ANALYSIS OF SET BACK STEP-BACK BUILDING RESTING ON SLOPING GROUND

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***Abstract*—The Buildings on hill differ from other buildings. The various floors of such building steps back towards the hill slope and at the same time buildings may have setbacks also. Buildings situated in hilly areas are much more vulnerable to seismic environment. In this study, 3D analytical model of 10 storied buildings have been generated for symmetric and asymmetric building Models and analyzed using structural analysis tool 'STADD-PRO" to study the effect of varying height of columns in ground stored due to sloping ground and the effect of shear wall at different positions during earthquake.From the above studies it has been observed that the performance of the buildings on sloping ground suggests an increased vulnerability of the structure with formation of column hinges at base level and beam hinges at each story level at performance point. For the buildings studied, it is found that the plastic hinges are more in case of buildings resting on sloping ground as compared to buildings resting on plain ground.**

***IndexTerms*—Seismic, Irregularities, Pushover, Non-linear, set back, step back**

I. INTRODUCTION

Earthquake is the most disastrous due to its unpredictability and huge power of devastation. Earthquakes themselves do not kill people, rather the colossal loss of human lives and properties occur due to the destruction of structures. Building structures collapse during severe earthquakes, and cause direct loss of human lives. Numerous research works have been directed worldwide in last few decades to investigate the cause of failure of different types of buildings under severe seismic excitations. Massive destruction of high-rise as well as lowrise buildings in recent devastating earthquake proves that in developing counties like India, such investigation is the need of the hour. Hence, seismic behavior of asymmetric building structures has become a topic of worldwide active research. Many Investigations have been conducted on elastic and inelastic seismic behavior of asymmetric systems to find out the cause of seismic vulnerability of such structures. 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.

II. SIGNIFICANCE OF STUDY

The economic growth & rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore; there is popular & pressing demand for the construction of multi - storey buildings on hill slope in and around the cities. The adobe burnt brick, stone masonry & dressed stone masonry buildings are generally made over level ground in hilly regions. Since level land in hilly regions is very limited, there is a pressing demand to construct buildings on hill slope. Hence construction of multi-storey R.C. Frame buildings on hill slope is the only feasible choice to accommodate increasing demand of residential & commercial activities. It is observed from the past earthquakes, buildings in hilly regions have experienced high degree of demand leading to collapse though they have been designed for safety of the occupants against natural hazards. Hence, while adopting practice of multi -storey buildings in these hilly & seismically active areas, utmost care should be taken, making these buildings earthquake resistant.

III SCOPE OF STUDY

.1. Three dimensional space frame analysis is carried out for three different configurations such as
  1) Step back
  2) Step back-Setback
  3) Setback
2. Height of buildings is ranging from 33m, 48m and 63m (10 to 20 storey) resting on sloping & plain ground.
3. Slope of ground ranging from 0°, 10°, 15° and 20°.
4. Dynamic response of these buildings, in terms of base shear & top floor displacement is presented & compared within the considered configuration as well as with other configurations.
5. At the end, a suitable configuration of building to be used in hilly area is suggested.

Building Configuration
Three different configurations are considered,
1) Step back (Resting on sloping ground)

2) Step back –Setback (Resting on sloping ground)
3) Setback.(Resting on plain ground)

IV .OBJECTIVE OF THE STUDY

This project report comprises of seismic analysis a R.C. building with rectangular plan.The design philosophy was established considering the following aspects:

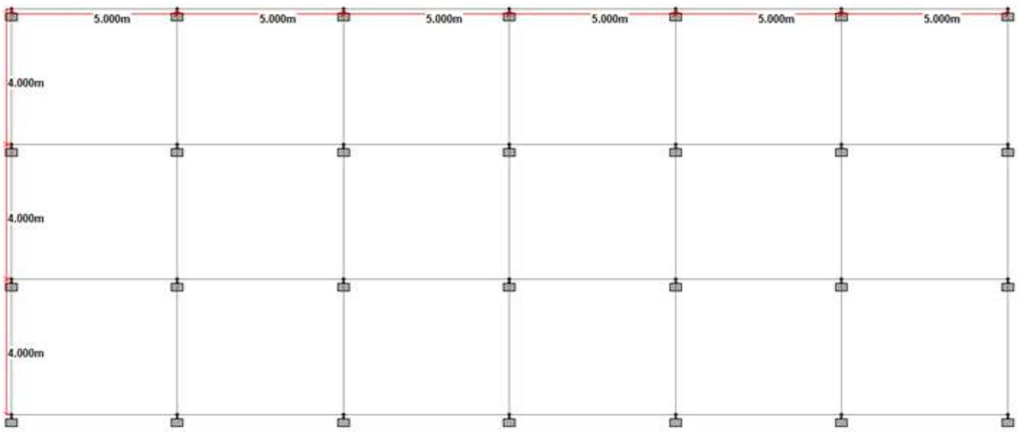
1. The structure should withstand the moderate earthquakes, which may be expected to occur during the service life of structure with damage within acceptable limits. Such earthquakes are characterized as Design Basis Earthquakes (DBE).
2. The building is modeled as a 3D space frame with six degrees of freedom at each node using the software STAAD- PRO.
3. Building (G+10) is analyzed using Response Spectrum method on 0°, 10°, 15° slope ground.
4. The Response Spectra as per IS 1893 (Part 1):2002 for medium soil is used.
5. Comparison of results for (G+10) building is done for same slope and same soil condition.
6. Various static checks are applied on the results.

V PROBLEM STATEMENT

Problem statement

The building considered in the present report is G+10 storied R.C framed building of symmetrical rectangular plan configuration. Complete analysis is carried out for dead load, live load & seismic load using STAD-Pro. Response spectrum method of seismic analysis is used. All combinations are Considered as per IS 1893:2002.

Typical plan of building is shown in Fig.



Building properties

Site Properties:

Details of building:: G+10
Plan Dimension:: 30m x 12m
Outer wall thickness:: 230mm
Inner wall thickness:: 230mm
Floor height ::3 m
Parking floor height :: 3m

Seismic Properties

Seismic zone:: IV
Zone factor:: 0.24
Importance factor:: 1.0
Response Reduction factor R:: 5
Soil Type:: medium

Material Properties

Material grades of M35 & Fe500 were used for the design.

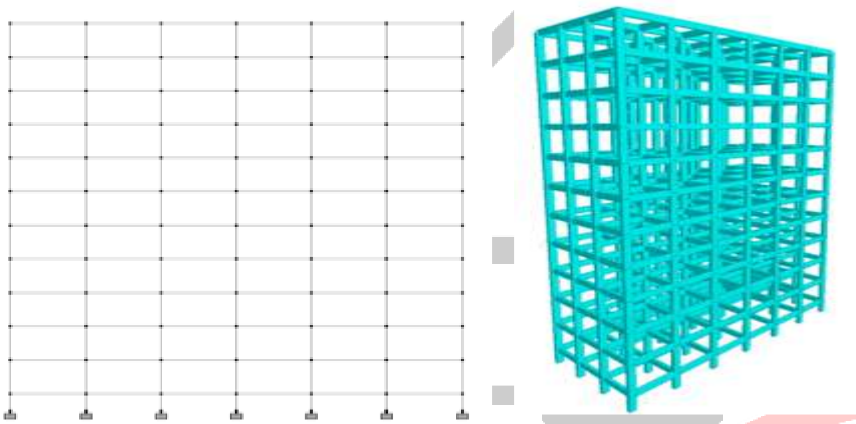
Loading on structure

Dead load :: self-weight of structure
Weight of 230mm wall :: 13.8 kN/m²
Live load:: For G+15:: 2.5 kN/m²
Roof :: 1.5 kN/m²
Wind load :: Not considered
Seismic load:: Seismic Zone IV

Preliminary Sizes of members
Column:: 700mm x 400mm
Beam:: 300mm x 550mm
Slab thickness:: 120mm

Load Combinations
Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.
1. 1.5(DL+LL)
2. 1.2(DL+LL±EQ-X)
3. 1.2(DL+LL±EQ-Y)
4. 1.5(DL±EQ-X)
5. 1.5(DL±EQ-Y)
6. 0.9DL±1.5EQ-X
7. 0.9DL±1.5EQ-Y

Case I – RCC G+10 building on plain groundPreliminarySizes of members
Column:: 700mm x 400mm
Beam:: 300mm x 550mm
Slab thickness:: 120mm



Case II – RCC G+10 building with setback on plain ground

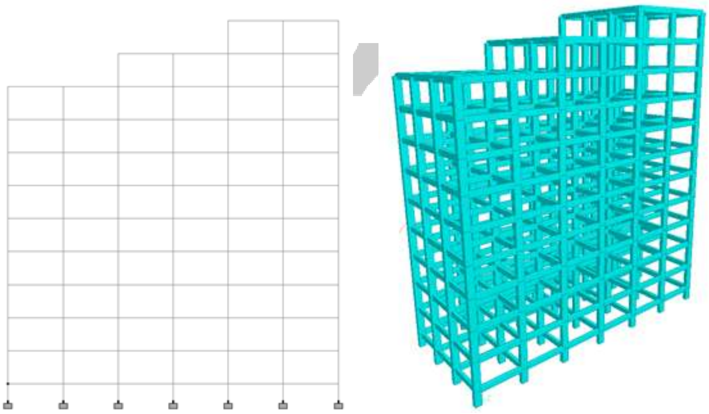


FIG Elevation & 3D View of RCC G+10 building with setback on plain ground

Case III – RCC G+10 building with stepback on 10^0 slope ground

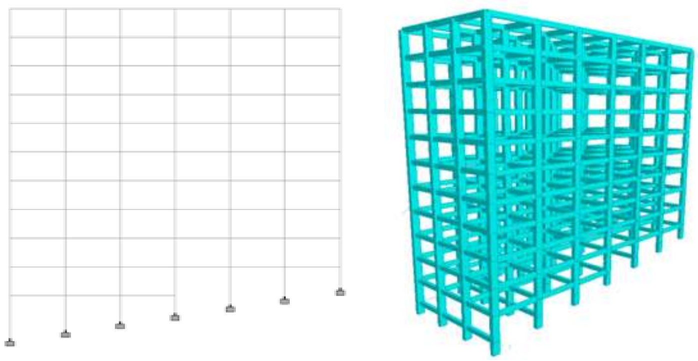


Fig. Elevation & 3D View of RCC G+10 building with step-back on 10^0 slope ground

Case IVRCC G+10 building with set - step back on 10^0 slope ground

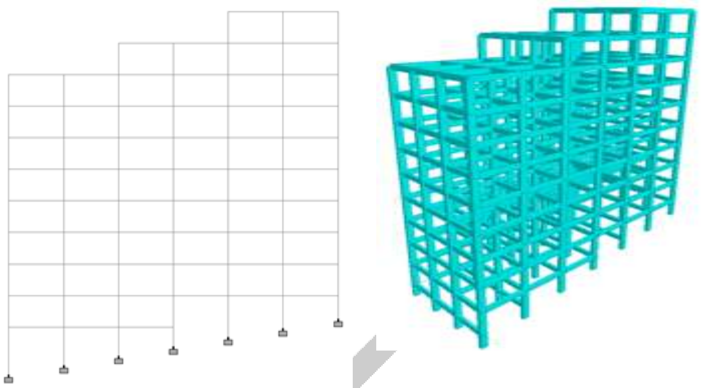


Fig. Elevation & 3D View of RCC G+10 building with set - step back on 10^0slope ground

Case V – RCC G+10 building with stepback on 15^0 slope ground

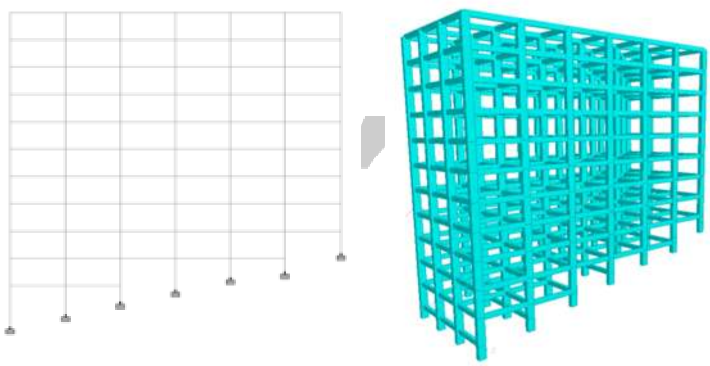


Fig. Elevation & 3D View of RCC G+10 building with stepback on 15^0 slope ground

Case VI– RCC G+10 building with set - step back on 15^0 slope ground

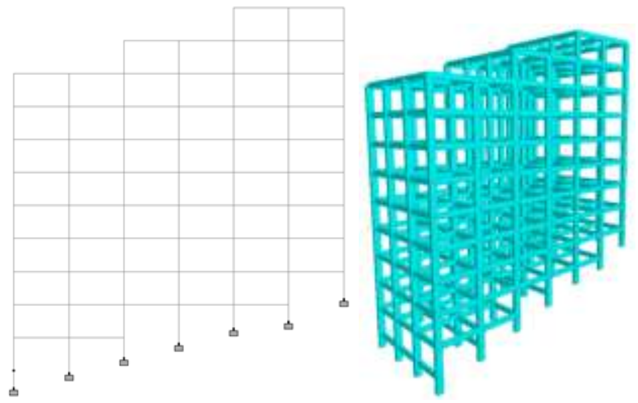


Fig. Elevation & 3D View of RCC G+10 building with set –step-back on 15^0 slope ground

Case VII– RCC G+10 building with stepback on 20^0 slope ground

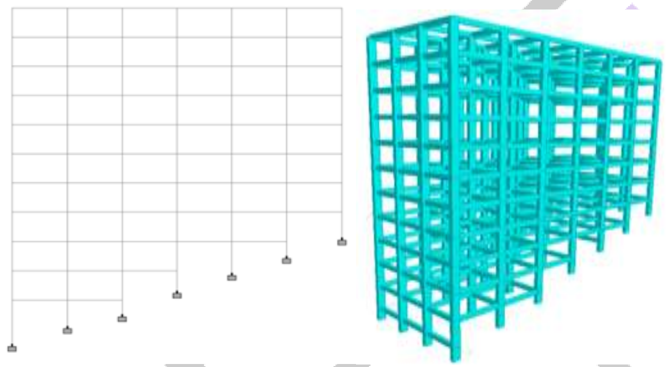


FIG Elevation & 3D View of RCC G+10 building with stepback on 20^0 slope ground

VI ANALYSIS & RESULTS

Type I – RCC G+10 building with setback, set – step back and step back on 0^0, 10^0, 15^0, 20^{0}slope ground

Table Lateral displacement of RCC G+10 on plain ground

RCC G+10 ON PLAIN GROUND				
	Horizontal	Vertical	Horizontal	Resultant
Node	X mm	Y mm	Z mm	mm
383	33.848	-5.189	0.016	34.244
350	-33.848	-6.816	0.015	34.528
380	0	0.942	36.708	36.72
378	0	-9.93	-0.026	9.93
374	0	-5.294	55.108	55.362
380	0	-8.118	-55.108	55.703
88	0	-1.912	13.985	14.115
109	0	-3.274	-13.985	14.363
363	-0.09	-5.034	53.836	54.071
342	-0.113	-7.79	-53.836	54.397
98	8.179	-1.949	-0.001	8.408
92	-8.179	-2.739	-0.001	8.625
378	0	-8.466	-55.076	55.722

Table Lateral displacement of RCC G+10 with setback on plain ground

RCC G+10 WITH SETBACK ON PLAIN GROUND				
	Horizontal	Vertical	Horizontal	Resultant
Node	X mm	Y mm	Z mm	mm
348	30.186	-7.756	0.019	31.167
350	-29.678	-4.3	0.009	29.988
364	8.618	1.014	46.484	47.287
349	0.254	-9.43	0.026	9.433
343	13.254	-3.253	69.761	71.084
364	-12.601	-6.296	-69.761	71.169
91	3.602	-1.092	17.947	18.338
112	-3.467	-2.572	-17.947	18.459
312	13.409	-4.567	41.346	43.705
333	-11.994	-6.606	-41.346	43.554
98	7.685	-1.997	-0.001	7.94
92	-7.578	-2.208	-0.001	7.893
364	-12.601	-6.296	-69.761	71.169

Table Lateral displacement of RCC G+10 with setback on 10^0 slope ground

RCC G+10 WITH SETBACK ON 10^0 SLOPE GROUND				
	Horizontal	Vertical	Horizontal	Resultant
Node	X mm	Y mm	Z mm	mm
344	26.105	-2.826	0.01	26.257
350	-28.577	-4.843	0.013	28.985
359	6.4	0.893	35.642	36.223
345	-1.591	-9.024	0.025	9.163
337	8.241	-3.399	59.786	60.447
358	-10.961	-6.075	-59.786	61.086
113	2.431	-1.579	21.557	21.751
134	-3.042	-3.246	-21.557	22.011
361	8.113	-4.7	39.501	40.599
340	-11.093	-6.623	-39.501	41.561
98	2.252	-0.534	-0.001	2.315
367	-1.368	-0.332	-0.001	1.407
358	-10.961	-6.075	-59.786	61.086

Table Lateral displacement of RCC G+10 with set – step back on 10^0 slope ground

RCC G+10 WITH SET- STEP BACK ON 10^0SLOPE GROUND				
	Horizontal	Vertical	Horizontal	Resultant
Node	X mm	Y mm	Z mm	mm
348	22.066	-3.732	0.01	22.38
350	-23.939	-4.746	0.013	24.405
342	2.781	0.602	26.31	26.463
348	-1.376	-7.502	0.022	7.628
343	3.058	-2.441	41.119	41.305

364	-5.286	-4.181	-41.119	41.667
119	0.873	-0.712	8.244	8.321
140	-1.289	-1.432	-8.244	8.466
312	3.432	-3.879	32.141	32.556
333	-4.743	-5.382	-32.141	32.932
98	2.023	-0.551	-0.001	2.097
367	-1.22	-0.322	-0.001	1.261
364	-5.286	-4.181	-41.119	41.667

VII- Conclusions

- Buildings resting on sloping ground have less base shear compared to buildings on Plain ground.
- Base shear increases as slope of ground increase.
- Buildings resting on sloping ground have more lateral displacement compared to buildings on Plain ground.
- Buildings with set back – step back is showing less displacement than step back model.
- Building is showing high value of displacement in z- direction than in x direction.
- The critical axial force in columns is more on plain ground than on sloping ground.
- The shear force and moment in columns is more on sloping ground than on plain ground.
- The shear force and bending moment value in beams is high in plain ground model than on sloping ground model.
- The performance of set- step back building during seismic excitation could prove more vulnerable than other configurations of buildings.
- The development of moments in set - step back buildings is higher than that in the set back building. Hence, Set back buildings are found to be less vulnerable building against seismic ground motion.
- Step back Set back buildings, overall economic cost involved in leveling the sloping ground and other related issues needs to be studied in detail.

VIII 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.

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