Seismic Analysis of Step-Back Set-Back Building Resting on Sloping Ground with Shear Wall

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***Abstract*—The study compares the seismic performance of step back set back building resting on slope (27°) in terms of various factors such as maximum story displacement, story drift, base shear and time period. Shear walls with thickness of 200 mm are placed at different positions. This study presents the seismic behavior of the Regular plan shear wall at corner locations. The results of the study reveal that the position of shear wall will affect the attraction of forces, so that shear wall must be in proper position. In Top storey displacement of all buildings without shear wall is maximum in X-direction and in Y-direction. As we provide shear wall the average displacement reduction is 35%-37% in X-direction and 37%-43% in Y-direction. The storey drift is maximum in 8th storey and average reduction in percentage is 65% and 74% in X-direction and Y-direction simultaneously. Average 24% more base shear is experienced by the building having shear wall configuration when compared to the building without shear wall. The overall performance of the building is influenced by the presence of shear walls, highlighting their importance in enhancing seismic resilience. From above it can be concluded that, top story displacement, storey drift and time period of the Stepback-Setback building with six steps from the top are all less than those of regular building.**

***Index Terms*—RC building (Regular), Response spectrum, Sloping ground, Shear wall, Multistory.**

I. INTRODUCTION

The susceptibility of a large portion of India to seismic hazards, it is crucial for design engineers to develop buildings that not only withstand the shocks of earthquakes but also minimize damage and loss. Understanding the seismic behavior of buildings resting on sloping ground is essential for achieving this goal. Shear walls play a crucial role in the structural integrity of buildings by resisting lateral loads. They are designed to transfer these forces to the foundation, ensuring the stability and safety of the structure.

II. LITERATURE REVIEW

Mohammad Umar Farooque patel etal [1] focused on performance study and seismic evaluation of RC building on sloping ground. They looked at how RC frames behaved on sloping terrain when shear walls were present, varying in location at the center and corners, and they evaluated how well shear walls performed in these kinds of situations. A parametric study was conducted on an eight-story seismic zone III building that has a bare frame and shear walls at the corner and center locations. They took into consideration models on plane ground for comparison. Linear static analysis, response spectrum analysis, and pushover analysis have all been used in seismic analysis. They draw the following conclusion: the presence of a shear wall significantly lessens the lateral displacement, as buildings resting on sloping ground have higher displacement., the presence of shear wall reduces the lateral displacement considerably The literature on studies on the seismic behavior of buildings resting on sloping ground was reviewed by Khadiranaikar [2]. It is found that most studies agree that during an earthquake, structures resting on sloping terrain experience more base shear and displacement than structures resting on level terrain, and that shorter columns are more likely to attract force and sustain damage. A five-story reinforced concrete building with different slope angles (7.50 and 150) was subjected to a seismic analysis by Sujit Kumar et al. [3] and compared to a building that was sitting on level ground. In their study, Ajay Kumar Sreerama et al. [4] examined how a G+3 building behaved at different slope angles namely, 15°, 30°, 45°, and 60°—and contrasted their findings with those obtained on level ground. It is observed that the short column resists almost all of the storey shear as the slope angle increases, in contrast to other columns that are flexible and have a propensity to oscillate. The Nagargoje group [5] A parametric study was carried out on 36 buildings in seismic zone III, focusing on three distinct configurations: step back, step back-set back, and set back buildings. The study is carried out considering storey levels ranging from 4 to 15 (15.2 m to 52.6 m). A range of seismic analysis methods were employed by Singh et al. [6], such as the Response Spectrum Method and the Linear and Non-linear Time History analysis. Additionally, they contrasted the buildings' dynamic characteristics at step-backs, along their slopes, and at vertical steep or cut slopes. The damage pattern of hill buildings observed after the 2011 Sikkim earthquake validated the study's conclusions. After examining various step-back and setback building configurations, Birajdar and Nalawade [7] discovered that in step-back buildings, the shorter frame on the uphill side draws more base-shear force than the other frames in the structure. Murty et al. [8] discussed the suitability of the plan size of the buildings to be built on steep slopes and discussed the adequacy of translational fixidity of column foundations under lateral loads in step-back buildings.

III. SYSTEM DEVELOPMENT

For the present work G+15 RCC frame having six different models are considered for study. The models are analysed on sloping ground having slope $27^{0.}$ All models are analysed by using response spectrum method. In the seismic design context, the following parameters are relevant:

Zone value: The Seismic zone value is 0.36 (V), as specified in Table 2, Clause 6.4.2. Response reduction factor: 5 (SMRF), Table 7, Clause 6.4.2.

Importance Factor: 1.2, Table 6, Clause 6.4.2.

Damping Ratio: 0.5. Soil type is categorized as Medium.

Model 1	Regular building without shear wall.
Model 2	Regular building with shear wall.
Model 3	Stepback setback building having three steps provided from top without shear wall.
Model 4	Stepback setback building having three steps provided from top with shear wall.
Model 5	Stepback setback building having six steps provided from top without shear wall.
Model 6	Stepback setback building having six steps provided from top with shear wall.

Model Statement

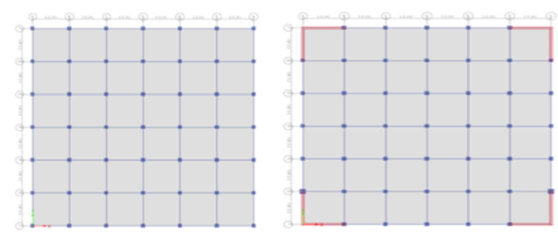
1. Type of Building	RCC Framed Structure
2. Number of story	Ground + 16
3. Plan Size	21 m X 21 m
4. Floor to floor height	3.0 m

Properties of Members

1. Grade of concrete	M30
2. Grade of steel	Fe500

Size of Members

1. Column size	600mm x 600mm
2. Beam size	450mm x 450mm
3. Slab thickness	150mm
4. Shear wall	200mm



a)Without shear-wall b) With shear-wall

Figure:1 Plan.

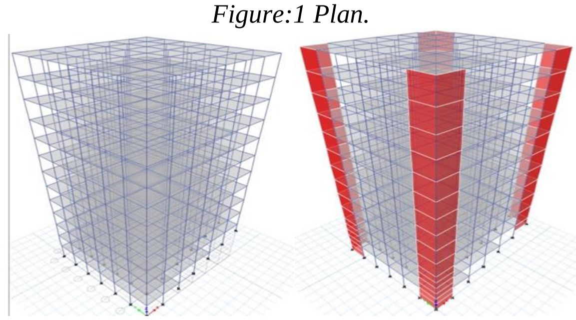


Figure:2 Regular structure.

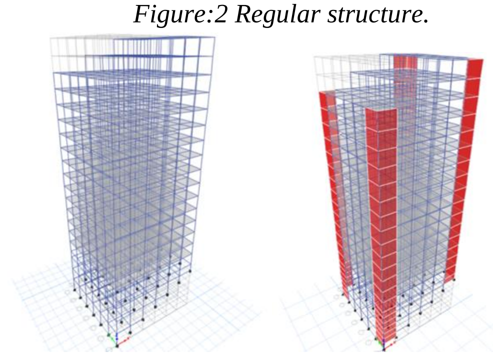


Figure.3 Stepback-setback structure having 3 steps from top.

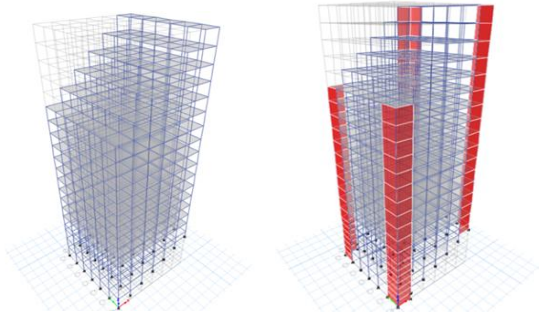


Figure:4 Square shape stepback structure having 6 steps from top.

IV. RESULT AND DISCUSSION

Storey Displacement:

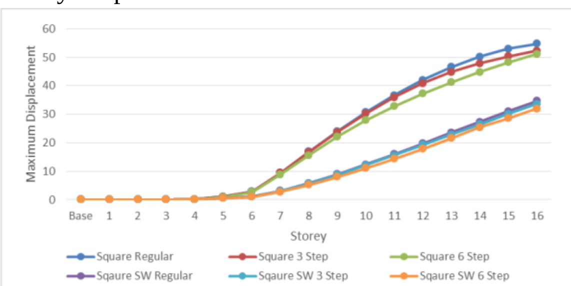


Figure:5 Storey Displacement for in X- direction

Figure:5 shows that, storey displacement in X-direction for Regular Building plan, the maximum value of storey displacement is occurred in Regular model without shear wall at top storey which is 54.786 mm and with shear wall at corner 34.589 mm i.e. decreased by 37% as compared to building without shear wall building. For S 3 step without shear wall at top storey the maximum displacement is 52.284 mm and with shear wall at corner 33.574 mm i.e. decreased by 36% as compared to building without shear wall building. For S 6 step without shear wall at top storey which is 51.078 mm and with shear wall at corner 32.015 mm i.e. decreased by 37% as compared to building without shear wall building.

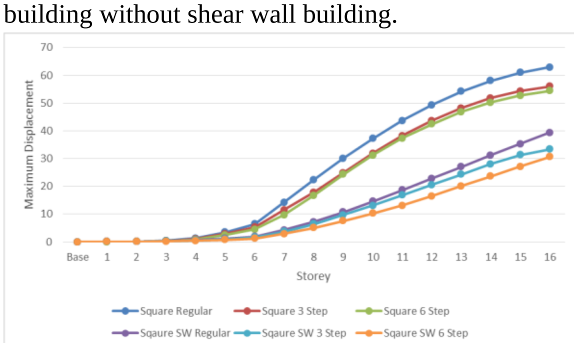


Figure:6 Storey Displacement in Y- direction

Figure:6 shows that, storey displacement in Y-direction for Regular Building plan, the maximum value of storey displacement is occurred in Regular model without shear wall at top storey which is 62.961 mm and with shear wall at corner 39.319 mm i.e. decreased by 37% as compared to building without shear wall building. For S 3 step without shear wall at top storey the maximum displacement is 55.996 mm and with shear wall at corner 33.372 mm i.e. decreased by 40% as compared to building without shear wall building. For S 6 step without shear wall at top storey which is 54.367 mm and with shear wall at corner 30.649 mm i.e. decreased by 43% as compared to building without shear wall building.

Storey drift:

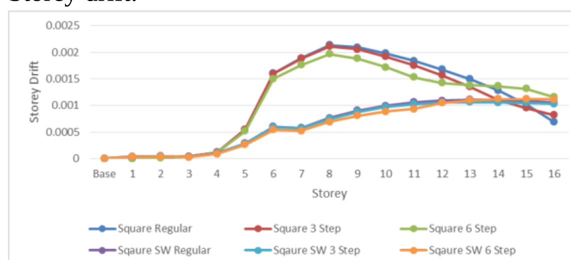


Figure:7 Storey Drift in X- direction

From figure 7, storey drift in X-direction for regular shaped building plan without shear wall effect, the maximum value of storey drift is occurred at storey 8 in regular building is 0.002137 mm but as we place shear wall it reduces to 0.000766 mm i.e.64.15%. Similarly, for three step setback model the maximum value of storey drift is occurred at storey 8 reduced from 0.002117 mm to 0.000746 mm i.e.65% and for basic 6 step setback model maximum value at storey 8, it get reduced from 0.001967 mm to 0.00069 mm i.e. 66% after application of shear wall.

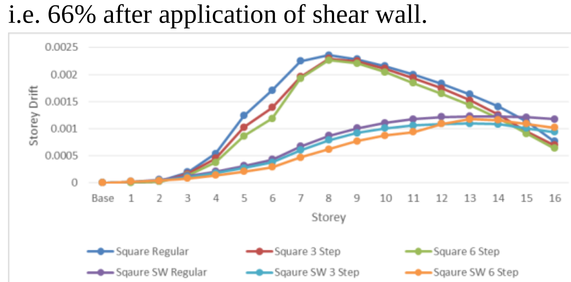


Figure:8 Storey Drift in Y- direction

From figure 8, storey drift in Y-direction for regular shaped building plan without shear wall effect, the maximum value of storey drift is occurred at storey 8 in regular building is 0.002338 mm but as we place shear wall it reduces to 0.0006 mm i.e. 74%. Similarly, for Basic 3 step set back model the maximum value of storey displacement is occurred at storey 08 reduced from 0.002233 mm to 0.000559 mm i.e. 75%and for basic 6 step setback model maximum value at storey 08, it get reduced from 0.001898 mm to 0.000495 mm which is 74% after application of shear wall.

Base Shear:

MODEL	FX KN
Square Regular	3248.531
Square 3 Step	3250.186
Square 6 Step	3192.825
SW Regular	4053.824
SW 3 Step	4040.021
SW 6 Step	3915.921

MODEL	FY KN
Square Regular	3209.715
Square 3 Step	3210.032
Square 6 Step	2961.789
SW Regular	4055.361
SW 3 Step	4072.069
SW 6 Step	3913.929

From above table, it is found that maximum storey shear in X direction for Regular building is 3248.531 kN and for SW Regular building is 4053.824 kN i.e. increased by 25% as compared to regular building in X direction. For S 3 Step it is increased by 24% and for S 6 step it is increased by 18%. It is found that maximum storey shear in Y direction for Regular building is increased by 26% as compared to regular building in Y direction. For S 3 Step it is increased by 27% and for S 6 step it is increased by 32%.

Time Period:

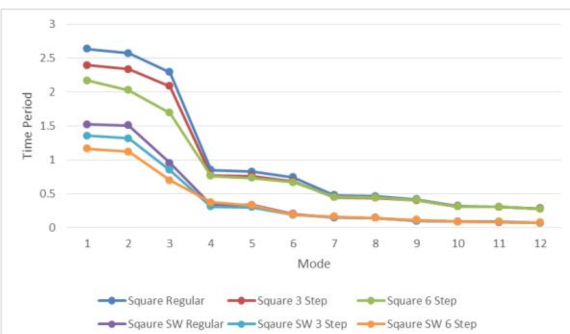


Figure:9 Time Period

The time period is significantly shortened by adding a shear wall, which increases the building's lateral stiffness.

V. CONCLUSION

In this paper, the response spectrum method is used to perform the seismic analysis of the structures resting on a slope angle of 27 degrees, both without and with shear wall consideration at corner position for all buildings. Structures on sloping terrain are thought to be more vulnerable than those on plain terrain.

1. Top storey displacement of all buildings without shear wall is maximum in X-direction and in Y-direction. As we provide shear wall the average displacement reduction is 35%-37% in X-direction and 37%-43% in Y-direction.
2. The storey drift is maximum in 8^{th} storey and average reduction in percentage is 65% and 74% in X-direction and Y-direction simultaneously.
3. Average 24% more base shear is experienced by the building having shear wall configuration when compared to the building without shear wall.
4. The time period is significantly shortened by adding a shear wall, which increases the building's lateral stiffness.

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