Seismic Performance of A Structure With Shear Wall on Hill Slopes

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Abstract- *Seismic performance of a structure with shear wall on hill slopes, carried out on a residential building by considering the gravity loads and lateral loads in the form of Earthquake loads and Wind loads includes the shear walls to reduce the lateral force effect on structural members. Here the structure located in hilly areas is very much more exposed to seismic environment to the structures that are situated in flat ground. The columns of ground storey have different height of columns due to sloping ground. Due to the sloping ground the column height differs as short and long columns. Hence the large amount of lateral force is attracted by short column due to its higher stiffness. It leads to severe damage to structure and causes loss of human life. Thus to increase the seismic performance of building on sloping ground the shear walls play very vital role. Hence in this study the attempt is made to analyze the high-rise structures on plain and sloping ground with and without shear walls. In this study a G+9 storied reinforced concrete (RC) building with varying ground slopes as 0o, 7o, 14o and 21°,27o without shear walls and with shear wall at peripheral corners in ZONE V(Srinagar) . The Wind load analysis according to IS : 875-(part-3)2015 and seismic loads according to IS : 1893(part-1) 2016.Shear wall analysis according toIS:13920-2016. The modeling and analysis of the structure has been carried out by Linear Dynamic analysis (Response Spectrum) is carried out by using structural engineering software ETABS 2016 is used to analyze buildings under the effect of earthquake forces in ZONE V and Medium soil condition. The main objective is to understand in this study is in order to reduce the effectiveness of lateral loads the structure is provided with these two models*

Keywords- Base shear, storey shear, story drift, fundamental time period, response spectrum method

I. INTRODUCTION

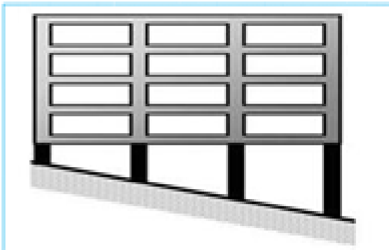
Earth quake is natural phenomenon, which can occur any time anywhere. Therefore, buildings must be built in such a way that they are during such occurrence. An earthquake is caused by a sudden slip on a fault. The tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake that releases energy in waves that travel through the earth's crust and cause the shaking that we feel.An earthquake may be defined as a wave-like motion generated by forces in constant turmoil under the surface layer of the earth (the lithosphere), travelling through the earth’s crust. Most of the earthquake related deaths are causes by total or partial collapse of buildings. In India both at towns and urban areas the construction of buildings are extremely growing with respect to population. The destruction and loss in these areas in case of seismic impact is due to the fact that most of the buildings are not designed without considering the seismic forces

II. SEISMIC ZONES

Seismic zoning map of India helps in identifying the lowest, moderate as well as the highest hazardous or earthquake-prone areas in India. Also, such maps are used or looked before the construction of high rise building so as to check the level of seismology in any particular area. In the long run, this helps in saving lives.The variation of geology in different areas of the country implies that the probability of damage to earthquakes occurring in different places is different. Therefore, we have to recognize these locations on seismic zone map. The version seismic zone map is based on the past earthquakes before 1970 that have occurred ,therefore India is subdivided into as five zones i.e., zone-I, zone-II, zone-III, zone-IV, zone-V.

III. SHORT COLUMN

During the earthquakes of the past, buildings with reinforced concrete structure (RC) that the columns having of different heights varying in a same storey, the shorter columns are damaged more than the longer columns in the one storey.



SHORT COLUMN EFFECT ON SLOPED GROUND:

Many situations with short column effect arise in buildings. When a building is rested on sloped ground, during earthquake shaking all columns move horizontally by the same amount along with the floor slab at a particular level (this is called rigid floor diaphragm action). If short and tall columns exist within the same storey level, then the short columns attract several times larger earthquake force and suffer more damage as compared to taller ones. The short column effect also occurs in columns that support mezzanine floors or loft slabs that are added in between two regular floors. There is another special situation in buildings when short-column effect occurs. Consider a wall (masonry or RC) of partial height built to fit a window over the remaining height. The adjacent columns behave as short columns due to presence of these walls. In many cases, other columns in the same storey are of regular height, as there are no walls adjoining them. When the floor slab moves horizontally during an earthquake, the upper ends of these columns undergo the same displacement. However, the stiff walls restrict horizontal movement of the lower portion of a short column, and it deforms by the full amount over the short height adjacent to the window opening. On the other hand, regular columns deform over the full height. Since the effective height over which a short column can freely bend is small, it offers more resistance to horizontal motion and thereby attracts a larger force as compared to the regular column. As a result, short column sustains more damage.

IV. SHEAR WALL

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can beas low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements (like glass windows and building contents).

Advantages of Shear Walls in RC Buildings :

The shear wall are more efficient in both i.e., reducing the tremor damage in buildings and in the cost of the construction also less due to time taken to construction of the wall is very less.

V. OBJECTIVES OF STUDY

The present study is taken up with the following objectives:

1. To study the behavior of G+9 storied building resting on plane ground is compared to the sloped ground buildings with varying slopes i.e.,0,7,14,21,27 degrees.
2. The buildings without shear wall are compared to buildings with shear walls placing at peripheral corners .
3. This comparison is carried out using Response Spectrum Method by using Etabs 2016 software.
4. The comparison for various ground slope angles considering parameters such as Displacement, Base Shear, Storey Drift, Storey Shear, Fundamental Time Period, Torsion.

VI. RESPONSE SPECTRUM

In the 'response spectrum method', the maximum response of a structure during an tremor is obtained directly by a response spectrum to the tremor (or design). This procedure provides an approximate maximum response, but is quite accurate for a structural designing applications. This approach, the multiple response modes of a building to an tremor are taken into consideration. For every mode, a response of a design spectrum is read, based on modal mass and modal frequency. The responses of the different modes are combined to provide an estimate of the total response of a structure using modal combination methods such as 'complete quadratic combinations'(CQC), 'square root of sum of squares'(SRSS), or 'absolute sum '(ABS) method. Response spectrum method must be performed using the design spectrum specified in the respective codes or from a site-specific design spectrum, which is prepared specifically for a structure at a particular project site.For most buildings, inelastic response can be expected to occur during a major earthquake, implying that an inelastic analysis is more proper for design. However, in spite of the availability of nonlinear inelastic programs, they are not used in typical design practice because:

1) Their proper use requires knowledge of their inner workings and theories,
2) Results produced are difficult to interpret and apply to traditional design criteria, and
3) The necessary computations are expensive.

Therefore, analyses in practice typically use linear elastic procedures based on the response spectrum method. The response spectrum analysis is the preferred method because it is easier to use.

VII. DESCRIPTION OF MODELS

The structure chosen for a study is a G+9 storied Residential building. The building is situated in seismic zone V(Srinagar) on medium stiff soil. Three dimensional mathematical models are generated in ETABS 2016 software. For structural elements, M30 grade of concrete is used. The floor diaphragms are assumed to be rigid. Using ETABS 2016 a G+9 RC structure with ground slope of 0˚,7˚,14˚,21˚,27°are modeled and analyzed.

Model-1 :

G+9 storied building without shear wall in Zone V at 0 degree.

Model-2 :

G+9 storied building with shear wall provided peripheral corners in plan in Zone V at 0 degree.

Model-3 :

G+9 storied building without shear wall in Zone V at 7 degree.

Model-4 :

G+9 storied building with shear wall provided peripheral corners in plan in Zone V at 7 degree.

Model-5 :

G+9 storied building without shear wall in Zone V at 14 degree.

Model-6 :

G+9 storied building with shear wall provided peripheral corners in plan in Zone V at 14 degree.

Model-7:

G+9 storied building without shear wall in Zone V at 21 degree.

Model-8 :

G+9 storied building with shear wall provided peripheral corners in plan in Zone V at 21 degree.

Model-9:

G+9 storied building without shear wall in Zone V at 27 degree.

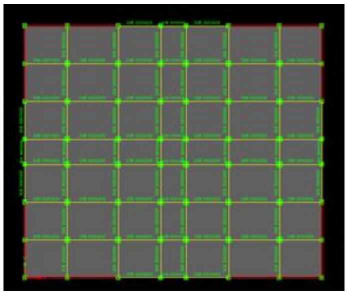
Model-10 :

G+9 storied building with shear wall provided peripheral corners in plan in Zone V at 27 degree.

VIII. STRUCTURAL DETAIL OF THE MODELS

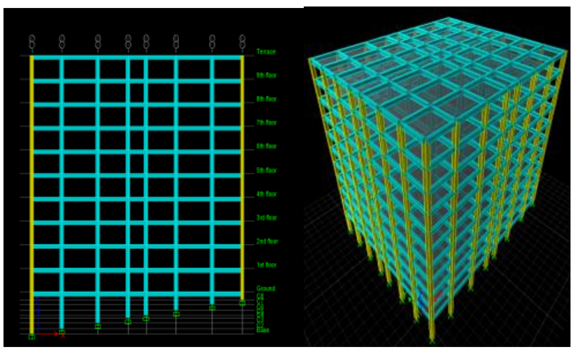
Plan dimension=35 X 30 m
Seismic zone=V
Zone factor, z=0.36
Wind Speed=39m/s
Number of storey=G+9
Floor height=3m
Depth of Slab=150 mm
Size of beam=600 x 600mm
Size of column=300 x 600 mm
Thickness of shear wall=230mm
Materials =M 30 concrete and Fe 415 steel
Thickness of external and internal walls=230mm
Type of soil=Medium soil
Importance Factor, I=1
Response spectrum analysis=Linear dynamic analysis
Damping of structure=5 percent
Response reduction factor=5
Wall load=12kN/m
Live load=2kN/m^2
Ground slopes=0,7,14,21 and 27degrees

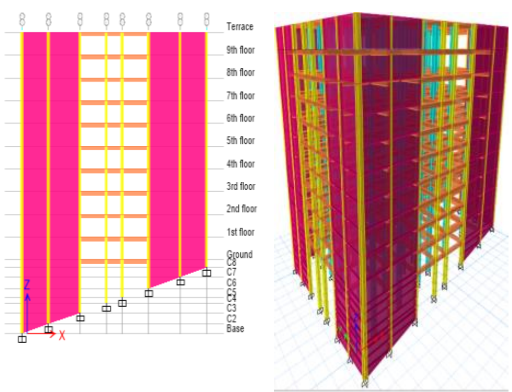
IX. PLAN



X. 2D AND 3D MODEL

WITH ANDWITHOUT SHEAR WALL





XI. RESULT AND DISCUSSIONS:

Linear dynamic analysis is performed on all models. Loads are calculated and distributed as per code IS 1893 (Part I) 2016, IS 456 2000, IS 13920 2016 using ETABS 2016.The results of various analyses for different ground slopes (0˚,7˚,14°,21°and 27˚) are presented and comparative study between results of different slopes and it is made to analyses the effect of sloping ground on structural forces. In the present work storey displacements, storey drift, storey shear, base shear, fundamental time period are compared for different ground slopes under different seismic loads. The analysis results obtained in ETABS 2016 are shown below in the form of tables for various ground slopes under seismic loads in X-direction and Y- direction. The building is in (G+9) storied.

Comparison of Lateral Displacement:

Displacement for buildings without providing shear walls in X Direction.

Here the values are taken for (G+9) storied building including Terrace

Storey level-X	Buildings without providing shear walls(mm)				
	0°	7°	14°	21°	27°
0	0.887	0.819	0.987	1.042	1.063
1	4.34	4.198	4.497	4.705	4.904
2	8.748	8.657	9.034	9.373	9.742
3	13.273	13.279	13.708	14.163	14.697
4	17.542	17.657	18.126	18.681	19.365
5	21.389	21.609	22.111	22.756	23.569
6	24.734	25.051	25.582	26.306	27.229
7	27.534	27.933	28.491	29.284	30.304
8	29.755	30.223	30.806	31.657	32.758
9	31.39	31.912	32.519	33.417	34.58
10	32.509	33.07	33.7	34.636	35.842

The displacements for the building resting on flat ground are found to berelatively less than the building resting on sloped ground. As the slope of the ground is increasing the displacements in the building are getting increasing.

Here the displacement values are comparing slope wise direction.

By the comparison of 0°to7°=1.876%

0°to14°=0.03%
0°to21°=6.54%
0°to27°=10%

The percentage varies 1.836%, 0.030%, 6.54%, 10%.

Displacement for buildings without providing shear walls in Y- Direction.

Storey level-Y	Buildings without providing shear walls(mm)				
	0°	7°	14°	21°	27°
0	0.867	2.414	4.259	5.319	5.854
1	4.192	6.654	8.883	10.051	10.736
2	8.373	11.535	14.058	15.348	16.21
3	12.626	16.365	19.124	20.529	21.557
4	16.622	20.853	23.806	25.314	26.484
5	20.216	24.869	27.987	29.589	30.881
6	23.336	28.351	31.612	33.298	34.7
7	25.939	31.254	34.638	36.399	37.904
8	27.993	33.544	37.031	38.858	40.452
9	29.485	35.21	38.777	40.66	42.321
10	30.477	36.318	39.945	41.872	43.579

The max displacement value is 37.6%in Y-direction at 27°.
By the comparison of 0°to7°=19.16%,

0°to14°=23.23%,
0°to21°=27.7%,
0°to27°=37.6%

Thepercentage varies 19.96%,23.23%,27.7%,37.6.

Displacement for buildings with shear walls provided at peripheral corners in X-Direction

Storey level-X	Buildings with providing shear walls(mm)				
	0°	7°	14°	21°	27°
0	0.169	0.236	0.313	0.379	0.453
1	0.598	0.886	0.901	1.001	1.138
2	1.162	1.755	1.624	1.753	1.954
3	1.831	2.791	2.453	2.608	2.875
4	2.575	3.946	3.356	3.537	3.87
5	3.367	5.18	4.307	4.513	4.912
6	4.185	6.455	5.281	5.51	5.975
7	5.006	7.738	6.256	6.509	7.04
8	5.811	9.002	7.214	7.492	8.086
9	6.588	10.227	8.141	8.445	9.103
10	7.322	11.393	9.023	9.356	10.077

The max displacement value is **55.5 in X-direction at 7°.**
The comparison and percentage values for the slopes

0°to7°= 55.5%
0°to14°=23.23%
0°to21°= 27.7% ,
0°to27°=37.26%

Displacement for buildings with shear walls provided at peripheral corners in Y-Direction

Storey level-Y	Buildings with providing shear walls(mm)				
	0°	7°	14°	21°	27°
0	0.212	0.611	0.909	1.185	1.546
1	0.791	1.635	1.872	2.205	2.738
2	1.573	2.97	3.048	3.427	4.149
3	2.514	4.552	4.384	4.801	5.725
4	3.566	6.314	5.834	6.282	7.418
5	4.692	8.199	7.356	7.832	9.182
6	5.856	10.152	8.912	9.414	10.98
7	7.027	12.129	10.47	11.001	12.779
8	8.18	14.091	12.003	12.566	14.552
9	9.294	16.015	13.493	14.092	16.282
10	10.352	17.868	14.918	15.56	17.947

The max displacement value is **73.36% in y-direction at 27°.**

The comparison and percentage values for the slopes

0°to7°=72.06%
0°to14°=44.46%
0°to21°= 50% ,
0°to27°=73.36%.

Comparison of Storey drift :

It is the displacement of one level relative of the other level above or below. The storey drift in any storey shall not exceeds 0.004 times the height of storey height, the permissible storey drift of each Storey is = 0.004(3000) = 12 mm.

During an earthquake, large lateral forces can be imposed on structures, Lateral deflection and drift have three primary effects on a structure, the movement can affect the structural elements (such as beams and columns); the movements can affect non-structural elements (such as the windows and cladding); and the movements can affect adjacent structures. Without proper consideration during the design process, large deflections and drifts can have adverse effects on structural elements, nonstructural elements, and adjacent structures.

Storey Drift for buildings Ground level models in X Direction

STOREY	WITH SHEAR WALL IN X-DIRECTION				
	0°	7°	14°	21°	27°
0	0.169	0.236	0.313	0.379	0.453
1	0.429	0.657	0.589	0.622	0.685
2	0.565	0.871	0.724	0.752	0.816
3	0.67	1.039	0.83	0.856	0.921
4	0.747	1.16	0.906	0.929	0.995
5	0.796	1.239	0.954	0.975	1.042
6	0.822	1.282	0.978	0.998	1.064
7	0.826	1.291	0.98	0.999	1.064
8	0.811	1.272	0.963	0.982	1.047
9	0.781	1.232	0.931	0.953	1.017
10	0.737	1.171	0.884	0.911	0.973

For story drift the maximum value is **32.02%at 27°**
The comparison and percentage values for the slopes

0°to7°=30.3%
0°to14°=19.94%
0°to21°= 23.60% ,
0°to27°=32.02%

Storey Drift for buildings Ground level models in X Direction

STOREY	WITHOUT SHEAR WALL IN X- DIRECTION				
	0°	7°	14°	21°	27°
0	0.887	0.819	0.987	1.042	1.063
1	3.453	3.379	3.511	3.664	3.841
2	4.416	4.466	4.545	4.675	4.842
3	4.554	4.651	4.707	4.819	4.974
4	4.342	4.451	4.495	4.595	4.728
5	3.981	4.087	4.126	4.219	4.332
6	3.55	3.647	3.684	3.766	3.872
7	3.064	3.149	3.184	3.255	3.351
8	2.515	2.587	2.62	2.682	2.749
9	1.915	1.972	2.002	2.048	2.076
10	1.334	1.377	1.403	1.432	1.44

The maximum storey drift value for the model in x-direction **9.22%at 27°.**

The comparison and percentage values for the slopes

0°to7°=2.12%
0°to14°=4.67%
0°to21°= 7.66%
,

Storey Drift for buildings Ground level models in Y-Direction without shear wall .

STOREY	WITHOUT SHEAR WALL IN Y-DIRECTION				
	0°	7°	14°	21°	27°
0	0.867	0.865	1.027	1.102	1.192
1	3.326	4.247	4.649	4.78	4.93
2	4.186	4.898	5.213	5.356	5.519
3	4.279	4.877	5.142	5.279	5.426
4	4.059	4.585	4.818	4.949	5.078
5	3.709	4.18	4.396	4.522	4.648
6	3.295	3.716	3.917	4.037	4.167
7	2.828	3.194	3.377	3.49	3.61
8	2.303	2.605	2.765	2.868	2.945
9	1.728	1.957	2.085	2.172	2.191
10	1.171	1.324	1.414	1.478	1.47

The maximum storey drift value for the model is **26.80% at 27°**in y-direction .

The comparison and percentage values for the slopes

0°to7°=7.56%
0°to14°=21.82%
0°to21°= 25.16% ,
0°to27°=26.80%

Storey Drift for buildings Ground level models inY-Direction With shear wall.

STOREY	WITH SHEAR WALL IN Y- DIRECTION				
	0°	7°	14°	21°	27°
0	0.212	0.241	0.309	0.26	0.36
1	0.579	1.025	0.964	1.021	1.192
2	0.784	1.338	1.177	1.223	1.411
3	0.942	1.585	1.339	1.21	1.577
4	1.056	1.767	1.454	1.486	1.693
5	1.131	1.89	1.527	1.555	1.765
6	1.17	1.961	1.563	1.589	1.798
7	1.178	1.986	1.566	1.593	1.799
8	1.159	1.972	1.541	1.571	1.773
9	1.121	1.931	1.496	1.532	1.73
10	1.061	1.859	1.429	1.472	1.665

The maximum storey drift value is **68.5% at0°**when compared to other degrees.

The percentage values for the slopes

0°to7°=68.5%
0°to14°=32.6%
0°to21°= 35,22% ,
0°to27°=52,63

Storey Shear :

Storey shear is calculated by using IS 1893-2002 method for two models and the results obtained are presented in Tables and Figures. Table 5.3 illustrate the values of comparison of storey shear of models using linear dynamic analysis. Storey shear is a very important parameter for earthquake resistant design of buildings

Storey Shear for buildings without providing shear walls in X Direction.

Storey level-X	Buildings without providing shear walls(kN)				
	0°	7°	14°	21°	27°
0	39.9692	37.0543	45.84	40.6253	32.0661
1	164.3197	164.143	173.1075	167.6596	147.4413
2	234.9418	238.6079	242.113	254.6909	252.9363
3	263.0887	268.8503	270.6108	276.9366	304.6274
4	281.2378	288.6944	288.8274	284.4969	305.4433
5	291.9041	299.4107	297.6151	310.7659	301.1795
6	332.3471	340.2517	339.6133	348.817	344.0797
7	407.5774	417.2301	417.7067	413.2424	451.4262
8	508.6943	519.7668	520.6819	543.387	598.9199
9	680.6958	696.7957	701.1773	731.8011	744.9418
10	788.2583	810.8637	819.4722	798.8613	748.4863

The maximum storey shear value for the model in x-direction without providing shear wall is **3.96% at 14°.**

The percentage values for the slopes

0°to7°=2.96%
0°to14°=3.96%

0°to21°= 1.346% ,
0°to27°=-5.04%

Storey Shear for buildings with providing shear walls in X Direction.(kN)

Storey level-X	Buildings with providing shear walls at peripheral corners(kN)				
	0°	7°	14°	21°	27°
0	92.8911	89.2743	119.1502	85.7939	96.7869
1	297.4145	313.1796	346.5396	261.108	280.3265
2	486.4828	506.5088	548.5461	457.2475	481.4029
3	661.3421	680.7351	725.7763	680.4253	708.3157
4	827.3423	841.856	883.5585	922.7256	953.4071
5	999.5373	1005.3999	1048.034	1177.1885	1209.997
6	1202.4867	1201.9633	1251.121	1437.486	1472.0179
7	1452.283	1450.5619	1512.845	1698.088	1734.1821
8	1756.616	1761.2007	1830.747	1954.3509	1992.0573
9	2113.9036	2140.4304	2181.744	2202.9785	2242.5234
10	1993.3289	2053.7173	2029. 084	1955.7982	1989.212

The maximum percentage for storey shear value in x-direction **6.08% at 27°** with providing shear wall at peripheral corners.

The percentage values for the slopes

0°to7°= 1.25%
0°to14°=-4.01%
0°to21°= 4.21% ,
0°to27°=6.08%

Storey Shear for buildings without providing shear walls in Y Direction (kN).

Storey level-Y	Buildings without providing shear walls(kN)				
	0°	7°	14°	21°	27°
0	40.1993	59.7861	94.9942	113.6552	99.9887
1	166.0352	178.2455	193.4885	198.4993	196.6231
2	242.5559	243.6658	243.2538	246.2162	261.9699
3	280.2963	277.4507	270.3448	266.9622	283.2023
4	308.4073	301.1997	286.3628	277.5726	278.1175
5	328.8754	320.6285	305.125	301.4443	287.0028
6	375.4661	367.9693	353.3331	347.6309	342.6313
7	452.195	443.8054	427.3409	417.2909	448.2729
8	552.1551	544.9199	531.3249	531.148	579.9194
9	717.0519	707.2481	691.2313	694.8314	704.0088
10	805.8765	788.219	761.2142	750.1505	694.4494

By the comparison of 0°,7°,14°,21°,27° slopes. The maximum percentage valueinY-direction is 12.23%at 0°slope when compared to other degrees.

The percentage values for the slopes0°to7°= 12.23%

0°to14°=5.54%
0°to21°= -6.914% ,
0°to27°=-12.64%.

Storey Shear for buildings with providing shear walls at peripheral corners in Y Direction (kN).

Storey level-Y	Buildings with providing shear walls at peripheral corners(kN)				
	0°	7°	14°	21°	27°
0	89.1371	114.6213	146.6901	184.0549	129.8013
1	292.016	335.2605	366.444	403.9517	302.2694
2	482.756	520.9234	561.2286	591.7661	492.7392
3	659.273	685.3851	732.1773	756.0114	711.309
4	823.3607	836.4723	883.2008	903.0122	949.6768
5	994.0272	992.543	1039.945	1058.6063	1200.491
6	1192.7295	1181.967	1235.507	1254.3235	1457.352
7	1442.1204	1424.497	1492.111	1510.3568	1714.812
8	1752.9041	1737.548	1809.354	1825.4341	1968.432
9	2124.6501	2132.212	2165.493	2178.7289	2215.316
10	2026.3401	2068.676	2024.469	2034.1029	1964.921

The percentage for the storey shear **4.26% at 27°** with providing shear wall at peripheral corners in Y-direction. By the comparison of 0°,7°,14°,21°,27° slopes. The maximum percentage value is **4.26% at 27°**slope when compared to other degrees. The percentage values for the slopes0°to7°= 0.35%

0°to14°=1.92%
0°to21°= 2.54% ,
0°to27°=4.26%

Base Shear :

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Table Base Shear for buildings which resting on different sloped grounds in X-direction(kN)

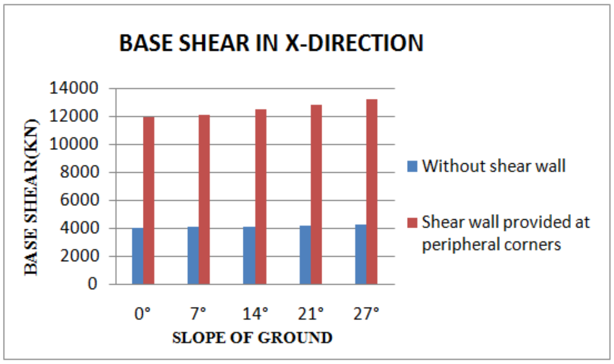
BASE SHEAR IN X- DIRECTION(kN)		
Slope	Without shear wall	Shear wall provided at peripheral corners
0°	3993.0342	11883.6283
7°	4081.669	12044.8273
14°	4116.7652	12477.15
21°	4171.284	12833.1904
27°	4231.5478	13160.2288

It is observed that the model lying on the 27° slope having high base shear in X-direction when compared to other degrees sloped ground model i.e; without shear wall.

The percentage value for **27° slope is 211.2%,**

21°is 198.24%
14° is 196.24%
7° is 195.2%
0° is 195.09%.
Base shear in x-direction.

GRAPH REPRESENTATION:



Base Shear for buildings which resting on different sloped grounds in Y-direction(kN)

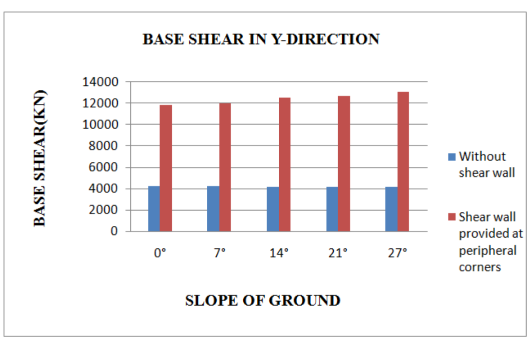
BASE SHEAR IN Y- DIRECTION(kN)		
Slope	Without shear wall	Shear wall provided at peripheral corners
0	4269.114	11879.3142
7	4233.138	12030.106
14	4158.0135	12504.1952
21	4145.4015	12700.3488
27	4176.1861	13107.1191

It is observed that the model lying on the 27° slope having high base shear Y-direction when compared to other degrees sloped ground model i.e; without shear wall.

The percentage value for **27° slope is 213.85%**

0°=178.26%
7°=184.18%
14°=200.7%
21°=206.37%
27°=213.85%

GRAPH REPRESENTATION:



FUNDAMENTAL TIME PERIOD :

When the ground shakes, the base of a building moves with the ground, and the building swings back and-forth. If the building were rigid, then every point in it would move by the same amount as the ground. But, most buildings are flexible, and different parts move back-and-forth by different amounts.

The building will oscillate back-and-forth horizontally and after some time come back to the original position, these oscillations are periodic. The time taken (in seconds) for each complete cycle of oscillation (i.e., one complete back-and-forth motion) is the same and is called Fundamental Natural Period T of the building. Value of T depends on the building flexibility and mass, more the flexibility, the longer is the T, and more the mass, the longer is the T. In general, taller buildings are more flexible and have larger mass, and therefore have a longer T. On the contrary, low- to medium-rise buildings generally have shorter T (less than 0.4 sec).

Maximum Fundamental time period for buildings which resting on different sloped grounds(0°,7°,14°,21°,27°) without shear wall:

Without providing shear wall					
Mode	0°	7°	14°	21°	27°
1	1.396	1.389	1.437	1.409	1.416
2	1.306	1.337	1.418	1.402	1.414
3	1.262	1.246	1.35	1.254	1.257
4	0.427	0.424	0.435	0.438	0.442
5	0.404	0.415	0.435	0.429	0.43
6	0.394	0.388	0.413	0.389	0.39
7	0.228	0.227	0.234	0.244	0.269
8	0.218	0.226	0.23	0.229	0.266
9	0.216	0.212	0.221	0.212	0.266
10	0.143	0.145	0.149	0.166	0.265

The percentage of the time period at different modes .

By the comparison of 0°,7°,14°,21°,27° slopes. The maximum percentage value is **2.93% at 14°** slope when compared to other degrees. The percentage values for the slopes0°to7°= 0.5%,

0°to14°=2.93%
0°to21°= 0.93% ,
0°to27°=1.43%.

Maximum Fundamental time period of buildings resting on different sloping ground (0°,7°,14°,21°,27°) with shear wall provided at peripheral corners .

With providing shear wall at peripheral corners					
Mode	0°	7°	14°	21°	27°
1	0.433	0.51	0.479	0.476	0.489
2	0.366	0.409	0.401	0.398	0.409
3	0.221	0.245	0.246	0.244	0.261
4	0.109	0.119	0.115	0.164	0.261
5	0.095	0.104	0.098	0.164	0.259
6	0.06	0.066	0.084	0.144	0.259
7	0.053	0.055	0.084	0.144	0.256
8	0.047	0.051	0.069	0.143	0.254
9	0.035	0.036	0.068	0.141	0.252
10	0.031	0.034	0.067	0.113	0.167

By the comparison of 0°,7°,14°,21°,27° slopes. The maximum percentage value is **12.93% at 27°** slope when compared to other degrees. The percentage values for the slopes 0°to7°=-5.54%,

0°to14°=10.62.%,
0°to21= 9.9307% ,
0°to27°=12.933%.

It is observed that maximum Fundamental Time Period is increasing along slope of the ground is increasing. The percentage of the time period at different modes .

XII. CONCLUSIONS

The main objective of the thesis is to study the behavior of a multi–storied building by incorporating shear walls to the buildings with varying slopes (0°,7°,14°,21° and 27°) with Earthquake loading and wind loading. To achieve the above objectives, a detailed Literature Review was carried out and presented in Chapter 2. Detailed Methodology is explained in Chapter 3. It discusses in detail issues related to Structural Modeling. Basic modeling for the linear and dynamic analyses of RC Framed Structures is discussed in detail. Chapter 4 presents the analysis results and the discussions. Buildings on sloped ground without shear wall and with shear walls at peripheral corners,. The buildings were analyzed using Linear Dynamic Analysis (Response Spectrum) as per the IS 1893 (part 1): 2016 loading requirement. For each case, Fundamental time period, Base shear, Storey displacement, Storey drift ,storey shear are estimated and studied.

1. For a structures on the sloping ground, location of shear walls is very important for resisting seismic forces.
2. Short columns are the most critical members for the building on the slope ground. To have a good control over the forces and displacements, it is preferable to locate the shear wall towards the shorter column side.
3. The displacements for the building resting on flat ground are found to be relatively less than the building resting on sloped ground. As the slope of the ground is increasing the displacements in the building are getting increasing.
4. The presence of shear wall influences the overall behavior of structures when subjected to lateral forces. Lateral displacements are considerably reduced while contribution of the shear wall on sloping ground.
5. The storey drifts observed in the two models are found to be within the limit as specified by code (IS: 1893-2016, part-1) by linear dynamic analysis.
6. Storey drift are also considerably reduced while contribution of the shear wall at different positions on flat and sloping ground.
7. The location of the shear wall in the models among the shear wall provided at peripheral corners in plan given better results.
8. It is observed that the buildings with shear walls provided at peripheral at corners in plan are having relatively higher base shear and storey shear values than the other model. It is observed that the buildings without shear wall in plan are having relatively less base shear and storey shear values than the shear wall provided at peripheral corners.
9. It is observed that minimum Fundamental Time Period is increasing along slope of the ground is increasing. By providing shear wall in plan it has been reduced .
10. It is observed that minimum Fundamental Time Period of the with shear wall provided at peripheral corners model is very high values compared to without shear wall .

6.3 Scope of future work :

1. The studies can be carried out for more number of varying hill slope angles for better understanding of the behavior of RC frame building on hill slopes.
2. The present study is based on linear dynamic analysis using response spectrum. The results need to be verified with the non-linear dynamic analysis.
3. The study can be further extended to the buildings on hill slopes by incorporating bracings or dampers

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