iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VI **Month of publication:** June 2020

DOI: http://doi.org/10.22214/ijraset.2020.6079

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Analysis of Building on Sloping Ground

Ms. Rudrani G. Sanap[1], Mr. Vishal Sapate[2]
[1, 2]Civil Department (structure), GHRU University Amravati

Abstract: The construction of a structure on a hilly area or on a sloping ground is different from other construction. The structures on a sloping ground are irregular and unsymmetrical in vertical as well as horizontal directions. Hence it is difficult to make the structure stable.

To construct a sustainable structure, we need to consider the configurations of building. In this research we are going to analyse three types of configurations of building based on a sloping ground by the method of dynamic analysis with the help of STAAD Pro. The configurations are step back, step back set back and set back. by comparing their performance we will decide the better configuration for a sloping ground.

This study shows that for sloping ground and levelled ground the building configuration gives effective response when earthquake occurs.

Keywords: Seismic, Building, Sloping, Ground, Set back, step back, step back-set back, response spectrum analysis

I. INTRODUCTION

As we all know earthquake is the most dangerous disaster .In past few years India as well as other parts of world witnessed such a major earthquakes that leads to not only structural but also livelihood destruction. In India we have several zones which are active zones for earthquake.

The north east part of India including the Himalayan is hilly terrain area which is an active zone for earthquake. The first reason for earthquake in this region is the movement of Indian plate towards the Eurasian belt. The earthquake is dangerous and gets more difficult for structures when it combines with slope.

The construction of structure on a hill is a task, but it gets more difficult when it comes along with seismic effects. The structures on a hill are irregular and unsymmetrical in vertical as well as horizontal directions. Also there is irregularity in foundations of these structures. Due to which the centre of mass does not coincides with centre of stiffness. These whole things make the structures more vulnerable.

Hence for the safety of a livelihood and structure, it is required to take in account the seismic effects as well as the sloping effects of structures in a hilly region. In this study, we will see the different configurations of a building based on a sloping ground and their performance according to the slope by the method of dynamic analysis with the help of STAAD Pro. The configurations are step back, step back set back and set back. By comparing the results of configurations of buildings we will be able to decide the better type of configuration which is more sustainable to damage.

II. STRUCTURAL DATA

The building types are as follows:

A. Step back building
B. Step back set back buildings
C. Set back buildings

1) Size of beam kept constant 230 mm x 500 mm in each and every configuration at each level.
2) As storey number increases size of column also increases.
3) Mostly variation of column size in step back building configuration because there is severe base shear condition in upward hill side.
4) Material – Properties
5) Modulus of Elasticity -25000 N/mm2
6) Poissions Ratio -0.20
7) Density -25 kN/m3
8) Thermal coefficient- 1x10-5
9) Critical Damping -.05

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

III. METHODOLOGY

A. Response Spectrum Analysis (RAS)

Response spectrum analysis method is used for dynamic analysis of all building structures configurations by using IS: 1893 (PART 1)-2002.Due to static and accidental generation of eccentricity torsion effect is also considered. The other parameters used in dynamic analysis are as given below –

1) Seismic zone – moderate (zone III)
2) Zone factor - .016
3) Importance factor - 1.0
4) Damping – 5%
5) Response reduction factor (sa /g) – 3.0

Assumed that all the building configuration and height of building structures is considered under ordinary moment resisting frame.For each building structure configuration, minimum six modes considered in which, the summation of modal masses of all modes was at least 99 % of the total earthquake/ seismic mass. Due to seismic loading, member forces were computed for each contributing mode and the modal responses were combined together using CQC method.

The following design spectrum was utilized in response spectrum analysis (sa/g):

$$Sa/g = \begin{cases} 1+15T & \text{when } 0.0 \le T \le 0.10 \text{ seconds} \\ 2.50 & 0.0 \le T \le 0.40 \text{ seconds} \\ 1/T & 0.40 \le T \le 4.0 \text{ seconds} \end{cases}$$

First, the seismic analysis of building structure was carried out without shifting the centre of mass (C.G.) from their real position. Then the results got from the application of torsion moment at each floor level equal to lateral force times to the addition result of static and accidental eccentricity at that were superimposed on the results from seismic analysis.

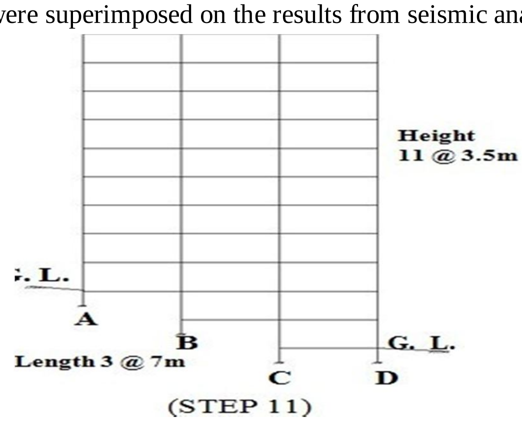


Figure 3.1: Building Models For Step Back Configuration On Sloping Ground (4 To 11 Storeys)

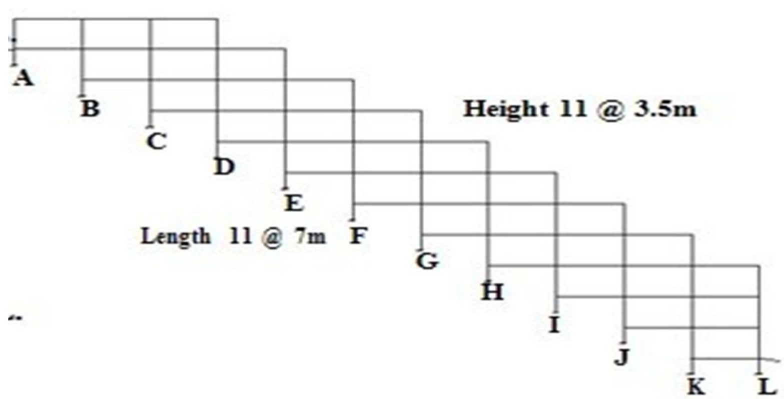


Figure 3.2 Building Model For Step Back Set Back Configuration On Sloping Ground (4 To 11)

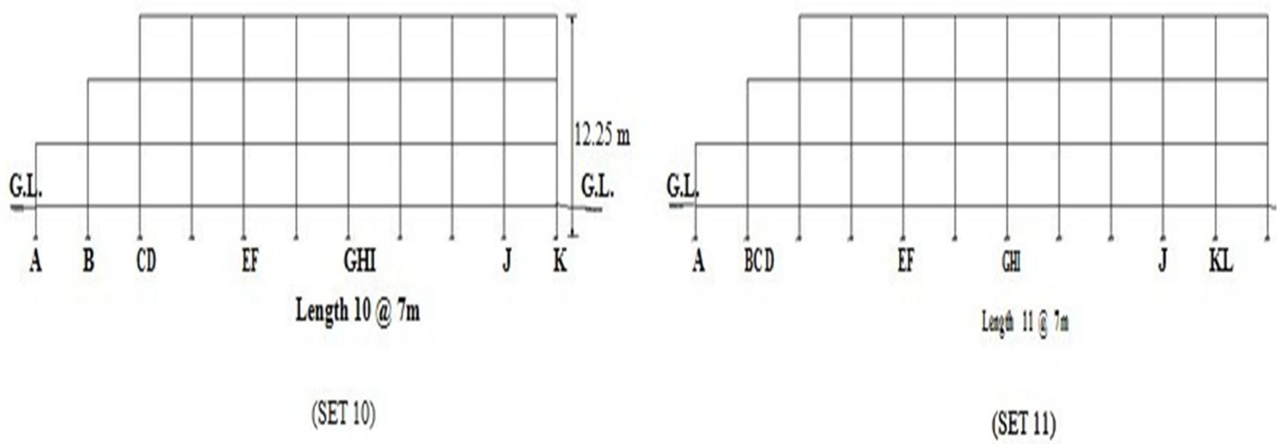


Figure 3.3: Building Model For Set Back Configuration On Plain Ground

B. Analysis Of Results

In all 24 building structures seismic analysis have been done with earthquake loads with an effect of accidental eccentricity. The seismic load was applied in X and Z direction means along the structures and across the structures applies independently. The important got results are described in the following sections.

1) *Step Back Building:* In this building configuration, total eight no. of structures models have been analysed with varying height 15.75 m to 40.25 m from 4 to 11 storeys. This building rests on 27 degree angle of ground slope.

a) *Case a: When earthquake force in X-direction (along the slope line):* The seismic response of each step back building in terms of natural time period, maximum top storey sway and base shear values in column base at ground level is presented in table4.1 (a). It was seen that there was linear increment in the top storey sway and time period value increases as the height of step building increases. Though the building structure configuration is regular along the slope line and in X direction torsion effect is insignificant due to accidental eccentricity. It is observed that in the extreme left column shear force is significant higher as comparison to rest of the column at ground level for different heights of building. Comparatively, extreme right and adjacent to it like frame D and frame C at ground level, shear force is very less, it is about 5 to 7% of the extreme left columns normalized shear force.

Table 4.1 (a): Dynamic Response Properties of STEP BACK Building due to Earthquake Force in X- Direction.

Designation	Storey no.	Storey height (m.)	Max.-displacement (mm)	Base shear force at ground level(kN)			
				Frame A	Frame B	Frame C	Frame D
Step 4	4	15.75	9.75	131.1	45.7	8.6	9.1
Step 5	5	19.25	19.86	175.5	58.1	11.3	10.9
Step 6	6	22.75	24.07	224.2	48.3	9.7	10.1
Step 7	7	26.25	31.45	247.9	51.9	10.5	10.5
Step 8	8	29.75	36.78	274.7	48.5	10.7	10.9
Step 9	9	33.25	44.54	287.9	52.5	11.3	12.5
Step 10	10	36.75	47.54	346.2	59.2	17.6	16.7
Step 11	11	40.25	57.05	360.3	61.0	15.4	15.5

b) *Case b: when earthquake force in Z – direction (across the slope line):* Table 4.1(b) shows the dynamic characteristics of each step back building structure for excitation in z direction. When earthquake force is in Z direction, the effect of static and accidental eccentricity is reduced.

Table 4.1(b): Seismic Response Properties of STEP BACK Building due to Earthquake Force in z- direction

Designation	Storey no.	Storey height (m.)	Max.-displacement (mm)	Base shear force at ground level(KN)			
				Frame A	Frame B	Frame C	Frame D
Step 4	4	15.75	44.29	64.7	52.1	21.4	30.6
Step 5	5	19.25	48.57	59.6	44.8	18.8	26.6
Step 6	6	22.75	50.87	71.5	48.3	17.3	22.5
Step 7	7	26.25	64.41	77.6	49.3	17.2	24.7
Step 8	8	29.75	57.92	82.2	49.8	13.3	22.4
Step 9	9	33.25	66.98	86.2	50.1	14.5	23.6
Step 10	10	36.75	74.99	101.2	51.8	13.4	17.7
Step 11	11	40.25	78.97	108.4	63.2	25.1	32.5

Torsion moment is maximum in Z – direction due to the effect of eccentricity generated, the normalized value of base shear force in extreme left column (frame A) at ground level is comparative less from the normalized value of base shear in X – direction. From design consideration special attention should be given to the size (strength) of the beam element, orientation of element (stiffness) and ductility and extreme left column at ground level should being safety condition under worst load combination in X and Z direction

2) *Step Back Set Back Building*

a) *Case (a) when Earthquake Force in X- direction (along the slope line)*

i) Frame A attracts maximum shear varying between the columns at extreme left

ii) The last two frames to the extreme right of the structures are subjected to least shear forces.

iii) Adjacent frames to extreme left (Frame B and onwards) attracts varying shear forces.

iv) Storey displacement also comes out to be very less and variation among the drift values is very less.

v) Its base shear values at extreme left column on upward hill side is comparative lesser to step back building.

vi) In this building configuration seismic activity is discontinuous in between so lesser base shear occurs.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Table 4.2 (a): Seismic Response Properties of STEP BACK SET BACK Building due to Earthquake Force in X- Direction.

Designation	Storey No.	Storey Height (m)	Max. Displacement (mm)	Base Shear Force at Ground Level (KN)							
				Frame A	Frame B	Frame C	Frame D	Frame I	Frame J	Frame K	Frame L
Step 4	4	15.75	3.59	86.26	50.74	29.06	6.52				
Step 5	5	19.25	3.93	93.93	63.67	54.61	29.97				
Step 6	6	22.75	4.15	98.1	67.0	74.36	57.20				
Step 7	7	26.25	4.12	96.92	62.97	75.94	76.65				
Step 8	8	29.75	4.20	99.07	62.48	76.32	87.45	6.95			
Step 9	9	33.25	4.25	100.9	61.45	72.99	88.54	8.04	8.25		
Step 10	10	36.75	4.45	102.6	58.93	71.87	87.95	27.70	7.12	5.26	
Step 11	11	40.25	4.29	103.8	54.47	66.88	81.43	56.15	25.13	5.47	6.71

b) *Case (b) when Earthquake Force in Z direction (across the slope line):* When seismic force is applied in Z direction, it is observed from table (b) that-

i) There is less significant variation of base shear force in all frames, in this configuration due to earthquake force X direction extreme left Frame A is not severely stressed including the lateral forces in Z direction cause in significant effect due to torsion.

ii) Results obtained from seismic analysis are dominant for design purpose against of results obtained from static analysis for the building structure of step back set back configuration having height 8 to 11 storey.

iii) The natural time period in Z direction by seismic analysis is not so much affected by the height of Step Back Set Back building structures whereas according to IS -1893 (PART 1) time period linearly varies with the height of building.

iv) It is perceived that in Step Back Set Back building structures, when earthquake force in X direction the required action force are dominant for design purpose.

v) The tope storey sway is lesser in X direction about 3.8 to 4 times comparatively Z direction values under dynamic forces.

vi) From design consideration , the uniform section having constant area of steel and constant area of concrete throughout from base level to top for extreme left column frame A, would be sufficient for fulfil the design purpose , requirements for heights of Step Back Set Back building structures considered . For the rest of the column similar trend is observed

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VI June 2020- Available at www.ijraset.com

Table 4.2(b): Seismic Response Properties of STEP BACK SET BACK Building due to Earthquake force in Z direction

Designation	Storey no.	Storey Height (m)	Max. Displacement (mm)	Base Shear Force at Ground Level (KN)							
				Frame A	Frame B	Frame C	Frame D	Frame I	Frame J	Frame K	Frame L
Step 4	4	15.75	13.41	43.14	40.85	36.00	14.09				
Step 5	5	19.25	15.52	35.31	41.15	38.45	32.02				
Step 6	6	22.75	13.62	31.29	36.85	37.84	32.0				
Step 7	7	26.25	12.61	22.95	22.80	31.19	29.85				
Step 8	8	29.75	13.42	21.59	25.56	28.68	29.45	11.50			
Step 9	9	33.25	13.32	19.96	23.89	27.08	28.32	8.29	12.38		
Step 10	10	36.75	12.45	18.92	24.31	27.48	27.96	18.92	16.39	7.93	
Step 11	11	40.25	13.50	18.24	27.29	26.96	26.24	24.1	15.59	8.90	11.12

3) *Set Back Building On Plain Ground:* For earthquake force in X as well as in Z directions Set back configurations of eight building structures on plain ground have been analyzed.

- The floor area of each set back building structures on flat terrain is same as that of the other configuration like Step Back and Step Back Set back building resting on sloping ground.
- Floor area of SET 4 =STEP 4 =STEPSET 4 and so on.
- This set back building configuration results intended to create a plain ground in a natural sloping ground terrain, extra cost will be added to make the plain level ground of sloped ground.
- In this present study of analysis only structural behaviour under the seismic forces has been carried without any emphasis in cost construction.

a) Case 3(a): when earthquake force is in X direction:

Table (a) shows the results obtained from seismic analysis of set-back building structures. It is to be noted that the peripheral frames (boundary surface) are found to carry lesser amount of shear force compared to interior frames.

Table (a): Seismic Response Properties of SET BACK Building due to Earthquake Force In X direction

Designation	Storey no.	Storey Height (m)	Max. Displacement (mm)	Base Shear Force at Ground Level (KN)							
				Frame A	Frame B	Frame C	Frame D	Frame I	Frame J	Frame K	Frame L
Step 4	4	15.7	12.46	27.02	40.73	40.11	41.58				
Step 5	5	19.2	13.41	28.44	44.20	43.71	43.60				
Step 6	6	22.5	13.62	30.20	45.29	44.80	44.71				
Step 7	7	26.2	14.47	35.31	47.34	47.82	45.72				
Step 8	8	29.7	14.86	33.33	49.88	49.35	49.25	35.64			
Step 9	9	33.2	15.13	36.05	52.95	50.43	51.32	52.01	36.39		
Step 10	10	36.5	15.33	33.35	51.85	51.31	51.31	51.31	52.31	36.97	
Step 11	11	40.25	15.47	35.09	54.43	51.89	52.89	53.89	51.89	53.89	35.57

b) *Case (b): when earthquake force in Z direction:* Due to action of earthquake forces in Z direction, it is observed that base shear in columns at base levels for different frames in Set back configuration is more or less same.

i) The natural time period is constant for all the Set Back building structures as predicted by IS : 1893 (Part 1) where prediction using response spectrum analysis (RSA) are found to achieve higher value of time period.

ii) The top storey sway in X direction is 3.5 times lesser than the values obtained from Z direction.

iii) The value of base shear is comparatively much higher i.e. about 2.835 to 3.025.

iv) These values of base shear ratio shows that in Set backing every building structures, the design of column is mainly influenced by action forces induced in Z directions.

v) Set back building structure configuration is suitable if making the hilly terrain to flat ground economical.

Table 4.3 (b): Seismic Response Properties of SET BACK Building due to Earthquake Force In Z direction

Designation	Storey no.	Storey Height (m)	Max. Displacement (mm)	Base shear Force at Ground Level (KN)							
				Frame A	Frame B	Frame C	Frame D	Frame I	Frame J	Frame K	Frame L
Step 4	4	15.75	41.94	44.37	42.30	41.60	41.33				
Step 5	5	19.25	39.44	43.75	41.69	42.80	42.89				
Step 6	6	22.75	46.68	49.49	47.45	44.83	43.84				
Step 7	7	26.25	47.68	51.26	49.30	46.48	48.17				
Step 8	8	29.75	51.17	55.05	58.30	51.55	50.16	68.20			
Step 9	9	33.25	41.76	55.85	53.62	52.85	51.17	58.85	62.19		
Step 10	10	36.75	52.24	59.47	58.80	55.90	54.23	63.89	68.00	72.30	
Step 11	11	40.25	54.01	60.85	59.85	57.55	55.38	60.12	64.28	64.50	72.43

IV. CONCLUSIONS

The conclusions are made up of the above observations as follows:

A. The performance of STEP BACK building configuration during earthquake excitations could prove more vulnerable than other configuration like Step Back Set Back and Set Back building structures.

B. Step Back Set back building Structures are found to be less susceptible than Step Back building against seismic ground motions.

C. Although the Set Back configuration resting on flat ground attracts lesser base shear action compared to step back set back configuration overall economical cost involved to level the sloping ground and other related issue with this can be study well.

D. As angle of ground increases top storey displacement decreases.

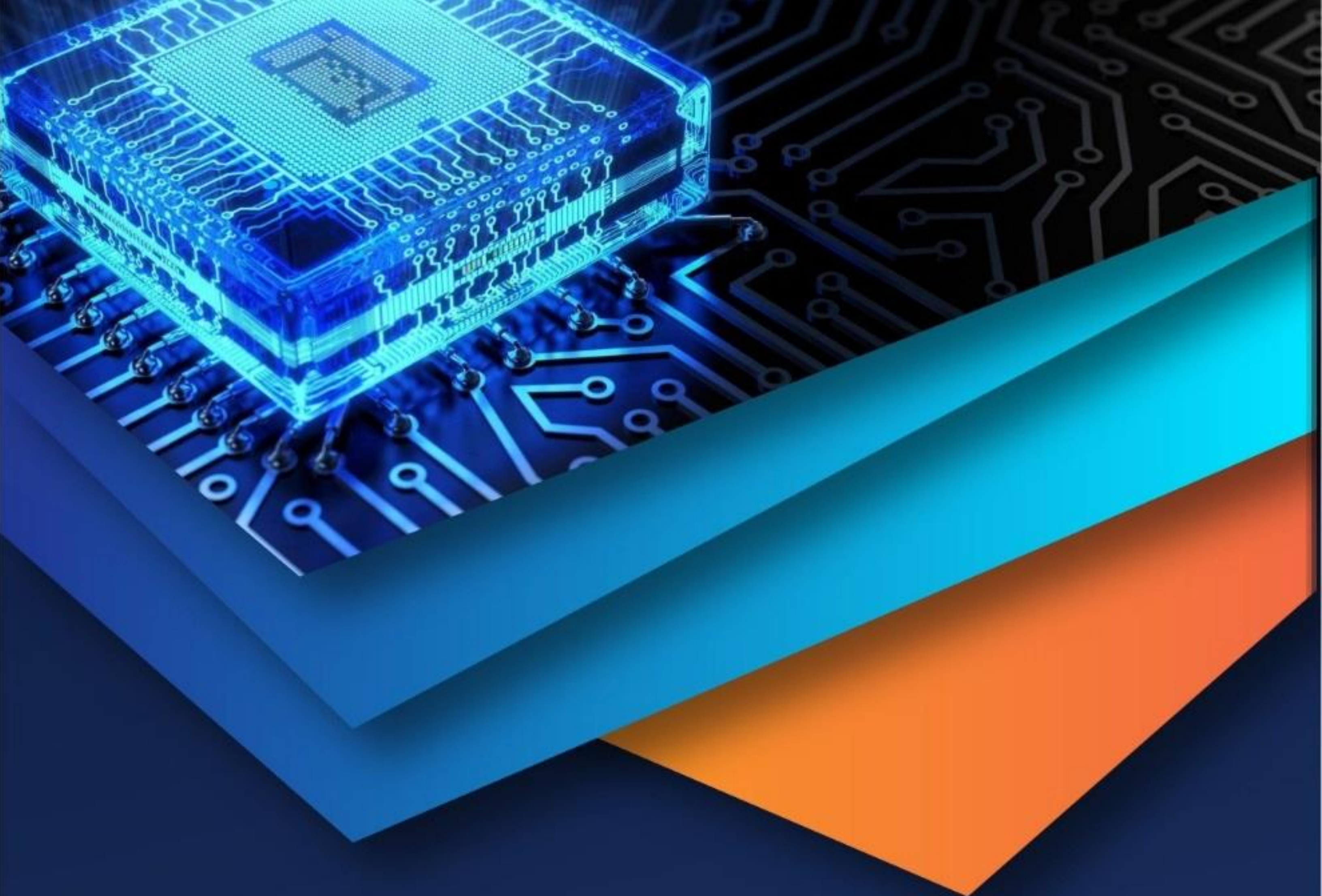
E. Top storey sway decreases as number of bays increases therefore it's confirmed that greater number of bays are observed to be better under seismic conditions.

V. ACKNOWLEDGMENT

I express my deep gratitude to Mr. Vishal Sapate, Professor of Civil Department (structure), GHRU University Amravati guide for the initiative, motivation, and guidance provided during the course of this work.

REFERENCES

[1] BirajdarBG, Nalawade SS (2004) Seismic analysis of buildings resting on sloping ground. In: 13th world conference on earthquake engineering, Vancouver, B.C., Canada, paper no. 1472.
[2] A.G.Sawant1 , Y. M. Ghugal , 'seismic Analysis Of Buildings Resting On Sloping Ground " (ijarse2018)
[3] B.Arif Basha1 , ABS Dada Peer2 Seismic Analysis of Buildings Resting on Sloping Ground and Considering Bracing System (IJSETR2016)
[4] Rajkumar Vishwakarma1, Anubhav Rai2 ,Analysis of a RCC frame Tall Structure using Staad Pro on Different Seismic Zone Considering Ground Slopes (IRJET) 2017
[5] Karan Singh, Manish Kumain, Jaibeer Chand, Dynamic Analysis Of Buildings On Slope: A REVIEW (IJRTM2018)
[6] Likhitharadhya Y R1, Praveen J V2, Sanjith J3, Ranjith A on Seismic Analysis of Multi-Storey Building Resting On Flat Ground and Sloping Ground (IJIRSET2016)



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY