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Evaluation of Multistorey RC Buildings with Openings on Sloping Ground

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Abstract— Base isolation tool has been extensively implemented for structure protection from seismic. It reduces the seismic demand rather than increasing the earthquake resistance capacity of the structure. In this present study ten storey building models with central openings (10%, 20% and 35%) on sloping ground 11.3^o is considered for modelling. The models with fixed base and base isolated tools at base considered by using equivalent static analysis has been done as per IS 1893 (Part 1): 2002. And also pushover analysis has been done. Time period, base shear, displacement and storey drift results were discussed by using equivalent static and response spectrum method.

Keywords—Base Isolation, Seismic Demand, Earthquake resistance, Equivalent static analysis, pushover analysis, response spectrum method.

I. INTRODUCTION

Seismic forces acts sever on sloping ground, because of structural irregularity which will be subjected to sever torsion in addition to lateral force under the action of lateral seismic forces. There is pecuniary development and fast growth in hilly area, has increased the real estate growth. Because of which, population in that region has improved. So that construction on hill area for multistorey building will be most popular and demanding and cost effective. Effecting on short column is another special situation that can be occurs in the RC building. Considering a restricted height wall built to appropriate a window over the remaining height.

II. OBJECTIVES

The primary objectives of the studies are,

1. The influence of openings on fundamental natural period, base shear, lateral displacement, and storey drift of the buildings with various percentages of central openings with help of fixed base and base isolation by using equivalent static and response spectrum method.
2. To study the Pushover curve.
3. To study the hinge location and performance level at yield state and ultimate state by using pushover analysis.

III.SCOPE OF THE STUDY

1. Structure is assumed to be located in zone III, as per Indian seismic code IS 1893 (Part 1): 2002.
2. The unsymmetrical building is modeled as five, seven and ten storey with fixed base and base isolation.
3. In ETABS V15 infill wall will be modeled as single equivalent diagonal struts of pin jointed.
4. In this present study attempts to understanding the lateral load resistance behavior of RC multi storey buildings, with various percentages of openings (10%, 20% and 35%) in the infill walls.
5. As per FEMA 440 guidelines Pushover analysis for performance levels are carried out.
6. The present study attempts to understand the fixed base and base isolated buildings with various percentages of central openings,
7. Pushover analysis for performance evaluation is carried out as per guidelines of FEMA 440.
8. By using ETABS software linear static analysis, response spectrum analysis and pushover analysis were carried out.

IV. LITERATURE REVIEW

Shunil Shirol and Jagadish G Kori (2017) [2], carried out a study on Seismic Base Isolation of RC Frame Structures with and without infill. In this paper seven storied models with infill and without infill were considered. In that BI tool LBR and friction type isolators were used. Masonry infill walls are modeled as a strut. Using ETABS V16 linear analysis were carried out. From this study they concluded that base isolators increased the time period. Displacement of structure was increased. Base shear and storey drift were reduced significantly.

Renu Dambaland Basavaraj Gudadappanavar (2015)[11], carried out a study on Performance based seismic evaluation of G+2 RC building with varying central opening in infill walls. In this paper, three storeyed RC building models with different percentage of central openings (10 to 35%) were considered. The building models are modeled as bare frame and with unreinforced masonry infill wall by using equivalent diagonal strut with pin joint. Analysis done in ETABS.Results like time period, base shear and displacement were compared with six different models. Author concluded that building with central opening greater than 30% seems to be weaker.

Shaik Imran andP.Rajesh (2017)[12], carried out a study on Earthquake Analysis of RCC Buildings on Hilly. They considered g+9 storeys building which was symmetric and analyzed using "Staad Pro Vi8". The plan layout is kept similar for both buildings on plane and sloping ground. They concluded that footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground. The present study emphasizes the need for proper designing of structure resting on sloping ground.

Goutam Mondal*et al* (2016) [18], carried out a study on masonry infilled (RC) Frames with Openings provided centrally. Author studied that, reduction factor for effective width of diagonal strut over that in filled strut to calculate its initial lateral stiffness when the presence of openings in structure. This study based on initial lateral stiffness that can be taken as 10% lateral strength of the in filled frame. Author concluded that if the area of openings less than 5% the effect of openings on initial lateral stiffness of in filled frame must be neglected.

Sumana C V *et al* (2016) [13], carried out a study on Comparative Study of Fixed Base Isolated for Building on Sloping Ground. In this Paper, comparative study carried to understand the result of seismic loads on sloping ground with fixed base and base isolated base under sever zone. Ordinary moment resisting frame 3D models was done in SAP2000 and to carry out time history analysis as per IS 1893 Part 1:2002. For maximum vertical load vertical stiffness, horizontal stiffness and design displacement of lead rubber isolator was designed. These designed values were assigned for isolated models in ETABS. This paper helps to recognize the effect of base isolated building models under seismic forces. This paper concluded that, for base isolated building base shear will be reduced than fixed base. Displacement and time period increases in base isolated structures compare to fixed base structure.

V. METHODOLOGY

Seismic Analysis : Lateral forces can be calculated as per IS 1893 (Part 1): 2002. Linear analysis can be done in two methods, one will be ESM and another will be RSM.

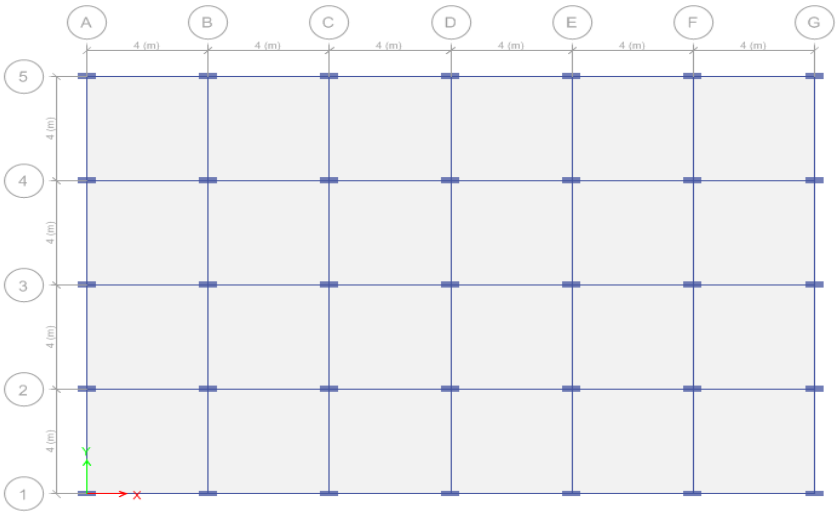
1. Equivalent Static Method [ESM]
2. Response Spectrum Method
3. Pushover Analysis.
4. Base isolation
5. Openings are provided as equivalent diagonal struts with infill's
6. Model analysis has been done in ETABs 2015 software.

VI.MODELLING AND ANALYSIS IN ETABS

In this work the modells of five, seven and 10 storiy buildings with openings of 10%, 20% and 35% with sloping ground of 11.3^{o}.total 24 models are analysed.

Model 1-Five storey bare frames building on sloping ground with fixed base.
Model 2-Five storey RC building with 10% central openings on sloping ground with fixed base.
Model 3- Five storey RC building with 20% central openings on sloping ground with fixed base.
Model 4-Five storey RC building with 35% central openings on sloping ground with fixed base.
Model 5-Seven storey bare frame building on sloping ground with fixed base.
Model 6-Seven storey RC building with 10% central openings on sloping ground with fixed base.
Model 7-Seven storey RC building with 20% central openings on sloping ground with fixed base.
Model 8-Seven storey RC building with 35% central openings on sloping ground with fixed base.
Model 9-Ten storey bare frame building on sloping ground with fixed base.
Model10-Ten storey RC building with 10% central openings on sloping ground with fixed base.
Model11-Ten storey RC building with 20% central openings on sloping ground with fixed base.
Model12-Ten storey RC building with 35% central openings on sloping ground with fixed base.
Model13-Five storey bare frame building on sloping ground with base isolation.
Model14-Five storey RC building with 10% central openings on sloping ground with base isolation.
Model15- Five storey RC building with 20% central openings on sloping ground with base isolation.
Model16-Five storey RC building with 35% central openings on sloping ground with base isolation.
Model17-Seven storey bare frame building on sloping ground with base isolation.
Model18-Seven storey RC building with 10% central openings on sloping ground with base isolation.
Model19-Seven storey RC building with 20% central openings on sloping ground with base isolation.
Model20-Seven storey RC building with 35% central openings on sloping ground with base isolation.
Model21-Ten storey bare frame building on sloping ground with base isolation.
Model22-Ten storey RC building with 10% central openings on sloping ground with base isolation.
Model23-Ten storey RC building with 20% central openings on sloping ground with base isolation.
Model24-Ten storey RC building with 35% central openings on sloping ground with base isolation.

Plan :



VII. RESULTS

Natural Time Periods

From the analysis it clearly observed that, base isolated buildings times longer as compared to fixed base buildings. The building stiffness is directly proportional to its natural frequency. Hence it is inversely proportional to the natural period.

Base Shear

From this study we concluded that as percentage of opening increases stiffness of the building decreases and base shear increases. And also base shear will be more in fixed base buildings as compared to base isolated buildings.

Lateral Displacement

It can be clearly observed that, as the percentage of opening increase the displacement will be increased in both fixed base and base isolated building models.

Performance Evaluation of Buildings

Performance evaluation of fixed base building and base isolated building models are carried out by using pushover analysis.

Location of Hinges and Performance Point of Building

Table 1.Hinge location and Performance point for RC five storey building with central openings on sloping ground with fixed base along X direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	23	1743.87	2756	160	0	0	0	2916
	Ultimate	109	2392.88	2236	660	20	0	0	2916
2	Yield	10.9	3811.2	3904	172	0	0	0	4076
	Ultimate	50.2	4066.3	3826	120	90	20	20	4076
3	Yield	11.3	3831.44	3284	172	0	0	0	3456
	Ultimate	44.1	3943.2	3204	162	60	12	18	3456
4	Yield	14.7	3714.1	3326	130	0	0	0	3456
	Ultimate	32.7	4010	3170	246	28	0	12	3456

Table 2: Hinge location and Performance point for RC five storey building with central openings on sloping ground with fixed base along Y direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force Kn	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	50.7	1262.65	2694	222	0	0	0	2916
	Ultimate	222.1	1498.73	2380	272	80	26	158	2916
2	Yield	17.1	1547.9	3950	126	0	0	0	4076
	Ultimate	79.6	1696.4	3886	50	58	46	36	4076
3	Yield	17.6	1551.2	3324	132	0	0	0	3456
	Ultimate	65.9	1704.83	3272	46	104	12	12	3456
4	Yield	19.1	1523.11	3346	110	0	0	0	3456
	Ultimate	71.5	1710.99	3268	50	102	12	14	3456

For five storey fixed base buildings with various central openings and base isolated buildings with various central openings, It can observed that, model 1, 2, 3 and 4 having more base force as compared to model 13, model 14, 15 and 16 by 15.38%, 36.55%, 35.47% and 35.26% along X-direction. 24.19%, 32.10%, 32.32% and 32.24% Y-direction.

For five storey building models with fixed base along X-direction, the table 5.21 shows that, the formed hinges are within the life safety range at the ultimate state are 100%, 99.51%, 99.48% and 99.61% for model 1, model 2, model 3 and model 4 respectively. Similarly along Y-direction, the table 5.22 shows that, the formed hinges are within the life safety range at the ultimate state are 94.58%, 99.12%, 99.65 % and 99.59% for model 1, model 2, model 3 and model 4 respectively.

Table 3: Hinge location and Performance point for RC five storey building with central openings on sloping ground with base isolation along X direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	29.7	1419.39	2792	124	0	0	0	2916
	Ultimate	286.8	2024.9	2166	350	380	10	10	2916
2	Yield	11.1	2049.5	4016	60	0	0	0	4076
	Ultimate	57.3	2580.12	3866	130	60	10	10	4076
3	Yield	11.5	2064.62	3386	70	0	0	0	4076
	Ultimate	80.6	2544.45	3242	84	80	20	28	3456
4	Yield	15.7	2140.21	3356	100	0	0	0	3456
	Ultimate	76.3	2595.973	3224	122	74	18	18	3456

Table 4: Hinge location and Performance point for RC five storey building with central openings on sloping ground with base isolation along Y direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	47.8	938.473	2832	84	0	0	0	2916
	Ultimate	94.7	1136.178	2656	218	42	6	6	2916
2	Yield	17.7	909.2147	4034	42	0	0	0	4076
	Ultimate	63.3	1151.822	3926	86	54	6	16	4076
3	Yield	18.7	937.0255	3406	50	0	0	0	3456
	Ultimate	63.4	1153.79	3306	54	6	16	54	3456
4	Yield	20.5	942.0293	3404	52	0	0	0	3456
	Ultimate	65.8	1159.288	3304	86	56	6	14	3456

For five storeyed building models with base isolation along X-direction, the table 5.23 shows that, the hinges which are formed within the life safety range at the ultimate state are 99.65%, 99.75%, 99.19% and 99.48% for model 13, model 14, model 15 and model 16 respectively. Similarly along Y-direction, the table 5.24 shows that, the formed hinges within the life safety range & ultimate state are 99.79%, 99.61%, 98.44% and 99.59% for model 13, model 14, model 15 and model 16 respectively.

Table 5: Hinge location and Performance point for RC seven storey building with central openings on sloping ground with fixed base along X direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	26.8	2250.52	3500	160	0	0	0	3660
	Ultimate	75	2821.91	3040	620	0	0	0	3660
2	Yield	9.2	5085.7	5190	94	0	0	0	5284
	Ultimate	17.9	5693.72	5024	260	0	0	0	5284
3	Yield	10.4	5191.3	5188	96	0	0	0	5284
	Ultimate	17.7	5738.44	5028	256	0	0	0	5284
4	Yield	7.7	2543.31	5274	10	0	0	0	5284
	Ultimate	15.2	4407.77	5204	80	0	0	0	5284

Table 6: Hinge location and Performance point for RC seven storey building with central openings on sloping ground with fixed base along Y direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	53.2	1397.86	3524	136	0	0	0	3660
	Ultimate	274.9	1771.32	3084	210	190	12	164	3660
2	Yield	4.5	700.6	5282	2	0	0	0	5284
	Ultimate	10.9	1464.62	5254	30	0	0	0	5284
3	Yield	4.8	719.5	5282	2	0	0	0	5284
	Ultimate	10.7	1414.1	5254	30	0	0	0	5284
4	Yield	8	859.1	5282	2	0	0	0	5284
	Ultimate	13.8	1411.34	5256	28	0	0	0	5284

For seven storey fixed base buildings with various central openings and base isolated buildings with various central openings, it can observed that, model 5, model 6, model 7 and model 8 having more base force as compared to model 17, model 18, model 19 and model 20 by 7.17%, 37.77%, 38.15% and 23.96% along X-direction. 24.74%, 5.25%, 1.82% and 1.73% Y-direction.

For seven storeyed building models with fixed base along X-direction, the table 5.25 shows that, the hinges which are formed within the life safety range at ultimate state are 100%, 100%, 100% and 100% for model 5, 6, 7 and 8 respectively. Similarly along Y-direction, the table 5.26 shows that, the hinges are formed within the life safety range at the ultimate state are 95.52%, 100%, 100% and 100% for model 5, model 6, model 7 and model 8 respectively.

Table 7: Hinge location and Performance point for RC seven storey building with central openings on sloping ground with base isolation along X direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	34.2	1819.051	3490	170	0	0	0	3660
	Ultimate	181.8	2619.506	2826	564	270	0	0	3660
2	Yield	12.2	2982.928	5198	86	0	0	0	5284
	Ultimate	40.5	3543.452	5100	144	40	0	0	5284
3	Yield	13	3016.571	5198	86	0	0	0	5284
	Ultimate	39.9	3549.075	5100	144	40	0	0	5284
4	Yield	10.9	1891.424	5274	10	0	0	0	5284
	Ultimate	25.5	3351.509	5130	150	0	0	4	5284

Table 8: Hinge location and Performance point for RC seven storeys building with central openings on sloping ground base isolation along Y direction by pushover analysis

Model No.	Performance Point			Location of Hinges					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	57.3	1139.312	3570	90	0	0	0	3660
	Ultimate	93.8	1333.16	3414	218	26	0	2	3660
2	Yield	17.2	1080.11	5246	38	0	0	0	5284
	Ultimate	67.6	1387.762	5128	70	60	4	22	5284
3	Yield	17.4	1081.396	5246	38	0	0	0	5284
	Ultimate	66.9	1388.359	5128	72	58	4	22	5284
4	Yield	21.8	1146.929	5236	48	0	0	0	5284
	Ultimate	66.3	1386.891	5136	72	52	8	16	5284

For seven storeyed building models with base isolation along X-direction, the table 5.27 shows that, the hinges which are formed within the life safety range in the ultimate state are 100%, 100%, 100% and 99.92% for model 17, model 18, model 19 and model 20 respectively. Similarly along Y-direction, the table 5.28 shows that, the hinges are formed within the life safety range at the ultimate state are 99.95%, 99.58%, 99.58% and 99.70% for model 17, 18, 19 20 respectively.

Table 9: Hinge location and Performance point for RC ten storey building with central openings on sloping ground with fixed base along X direction by pushover analysis

Model No.	Performance Point			Hinge Location					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	33	3321.9	4556	220	0	0	0	4776
	Ultimate	54.9	3857.4	4146	630	0	0	0	4776
2	Yield	6.7	4870.6	6934	2	0	0	0	6936
	Ultimate	11.3	6856	76	0	0	0	4	6936
3	Yield	7.7	4908.0	6932	4	0	0	0	6936
	Ultimate	12.5	7222.3	6850	82	0	0	4	6936
4	Yield	15.3	4668.1	10	0	0	0	0	6936
	Ultimate	19.3	5742.25	50	0	0	0	0	6936

Table 10: Hinge location and Performance point for RC ten storey building with central openings on sloping ground with fixed base along Y direction by pushover analysis

Model No.	Performance Point			Hinge Location					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	39.9	1106.6	4774	2	0	0	0	4776
	Ultimate	60.8	1653.3	84	0	0	0	2	4776
2	Yield	4.5	797.8	6934	2	0	0	0	6936
	Ultimate	9	1450.7	6914	22	0	0	0	6936
3	Yield	4.9	820.91	6934	2	0	0	0	6936
	Ultimate	9.3	1428.1	6916	20	0	0	0	6936
4	Yield	9.2	983.2	6936	0	0	0	0	6936
	Ultimate	14.5	1496.62	6914	22	0	0	0	6936

For ten storey fixed base buildings with various central openings and base isolated buildings with various central openings, it can observed that, model 9, model 10, model 11 and model 12 having more base force as compared to model 21, model 22, model 23 and model 24 by 7.17%, 37.77%, 38.15% and 23.96% along X-direction. 24.74%, 5.25%, 1.82% and 1.73% Y-direction.

For Ten storeyed building models with fixed base along X-direction, the table 5.29 shows that, the hinges which are formed within the life safety range and the ultimate state are 100%, 99.94%, 99.94% and 100% for model 9,10, 11 and 12 respectively. Similarly along Y-direction, the table 5.30 shows that, the hinges are formed within the life safety range at the ultimate state are 99.96%, 100%, 100% and 100% for model 9, 10, 11 and 12 respectively.

Table 11: Hinge location and Performance point for RC ten storey building with central openings on sloping ground with base isolation along X direction by pushover analysis

Model No.	Performance Point			Hinge Location					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	43.9	1785.878	4588	188	0	0	0	4776
	Ultimate	142.8	2363.634	4084	642	50	0	0	4776
2	Yield	9.5	3158.952	6926	10	0	0	0	6936
	Ultimate	15.8	4887.032	6830	106	0	0	0	6936
3	Yield	16	4740.78	6834	102	0	0	0	6936
	Ultimate	16.9	4894.015	6826	110	0	0	0	6936
4	Yield	15.2	2899.661	6926	10	0	0	0	6936
	Ultimate	25.5	4549.579	6808	128	0	0	0	6936

Table 12: Hinge location and Performance point for RC ten storey building with central openings on sloping ground with base isolation along Y direction by pushover analysis

Model No.	Performance Point			Hinge Location					
	Displacement mm		Base Force kN	A-B	B-IO	IO - LS	LS-CP	CP to E	Total
1	Yield	70.6	1119.101	4690	86	0	0	0	4776
	Ultimate	80.4	1191.536	4622	154	0	0	0	4776
2	Yield	11.9	959.7746	6934	2	0	0	0	6936
	Ultimate	15.7	1215.045	6916	20	0	0	0	6936
3	Yield	12.4	968.7889	6934	2	0	0	0	6936
	Ultimate	16.1	1219.204	6916	20	0	0	0	6936
4	Yield	16.8	1033.861	6934	2	0	0	0	6936
	Ultimate	21.7	1298.565	6914	22	0	0	0	6936

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For Ten storeyed building models with base isolation along X-direction, the table 5.29 shows that, the hinges which are formed in the life safety range and the ultimate state are 100%, 100%, 100% and 100% for model 21,22,23 and 24 respectively. Similarly along Y-direction, the table 5.30 shows that, the hinges are formed within the life safety range at the ultimate state are 100%, 100%, 100% and 100% for model 21, 22,23 and 24 respectively.

From the above results we can conclude that, base force will more in fixed base model as compared to base isolated model. In base isolated buildings all hinges formed in life safety only.

VIII. CONCLUSION

The following conclusions are obtained from above analysis,

1. As the increase in openings percentage, fundamental natural time period also increases in both fixed base and base isolated structure.
2. Fundamental natural time periods are increased after providing base isolation devise (Rubber bearing). And time period decreased in fixed base building models.
3. As increasing the central openings percentage, the base shear goes on decreases. And also base shear reduced in base isolated buildings as compared with fixed base building models.
4. Displacement goes on increasing as increases the central openings.
5. The base force found less in base isolated building models as compared with fixed base building models.
6. Hinges are formed in within the life safety at the ultimate stage.

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