SEISMIC ANALYSIS OF LOW RISE, MID RISE AND HIGH RISE RCC STRUCTURE ON SLOPING GROUND

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Abstract - *Due to scarcity of plain ground rapid construction is taking place in hilly areas i.e., on sloping ground. Earthquake is such an unpredictable calamity that it is very necessary for survival to ensure the strength of the structure against seismic forces. Therefore there is continuous research work is going on around the globe, revolving around development of new and better techniques that can be incorporated in structures for better seismic performance. Obviously, buildings designed with special techniques to resist damages during seismic activity have much higher cost of construction than normal buildings, but for safety against failures under seismic forces it is a prerequisite.*

RCC structures are considered in seismic areas that may be main targets of seismic activities. Due to such conditions now a days there is a heavy demand of earthquake resisting RCC structural design. Not only seismic activities but also due to accidental failures, structure can fail. To analyse RCC structure for earthquake zone, we have to make model using ETABS software which can resist all types of loading such as dead load, live load, seismic load using IS 1893.

In this study Low rise (G+5), Mid rise (G+10) and High rise (G+15) storey structures will be analysed by using Equivalent static method, Response spectrum method and Time history methods of analysis in ETABS. This structure placed on Plain ground as well as on sloping ground. These structures placed on different angles of sloping ground. After analysing models in ETABS the results for Storey displacement, Base shear, Storey drift, Time period and Modal participating factors are then obtained. After observing this result some conclusions are made.

***Key Words*: Sloping ground, Response spectrum method, Time history method, Base shear, Storey drift.**

1. INTRODUCTION

Earthquake has always been a threat to human civilization from the day of its existence, devastating human lives, property and man-made structures. The very recent earthquake that we faced in our neighbouring country Nepal has again shown nature's fury, causing such a massive destruction to the country and its people.
Earthquake causes random ground motions, in all possible directions emanating from the epicentre. Vertical ground motions are rare, but an earthquake is always accompanied with horizontal ground shaking. The ground vibration causes the structures resting on the ground to vibrate, developing inertial forces in the structure. As the earthquake changes directions, it can cause reversal of stresses in the structural components, that is, tension may change to compression and compression may change to tension. Earthquake can cause generation of high stresses, which can lead to yielding of structures and large deformations, rendering the structure non-functional and unserviceable. There can be large storey drift in the building, making the building unsafe for the occupants to continue living there.

1.1 Seismic Performance of Structure

Seismic performance defines a structure's ability to sustain its due functions, like its safety and usefulness, at and once a specific earthquake exposure. A structure is, commonly thought of safe if it doesn't endanger the lives and well-being of these in or around it by partly or fully collapsing. A structure may be considered serviceable if is able to fulfil its operational function for which it was designed.

1.2 Seismic Behaviour of RCC Structure

In recent times, ferroconcrete buildings became common in Republic of India, particularly in towns and cities. Reinforced concrete (or merely RC) consists of 2 primary materials, particularly concrete with reinforcing steel bars. Concrete is formed of sand, crushed stone (called aggregates) and cement, all mixed with pre-determined amount of water. Concrete can be moulded into any desired shape, and steel bars can be bent into many shapes. Thus, structures of complicated shapes area unit doable with RC.

1.3 Objectives

1. To study response of RCC structure which are designed for all load combinations against seismic analysis.
2. For this analysis we consider the structure is on different sloping ground.
3. For this study we consider 5, 10, 15 storey RCC structure analysis for all types of load combinations.
4. Using IS 1893:2002 we again analyse same structure and find performance of structure against seismic analysis.
5. For this we consider linear static analysis.
6. To check performance of structure Base shear, Mode shape, Storey displacement, Storey drift and bending moment are consider.
7. Check the structural performance on sloping ground.

2. LITERATURE REVIEW

B.G. Birajdar, S.S. Nalawade (2004), "Seismic analysis of buildings resting on sloping ground" In brief it is found that: The performance of STEP back building during seismic excitation could prove more vulnerable than other configurations of buildings. The development of torsional moments in Step back buildings is more than that within the Step back Set back buildings. Hence, Step back Set back buildings are found to be less vulnerable than Step back building against seismic ground motion.

Sujit Kumar, Dr. Vivek Garg, Dr. Abhay Sharma (2014), "Effect of sloping ground on structural performance of RCC building under seismic load" The analysis is carried out to evaluate the effect of sloping ground on structural forces. It has been observed that the footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of those columns ought to be designed for changed forces thanks to the impact of sloping ground. The present study emphasizes the necessity for correct coming up with of structure resting on sloping ground.

Deepak Suthar, H.S.Chore, P.A. Dode (2014), "High rise structures subjected to seismic forces and its behaviour" The behaviour of high rise structure for both the scheme is studied in present paper. In this paper we got the results from mathematical model for model I and model II. The graph clearly shows the story drift, lateral displacement and time period is more in model I as compared to model II. It is also observed that the results are more conservative in Static analysis as compared to the dynamic method resulting uneconomical structure.

K. Venkatesh, A. L. Neeharika (2016), "Static linear and nonlinear analysis of RC buildings on varying hill slopes" Seismic loads were considered acting along either of the two principal directions. Using ETABS a 4, 5 storey RC structure with typical ground slope is chosen in between 0° and 25°and building that which produce less torsion effect for set-back and step-back with irregular configuration in horizontal and vertical direction is modelled and analyzed.

3. MATERIAL AND METHODS

Seismic analysis is performed on the basis on behaviour of the structure, material of structure, type of structure, external action and the type of selected structural model. Depending on the type of behaviour of external action the analysis can be divided into 4 types. Our main objective is to analyse seismic performance of RCC structure on sloping ground by equivalent static analysis.

3.1 Equivalent static analysis

The equivalent static lateral force methodology could be a simplified technique to substitute the impact of dynamic loading of associate expected earthquake by a static force distributed laterally on a structure for design purposes. The total applied unstable force V is mostly evaluated in 2 horizontal directions parallel to the most axes of the building. It assumes that the building responds in its basic lateral mode.

3.2 Response spectrum method

Response spectra unit of activity terribly helpful tools of earthquake engineering for analyzing the performance of structures and instrumentality in earthquakes, since many behave principally as simple oscillators (also known as single degree of freedom systems). Thus, if you'll be able to verify the natural frequency of the structure, then the peak response of the building can be estimated by reading the value from the ground response spectrum for the appropriate frequency.

3.3 Time history method

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques area unit applicable once higher mode effects don't seem to be vital. This is for the foremost half valid for brief, regular structures. Thus, for tall structures, structures with torsion asymmetries, or no orthogonal frameworks, a dynamic method is needed. In linear dynamic method, the structure is modelled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix.

3.4 Software of analysis

ETABs is associate engineering merchandise that caters to multi-story building analysis and style. Modelling tools and templates, code-based load prescriptions, analysis strategies and answer techniques, all coordinate with the grid-like pure mathematics distinctive to the present category of structure. Basic or advanced systems beneath static or dynamic conditions are also evaluated exploitation ETABs.

• Create and modify a model.
• Execute the analysis.
• Design a model as well as optimize the design.
• It displays results in graphical forms and also display real time- history displacements and generates reports.

3.5 Modelling

To study the seismic behaviour of RCC structure, different cases have been defined and their comparative graphs for these cases have been plotted. A typical RCC building will be designed and analysed for dead load, live load, wind load and earthquake load.

• Seismic zone, Z (IS 1893: 2002, clause 6.4.2, table 2)
• Response reduction factor, R (IS 1893: 2002, clause 6.4.2, table 7)
• Importance factor, I (IS 1893: 2002, clause 6.4.2, table 6)
• Soil type (IS 1893: 2002, clause 6.4.5, page 16)

Table -1: Modelling Details For RCC Structure

Parameters	Modelling Details		
No. of storey	G+5	G+10	G+15
Height of the building	18 m	33 m	48 m
Each storey height	3 m	3 m	3 m
Soil condition	Medium	Medium	Medium
Response reduction factor	5	5	5
Importance factor	1	1	1
Zone	3	3	3
Thickness of slab	200 mm	200 mm	200 mm
Live load	4 KN/m^2	4 KN/m^2	4 KN/m^2
Floor finish	1.5 KN/m^2	1.5 KN/m^2	1.5 KN/m^2
Grade of concrete	M30	M30	M30
Beam size	300×600 mm	300×600 mm	300×600 mm
Column size	350×750 mm	350×750 mm	350×750 mm

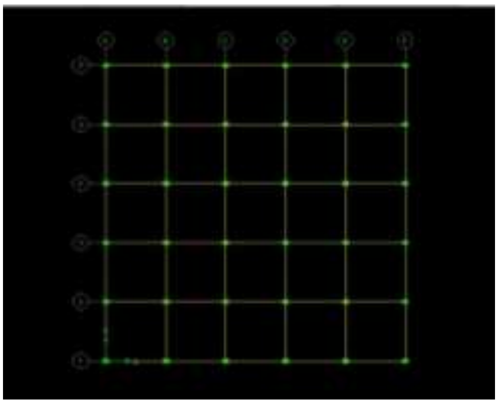

Fig - 1: Top View of Typical Structure

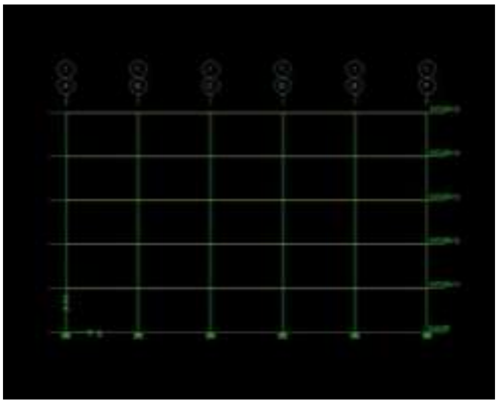

Fig - 2: Plain Ground Structure

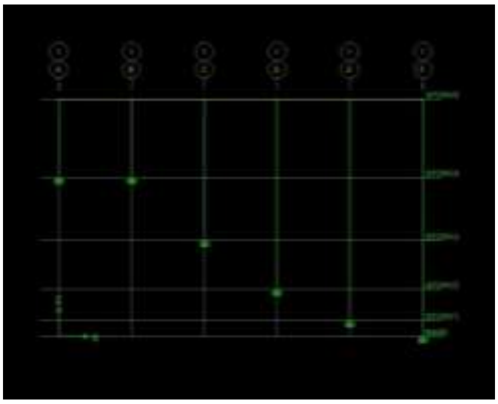

Fig - 3: Storey G+10º Slping Ground

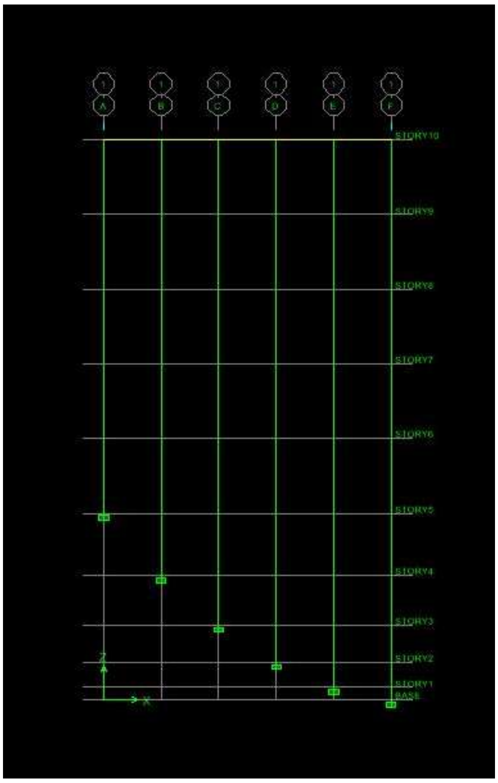

Fig – 4: G+10 Storey 10º Sloping Ground

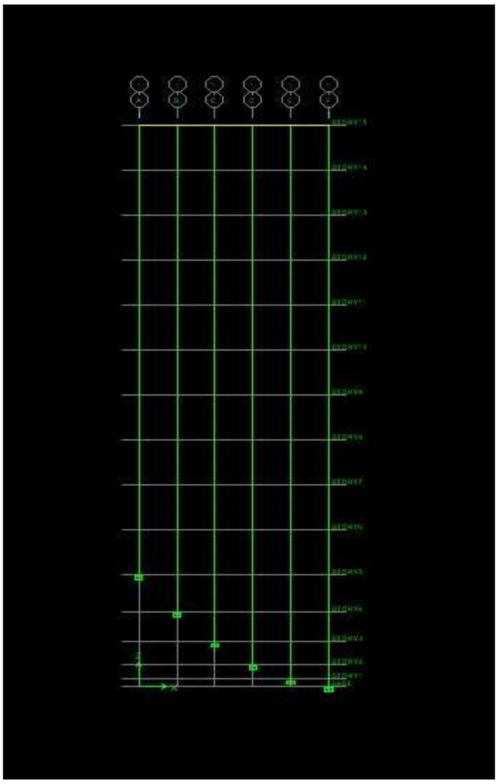

Fig – 5: G+15 storey 10º sloping ground

4. RESULTS AND ANALYSIS

4.1 Mode Period

Table - 2: Mode Period For Plain Ground

Mode	Mode Period For Stories		
	For Storey 5	For Storey 10	For Storey 15
1	0.58	1.084	1.613
2	0.58	1.084	1.613
3	0.523	0.968	1.416
4	0.187	0.355	0.53
5	0.187	0.355	0.53
6	0.169	0.318	0.468
7	0.106	0.205	0.306
8	0.106	0.205	0.306
9	0.096	0.186	0.276
10	0.073	0.142	0.214

Table - 3: Mode Period For 10º Sloping Ground

Mode	Mode Period For Stories (10º)		
	For Storey 5	For Storey 10	For Storey 15
1	0.5	1.001	1.526
2	0.489	0.992	1.518
3	0.437	0.884	1.333
4	0.16	0.327	0.5
5	0.157	0.324	0.497
6	0.14	0.29	0.44
7	0.091	0.189	0.289
8	0.089	0.187	0.287
9	0.08	0.169	0.259
10	0.062	0.13	0.202

Table - 4: Mode Period For 20º Sloping Ground

Mode	Mode Period For Stories (20º)		
	For Storey 5	For Storey 10	For Storey 15
1	0.405	0.903	1.426
2	0.378	0.879	1.403
3	0.341	0.788	1.237
4	0.129	0.294	0.465
5	0.12	0.285	0.457
6	0.109	0.258	0.408
7	0.074	0.17	0.269
8	0.069	0.164	0.264
9	0.063	0.15	0.24
10	0.052	0.117	0.188

Table - 5: Mode Period For 30º Sloping Ground

Mode	Mode Period For Stories (30º)		
	For Storey 5	For Storey 10	For Storey 15
1	0.248	0.738	1.256
2	0.218	0.715	1.235
3	0.196	0.643	1.092
4	0.102	0.239	0.408
5	0.075	0.23	0.4
6	0.073	0.209	0.359
7	0.068	0.139	0.236
8	0.062	0.132	0.231
9	0.059	0.121	0.211
10	0.051	0.103	0.165

In Plain ground, G+15 storey takes maximum than G+5 storey and G+10 storey time to show the mode shapes. In 10º Sloping ground, G+15 storey takes maximum period.

In 20º Sloping ground, G+15 storey takes maximum period. In 30º Sloping ground, G+15 storey takes maximum time period. Thus, from this results for Sloping ground, G+15 storey RCC structure takes maximum period. This result shows the height of the structure increases then the Mode period of structure is increases.

4.2 Base Shear

Table - 6: Base Shear of structure

Ground Profile	Base Shear (KN)					
	5 Storey		10 storey		15 Storey	
	X dir	Y dir	X dir	Y dir	X dir	Y dir
Plain Ground	612.341	612.341	332.855	332.855	223.782	223.782
10º	631.666	631.666	352.416	349.324	230.292	229.131
20º	564.493	564.493	356.229	346.508	223.116	219.487
30º	464.275	464.275	361.757	350.27	209.404	205.78

In Plain ground Base shear is maximum at 5 storey RCC structure along X- direction and Y- direction. In sloping ground Base shear is maximum at 10º sloping ground than 20º and 30º sloping ground. Base shear of G+ 5 storey structure is greater than all other structures, so that the results are suggesting that the base shear varies with the height of the structure, it goes on decreasing as the height of the structure decreases.

4.3 Storey Displacement

Table - 7: Storey Displacement For 5 Storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
6	0.004201	0.004201	0.00311	0.003792	0.001856	0.002549	0.000598	0.001021

5	0.003901	0.003901	0.002808	0.003456	0.001566	0.002216	0.000354	0.00071
4	0.003362	0.003362	0.002267	0.002848	0.001063	0.001625	5.48E-05	0.000305
3	0.002605	0.002605	0.001525	0.002006	0.00044	0.000859	6.48E-05	0.000166
2	0.001682	0.001682	0.000675	0.001021	3.36E-05	0.000189	3.60E-05	7.07E-05
1	0.00069	0.00069	5.09E-05	0.000176	2.39E-06	4.96E-06	3.25E-06	7.13E-06
Base	0	0	0	0	0	0	0	0

Table - 8: Storey Displacement For 10 Storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
11	0.007811	0.007811	0.007092	0.007805	0.00634	0.007242	0.005258	0.006184
10	0.007593	0.007593	0.006867	0.00757	0.006097	0.006987	0.004979	0.005885
9	0.007238	0.007238	0.006496	0.007179	0.00569	0.006558	0.004498	0.005371
8	0.006749	0.006749	0.00598	0.006637	0.005122	0.00596	0.003824	0.00465
7	0.006138	0.006138	0.005336	0.005956	0.004411	0.005208	0.002987	0.00375
6	0.005419	0.005419	0.004576	0.005154	0.003577	0.004324	0.002023	0.002706
5	0.004603	0.004603	0.003717	0.004245	0.002642	0.003327	0.000992	0.001574
4	0.003701	0.003701	0.002773	0.003243	0.001636	0.002243	0.000132	0.000577
3	0.002728	0.002728	0.001768	0.00217	0.00064	0.001128	2.70E-05	0.000212
2	0.001703	0.001703	0.000757	0.001071	4.69E-05	0.00024	1.20E-05	6.81E-05
1	0.000684	0.000684	5.60E-05	0.000182	3.59E-06	5.44E-06	7.90E-07	5.86E-06
Base	0	0	0	0	0	0	0	0

Table - 9: Storey Displacement For 15 Storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
16	0.011711	0.011711	0.011035	0.011767	0.010139	0.011071	0.008909	0.009899
15	0.011482	0.011482	0.010806	0.011532	0.009908	0.010833	0.008674	0.009653
14	0.011155	0.011155	0.010475	0.01119	0.009568	0.010482	0.008318	0.009279
13	0.010732	0.010732	0.010042	0.010743	0.009121	0.010018	0.007842	0.008779
12	0.010223	0.010223	0.009518	0.0102	0.008577	0.009453	0.007258	0.008165
11	0.009636	0.009636	0.008912	0.009572	0.007946	0.008797	0.006577	0.007448
10	0.008981	0.008981	0.008233	0.008867	0.007236	0.008059	0.005808	0.006638
9	0.008262	0.008262	0.007486	0.008092	0.006454	0.007246	0.004959	0.005744
8	0.007485	0.007485	0.006677	0.007252	0.005605	0.006362	0.004039	0.004773
7	0.006652	0.006652	0.005807	0.006348	0.004693	0.005411	0.003055	0.003732
6	0.005764	0.005764	0.004881	0.005385	0.003724	0.004399	0.002022	0.002634
5	0.004823	0.004823	0.003901	0.004366	0.002705	0.003332	0.000977	0.001509
4	0.003833	0.003833	0.002874	0.003295	0.001654	0.00222	0.000128	0.000544
3	0.002798	0.002798	0.001815	0.002184	0.000642	0.001109	2.78E-05	0.000174
2	0.001733	0.001733	0.000772	0.001071	4.66E-05	0.000235	1.25E-05	4.17E-05
1	0.000693	0.000693	5.68E-05	0.000181	3.67E-06	5.10E-06	8.28E-07	2.24E-06
Base	0	0	0	0	0	0	0	0

As the base of the structure is fixed, lateral displacement at base is equal to zero. Lateral displacement is increases with increase in number of storey. Height of the structure is another factor which affects the displacement. Lateral displacement of G+5 storey structure is lesser than that of G+15 storey structure. Storey displacement is more in plain ground as compared to sloping ground.

4.4 Storey Drift

Table - 10: Storey Drift For 5 Storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
6	1.04E-07	1.04E-07	1.04E-07	1.17E-07	9.94E-08	1.15E-07	8.18E-08	1.06E-07
5	1.84E-07	1.84E-07	1.84E-07	2.06E-07	1.70E-07	1.99E-07	1.10E-07	1.42E-07
4	2.55E-07	2.55E-07	2.49E-07	2.83E-07	2.16E-07	2.57E-07	2.56E-08	6.11E-08
3	3.09E-07	3.09E-07	2.89E-07	3.29E-07	1.40E-07	2.25E-07	1.02E-08	3.39E-08
2	3.32E-07	3.32E-07	2.19E-07	2.84E-07	1.20E-08	6.15E-08	1.09E-08	2.12E-08
1	2.30E-07	2.30E-07	1.70E-08	5.87E-08	7.96E-10	1.65E-09	1.08E-09	2.38E-09
Base	0	0	0	0	0	0	0	0

Table – 11: Storey Drift For 10 Storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
11	0.007811	0.007811	0.007092	0.007805	0.00634	0.007242	0.005258	0.006184
10	0.007593	0.007593	0.006867	0.00757	0.006097	0.006987	0.004979	0.005885
9	0.007238	0.007238	0.006496	0.007179	0.00569	0.006558	0.004498	0.005371
8	0.006749	0.006749	0.00598	0.006637	0.005122	0.00596	0.003824	0.00465
7	0.006138	0.006138	0.005336	0.005956	0.004411	0.005208	0.002987	0.00375
6	0.005419	0.005419	0.004576	0.005154	0.003577	0.004324	0.002023	0.002706
5	0.004603	0.004603	0.003717	0.004245	0.002642	0.003327	0.000992	0.001574
4	0.003701	0.003701	0.002773	0.003243	0.001636	0.002243	0.000132	0.000577
3	0.002728	0.002728	0.001768	0.00217	0.00064	0.001128	2.70E-05	0.000212
2	0.001703	0.001703	0.000757	0.001071	4.69E-05	0.00024	1.20E-05	6.81E-05
1	0.000684	0.000684	5.60E-05	0.000182	3.59E-06	5.44E-06	7.90E-07	5.86E-06
Base	0	0	0	0	0	0	0	0

Table – 12: Storey Drift For 15 storey

Storey	Plain Ground		10º Sloping Ground		20º Sloping Ground		30º Sloping Ground	
	X dir	Y dir	X dir	Y dir	X dir	Y dir	X dir	Y dir
16	0.011711	0.011711	0.011035	0.011767	0.010139	0.011071	0.008909	0.009899
15	0.011482	0.011482	0.010806	0.011532	0.009908	0.010833	0.008674	0.009653
14	0.011155	0.011155	0.010475	0.01119	0.009568	0.010482	0.008318	0.009279
13	0.010732	0.010732	0.010042	0.010743	0.009121	0.010018	0.007842	0.008779
12	0.010223	0.010223	0.009518	0.0102	0.008577	0.009453	0.007258	0.008165
11	0.009636	0.009636	0.008912	0.009572	0.007946	0.008797	0.006577	0.007448
10	0.008981	0.008981	0.008233	0.008867	0.007236	0.008059	0.005808	0.006638
9	0.008262	0.008262	0.007486	0.008092	0.006454	0.007246	0.004959	0.005744
8	0.007485	0.007485	0.006677	0.007252	0.005605	0.006362	0.004039	0.004773

7	0.006652	0.006652	0.005807	0.006348	0.004693	0.005411	0.003055	0.003732
6	0.005764	0.005764	0.004881	0.005385	0.003724	0.004399	0.002022	0.002634
5	0.004823	0.004823	0.003901	0.004366	0.002705	0.003332	0.000977	0.001509
4	0.003833	0.003833	0.002874	0.003295	0.001654	0.00222	0.000128	0.000544
3	0.002798	0.002798	0.001815	0.002184	0.000642	0.001109	2.78E-05	0.000174
2	0.001733	0.001733	0.000772	0.001071	4.66E-05	0.000235	1.25E-05	4.17E-05
1	0.000693	0.000693	5.68E-05	0.000181	3.67E-06	5.10E-06	8.28E-07	2.24E-06
Base	0	0	0	0	0	0	0	0

From the results it can be concluded that Storey drifts are increased with the increase in height of the structure. Storey drift increases from bottom storey to top storey. Storey drift is maximum at top storey. Storey drift is increases in plain ground structure and decreases in sloping ground structure. In Plain ground storey drift is maximum for G+15 storey structure. In plain ground it is maximum at G+15 storey structure.

5. CONCLUSIONS

1. The sloping ground structure possess relatively more maximum displacement which may give to critical situations than the flat ground.

2. Mode shape for 15 storey takes maximum period at top storey as well as at bottom storey.

3. Base shear is maximum at 10º slope compared to other models.

4. Base shear is maximum in X- direction as compared to Y- direction for sloping ground structure.

5. Mode period decreases with increase in slope angle.

6. Storey displacement is maximum at 10º slope.

7. Displacement is maximum at top storey when compared with bottom storey in all other models along X- direction and Y-direction.

8. Storey drift is maximum at 10º slope for all models.

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