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ANALYSIS OF 3D RC FRAME ON SLOPING GROUND

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Abstract: *The buildings resting on hill areas have to be configured differently from flat ground. Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled & hence susceptible to sever damage when affected by earthquake. The floors of such buildings have step back towards the hill slope and at the same time set-back also. In this study 3D analytical model of G+10 storied building have been generated for symmetric and asymmetric case. Building models are analyzed and designed by finite element software SAP2000 V19 to study the effect of influence of shear wall at different positions and results are compared with respect to storey displacement, time period and base shear. Seismic analysis done by linear static analysis and linear dynamic analysis. Results indicate that model Step Back Set Back on Sloping ground is the most preferred configuration in hilly regions.*

Keywords: *Earthquake, Sloping Ground, SAP2000, Lateral Storey Displacement, Time Period and Base Shear.*

1. INTRODUCTION

Now a day, rapid construction is taking place in hilly areas due to scarcity of plain ground. As a result the hilly areas have marked effect on the buildings in terms of style, material and method of construction leading to popularity of multi-storied structures in hilly regions. Due to sloping profile, the various levels of such structures step back towards the hill slope and may also have setback also at the same time. The step-back structures usually have the number of storey's decreasing successively at the bottom in each bay, in the direction of the slope maintaining same roof level, whereas setback-step-back buildings do not have same roof level. These structures become highly uneven and asymmetric, due to variation in mass and stiffness distributions on different vertical axis at each floor. Such construction in earthquake prone areas makes them to attract greater shear forces and torsion compared to normal construction.

Multi-storied buildings on sloping ground are infrequent over level grounds whereas on hilly slopes these are quite common. Disaster due to Earthquake has always been one of the greatest natural calamities thrust upon the mankind since time immemorial and bringing in its wake untold miseries and hardships to the people affected. The economic growth & rapid urbanization in sloping region has accelerated the real estate development .due to this population density in hilly region has increased enormously. Therefore there is popular & pressing demand for the construction of multi-storied on sloping ground in around the cities.

1.1 Shear Wall

The usefulness of the shear wall in structural planning of multistory building has long been recognized. When walls are situated in the advantageous position in a building ,they can very efficient in resisting lateral load on building , if not the whole amount & the horizontal shear force originated from the load , are offend assign to such structural elements ,they have been called shear wall. The uses of shear walls or their equivalent become impressive in certain high rise structure if inter story deflections, caused by lateral loading are to be controlled. Well design shear walls in seismic areas have a very good performance.

Shear wall in high-rise structure resist the major portion of large lateral forces caused due to wind or earthquake. Use of shear walls becomes a necessity for speedier construction and superior quality control. .In the analysis of the shear wall, both bending and shear deformation are significant and may have to be included.

2. MODEL DESCRIPTION

Basically model consists of 3 bays X Direction at columns spacing at 7m c/c and 5 Bays along Y direction at 5m c/c and in Z direction 12 bays (G+10) at 3.5 mtr c/c. The depth of footing below ground level is taken as 1.50m below ground level. Beam size is of 0.30mX0.60m and Column size is of 0.60mX0.45m. Slab Thickness is of 0.15m. Degree of Slope considered is 27^0 with respect to horizontal Ground Level, Thickness of Shear Wall 0.23m, The models are analyzed on sloping ground as well as level ground.

2.1 Models under Study

2.1.1 Set 1: Building on Plane Ground with Fixed Base Condition

- Model 1(M1): Building Modeled as Bare Frame. However masses of the wall are included with Fixed Base Foundation. Fig:1.
- Model 2(M2): Building Model has Shear wall (Core Wall) at Center of building in all four Directions with Fixed Base Foundation. Fig:2.
- Model 3(M3): Building Model has L Shape Shear wall at Corner of building in all four Directions with Fixed Base Foundation. Fig:3

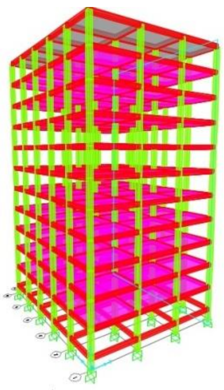


Fig:1

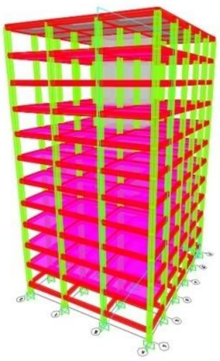


Fig:2

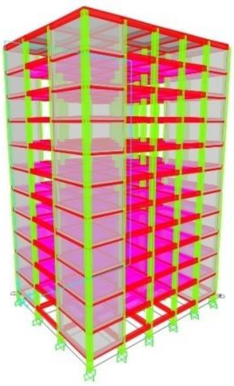


Fig:3

Set 2: Step Back Building on Sloping Ground with Fixed Base Condition.

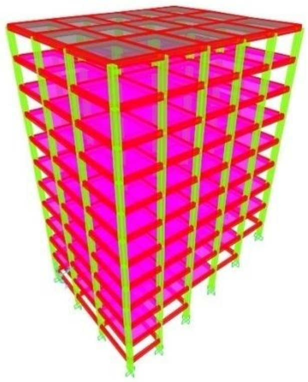


Fig:4

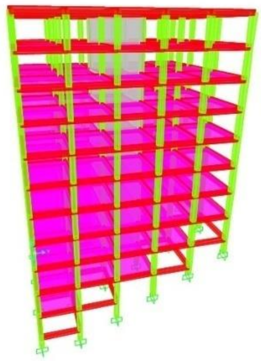


Fig:5

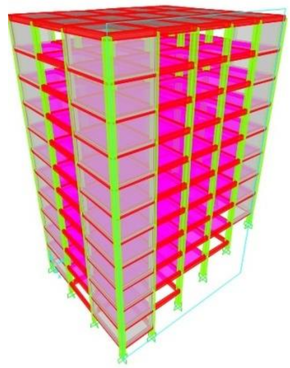


Fig:6

- Model 4(M4): Step Back Building Modeled as Bare Frame. However masses of the wall are included with Fixed Base Foundation. Fig:4.
- Model 5(M5): Step Back Building Model has Shear wall (Core Wall) at Center of building in all four Directions with Fixed Base Foundation. Fig:5.
- Model 6(M6): Step Back Building Model has L Shape Shear wall at Corner of building in all four Directions with Fixed Base Foundation. Fig:6

2.1.2 Set 3: Step Back Building on Sloping Ground with Fixed Base Condition.

Fig:7

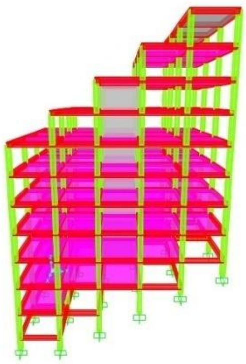


Fig:8

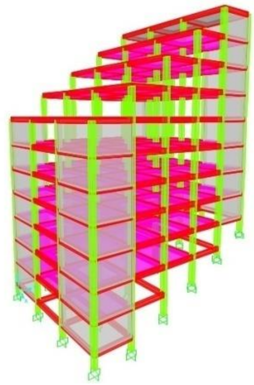


Fig:9

- Model 7(M7): Step Back – Set Back Building Modeled as Bare Frame. However masses of the wall are included with Fixed Base Foundation. Fig:7
- Model 8(M8): Step Back – Set Back Building Model has Shear wall (Core Wall) at Center of building in all four Directions with Fixed Base Foundation. Fig:8.
- Model 9(M9): Step Back – Set Back Building Model has L Shape Shear wall at Corner of building in all four Directions with Fixed Base Foundation. Fig:9

3. RESULTS AND DISCUSSION

3.1 Lateral Displacement

The Maximum displacement at each floor level with respect to ground are shown in Table:1 to 3 for better compatibility the displacement for each model along both direction of ground motion are plotted in graphs as shown from Fig 10 to 15

Table: 1 Lateral Displacement in mm for Set: 1(Plane Ground)

Storey No.	Displacement Along Longitudinal (X) Direction			Displacement Along Transverse (Y) Direction		
	M1	**M2**	**M3**	**M1**	**M2**	**M3**
1	2.76	1.44	1.13	2.76	1.61	1.39
2	5.90	2.61	1.89	5.64	2.97	2.45
3	9.16	3.93	2.83	8.57	4.53	3.74
4	12.41	5.43	3.92	11.47	6.26	5.18
5	15.56	7.06	5.12	14.28	8.11	6.74
6	18.55	8.78	6.41	16.95	10.02	8.37
7	21.28	10.54	7.75	19.41	11.96	10.04
8	23.69	12.32	9.11	21.58	13.89	11.72
9	25.68	14.08	10.47	23.39	15.77	13.37
10	27.15	15.81	11.81	24.72	17.59	14.97
11	28.09	17.40	13.13	25.54	19.26	16.54

Fig: 10 Displacement along Longitudinal X Direction for Set: 1(Plane Ground)

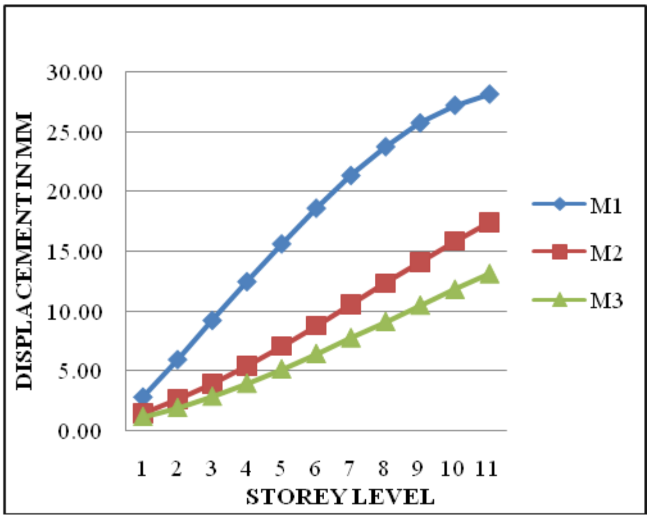


Fig: 11 Displacements along Transverse Y Direction for Set: 1(Plane Ground)

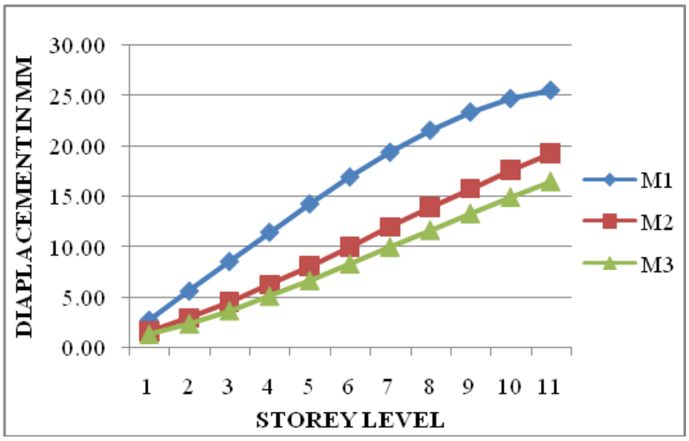


Table: 2 Lateral Displacement in mm for Set: 2(Step Back Building)

Storey No.	Displacement Along Longitudinal (X) Direction			Displacement Along Transverse (Y) Direction		
	M4	**M5**	**M6**	**M4**	**M5**	**M6**
1	0.85	1.27	0.93	0.01	0.15	0.30
2	2.24	2.66	1.61	0.32	0.63	0.94
3	4.78	4.00	2.50	1.83	1.85	1.93
4	7.98	5.37	3.55	4.73	3.41	3.16
5	11.21	6.72	4.73	7.83	5.09	4.55
6	14.30	8.17	6.00	10.78	6.86	6.05
7	17.15	9.67	7.34	13.51	8.67	7.63
8	19.66	11.19	8.71	15.91	10.48	9.23
9	21.72	12.70	10.08	17.89	12.25	10.83
10	23.24	14.18	11.43	19.35	13.97	12.38
11	24.18	15.54	12.75	20.22	14.54	13.89

Fig: 12 Displacements along Longitudinal X Direction for Set: 2(Step Back Building)

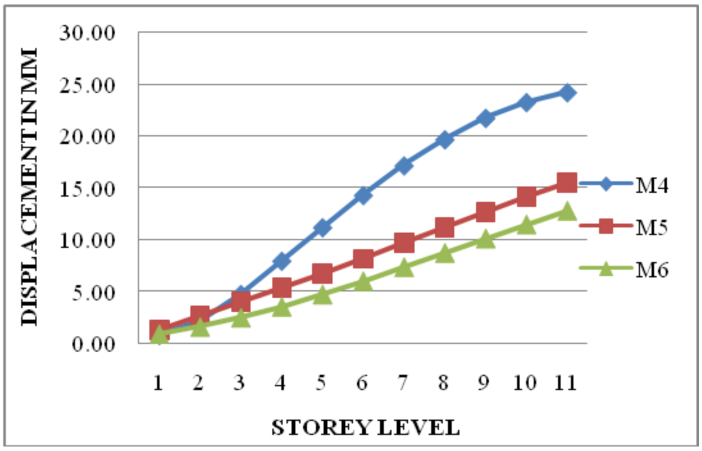


Fig: 13 Displacements along Transverse Y Direction for Set: 2(Step Back Building)

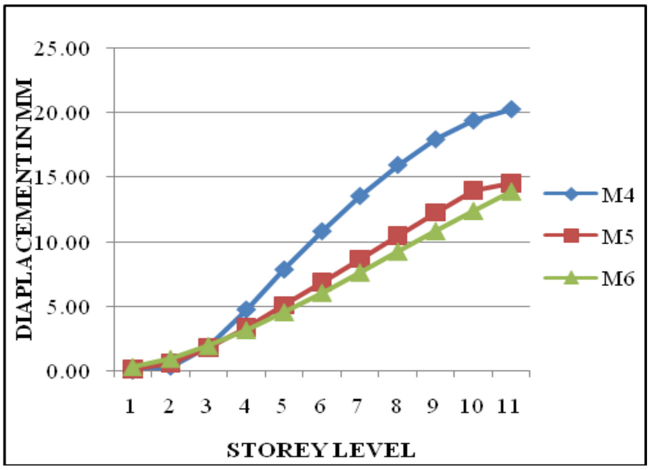


Table: 3 Lateral Displacement in mm for Set: 3(Step Back-Set Back Building)

Storey No.	Displacement Along Longitudinal (X) Direction			Displacement Along Transverse (Y) Direction		
	M7	M8	M9	M7	M8	M9
1	0.74	1.09	0.72	0.02	0.17	0.33
2	1.89	2.23	1.23	0.33	0.65	0.94
3	3.85	3.21	1.88	1.84	1.84	1.89
4	6.17	4.13	2.64	4.70	3.36	3.06
5	8.37	4.99	3.49	7.68	4.97	4.35
6	10.31	5.93	4.38	10.41	6.67	5.73
7	11.89	6.88	5.28	12.76	8.35	7.10
8	14.52	8.53	7.67	14.85	10.05	8.90
9	17.39	10.43	9.38	16.71	11.76	10.55
10	20.25	12.52	10.62	18.25	13.65	12.15
11	22.78	14.86	11.45	19.38	15.07	13.76

Fig: 14 Displacements along Longitudinal X Direction for Set: 3(Step Back Building)

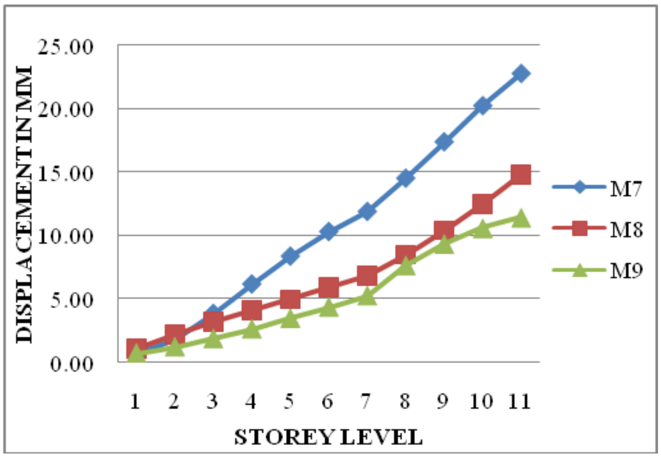
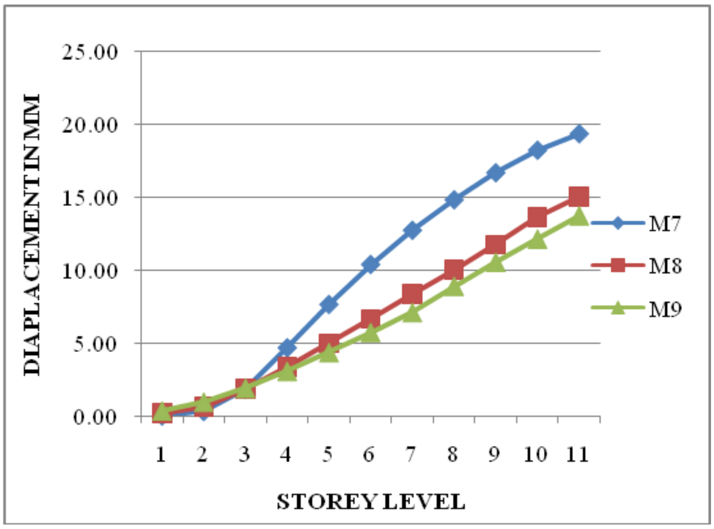


Fig: 15 Displacements along Transverse Y Direction for Set: 3(Step Back-Set Back Building)



Set 1: Building on Plane Ground.

It has been found from Table 1, that a buildings resting on Plane Ground M-2, M-3 has 38.05% & 53.25% respectively less displacement compared to M-1 in Longitudinal direction & in Transverse direction M-2, M-3 has 24.58% & 35.25% respectively less displacement compared to M-1.

Set 2: Step Back Building on Sloping Ground.

It has been found from Table 2, that a buildings resting on sloping Ground M-5, M-6 has 35.75% & 47.29% respectively less displacement compared to M-4 in Longitudinal direction & in Transverse direction M-5, M-6 has 28.09% & 31.31% respectively less displacement compared to M-4.

Set 3: Step Back – Set Back Building on Sloping Ground.

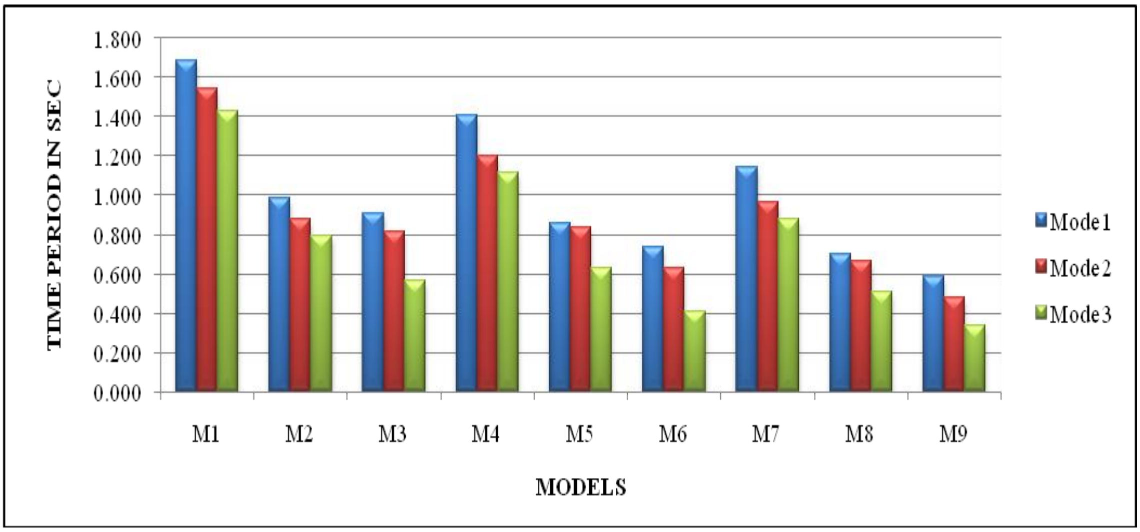
It has been found from Table 3, that a buildings resting on sloping Ground M-8, M-9 has 34.77% & 49.71% respectively less displacement compared to M-7 in Longitudinal direction & in Transverse direction M-8, M-9 has 22.25% & 28.98% respectively less displacement compared to M-7.

From the results it is clear that the **Set 3: Step Back – Set Back Building on Sloping Ground** produce less displacement compared to of Set 2 Step back Buildings & the Presence of L shape Shear Walls at Corner of all sides of building reduces the lateral displacement considerably.

Table: 4 Fundamental Time Period (Sec)

MODES	M1	M2	M3	M4	M5	M6	M7	M8	M9
Mode 1	1.687	0.989	0.904	1.410	0.860	0.738	1.146	0.699	0.587
Mode 2	1.544	0.882	0.813	1.204	0.836	0.627	0.964	0.665	0.478
Mode 3	1.429	0.790	0.563	1.117	0.632	0.412	0.877	0.510	0.336

Fig: 15 Fundamental Time Period (Sec)



Time Period for Set 1: Building on Plane Ground.

It can be observed that from the tables 4, the natural time period Mode 3 for Models M-2 & M-3 is reduced by 44.69% & 60.58% respectively when compared with M-1 for Building Resting on Plane Ground.

Time Period for Set 2: Step Back Building on Sloping Ground.

It can be observed that from the tables 4, the natural time period Mode 3 for Models M-5 & M-6 is reduced by 43.39% & 63.15% respectively when compared with M-4 for Building Resting on Sloping Ground.

Time Period for Set 3: Step Back – Set Back Building on Sloping Ground.

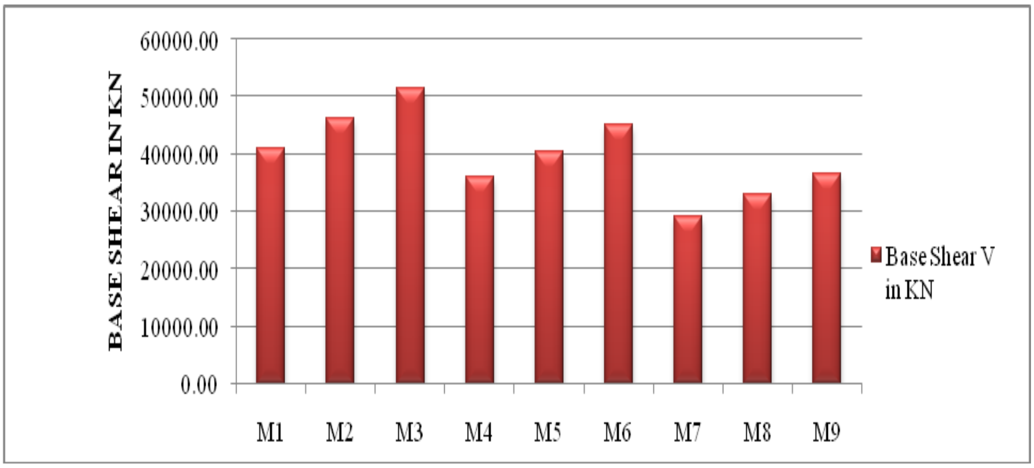
It can be observed that from the tables 4, the natural time period Mode 3 for Models M-8 & M-9 is reduced by 41.86% & 61.70% respectively when compared with M-7 for Building Resting on Sloping Ground.

It can be observed that the in the M-9 **Step Back – Set Back Building on Sloping Ground** with presence L shape shear wall at corner to all four sides of building significantly reduces the fundamental periods of vibration, which is a function of stiffness mass and damping characteristics of the building.

Table: 5 Base Shear V in KN

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Base Shear V in KN	40935.55	46246.98	51558.42	35948.18	40434.73	45122.47	29207.75	32869.42	36450.61

Fig: 16 Base Shear V in KN



Set 1: Building on Plane Ground.

It can be observed that from the tables 5, the Base Shear for Models M-2 & M-3 is increased by 11.48% & 20.60% respectively when compared with M-1 for Building Resting on Plane Ground.

Set 2: Step Back Building on Sloping Ground.

It can be observed that from the tables 5, the Base Shear for Models M-5 & M-6 is increased by 11.10% & 20.33% respectively when compared with M-4 for Building Resting on Sloping Ground.

Set 3: Step Back-Set Back Building on Sloping Ground.

It can be observed that from the tables 5, the Base Shear for Models M-8 & M-9 is increased by 11.10% & 20.33% respectively when compared with M-7 for Building Resting on Sloping Ground.

It can be observed that the in the M-3 **Building on Plain Ground** with presence L shape shear wall at corner to all four sides of building significantly has Base shear high, this is because Base shear is related to Mass and as time period and Lateral displacement reduces Base shear increases.

4. CONCLUSION

Based on the proposed work we draw the conclusions as mentioned below.

1. The Present Study gave an idea shear wall at corner increases maximum stiffness when compared with shear wall at center.
2. From the results it can be stated that as no. of bays increases relatively lateral displacement reduces.
3. Influence of Shear wall reduces the fundamental periods of vibration, which is a function of stiffness mass and damping characteristics of the building.
4. The Present Study gave an idea L Shape shear wall at corner has maximum effect to reduce the fundamental periods of vibration.
5. From the results it can be stated that as stiffness increases relatively Base Shear value also increases.
6. Form overall study it is concluded that Step Back Set-Set Back Building on sloping ground possess Less lateral displacement when compared with Step Back Building on sloping Ground.

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