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Push Over Analysis of RCC Building with Soft Stories at Different Levels

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Abstract: The increase in population, parking spaces is a major problem for the apartments of the cities. Hence fresh trend is making use of the open ground storey for parking. Also, for office, shop spaces, or conference hall etc., soft story at different levels of structure is construction. In the beyond (past) earthquake has shown that the buildings with simple (unsophisticated) and uniform configurations are subjected to less damage. The regularity and continuity of stiffness in the horizontal planes as well as in vertical direction is very important from earthquake safety point of view. A building with discontinuity is subjected to concentrated of forces and deformations at dot of the discontinuity which may leads to the failure of members at the junction and collapse of building. Open first storey is a typical feature in the modern multi-storey constructions in metro city India. Such as the features highly unacceptable of the buildings built in seismically active areas; as a been verified of numerous experiences the strong shaking during the past earthquakes. It is the thought of multi-storey buildings with soft ground floor are inherently vulnerable to breakdown due to earthquake load, their construction is still widespread in the developing nations like India. It is the social and functional demand to provide car parking space at ground level and for offices open stories at other level of structure away out-weighs the warning against such buildings from engineering community. The ground soft story for office space open floor is required on other levels of building. In present work we are concentrating on finding the best place for soft stories in high rise buildings.
Keywords: Population Increase, Parking Problem, Open Ground Storey, Office Space, Earthquake, Structural Safety.

I. INTRODUCTION

In recent years, the rapid growth of tall residential and commercial buildings, particularly slender structures, has made the consideration of lateral loads such as wind, earthquakes, and blast forces a primary concern in structural design. Unlike earlier practices where buildings were mainly designed for vertical loads and lateral forces were checked later, modern engineering requires a thorough understanding of how these forces affect overall structural behavior and individual components. Seismic design, in particular, focuses on ensuring structural safety during major earthquakes while also addressing serviceability and economic loss. Earthquake loading differs significantly from gravity and wind loading because it induces large inelastic deformations, requiring detailed analysis to ensure acceptable performance beyond the elastic range; most codes allow controlled structural damage to dissipate energy without collapse. The devastating January 26, 2001 earthquake in the Kutch region of Gujarat highlighted the severe consequences of inadequate earthquake-resistant construction, as many traditionally built structures of stone, brick, adobe, and wood collapsed, causing heavy loss of life and property. Earthquake damage depends on factors such as ground motion intensity, soil conditions, and construction quality, making it essential to enforce seismic regulations for new buildings and to evaluate and strengthen existing ones. Buildings must possess adequate strength, ductility, and integrity to withstand large deformations and remain stable as a unit. Observations from past earthquakes reveal that properly designed buildings often remain intact while poorly designed adjacent structures may collapse, creating additional hazards and limiting access. To address such issues, performance-based engineering is recommended, where tools like static pushover analysis are used to achieve predefined performance objectives such as Immediate Occupancy, Life Safety, or Collapse Prevention, thereby enhancing urban resilience and ensuring safer, more reliable built environments during seismic events.

II. MATERIAL AND METHOD

In the Present work six building models of G+1, G+3, G+5, G+7, G+9, G+11 has been developed for RCC, for different position of soft storey situated in zone V with subsoil. Type medium -II were analyzed in ETAB software. All the buildings are subjected to same earthquake loadingto check their seismic behavior for same storey and storey height. For the analysis of these models' various methods of seismic analysis are available but for present workLinear dynamic, linear static and non-linear static method is used.

Details of the methods are as given below.

A. Pushover Analysis

Pushover analysis is a nonlinear static analysis method used in structural engineering to evaluate the seismic performance and capacity of a structure. In this method, a building model is subjected to gradually increasing lateral loads (representing earthquake forces) applied in a predefined pattern until a target displacement is reached or the structure reaches failure.

Pushover analysis which is an iterative procedure is looked upon as an alternative for the conventional analysis procedures. Pushover analysis of multi-story RCC framed buildings subjected to increasing lateral forces is carried out until the present performance level (target displacement) is reached. The promise of performance based seismic engineering (PBSE) is to produce structures with predictable seismic performance. The pushover analysis is more convenient than full dynamic analysis because of computational time. With pushover analysis, results took considerably much lesser time than dynamic analysis. Thus, pushover analysis is more practical for use in a design office. After the structure has been designed or retrofitted using appropriate codes or design guidelines, is that it yields additional information on the limit states, the plastic hinge sequence and the force redistribution caused by a seismic event.

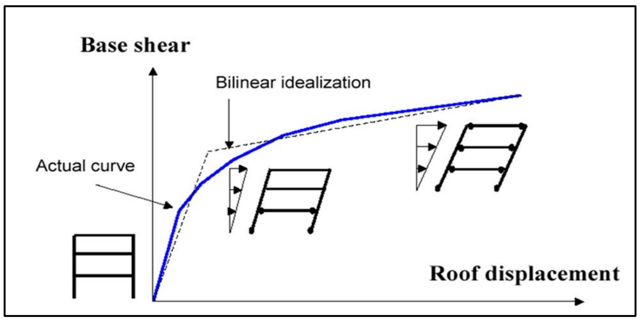

Fig. 1 Pushover Curve

III. MODEL AND RESULTS

A. Problem Data

1) We are taking plan of structure and doing modeling in ETABS software. After modeling we are doing design and then we are performing pushover analysis.
2) But in our research work we are making a soft-story at different level of building and then perform pushover analysis and let us see how results will vary. How react a soft story during earthquake at different level of structure.
3) We are making 6 model of same plan of structure and design it.
4) After design we are making soft story at G+1, G+3, G+5, G+7, G+9 and G+11 of the building.
5) Consider soil type-2
6) Zone factor-5
7) Response reduction factor-4

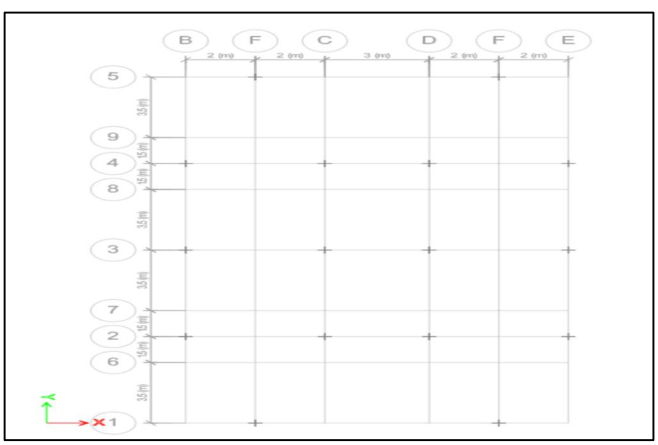

Fig: Plan

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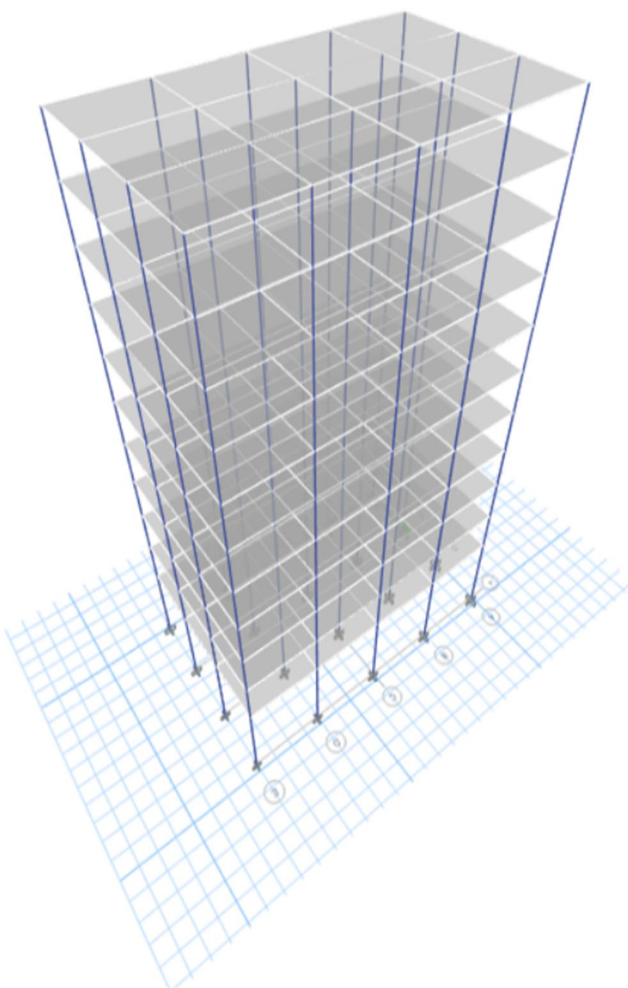
1) *Model 1: Soft Storey at 1st Storey Level:*
- ✓ If story stiffness variation is more than 70% that story reacts like a soft story.
- ✓ In this case at G+1 story stiffness variation is around 92% so G+1 story act like soft story.
- ✓ Let us perform pushover analysis.



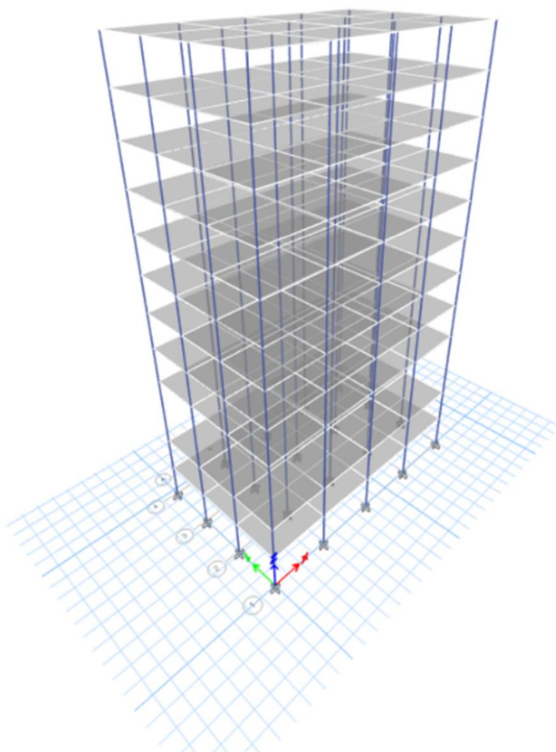
Performance Point

Point Found	Yes	T secant	2.992 sec
Shear	3856.2304 kN	T effective	3.131 sec
Displacement	-447.126 mm	Ductility Ratio	2.716578
Sa	0.133933	Effective Damping	0.1387
Sd	297.986 mm	Modification Factor	1.094725

Base Shear vs Monitored Displacement

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	-20.026	321.0328	918	0	0	0	0	918	0	0	0	918
2	-66.026	1064.6018	918	0	0	0	0	918	0	0	0	918
3	-112.026	1800.8176	900	18	0	0	0	918	0	0	0	918
4	-158.026	2408.832	813	105	0	0	0	918	0	0	0	918
5	-204.026	2776.5348	721	197	0	0	0	918	0	0	0	918
6	-250.026	3021.4527	686	232	0	0	0	918	0	0	0	918
7	-296.026	3245.8878	662	256	0	0	0	890	28	0	0	918
8	-342.026	3447.7663	652	266	0	0	0	870	48	0	0	918
9	-388.026	3641.4309	628	290	0	0	0	845	73	0	0	918
10	-434.026	3815.6166	610	308	0	0	0	791	127	0	0	918
11	-460	3896.1455	600	318	0	0	0	765	153	0	0	918

2) *Model 2: Soft Storey at 3rd Storey Level:*
- ✓ If story stiffness variation is more than 70% than particular story reacts like a soft story.
- ✓ In this case at G+3 story stiffness variation is around 84% so G+3 story act like soft story.
- ✓ Let us perform pushover analysis.



Performance Point

Point Found	Yes	T secant	2.972 sec
Shear	3746.2659 kN	T effective	3.074 sec
Displacement	-437.547 mm	Ductility Ratio	2.598921
Sa	0.134511	Effective Damping	0.1303
Sd	295.209 mm	Modification Factor	1.069449

Base Shear vs Monitored Displacement

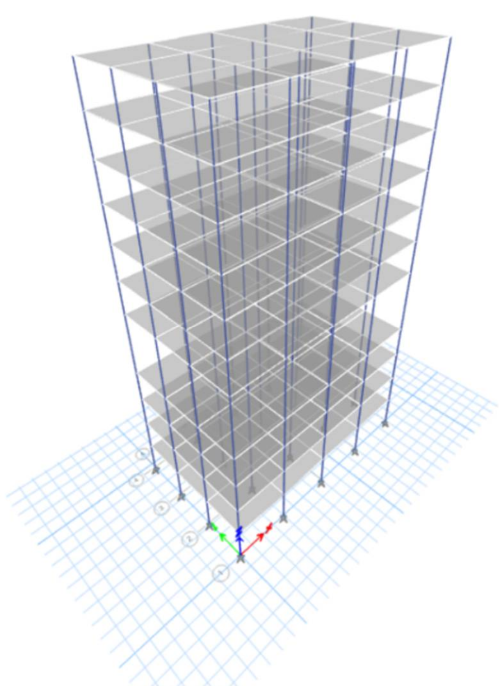
Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	-17.625	271.8251	918	0	0	0	0	918	0	0	0	918
2	-61.625	955.9538	918	0	0	0	0	918	0	0	0	918
3	-105.625	1635.0191	918	0	0	0	0	918	0	0	0	918
4	-149.625	2242.2096	845	73	0	0	0	918	0	0	0	918
5	-193.625	2632.9889	753	165	0	0	0	918	0	0	0	918
6	-237.625	2882.9595	701	217	0	0	0	918	0	0	0	918
7	-281.625	3102.8143	673	245	0	0	0	902	16	0	0	918
8	-325.625	3306.3799	653	265	0	0	0	886	32	0	0	918
9	-369.625	3492.9776	632	286	0	0	0	870	48	0	0	918
10	-413.625	3664.3997	616	302	0	0	0	822	96	0	0	918
11	-440	3754.6625	610	308	0	0	0	794	124	0	0	918

3) *Model 3: Soft Storey at 5th Storey Level*

✓ If story stiffness variation is more than 70% than particular story react like a soft story.

✓ In this case at G+5 story stiffness variation is around 142% so g+5 story act like soft story.

✓ Let us perform pushover analysis.

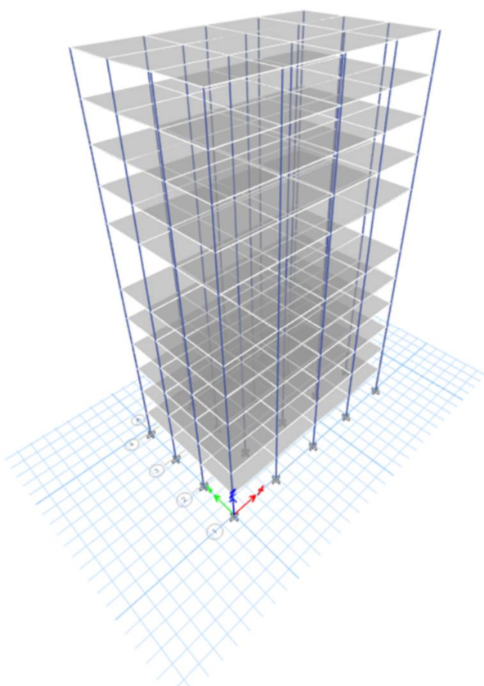


Performance Point

Point Found	Yes	T secant	2.945 sec
Shear	3633.9437 kN	T effective	3.02 sec
Displacement	-430.248 mm	Ductility Ratio	2.526587
Sa	0.135563	Effective Damping	0.1251
Sd	292.034 mm	Modification Factor	1.052092

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	-19.465	289.6599	918	0	0	0	0	918	0	0	0	918
2	-64.465	964.9107	918	0	0	0	0	918	0	0	0	918
3	-109.465	1635.0827	918	0	0	0	0	918	0	0	0	918
4	-154.465	2235.4607	844	74	0	0	0	918	0	0	0	918
5	-199.465	2601.6423	744	174	0	0	0	918	0	0	0	918
6	-244.465	2840.0863	702	216	0	0	0	918	0	0	0	918
7	-289.465	3058.1219	672	246	0	0	0	904	14	0	0	918
8	-334.465	3259.1397	649	269	0	0	0	878	40	0	0	918
9	-379.465	3445.2545	632	286	0	0	0	862	56	0	0	918
10	-424.465	3614.1624	618	300	0	0	0	819	99	0	0	918
11	-450	3701.497	606	312	0	0	0	795	123	0	0	918

4) *Model 4: Soft Storey 7th Storey Level*
- ✓ If story stiffness variation is more than 70% than particular story reacts like a soft story.
- ✓ In this case at G+7 story stiffness variation id around 128% so G+7 story act like soft story.
- ✓ Let us Perform pushover analysis.

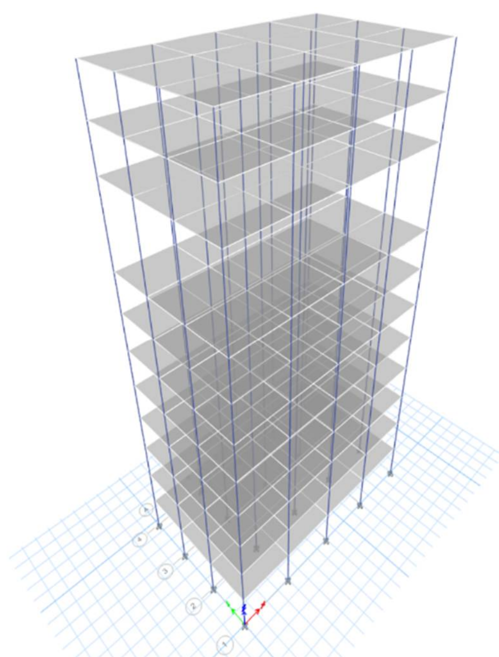


Performance Point

Point Found	Yes	T secant	2.889 sec
Shear	3589.4325 kN	T effective	2.951 sec
Displacement	425.027 mm	Ductility Ratio	2.497538
Sa	0.138109	Effective Damping	0.1229
Sd	286.445 mm	Modification Factor	1.043408

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	19.516	287.0343	918	0	0	0	0	918	0	0	0	918
2	62.516	924.6813	918	0	0	0	0	918	0	0	0	918
3	105.516	1557.6115	918	0	0	0	0	918	0	0	0	918
4	148.516	2156.3375	856	62	0	0	0	918	0	0	0	918
5	191.516	2532.2591	754	164	0	0	0	918	0	0	0	918
6	234.516	2759.611	706	212	0	0	0	918	0	0	0	918
7	277.516	2970.5905	678	240	0	0	0	910	8	0	0	918
8	320.516	3165.9523	658	260	0	0	0	886	32	0	0	918
9	363.516	3351.7129	634	284	0	0	0	878	40	0	0	918
10	406.516	3521.6273	620	298	0	0	0	837	81	0	0	918
11	430	3607.6504	616	302	0	0	0	809	109	0	0	918

5) *Model 5: Soft Storey 9th Storey Level*
- ✓ If story stiffness variation is more than 70% than particular story reacts like a soft story.
- ✓ In this case G+9 story stiffness variation is around 132% so G+9 story act like soft story.
- ✓ Let us perform pushover analysis.



Performance Point

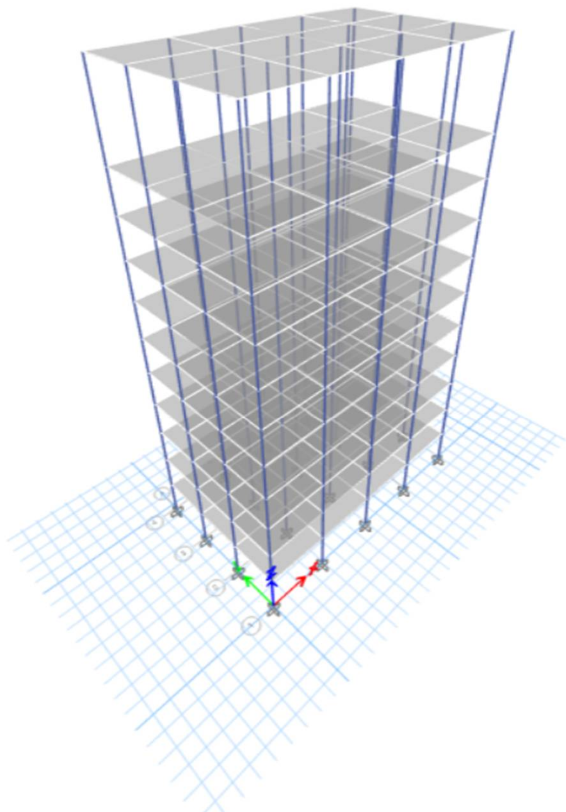
Point Found	Yes	T secant	2.727 sec
Shear	3851.1117 kN	T effective	2.819 sec
Displacement	-431.276 mm	Ductility Ratio	2.586251
Sa	0.147791	Effective Damping	0.1294
Sd	273.066 mm	Modification Factor	1.068667

Base Shear vs Monitored Displacement

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	-19.272	306.7036	918	0	0	0	0	918	0	0	0	918
2	-62.772	1004.3206	918	0	0	0	0	918	0	0	0	918
3	-106.272	1697.1494	918	0	0	0	0	918	0	0	0	918
4	-149.772	2346.709	853	65	0	0	0	918	0	0	0	918
5	-193.272	2703.8604	746	172	0	0	0	918	0	0	0	918
6	-236.772	2951.1264	698	220	0	0	0	918	0	0	0	918
7	-280.272	3177.1263	675	243	0	0	0	912	6	0	0	918
8	-323.772	3389.7921	650	268	0	0	0	882	36	0	0	918
9	-367.272	3585.7329	634	284	0	0	0	878	40	0	0	918
10	-410.772	3770.9169	620	298	0	0	0	836	82	0	0	918
11	-435	3865.6758	616	302	0	0	0	809	109	0	0	918

6) Model 6: Soft Storey 11th Storey Level

- ✓ If story stiffness variation is more than 70% than story reacts like a soft story.
- ✓ In this case G+11 story stiffness variation is around 132% so G+11 story act like soft story.
- ✓ Let us perform pushover analysis.



Performance Point

Point Found	Yes	T secant	2.815 sec
Shear	3645.2311 kN	T effective	2.883 sec
Displacement	-425.003 mm	Ductility Ratio	2.522995
Sa	0.142005	Effective Damping	0.1248
Sd	279.638 mm	Modification Factor	1.048293

Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	918	0	0	0	0	918	0	0	0	918
1	-19.408	291.7371	918	0	0	0	0	918	0	0	0	918
2	-62.408	943.2666	918	0	0	0	0	918	0	0	0	918
3	-105.408	1590.1528	918	0	0	0	0	918	0	0	0	918
4	-148.408	2203.7569	863	55	0	0	0	918	0	0	0	918
5	-191.408	2571.3444	750	168	0	0	0	918	0	0	0	918
6	-234.408	2799.084	705	213	0	0	0	918	0	0	0	918
7	-277.408	3014.0975	677	241	0	0	0	914	4	0	0	918
8	-320.408	3214.3232	660	258	0	0	0	882	36	0	0	918
9	-363.408	3403.4973	634	284	0	0	0	878	40	0	0	918
10	-406.408	3577.4665	620	298	0	0	0	840	78	0	0	918
11	-430	3663.4406	616	302	0	0	0	812	106	0	0	918

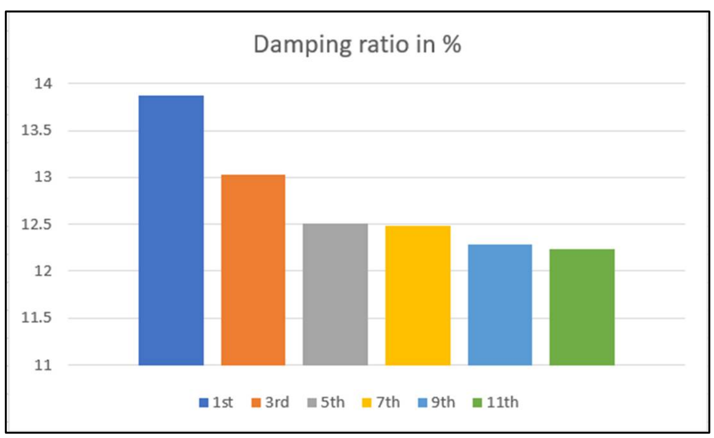
IV. COMPARISON

A. Comparison of Damping Ratio at Performance Point

→ Thus, effective damping ratio value at performance point.

→ Its soft story shift high to low rise effective damping ratio will increase and it will be good for structure during lateral loading.

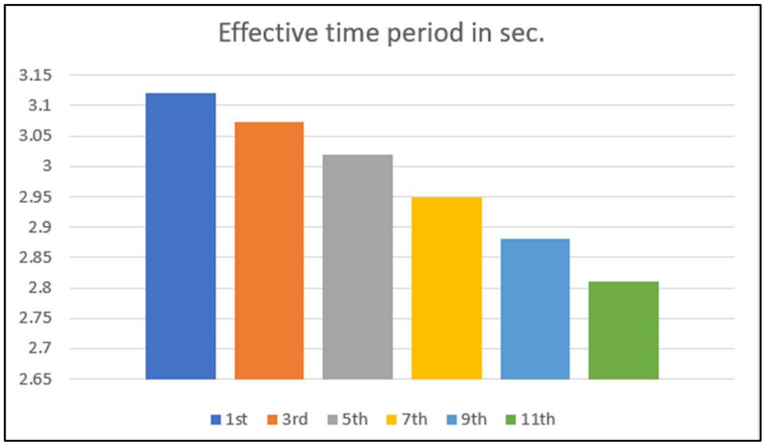
Soft Story Level	Damping Ration in %
1st	13.87
3rd	13.03
5th	12.51
7th	12.48
9th	12.29
11th	12.24



B. Comparison of Effective Time Period in Second ($T_{effective}$)

→ If Soft Story high to low rise effective time will decrease and time should not be much more if time is more than structure will more time to stable during seismic event and it will be good for structure during lateral loading if time is less.

Soft Story Level	Effective Time Period in Sec
1st	3.121
3rd	3.074
5th	3.02
7th	2.95
9th	2.88
11th	2.81

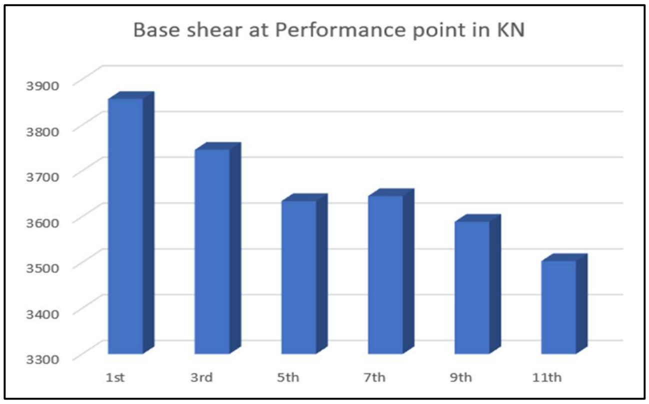


C. Comparison of Base Shear at Performance Point:

→ In structure Base Shear is dominate major role during ground shaking. If Base Shear is less so it will beneficial for structure. But majority dependency of Base Shear is on structure weight and earthquake parameters.

→ In this study we can be if we shift the soft story from low level to higher level of structure then base shear will be reduced and it will be good for structure.

Soft Story Level	Base shear at performance point in KN
1st	3857
3rd	3746
5th	3634
7th	3645
9th	3589
11th	3503



V. CONCLUSION

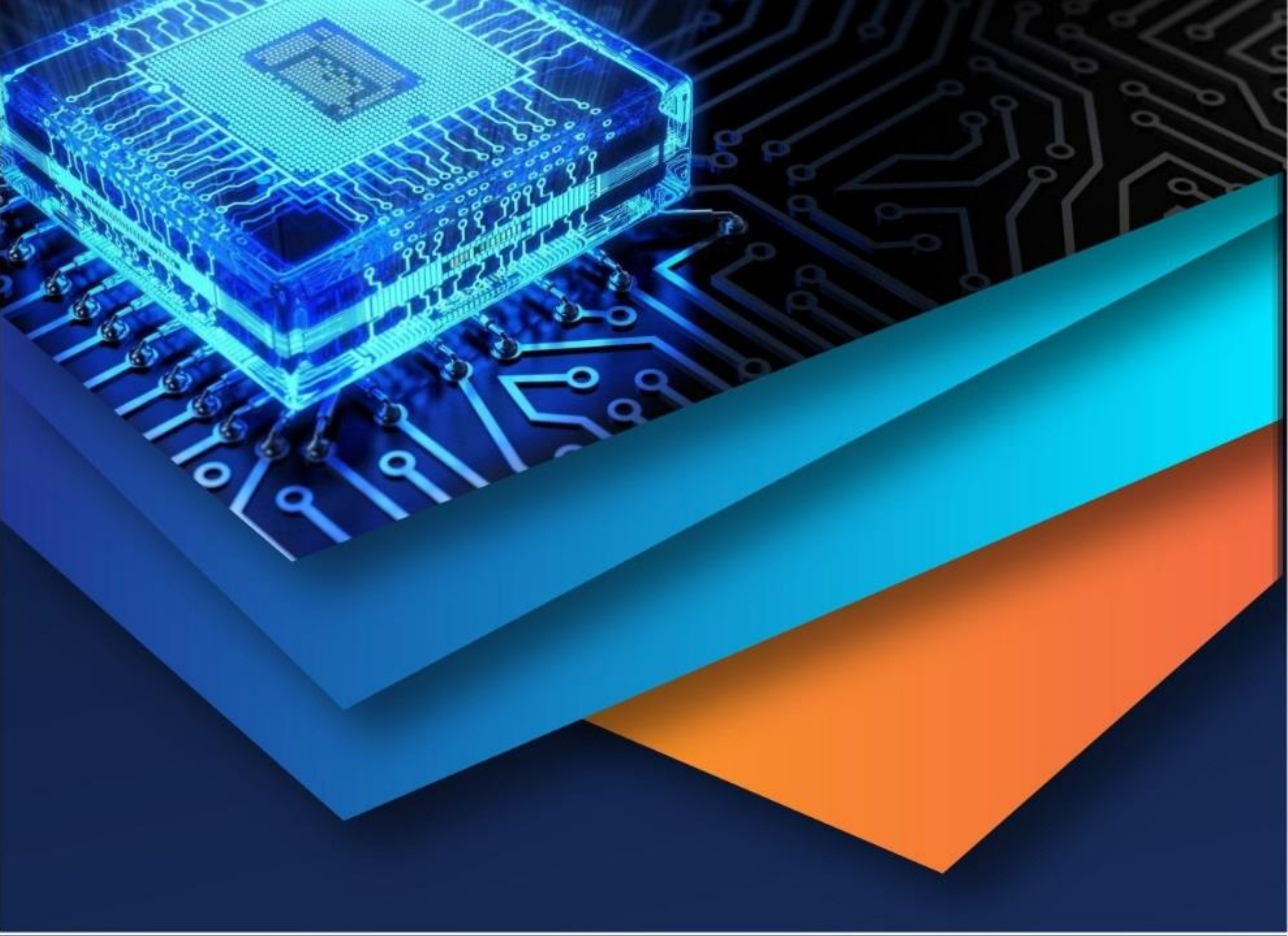
In the present study, the nonlinear response of a reinforced concrete (RC) high-rise frame building with a soft storey located at different levels, in addition to the ground floor, was analyzed using ETABS under seismic loading. The main objective was to evaluate the variation in the load–displacement behavior and to determine the maximum base shear and displacement of the frame when the soft storey is placed at different elevations. The formation of plastic hinges was examined for configurations with a ground-floor soft storey and with soft storeys at higher levels, and hinge development was observed at various displacement stages. In a well-planned building without a soft storey irregularity, plastic hinge formation typically initiates at the beam ends and base columns of the lower storeys, then gradually propagates to the upper storeys, followed by yielding of interior intermediate columns in the upper levels, maintaining a desirable ductile mechanism.

However, the comparison of models in this study reveals that the pattern of plastic hinge formation changes significantly with the location of the soft storey. When the soft storey is positioned at lower levels, hinge formation is more intense and severe, whereas shifting the soft storey to higher levels reduces the concentration and severity of hinges within that storey.

Since the modeled building in this study is relatively stiff, only a limited number of hinges formed, and most remained within the Life Safety (LS) performance level. In less stiff structures, hinges may propagate up to the Collapse Prevention (CP) level or even beyond, indicating more severe damage. The results show that when the soft storey is located at the bottom of the building, hinge severity and the number of hinges are significantly higher compared to cases where the soft storey is placed at upper levels. As the soft storey is shifted upward, both the number and severity of hinges decrease, which is beneficial for structural performance. Additionally, moving the soft storey from lower to higher levels results in a reduction in overall structural displacement and base shear. In terms of effective damping, shifting the soft storey upward leads to a decrease in effective damping, which corresponds to reduced structural damage. Therefore, when the soft storey is located at lower levels, the structure experiences maximum damage, while placing it at higher levels results in comparatively less damage. Based on these observations, it is advisable to provide a soft storey at higher levels rather than at the bottom of the structure to achieve improved seismic performance.

REFRENCES

[1] IS 1893 (Part 1):2016 Criteria for Earthquake Resistant Design of Structures, Part 1, General Provisions and Buildings
[2] IS 456 (2000): Plain and Reinforced Concrete
[3] FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings
[4] FEMA 440: Improvement of Nonlinear Static Analysis Procedures
[5] ATC 40: Seismic Evaluation and Retrofit of Existing Buildings
[6] ASCE 41-31: Seismic Evaluation and Retrofit of Existing Buildings
[7] Pushover Analysis of Building using Soft Storey at Different Levels, Mr. Prathamesh Sonawane, Dr. M.P. Wagh, Volume 7 Issue 5 – May 2021www.ijsart.com
[8] Review on Pushover Analysis of Building Using Soft Storey at Different Level, Nilesh Bharat Vidhate, G.A. Sayyed, Volume 7 Issue 2, February 2021www.ijsart.com
[9] Comparative Study on Reducing Soft Storey Effect in RC Structures, Mostafa Mahumud, Md Faiyaz Shahriar, Akib Mohammad Sunny https://doi.org/10.2991/978-94-6463-672-7_7
[10] A Review on Seismic Analysis of RCC Building with Soft Storey at Different Level, Alhat Sneha Dnyananeshwar, D.N. Mandik, V.P. Bhasure, N.V. Khadake, IJRESM Volume 5, Issue 2, February 2022 https://www.ijresm.com | ISSN (Online): 2581-5792
[11] Design and Analysis of High-Rise Buildings using ETABS, Jenita Kuriakose, Sreya Shaji, Roshan Daniel, Jitu Sreekuman, IJERT Volume 11, Issue 02, 2023www.ijert.org
[12] Analysis of RCC Building with Multiple Soft Storey using ETABS, Omkar P. Khandagle, Prof., Jayant S. Kanase, IJRES Volume 10 Issue 6, 2022 www.ijres.org
[13] Preventing Soft Storey Irregularity in RC Building by Pushover Analysis, Md. Abdul Alim, Nazrul Islam, IEB 49 (2) 13 October 2021
[14] Pushover Analysis of Reinforced Concrete Frames, Mila Svilar, Aleksandar Prokic, SERBIA 23-24 April 2019 CONFERENCE PROCEEDINGS INTERNATIONAL CONFERENCE (2019)
[15] Nonlinear Static Pushover Analysis of Medium Rise and High-Rise Building, Dr, M. Keshava Murthy, Ashwini L K, Volume 6, 20 May 2019 https://doi.org/10.32628/IJSRST1196337\
[16] Comparative study Nonlinear Pushover Analysis and Displacement Based adaptive Pushover Analysis Method, Int. J. Structural Engineering, Rutvik Sheth, Jayesh Prajapati, Devesh Soni, Vol. 9, No. 1, 2018
[17] M.Hafezolghorani, F. Hejazi, R. Vaghri, M.S. Bin Jaafar, and K. Karimzade, "Simplified damage Plasticity Model for Concrete", in Structural Engineering International, 2017. DOI: 10.2749/1016816X1081.
[18] C.P. Pantelides, C. Clyde, and L.D. Reaveley, "Performance-Based Evaluation of reinforced concrete building exterior joints for seismic excitation", Earthquake Spectra, Vol. 18, No. 3, pp.449-480, 2002.
[19] ASCE "American Society of Civil Engineers, Fema 356 Prestandard and Commentary for the Seismic Rehabilitation of Building", Rehabilitation, no. November, 2000.
[20] T. Paulay and R. Park, Reinforced Concrete Structures. John Wiley and Sons, 1975.
[21] W. W. L. Chan, "The ultimate strength and deformation of plastic hinges in reinforced concrete frameworks", ASCE J Struce Div, vol. 106, no. 5, 1980, DOI: 10.1061/jsdeag.0005416.
[22] H. E. H. Roy and M. A. Sozen, "Ductility of Concrete", Special Publication, vol. 12, pp. 213-235, 1965.
[23] T. Paulay and M. J. N. Priestly, Seismic Design of Reinforced Concrete and Masonry Buildings. 1992. DOI: 10.1002/9780470172841.sssss



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