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SEISMIC ANALYSIS OF MULTI-STORIED BUILDING ON SLOPING GROUND USING SAP 2000

Unnati D Bhagat[1], Dharmesh K Bhagat[2], Anand D Patel[3]

[1]*Student, Civil Engineering Deprtment, Chhotubhai Gopalbhai Patel institute of Technology,Bardoli, Gujarat*
[2]*Associate Professor, Civil Engineering Department, Sarvajanik College of Engineering and Technology,Surat, Gujarat*
[3]*Student, Civil Engineering Department, Shree Swami Atamanand Saraswati Institute of Technology,Surat, Gujarat*

Abstract *— The recent development reveals that there is an unprecedented concentration of residential and commercial units in a particular area due to shortage of land resulted in vertical development of structures. An analysis and design of multi-storied building on flat ground is common practice. An attempt is made here to give an idea to analyze a multi-storied building on sloping ground using software SAP 2000. The shorter column attracts more forces & undergoes damage, when subjected to earthquakes. In our study, we have considered buildings on plain ground, on 15 degree and 20 degree sloping ground and analyzed the parameters such as Shear Force, Bending Moment and Top Joint Displacement using software SAP2000.*

Keywords*- Short-column Effect, Shear Force, Bending Moment, Displacement, SAP2000.*

I. INTRODUCTION

Now a days due to increase in population and concentration of them on plain ground its necessary to construct buildings on sloping ground. Here we completed this study with aim to fulfill this requirement of population by constructing building on sloping ground by considering all criteria important for this and with the use of important software SAP 2000.

The scarcity of plain ground in hilly areas compels construction activity on sloping ground resulting in various important buildings such as colleges, hotels and offices erecting on hilly slopes. Since, the behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings, both of which vary in case of buildings erecting on slope with irregularity and asymmetry due to step-back and step back-set back configuration [2]. The presence of such structures in seismically prone areas makes them exposed to greater shears and torsion as compared to conventional structure. Current building codes including IS: 1893 (Part 1): 2002 suggest detailed dynamic analysis of these types of buildings on different soil (hard, medium and soft soil) types [1].

In some parts of world, hilly area is more prone to seismic activity; e.g. northeast region of India. In this hilly regions, traditional material like, the brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, are used for the construction of different structures. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic codal provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions [5].

II. THEORETICAL CONSIDERATIONS

There are different criterion and effects which are necessary to consider at the time of analysis, which are given below:

2.1 Design Criteria:

- In case of building with floors capable of providing rigid horizontal diaphragm action, a separate building or any block of a building between two separate sections shall be analyzed as a whole for seismic force.
- In case of buildings where floors are not able to provide the diaphragm action as in above the building frames behaves independently; and may be analyzed frame by frame with tributary masses for seismic forces.
- As per the building height and as per the zone where the building is situated at that place different methods are recommended for the analysis.
- For multistoried buildings, it is assumed that the storey heights are more or less uniform, ranging between 2.7 m and 3.6 m.

2.2 Planning Criteria:

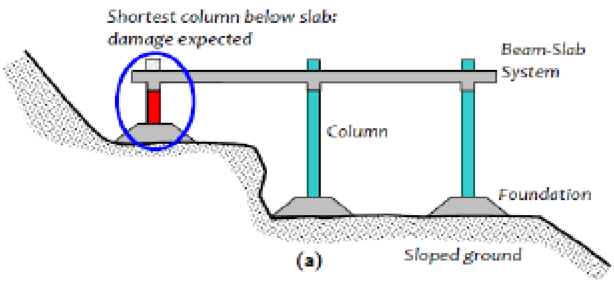
- The influence of site condition.
- The structural form.

2.3 Short Column Effect:

Short column effect arises when a column in a RC frame building is restricted from moving owing to any obstruction. The obstruction can be:

(1) Presence of unreinforced masonry infill of partial height of adjoining RC column.
(2) Conditions arising from sloping ground, when some basement columns are shorter than others.
(3) Presence of a mezzanine slab (which meets the columns at an intermediate height between the usual beam-slab systems of the floors in RC buildings).
(4) Presence of a staircase beam/slab or K-braces on building columns (which meets the columns at an intermediate height between the usual beam-slab systems of the floors in RC buildings).
(5) Presence of a plinth beam making the height of the column below it to be shorter than that of the column above.

Effective height of column over which it can bend is restricted by adjoining items mentioned above. Since lateral stiffness of a column is inversely proportional to the cube of its height, this short column effect is more severe when heights over which the columns are prevented from moving is large (or the unrestricted height of columns is small).



"*Figure 1. Short Column Effect on Sloping Ground*"

2.4 Seismic Design Requirements:

The basic intent of design theory for earthquake resistant structure is that building should be able to resist minor earthquakes without damage, resist moderate earthquakes without structural damage but with some non-structural damage, and resist major earthquakes without collapse but with some structural and non-structural damage.

2.5 Basic Assumptions:

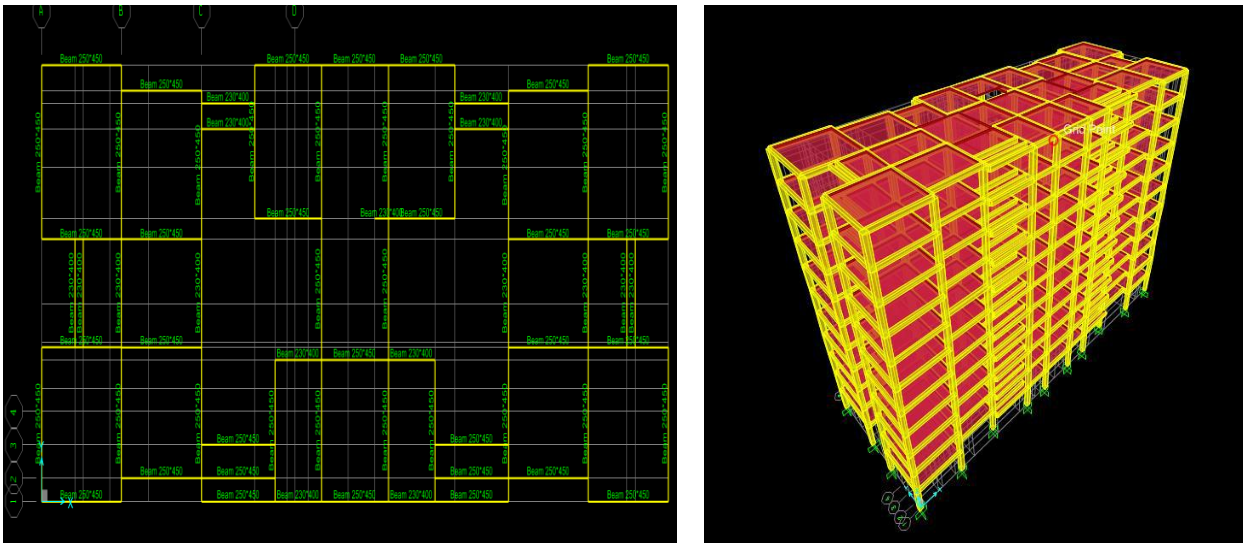
The following assumptions are made in the analysis of earthquake-resistant design of structures:

- An earthquake causes impulsive ground motions, which are complex and irregular in character, with each change in period and amplitude lasting for a small duration. Therefore, resonance of the type visualized under steady-state sinusoidal excitations will not occur, as it would need time to build up such amplitudes. However, there are exceptions where resonance-like conditions have been seen to occur between long distance waves and tall structures founded on deep soft soils.

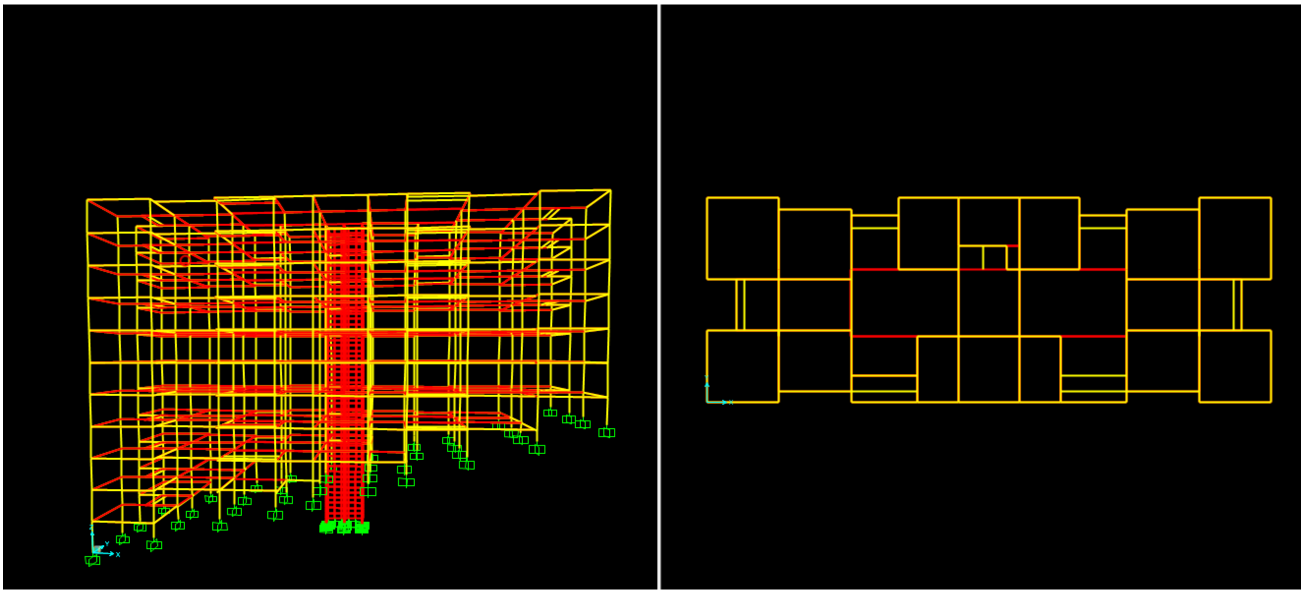
- An earthquake is not likely to occur simultaneously with winds or powerful floods and sea waves. The probability of occurrence of strong earthquake motion along with strong winds and/or maximum sea waves is low. Therefore, it is justified to assume that these hazardous events are not occurring at the same time.
- The value of elastic modulus of materials, wherever required, may be taken as the one used for static analysis, unless a more definite value is available for use in such a condition. It may be noted that the values of modulus of elasticity for various construction materials display large variations.

III. PROBLEM DEFINATION

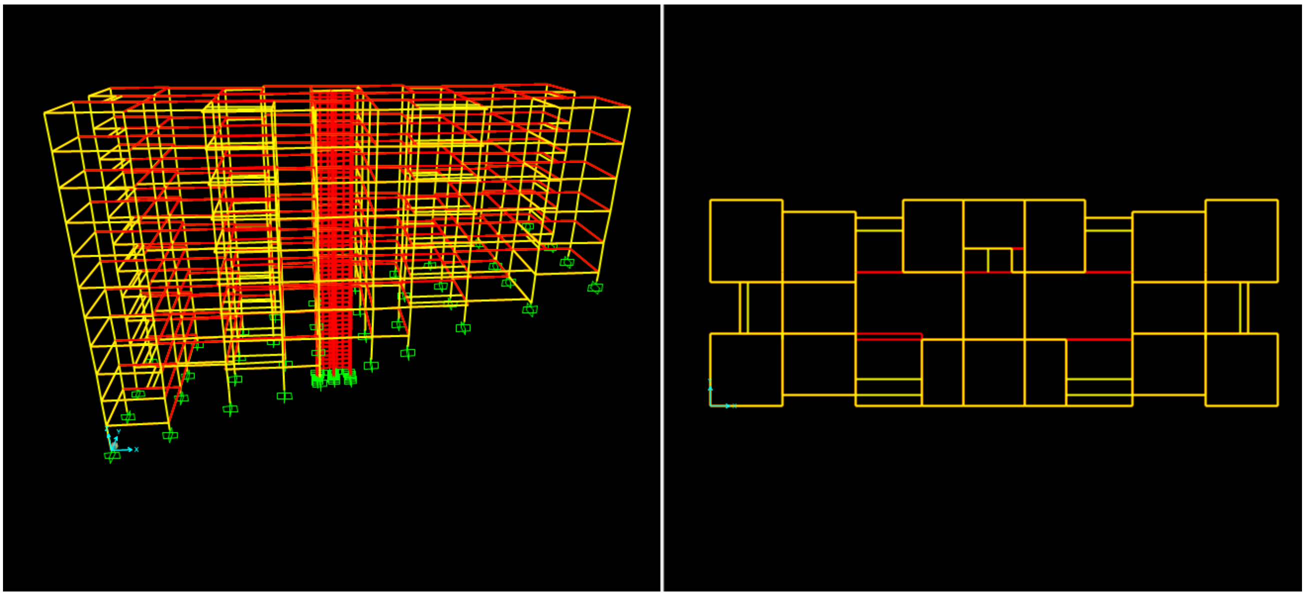
The building having 10 storeys is analyzed for plain ground and sloping ground having slope 15 degree and 20 degree.



"***Figure 2. Plan and 3D View of Building on Plain Ground***"



"***Figure 3. Plan and Elevation of Building on 15 degree sloping Ground***"



"*Figure 4. Plan and Elevation of Building on 20 degree sloping Ground*"

The table of input data is given below. The seismic analysis of building is carried out using this data and results are obtained.

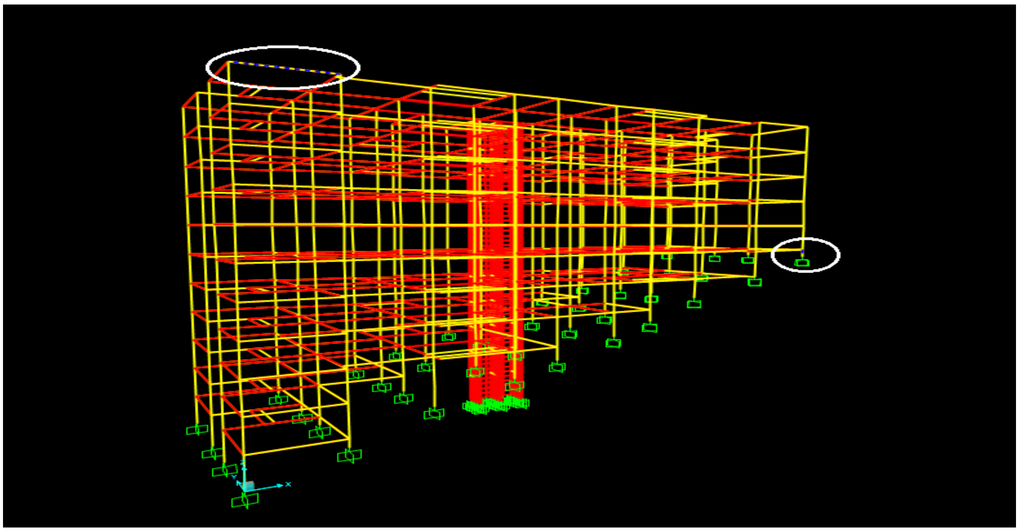
"*Table 1. Input Data for Building Modeling and Analysis*"

Type of Structure	Multi-Storey medium rise rigid jointed frame (RC moment resisting frame)
Concrete Grade	M25
Steel Grade	Fe415
Beam sections	230 mm x 400 mm 250 mm x 450 mm 300 mm x 700 mm
Column Section	**For plain Ground:** 300 mm x 300 mm (1 to 3 storey) 400 mm x 400 mm (4 to 7 storey) 500 mm x 500 mm (8 to 10 storey)
	For sloping ground: 350 mm x 750 mm (1 to 3 storey) 400 mm x 600 mm (4 to 7 storey) 500 mm x 500 mm (8 to 10 storey)
Slab Thickness	125 mm
Floor Height	3 m
Dead Load	Self-Weight
Live Load	3 kN/m^2
Earthquake load	In both direction x and y
Seismic Zone	V
Zone Factor	0.36
Importance Factor	1
Type of Soil	Medium Soil
Response Spectra	As per IS 1893 (part 1): 2002 for 5% Damping

Seismic Analysis of 3 buildings (Building on plain ground, on 15 degree and on 20 degree sloping ground) models are run after necessary inputs like section properties, material properties, loads, etc. in software SAP2000.

IV. RESULTS AND DISCUSSION

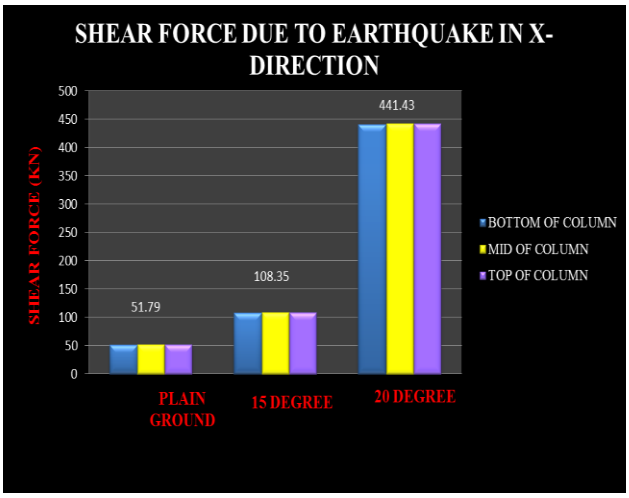
After completing seismic analysis results are obtained in terms of Shear Force, Bending Moment, Top Joint Displacement, for earthquake in x-direction and also in Y-direction using SAP2000. Below is the figure which shows the selected section related to that the results are compared in this study. For top most beam top joint displacement is compared and for right bottom most column shear force and bending moment are compared.

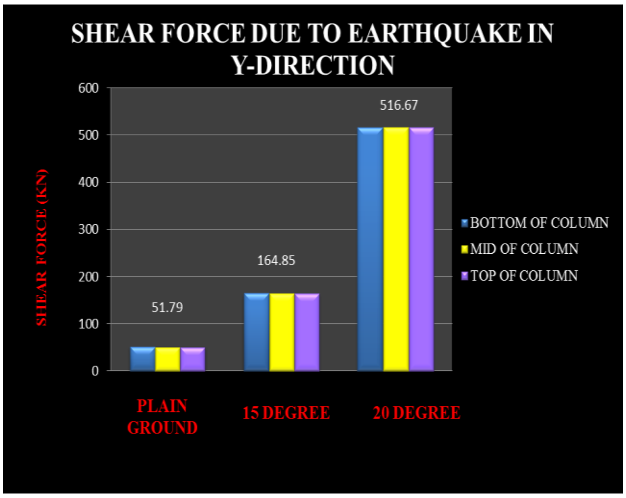


"*Figure 5. Selected Beam and Column to Compare Results*"

"*Table 2. Maximum Value of Shear Force*"

SHEAR FORCE (kN)									
	PLAIN GROUND			15 DEGREE			20 DEGREE		
	BOTTOM	MID	TOP	BOTTOM	MID	TOP	BOTTOM	MID	TOP
X-DIRECTION	51.79	51.79	51.79	108.35	108.35	108.35	441.43	441.43	441.43
Y-DIRECTION	51.79	51.79	51.79	164.85	164.85	164.85	516.67	516.67	516.67

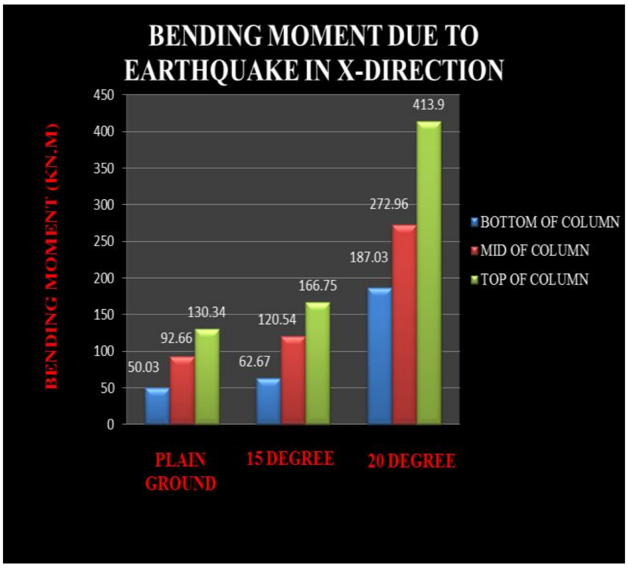


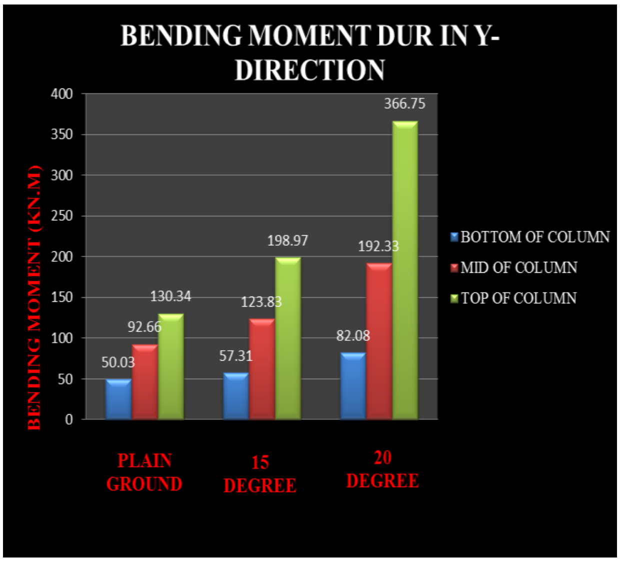


"*Figure 6. Graph of Maximum Shear Force*"

"*Table 3. Maximum Value of Bending Moment*"

BENDING MOMENT (kN.m)									
	PLAIN GROUND			15 DEGREE			20 DEGREE		
	BOTTOM	MID	TOP	BOTTOM	MID	TOP	BOTTOM	MID	TOP
X-DIRECTION	50.03	92.66	130.34	62.67	120.54	166.75	187.03	272.96	413.9
Y-DIRECTION	50.03	92.66	130.34	57.31	123.83	198.97	82.08	192.33	366.75

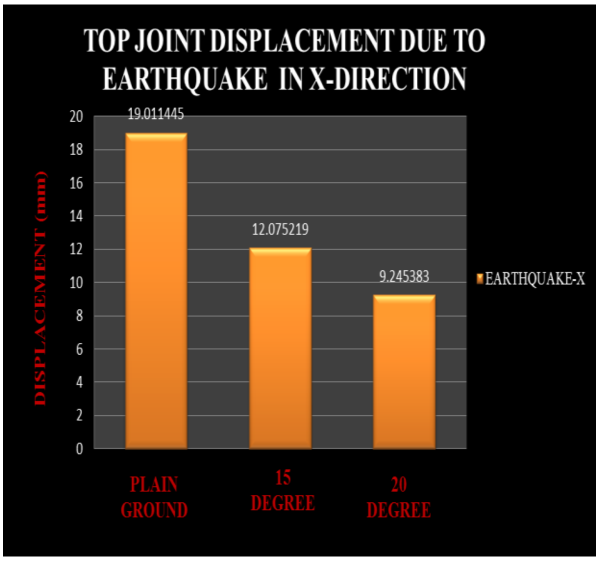


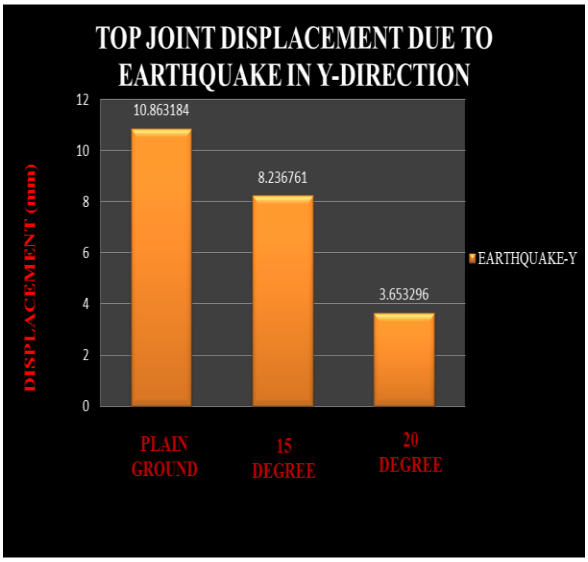


"*Figure 7. Graph of Maximum Bending Moment*"

"*Table 4. Maximum Value of Top Joint Displacement*"

TOP JOINT DISPLACEMENT (mm)			
EQ. Force	**PLAIN GROUND**	**15 DEGREE**	**20 DEGREE**
X-Direction	19.011445	12.075219	9.245383
Y-Direction	10.863184	8.236761	3.653296





"*Figure 8. Graph of Maximum Top Joint Displacement*"

V. CONCLUSION

The performance of buildings on sloping ground during seismic excitation could prove more vulnerable than the building on Plain ground. There is increase in the value of Maximum Top Storey Displacement (19.011445 mm) as the height of building (No. of Storey) increases. The Displacement of building at any point is higher for Building resting on Plain ground than the sloping ground. The value of Shear Force in columns at ground level (51.79 KN) increases as we increase the Angle of Slope from 15 degree (108.352 KN) to 20 degree (441.427 KN). Same way the value of Bending Moment also increases with increase in slope angle. The value of Shear Force in extreme right column is much higher than other frames in case of sloping ground (Angle of slope 15 & 20 Degree) due to Short Column Effect.

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