A Comparative Study on Seismic Resistance of A Structure With Shear Wall on Sloping Ground

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Abstract- *A COMPARATIVE STUDY ON SEISMIC RESISTANCE OF A STRUCTURE WITH SHEAR WALL ON SLOPING GROUND, carried out on a residential building by considering the gravity loads and lateral loads in the form of Earthquake loads and Wind loads incorporating the shear walls to reduce the lateral force effect on structural members. The structure located in hilly areas are very much more prone to seismic environment in comparison to the structures that are situated in flat 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 and property. 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.*

A G+15 storey reinforced concrete (RC) building with varying ground slope as 0°,10°, 20° and 30° without shear walls and incorporating shear walls at center in plan four sides ,at peripheral corners and providing complete external walls with shear wall have been considered for the analysis. The structure proposed is designed by Limit State Method according to IS : 456-2000, 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 to IS : 13920-2016. The modeling and analysis of the structure has been carried by Linear Dynamic analysis (Response Spectrum) by using software ETABS 2016. Building in zone IV at medium soil condition is analyzed for earthquake forces by using ETABS. The main objective is to understand the behavior of the building on sloping ground for the effect of varying height of the column in bottom storey ,various positions of shear walls and the effect of shear wall on sloping ground. The seismic performance of structure with various shear walls configurations is compared with respect to parameters like base shear, lateral displacement, fundamental time period, story drift and story shear.

Keywords- Reinforcement, ETABS ,base shear, lateral displacement, fundamental time period, story drift, story shear and shear wall..

I. INTRODUCTION

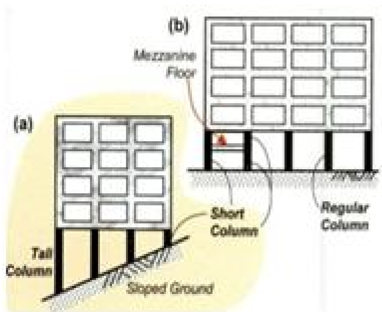
"Earthquakes do not kill people, buildings do". This statement is from seismologists who trust that human construction and buildings that collapse during earthquakes are the cause of most deaths. Most of the earthquake related deaths are causes by total or partial collapse of buildings. In India both 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.

Earthquake Resistance Design Philosophy : (I) Small but frequent tremors : the load carrying elements of the structure with horizontal and vertical forces must not be damaged though, parts of the structure that do not carry a load can be sustain and repairable of a damage. (II) With moderate but rare tremor : The main element can be sustain to the repairable damage, while other elements of a building can be damaged, so they may be require to replaced the member after the tremor. (III) Under very strong but occasional tremor : The main element may sustain large damage, but the structure should not be collapse.

Therefore, after minor shaking, the building will be completely operational within a small time and the repair expenses will be little. After a moderate tremor, the building will be operational once the strengthening and repair of the damaged main element is completed. But after a very strong tremor, the building may not useful for later use, but the structure must be withstand so people can be safely evacuated.

SHORT COLUMN :

For example a building with a short column constructed on sloping ground as shown in figure 1.2(a) and building constructed on a mezzanine as shown in figure 1.2(b). The bad behavior of the short columns is due to fact that in an earthquake, a short column and long column of same dimensions move horizontally in the same quantity Δ shown in figure (1.3). Therefore, the short column is more stiffer than the long column and it is subjected to large tremor force. More stiffness of the column is nothing but resistance to the deformation i.e., the greater is the stiffness the greater in the force to damage it. Where the short column is not design for perfectly for the lateral load, it can be suffer more damage when the earthquake occurs. This is known as Shorter Column Effect. Due to large force the short column is damaged in form of X-shaped cracks as shown in figure 1.2(c). This damage is due to the shear failure of the column.



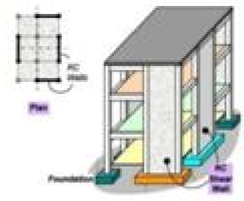
Building frame with short columns

X-shaped cracking damage due to short column

Shear Wall Structures :

A shear wall is the concrete wall with a reinforcement is designed to withstand the shear, the horizontal force that causes most of the damage in tremors. Most of the building codes require to use of such RCC structure walls to make houses safer, more stable and learning to know them is an importance of shear wall in architectural education. Reinforced concrete structure often have vertical walls similar to vertical plates called shear walls as shown in the figure 1.4, in addition of columns, beams and slabs. The shear wall usually start at the foundation level and are also continuous along the height of the building. The shear wall nothing but a vertically-oriented like beams they carry tremor load to the surface. The minimum thickness of shear walls should not be lesser than, (IS 13920 : 2016,clause 10.1.2)

a) 150mm , and
b) 300mm for structure with coupled shear walls in any tremor zones.



Reinforced Concrete Shear wall in building

Objectives Of Study :

The present study is taken up with the following objectives :

1) To study the behavior of G+15 storied building resting on plane ground is compared to the sloped ground buildings with varying slopes i.e.,0, 10, 20, 30 degrees.
2) The buildings without shear wall are compared to buildings with shear walls placing at peripheral corners, shear wall provided symmetrically in plan and shear wall provided complete external walls.
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.

II. LITERATURE REVIEW

Nagarjuna and Shivakumar B. Patil (2015) :

They studied a G + 10 storey RCC structure that rests on a sloping ground whose slope of the ground varying from 10 ˚ to 40 ˚ .A comparison was made with the structure supported on a flat ground The goal is to study the effect of different height of the column in the lower floor and the effect of the structural wall in a different position during the tremor. The tremor analysis was performed by linear static analysis and also analysis of the response spectrum. The comparison made with drift, storey displacement, time period and base shear. They observed that a short column is more affective during of the tremor.

Prasad Ramesh Vaidya (2015) :

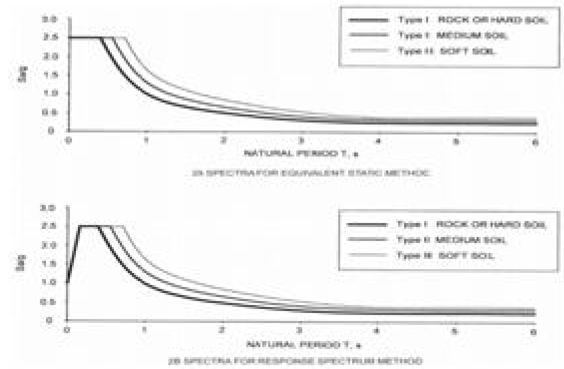
They study the tremor performance of RCC structural walls on a sloping ground. Their aim is to study the structure on a sloping ground for different positions of the structural walls and also to study the effectiveness of the RCC structural wall on sloped ground. The structure have been studied by taking the four models. One model is a frame-type structural system and three other models are of a dual-type structural system with three different structural wall positions. The analysis of the response spectrum is performed using the finite element software SAP 2000. The performance of a structure with respect a to displacement, the drift and the maximum forces in a columns are compared.

S.P.Pawar ,Dr.C.P.Pise and N. K. Shelar(2016) :

They have studied an RCC building with G + 7 floors resting on a sloping ground with a structural wall. He had noted that the seismic behavior of structures on sloping terrain different from other structures. The structures that rest on sloping ground have more displacement and shears than basic structures that rest on a flat ground and the short column subjected more forces and suffers damage when subjected to an earthquake. The setback in construction could be vulnerable to tremor excitation. Base shear of structures on slopes for the configuration of different structural walls increases by about 50% along the direction parallel to the slope, while increasing by 30-45% in another transverse direction. The horizontal displacement are observed in the direction parallel to the slope is greater than the displacement in the transverse direction. Time period and the horizontal displacement observed are less for the straight shape RCC structural wall model between all configurations.

Response Spectrum Method :

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.



RESPONSE SPECTRA FOR ROCK AND SOIL SITES FOR 5 PERCENT DAMPING

Description of Models :

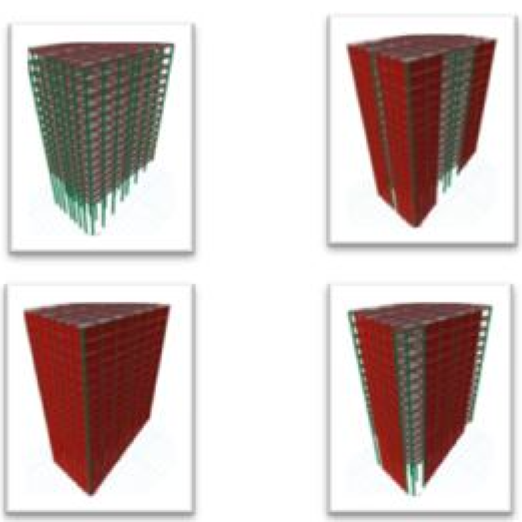
Model-1 : G+15 storied building without shear wall in Zone IV at 0 degree.
Model-2 : G+15 storied building with shear wall provided symmetrically in plan in Zone IV at 0 degree
Model-3 : G+15 storied building with shear wall provided peripheral corners in plan in Zone IV at 0 degree.
Model-4 : G+15 storied building with shear wall provided complete external walls in plan in Zone IV at 0 degree.
Model-5 : G+15 storied building without shear wall in Zone IV at 10 degree.
Model-6 : G+15 storied building with shear wall provided symmetrically in plan in Zone IV at 10 degree .
Model-7 : G+15 storied building with shear wall provided peripheral corners in plan in Zone IV at 10 degree.
Model-8 : G+15 storied building with shear wall provided complete external walls in plan in Zone IV at 10 degree.
Model-9 : G+15 storied building without shear wall in Zone IV at 20 degree.
Model-10 : G+15 storied building with shear wall provided symmetrically in plan in Zone IV at 20 degree .
Model-11 : G+15 storied building with shear wall provided peripheral corners in plan in Zone IV at 20 degree.
Model-12 : G+15 storied building with shear wall provided complete
external walls in plan in Zone IV at 20 degree.
Model-13 : G+15 storied building without shear wall in Zone IV at 30 degree.

Model-14 : G+15 storied building with shear wall provided symmetrically in plan in Zone IV at 30 degree .
Model-15 : G+15 storied building with shear wall provided peripheral corners in plan in Zone IV at 30 degree.
Model-16 : G+15 storied building with shear wall provided complete external walls in plan in Zone IV at 30 degree.

Load combination :

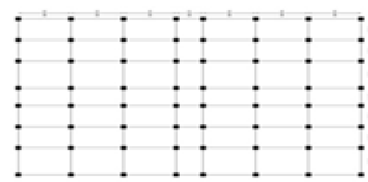
The analysis results obtained for the following load combination as per IS 456-2000 and IS 1893-2016

COMB1	=	1.5 (DL+LL)
COMB2	=	1.2(DL+LL+WX)
COMB3	=	1.2(DL+LL-WX)
COMB4	=	1.2(DL+LL+WY)
COMB5	=	1.2(DL+LL-WY)
COMB6	=	1.5(DL+WX)
COMB7	=	1.5(DL-WX)
COMB8	=	1.5(DL+WY)
COMB9	=	1.5(DL-WY)
COMB10	=	0.9DL+1.5WX
COMB11	=	0.9DL-1.5WX
COMB12	=	0.9DL+1.5WY
COMB13	=	0.9DL-1.5WY
COMB14	=	1.2(DL+LL+EX)
COMB15	=	1.2(DL+LL-EX)
COMB16	=	1.2(DL+LL+EY)
COMB17	=	1.2(DL+LL-EY)
COMB18	=	1.5(DL+EX)
COMB19	=	1.5(DL-EX)
COMB20	=	1.5(DL+EY)
COMB21	=	1.5(DL-EY)
COMB22	=	0.9DL+1.5EX
COMB23	=	0.9DL-1.5EX
COMB24	=	0.9DL+1.5EY
COMB25	=	0.9DL-1.5EY
COMB26	=	RESPONSE SPECTRUM IN X
COMB27	=	RESPONSE SPECTRUM IN Y



3D models with shear wall on sloping ground 30˚

Plan dimension	32.5 X 22.48 m
Seismic zone	IV
Zone factor, z	0.24
Wind Speed	47m/s
Number of storey	G+15
Floor height	3m
Depth of Slab	150 mm
Size of beam	400 x 500 mm
Size of column	500 x 500mm
Thickness of shear wall	230mm
Materials	M 40 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/m²
Ground slopes	0,10,20 and 30 degrees



PLAN

III. RESULT AND DISCUSSIONS

Comparison of Lateral Displacement :

Storey level-X	Structure without providing shear walls, mm			
	0˚	10˚	20˚	30˚
1	1.164	1.99	2.103	2.436
2	4.198	4.613	4.962	5.297
3	7.839	8.465	8.657	9.078
4	11.536	12.352	12.05	13.209
5	15.211	15.43	15.998	17.269
6	18.763	18.82	19.944	21.222
7	22.008	22.324	23.571	25.033
8	25.123	25.679	27.034	28.667
9	28.06	28.84	30.291	32.087
10	30.766	31.755	33.299	35.258
11	33.184	34.371	36.013	38.14
12	35.253	36.632	38.386	40.693
13	36.907	38.478	40.368	42.878
14	38.086	39.855	41.915	44.659
15	38.783	40.76	43.032	46.044

The displacements of a structure resting on a sloped ground are found to be relatively more than the structure resting on flat ground (0˚) . As compare to 0˚ model the percentage increasing of the models without shear wall resting on 10˚, 20˚, 30˚ i.e., 5.09 % , 10.95 % , 18.72 % .

Storey level-X	Structure with shear walls provided symmetrically in plan, mm			
	0°	10°	20°	30°
1	0.314	0.497	0.96	1.448
2	1.119	1.174	1.826	2.473
3	1.979	2.049	2.806	3.593
4	2.893	3.169	3.885	4.803
5	3.903	4.441	5.041	6.08
6	4.986	5.835	6.257	7.407
7	6.121	7.32	7.524	8.768
8	7.292	8.823	8.867	10.148
9	8.481	10.135	10.45	11.535
10	9.671	11.444	12.744	13.93
11	10.848	12.737	13.628	14.309
12	11.998	14.002	15.181	17.661
13	13.107	15.229	16.688	18.977
14	14.168	16.411	18.011	20.251
15	15.167	17.534	20.076	22.523

As compare to 0° model with shear walls provided symmetrically in plan the percentage increasing of the models resting on 10°, 20°, 30° i.e., 15.60% , 32.36% , 48.50% .

Storey level-X	Structure with shear walls provided at peripheral corners(mm)			
	0°	10°	20°	30°
1	0.292	0.383	0.616	0.803
2	0.942	1.16	1.547	1.836
3	1.637	1.978	2.674	3.05
4	2.445	3.069	3.664	4.416
5	3.347	4.208	4.981	5.897
6	4.324	5.461	5.896	7.365
7	5.357	6.998	7.48	8.493
8	6.429	8.291	8.608	9.758
9	7.521	10.116	10.358	11.438
10	8.617	11.147	12.408	12.615
11	9.701	11.965	13.04	13.973
12	10.759	13.751	14.64	16.398
13	11.776	14.291	16.197	17.981
14	12.744	15.777	17.703	18.518
15	13.647	16.197	19.149	20.199

As compare to 0° model with shear walls provided at peripheral corners in plan the percentage increasing of the models resting on 10°, 20°, 30° i.e., 18.68% , 40.31% , 48.01% .

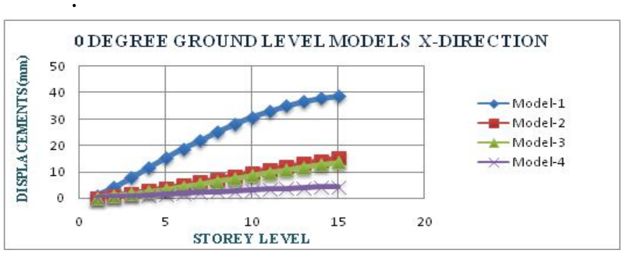


Fig: 5.1 (a) The Displacements of a models in the direction of X on plane ground (0°)

The lateral displacement is minimum for shear walls are provided complete external walls in plan and it is reduced by 88.69% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 60.89% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 64.81% compared to structure without providing shear walls.

Storey level-X	Structure with shear walls provided completely external walls(mm)			
	0°	10°	20°	30°
1	0.227	0.27	0.486	0.726
2	0.497	0.611	0.92	1.268
3	0.79	0.976	1.376	1.828
4	1.103	1.361	1.852	2.407
5	1.431	1.761	2.34	2.998
6	1.769	2.169	2.835	3.594
7	2.111	2.581	3.332	4.192
8	2.454	2.992	3.827	4.785
9	2.791	3.397	4.315	5.371
10	3.117	3.79	4.791	5.943
11	3.427	4.166	5.249	6.499
12	3.714	4.52	5.685	7.033
13	3.973	4.846	6.095	7.542
14	4.198	5.139	6.474	8.022
15	4.385	5.396	6.82	8.47

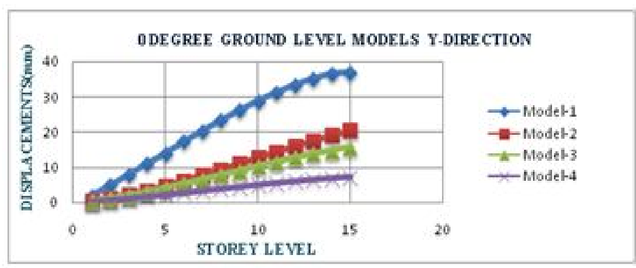


Fig: 5.1 (b) The Displacements of a models in the direction of Y on plane ground (0°)

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 80.44% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 44.45% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 57.56 % compared to a structure without providing shear walls.

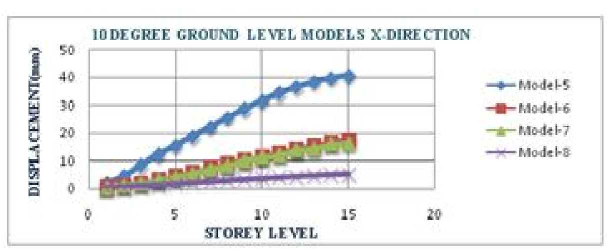


Fig:5.2 (a) The Displacements of a models in the direction of X on slope ground (10°)

The lateral displacement is minimum for shear walls are provided complete external walls in plan and it is reduced by 86.76% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 56.98% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 60.26% compared to structure without providing shear walls.

Fig:5.2 (b) The Displacements of a models in the direction of Y on slope ground (10°)

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 80.94% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 44.08% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plane displacements are reduced by 57.56% compared to structure without providing shear walls.

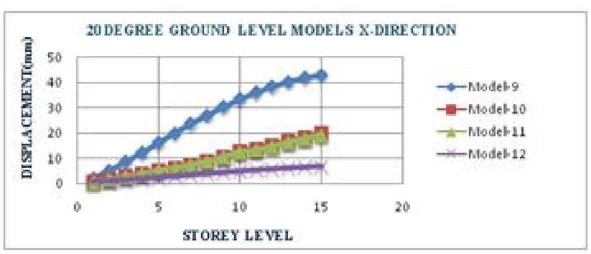


Fig:5.3 (a) The Displacements of a models in the direction of X on slope ground (20°)

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 84.15% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 53.34% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 55.50% compared to structure without providing shear walls.

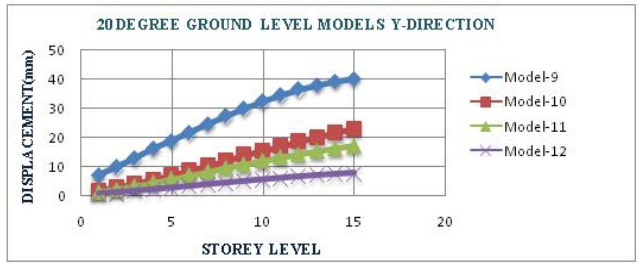


Fig:5.3 (b) The Displacements of a models in the direction of Y on slope ground (20°)

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 80.14% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 42.46% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 56.93% compared to structure without providing shear walls.

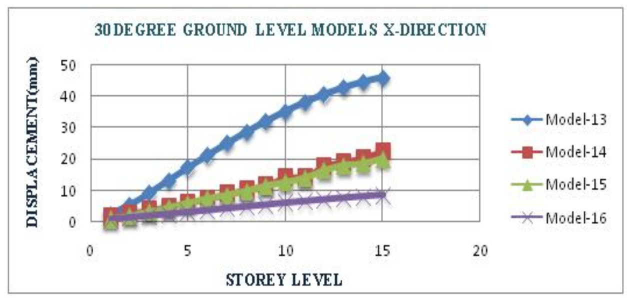


Fig : 5.4 (a) The Displacements of a structure in the direction of X on sloping ground (30°).

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 81.60% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 51.08% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plane displacements are reduced by 56.13% compared to structure without providing shear walls.

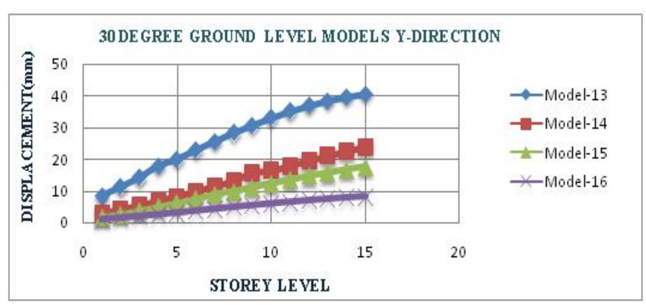


Fig : 5.4 (b) The Displacements of a structure in the direction of Y on sloping ground (30°).

The lateral displacements is minimum for shear walls are provided complete external walls in plan and it is reduced by 79.36% compared to without providing shear walls. Shear walls provided symmetrically displacements are reduced by 40.84% compared to structure without providing shear walls. Shear walls provided at peripheral corners in plan displacements are reduced by 56.25% compared to structure without providing shear walls.

Comparison of Storey drift :

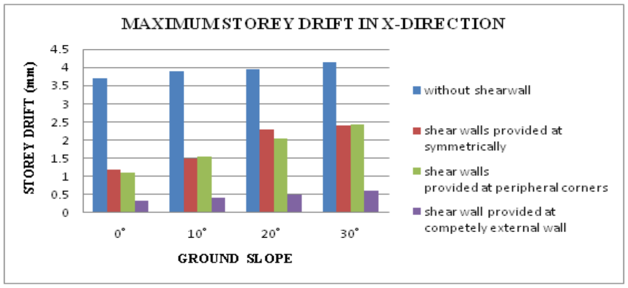


Fig : 5.5 (a) Maximum storey drift in X-direction of buildings resting on different slopes (0°, 10°, 20°, 30°)

The storey drift for the building resting on the flat ground have less values compare to sloped ground. As the slope of the ground is increasing the storey drift also increasing.

As compare to 0° model in x-direction with slope ground and without providing shear walls in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 5.13% , 6.78% , 11.73%.

As compare to 0° model in x-direction with slope ground and shear walls provided at symmetrically in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 26.30% , 92.77% , 101.26%.

As compare to 0° model in x-direction with slope ground and shear walls provided at peripheral corners in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 40.23% , 87.04% , 121.25%.

As compare to 0° model in x-direction with slope ground and shear wall provided at completely external wall in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 20.11% , 44.89% ,74.34%.

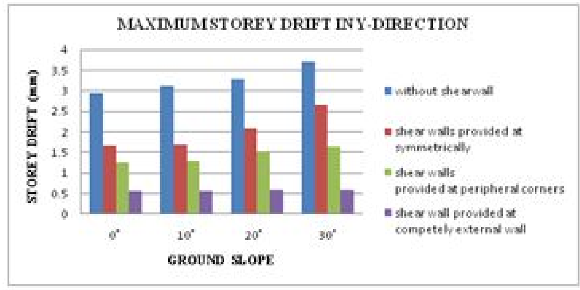


Fig : 5.5(b) Maximum storey drift in Y-direction of buildings resting on different slopes (0°, 10°, 20°, 30°)

As compare to 0° model in y-direction with slope ground and without providing shear walls in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e.,5.82% , 11.85% , 26.53%.

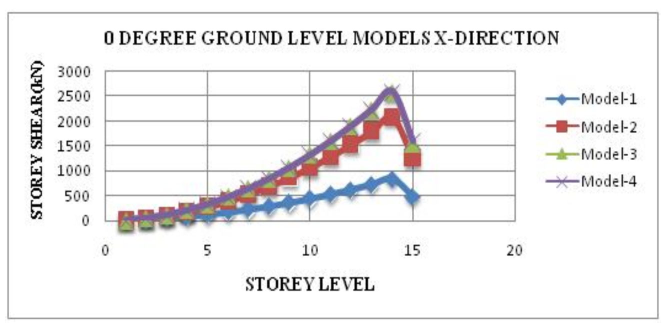
As compare to 0° model in y-direction with slope ground and shear walls provided at symmetrically in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 1.85% , 24.88% , 59.11%.

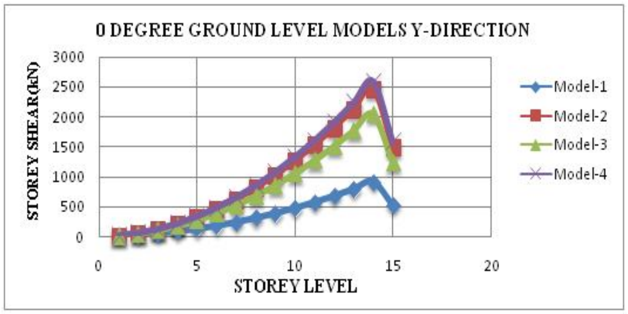
As compare to 0° model in y-direction with slope ground and shear walls provided at peripheral corners in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 2.29% , 20.66% , 30.00%.

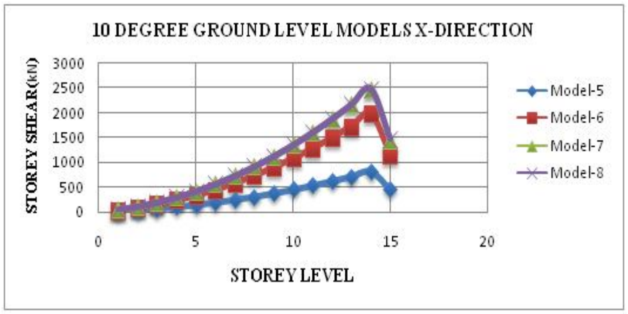
As compare to 0° model in y-direction with slope ground and shear wall provided at completely external wall in plan, the percentage increasing of the models resting on 10°, 20°, 30° i.e., 0.35% , 2.47% , 4.06%.

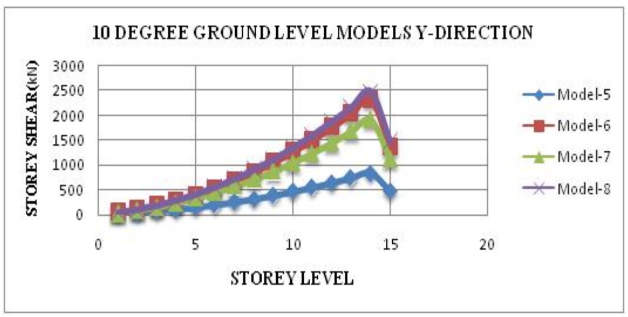
It is observed that storey drift of all models at every storey are found to be within the permissible limit i.e 12 mm.

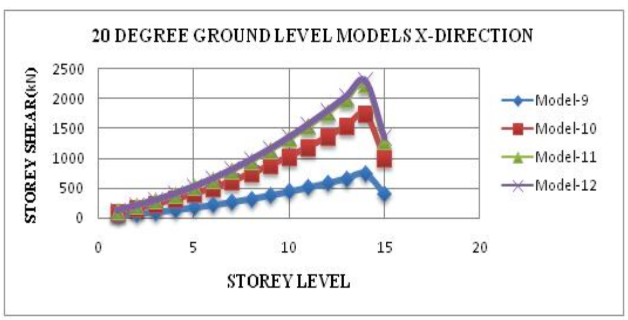
Storey Shear :

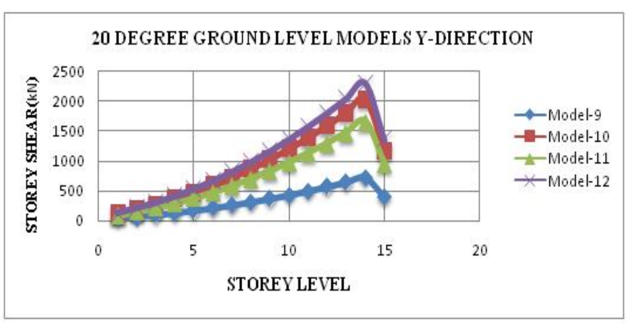


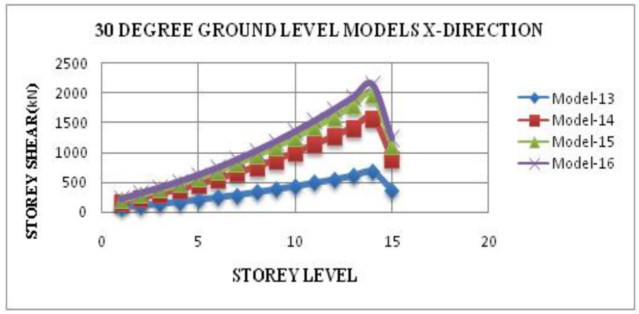












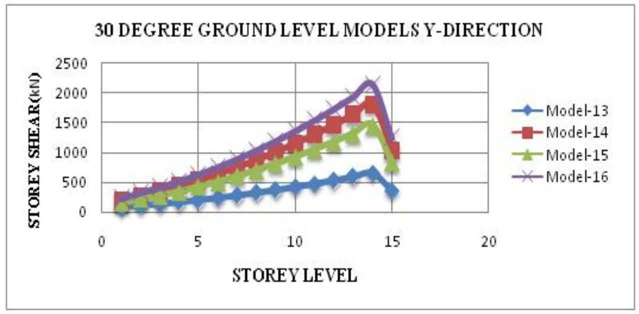


Fig : Storey Shear at X and Y direction of buildings resting on (0°, 10°, 20°, 30°).

It is observed that maximum storey shear values occur in complete external walls in plan compare to without providing shear walls, providing at peripheral corners, providing symmetrically in plan. It is also observed that the maximum value of storey shear that occurred at upper storey are decreasing when the slope of the ground is increasing. It is also observed that the minimum values of storey shear that occurred at lower storey are increasing when the slope of the ground is increasing.

Base Shear :

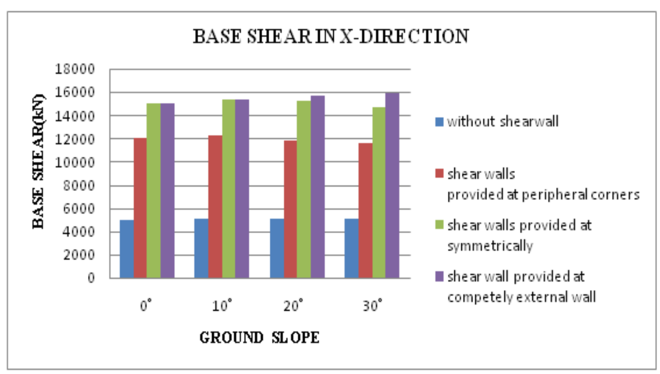


Fig : 5.10 (a) Base Shear X-direction of buildings resting on different sloping ground(0°, 10°, 20°, 30°).

It is observed that the model lying on 10 degree slope ground have relatively higher base shear value compare to the 0,20 degree sloped ground models i.e. without shear wall, with shear wall provided symmetrically in plan and at peripheral corners in plan. It is also observed that shear wall provided completely external walls in plan have higher base shear values compare to other models. It is also observed that shear wall provided at symmetrical in plan have higher base shear values compare to other models i.e., at peripheral corners in plan and without shear wall.

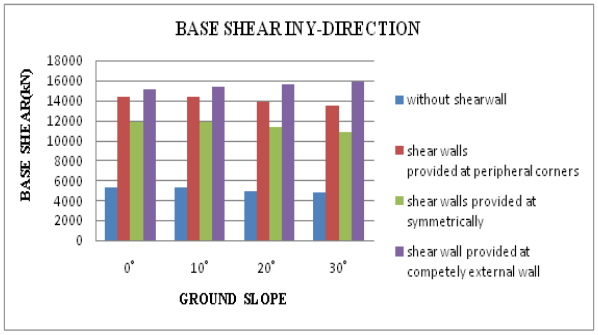


Fig : 5.10 (b) Base Shear Y-direction of buildings resting on different sloping ground (0°, 10°, 20°, 30°) .

It observed that base shear is less for without shear wall model compare to other models. The model having with shear wall provided symmetrically in plan less base shear compare to models i.e., at peripheral corners and complete external walls**.** It is also observed that shear wall provided completely external walls in plan have higher base shear values compare to other models.

IV. FUNDAMENTAL TIME PERIOD

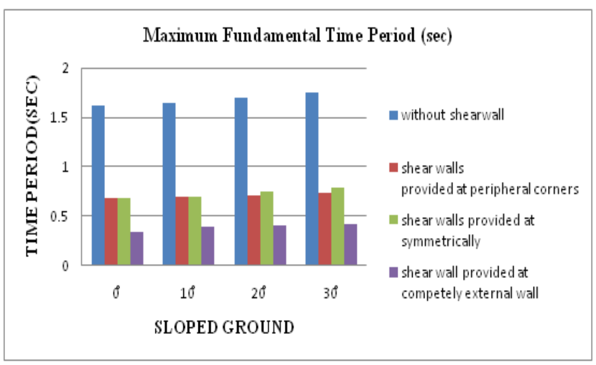


Fig : 5.11 Maximum Fundamental time period of buildings resting on different sloping ground (0°, 10°, 20°, 30°).

It is observed that maximum Fundamental Time Period is increasing along slope of the ground is increasing. Fundamental Time Period is increasing when without shear wall along the slope (0°,10°,20°,30°) is about 1 to 8%.By Providing shear wall at different positions maximum Fundamental Time Period is reduce by 54% to 79%.

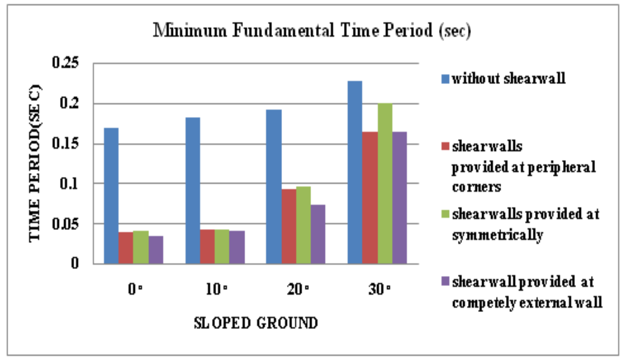


Fig : 5.12 Minimum Fundamental time period of buildings resting on different sloping ground (0°, 10°, 20°, 30°).

It is observed that minimum Fundamental Time Period is increasing along slope of the ground is increasing. Fundamental Time Period is increasing when without shear wall along the slope (0°, 10°, 20°, 30°) is about 7% to 33%. By Providing shear wall at different positions minimum Fundamental Time Period is reduce by 11% to 80%.

V. CONCLUSIONS

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. It is observed that the displacements of a structure without shear wall resting on a sloped ground are found to be more compare to flat ground (0°) i.e., as the slope of the ground increasing the displacements also increasing. The displacements are increasing about 5 to 19 % depending upon the ground slope (10°, 20°, 30°).
4. It is observed that the presence of shear wall influences the overall behavior of structures when subjected to lateral forces. Lateral displacements are considerably reduced about 40 to 89% while contribution of the different position of shear wall in plan on sloping ground.
5. From the present work that has been identified that storey drift of a structure without shear wall resting on a sloped ground are found to be more compare to flat ground(0°) i.e., as the slope of the ground increasing the storey drift also increasing. The displacements are increasing about 5 to 27 % depending upon the ground slope (10°, 20°, 30°).
6. Storey drift are considerably reduced about 28 to 90% while contribution of the different position of shear wall in plan on sloping ground.
7. It is also observed that the maximum value of storey shear that occurred at upper storey are decreasing when the slope of the ground is increasing. It is also observed that the minimum values of storey shear that occurred at lower

storey are increasing when the slope of the ground is increasing.

8. It is observed that a structures with RC structural wall provided complete external wall in plan are having relatively higher base shear and storey shear values than the other models.
9. It is observed that the models lying on 10 degree slope ground have relatively higher base shear value compare to the 0, 20 degree sloped ground models.
10. It is observed that maximum Fundamental Time Period is increasing along slope of the ground is increasing. Fundamental Time Period is increasing when without shear wall along the slope (0°, 10°, 20°, 30°) is about 1 to 8%. By Providing shear wall at different positions maximum Fundamental Time Period is reduce by 54% to 79%.
11. It is observed that minimum Fundamental Time Period is increasing along slope of the ground is increasing. Fundamental Time Period is increasing when without shear wall along the slope (0°, 10°, 20°, 30°) is about 7% to 33%. By Providing shear wall at different positions minimum Fundamental Time Period is reduce by 11% to 80%.

VI. 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 and dampers.

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