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Seismic performance and shear wall Location assessment of a RC building- Evaluating between plain and sloping grounds

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Abstract - *Since two decades the principles of Structural design has not changed, now limit state method is turning into conventional it is no more accounted as modern design principle. Based on the conventional Standards Designs of RC and steel both, the method we here been following involves is based on elastic design principles of elastic design which is conventional and this is followed since many years. Beyond the elastic design there is also a modern and futuristic method which involves the design beyond the material inelastic range and is known as '**Performance based design**'. A performance based design is an choice of the design based on extent of damage of the structure caused due to seismic forces,before it is subjected to or if the structure is seismically deficit proper response parameter has to be estimated.The objective study is to evaluate state of art of the Seismic performance of a Moment Resisting Reinforced concrete structure. The evaluation is majorly between the structure supported on plane and sloping terrain. Where the further study involves, deciding the possible methods adopted for improving the lateral resistance of the building by shear walls with various and best suitable positions within the respective structural frames. This analysis is carried out using non-linear static pushover analysis method using SAP 2000, the results of pushover is checked for its yeilding behavior of the sturctural elements against the same lateral displacement and force which was computed from the elastic design and checking its seismic performance for both the cases mentioned above.The comparison of various results obtained from pushover analysis such as base shear,storey displacement,storey drift and storey shear is done on G+10 building.In order to ensure that we have a validated results, the structure is checked for various methods of seismic anaysis like static, Dynamic and nonlinear dynamic analysis, which is necessary for concluding remarks for the comparision study.*

Key Words: **Storey Drift, displacement, non linear dynamic analysis, performance based, Pushover**.

1. INTRODUCTION

Earthquake is a natural phenomenon which is most uncertain and is most disastrous to human kind of all characteristic adverse effects and causes movement of earth soil due to arrival of extensive strain vitality at the fault and this strain energy travels as seismic waves in every direction of the earth crust. These waves may occur at any immediate time and has different wave amplitudes and also has different energy levels. Sometimes the sharpness of the ground shaking at this event of earthquake may be major, moderate, or minor effect. The intensity of the earthquake may be measured by extent which will be acquired by taking the information of ground movements in seismograph. Be that as it may, unsettling influence of the ground will have distinctive, extraordinary at various areas of the same greatness. It can valued on (Modified Mercalie Intensity) MMI scale. Globally, natural forces or natural disasters, earthquake have capacity to make greatest disaster or damage. Seismic waves are arbitrary in nature and are not predictable in nature, different engineering tool or structure to be the structure under the action on seismic forces. Seismic forces delicately modeled so that to determine the actual behavior of the building with getting the idea of failure and it should be managed. Due to Improper Availability of flat land in hilly areas ,most of the buildings have to be constructed on sloping grounds with the regular or irregular configuration of building. Due to increase in population as well residential demand is also increasing day by day. Because of this reason scarcity of plain grounds is also there, and also some of the cities are also situated in sloping grounds because lack of plain grounds. In India, the northern part is covered with most of the hilly areas and most of the tourist places are available. So that many hotels and many other buildings are constructed on sloping grounds.

1.1 SHEAR WALL

The RCC structural walls is one of the lateral force resisting system element in RC building because by providing these element the building will be stiffer and it can resist the earthquake force and lateral displacement. The RC shear walls are connected to the floor slab so that it can act as diaphragms resisting aerial force. Shear walls can also be used as retrofitting of the constructed building. It is now fact that established, the stiffer buildings attract more forces, hence the stiffer building should attract, dissipate or absorb more seismic energy. Practically such RC structures can sustain for short duration earthquakes very efficiently.

1.2 Performance Based Design

Performance based earthquake engineering is new techniques used in the earthquake resistant structure. It is limited state design which covers the entire range of these problems faced by engineers. This technique used to predict the performance of building under seismic actions. The two main elements which are considered in performance based design is demand & capacity capacity represents that the resistance offered by the building due to seismic demand represents the ground motion during earthquake. When the seismic forces are generated and acted upon the building which is the demand & the considerable amount of resistance should be given by the structure so that at least the occupants can & scape from the building. One when the demand & capacity is defined performance check is done so as to check the defined cross sections non- structural & structural components deteroited within the safer limit.

2. Pushover Analysis

The analysis of pushover is a non-linear procedure for static structure in which the loads which are applied sideways magnitude intensities in increased incrementally carry on the loading arrangements in predefined in addition to the building height. Failure modes & the links which are weak are identified in the structure. The Pushover analysis which is the non-linear stile analysis & solved by using software's such as ETABS, SAP-2000, ADINA ,SC-Push 3D Fig 1.3 shows the curve (i.e.) Base shear Vs displacement which we can get in above software's Missioned these software analysis the structure using iterative procedure & is difficult to solve manually & works on finite elements program with complex geometry & checks for deformation of tinges to determine ultimate deformation.

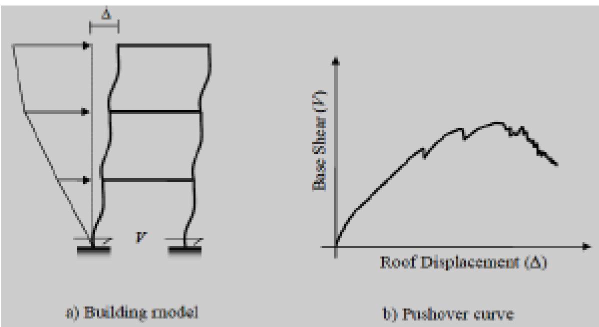

Fig -1: Pushover Analysis

1.3 LITRATURE REVIEW

"Birajdar and Nalawade, (2004), [1], paper entitled ''Seismic analysis of building resting on sloping ground", Studied the earthquake performance of a complex sructure or on sloping ground. In this literature, the structure was analyzed for 24 storey building (ie) RC structure frame with 3-different modification of structure as step back building set back building and set back building. There 3-configuration of the social system is positioned on a gradient of 27 stages with the horizontal ground surface. With this building configuration and the building is located in zone III and is analyzed using response spectrum method to arrive out the performance of the structure for seismic force they also carried 3D analysis for the analysis of torsional effect of the building, for analysis it was established that increase in the top story of building the displacement and the time period was increased and also in this literature they found that the column has maximum shear for at external left was greater then the in comparison to the other column. Thus they gave conclusion that the acute left column in building whichever is short and is more affectionate for earthquake force than any other column they concluded that the uneven distribution of shear force leads to torsional moment.

Nagargoje and sable,(2012), [2], paper entitled, **"Seismic Performance of Multi-Storeyed building on Sloping ground",** In this journal that analysis is done arranged the structure to find out and realization of a structure on sloping ground, using the method of Dynamic analysis in the form of highest floor movement & base shear. These study of different cases was taken out on 36 structures with three different types of configurations with set back step back and set back in zone III. In this literature the contrastive study of storey displacement between step back structure is more when compared to step back set back and set back building and also found base shear was excess in step back ,set back building in the range 60-260% and concluded that step back set back building was more commending for hill slopes.

Singh et all ,(2012),[3], ''Seismic Behavior of building located on Slopes-An analytical study ad some observations from Sikkim Earthquake of September 18-2011'',An analytical case study was taken out on buildings which is positioned on slope 45 degree has of 7 bays on slope and three bays across the hill slopes. The building is in the zone IV and analyzed with time history analysis method. The footings were provided at two different levels on ground. To analyze and compare the different configuration models of the building is analyzed for five set of earthquake motions in which they have taken into account from strong earthquake motion database of pacific earthquake engineering research Centre. After analyzing they found that the storey shear was resisted by short column. The torsional effect was also seen and is characterized by on average storey drift. They achieved that the step back building are susceptible to torsional affect under hill slope for earthquake excitation. They also came to conclusion that inter storey drift in top 3 storey of hill slope structure are very close to those in the 3 storey normal configuration building.

Prashant D and Jagadish.Kori.G, (2013) ,[4], "Seismic Response of One way Slope RC frame building with Soft storey", in this journal they considered the model of 10 storey building with 27° sloping ground and as well 5 bays in each direction that is X and Y direction. In this paper they also made consideration of infill that is with infill and without infill that is bare frame structure and studied about the displacement, base shear, time period etc. Consideration of building in seismic zone III with SMRF, they concluded that the time period of without infill model is 1.975 sec and is 96% - 135% more than the infill model. They also observed the variation of displacement in the model like infill and without infill was found to be more in bare frame compared infill model, which clearly shows the influence of brick infill. They also considered the base shear which was almost 250% more comparison with model without infill. As even they concluded lastly with formation of plastic hinges and it was shown that more number of hinges were formed in without infill model. This clearly determines the stiffness in a building.

Rayyan-Ul Hassan and H.S.Vidyadhara ,(2013),[6] "Seismic Analysis of Earthquake Resistant Multi Bay Multi Storyed 3D - RC Frame", In this literature they wanted to study the multi-storey bay RC frame with model configuration of 12 storey building with 4 bays in each direction which is located on sloping ground 1:1/3. Here in this literature they also considered the building with infill walls in upper storey including shear wall at corner of the structure and is seismic zone V. they used the method such as pushover ,static analysis and response spectrum and found the values of displacement ,base shear and reviewed the paper. They found in displacement result that there was reduction in that in the model of infill shear wall which was combination and compared with bare frame, which clearly tells us that the infill with shear wall contribute to the stiffness and there will be reduction in displacement. From response spectrum analysis it was concluded that they found 50.95% and 73.97% for infill and bare frame respectively. As per the standards of code the displacement is permitted or lateral drift should be 0.004 times the height of building overall and in this study they found that the drift was more in bare frame when compared by infill and sloping ground. The overall conclusion of this journal is that bare frame will have more displacement and stiffness also, but analyzed from infill and sloping ground it was reduced, it clearly determines that shear wall and infill contributes for overall stiffness of the building.

Jitender Babu et al,(2012),[7] "Pushover Analysis of Existing 3 Stories RC Flat slab Building" In this literature the author considered the plan symmetry and asymmetry with different bay sizes and carried out pushover analysis for the performance analysis on sloping ground with 4 storey and 30 degree sloping. After analyzing the author found that the short column lies in vulnerable area that is beyond the collapse prevention. They considered the values of displacement and base shear. For asymmetry building displacement was 104×10^{-3} m and base shear was 2.7×10^{3} kN.

1.4 DETAILED DISCRIPTION OF BUILDING FOR ANALYSIS

STRUCTURE TYPE	SMRF	
RESPONSE REDUCTION FACTOR	5	
SEISMIC ZONE	IV	
SEISMIC ZONE FACTOR	0.24	
HEIGHT OF THE BUILDING	38.5m	
SOIL CONDITION	Medium	
THICKNESS OF SLAB	150mm	
BEAM SIZE	300x450	
COLUMN SIZE	380x700	
LIVE LOAD	3kN/m^2	
WALL LOAD	13.92kN/m^2	
FLOOR FINISH	1kN/m^2	
MATERIAL PROPERTIES	**Concrete grade**	**Steel grade**
	M30	Fe-415

Sloping ground angle	27 degree
No of bays in X- direction	5 No's
No of bays in Y-direction	5 No's
Young's modulus 5000√fck	2.74×10^{10}N/mm^2
Poisson's ratio	0.2

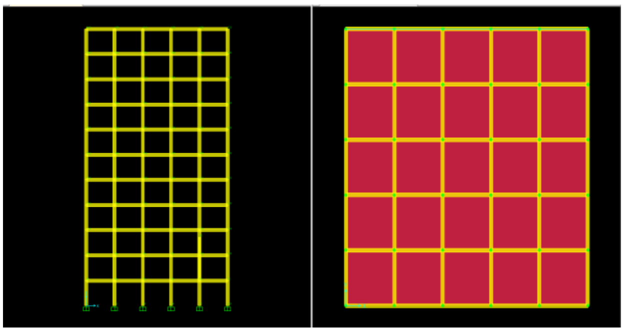

Figure 2- Model-1

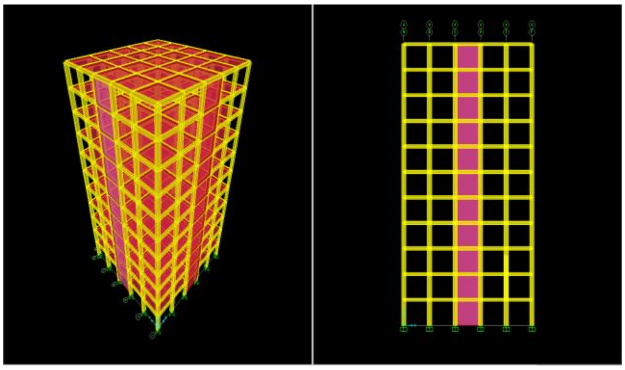

Figure 3- Model-2

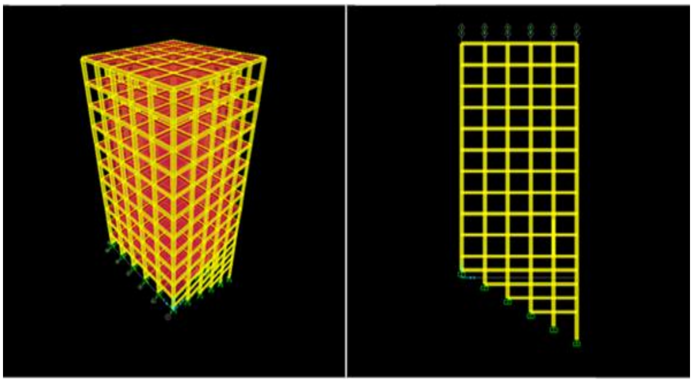

Figure 4- Model-3

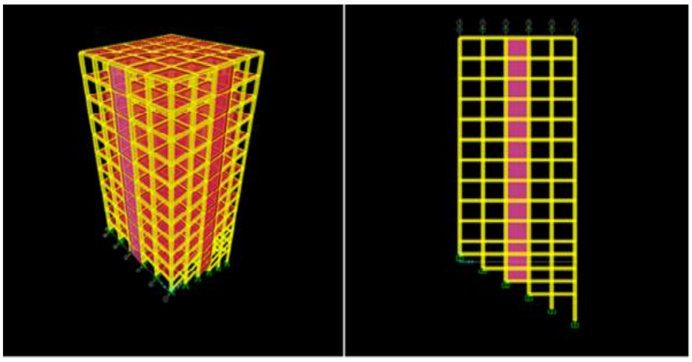

Figure 5- Model-4

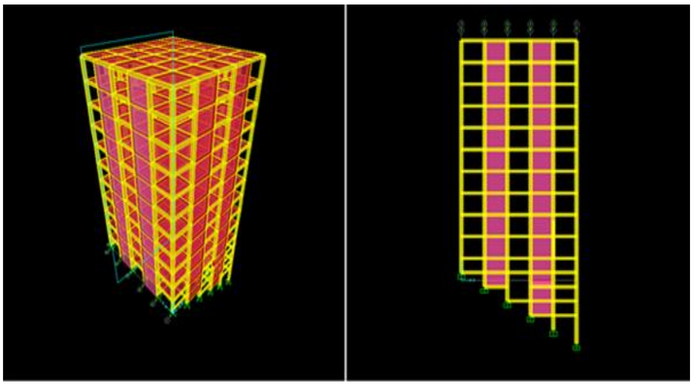

Figure 6- Model-5

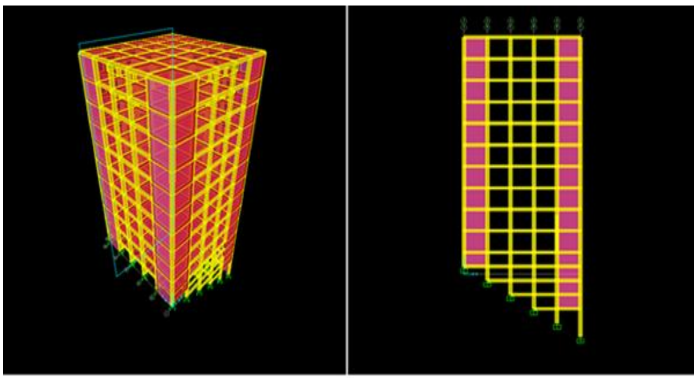

Figure 7- Model-6

1.5 ANALYSIS RESULTS

1.5.1. COMPARISON OF STORY DISPLACEMENT

TABLE-1

DISPLACEMENT IN X- DIRECTION(DYNAMIC) IN mm					
MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
22.337548	20.059578	24.514045	22.058231	19.274702	18.075273
21.782246	18.346943	23.750728	20.322687	17.560701	16.303041
20.825872	16.452194	22.575265	18.410482	15.746917	14.490835
19.468149	14.448864	20.964165	16.391605	13.868682	12.631109
17.750447	12.346275	18.952046	14.267201	11.931866	10.748448
15.705826	10.170525	16.571131	12.054614	9.958751	8.866845
13.363572	7.965634	13.857313	9.784622	7.982581	7.020049
10.750008	5.796624	10.850197	7.504996	6.049791	5.251072
7.88744	3.756631	7.604267	5.289968	4.228392	3.620968
4.836167	1.984154	4.277833	3.229988	2.599633	2.196958
1.844201	0.635789	1.395138	1.450207	1.255434	1.057642
0	0	0	0	0	0

TABLE-2

DISPLACEMENT IN Y- DIRECTION(STATIC) IN mm					
MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
102.595984	20.107428	195.152221	80.009874	59.688242	54.629219
99.555709	18.224395	190.475015	74.141948	54.908171	49.757909
94.287434	16.173358	182.009411	67.721068	49.859429	44.78557
86.864752	14.025553	169.902651	60.908658	44.599802	39.689201
77.684258	11.795366	154.823607	53.695244	39.141108	34.526198
67.154507	9.529326	137.338735	46.168638	33.547939	29.356811
55.646086	7.292804	117.936933	38.477204	27.928076	24.277653
43.483422	5.167671	97.047953	30.823252	22.418076	19.397013
30.96328	3.251485	75.056011	23.462298	17.186294	14.84402
18.457108	1.660155	52.234724	16.698249	12.419417	10.748996
6.843148	0.520259	30.188372	10.784068	8.271626	7.224244
0	0	0	0	0	0

TABLE-3

DISPLACEMENT IN Y- DIRECTION(DYNAMIC) IN mm					
MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
19.772432	21.680782	34.45706	26.024768	22.089938	20.937613
19.283912	19.718348	33.733443	24.078201	20.303125	19.061733
18.440565	17.592668	32.442543	21.986066	18.438219	17.160684
17.242086	15.381185	30.602009	19.81148	16.521822	15.229433
15.724959	13.089318	28.266725	17.552698	14.559104	13.291053
13.918418	10.745238	25.476084	15.227786	12.56828	11.365751
11.848329	8.392122	22.270141	12.863086	10.576789	9.483155
9.537602	6.094222	18.687029	10.495657	8.618354	7.67415
7.005455	3.945724	14.755554	8.179932	6.73752	5.97591
4.29741	2.083436	10.482632	5.993136	4.988643	4.426753
1.629471	0.682629	6.180834	4.006244	3.420109	3.060057
0	0	0	0	0	0

TABLE-4

DISPLACEMENT IN Y- DIRECTION(DYNAMIC) IN mm					
MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
19.772432	21.680782	34.45706	26.024768	22.089938	20.937613
19.283912	19.718348	33.733443	24.078201	20.303125	19.061733
18.440565	17.592668	32.442543	21.986066	18.438219	17.160684
17.242086	15.381185	30.602009	19.81148	16.521822	15.229433
15.724959	13.089318	28.266725	17.552698	14.559104	13.291053
13.918418	10.745238	25.476084	15.227786	12.56828	11.365751
11.848329	8.392122	22.270141	12.863086	10.576789	9.483155
9.537602	6.094222	18.687029	10.495657	8.618354	7.67415
7.005455	3.945724	14.755554	8.179932	6.73752	5.97591
4.29741	2.083436	10.482632	5.993136	4.988643	4.426753
1.629471	0.682629	6.180834	4.006244	3.420109	3.060057
0	0	0	0	0	0

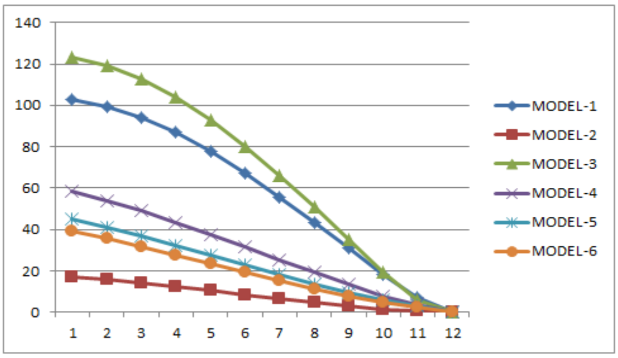

Figure 8

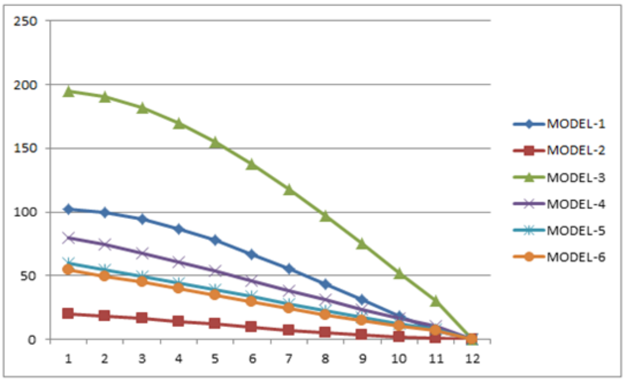

Figure 7

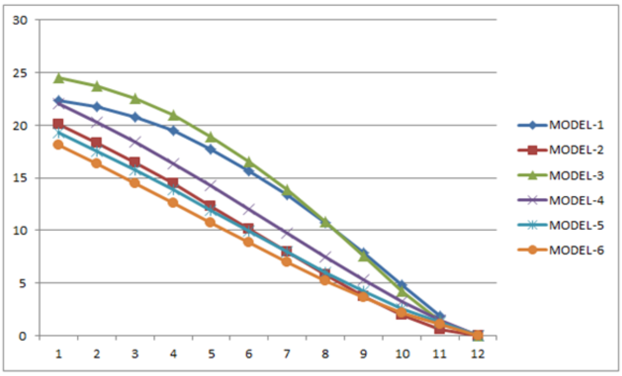

Figure 8

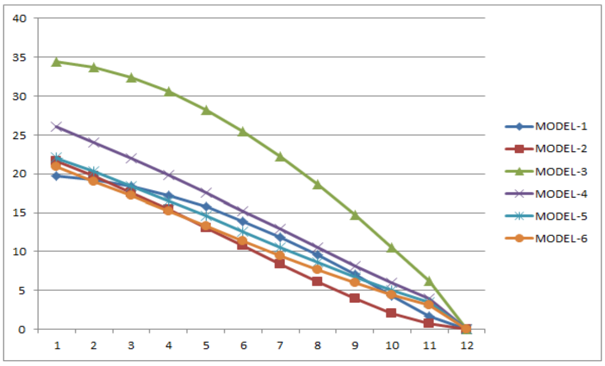

Figure 9

1.5.2. COMPARISON OF BASE SHEAR

TABLE-5

TYPE OF MODEL	STATIC		DYNAMIC	
	EX (kN)	EY(kN)	RX(kN)	RY(kN)
Model-1	3831.482	3831.482	1060.625	935.008
Model-2	4167.785	4167.785	2240.885	2165.625
Model-3	5918.573	5918.573	1390.927	1187.422
Model-4	4435.846	4435.846	2141.544	1834.202
Model-5	4730.674	4730.674	2502.066	2242.218
Model-6	4722.116	4722.116	2648.695	2375.747

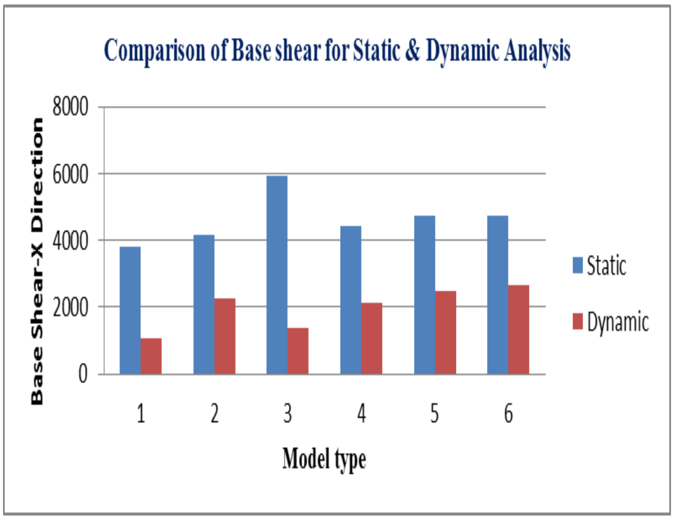

Fig-10

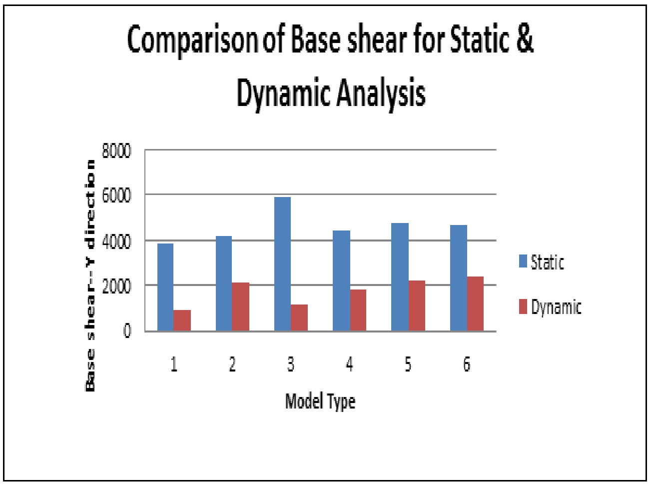

Fig-11

1.5.3 COMPARISON OF TIME PERIOD AND NATURAL FREQUENCY

TABLE-6

Plain Ground without Shearwall	
MODEL-1	
Natural Period	Frequency
2.695865	0.37094
2.695197	0.37103
2.420037	0.41322
0.875958	1.1416
0.875743	1.1419
0.78907	1.2673
0.499749	2.001
0.49968	2.0013
0.454159	2.2019
0.338466	2.9545
0.338459	2.9546
0.308363	3.2429

TABLE-7

Plain Ground with Shearwall	
MODEL-2	
Natural Period	Frequency
1.853496	0.53952
1.728134	0.57866
1.319694	0.75775
0.468925	2.1325
0.445167	2.2463
0.316454	3.16
0.215123	4.6485
0.205661	4.8624
0.185876	5.3799
0.175008	5.714
0.173624	5.7596
0.165715	6.0345

TABLE-8

Sloping Ground without Shearwall	
MODEL-3	
Natural Period	Frequency
3.055243	0.32731
2.462956	0.40602
2.388253	0.41872
1.00329	0.99672
0.778841	1.284
0.772965	1.2937
0.582467	1.7168
0.444217	2.2512
0.430591	2.3224
0.401038	2.4935
0.31598	3.1648
0.287128	3.4828

TABLE-9

Sloping Ground with Shearwall(Center)	
MODEL-4	
Natural Period	Frequency
2.19733	0.4551
1.915405	0.52208
1.499748	0.66678
0.608936	1.6422
0.495018	2.0201
0.375045	2.6663
0.286454	3.491
0.226445	4.4161
0.215098	4.649
0.200872	4.9783
0.194089	5.1523
0.192918	5.1835

TABLE-10

Sloping Ground with Shearwall(Center apart)	
MODEL-5	
Natural Period	Frequency
1.88215	0.53131
1.653572	0.60475
1.22547	0.81601
0.508632	1.9661
0.402928	2.4818
0.298596	3.349
0.232164	4.3073
0.2134	4.686
0.196773	5.082
0.192738	5.1884
0.192449	5.1962
0.191528	5.2212

TABLE-11

Sloping Ground with Shearwall(pheriphery)	
MODEL-6	
Natural Period	Frequency
1.777832	0.56248
1.533276	0.6522
1.046161	0.95588
0.457902	2.1839
0.348046	2.8732
0.234737	4.2601
0.216583	4.6172
0.211263	4.7334
0.19943	5.0143
0.195278	5.1209
0.18985	5.2673
0.189759	5.2698

1.5.4 PERFORMANCE POINT-PUSHOVER RESULT

Performance point of the structure can be found by overlapping the capacity curve and demand curve the point where the intersection of both the curves take that point is called as performance point.

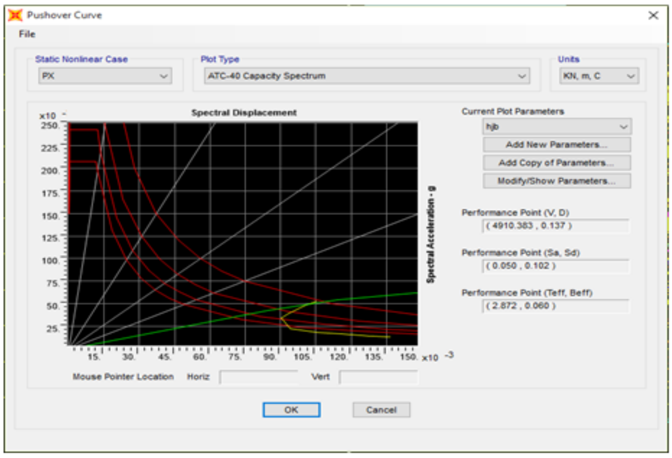

Fig 5.9 Performance point of Model-1 in X-Direction

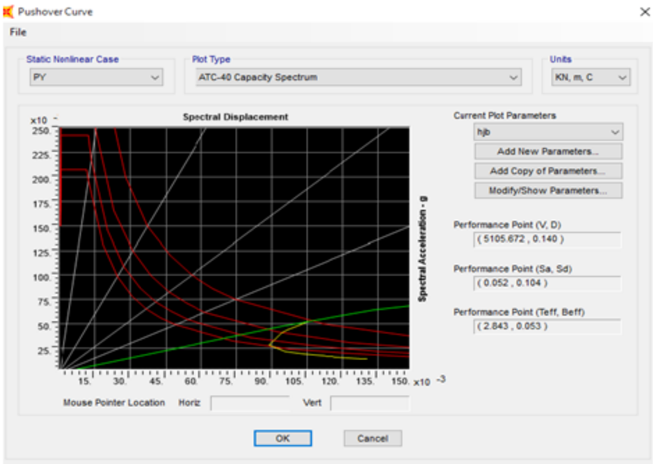

Fig. 5.10Performance point of Model-1 in Y-Direction

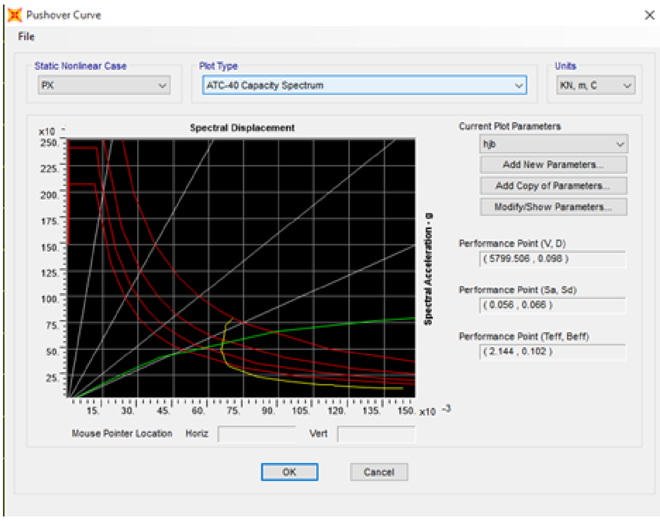

Fig.5.11 Performance point of Model-2 in X-Direction

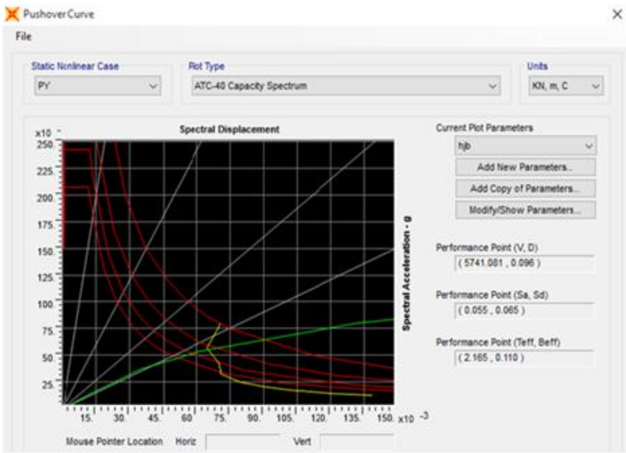

Fig.5.12 Performance point of Model-2 in Y-Direction

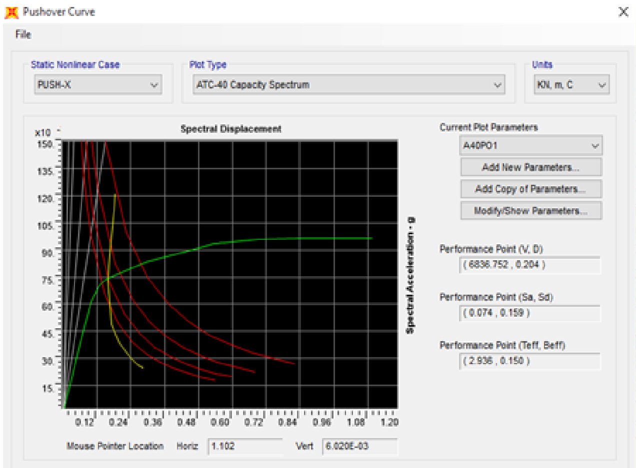

Fig.5.13 Performance point of Model-3 in X-Direction

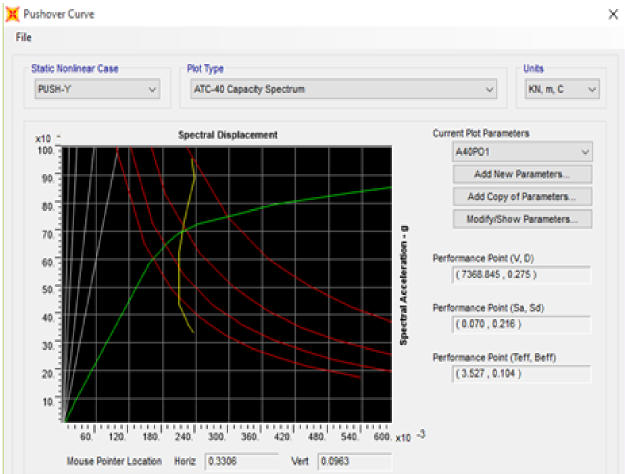

Fig.5.14 Performance point of Model-3 in Y-Direction

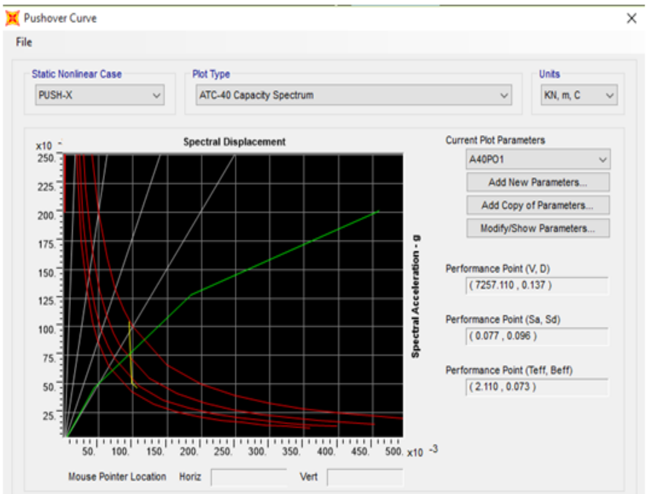

Fig. 5.15 Performance point of Model-4 in X-Direction

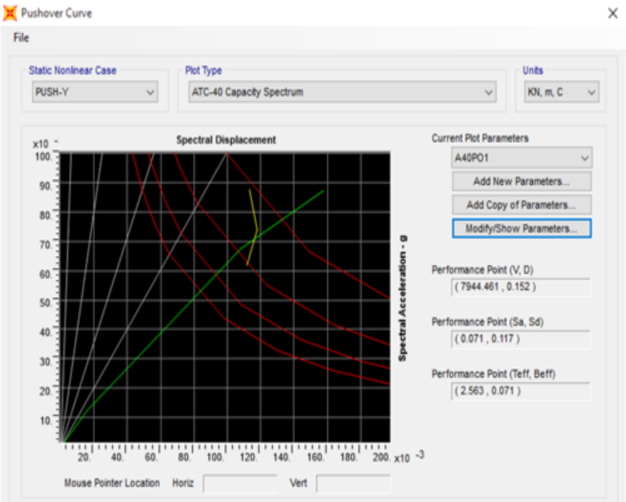

Fig. 5.16 Performance point of Model-4 in Y-Direction

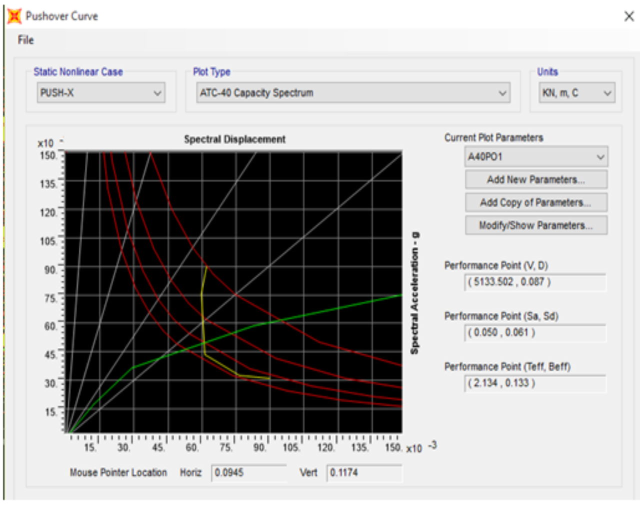

Fig. 5.17 Performance point of Model-5 in X-Direction

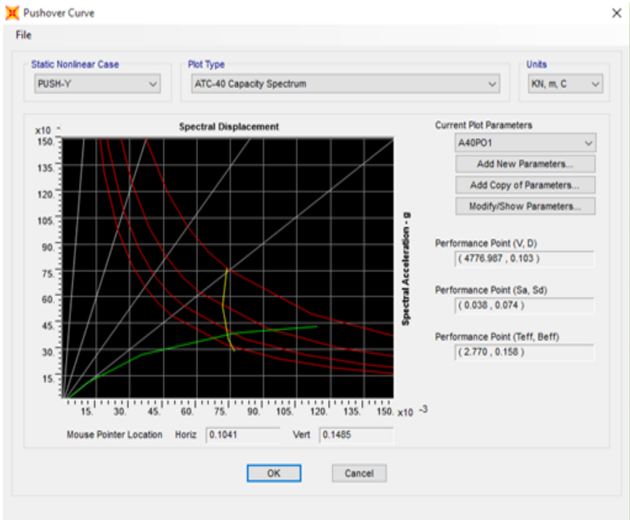

Fig. 5.18 Performance point of Model-5 in Y-Direction

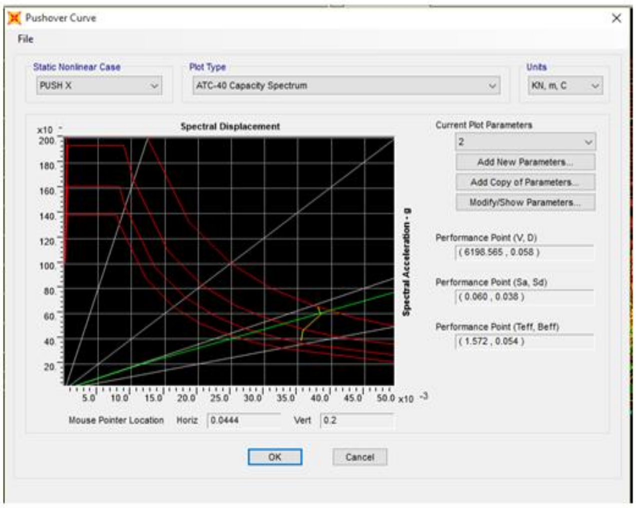

Fig. 5.19 Performance point of Model-6 in X-Direction

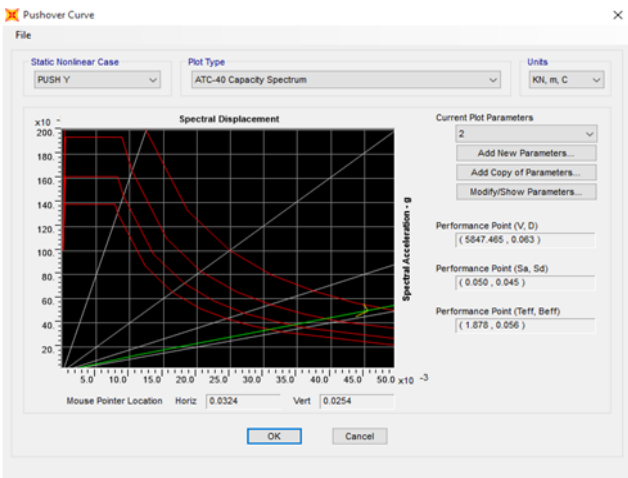

Fig. 5.20 Performance point of Model-6 in Y-Direction

1.5.5 CONCLUSION

1. Base shear vs displacement results shows that the roof displacement is more in for the buildings on sloping ground which shows that buildings on sloping ground is more vulnerable for seismic forces compared to the building on plain grounds.

2. By introducing the shearwall in the building, which has drastically influenced the structure's nature resisting against lateral forces which can be witnessed in the reduced strorey Drifts, Hence shearwall significantly increases the lateral stability.

3. Under three different cases of shearwall at center, center apart and corner, the study has suggested the shearwall at the corners can resist lateral forces well and is better compared to the shearwalls at center apart and shearwall at center apart is better than the shearwall at centre.

4. Looking into the storey shear vs displacement the shear wall at the corner has least storey displacement at top compared with center apart and center apart is least compared to shear wall at center.

5. Twisting moment is more towards the shorter column than the longer columns at the sloping side.

6. Torsional moment is more at the other direction compared to sloping side. There is a substantial decrease in bending moment and shear forces in the columns at the base, when shear wall is introduced compared to building without shear wall.

7. Building on the sloping ground tends to be more vulnerable for seismic forces which can be seen in the performance check. The hinge formation at the base towards the column at the shorter direction is more, this is because the geometry of the building where we can see increased torsional moment nearer to the shorter columns

8. Natural period vs frequency of the building is least for the model no 6 whereas the shearwall is positioned at the corner, hence suggesting us to this location could be preferable for resisting lateral loads more efficiently than any other location.

9. As per the nonlinear results, the hinges formed in the sloping ground is more compared to the plain ones. Most of the hinges is between the range of LS-CP and some of the elements in the range beyond CP which indicates the failure in the plastic range. Retrofitting is possible solution for reducing the seismic vulnerability for the buildings on sloping grounds.

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