Design, Analysis & Performance Check of A Multi-Story (G+23) RCC Building by Pushover Analysis using Sap 2000

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Abstract**—** *Pushover analysis is one of the most-used nonlinear static procedures for the seismic assessment of structures, due to its simplicity, efficiency in modeling and low computational time. The previous studies about pushover analysis are almost based on symmetric building structures and unidirectional earthquake excitation. This analysis is conducted to evaluate the seismic capacities of a asymmetric-plan building. The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi storey building frame with the help of pushover analysis is carried out in this paper. In the present study the building frame is designed as per IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis and design software SAP 2000 (version 14).*

Keywords**— *Capacity Curve, Performance Point, Pushover analysis, RC building.***

I. INTRODUCTION

Pushover analysis is stated as a nonlinear analysis in which, the nonlinear load-deformation characteristics are determined directly by incorporating the mathematical model of the building frame. The response of individual components and elements of buildings can be calculated separately. Each element shall be exposed to monotonically increasing lateral loads. During an earthquake, the inertia forces generated act as the lateral loads. As the intensity of the load increases, the structure is pushed. Due this, cracks are generated at various locations. When it exceeds the elastic limit, yielding occurs and it leads to plastic hinge formations along the span of the member. The deformations are recorded as a function of the increasing lateral load up to the failure of various structural components. This load incremental process is discontinued when the target displacement is reached at the roof level. Target displacement is the maximum expected displacement by combining both elastic and inelastic responses of the building under selected earthquake ground motion. Pushover analysis evaluates the structural performance by computing the force, drift capacity and seismic demand by a nonlinear static analysis algorithm. The analysis accounts for material inelasticity, geometrical nonlinearity and the redistribution of internal forces. The seismic demand parameters are component deformations, component forces, global displacements (at roof or any other reference points), storey drifts and storey forces.

The static pushover analysis is mainly based on the assumption that the response of the structure is regulated by the first mode of vibration and mode shape, or by the first few modes of vibration, and that this shape remains constant throughout the elastic and inelastic response of the structure. This provides the basis for transforming a dynamic problem into a static problem.

Capacity spectrum method is another approach for getting the target displacement. The basic assumption is that, for the nonlinear SDOF system, the maximum inelastic deformation can be approximated from corresponding value of the linear elastic SDOF system with an equivalent period and damping, and it is same as the displacement coefficient method. In this method the term ductility is incorporated in calculation of effective period and damping. In the capacity spectrum method the pushover curve is considered in the form of acceleration-displacement response spectrum (ADRS) format, and is termed as capacity spectrum. The Figure.1 shows the ADRS format for the capacity spectrum method.

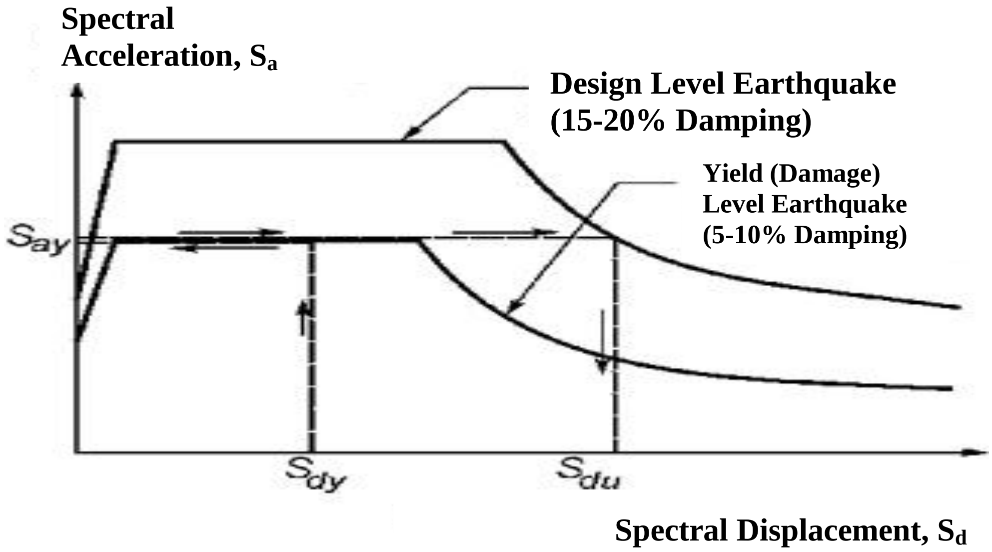


FIG. 1 ADRS FORMAT

II. MATERIALS AND METHODS

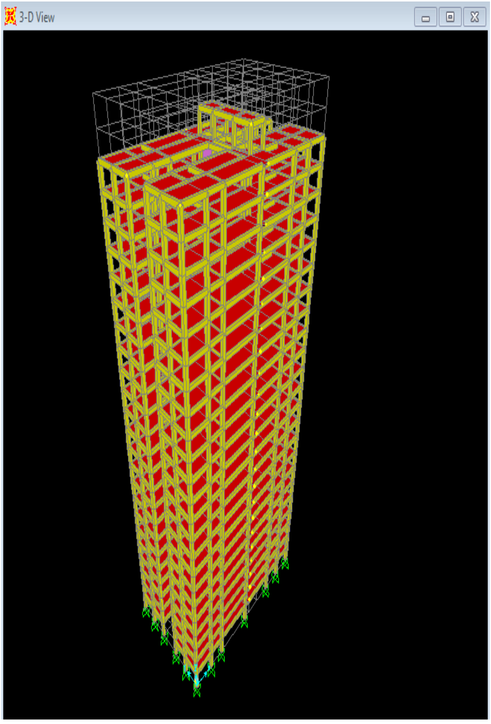
TABLE 1
MATERIALS

Material/Section	Grade/Size	Unit	Material/Section	Grade/Size	Unit
Concrete grade	M30		**slab thickness**	0.15	M
Steel grade	Fe500		**wall thickness**	0.23	M
E (concrete)	27386.12788	N/mm^2	**Density of concrete**	25	kN/m^3
E (steel)	210000	N/mm^2	**Density of brick work**	20	kN/m^3
Beam	0.4 x 0.6	m	**live Load**	3	KN/m^2
Column	0.6 x 0.6	m			

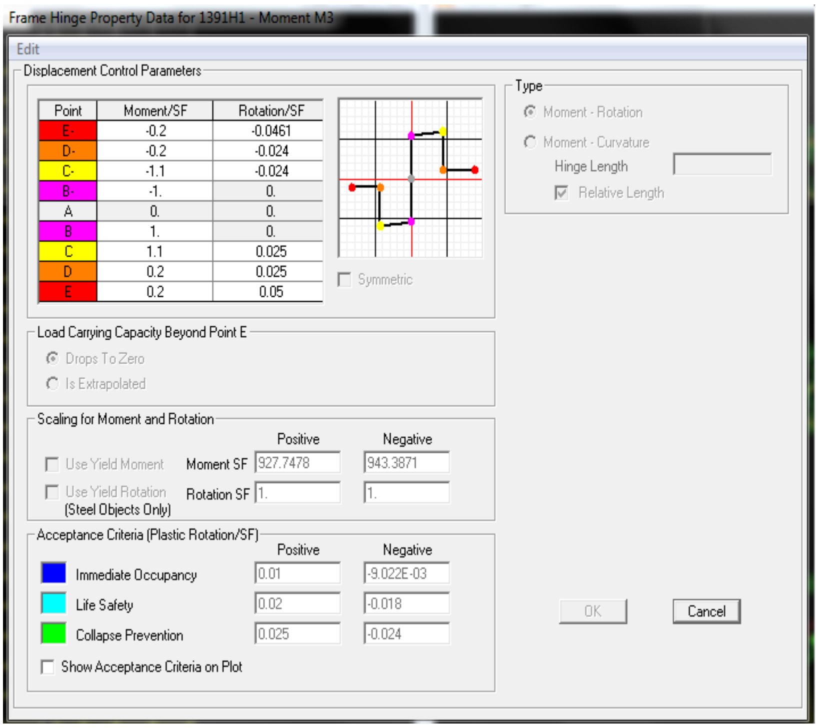
Software Used: *SAP2000 V.14.00 and all the analysis (i.e. base shear) have done by using IS 1893.*

2.1 Analysis In SAP2000

The 23 storey residential building is in seismic zone III (Location Vadodara). For the analysis of the building, the basic computer model in the usual manner was created. The figure (2) shows the 3-D model of the building Frame for the pushover analysis of the building the properties of the various plastic hinges such as flexural, shear, torsional and joint hinges are defined. For every beam and column the hinge length is calculated as half of their effective depth. Shear failure mostly occur in beams and columns owing to inadequate shear design. There are a lot of existing buildings which are not detailed as per IS 13920: 1993. Also, poor construction practice may lead to shear failure in framed building in the event of severe earthquakes. This residential building was designed as per IS 456:2000 and detailed as per IS 13920:1993, for adequate main and shear reinforcements, corresponding to the ultimate moment capacity level. When there is no prior failure in shear, flexural plastic hinges will be developed along with the predicted values of ultimate moment capacity. Therefore, it is obvious for a code designed building to fail in flexure and not in shear and there is no need of shear hinge modeling.



3D MODEL



PLASTIC HINGE MODELING

FIGURE 2

III. RESULT AND DISCUSSION

A static non-linear (pushover) analysis of the residential building was carried out using SAP2000. The maximum roof displacement of 0.64 m was chosen to be applied. For pushover analysis the various pushover cases are considered such as push gravity, push X (i.e. loads are applied in X direction), push Y (i.e. loads are applied in Y direction). The various load combinations are also used for this purpose. On the above residential building frame the non-linear static pushover analysis was performed to investigate the performance point of the building frame in terms of base shear and displacement. After pushover analysis the demand curve and capacity curves are plotted to get the performance point of the structure. The performance point is obtained as per ATC 40 capacity spectrum method. The base shear for PUSH X load case is 10202.70 KN and for PUSH Y base shear at performance point is at 13505.90 KN as shown in figure 3 and 4.

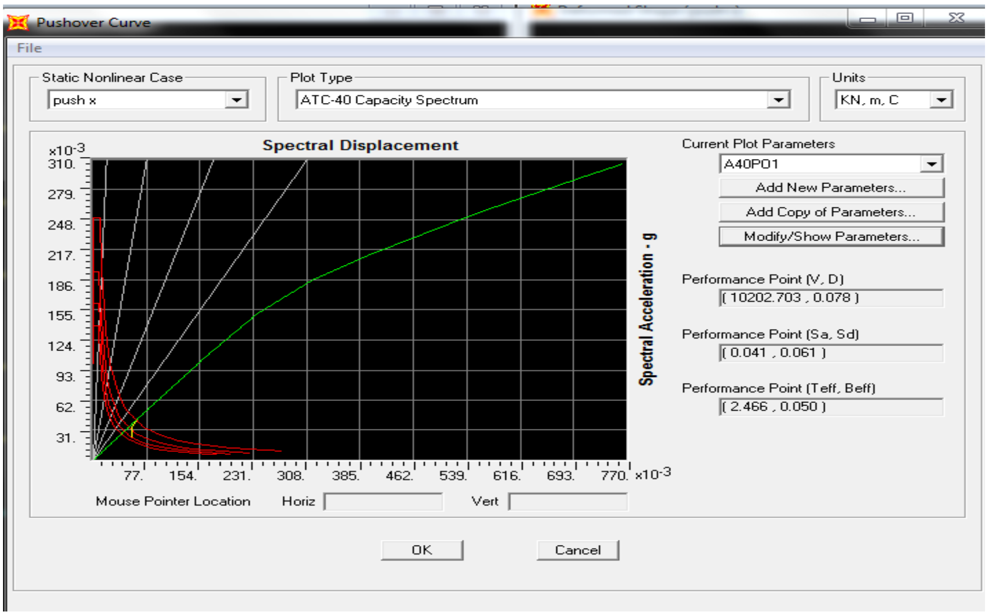


FIGURE 3 CAPACITY CURVE IN X-DIRECTION

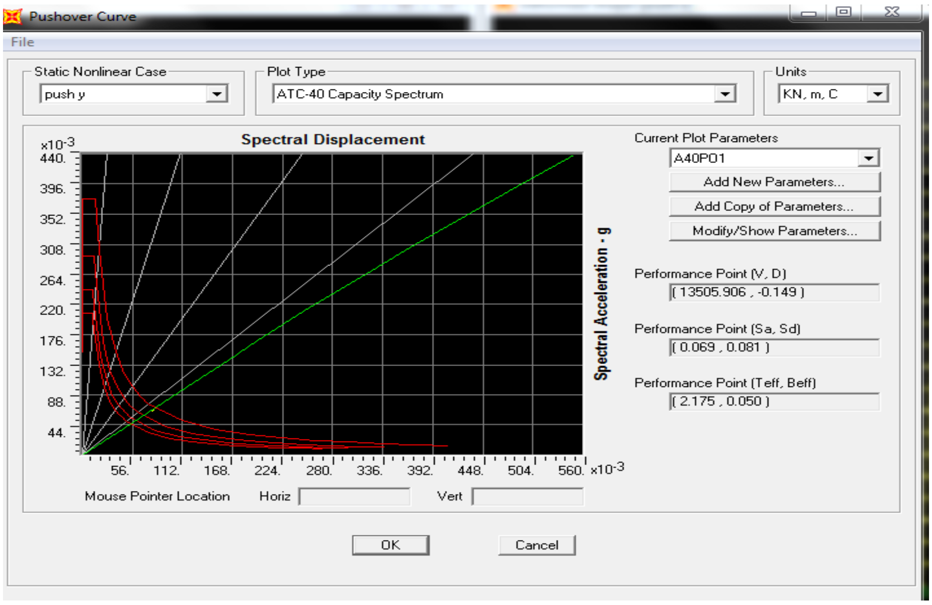


FIGURE 4 CAPACITY CURVE IN Y-DIRECTION

The design base shear of the building frame is found to be 2300 KN as per calculation. After performing the analysis the base shear at performance point is found to be 10202.70 KN for X directional loading and 13505.90 KN for Y directional loading, which is greater than design base shear. Since at the performance point base shear is greater than the design base shear the building frame is safe under the earthquake loading. Both the pushover curves show no decrease in the load carrying capacity of buildings suggesting good structural behavior. Also due to the demand curve intersects the capacity curve near the elastic range, the structure has a good resistance.

TABLE 2
DISTRIBUTION OF DESIGN BASE SHEAR

Story/Floor i	Height From Ground h_i(Meter)	Lumped Mass W_i(KN)	W_i* h_i^2	Distribution Of Base Shear (KN)	Shear (KN)
23(roof)	69	3352.6	15961728.6	210.8625534	210.862553
22	66	4630.13	20168846.28	266.4407178	477.303271
21	63	4630.13	18376985.97	242.7693317	720.072603
20	60	4630.13	16668468	220.1989404	940.271543
19	57	4630.13	15043292.37	198.7295437	1139.00108
18	54	4630.13	13501459.08	178.3611417	1317.36222
17	51	4630.13	12042968.13	159.0937344	1476.45596
16	48	4630.13	10667819.52	140.9273218	1617.38328
15	45	4630.13	9376013.25	123.8619039	1741.24518
14	42	4630.13	8167549.32	107.8974808	1849.14267
13	39	4630.13	7042427.73	93.0340523	1942.17672
12	36	4630.13	6000648.48	79.27161853	2021.44834
11	33	4630.13	5042211.57	66.61017946	2088.05852
10	30	4630.13	4167117	55.04973509	2143.10825
9	27	4630.13	3375364.77	44.59028542	2187.69854
8	24	4630.13	2666954.88	35.23183046	2222.93037
7	21	4630.13	2041887.33	26.97437019	2249.90474
6	18	4630.13	1500162.12	19.81790463	2269.72264
5	15	4630.13	1041779.25	13.76243377	2283.48507
4	12	4630.13	666738.72	8.807957614	2292.29303
3	9	4630.13	375040.53	4.954476158	2297.24751
2	6	4630.13	166684.68	2.201989404	2299.449503
1	3	4630.13	41671.17	0.550497351	2300
0(Ground)	0	0	0	0	2300
VB(KN)	2300				
∑Wihi^2	174103818.8				

Design Base shear = 2300 KN (Calculated as per IS 1893 guidelines)

IV. CONCLUSION

The performance of reinforced concrete frames was investigated using the pushover analysis. As a result of the work that was completed in this study, the following conclusions were made:

1. It is concluded that the residential building frame used for pushover analysis is seismically safe, because of the performance point base shear is greater than design base shear.
2. Since the demand curve intersects the capacity curve near the elastic range, the structure has a good resistance and high safety against collapse.
3. The behavior of properly detailed reinforced concrete frame building is adequate as indicated by the intersection of the demand and capacity curves.

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