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Pushover Behaviour of Multi Storey Reinforced Concrete Building

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ABSTRACT: For structural design and assessment of reinforced concrete members, the non-linear analysis has become an important tool. The method can be used to study the behaviour of reinforced concrete structures including force distribution properties. Pushover analysis is a preferred method for seismic performance evaluation which directly incorporates nonlinear material characters. It includes Capacity Spectrum Method, Displacement Coefficient Method and Secant Method. Pushover analysis is static, nonlinear procedure in which, the magnitude of the structural loading is incrementally increased in accordance with a certain predefined distribution pattern along the height of the building. With the increase in the magnitude of loading, weak links and failure modes of the structure are found. In this present study, an RC building with symmetrical plan(designed according to IS456-2000)isanalyzedusingpushoveranalysisandredesigningbychangingthemainreinforcementof various frame elements and again analysing. The pushover analysis has been carried out using ETABS 2013 version 13.2.2, a product of Computers and Structures International. The results of analyses are compared in terms of base shear and storey displacements.

I.INTRODUCTION

Recent earthquake disasters in the world have shown that significant damage can occur even when the buildings are designed to satisfy the codal provisions, thus exposing the inability of the codes to ensure minimum safety of the structures under an earthquake. The displacement based approach known as the performance based seismic design (PBSD), which evaluates how building systems are likely to perform under a variety of conditions associated with potential hazard events, is becoming very popular now. In contrast to force based approaches, PBSD provides a systematic methodology for assessing the seismic performance of a building, thus ensuring life safety and minimum economic losses. PBSD demands the use of nonlinear analysis procedures to evaluate the response of structures under lateral loads. The nonlinear time history analysis is the most accurate, but requires much computational effort, time and cost. Thus, the use of nonlinear static analysis procedure known as the pushover analysis has been proposed. In pushover analysis, the magnitude of the lateral loads is incrementally increased, maintaining a predefined distribution pattern along the height of the building. It gives an insight on the progressive mode of failure of the structure, thus making it more performance based. Below shows a flow chart that presents the key steps in the performance-based design process. It is an iterative process that begins with the selection of performance objectives, followed by the development of a preliminary design, an assessment as to whether or not the design meets the performance objectives, and finally redesign and reassessment, if required, until the desired performance level is achieved. **(ATC,1997a)**

II. METHODOLOGY

A. PUSHOVER ANALYSIS:

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. A series of iterations are usually required during which, the structural deficiencies observed in one iteration, are rectified and followed by another. This iterative analysis and design process continues until the design satisfies pre-established

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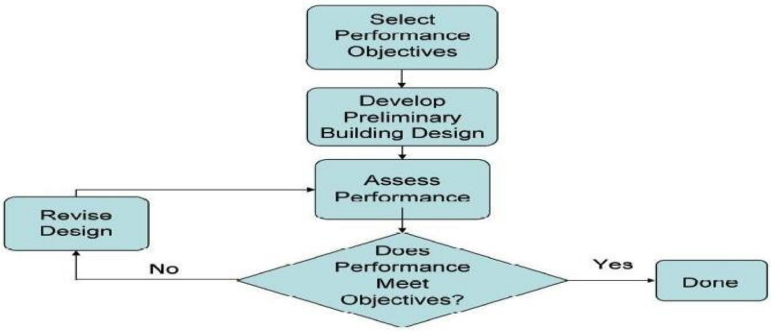
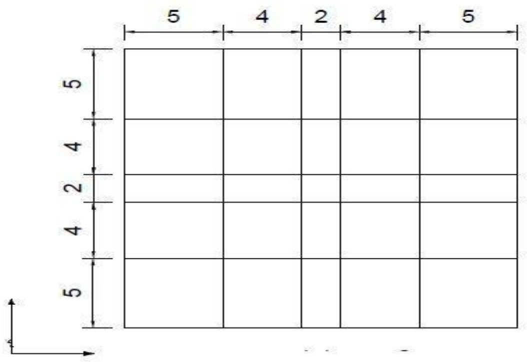
performance criteria. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude. Static Nonlinear Analysis technique, also known as sequential yield analysis, or simply "pushover" analysis has gained significant popularity during the past few years. It is the one of the three analysis techniques recommended by FEMA-273/274 and a main component of the Spectrum Capacity Analysis method (ATC-40). Proper application can provide valuable insights into the expected performance of structural systems and components. Misuse can lead to an erroneous understanding of the performance characteristics. Unfortunately, many engineers are unaware of the details that have to be observed in order to obtain useful results from such analysis.

The pushover is most useful for the evaluation at performance levels that are associated with large inelastic deformations (e.g., collapse prevention level). The method is applicable and useful, however, for evaluation at any performance level at which inelastic deformations will occur.

Performance-Based Design Flow Diagram (ATC, 1997a)



Plan of the building & 3D VIEW of the building in E-Tabs



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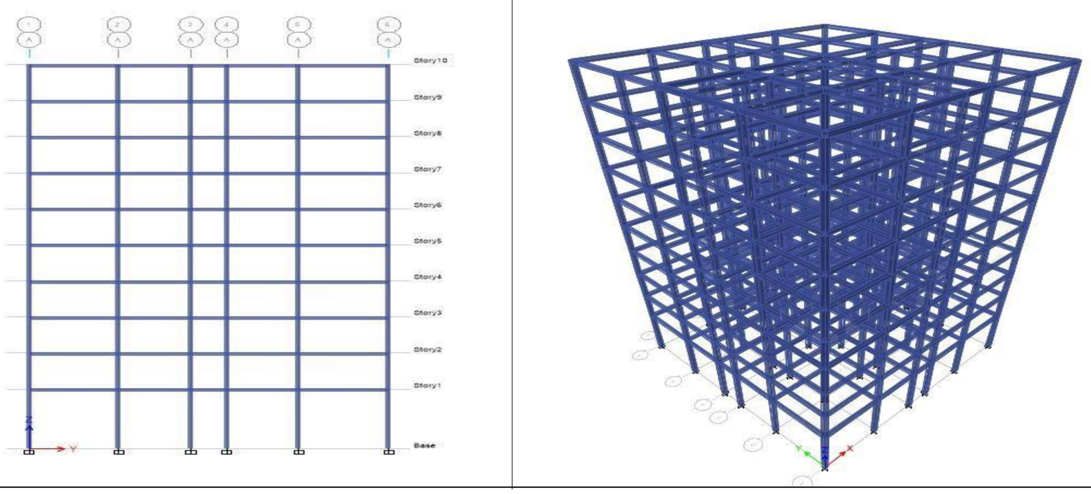

Elevation &3d view

III.ANALYSIS & RESULTS

Tabular data for pushover curve of basic structure

Step	Monitored Displacement (mm)	Base Force (KN)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
0	3.74E-02	0	1920	0	0	0	0	1920	0	0
1	12	99.4153	1920	0	0	0	0	1920	0	0
2	24	198.8306	1920	0	0	0	0	1920	0	0
3	30.8	255.1054	1914	6	0	0	0	1914	6	0
4	43.1	348.9052	1852	68	0	0	0	1852	68	0
5	55.8	420.2065	1760	160	0	0	0	1760	160	0
6	68.4	472.5029	1702	218	0	0	0	1702	218	0
7	80.4	508.2849	1644	276	0	0	0	1644	276	0
8	92.7	533.3951	1610	310	0	0	0	1610	306	4
9	109.1	555.3086	1574	346	0	0	0	1574	308	38
10	122	568.5677	1560	360	0	0	0	1560	266	94
11	136.9	581.8679	1540	380	0	0	0	1540	244	136
12	151.8	593.4631	1526	394	0	0	0	1526	202	192
13	166.1	603.6077	1514	406	0	0	0	1514	172	234
14	183.7	615.406	1504	416	0	0	0	1504	158	258
15	200.4	625.2112	1480	440	0	0	0	1480	156	284
16	217.4	633.3402	1466	454	0	0	0	1466	156	298
17	233.4	639.2979	1456	464	0	0	0	1456	150	314
18	248.2	644.6161	1450	470	0	0	0	1450	142	326
19	268.4	651.5691	1444	476	0	0	0	1444	132	338
20	282.5	656.0679	1436	480	4	0	0	1436	124	350

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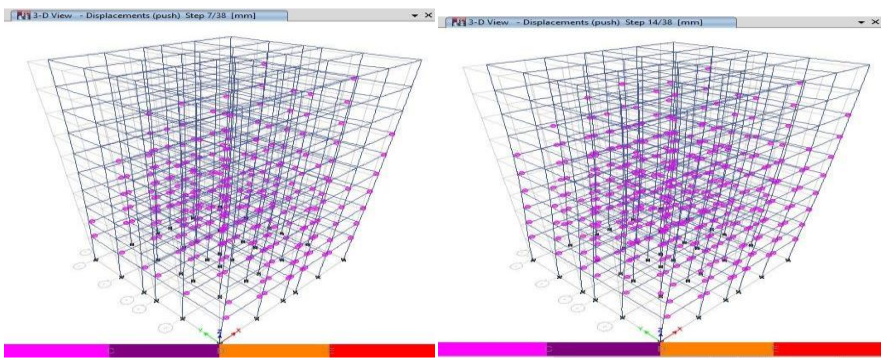
21	295.4	659.7394	1432	482	6	0	0	1432	110	366
22	307.4	662.9228	1430	482	8	0	0	1430	106	368
23	321.5	666.3474	1428	480	12	0	0	1428	100	370
24	330.5	668.0928	1428	466	26	0	0	1428	98	362
25	335.6	668.7078	1426	460	34	0	0	1426	98	352
26	339.9	668.9109	1426	456	38	0	0	1426	98	346
27	343	668.9613	1426	446	48	0	0	1426	98	334
28	348.5	668.4644	1426	438	56	0	0	1426	94	330
29	353.4	667.473	1426	424	70	0	0	1426	94	320
30	358.5	665.4215	1426	396	98	0	0	1426	94	290
31	366.9	654.0475	1426	368	126	0	0	1426	94	264
32	379.9	612.2055	1426	320	174	0	0	1426	94	220
33	389.6	571.4179	1426	300	176	18	0	1426	94	206
34	406.7	533.3228	1426	286	184	24	0	1426	94	192
35	422.7	492.1995	1426	280	190	24	0	1426	94	186
36	427.6	484.8509	1426	280	186	12	16	1426	94	186
37	432	469.0791	1426	278	186	12	18	1426	94	184
38	443.1	438.1609	1426	278	166	0	50	1426	94	184

Pushover curve for basic structure



Step by step deformations for pushover

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ANALYSIS RESULTS OF DIFFERENT CASES WITH CHANGEIN REINFORCEMENT AND SECTIONALPROPERTIES

Variation of base shear and roof displacement with storey level for increase in reinforcement of beams at selected storey level

Storey level	Percentage increase in reinforcement	Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
1	77.8	726.58	356.2	8.62	3.85
2	77.8	731.11	376.16	9.30	9.67
3	77.8	718.04	338.86	7.34	-1.2
4	77.8	706.07	307.02	5.55	-10.4
5	77.8	694.8	297.7	3.87	-13.2
6	77.8	683	307.15	2.10	-10.4
7	77.8	674.17	352.6	0.78	2.80
8	77.8	670.3	340.21	0.20	-0.8
9	77.8	669.48	340.2	0.08	-0.81
10	77.8	668.9	342.9	0	-0.02

Variation of base shear and roof displacement with storey level for increase in reinforcement of columns at selected storey level

Storey level	Percentage increase in reinforcement	Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
1	77.7	699.4	350.04	0.07	2.05
2	77.7	668.9	342.98	0	0
3	77.7	668.9	342.98	0	0
4	77.7	668.9	342.98	0	0
5	77.7	668.9	342.98	0	0
6	77.7	668.9	342.98	0	0
7	77.7	668.9	342.98	0	0
8	77.7	668.9	342.98	0	0
9	77.7	668.9	342.98	0	0
10	77.7	668.9	342.98	0	0

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Variation of base shear and roof displacement with storey level for increase in reinforcement of beams & columns at selected storey level

Storey level	Percentage increase in reinforcement		Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
	beams	columns				
1	77.8	77.7	738.18	357.87	10.35	4.34
2	77.8	77.7	731.53	375.25	9.36	9.40
3	77.8	77.7	718.04	333.86	7.34	-2.6
4	77.8	77.7	706.67	307.07	5.64	-10.46
5	77.8	77.7	694.97	297.7	3.8	-13.2
6	77.8	77.7	683.09	307.07	2.12	-10.46
7	77.8	77.7	673.49	325.58	0.68	-5.07
8	77.8	77.7	670.03	340.23	0.16	-0.8
9	77.8	77.7	668.08	341.28	-0.12	-0.49
10	77.8	77.7	669.7	342.5	0.11	-0.13

Variation of base shear and roof displacement with storey level for increase of reinforcement in beams at cumulative storey level

Storey levels	Percentage increase in reinforcement	Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
1	77.8	726.46	356.9	8.60	4.05
2	77.8	780.36	373.3	16.66	8.84
3	77.8	836.23	389.55	25.01	13.57
4	77.8	882.75	394.8	31.97	15.10
5	77.8	906.7	345.03	35.55	0.59
6	77.8	919.59	267.66	37.47	-21.96
7	77.8	922.14	259.5	37.85	-24.33
8	77.8	922.4	255.08	37.89	-25.62
9	77.8	922.99	257.54	37.98	-24.91
10	77.8	922.9	257.53	37.97	-24.91

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Variation of base shear and roof displacement with storey level for increase of reinforcement in columns at cumulative storey level

Storey levels	Percentage increase in reinforcement	Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
1	77.7	699.22	350.27	4.53	2.12
2	77.7	699.22	350.27	4.53	2.12
3	77.7	699.22	350.27	4.53	2.12
4	77.7	699.22	350.27	4.53	2.12
5	77.7	699.22	350.27	4.53	2.12
6	77.7	699.22	350.27	4.53	2.12
7	77.7	699.22	350.27	4.53	2.12
8	77.7	699.22	350.27	4.53	2.12
9	77.7	699.22	350.27	4.53	2.12
10	77.7	699.22	350.27	4.53	2.12

Variation of base shear and roof displacement with storey level for increase of reinforcement in beams & columns at cumulative storey level

Storey levels	Percentage increase in reinforcement		Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
	Beams	columns				
1	77.8	77.7	738.18	357.79	10.35	4.31
2	77.8	77.7	788.68	361.11	17.90	5.28
3	77.8	77.7	848.39	380.2	26.83	10.85
4	77.8	77.7	919.21	414.38	37.42	20.81
5	77.8	77.7	982.51	465.22	46.88	35.64
6	77.8	77.7	1000.11	399.15	69.51	16.37
7	77.8	77.7	1008.31	349.8	50.74	1.98
8	77.8	77.7	1011.9	346.18	51.27	0..93
9	77.8	77.7	1010.92	344.23	51.13	0.36
10	77.8	77.7	1010.76	344.12	51.10	0.33

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Variation of base shear and roof displacement with core for increase in reinforcement of beams & columns in different cores

Core frames	Percentage increase in reinforcement		Base shear (KN)	Roof displacement (mm)	Percentage increase in base shear	Percentage increase in roof displacement
	beams	columns				
Inner core frame	77.8	77.7	691.88	342.05	3.4	0.2
Central core frame	77.8	77.7	743.89	346.25	11.2	0.9
Outer core frame	77.8	77.7	792.53	347.44	18.4	1.3

Variation of base shear and roof displacement with storey level for increase of reinforcement and cross section in beams at cumulative storey level

Storey level	Percentage increase in reinforcement	Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displace ment
1	50.02	761.27	351.32	13.8	2.4
2	50.02	837.08	335.45	25.1	-2.19
3	50.02	929.86	333.89	39.07	-2.65
4	50.02	1039.05	371.80	55.3	8.4
5	50.02	1108.8	357.06	65.7	4.1
6	50.02	1129.10	241.15	68.7	-29.6
7	50.02	1131.49	224.04	69.1	-34.6
8	50.02	1130.13	216.56	68.9	-36.8
9	50.02	1128.84	213.46	68.7	-37.7
10	50.02	1128.20	214.50	68.6	-37.4

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Variation of base shear and roof displacement with storey level for increase of reinforcement and cross section in beams & columns at cumulative storey level

Storey levels	Percentage increase in reinforcement		Base shear (KN)	Roof displacement (mm)	Percentage change in base shear	Percentage change in roof displacement
	beams	columns				
1	50.02	77.7	771.7	335.9	15.3	-2.0
2	50.02	77.7	840.09	308.6	25.5	-10.02
3	50.02	77.7	928.9	302.27	38.8	-11.8
4	50.02	77.7	1046.34	305.10	56.4	-11.04
5	50.02	77.7	1202.67	385.04	79.7	12.2
6	50.02	77.7	1326.96	461.65	98.3	34.5
7	50.02	77.7	1363.49	364.64	103.8	6.3
8	50.02	77.7	1373.84	328.21	105.3	-4.4
9	50.02	77.7	1370.38	326.35	104.8	-4.84
10	50.02	77.7	1367.8	328.12	104.4	-4.33

IV.CONCLUSION

Based on present study the following conclusions are made:

1. Performance of building increases when sectional sizes and reinforcement of beams and columns are increased.
2. Increase in reinforcement of columns results a nominal increase in base shear, it is observed that change in reinforcement of 1st storey affects base shear more than other stories.
3. with increase in reinforcement in beams, base shear gets increased up to2ndStorey and minimum roof displacement is observed in 5thstorey.
4. Increase in reinforcement in both beams & columns results in nominal increase in base shear and minimum roof displacement is observed at 5thstorey.
5. With increase in reinforcement in beams & columns at each cumulative storey level there is an appreciable increase in base shear of about 51.1% whereas nominal change in roof displacement.
6. With increase in reinforcement in beams at each cumulative storey level there is an appreciable increase in base shear of 38% whereas roof displacement increases up to 4th storey and there after decreases about25.6%.
7. Increase in reinforcement of columns at each cumulative storey level results in nominal increase in base shear, it is observed that change in reinforcement of 1st storey affects base shear more than other stories.
8. Increase in reinforcement in beams of all stories among 3 core frames (2x2, 10x10, 20x20) results in appreciable increase of base shear and decrease of roof displacement with increase in perimeter of core frame.
9. Increase in reinforcement in columns of all stories among 3 core frames (2x2, 10x10, 20x20) results in nominal increase in base shear and roof displacement with increase in perimeter of core frame.

10. Increase in reinforcement in beams & columns of all stories among 3 core frames (2x2, 10x10, 20x20) results in appreciable increase in base shear with increase in perimeter of core frame, whereas minimum roof displacement is observed in 2x2 core frame.

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