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Seismic Evaluation with Shear Walls and Braces for Buildings on Sloping Ground

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ABSTRACT:Building frames on sloping ground reduces the capacity of the structure due to the fact that the column in the ground storey are of different heights which leads to combination ofshort column and long column. Along with this if building has an open ground storey, it isoften induced in structures either due to client requirement or improper planning. If thisstructure is subjected to earthquake and wind velocity which becomes more vulnerable in severe zones. The present study made an attempt to understand the effect of earthquake onbuilding frames resting on sloping ground with shear walls and bracings under severe zone.The computation models of ordinary moment resisting frame was developed in SAP2000 as3D space frame to carry the seismic analysis as per IS 1893 Part (I) -2002.This study may helpto understand the effect of buildings on sloping ground under seismic forces to suggest theefficient lateral force resisting configuration based on parametric study.

KEYWORDS: sloping ground, displacement reduction factor, response spectrum analysis, hilly area.

I. INTRODUCTION

The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multi-storey buildings on hill slope in and around the cities. The scarcity of plain ground in hilly area compels the construction activity on sloping ground. Buildings on hills are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsional coupled. Most of the hilly areas come under seismic zones; hence buildings built in such areas are highly vulnerable to earthquake. This is due to the fact that columns in the ground floor differ in their heights according to the slope of the ground. For tall buildings and high towers, wind load may also be taken as critical loading. The knowledge of seismic and wind performances on the sloping ground buildings becomes an essential part in the engineering design works. [1]

For resisting the lateral forces acting due to seismic and wind loadings the shear walls or bracings are provided to resist the lateral sway. Hence, they are susceptible to severe damage when affected by earthquake ground motion. Shear wall system are one of the most commonly used lateral load resisting in high rise building. Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads. For the buildings on sloping ground, the height of columns below plinth level is not same which affects the performance of building during earthquake. Hence to improve the seismic performance of building shear walls and bracings play very important role. So there is a need to study the shape and positioning of shear walls and bracings on seismic performance of building situated on sloping ground.

Aspects that are to be considered while optimizing earthquake effects on buildings are

1. Selection of load resisting system
2. Its configuration system
3. Its basic dynamic characteristics
4. Its construction quality

Lateral Load Resisting Systems:

The essential role of the lateral resisting frame systems is to carry the wind and earthquake loads. The lateral load resisting system consists of moment resisting building frame system, shear wall systemandbracing system.These systems are further categorised based on the types of construction material used. Table 7 of IS 1893 (Part 1): 2002 lists the different framing system and response reduction factors.

1. **Moment Resisting Frames:**
   These frames are resisting the earthquake forces primarily by flexure. It consists of columns and beams. The lateral stiffness of a moment resisting frame depends on the bending stiffness of the columns and beams. The

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advantage of moment resisting frame is that it is open rectangular arrangement which allows freedom of planning and easy fitting of doors and windows. It is economical only for buildings up to about 25 stories. Above 25 stories the relatively high flexibility of the frame calls for uneconomically large members in order to control the drift and displacements.

2. **Shear Walls:** These are the reinforced concrete members which are used to resist gravity and lateral loads. Their high stiffness and strength makes them ideal for tall buildings. Shear wall structures can be economical up to 35 stories. These are more flexible and help in controlling the side bending of structure when compared to other building frames. A structure of shear walls in the centre of a large building often encasing an elevator shaft or stairwell form a shear core.
3. **Bracings:** These are the structural members which are provided in wall panels to resist tension and compression forces. Bracings hold the structure stable by transferring the loads sideways down to the ground and are used to resist lateral loads, thereby preventing sway of the structure. The bracing members are arranged in many forms, which carry solely tension, or alternatively tension and compression. One of the most common arrangements is the cross bracing. Based on the direction of wind, one diagonal takes all the tension while the other diagonal is assumed to remain inactive.

II. RELATED WORK

In the early days the designers included only vertical loads in consideration for design of a building and checked it with seismic capacity. The basic problems included increase in cost, instability of irregular buildings and improper achievement of strength against lateral forces. The importance of wind, earthquake and blast loads increased and lead to design of shear walls, braces and isolation systems. The present challenge mainly deals with selection of efficient and economic lateral load resisting system. Literature survey has been carried out to study the present state-of-art on available techniques used to determine effect of shear walls and braces. The following literatures were studied for the present work.

1. Seismic analysis has been done using linear static, Response spectrum analysis on eight storey building which includes a bare frame, building with shear wall located in seismic zone III(Mohammad Umar Farooque patel, et al., 2014)[2]. Lateral displacements and storey drifts are considerably reduced while contribution of shear wall is taken into account.
2. Response system analysis is carried out by using SAP2000 for four mathematical models. Displacements, storey drift and maximum forces were studied (Prasad, et al., 2015)[3]. Short columns are the most critical member for the building on sloping ground. It is preferable to locate the shear wall towards the shorter column side in order to have control on shear force and bending moment.
3. Dynamic response of different parameters of step back and step back-set back frames were compared for midrise multi-storey buildings (G Suresh, et al., 2014)[4]. Step back frame with bracings is preferred over step back frame without bracings and set back-step back frame.
4. Seismic performance of soft storey building retrofitted with shear wall is checked using SAP2000 (S. Swathi, et al., 2015)[6]. Performance is improved by addition of shear wall and it is an ideal solution to improve the seismic performance of open ground storey building on sloping ground**.**
5. Seismic performance of combination of shear wall and braces is checked using STAAD-Pro (S. K. Madan, et al., 2015)[10]. Combination of braces and shear walls in a specific arrangement containing shear walls inmiddlebay and braces in outer bays was the most effective arrangement for lateral load resistance in the elastic range.

III. OBJECTIVES AND SCOPE OF PRESENT STUDY

Buildings on hilly area are very irregular and unsymmetrical in vertical planes, and are subjected to lateral forces. There has been a considerable demand for the buildings to resist the lateral forces effectively. To resist the lateral forces different structural members such as shear walls and bracings can be adopted.

1. To study the effect of different storey buildings resting on sloping ground.
2. To assess the behaviour of building frames resting on sloping ground with shear wall, bracings and combination of both under the action of lateral forces.
3. To compare the base shear, displacement and displacement reduction factor for various configurations in order to suggest the effective configuration.

Three dimensional space frame analysis is carried out for four different configurations resting on sloping ground under the action of seismic load using SAP2000. Response spectrum analysis of these buildings, in terms of base shear and roof displacementis presented and compared with the bare frame. From the parametric study displacement reduction factor is obtained for different configurations. At the end, a suitable configuration of building to be used in hilly area is suggested.

IV. MODELLING DETAILS

A five, seven and nine storey building, with ordinary moment resisting frames in two orthogonal directions, was selected for the study. The building had a one brick thick exterior infill wall along the periphery. The material and sectional properties in the analysis of different building frames are shown in table 4.1 confirming to IS 456:2000

Table 4.1 Material and Sectional Properties

Sl. No.	Model Parameters	Details
1	Column	450 x 450 mm
2	Beam	230 x 450 mm
3	Slab	150 mm thick
4	Main wall	230 mm thick
5	Partition wall	115 mm thick
6	Parapet	750 mm height
7	Unit weight of masonry	20 kN/m^3
8	Support conditions	Fixed support
9	Ground slope	27°
10	Grade of concrete	M25
11	Grade of steel	Fe415

Dead loads and live loads are compared as per IS 875 (part 1):1987 and IS 875(part 2):1987 respectively and are shown in table 4.2

Table 4.2 Loading Parameters

Sl. No.	Parameters	Details
1	Roof finish	1.50 kN/m^2
2	Floor finish	0.75 kN/m^2
3	Main wall load	12.65 kN/m
4	Partition wall load	6.325 kN/m
5	Parapet wall load	3.45 kN/m
6	Roof live load	2 kN/m^2
7	Floor live load	4 kN/m^2

Lateral load parameters are considered confirming to IS 1893 (Part 1): 2002 and are listed in table 4.3

Table 4.3 Seismic Load Parameters

Sl. No.	Seismic parameters	Details	IS 1893 (Part 1) : 2002
1	Response reduction factor	3	Table 7 (clause 6.4.2)
2	Importance factor	1	Table 6 (clause 6.4.2)
3	Seismic zone	V	ANNEX E
4	Zone factor	0.36	Table 2 (clause 6.4.2)
5	Soil type	Medium soil	Table 1 (clause 6.3.5.2)

Different 5, 7 and 9 storey building frames are modelled using SAP2000 and are designated as follows:

1. Bare frames (5-BARE, 7-BARE & 9-BARE)
2. Frames with shear walls (5-SW, 7-SW & 9-SW)
3. Frames with X bracings (5-BR, 7-BR & 9-BR)
4. Frames with combination 1 (5-C1, 7-C1 & 9-C1)
5. Frames with combination 2 (5-C2, 7-C2 & 9-C2)

Combination (1) includes building frames with shear walls and braces at alternative levels.
Combination (2) includes building frames with braces at top stories and shear wall at the bottom stories.
Different series models are shown in following Fig 4.1 and 4.2.

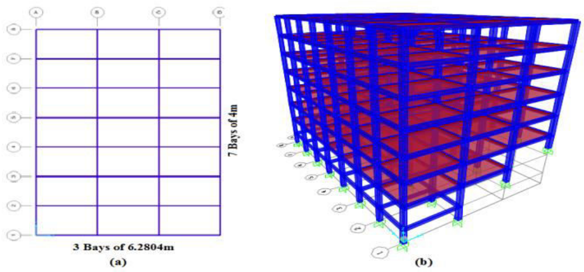

Fig 4.1 (a) Plan (b) Isometric view of building frame

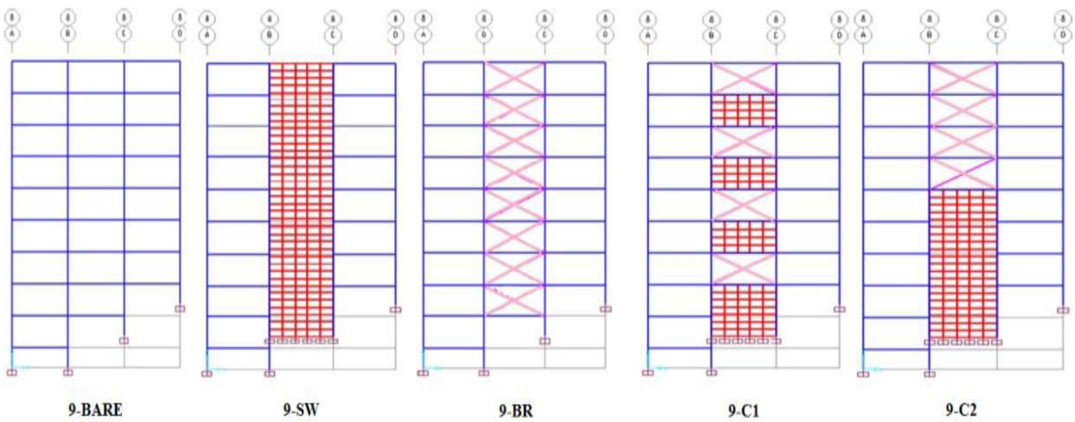

Fig 4.2 9 Storey models with bare frame(9-BARE), shear wall(9-SW), bracings (9-BR),combination 1(9-C1) & combination 2(9-C2)

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V. RESULTS AND DISCUSSIONS

5.1 Bending Moments in Bare Frame:

Fig 5.1 shows that bending moment in the short column increased for higher storey frames. Increase in bending moment is by 58.11% and 72.26% for 7 and 9 storey frames respectively compared to bare frame.

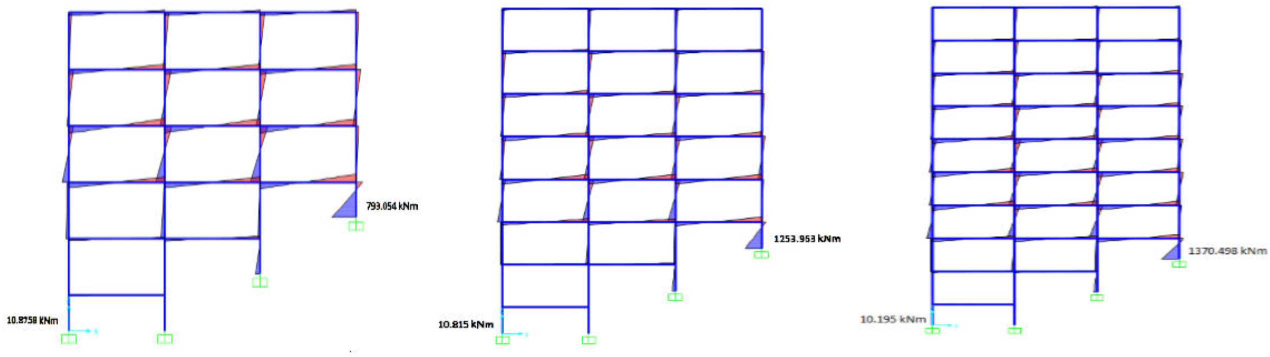

Fig 5.1: (a) 5–BARE, (b) 7-BARE, (c) 9-BARE

5.2 Deformed Shapes of Bare frames:

The deformed shapes of bare frame of different storey buildings are shown in Fig 5.2 .Maximum displacement is seen for highest point of the building and increases with building height. The roof displacement for 7 and 9 storey building frames is 1.44 and 2.73 times the roof displacement of 5 storey bare frame.

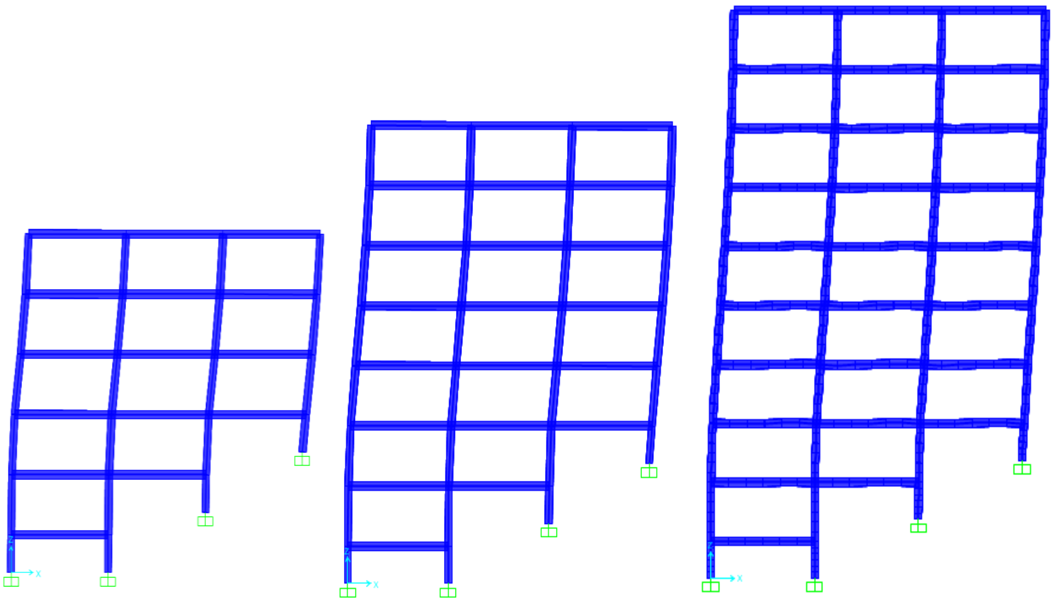

Fig 5.2: (a) 5–BARE, (b) 7-BARE, (c) 9-BARE

5.3 Deformed Shapes of different configurations:

The study of the various parameters such as design base shear, storey displacement and displacement reduction factor for the various building models considered is carried out. The deformed shapes of 9 storey buildings are shown in Fig 5.3.

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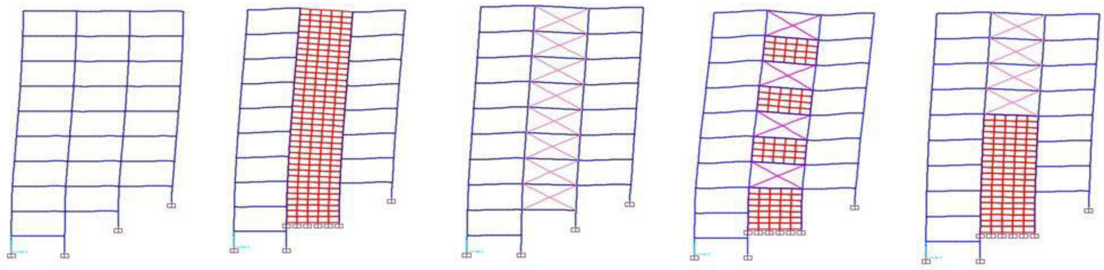


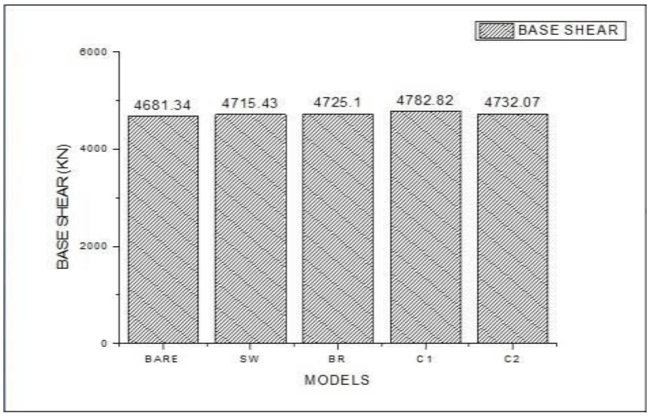
Fig 5.3 Deformed shapes of 9 storey models with bare frame(9-BARE), shear wall (9-SW), bracings(9-BR),combination 1(9-C1) & combination 2(9-C2)

5.4 Parametric Study:

The parameters such as base shear, lateral displacement and displacement reduction factor are obtained by response spectrum analysis are shown below in the form of graphs and tables.

5.4.1 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. Calculations of base shear (V_B) depend on soil conditions at the site. The base shear values obtained from the analysis of 5, 7 and 9 storey building frames are graphically shown in Fig 5.4, 5.5&5.6.



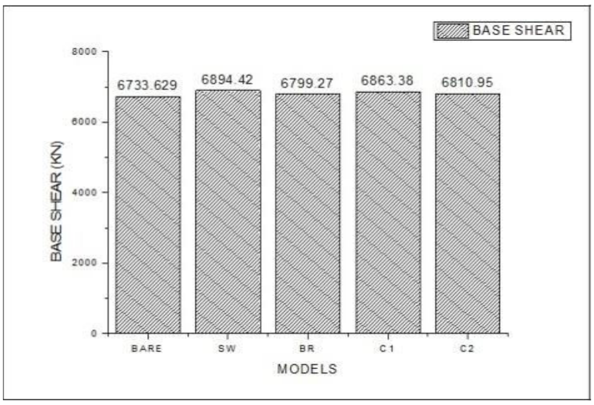


Fig 5.4:Base shear values of 5 storey models Fig 5.5: Base shear values of 7 storey models

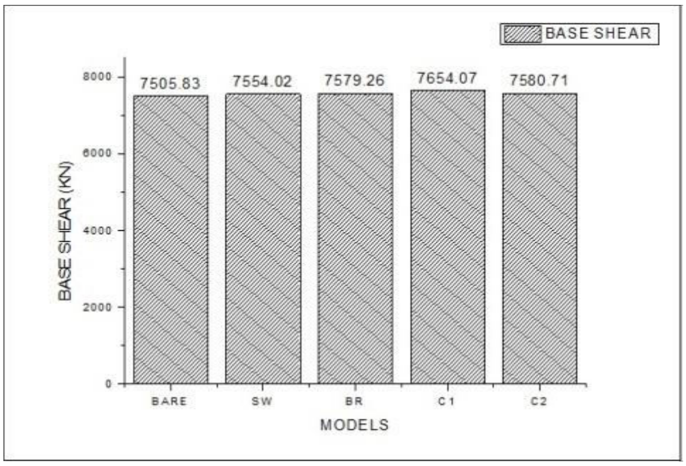


Fig 5.6: Base Shear values of 9 Storey Models

From Fig 5.4, 5.5 and 5.6 it is observed that, there is no significant change in base shear value for the same storey building with different building configuration. This is because of addition of shear walls and bracings in the building frame. The model with shear wall shows higher value of base shear compared to other models. There is approximately 2% increase in the value of base shear for shear wall configuration compared to bare frame model.

5.4.2 Displacement:
Maximum displacement of building frame due to seismic force is at the roof level. The roof displacement values determined for 5, 7 and 9 storey building frames are graphically shown in Fig. 5.7, 5.8 and 5.9.

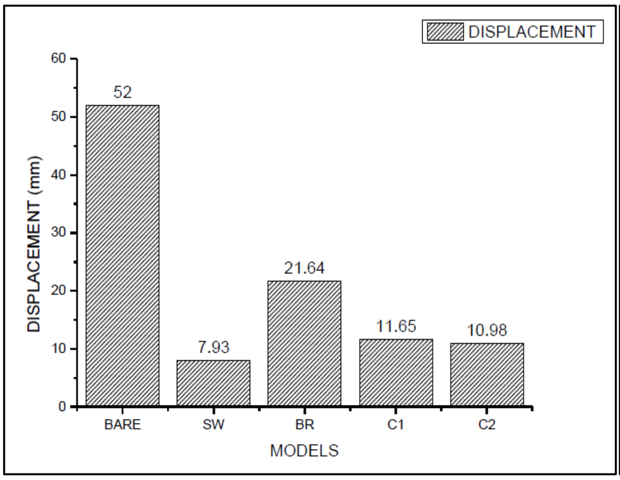


Fig 5.7: Roof displacement value of 5 models

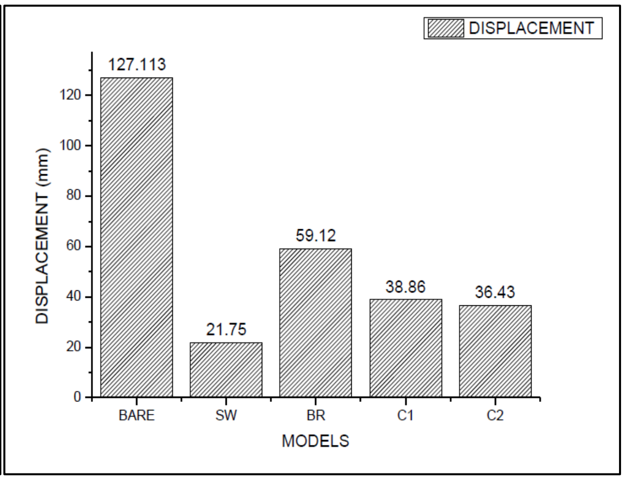


Fig 5.8: Roof displacement value of 7 Storey Models

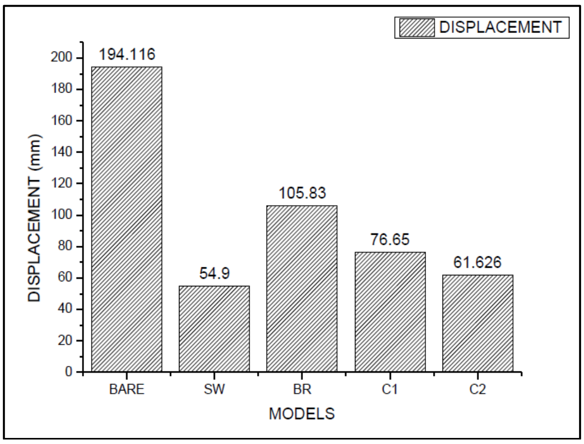


Fig 5.9: Roof displacement value of 9 Storey Models

Addition of shear wall and bracings increases the stiffness of the building. From Fig 5.5, 5.6 and 5.7. It is observed that, the frame with shear wall shows the highest reduction in roof displacement among all the considered frame configurations. The 5-SW, 7-SW and 9-SW configuration reduces the lateral displacement when compared with bare frame by 84.75%, 82.88% and 71.71%.

5.4.3 Displacement Reduction Factor:
For comparing the performance of frames in the linear range of deformation Displacement reduction factor (DRF) is introduced. It is defined as the ratio of difference in maximum lateral displacement in the bare frame (D_{Bare}) and maximum lateral displacement in a frame with lateral load resisting elements (Shear wall, Braces or combinations) (D_c) to the maximum lateral displacement in the bare frame (D_{Bare}). It is given by the equation,

$$DRF = \frac{D_{Bare} - D_c}{D_{Bare}}$$

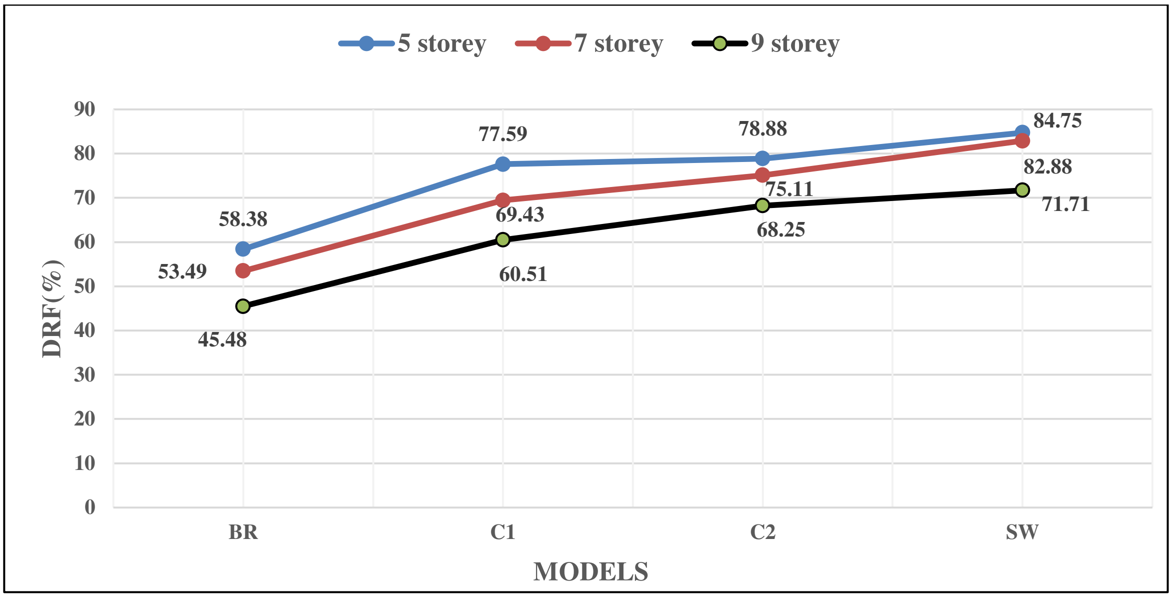


Fig 5.10: Displacement Reduction Factor Values of Different 5, 7 & 9 storey models

Addition of shear wall and bracings increases the stiffness of the building. From Fig 5.10, it is observed that, the frame with shear wall shows the highest reduction in roof displacement among all the considered frame configurations.

VI. CONCLUSIONS

The objective of the study was to suggest an effective configuration for a building frame resting on sloping ground to resist the lateral forces. Dynamic analysis was performed for 5, 7, and 9 storey building frames using SAP2000. The following conclusions may be drawn from analysis results obtained.

1. Maximum moments in column increases with increase in the height of building frame on sloping groun.
2. Addition of shear walls and bracings leads to an increase in the value of base shear.
3. Inclusion of bearing wall system enhances the seismic performance of the building frame.
4. The frame with shear wall showed minimum displacement as compared to other configurations.
5. From DRF results it can be stated that, as the number of storeys increases lateral displacement also increases.
6. From the present study it can be concluded that models with shear walls are more efficient arrangements for lateral load resistance when compared to all other configurations.

REFERENCES

[1] B. G. Birajdar and S.S. Nalawade (2004), "Seismic Analysis of Buildings Resting on Sloping Ground", 13th World conference on Earthquake Engineering, Vancouver, B.C., Canada.

[2] Mohammad Umar Farooque patel, A.V. Kulkarni and Nayeemulla Inamdar (2014), "A Performance study and seismic evaluation of RC frame buildings on sloping ground", *IOSR Journal of Mechanical and Civil Engineering.*

[3] Prasad, Ramesh and Vaidya (OCT 2014 – MAR 2015), "Seismic Analysis of Building with Shear Wall on Sloping Ground", *International Journal of Civil and Structural Engineering Research.*

[4] G Suresh and Dr. E Arunakanthi(SEP 2014), "Seismic Analysis of Buildings Resting on Sloping Ground and Considering Bracing System", *International Journal of Engineering Research & Technology.*

[5] Umakant Arya, Aslam Hussain and Waseem Khan (MAY 2014), "Wind Analysis of Building Frames on Sloping Ground", *International Journal of Scientific and Research Publications.*

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 3, May 2015 |

[6] S. Swathi, G.V. Rama Rao and R. A. B. Depaa (MAY 2015), "Seismic Performance of Buildings on Sloping Grounds", *International Journal of Innovative Research in Science, Engineering and Technology*.

[7] IS: 1893(Part 1). Indian Standard Code of Practice for Criteria for Design of Earthquake Resistant Structures, Bureau of Indian Standards, New Delhi, 2002.

[8] IS: 875(Part 3):1987, "Code of Practice for Design Loads (Other Than Earthquake) for Buildings and Structures", Part 3 Wind Loads, Second Revision, Bureau of Indian Standards, New Delhi, 1989.

[9] IS 875(Part 2):1987, "Code of Practice for Design Loads" (Other Than Earthquake) for Buildings and Structures", Part 2 Imposed Loads, Second Revision, Bureau of Indian Standards, New Delhi, 1998.

[10] S. K. Madan, R.S. Malik and V.K. Sehgal (2015), "Seismic Evaluation with Shear walls and Braces for Buildings", International journal of civil, Environmental, Structural, Construction and Architectural Engineering Vol: 9, N0:2.

[11] A.r. Vijaya Narayanan, Rupa Goswami and C.V.R. Murty (2012), "Performance Of RC Buildings Along Hill Slopes Of Himalyas During 2001 Sikkim Earthquake" *Indian Institute of Technology Madras, Chennai, India.*

[12] P Jayachandran (2009), "Design of Tall Building Priliminary Design And Optimization", *National workshop on high rise and tall building, University of Hydrabad, India.*

[13] Abhijeet Baikerikkar and Kanchan Kanagali (2014), "Study of Lateral Load Resisting Systems Of Variable Heights In All Soil Types Of High Seismic Zone", *International journal of Research in Engineering and Technology.*

[14] Pankaj Agarwal and Manish Shrikhande, (2006) "Earthquake Resistant Design of Structures", Prentice Hall of India Private Limited New delhi.