An Analytical approach of moment resisting frame on inclined surface in case of seismic loading

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Abstract - *Rigid frame structure constructed on hilly terrain have different behavior because of unsymmetrical in nature and this nature is the cause of additional shear force and torsional moment. In hilly region step back building construction is very common but this construction method can cause inevitably results in structure which is not same for different height of column which can be cause of additional forces during the seismic activity. In this study SMRF building considered which resting on slope ground. Modeling and analysis have been done by using ETAB 2016, to study the effect of response of seismic loading for different configuration of rigid frame. The seismic analysis was done by time history analysis. Dynamic response, storey shear, storey drift, time period of vibration, displacement have been analyzed with different building configuration and different slopes. Frame with critical condition was also analyzed with shear walls.*

Key Words: Moment resisting frame, Sloping ground, ETAB, Time history analysis, shear wall.

1.INTRODUCTION

For economic development of hilly region construction is necessary. Due to less availability of flat terrain in that region structures are constructed on slope. In hilly terrain multistorey rigid frame structure has different behaviour with frame on flat ground. Some buildings have mass and stiffness varying alongside and vertical and horizontal planes in that case torsional analysis is required with seismic loading. Construction on slope surface in seismic prone area exposed to greater shear and torsion.

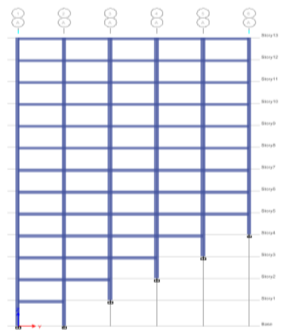
According to Mr. B.G. Birajdar and Mr.S.S. Nalawade[8] step back buildings are more vulnerable than the other configurations of building and torsional moment developed more in step back building. According research of Mr. Satish Kumar and Mr. D.K.Paul[11] irregular buildings with rigid floor system, every floor has different vertical axis for centre of mass and centre of stiffness. And also state that short columns are worst affected. As stated by Zaid Mohammada, Abdul Baqib, Mohammed Arif[2] the step-back set back building experience less torsional and seismic force when contrasted with step-back structures due with less seismic load of the structure. Around 45 % decrease in base shear esteem is seen in instance of venture back mishap structures when contrasted with step-back setups. According Y. Singh & Phani Gade[7] in Sikkim during the earthquake on 18 September 2011 shows the strange failure pattern of buildings. The behaviour is different form the normal buildings on flat surface. In slope surface varying column heights cause stiffness irregularity and the short column resist mostly storey shear. In this study different configuration of building on varying slope analysed by using time history method of dynamic analysis. Results of storey drift, time period of vibration, joint displacement and storey shear has been compared between different configuration of building frame and different ground slope and forces on columns and beams also studied

2. METHODOLOGY

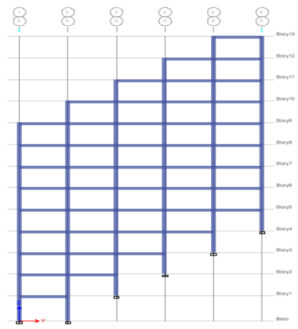
Three-dimension special moment resisting frame used for two different configuration of building one is step back and other is step back set back. Concrete material assumed to be homogenous, isotropic and elastic in nature with modulus of elasticity 5000√fck [10] and Poisson's ratio is 0.2. The seismic analysis is carried out by using non-linear time history analysis using ETABS v 16. Storey shear, storey drift and maximum storey displacement, natural time period of vibration, shear in columns are determined and compare with different configuration of frame structures by using SRSS model combinations. Fe 415 grade of steel reinforcement [10] is used. For analysis point of view, it is assumed that all the foundation supports are fixed. Most critical condition of building frame find out by analyzing and comparing various analytical results of different configurations of building frame. Highly critical cases identified and frames installed with shear walls separately and compare it and find out which method is most suitable for building frame resting on sloping ground in case of seismic loading.

3. STRUCTURAL MODELLING

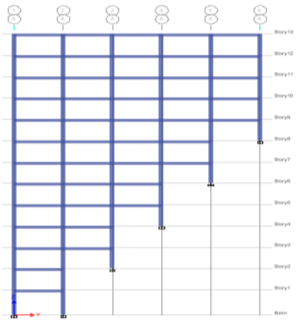
For this study six SMR frame model generated in ETAB V16 simulator. Dimensions of all beams and columns remain same in each model. Beam of size [10] 400X400 mm and size of column 500X500 mm. Fe 415 HYSD [10] bars used for reinforcement. Grade of concrete used in column M30 and in beam grade of concrete M25[10]. Indian standard code IS1893-2002 part 1 used for analysis of seismic response [9] of different configuration of buildings. Different configuration of building frames shown in figures. [11]



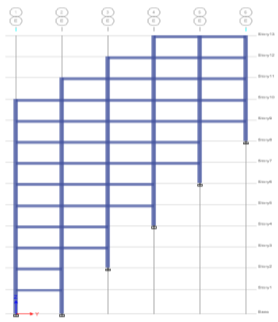
Model 1
Fig. 1 Set Back Frame, Elevation with slope 25°



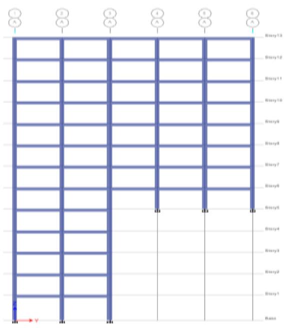
Model 2
Fig. 2 Step Back Set Back Frame Elevation with slope 25°



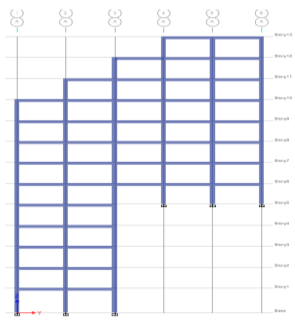
Model 3
Fig. 3 Set Back Frame, Elevation with slope 43°



Model 4
Fig. 4 Step Back Set Back Frame Elevation with slope 43°



Model 5
Fig. 1 Set Back Frame Elevation with Steep Slope



Model 6
Fig. 4 Step Back Set Back Frame Elevation with Steep Slope

Seismic analysis was done by time history analysis [9]. For this study of San Farnando earthquake February 9th, 1971 adopt with peak ground acceleration 1.054 g, durations of 41.72 sec. Height of each storey is 3m and bay width in both x and y direction is 5m.

4. RESULTS AND COMPARISON

4.1 DISPLACEMENT

Table -1 Maximum Storey Displacement

Sr. No.	Model No.	Building Slope	Maximum Displacement
1	Model 1(Set Back Frame)	25°	6.8 mm
2	Model 2(Step Back Set Back Frame)	25°	5.4 mm
3	Model 3(Set Back Frame)	43°	6.13 mm
4	Model 4(Step Back Set Back Frame)	43°	3.6 mm
5	Model 5 (Set Back Frame)	90°	7.79 mm
6	Model 6 (Step Back Set Back Frame)	90°	4.34 mm

Maximum displacement occurs in all six models shown in table 1. All generated models have three different slopes 25°,43°,90° with set back and step set back frame. Table 1 shows that step back set back frames have less displacement comparatively set back frame minimum displacement occurs in model 4. step back set frames have 50% less [1] displacement. It shows that step back set back frame have more stability than the others. But in case of steep slope top storey displacement is maximum in setback frame. But in case of steep slope or 90o slope structure has two different level bases in that case lateral stability provided by slope only work at storey level 5 after that structure behave like it behaves on plain ground. This can be seen in Fig.7 of storey displacement of model 5.

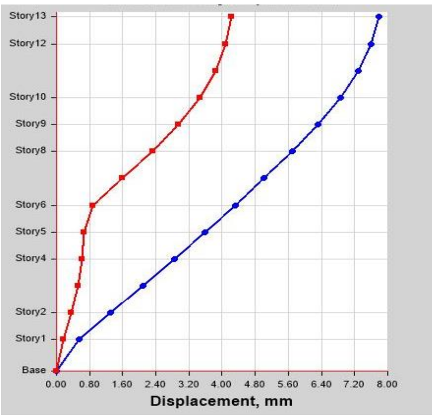


Fig. 7: Storey Displacement of Model 5

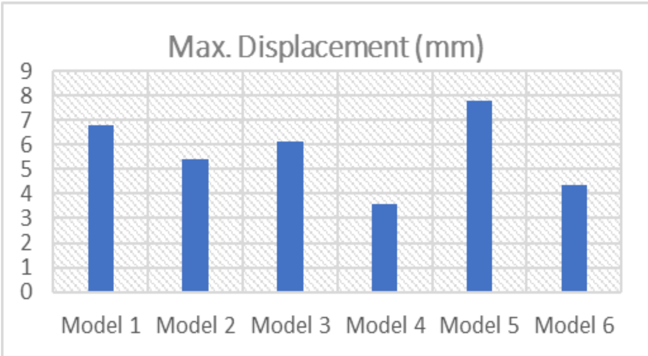


Chart -1: Maximum Storey Displacement

4.2 MAXIMUM STOREY SHEAR

From the analysis step back set back frame is more stable than the setback frame as show in table 2. Maximum storey shear occurred in model 1which has minimum slope and minimum storey shear occurred in model 4 step back set back frame with 43° slope. In every case of slope step back frame show less storey shear. In case of 43° slope storey shear reduced 38.6%. and in case of 25° slope it reduced 29.53 % and in case of slope 90o or steep slope it reduced only 4.73% [8]. This data shows that the when the slope increase value of storey shear decrease this was happening because that slope provides lateral stability to the structure. In case of model 5 and 6 structure model has two bases so in that storey shear in increased as compared with model 3 and 4.

Table – 2: Maximum Storey Shear

Sr. No.	Model No.	Building Slope	Max. Storey Shear (KN)
1	Model 1(Set Back Frame)	25°	264.9
2	Model 2(Step Back Set Back Frame)	25°	207.315
3	Model 3(Set Back Frame)	43°	137.008
4	Model 4(Step Back Set Back Frame)	43°	96.54
5	Model 5 (Set Back Frame)	90°	182.437
6	Model 6 (Step Back Set Back Frame)	90°	173.79

4.3 MAXIMUM STOREY DRIFT

Drift is the result of shear and flexural forces and the column axis deformation. The maximum drift value for different models in table 3. From the table its clearly seen that at slop 25o and 43o drift values are almost same for both configuration of building frame [8]. But in model 5(Step Back Set Back Frame) with steep slope drift value was minimum. Drift is building frame can be determine by difference of two stories displacement divided by the storey height. If the drift value is higher than the permissible limit that can be the cause of joint failure and carks in partition walls.

Table- 3: Maximum Storey Drift

Sr. no.	Model No.	Building Slope	Storey level	Storey drift
1	Model 1(Set Back Frame)	25°	Storey5	0.000484
2	Model 2(Step Back Set Back Frame)	25°	Storey5	0.000332
3	Model 3(Set Back Frame)	43°	Storey9	0.000444
4	Model 4(Step Back Set Back Frame)	43°	Storey9	0.0003
5	Model 5 (Step Back Set Back Frame)	90°	Storey7	0.000319
6	Model 6 (Step Back Set Back Frame)	90°	Storey9	0.000297

4.4 SPECTRAL ACCLERATION

Spectral acceleration for damping 0.05 mm/sec2 shows in chart-2 at top storey level. Model 1 has the maximum acceleration and model 4 has minimum. Step back set back building frame has less mass at top storey level so spectral acceleration is less [1], but in case of setback building frame top storey mass is very large, so value of spectral acceleration is large.

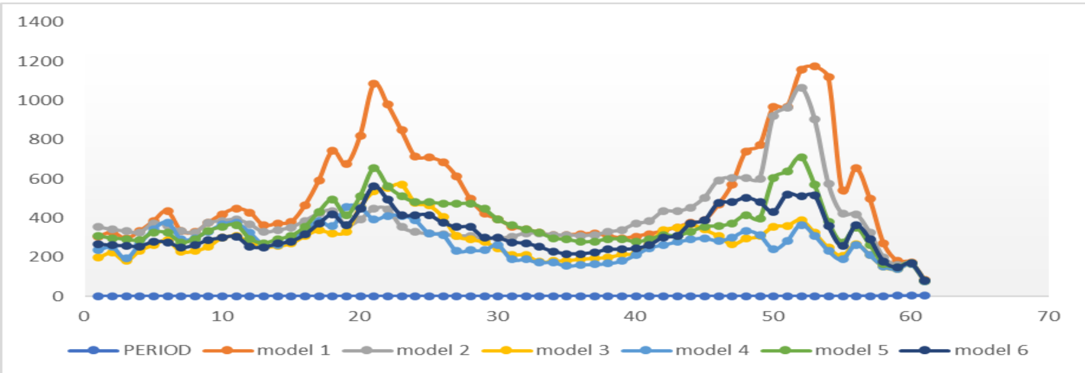


Chart -2: Spectral Acceleration (Damping 0.05) mm/Sec^2

4.5 MAXIMUM NATURAL TIME PERIOD OF VIBRATIONS

Natural time period of vibration is maximum in model 1 and after that in model 5 and it is minimum in model 4 [3]. Its show that the in-sloping ground step back set structural frame has less time period of vibration.

Table – 4 Maximum Natural Time Period of Vibrations

Sr. No.	Model No.	Building Slope	Time of Vibration(sec.)
1	Model 1(Set Back Frame)	25°	1.093
2	Model 2(Step Back Set Back Frame)	25°	0.871
3	Model 3(Set Back Frame)	43°	0.864
4	Model 4(Step Back Set Back Frame)	43°	0.742
5	Model 5 (Step Back Set Back Frame)	90°	0.985
6	Model 6 (Step Back Set Back Frame)	90°	0.824

Fig. 9 shows the graph of cumulative energy in case of seismic loading. This figure shows that at time step 40.34 sec. maximum energy 2.92Kn-m generated for model 1. In model 2 maximum energy at time 40.18 sec is 1.54Kn-m. Model 2 is step back set back frame in that in case of slope 25o. So, in model 1 which is set back frame building has more energy generated. The same behavior can see in model 3,4 and model 5,6. Energy generated in setback building was more than energy generated is step back set back building in each type of slope. Stability of building frame depends upon other than ground motion and material parameters, mass and shape of frame. In step back set back frame mass of structure was less than the setback frame building.

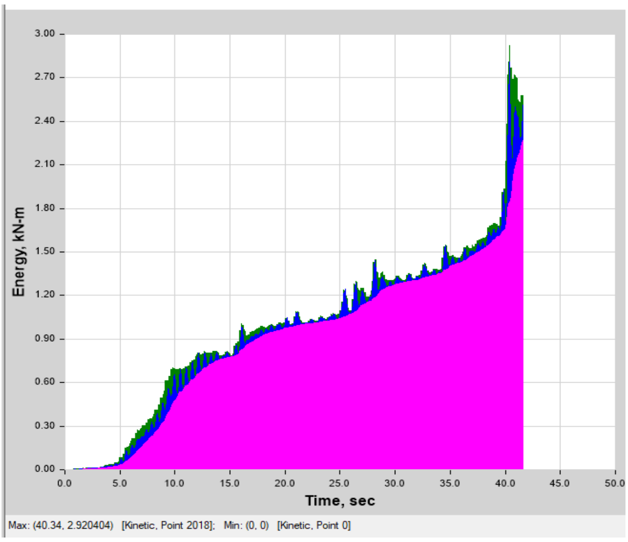


Fig. 9 : cumulative energy for Model 1

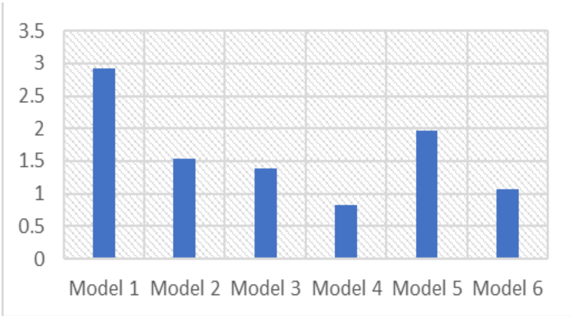


Chart -3: cumulative energy

So, displacement in every step back set back frame model is less and natural time period of vibration was less, so force and storey drift were also less. In all these 6 models, model 1 was the most critical

5. ANALYSIS OF CRITICAL CASE

All the data shows in above paragraphs explain that model 1 is most critical in all 6 models. We can enhance the lateral stability of model. There are many methods for this purpose, but for this study shear walls selected as So if use shear walls to provide lateral stability in model 1 frame.

5.1 POSITION OF SHEAR WALL

The shape and location of shear wall also effect the response of frame structure. Most suitable position of shear in frame in mid portion of every side or at the end point of sides [5]. For the study shear walls are provided at ends of every corner of frame structure. Model 1 with shear show in fig.12. Wall thickness was taken 250 mm and compressive strength of concrete was take 20 N/mm2, Shear wall were provided at all floors from ground to top storey as shown in fig 11 and 12.

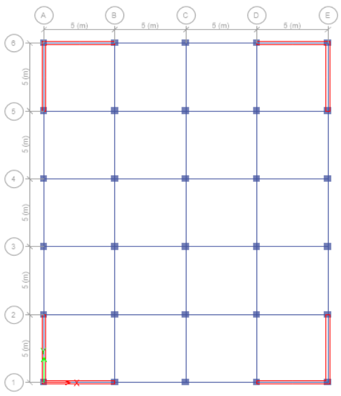


Fig. 11 : Plan

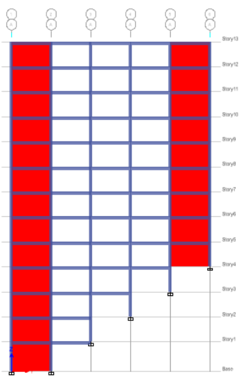


Fig. 12 : Elevation

5.2 RESULT AND COMPARISON OF CRITICAL CASE

5.2.1 DISPLACEMENT

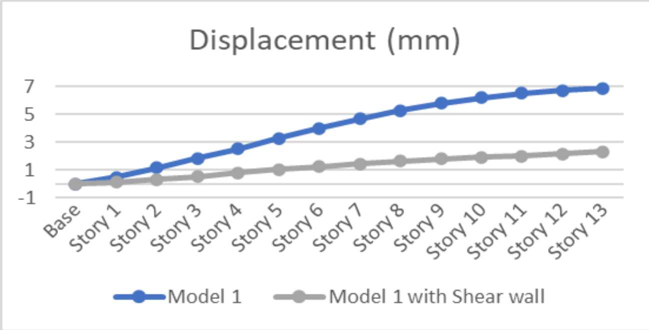


Chart-4 : Storey Displacement

5.2.1 Spectral Acceleration

Fig. 11 and 12 shows that the model with shear wall has more lateral stability than the model 1. Maximum cumulative energy generated in model 1 was 2.92Kn-m and in model 1 with shear wall was 0.92Kn-m, that is 31% less, it means forces acting on frame of model 1 with shear wall due lateral loading was less comparatively. Spectral acceleration was also very high in modal 1.

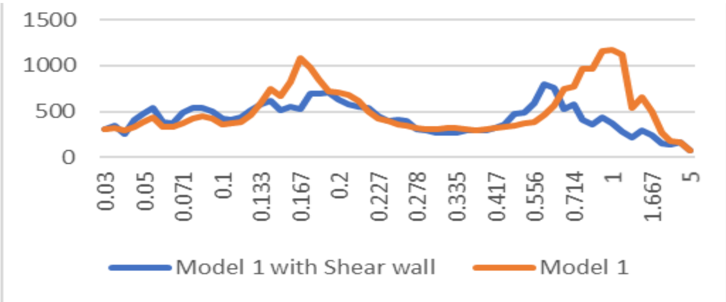


Chart-5 : Spectral Acceleration (Damping 0.05) mm/Sec^2

6. CONCLUSION

In hilly region in general set back frame configuration was used in every type of slope [4] as shown in fig.13. Set back configuration was used because of maximum utilization of area, but as we can see from the analysis of different configuration of building shows in above paragraphs step back set back frame has more stability against lateral loading.

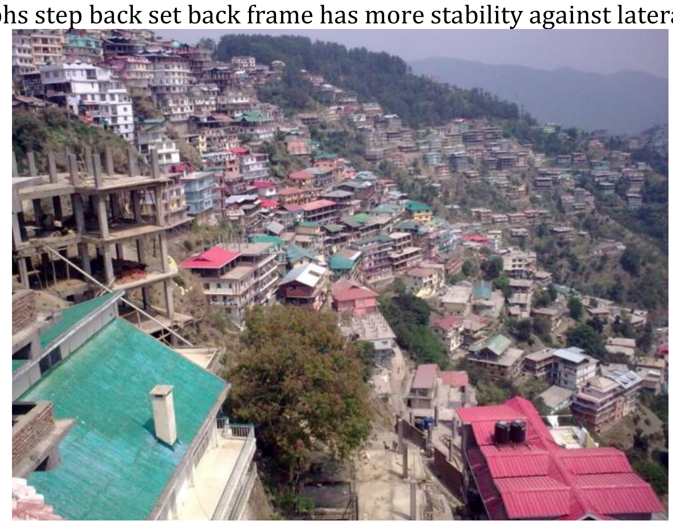


Fig. 13 : set back frame configuration of Buildings in Hilly Area

As the ground slope increase, the value of storey displacement was less and so the all other forces, storey drift and spectral acceleration also less. In case of 25^o slope, model 2 with the step back set back configuration has 20% less displacement as compared to the model 1has set back configuration and the values of storey shear, storey drift and natural time period of vibration were 21.73 %, 31.04%, 20.31% less respectively. Same behavior has seen in model 3,4 and model 5,6. So step back frames are more stable in case of lateral loading, but most of constructions in hilly region was setback frame used for construction, if this was used it should constructed with shear walls, as shown in study model1 frame has 67% less displacement and maximum cumulative energy 31% so the forces acting on step-back setback frame was less. So, in hilly regions step back set back frame should adopt for the construction and if they adopt setback frame this frame should be construct with shear walls or used other techniques for the lateral stability of step back frame structure.

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