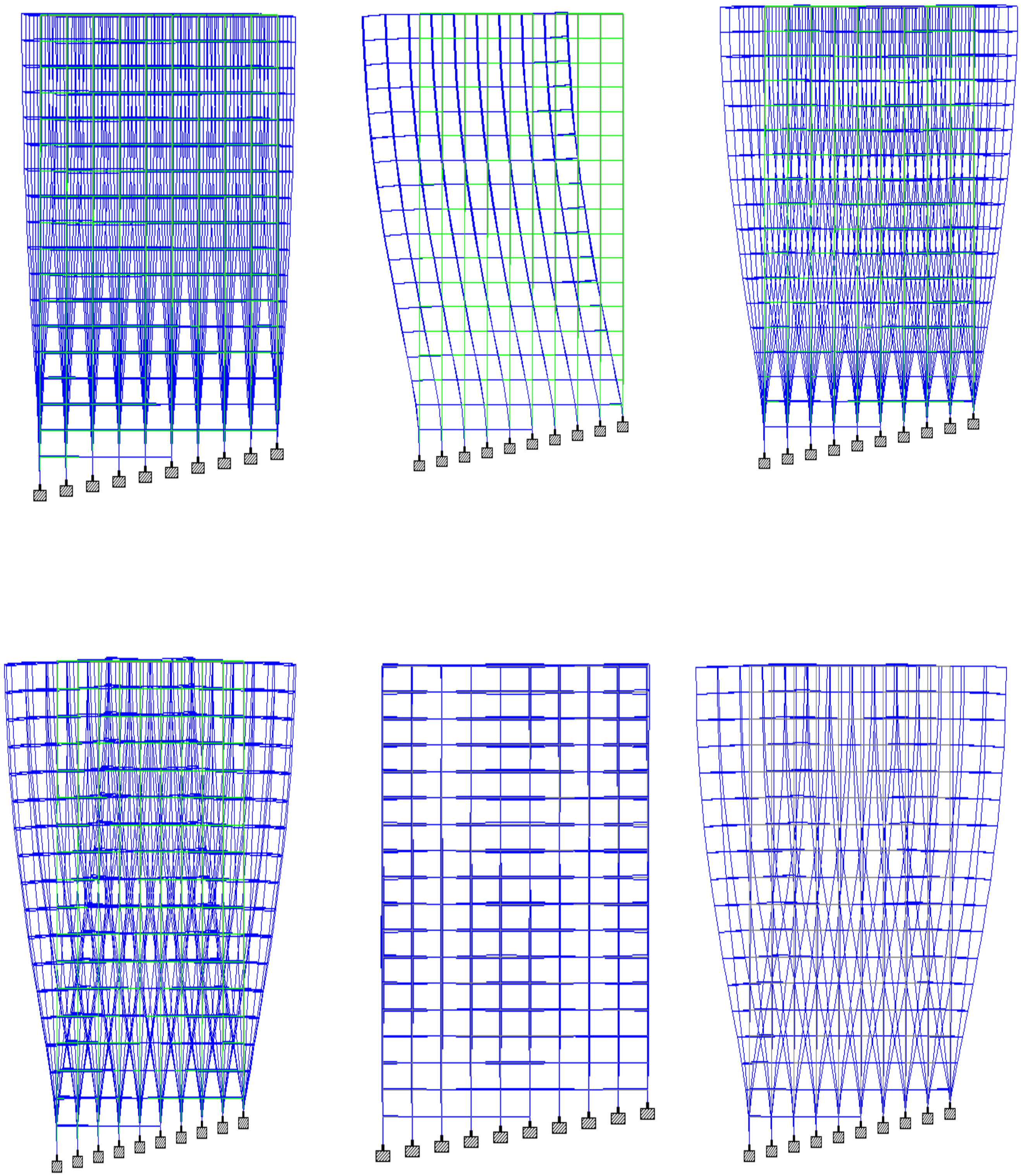

fig. 3.2 Mode shapes for 7.5°slope ground

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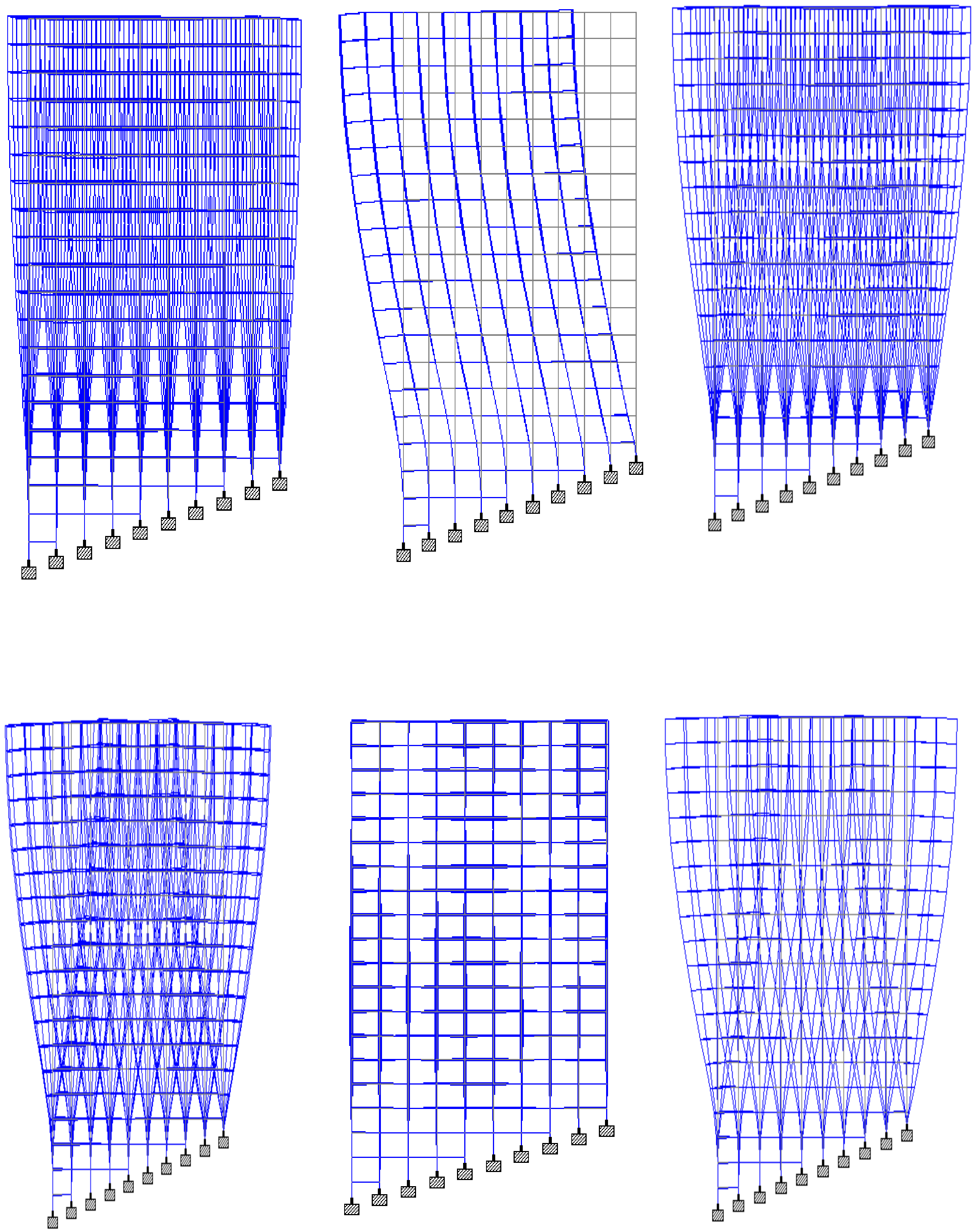


fig. 3.3 Mode shapes for 15°slope ground

ISSN 2348 – 7968

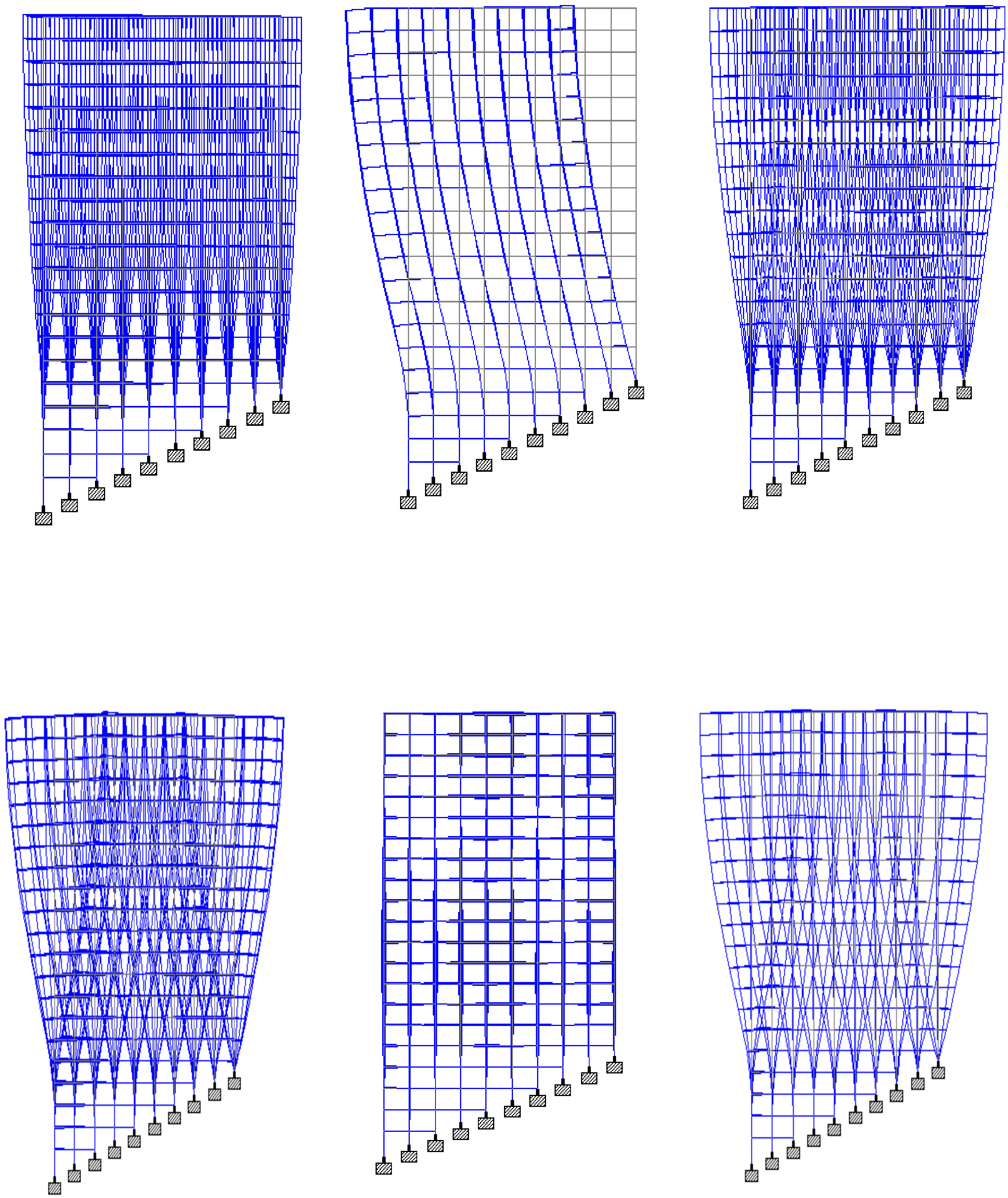


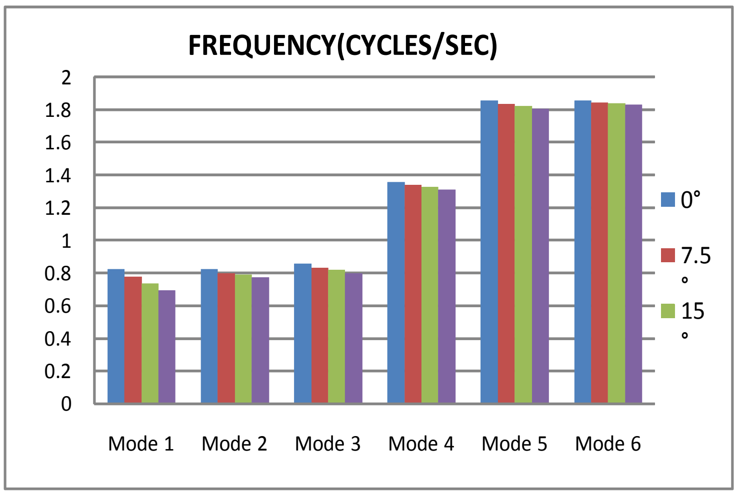
fig. 3.4 Mode shapes for 22°slope ground

4) Mass calculations and Base shear

Ground slope	Soil Type	Zone factor	Time period	Sa/g	Total mass (kN)	Base shear (kN)
0°	Medium	0.24	0.72	1.89	317134.5	14377.61
7.5°	Medium	0.24	0.78	1.74	332861.38	13932.25
15°	Medium	0.24	0.81	1.68	334065.19	13461.49
22°	Medium	0.24	0.85	1.60	336245.06	12911.81

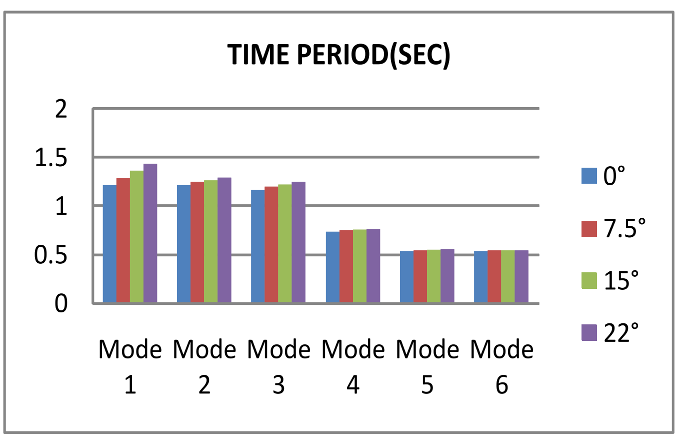
5) Results

5.1 Calculated frequencies for load case (eqx)/(eqz)



MODE	FREQUENCY(CYCLES/SEC)			
	0°	7.5°	15°	22°
1	0.825	0.778	0.735	0.695
2	0.825	0.8	0.79	0.774
3	0.858	0.832	0.819	0.8
4	1.359	1.339	1.326	1.31
5	1.858	1.838	1.822	1.805
6	1.858	1.846	1.841	1.834

5.2 Calculated time period for load case (eqx)/(eqz)



MODE	TIME PERIOD(SEC)			
	0°	7.5°	15°	22°
1	1.2117	1.28483	1.36098	1.43835
2	1.21178	1.25073	1.26543	1.29146
3	1.16508	1.20201	1.22042	1.24942
4	0.73573	0.74691	0.75441	0.76313
5	0.5382	0.54399	0.54883	0.55409
6	0.5382	0.54182	0.54305	0.54519

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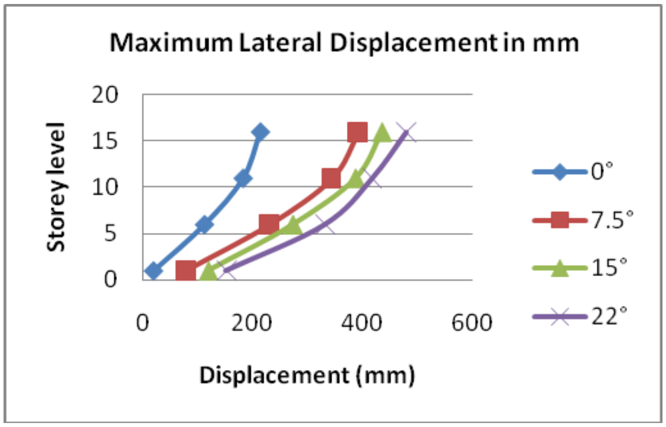
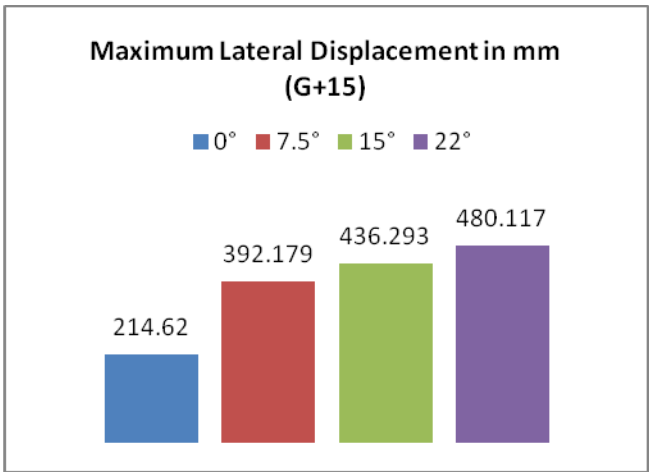
5.3) Lateral displacements



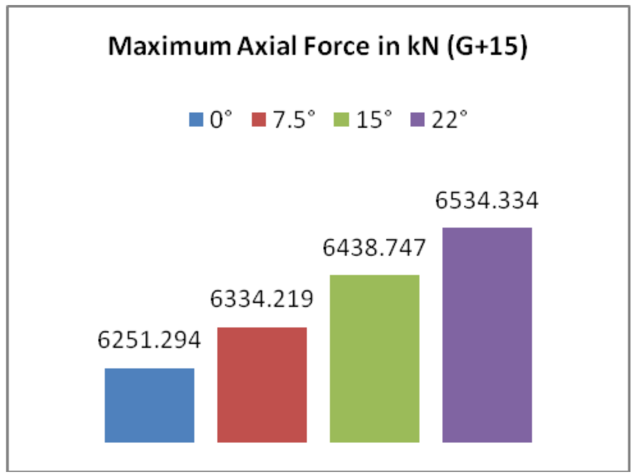
5.3) Maximum lateral displacement at story level

Maximum Lateral Displacement in mm					
Storey Level	Soil Type	Slope of ground			
		0°	7.5°	15°	22°
First	Medium	18.862	77.019	118.471	151.568
Sixth		112.275	230.393	273.046	331.716
Eleventh		183.124	344.025	387.581	417.796
Sixteenth		214.62	392.179	436.293	480.117

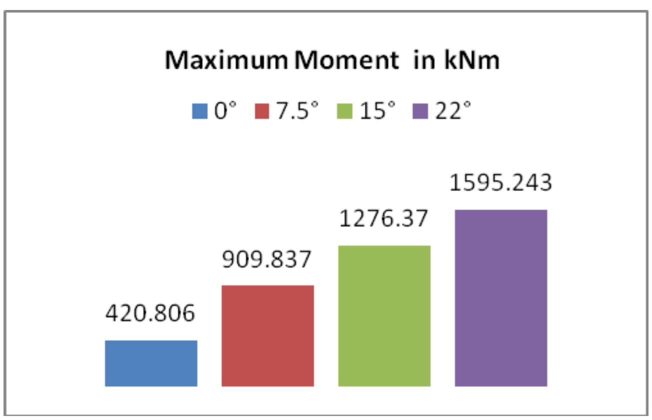
5.4) Maximum lateral displacement at (G+15)



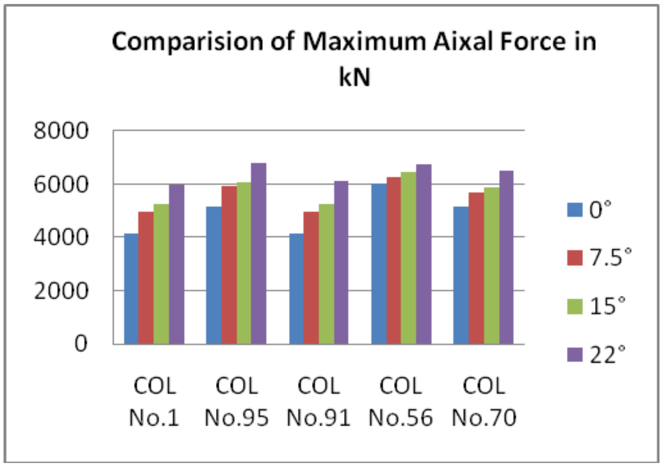
5.5) Maximum Axial Force in kN at (G+15)



5.6) Moments in columns (G+15)

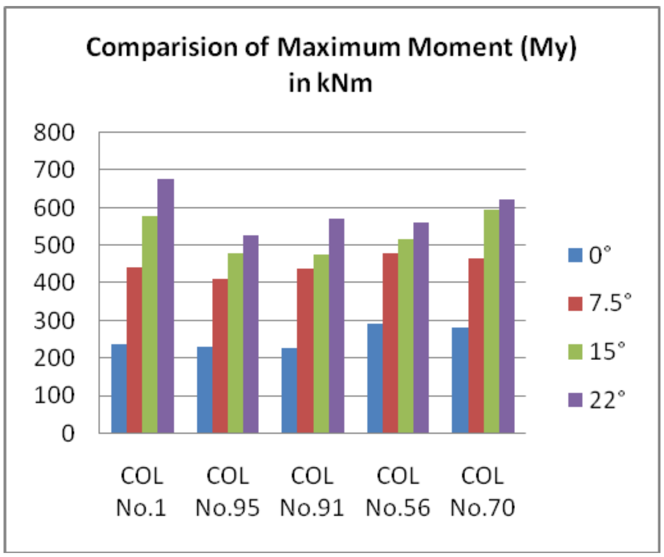


5.7) Comparison of Axial Force in columns

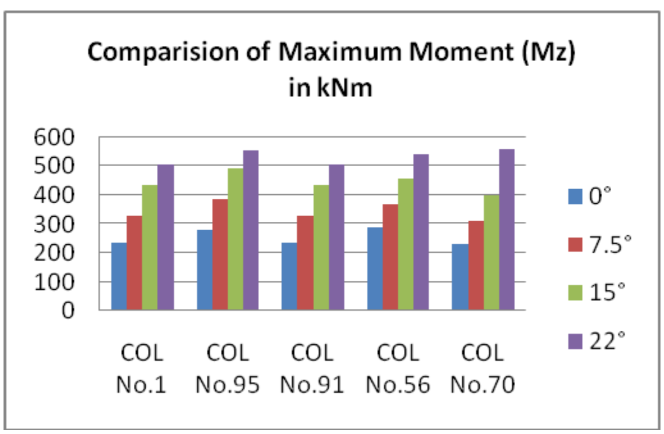


Comparison of Maximum Axial Force in kN					
Column No.	Soil Type	Slope of ground			
		0°	7.5°	15°	22°
1	Medium	4126.905	4960.864	5271.211	5999.922
2		5155.712	5903.877	6066.072	6814.768
3		4126.904	4960.865	5271.211	6099.922
4		6034.219	6251.294	6438.746	6734.334
5		5155.712	5666.341	5889.111	6515.48

5.8) Comparison of Moments in columns



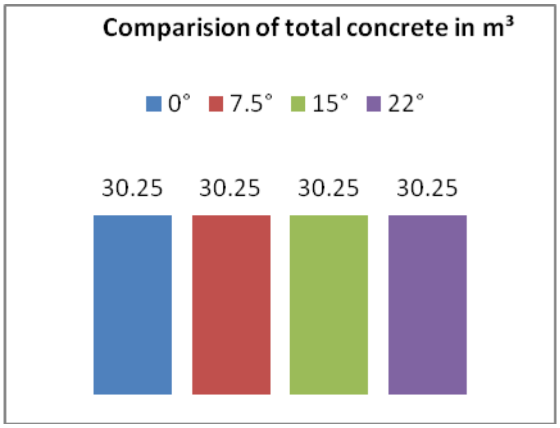
Comparison of Maximum Moment (My) in kNm					
Column No.	Soil Type	Slope of ground			
		0°	7.5°	15°	22°
1	Medium	234.993	441.357	578.996	675.965
2		230.745	409.422	480.335	527.888
3		224.577	435.946	475.234	571.274
4		289.691	478.065	515.799	560.363
5		281.219	463.826	593.758	623.523



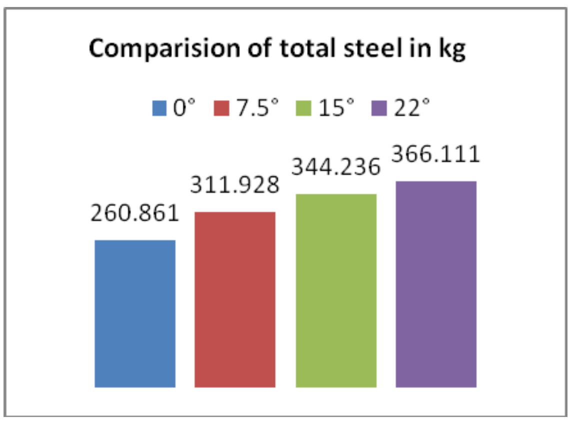
Comparison of Maximum Moment (Mz) in kNm					
Column No.	Soil Type	Slope of ground			
		0°	7.5°	15°	22°
1	Medium	234.993	330.178	436.297	506.525
2		281.219	385.311	494.213	555.799
3		234.993	330.178	436.297	506.525
4		289.691	370.677	457.01	544.078
5		230.745	309.837	402.083	557.814

ISSN 2348 – 7968

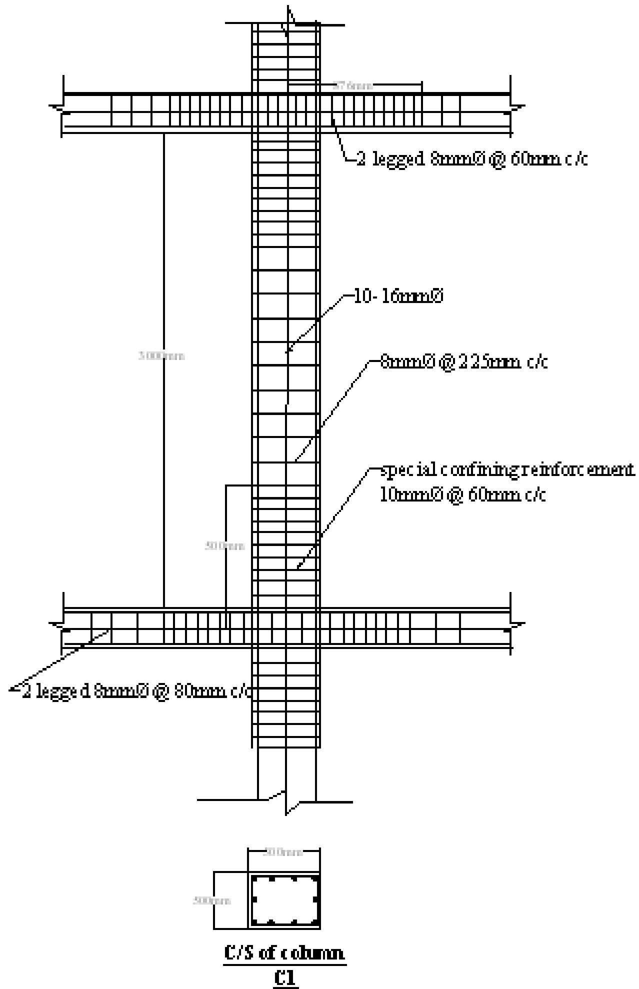
5.9) Comparison of total concrete volume



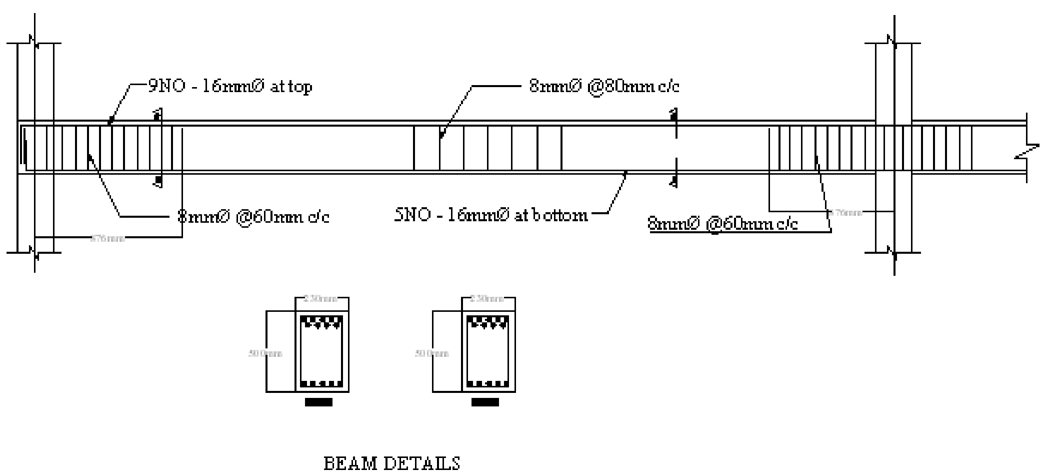
5.10) Comparison of total steel in Kg



6) DUCTILE DETAILING



6.1) c/s of column



6.2)c/s of beam

ISSN 2348 – 7968

7) Conclusions

- Buildings resting on sloping ground have more lateral displacement compared to buildings on Plain ground.
- The presence of bracings in soft stories reduces the lateral displacement.
- The critical axial force in columns increases as slope increases.
- The critical bending moments is increased on 22° slope than 7.5° slope and 15° slope ground.
- Calculated frequency decreases as slope of ground increases.
- Calculated time period decreases as slope of ground increases.

- high quality of construction to be provided conforming to related IS codes such as IS 1893 , IS 13920 to ensure good performance during future earthquakes.
- To implement the design of building elements and joints between them in accordance with analysis .i.e. ductility design should be done.
- After designing, it is concluded that steel quantity on sloping ground is more than on plain ground for same cross section of column and beam.
- Thus cross section required more steel on sloping ground to make earthquake resistant structures.

8)Future scope

- The study can be further extended to analysis of irregular building.
- Irregular buildings with different position of shear wall can be analyzed.
- Analysis can be done by using software SAP 2000, ETAB etc.
- Analysis can be carried out using time history method.
- Comparison of Time history method and response spectrum method can be done.
- Analysis can be doing with different soil conditions.
- Analysis can be done with different seismic zone.