International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in **ISSN: 2321-7758**

Vol.4., Issue.5., 2016 (Sept.-Oct.)

RESEARCH ARTICLE

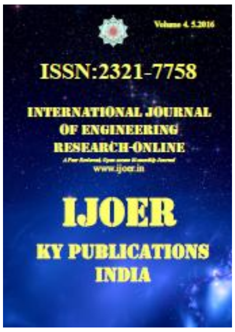
ISSN: 2321-7758

SEISMIC ANALYSIS OF STEP BACK STRUCTURE ON INCLINED GROUND

YELLAMRAJUSAI APARNA DEEPTHI[1], G.GANESH NAIDU[2]

[1]M.Tech student, IV semester, PACE Institute of technology and sciences, Ongole

[2]Assistant Professor and Head, Department of Civil Engineering, PACE Institute of technology



ABSTRACT

This project focuses on the analytical investigation of a step back structure on slope ground with four different inclinations (150,300,450and600). The inclination is achieved in two different phases, in first phase four different inclinations are obtained by maintaining the height of the building constant and in second phase width of the structure was maintained constant. The modeling and analysis was completed using E-tabs. Seismic analysis was carried out in three different methods: Seismic coefficient method, response spectrum method and non –linear static (pushover) method. From the analysis it was observed that for any inclination ground story short column in middle of the structure carries more load compared to the long length column. Increasing the angle for fixed height the column forces and stiffness of the structure decreases with increase in the angle whereas for fixed width structures it was increasing.

KEYWORDS: Setback and step-back buildings, Pushover analysis, target Displacement.

1. INTRODUCTION

Some places in the India are hilly areas, mainly in north-east regions (like Meghalaya, Arunachal Pradesh, Sikkim and etc...) Hilly regions are more and these are mainly in zone IV and V category. In hilly regions the occurrence of earthquakes are also more, considering recent major earthquakes in Sikkim the earthquake of magnitude of 6.9 and Doda earthquake is of a magnitude 4.9, the past earthquakes Uttarkashi earthquake in India 1991, in japan (Tokachi) in the year 1968, Assam earthquake in India 1950 Bihar and Nepal in the year of 1934&1980.

As the density of population in hilly areas is increasing it is necessary to go for multistory structures and because of different contour levels in base of the structures the length of the column may varies at ground story, to study this in this project four different inclinations15^0,30^0,$45^0$and$60^0$are considered. At each inclination the modeling of the structure was done with respect to fixed length and fixed width, so force at the ground level of the columns will be different during seismic events hence it is necessary to investigate the column forces while considering the design of the structures.

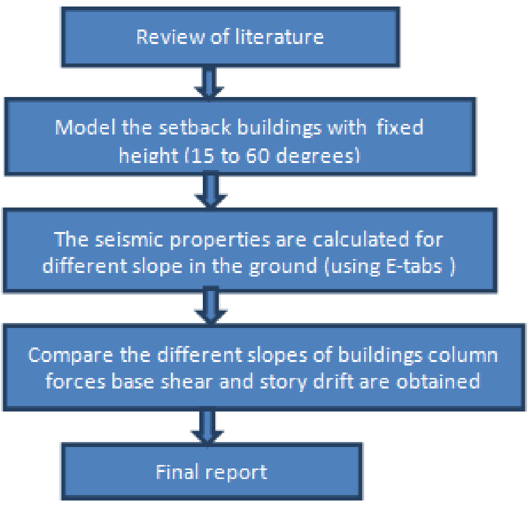
1.2 OBJECTIVES AND SEISMIC BEHAVIOUR OF STRUCTURE ON SLOPES IN INDIA

The main objective of the study was to determine seismic analysis of a structure with different slope levels of a ground. By considering different angles starts from 15 degrees to 60 degrees (setback buildings)

Earthquake in Shillong plateau (M8.0) of 1897 and the Kangra earthquake (M7.8) of1905, and koyna earthquake in maharastra (M6.5) of 1967were the major of several devastating earthquakes to occur in northern India. An estimated of more than 370,000 population were killed in epicentral region, and over 100,000 buildings were destroyed by the earthquake. Similarly in recent earthquakes like Nepal-Bihar (1934), Assam (1950) Uttarkashi(1991), Sikkim (2011), and Doda(2013) affected many buildings on hill slopes.

The presence of such constructions in earthquake prone areas makes them exposed to greater shears and torsion as compared to conventional construction. In order to highlight the differences in behavior, which may further be influenced by the characteristics of the locally available foundation material, a parametric study has been conducted on five different step back and set back buildings. 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. To assess acceptability of the design it is important to predict the force and deformation demands imposed on structures and their elements by severe ground motion by means of static pushover analysis.

2. METHODOLOGY



Modeling of the structure is different for a fixed height and for fixed width, for a fixed height the total height 15m is constant the value of width is changing for 15^0 to 60^0 for 15^0 the total width of the structure in x-direction two bay each of 10.5m. For 30^0 the total width of the structure in x-direction two bay each of 5.2m. For 45^0 the total width of the structure in x-direction two bay each of 3m. For 60^0 the total width of the structure in x-direction two bay each of 1.73m. The width is constant for in z-direction for all degrees of inclination it is constant two bay each of 3.5m length

For a fixed width 10m length is constant in x-direction of two bays height of the is changing from 15^0 to 60^0 for 15^0 the total height of the structure is 11.8 m. for 30^0 the total height of the structure was 14.8m. 45^0 the total height of the structure is 19m. For 60^0 the total height of the structure is 26.2 m

3. MODELING

3.1 For 15^0 inclination

I. Plan in X- direction 2bay each of 10.5 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 15m each story height 3m base 6m.
II. The column dimension on ground level 1300×1800mm for the short length column (3m) at middle of the structure and the long length columns (6m) on ground level.
III. The column dimension 1000×1500mm for remaining two short columns on ground story.
IV. The column dimension 700×1000mm for left side 3 columns on story1.
V. The column dimension 500×700mm for remaining all columns.
VI. The beam dimension 300mm×600mm for all beams.

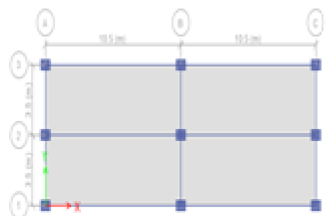


Figure 3.1(a): plan view 15^0 inclination

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in ISSN: 2321-7758
Vol.4., Issue.5., 2016
(Sept.-Oct.)

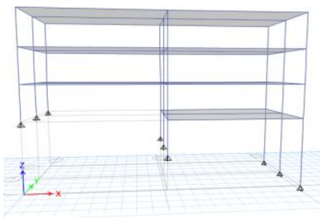


Figure 3.1(b): 3-D view 15^0 inclination

3.2. For 30 ^{0}inclination

I. Plan in X- direction 2bay each of 5.2 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 15m each story height 3m base 6m.

II. The column dimension on ground level 500×700mm for long length columns (6m).

III. The column dimension on ground level 400×600mm for short length column (3m).

IV. The column dimension 300×500mm for remaining all columns.

V. The beam dimensions 230×380mm for all beams.

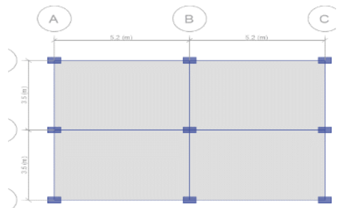


Figure 3.2(a): plan view 30^0 inclination

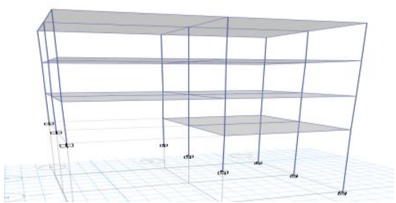


Figure 3.2(b): 3-D view 30^0 inclination

3.3 For 45 ^{0}inclination

I. Plan in X- direction 2bay each of 3 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 15m each story height 3m base 6m.

II. The column dimension on ground level 500×700mm for long length columns (6m).

III. The column dimension on ground level 400×600mm for short length column (3m).

IV. The column dimension 300×500mm for remaining all columns.

3. The beam dimensions 230×380mm for all beams.

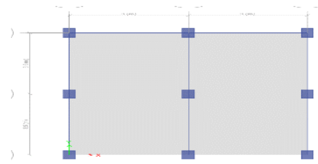


Figure 3.3(a): plan view 45^0 inclination

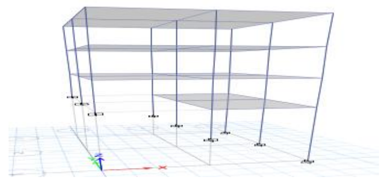


Figure 3.3(b): 3-D view 45^0 inclination

3.4 for 60^{0}inclination

I. Plan in X- direction 2bay each of 1.73 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 15m each story height 3m base 6m.

II. The column dimension on ground level the 350 ×500mm for long length column (6m).

III. The column dimension 280×400mm for short column (3m).

IV. The column dimension 250×380mm for remaining all columns.

V. The beam dimensions 230×380 for all beams.

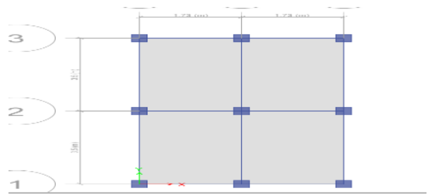


Figure 3.4(a): plan view 60^0 inclination

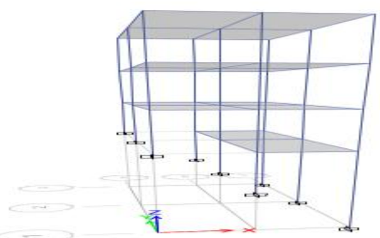


Figure 3.4(b): 3-D view 60^0 inclination

3.5. For 15^{0}inclination

I. Plan in X- direction 2bay each of 5 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 11.8m each story height 3m base 2.8m.

II. The column dimension on ground level the 500 ×700mm for long length column (2.8m).

III. The column dimension 450×550mm for short column (1.4m).

IV. The column dimension 380×500mm for remaining all columns.

V. The beam dimensions 230×380 for all beams.

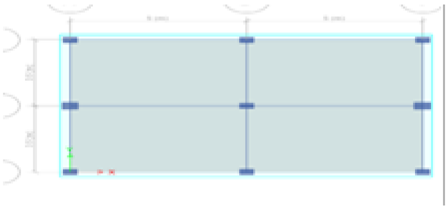


Figure 3.5(a): Plan view 15^0 inclination

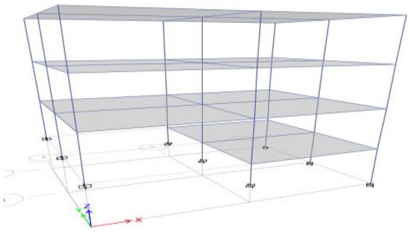


Figure 3.5(b): 3-D view 15^0 inclination

3.6 For 30^0inclination

I. Plan in X- direction 2bay each of 5 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 14.8m each story height 3m base 5.8m.

II. The column dimension on ground level the 500 ×800mm for long length column (5.8m).

III. The column dimension 450×700mm for short column (2.9m).

IV. The column dimension 425×700mm for remaining all columns.

V. The beam dimensions 250×400 for all beams.

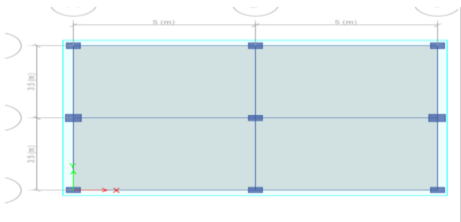


Figure 3.6(a): Plan view 30^0 inclination

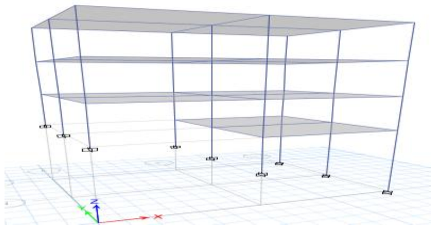


Figure 3.6(b): 3-D view 30^0 inclination

3.7. For 45^0inclination

I. Plan in X- direction 2bay each of 5 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 19m each story height 3m base 7m.

II. The column dimension on ground level the 600 ×900mm for long length column (7m).

III. The column dimension 500×800mm for short column (2m).

IV. The column dimension 400×600mm for remaining all columns.

V. The beam dimensions 230×380 for all beams.

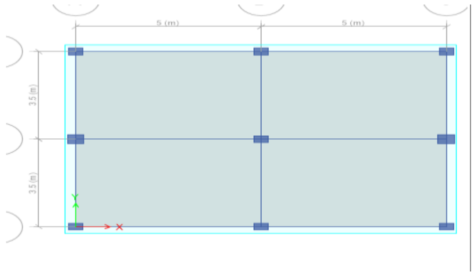


Figure 3.7(a): Plan view 45^0 inclination

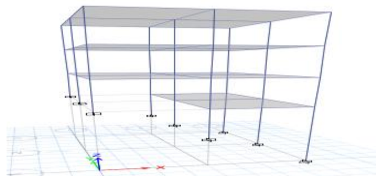


Figure 3.7(b): 3-D view 45^0 inclination

3.8 For 60^0inclination

I. Plan in X- direction 2bay each of 5 m length and in Z- direction 2 bay each of 3.5 m length. Total height of the structure is 26.2m each story height 3m base 11.2m.

II. The column dimension 600 ×900mm for all columns.

III. The beam dimensions 230×380mm for all beams.

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in ISSN: 2321-7758
Vol.4., Issue.5., 2016
(Sept.-Oct.)

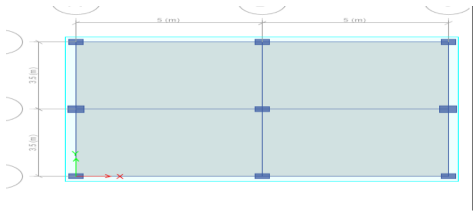


Figure 3.8(a): Plan view 60^0 inclination

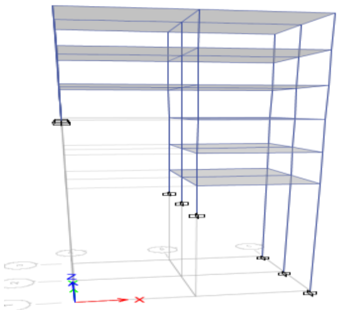


Figure 3.8(b): 3-D view 60^0 inclination

4. ANAYLSIS

4.1 PUSHOVER ANALYSIS – AN OVERVIEW: The use of nonlinear static analysis (pushover analysis) came in to practice in 1970's but the potential of the pushover analysis has been identify for last 10-15 years. This procedure is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake. This procedure can be used for checking the adequacy of new structural design as well. The effectiveness of pushover analysis and its computational simplicity brought this procedure in to several seismic guidelines (FEMA 356and ATC 40) and design codes (PCM 3274and Eurocode 8) in last few years. Pushover analysis is defined as an analysis wherein a mathematical model directly incorporating the nonlinear load-deformation characteristics of individual components and elements of the building shall be subjected to increasing monolithically the lateral loads representing inertia forces in an earthquake until a 'target displacement' is exceeded. The Target displacement is the maximum displacement (elastic plus inelastic) of the building at roof expected to be under selected earthquake and ground motion. A Pushover analysis assesses the structural performance by estimating the force and distorting capacity and seismic demand using a nonlinear static analysis algorithm. The seismic demand parameters of the global displacements (at roof or any other reference point), storey drifts, storey forces, and component distorting and component forces. The analysis accounts for geometrical nonlinearity, material inelasticity and the redistribution of internal forces.

The Nonlinear static pushover analysis is a relatively solution is simple to the problem of predicting force and distorting demands imposed on structures and their elements by severe ground motion. Nonlinear static methods involve three distinct phases: estimation of capacity, estimation of demand and correlating the two to decide the performance of the buildings. The non¬linear static pushover analysis is a comprehensive method of evaluating earthquake response of structures explicitly considering non¬linear behavior of structural elements. The capacity spectrum method is adopted for implementing pushover analysis that compares structural capacity with ground shaking demand to determine peak response during an earthquake. The capacity spectrum method estimates peak responses by expressing both structural capacity and ground shaking demand in terms of spectral acceleration and displacement. The capacity spectrum method assumes peak response of the non¬linear structure to be equal to the modal displacement of an equivalent elastic system with an effective period, Teff based on secant stiffness. The intersection of capacity curve and demand curve established the performance point.

4.2.RESPONSE SPECTRUM

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions.

The dynamic analysis of structures is carried out by two methods, Response Spectrum Method and Time History Method. The Response Spectrum Method consists of determining the response in each mode of vibration and then superimposing the responses in various modes to obtain the total response. The seismic analysis of all buildings was carried out by Response Spectrum Method in accordance with IS: 1893 (Part1): 2002, including the effect of eccentricity (static and accidental). Damping considered for all modes of vibration was five percent. For determining the response of the buildings in different directions for ground acceleration the response spectrum analysis was conducted in longitudinal and transverse direction. The other parameters used in seismic analysis were, moderate seismic zone (V), zone factor 0.36, importance factor 1 and the response reduction factor as 5. Ordinary moment resistant frame for all configurations was assumed for OMRF we take factor 3 and for Special moment resistant frame we take the factor 5

4.3 LOADS AND CALCULATIONS

4.3. Dead load:

Slab of thickness 150 mm is considered

Unit weight of concrete is 25 kN/m^3

Floor finish is 1 kN/m^2

Total dead load on slab is 4.75 kN/m^3

4.3.1 Wall load

Wall of thickness 230 mm

Unit weight of brick 19 kN/m^3

Total wall load on beam is 13.11 kN/m

4.4. Live load

Live load was considered as per IS 875 part II 3kN/m^2

4.5. Seismic load

Seismic load was consider as per zone V of IS 1893

Seismic Zone Factor, Z [IS Table 2] Z=0.36

Response Reduction Factor, R [IS Table 7] R=5

Importance Factor, I [IS Table 6] I=1

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, Sa /g [IS6.4.5] S_a/g=2.5 S_a/g=2.5

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

Eccentricity Ratio = 5% for all diaphragms

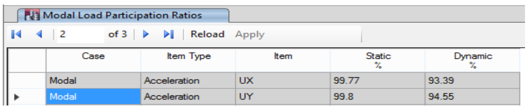
5. RESULTS

From the analysis it was observed that the column forces are constant for seismic coefficient method and pushover analysis and for a fixed height and fixed width the short column at the middle of the structure was taking more force from the pushover analysis stiffness was calculated by using pushover curves from the response spectrum analysis the model mass participation factor was considered. From the seismic coefficient method story drift and base shear values are tableted

5.1 RESPONCE SPECTRUM: Response spectrum analysis is done as per IS 1893:2002 the minimum values model mass partition factor should considered as more than 90 percentage total seismic mass and the ratio between the design base shear and fundamental base shear value is equal to one.

5.2 PUSHOVER: Pushover analysis is carried out by considering displacement control method with a load to a monitored displacement of magnitude of magnitude of 0.04h. h is the total height of the structure for a fixed height it is the displacement was constant. Hing values for beams and columns was taken as per ASCE 41-06.

Model mass partition factor:


Modal Load Participation Ratios

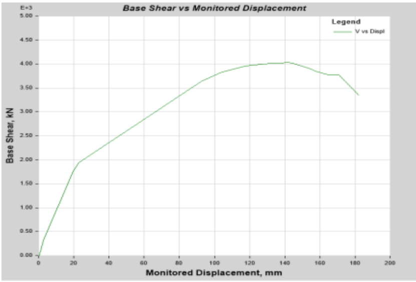
2 of 3 Reload Apply

	Case	Item Type	Item	Static %	Dynamic %
	Modal	Acceleration	UX	99.77	93.39
▸	Modal	Acceleration	UY	99.8	94.55

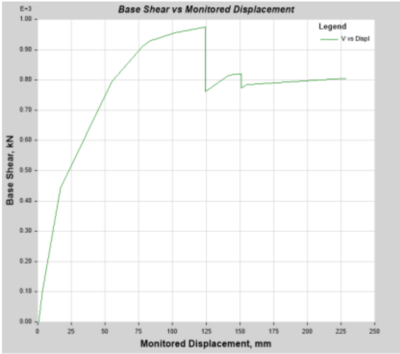
Figure 5.1(a): model mass participation factor for first 6 modes

Pushover curves

Pushover Curve - Base Shear vs Monitored Displacement fixed height 15^0



fixed height 30^0

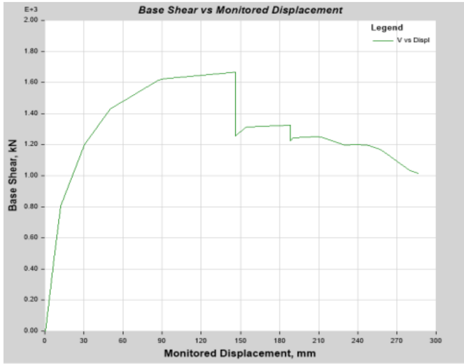


fixed height 45^0

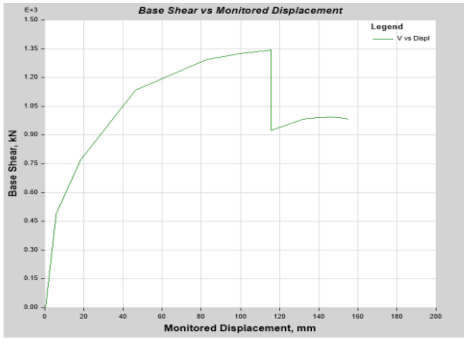
fixed height 60^0

fixed width 15^0

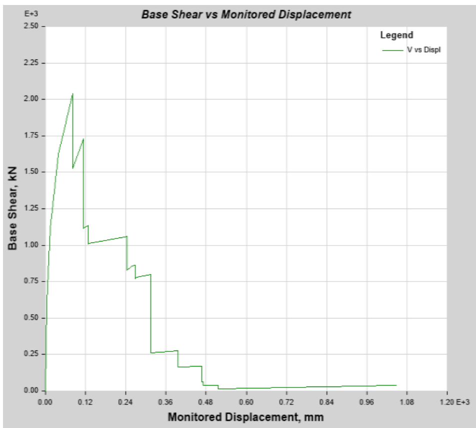
Fixed width 30^0



Fixed width 45^0



fixed width 60^0



Fixed height results

Model Fixed width	Storey height in (m)	Maximum on top Story drift In (mm)	Base shear (V_b) in KN	Maximum Column forces on ground story Middle Frame left side column Of 3m length In (KN)	Maximum Column forces on ground story Middle Frame right side column Of 6m length In (KN)	Stiffness of pushover curve in kn/mm	Model load participation depending on 90% no og modes
AT 15 degrees	15	0.0015	436.51	3988.15	2828.012	100	9
At 30 degrees	15	0.001	158.28	1943.98	1330.67	64	5
At 45 degrees	15	0.0006	112.78	1327.14	974.13	28	4
At 60 degrees	15	0.0006	71.23	813.84	719.18	16	4

Fixed width results

Model Fixed width	Storey height in (m)	Maximum on top Story drift In (mm)	Base shear (V_b) in KN	Maximum Column forces on ground story Middle Frame left side column Of 3m length In (KN)	Maximum Column forces on ground story Middle Frame right side column Of 6m length In (KN)	Stiffness of pushover curve in kn/mm	Model load participation depending on 90% no og modes
AT 15 degrees	11.8	0.001	148.17	1906.15	1272.42	36	6
At 30 degrees	14.8	0.00072	187.72	1943.6	1346.23	63	6
At 45 degrees	19	0.0008	201.39	2204.45	1571.289	85	7
At 60 degrees	26.2	0.0008	317.214	2260.11	1893.07	125	7

CONCLUSIONS

- From the results it was concluded the short length column at ground level will take more force when compare to the long length columns and the opposite long length column was also taking more fore (which was less than short column force) compare to remaining columns.
- While increasing inclination of the structure the for fixed height the column forces are decreasing and for the fixed width it was increasing while increasing the angle and the story drift was increasing while increasing, for the inclination at 45^0 and 60^0 was equal. The value of base shear was decreasing while increasing the angle of inclination of the structure.
- For fixed width the value of base shear was increasing from pushover analysis results it was observed that for fixed height while increasing the inclination stiffness of the structure was decreasing for fixed width case while increasing the inclination stiffness of the structure was increasing.
- From response spectrum results it was observed that for fixed height model load participation

ratio value increasing for fixed width case the model load participation ration is decreasing.

REFERENCES

[1]. Birajdar.B.G,"Seismic analysis of buildings resting on sloping ground", 13thWorld Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 1472, 2004.

[2]. Fardis M. N. (2009): Seismic Design, Assessment and Retrofitting of Concrete Buildings, Springer Publication.

[3]. Griffith M. C., Pinto A. V. (2000):"Seismic Retrofit of RC Buildings - A Review and Case Study", University of Adelaide, Adelaide, Australia and European Commission, Joint Research Centre, Ispra Italy.

[4]. Griffith M. C., Pinto A. V. (2000):"Seismic Retrofit of RC Buildings - A Review and Case Study", University of Adelaide, Adelaide, Australia and European Commission, Joint Research Centre, Ispra Italy.

[5]. Goel R. K. (2008): Evaluation of Current Nonlinear Static Procedures for Reinforced Concrete Buildings, The 14th World Conference on Earthquake Engineering October 12- 17, 2008, Beijing, China.

[6]. Halkude et al "Seismic Analysis of Buildings Resting on Sloping Ground With Varying Number of Bays and Hill Slopes" International Journal of Engineering Research and Technology ISSN:2278-0181,Vol.2 Issue 12, December-2013