Seismic analysis of multi-storey Building on Sloping grounds with different earthquake resisting technique using ETABS

Nandini Naresh Raut[1], Nimish Patankar[2], Prof. Pallavi Nikhil Bhende [3]

[1] M.Tech Computer Aided Structural Engineering Student WCEM, Nagpur
[2]Structural Engineer, RCC and steel structural Consultant, Nagpur
[3]Head of Dept. of civil Engineering WCEM, Nagpur

---***---

Abstract - *Because of the current circumstances, which includes a growing population, expanding cities, and uneven terrain, most buildings are usually constructed on sloping terrain. The distribution of mass and stiffness in both the horizontal and vertical planes varies when a building is situated on a sloping site. These structures are susceptible to severe damage from ground motion during an earthquake because they are frequently torsional linked and situated on steep hillsides in seismically active areas. Model analysis software is done using ETABS 16. On both level and sloping surfaces, models are assessed. First, the model is subjected to a seismic analysis procedure that entails allocating various load scenarios and combinations. Among the study's findings are maximum storey displacement, overturning moment, storey drift, and storey shear. For structures of various heights, the dynamic response—basic time period, storey displacement, and base shear action caused in columns—has been examined. As is well known, reinforced concrete structures built on mountain slopes frequently have asymmetrical shapes with downward gradients, making them vulnerable to severe damage during earthquake activity. The aim of this study is to conduct a comparative examination of the results obtained from the dynamic method of earthquake analysis on reinforced concrete structures with five distinct forms, including ordinary buildings. Analysis that includes storey shear, storey drift, and storey displacement in the X and Z dimensions.*

Key Words*: - Seismic Analysis, ETABS 16, Sloping ground*

1. INTRODUCTION

The economic growth & rapid urbanization in hilly region has accelerated the real estate development. As a result, the hilly region's population density has significan tly expanded.In steep areas, adobe burnt brick, stone masonr y, and dressed stone masonry structures are typically constru cted on level terrain. Since level land in hilly regions is very limited, there is a pressing demand to construct buildings on hill slope. Hence construction of multi-story R.C. Frame buildings on hill slope is the only feasible choice to accommodate increasing demand of residential & commercial activities. Earth quakes are the natural phenomenon's which are caused by the release of large strain energy by the moving faults below the surface of the earth, the lateral force amplitudes and intensities causing the earth's surface to tremble in all possible directions.

1.1 Motivation and background

One of the world's most seismically active areas is the Indian Himalayas, which run from Nagaland in the northeast to Kashmir in the northwest. The Indian Zonation map places the entire area under seismic zones IV and V. The demand for multi-story Reinforced Concrete (RC) buildings has surged over the existing local traditional constructions in hilly regions due to rapid urbanization and population growth. But because the majority of these structures are not engineered, they have a great deal of issues, such as low material quality, inadequate seismic detailing and design, and disconnected vertical and horizontal building elements. During previous earthquakes, such as the 2005 Kashmir earthquake, the 2011 Sikkim earthquake, and the 2015 Nepal earthquake, significant damage was noted in these buildings.

1.2 Fundamental Natural period of a building

Natural period of a building is one such important dynamic property, which has its key role during the design phase of the construction of a building. The fundamental natural period of a building is one of the significant parameters that is used to calculate the design base shear and lateral forces acting on a building, which are used in the design procedures. But as this building property cannot be computed for a structure during the initial stages of design, building codes provide empirical formulas to calculate the approximate value depending on the building material [steel, reinforced concrete etc.], structural system (frame, shear wall, etc.), and overall dimensions. But the existing expressions of fundamental natural period of a building prescribed by Indian Seismic code IS 1893:2016 are adopted from earlier versions of US codes which are originally developed based on response of buildings founded on flat ground during Californian earthquakes.

2. LITERATURE REVIEW

2.1 Prashant D, et al. (2013) - "Seismic Reaction of RC Frame One-Way Slope Building with Soft Storey" [1]. The building situated on a hillside with a 27° horizontal slope is studied to find out how the soft storey impacts the response of the structure. The present paper investigates performance based seismic evaluation of building models namely: bare frame, soft storey, fully infill buildings with unreinforced masonry infill for G+9 stories located in seismic zone V. The addition of masonry infill walls to the ground storey efficiently minimizes the storey drift of soft storey; base shear increases as building stiffness increases. The natural period decreases as the stiffness of the building increases and thereby leading to increase in base shear. Analysis reveals that, in comparison to other models, the bare frame model's time period is roughly 90 to 135 percent longer.

2.2 Umakant Arya, et al. (2014) - "Wind Analysis of Building Frames on Sloping Ground" [2]. In this research paper, the effect of wind velocity and structural response of building frame on sloping ground has been studied. Considering various frame geometries and slope of grounds.Max axial force in beams increases with increase in the ground slopes. Max axial force in beam is more affected for sloping ground and wind velocity on building frame. Max axial force in column increases with increases in the height of building frame.Max shear force in beams increases with increase in the height of building frame on sloping ground as well as plane ground.Max moment in beams for different building heights increases with increase in the wind velocity. Max moment in beams does not get affected by increase in the ground slope. Ax moments in column increases with increase in the height of building frame.

2.3 Narayan Kalsulkar, et al.(2015)- "Seismic Analysis of RCC Building Resting on Sloping Ground with varying Number of Bays and Hill Slopes" [3]. In this paper 48 models with step back structural frame are studied on account of higher story displacement. Step back-set back frames result in less base shear than step back frames. The most damaged columns are found to be the extreme left ones, which are short and located on the higher side of the sloping land. The performance of step back frames during seismic excitation could prove more vulnerable than other configurations of building frames, hence step back-set back frames are more desirable than step back frames. As number of bays increases time period & top storey displacement decreases. Therefore, it is concluded that greater number of bays are observed to be better under seismic conditions. The top story displacement diminishes and the time period increases with hill slopes.

2.4 Anjeet Singh Chauhan, et al. (2021) -"Seismic response of irregular building on sloping ground" [4]. In this paper, a G+10 RCC Stepback building having each storey of height 3.6m with a horizontal angle of inclination 20°, 30°, 40º, and 45 Model-1. Stepback Bare Frame. Model-2. Stepback Bare Frame with Mass Irregularity. Model-3. Stepback Bare Frame with Diaphragm Irregularity. Model-4. Stepback Bare Frame with Mass & Diaphragm Irregularity. As the angle of slope increase then every Model frames of Mode period, Base shear, Storey displacement, and storey drift values increases in both directions, but in the case of storey shear, its values decrease in both directions of each Model frames as the angle of slope increases. Base shear and storey shear of Model-1 is more than 14.60% and 19.37% in X-direction and 10.80% and 21.98% in Y-direction of Model-4.Storey displacement and storey drift of Model-1 is less than 3.49% and 4.62% in the X-direction of Model-4. On comparison and dynamic results, it is observed that Model-2 found maximum mode period, storey displacement and storey drift at 45° from other models. On the comparison of models, it is found that the performance of step back bare frame with mass irregularity (Model-2) during seismic excitation could prove more vulnerable on 45° slopes than another Model frame. On comparison and dynamic results, it is observed that Model-3 found minimum mode period, storey displacement and storey drift at 20° from other models.

2.5 Pawan Pawar, et al. (2023) - A comparison between a multi-storey building resting on a level and sloping ground in terms of seismic analysis [5].The purpose of this paper is to analysis G+8 storey building on the basis of shear wall analysis in setback structural frame building, from this paper it is concluded that-Combination with shear wall shows minimum base shear as compared to other. Shear wall have great effect to resist lateral displacement of building as compared to main models. Building combination with shear wall shows minimum Absolute displacement as compared to other. The building combination with shear wall shows minimum results as compared to another building. Inclined from front - setback building frame shows minimum results as compared to other building Hence Inclined from front - setback building frame is better as compared to other.

2.6 Prasad Ramesh Vaidya. (2015)- "Seismic Analysis of Building with Shear Wall on Sloping Ground" [6]. The seismic performance of shear wall buildings on sloping terrain is examined in this study. The principal aim is to comprehend the behavior of the structure on sloping terrain for different shear wall placements and to investigate the efficiency of shear walls on sloping terrain. Shear wall placement is crucial for buildings on sloping terrain to withstand seismic effects. The most important component of a construction on sloping terrain are short columns. The most important component of a construction on sloping terrain are the short columns. To have a good control over the forces such as shear force and bending moment it is preferable to locate the shear wall towards the shorter column side. Bending moment and shear force along sloping side is found to be minimum for shear wall towards shorter column, whereas on other side Shear wall located symmetrically in plan gives minimum shear force and bending moment.

2.7 D. J. Misal, et al. (2016) - "Study of Seismic Behaviours of Multi-Storied R.C.C. Structures Considering Bracing Systems and Resting on Sloping Ground" [7].The study of these vibrations by various techniques, understanding the nature and various physical processes by applying the bracings. It is explained that the short column is stiffer as compared to tall column and it attracts larger earthquake force. Stiffness of a column means resistance to deformation the larger is the stiffness, larger force required to deform it. As per IS1893(Part-1)-2002 buildings with dual system consist of shear walls or bracing frames so that these are designed to resist the total design lateral force in proportion to their lateral stiffness. The step back building frames without bracings give higher values of top storey displacement as compared with step back and set back frames. Time period and top storey displacement both grow with the number of stories.

3. METHODOLOGY

3.1 MATERIAL PROPERTIES

Elastic material properties of these materials are taken as per Indian Standard IS 456: 2000.

A) CONCRETE: Concrete with following properties is considered for study.

- Characteristic compressive strength (fck) = 25 MPa
- Poisson Ratio = 0.3
- Density = 25 KN/m3
- Modulus of Elasticity (E) = 5000 x √ fck = 25x103 MPa fck is the characteristic compressive strength of concrete cube in MPa at 28-day.

B) STEEL: Steel with following properties is considered for study.

- Yield Stress (fy) = 415 MPa
- Modulus of Elasticity (E) = 2x105 MPa

C) MASONRY INFILL: Masonry with following properties is considered for study. Clay burnt brick, Class A, confined unreinforced masonry, Where fm= Compressive Strength of Masonry and it has been taken from the Table E-1, Page -8 and Fig E-10 Page no 8 of SP 20)

- Compressive strength of Brick, fm = 10 MPa
- Modulus of Elasticity of masonry (Ei) = 550 x fm = 5500MPa
- Poisson Ratio = 0.15

3.2 SELECTION OF MODEL

1	Plan Dimension	18 M x 24 M
2	Number of Stories	G+9
3	Total Height of building	32.75 M
4	Height of each story	3 M
5	Size of column	230 mmX500mm
6	Size of Beam	230mmX500mm
7	Thickness of Slab	150 mm
8	Thickness of wall	230 mm
9	Seismic zone	V
10	Soil condition	MEDIUM
11	Importance Factor	1
12	Response Reduction	5
13	Damping of Structure	0.05
14	Live Load	a) On Roof = 2 kN/M² b) On floor = 2 kN/M²
15	Floor Finish	0.5 kN/M²
16	Material	M25 & M30 Grade of Concrete Fe-415 Reinforcement
17	Unit Weight	a) Concrete =25kN/cuM b) Masonary = 20 kN/cuM

Table 3.1: Structural Modeling (Building Modeling)

3.3 COMPARATIVE PARAMETER

Selected models are compared on the basis of following criteria for better understanding of the structural behaviour during sesmic activity on sloping ground.

- Displacement in X direction
- Displacement in Y direction
- Base shear

3.4 LOADING PATTERNS

4. ANALYSIS OF STRUCTURE

Name	Type	Self-Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	0	
EQX	Seismic	0	IS1893 2002
EQY	Seismic	0	IS1893 2002
SDL	Superimposed Dead	0	

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 04 | Apr 2024 www.irjet.net p-ISSN: 2395-0072

4.1 ANALYSIS OF STRUCTURE IN ZONE V

Values of lateral displacement, axial force, shear force, bending moment, storey drift and base shear for zone V, for load combinations 1.2DL+1.2LL+1.2SDL+1.2EQX along X direction for Six different cases will be analyzed and summarized next to this project.

MODEL	Load Case/Combo	FZ kN
M1	1.2(DL+LL+SDL+EQX)	86727.814
M2	1.2(DL+LL+SDL+EQX)	88790.455
M3	1.2(DL+LL+SDL+EQX)	76889.357
M4	1.2(DL+LL+SDL+EQX)	78651.711
M5	1.2(DL+LL+SDL+EQX)	71520.536
M6	1.2(DL+LL+SDL+EQX)	74202.469

Table 4.2 Base Shear along X direction -zone V (mm)

Story	Load Case/Combo	MODEL					
		M1	M2	M3	M4	M5	M6
10TH	1.2(DL+LL+SDL+EQY)	0.000315	0.000597	0.000487	0.000732	0.000607	0.000783
9TH	1.2(DL+LL+SDL+EQY)	0.000504	0.000679	0.000709	0.000819	0.000884	0.000852
8TH	1.2(DL+LL+SDL+EQY)	0.000668	0.000762	0.000899	0.000902	0.001119	0.000906
7th	1.2(DL+LL+SDL+EQY)	0.000796	0.000839	0.001048	0.000967	0.001301	0.000928
6th	1.2(DL+LL+SDL+EQY)	0.000892	0.000896	0.001159	0.000997	0.001423	0.000892
5th	1.2(DL+LL+SDL+EQY)	0.00096	0.000926	0.001234	0.000977	0.001407	0.00078
4th	1.2(DL+LL+SDL+EQY)	0.001004	0.00092	0.001282	0.000893	0.000631	8.60E-05
3rd	1.2(DL+LL+SDL+EQY)	0.001031	0.000871	0.001934	0.001148	0	0.000193
2nd	1.2(DL+LL+SDL+EQY)	0.001075	0.000765	0.000907	0.000447	0	0
1st	1.2(DL+LL+SDL+EQY)	0.001285	0.000569	0.000264	6.90E-05	0	0

Table no. 4.2 Maximum Story Drift along Y direction zone V (M)

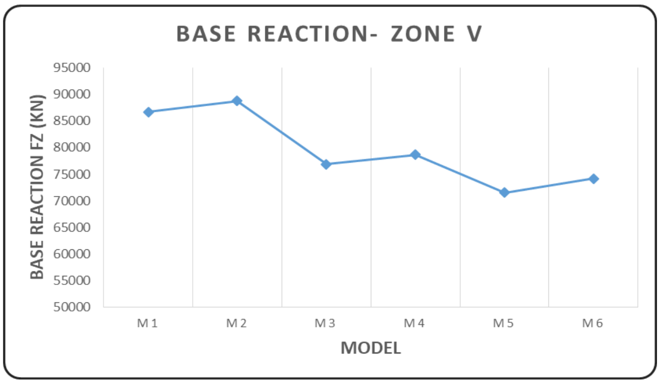
Story	Load Case/Combo	MAXIMUM DISPLACEMENT (MM)					
		M1	M2	M3	M4	M5	M6
10TH	1.2(DL+LL+SDL+EQX)	41.769	34.087	36.044	29.423	29.385	23.006
9TH	1.2(DL+LL+SDL+EQX)	40.449	31.496	34.567	26.582	27.658	19.886
8TH	1.2(DL+LL+SDL+EQX)	38.258	28.616	32.042	23.419	24.638	16.483
7TH	1.2(DL+LL+SDL+EQX)	35.353	25.398	28.663	19.9	20.566	12.819
6TH	1.2(DL+LL+SDL+EQX)	31.89	21.865	24.617	16.09	15.672	9.052
5TH	1.2(DL+LL+SDL+EQX)	28.009	18.095	20.072	12.133	10.16	5.471
4TH	1.2(DL+LL+SDL+EQX)	23.833	14.199	15.177	8.25	4.097	2.493
3RD	1.2(DL+LL+SDL+EQX)	19.468	10.327	10.016	4.741	0.307	0.618
2ND	1.2(DL+LL+SDL+EQX)	15.001	6.664	5.002	2.092	0.031	0.171
1ST	1.2(DL+LL+SDL+EQX)	10.423	3.45	1.908	0.56	0.031	0.177

Table no. 5.3 Maximum Displacement along X direction zone V (MM)

5. RESULT AND DISCUSSION

5.1 GRAPHICAL REPRESENTATION FOR BASE SHEAR

The base shear in the columns in longitudinal and transverse direction is considered for analysis in seismic zone V shown in table no 5.1and graphical representation of data is shown in Fig no.5.1.



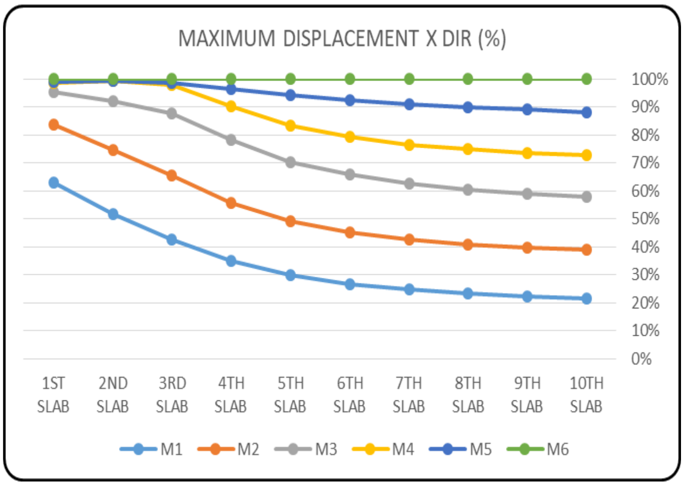
Graph 5.1 Base Shear along X direction -zone V (mm)

5.1 Observations: -

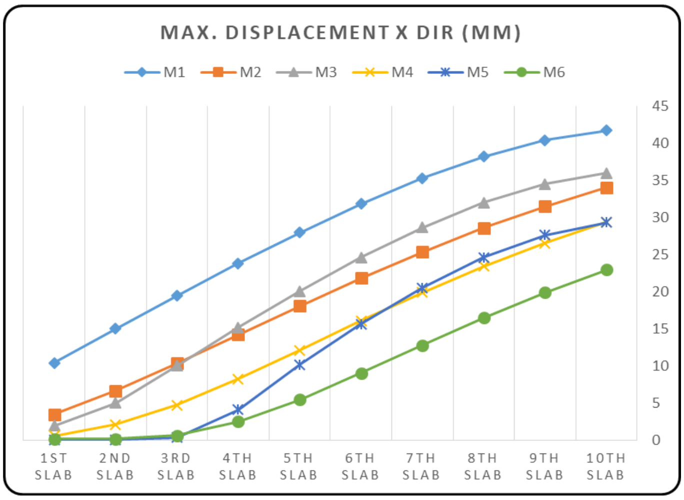
1. Plots of the base shear in longitudinally are made for six models, all imposed on the same graph. The base shear is directly proportional to weight of structure.
2. From the above graphs base shear profiles it is observed that minimum shear occurs in 30o slope with shear wall and maximum base shear is occurred on bare frame building with no slope.

5.2 GRAPHICAL REPRESENTATION FOR MAXIMUM DISPLACEMENT

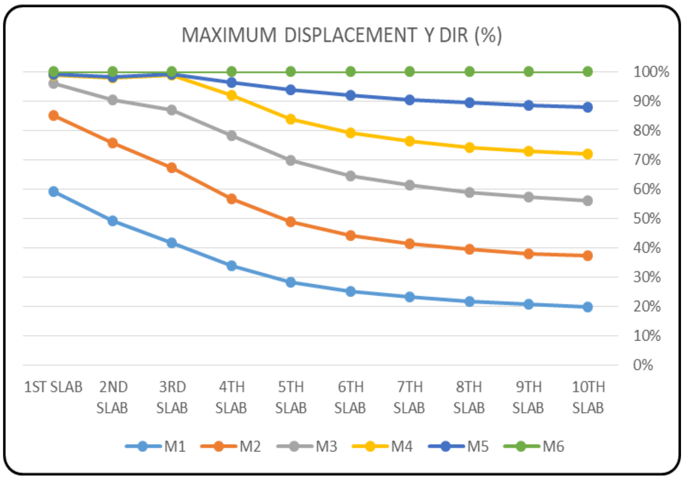
The maximum displacement in the columns in longitudinal and transverse direction is considered for analysis in seismic zone V shown in table no 5.2 to 5.3 and graphical representation of data is shown in Fig no.5.2.1 to 5.2.5



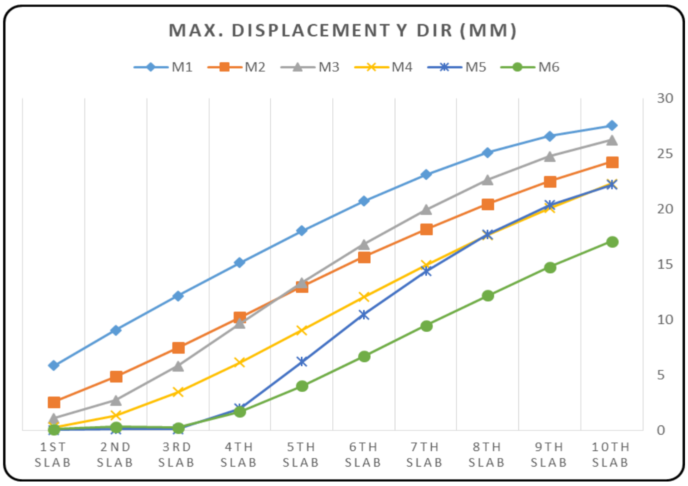
Graph No. 5.2.1. Maximum Displacement along X direction zone V (%)



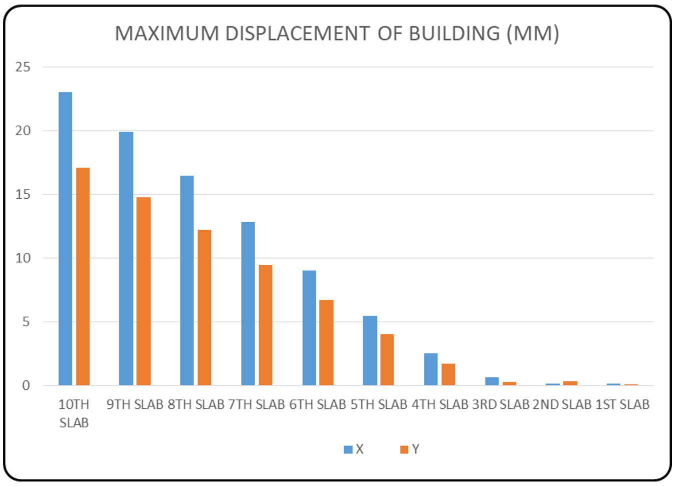
Graph No. 5.2.2. Maximum Displacement along X direction zone V (MM)



Graph No. 5.2.3 Maximum Displacement along Y direction zone V (%)



Graph No. 5.2.4 Maximum Displacement along Y direction zone V (MM)



Graph No. 5.2.5 Maximum Displacement comparative 1.2(DL+LL+SDL+EQX) along X & 1.2(DL+LL+SDL+EQY) Y direction zone V (MM)

5.2.1 Observations: -

1. For easy comparison of the lateral displacement of the selected building, plots of the story level displacement in longitudinal or transverse versus height are made for the six cases, all imposed on the same graph.
2. From the above graphs displacement profiles it is observed that maximum displacement occurs in bare frame building with zero slope building.
3. From the above mentioned graphs it is clearly observed that maximum displacement is occurred in case 1 and minimum displacement is obtained in the building with 30o slope with shear wall. From this representation of the graphs it can be said that displacement is significantly reduce as slope in increased.

4. From the above analysis there is remarkable 80% difference in first and last readings taken on graphs for model 1 and model 5.
5. Shear wall plays significant role in reducing the lateral displacement, provision of shear walls in a single bay reduce the displacement up to 20%.
6. In the graph no.5.2.5 displacement is plot for 1.2(DL+LL+SDL+EQX) in x direction and 1.2(DL+LL+SDL+EQY) in Y direction, displacement in X direction is significantly higher as compare with Y direction.

5. CONCLUSION

1. Earthquake is happened due to the ground motion intensity of which is mapped by the rector scale, due to such adverse shaking of ground building structure faces a severe damage and to take care of such effects it is important to understand the properties of earthquake and predict the possible reaction on the building structure.
2. Story comparing the X direction force for 1.2(DL+LL+SDDL+EQX) and Y direction for 1.2(DL+LL+SDL+EQY) it is clearly seen that displacement in Y direction with EQY forces gives higher displacement it is due the less support in Y direction.
3. In the case of Base shear, it is concluded that value for the model-1 (i.e. 0o slope with bare frame) is higher and gradually reduce as slope of the building goes on increasing though it is lesser in the case of 300 slope with shear wall.

6. REFERENCES

1. Prashant D, Dr. Jagadish Kori G " Seismic Response of one way slope RC frame building with soft storey" International Journal of Emerging Trends in Engineering and Development Issue 3, Vol.5 (September 2013).

2. Umakant Arya1, Aslam Hussain2, Waseem Khan3 Wind Analysis of Building Frames on Sloping Ground Max

3. Narayan Kalsulkar And Satish Rathod " Seismic analysis of RCC building resting on sloping ground with varying number of bays and hill slopes". IJCET journal volume 5.No.3 (june 2015) paper No 2063.

4. Anjeet Singh Chauhan, Rajiv Banerjee, "Seismic response of irregular building on sloping ground". Volume 12, Issue 5, May 2021, pp., International Journal of Advanced Research in Engineering and Technology (IJARET).181-202, Article ID: IJARET_12_05_017 ISSN Print: 0976-6480 and ISSN Online: 0976-6499

5. Pawan Pawar Asst. Prof. Deepa Telang A Comparative Study on Seismic Analysis of Multistory Building Resting on a Sloping Ground and Flat Ground.

6. Prasad Ramesh Vaidya, "Seismic Analysis of Building with Shear Wall on Sloping Ground". International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online) Vol. October 2014 - March 2015, Volume 2, Issue 2, pages 53-60, accessible at www.researchpublish.com

7. D.J.Misal, M.A.Bagade, "Study of Seismic Behaviors of Multi-Storied R.C.C. Buildings Resting on Sloping Ground and Considering Bracing System"(IJREST ISSN 2395-6453(Online) Vol. 2, Issue 1 (2016)

- IS CODES:-

1. IS 1893:2002 (Criteria for earthquake resistant design of structures part 1 general provision and buildings)
2. IS 456:2000 (Plain and Reinforced Concrete - Code of Practice)
3. IS 13920: 1993 (Ductile detailing of reinforced concrete structures subjected to seismic forces — code of practice)