International Research Journal of Education and Technology
ISSN 2581-7795

Seismic Analysis of 3D Building RC Framed Resting on Varying Hill Slopes

Mithun K Sawant[1], Asmita Patel[2], Mariyam K[3] , Renuka Wagh[4]

[1]*Assistant Professor, Department of Civil Engineering, DYPIEMR, Akudi, Pune*
[2,3,4]*UG Student, Department of Civil Engineering, DYPIEMR, Akudi, Pune*

Abstract - *India is one of the world's most vulnerable countries to natural disasters. There are a plethora of studies being conducted. The major goal of this research is to conduct a seismic examination of buildings on various hill slopes from various perspectives. The examination of G+5 structures on varied hill slope angles comprises 0°.10° and 15°, respectively, in the current study. IS 1893-2016 is used to calculate seismic forces. With a damping ratio of 5%, the structure is considered to be positioned in seismic zone IV. Equivalent static analysis was used to accomplish seismic analysis. To investigate the effect of varying column height in ground storey due to sloping ground, a 3D analytical model of buildings was created and analysed using STAAD PRO.*

Key Words: Seismic analysis, 3D, STAAD PRO.

1. INTRODUCTION

Because the columns of the building sit at different levels on the slope, the analysis of buildings in hilly regions differs from that of buildings on flat ground. Because the mass and stiffness of such structures vary in the vertical and horizontal planes, the centre of mass and rigidity do not coincide on different floors, torsional analysis is required in addition to structural analysis of lateral forces under the earthquake action. Unsymmetrical structures necessitate careful analysis and design when subjected to earthquakes. Buildings on sloping land have been severely damaged in previous earthquakes.

During an earthquake, structural failure begins at weak places. The discontinuity in mass, stiffness, and shape of the structure causes this weakness. Irregular structures are constructions that have this form of discontinuity. Irregular structures make up a significant part of urban infrastructure. One of the most common causes of structural failure during earthquakes is vertical abnormalities. Structures with a soft storey, for example, were the most likely to collapse. As a result, the impact of vertical abnormalities on structural seismic activity becomes critical. Seismic analysis is a sort of structural analysis that examines a building's response to a natural disaster in the event of an earthquake It is a part of the structural design process, earthquake engineering, or structural engineering, and it is used in areas where earthquakes occur frequently. A collection of forces acting on a building to manifest the influence of seismic motion is used in this method. The building must be low-rise building and should not twist when the ground moves.

Throughout this phase, the structure's genuine performance is tested to ensure that it meets all of the standards for collapse prevention under the most severe possible earthquake.

2. LITERATURE REVIEW

Birajdar and Nalawade (2004) investigated the unsteady behaviour of structures perched on a hillside. They looked examined twenty-four RC building frames in three different configurations: step back building, step back building with a twenty-seven-degree slope, and step back building with a Horizontal slope. They looked at structures with varying storey heights ranging from four to eleven (15.75m to 40.2m). It has three bays on the slope and one bay across the hill, and it is located in unstable zone III.

Rayyan-Ul Hassan and H. S. Vidyadhara (2013) investigated the effects of earthquakes on six different models resting on flat and sloping ground: clean frame model, building with initial soft floor and different floors with brick infill wall, building with initial soft storey and different storeys with brick infill wall, and building with initial soft storey and different storeys with brick infill and additionally supplied with shear wall at corners. The number of bays in the horizontal direction was unbroken four, each with twelve floors, and each structure was located in seismal zone V.

Ravikumar C. M et al. (2012) investigated the seismic performance of RC buildings, focusing on vertically irregular buildings resting on flat ground and buildings resting on slopes, with two types of configurations considered: buildings resting on diagonal ground in the X-direction and buildings resting on diagonal ground in the Y-direction. The number of bays in the X and Y directions, respectively, were unbroken five and four, with three floors and set in severe zone V. The performance of those buildings was investigated using linear analysis and the IS 1893 (part-1) 2002 code. Buildings on sloping terrain are more vulnerable to earthquakes than buildings on flat ground.

Sunilsingh Rawat (2015) In his research, he looked at G+3 and G+4 structures with different slope angles, such as 0°, 7.5°, 15°, 22.5°, and 30°. Both types of building configurations have been explored (step back and step back setback). The earthquake forces are calculated according to IS: 18932002. The structures are classified as seismic zone IV, with a damping ratio of 5%. Linear Static and Linear Dynamic methods were used to conduct

the seismic study. To investigate the influence of shifting column heights in the ground level due to sloping ground, a 3D analytical model of buildings was created and studied using the structural analysis application "STAAD.Pro he response parameters include base shear, top storey displacement, shear in the bottom storey column, and time period. The impacts of diverse sloping ground were rigorously examined in order to quantify them. It has been discovered that short columns on the higher side of the slope are subjected to a greater shear force than longer columns on the lower side. Under earthquake stresses, step back setback structures performed better than step back buildings. Step back setback buildings have substantially lower base shear and top floor displacement than setback buildings on sloping land.

Babu et al. (2012): Seismic analysis of several symmetric and asymmetric structures erected on flat and inclining ground was carried out in this study. They led research using structures with a variety of settings, including plan symmetry and asymmetry, as well as diverse seismic zones. They considered a G+4 construction, which has one floor above ground level and is built at a 30 degree slant. They discovered that the short column was subjected to the highest level of harshness and was beyond repair.

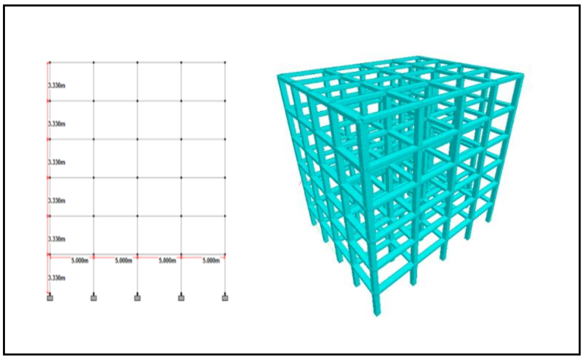
Achin Jain, Rakesh Patel (2017): The seismic behaviour of multi-story buildings on sloping terrain is investigated in this work, taking into account soil-structure interaction. On different slope angles, the study of a G+4 storey RCC building. The analysis of structures resting on sloping land for different soil conditions such as Soft Clay, Hard Clay, Dense Sand, and Rock is also included in this article. The structure's maximum top storey displacement was calculated using equivalent static analysis for soft clay, dense sand, hard clay, and rock.

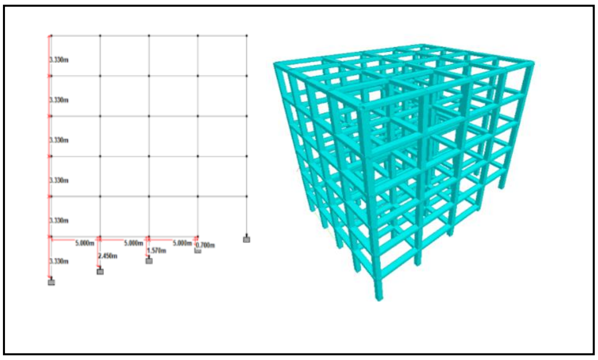
Narayan Kalsulkar, Satish Rathod (2015): The response spectrum method is used to investigate the sort of construction that rests on sloping terrain in this study. Building frames found in hilly areas have been condensed down to two basic formats: step back frames and step back-set back frames, and dynamic responses for various building configurations have been examined. They've also stated that step back frames' performance during seismic excitation may be more vulnerable than other building frame configurations, hence step back-set back frames are preferable to step back frames. Time duration and top storey displacement decrease as the number of bays increases. As a result, they came to the conclusion that in seismic conditions, having a larger number of bays is beneficial.

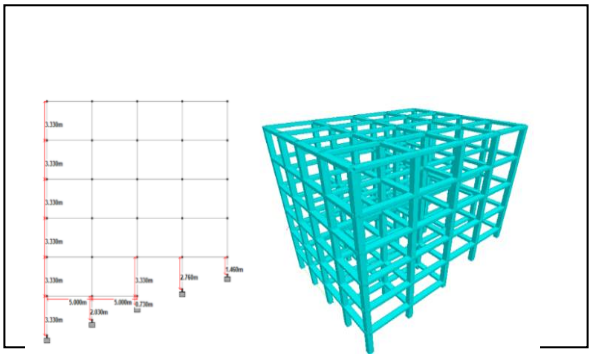
3. Analytical Study

Angle of ground slope = 0°,10° and 15°.
Number of bays in X direction=4
Number of bays in Z direction=4
Bay width in X direction=5 m
Bay width in Z direction=4 m
Storey height=3.33 m
Size of beams =0.3m× 0.6m
Size of columns =0.5m× 0.5m
Slab thickness=150 mm
Exterior masonry wall thickness=200 mm
Interior masonry wall thickness=100 mm
Type of supports=Fixed
Grade of concrete= M25
Grade of steel reinforcement= Fe415
Density of brick masonry= 25 kN/m3
Elasticity of concrete = 2.5×104 N/mm2
Live load on floor = 4 kN/m2
Live
load on roof = 1.5 kN/m2
Dead load = 4.5 kN/m2
Type of structure= Special Momemt Resisting Frame
Seismic zone= IV
Response reduction factor= 5
Importance factor= 1.2
Damping= 5%Soil type= medium soil

Figure 1 model for 0°
Figure 2 model for 10°
Figure 3 model for 15°







4. RESULTS AND DISCUSSION

4.1. Manual Time period and Base shear calculations:

Fundamental time period of building, T= 0.075h0.75

4.1.1. Base shear calculations of 0° model building

Height of building, h= 19.98 m
∴ Time Period T= 0.075×19.980.75
= 0.77 sec
∴ Response acceleration coefficient,
Sa/g = 1.943
∴ Self weight of slab= 20 x 16 x 0.15 x 25

= 1200 KN

Self-weight of beam = Area x length x Density x no. of beams =0.3x0.6x5x25x40 =900 KN

Self-weight of column= Area x height x Density x no. of columns = 0.5x0.5x3.33x25x25 =520.31 KN

Dead load on roof slab = 2360.155 KN
Dead load on each floor= 2620.31 KN
Live load on roof slab= 120 KN
Live load on each floor=320 KN
Seismic weight of each floor= 2940.31 KN
Seismic weight of roof slab=2480.155
W= 2940.31 + 2940.31 + 2940.31 + 2940.31 + 2940.31 + 2480.155 = 17181.705
Base shear VB= Ah* w
Ah= (Z*I*Sa)/(2R*g) = 0.05
∴Vb= 0.05*17181.705 = 859.08 KN

4.1.2. Base shear calculations of 10° model building

Height of building, h= 19.98 m
∴ Time Period T= 0.075×19.980.75
= 0.77 sec
∴ Response acceleration coefficient,
Sa/g = 1.943
Self-weight of slab = Area x thickness x Density
∴ Self weight of slab= 20 x 16 x 0.15 x 25 = 1200 KN
Self-weight of beam = Area x length x Density x no. of beams =697.5 KN

Self-weight of column= Area x height x Density x no. of columns = 0.5x0.5x3.33x25x20 =416.25KN

Dead load on roof slab = 2105.625 KN
Dead load on each floor= 2313.75 KN
Live load on roof slab= 120 KN
Live load on each floor=320 KN
Seismic weight of each floor= 2633.75 KN
Seismic weight of roof slab=2225.625 KN
W= 2633.75 + 2633.75 + 2633.75 + 2633.75 + 2633.75 + 2225.625
= 15394.375
Base shear VB= Ah* w
Ah= (Z*I*Sa)/(2R*g) = 0.05
∴Vb= 0.05*15394.374 = 790.71 KN

4.1.3. Base shear calculations of 15° model building

Height of building, h= 19.98 m
∴ Time Period T= 0.075×19.980.75
= 0.77 sec
∴ Response acceleration coefficient,
Sa/g = 1.943
Self-weight of slab = Area x thickness x Density
∴ Self weight of slab= 20 x 16 x 0.15 x 25
= 1200 KN
Self-weight of beam = Area x length x Density x no. of beams
=495 KN

Self-weight of column= Area x height x Density x no. of columns
= 0.5x0.5x3.33x25x15
=312.18 KN
Dead load on roof slab = 1900 KN
Dead load on each floor= 2007.19 KN
Live load on roof slab= 120 KN
Live load on each floor=320 KN
Seismic weight of each floor= 2327.18 KN
Seismic weight of roof slab=2020 KN
W= 2327.18 + 2327.18 + 2327.18 + 2327.18 + 2327.18 + 2020 = 14000
Base shear VB= Ah* w
Ah= (Z*I*Sa)/(2R*g) = 0.05
∴Vb= 0.05*14000 = 700 KN

4.2. Base shear values given by STAAD Pro for different sloping conditions

Slope of the building (degree)	Base shear V_b (kN)
0°	868.41
10°	830.36
15°	792.31

Table 1: Slope and Base Shear

```
************************************************************
*                                                          *
* TIME PERIOD FOR X 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     15520.00=     868.41 KN    *
*                                                          *
************************************************************
```

```
************************************************************
*                                                          *
* TIME PERIOD FOR Z 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     15520.00=     868.41 KN    *
*                                                          *
************************************************************
```

Figure 4 model for 0°

```
************************************************************
*                                                          *
* TIME PERIOD FOR X 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     14160.00=     792.31 KN    *
*                                                          *
************************************************************
```

```
************************************************************
*                                                          *
* TIME PERIOD FOR Z 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     14160.00=     792.31 KN    *
*                                                          *
************************************************************
```

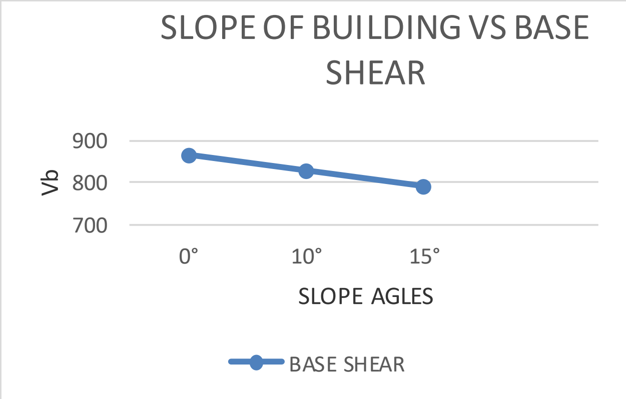
Figure 5 model for 10°

```
************************************************************
*                                                          *
* TIME PERIOD FOR X 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     14840.00=     830.36 KN    *
*                                                          *
************************************************************
```

```
************************************************************
*                                                          *
* TIME PERIOD FOR Z 1893 LOADING =     0.70000 SEC         *
* SA/G PER 1893=     1.943, LOAD FACTOR= 1.000             *
* VB PER 1893=     0.0560 X     14840.00=     830.36 KN    *
*                                                          *
************************************************************
```

Figure 6 model for 15°

International Research Journal of Education and Technology
ISSN 2581-7795



Graph 1 Base Shear and Various Slopes

4.3. Distribution of lateral loads and base shear

Storey	Wi(KN)	hi (m)	Wi hi² x 10³	Qi (KN)	V_b (KN)
6	2480.155	19.98	990	305.57	305.57
5	2940.31	16.65	815.12	251.59	557.16
4	2940.31	13.32	521.67	161.01	718.17
3	2940.31	9.99	293.443	90.57	808.74
2	2940.31	6.66	130.419	40.25	848.99
1	2940.31	3.33	32.604	10.06	859.08
			2783.25	859.08	

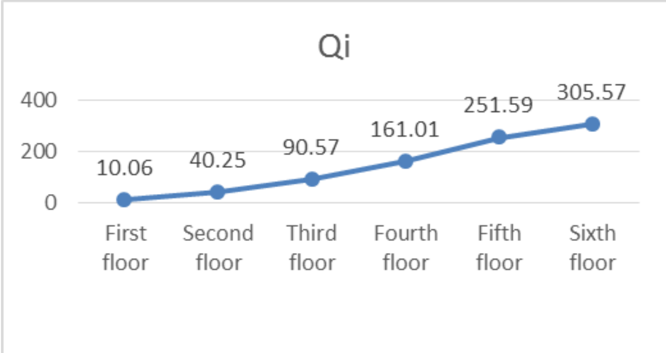
Table 2 Distribution for 0°

Storey	Wi(KN)	hi (m)	Wi hi² x 10³	Qi (KN)	V_b (KN)
6	2225.62	19.98	888.46	282.16	282.16
5	2633.75	16.65	730.134	231.88	514.04
4	2633.75	13.32	462.286	146.81	660.85
3	2633.75	9.99	262.848	83.47	744.32
2	2633.75	6.66	116.821	37.11	781.43
1	2633.75	3.33	29.205	9.27	790.71
			2489.754	790.71	

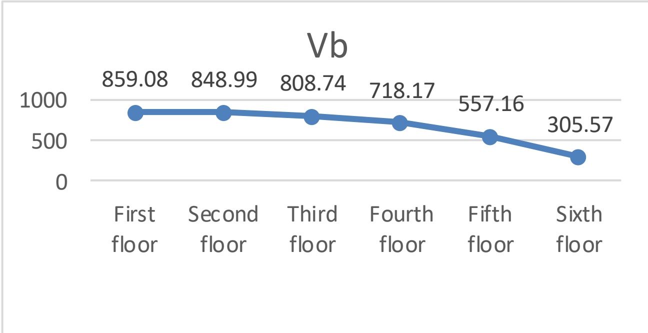
Table 3 Distribution for 10°

Storey	Wi(KN)	hi (m)	Wi hi² x 10³	Qi (KN)	V_b (KN)
6	2020	19.98	806.384	252.59	252.59
5	2327.18	16.65	654.146	204.90	457.49
4	2327.18	13.32	412.893	129.33	586.82
3	2327.18	9.99	232.252	72.75	659.57
2	2327.18	6.66	103.223	32.33	691.9
1	2327.18	3.33	25.805	8.08	700
			2234.703	700	

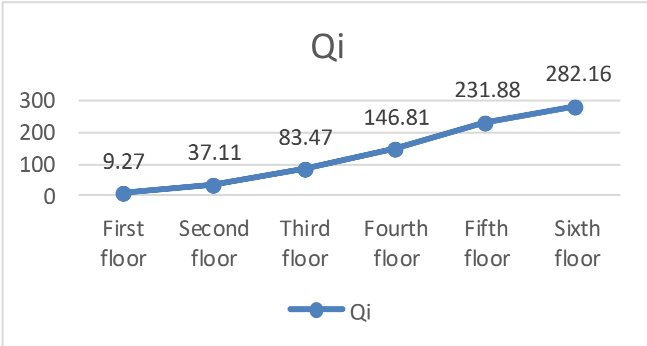
Table 4 Distribution for 15°



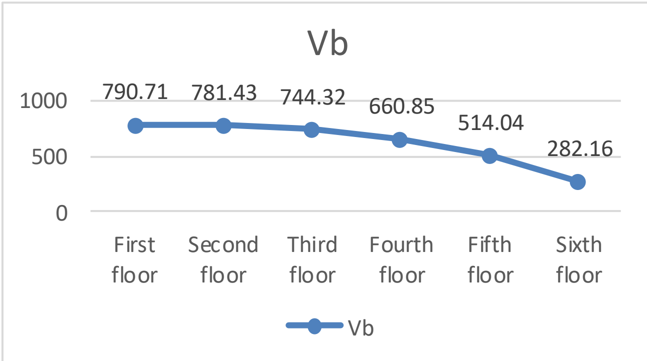
Graph 2 Lateral Loads for each floor (0 Degree)



Graph 3 Base Shear For Each Floor (0 Degree)

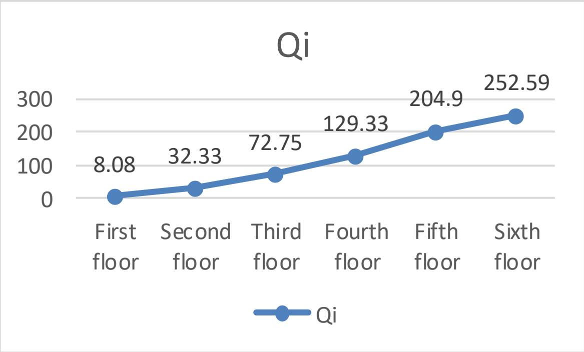


Graph 4 Lateral loads For Each Floor (10 Degree)

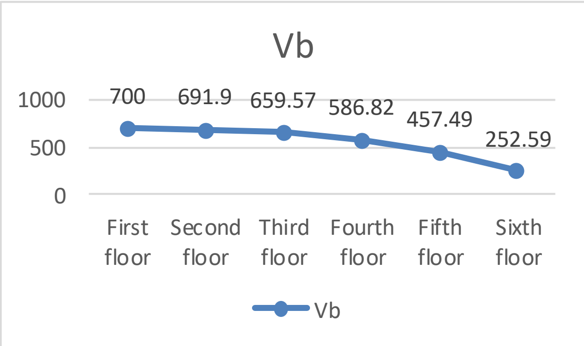


Graph 5 Base Shear For Each Floor (10 Degree)

International Research Journal of Education and Technology
ISSN 2581-7795



Graph 6 Lateral loads For Each Floor (15 Degree)



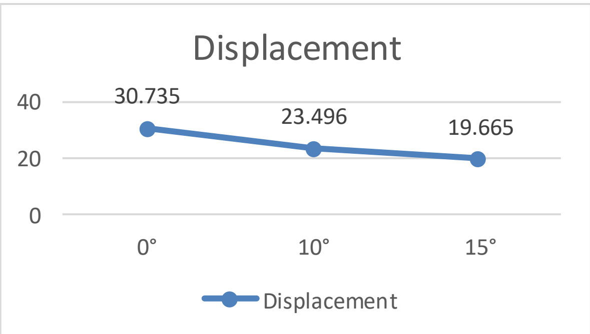
Graph 7 Base Shear For Each Floor (10 Degree)

4.4. Displacement

Allowable displacement = H / 500
Height of building = 19.98 m
Displacement =19.98/500 = 39.96 mm

Slope of building (degree)	Displacement (mm)
0°	30.375
10°	23.496
15°	19.665

Table 5: Slope and Displacement



Graph 8 Displacement For Various Slopes

5. CONCLUSION

Since plain ground is scarce, the majority of structures are built on hill slopes with irregular structural configurations and foundations at various levels. When these structures are subjected to lateral loads, they typically exhibit strong torsional reaction. Buildings lying on varying slopes are subjected to seismic examination. It's primarily due to column loading differences and the mixture of short and long columns. The most significant component in constructing earthquake-resistant constructions is base shear. As the slope of the hill increases, the value of base shear falls. The lareral loads grow as the storey height increases, but the base shear decreases. However, at a 0° slope, displacement is greatest. The value of displacement falls after that due to the decrease in the number of bays and the length of the column. As a result, shear walls and retaining walls can be used to reduce seismic forces on mountainous slopes.

REFERENCES

[1] Birajdar.B.G and Nalwade S.S, - Seismic Analysis of Hill Buildings Resting On Sloping Ground, 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, 2004, pp. 1472

[2] Rayyan- Hasan Siddiquiand H.S.Vidyadhara , - Seismic Analysis of Earthquake Resistant Multi Bay Multi Storeyed 3D -RC Frame, International Journal of Engineering Research & Technology (IJERT), 2013 ISSN: 2278-0181 Vol. 2 Issue 10.

[3] Ravikumar C M and Babu Narayan K S, - Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings, Architecture Research, 2012.

[4] Sunil singh rawat Behaviour of RCC buildings on hill slopes under seismic loads - 2015 Sunil singh rawat

[5] Achin Jain andDr.Rakesh Patel, - Analysis of building constructed on sloping groundfor different types of soil,International Journal For Technological Research In Engineering, 2017, Volume 4, Issue 12

[6] Agarwal P. and Shrikhande M. (2006), "Earthquake resistant design ofstructures", Prentice- Hall of India Private Limited, New Delhi, India.

[7] Annigeri Satish and Jain Ashok K, - Torsional provisions for asymmetrical multistorey buildings in IS: 1893, International journal ofstructures, Paper No.139, vol. 14 No. 2, 1994,pp. 115-142.

[8] I.S. 456-1993, Indian standard code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian standards, New Delhi.

[9] I.S. 1893(Part 1)-2002, Criteria for earthquake resistant design of structure, general provision and building, Bureau of Indian standards, New Delhi.