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SEISMIC ASSESSMENT OF STRUCTURE USING PUSH OVER ANALYSIS

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Abstract – *This paper tells about the behavior of multistory building using Push Over Analysis, POA, is simplified computer method for seismic performance evaluation of structures. POA is one of the most-used non linear static procedures for the seismic assessment of structures. This analysis is to get the seismic response of RC building frame and the effect of earthquake forces on multistory building. Analysis was done in SAP 2000 version 19 and from this analysis performance points are obtained. The pushover curve is drawn in terms of base shear – roof displacement .The building is designed as per IS 456:2000 & IS 1893:2002 .Objective of this study is to check the behaviour of building. When designed as per Indian Standards .*

***Key Words*: seismic assessment, pushover analysis, performance point, capacity curve, IS 1893 , SAP 2000**

1. INTRODUCTION

The term earthquake is used to any type of seismic event either natural or indicated by humans , due to which seismic waves forms. According to earthquakes today, around 500,000 earthquakes occur each year ; 100,000 of these are actually felt. The destruction and damage of constructed and natural environment and the loss of impairment of human life are of prime concern eg: collapse of building, bridges, dams, etc. During an earthquake, ground shakes at building site due to which building foundation vibrates. To overcome this effect; research has spawned numerous innovations like ductile detailing of structures, improved connections for moment frames, base – isolation technology, energy – dissipation technology and computing tools. As famous saying "Earthquake do not kill ; unsafe buildings do" .A pushover analysis is a method in which structure is subjected to increasing lateral forces with invariable height wise distributed until the target displacement is reached. Push over analysis is a static non linear analysis under which a plot of total base shear versus top displacement in a structure is obtained and from this curve , it indicates any premature failure or weakness. The analysis is carried out until failure, so it determine of collapse load and ductility capacity.

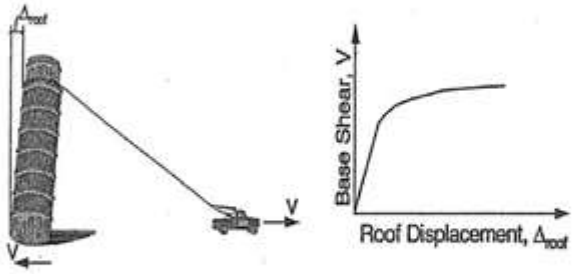

Fig. 1 Description of Pushover Analysis [ATC 40]

This Figure 1 illustrates the phenomena of Push over analysis is carried to obtain a capacity curve. This procedure analysis the structure that allows monitoring progressive yielding of the structure. The building is exposed to lateral load which magnitude increased until the building reaches target displacement. This displacement represnts the top displacement when building is subjected to ground level excitation.

2. PUSHOVER ANALYSIS

2.1 General

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out upto failure, thus it enables determination of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified. The decision to retrofit can be taken in such studies.

The seismic design can be viewed as a two step process. The first, and usually most important one, is the conception of an effective structural system that needs to be configured with due regard to all important seismic performance objectives, ranging from serviceability considerations. This step comprises the art of seismic engineering. The rules of thumb for the strength and stiffness targets, based on fundamental knowledge of ground motion and elastic and inelastic dynamic response characteristics, should suffice to configure and rough-size an effective structural system.

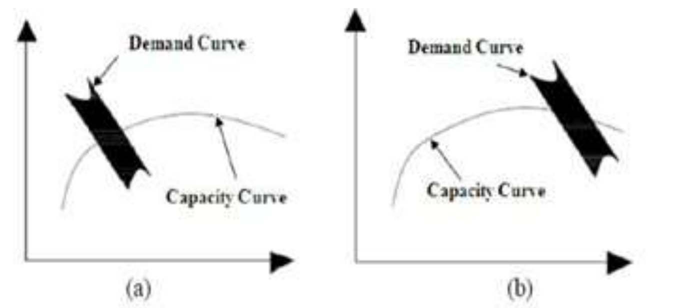

Fig. 2 Typical seismic demand vs. capacity (a) - Safe design (b) - Unsafe design

2.2 Case Study of Push Over Analysis Using SAP 2000

The recent advent of performance based design has brought the nonlinear static pushover analysis procedure to the forefront. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behavior and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

The ATC-40 and FEMA-273 documents have developed modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force-deformation criteria for hinges used in pushover analysis. As shown in Figure 3, five points labeled A, B, C, D, and E are used to define the force deflection behavior of the hinge and three points labeled IO, LS and CP are used to define the acceptance criteria for the hinge. (IO, LS and CP stand for Immediate Occupancy, Life Safety and Collapse Prevention respectively.) The values assigned to each of these points vary depending on the type of member as well as many other parameters defined in the ATC-40 and FEMA 273 documents.

This paper presents the steps used in performing a pushover analysis of a simple three dimensional building. SAP2000, a state-of-the-art, general-purpose, three dimensional structural analysis program, is used as a tool for performing the pushover. The SAP2000 static pushover analysis capabilities, which are fully integrated into the program, allow quick and easy implementation of the pushover procedures prescribed in the ATC-40 and FEMA-273 documents for both two and three-dimensional buildings.

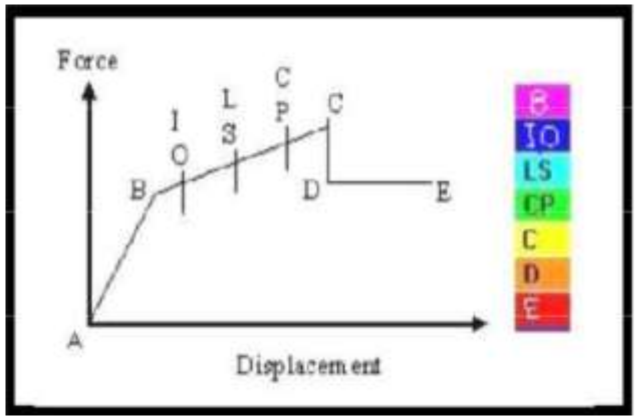

Fig. 3 Load vs Deformation

2.3 Limitations of Push Over Analysis

There are many unsolved issues that need to be addressed through more research and development. Examples of the important issues that need to be investigated are:

1. Incorporation of torsional effects (due to mass, stiffness and strength irregularities).

2. 3-D problems (orthogonality effects, direction of loading, semi-rigid diaphragms, etc)

3. Use of site specific spectra.

4. Cumulative damage issues.

5. Most importantly, the consideration of higher mode effects once a local mechanism has formed.

Since the pushover analysis is approximate in nature and is based on static loading, as such it cannot represent dynamic phenomena with a large degree of accuracy. It may not detect some important deformation modes that occur in a structure subjected to severe earthquakes, and it may significantly from predictions based on invariant or adaptive static load patterns, particularly if higher mode effects become important.

3. MODELING AND ANALYSIS OF BUILDING

3.1 Descriptive of Test Building

The prototype building is a 10-story reinforced concrete structure, with a height story of 3.3 m. The overall plan is 20x20 square meters. Figure 4 shows the typical structural layout. All beams are 300/400. The columns are 700/700 mm rectangular. The type of soil is medium soil.

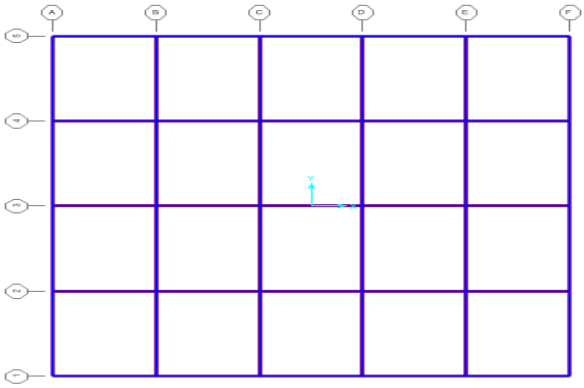

Fig. 4 Beam Layout of Building

Properties and modeling of building are describes in Table 1

Table 1 : Description of Building

Properties	
Concrete	M25 , M30
Steel	HYSD500
Size of Beam	300x400 mm
Size of Column	700x700 mm
Live Load	4 kN/m^2
Floor Finish	2 kN/m^2
Wall Load	7.5 kN/m
Height of Building	33 m
Floor to Floor Height	3.3 m
Diaphragm	Membrane element for SLab
Support	Fixed

3.2 Seismic Design

The base shear force is calculated based as per IS-1893 (Part-1) 2002 [14], by using the formula,

$$V_B = \frac{ZI\left(\frac{Sa}{g}\right)}{2R}W$$

Here, Z = Zone factor = 0.24

I= Importance factor = 1.2

R= Response reduction factor = 5 (Special RC moment-resisting frames)

Sa/g = Average response acceleration coefficient for soil

(Sa/g) at x- direction = 2.06

(Sa/g) at y- direction = 2.06

W = Total Seismic weight of the building.

The dead load intensity on each floor, D.L= 17.5 kN/m^2

The live load intensity on each floor, L.L= 4.0 kN/m^2

The floor finish load on each floor, F.F = 2 kN/m^2

The total floor area on each floor = 400.00 m^2

Total seismic load, W = 86000.00 kN.

The base shear, V_B = 5074.00 kN.

The base shear force is distributed as a lateral force, which affects the joint, at each level of the building. For this study, the distribution of the lateral seismic loads along the height of the building as per IS 1893 is shown in Table 2 for both directions.

Seismic design is done to know the structural behaviour under seismic forces. From this analysis ,the information about the distribution of lateral forces and distribution of base shear along the building is carried out. This is a static linear analysis which further done with pushover analysis which is static non linear analysis .

Table 2: Lateral load distribution with heights

Storey Level	Wi(kN)	Hi(m)	WixHi^2	(WixHi^2)/(∑WixHi^2)	Lateral Force, Qi (kN)
10	8600	33	9365400	0.2597	1317.72
9	8600	29.7	7585974	0.2103	1068.06
8	8600	26.4	5993856	0.166	843.284
7	8600	23.1	4589046	0.127	645.398
6	8600	19.8	3371544	0.0935	474.419
5	8600	16.5	2341350	0.0649	330.412
4	8600	13.2	1498464	0.0415	210.571
3	8600	9.9	842886	0.0234	118.732
2	8600	6.6	374616	0.0103	52.262
1	8600	3.3	93654	0.00259	13.142
		Sum	36056790		5074

3.3 Pushover Analysis in SAP2000

The building is a ten storey building in seismic zone IV. For the analysis of the building, the basic computer model in the usual manner was created . The figure 5 shows the 3-D model of the building Frame.

In this study, pushover analysis is carried out using the SAP2000 program. A three-dimensional model of structure has been created as shown in Figure 5. Beams and columns are modeled as nonlinear frame elements at the start and the end of element. The FEMA 356 rule, which is built in SAP

2000 with the IO, LS, and CP limit states for hinge rotation have been used for the acceptance criteria.

The pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis, and comparing these demands to available capacities at the performance levels of interest.

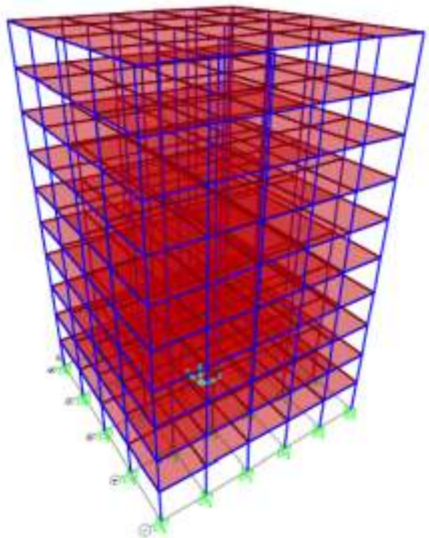

Fig. 5 3d Model

4. RESULT AND DISCUSSION

In the present study, A static non-linear(pushover) analysis of the building under the loading was carried out using SAP 2000. The objective of this study is to get the variation of load – displacement graph and check the maximum base shear at performance point.

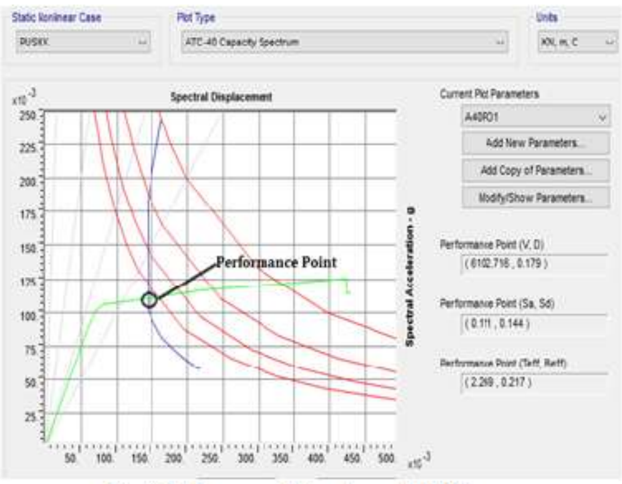

Fig. 6 Performance Point due to PUSHX

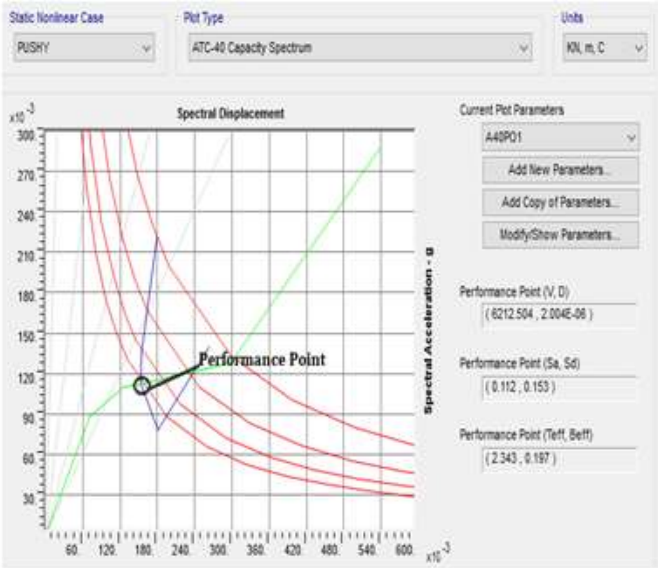

Fig. 7 Performance Point due to PUSHY

After running the analysis, the pushover curve is obtained as shown in figure 6 and figure 7 for PUSH X (i.e. loads are applied in X direction), PUSH Y (i.e. loads are applied in Y direction). The global behaviour of the frame in terms of stiffness and ductility are represented by these curves. Under incrementally increasing loading lateral load, the element may yield sequentially. At every step, the structure experience loss in stiffness. Therefore slope of pushover curve gradually is decreasing.

For this analysis the different pushover cases are considered such as pushX, pushY and various load combination are also used. After analysis the demand curve and capacity curve are meeting at the performance point of the structure. The performance point is obtained by ATC 40[1] capacity spectrum method.

The base shear for PUSHX load case is 6102.716 and for PUSHY base shear at performance point is at 6212.504 as shown in figure 6 and figure 7 and from our calculation design base shear is 5074. As base shear at performance point in X and Y direction is greater than design base shear so building is safe under the earthquake loading. Both the 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.

Plastic hinge mechanism shown in figure 8 and figure 9 for PUSHX and for PUSHY it is shown in figure 10 and 11.

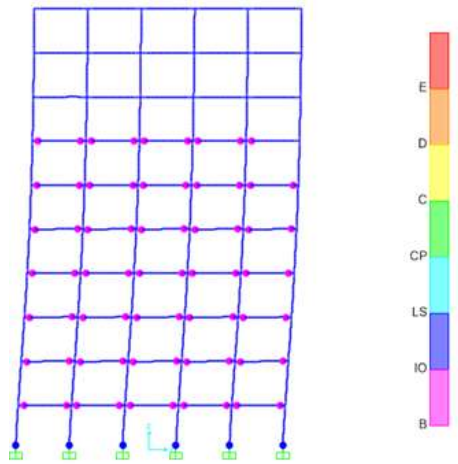

Fig. 8 Plastic hinge mechanism for PUSHX (step 5)

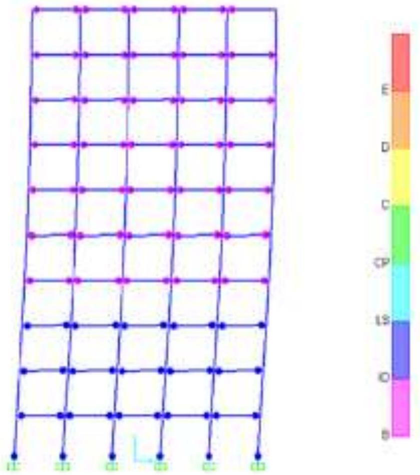

Fig. 9 Plastic hinge mechanism for PUSHX (step 7)

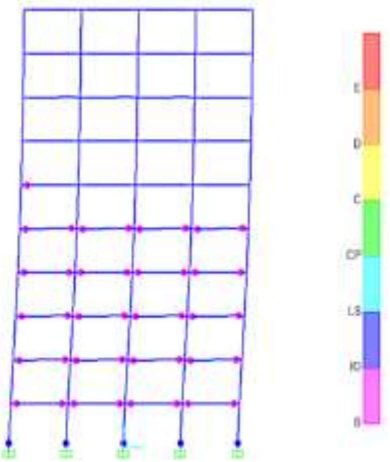

Fig. 10 Plastic hinge mechanism for PUSHY (step 3)

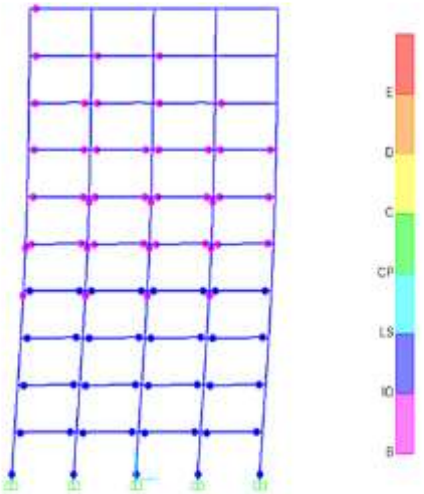

Fig. 11 Plastic hinge mechanism for PUSHY (step 5)

At every step of deformation, pushover analysis determines plastic hinge location in the elements and which hinge reaches the FEMA limit state, which are IO, LS, and CP using colors for identification. Plastic hinges formation have been obtained at different displacement levels or performance points.

5. CONCLUSION

The performance of reinforced concrete building was investigated using the pushover analysis. As a result there are some conclusions obtained regarding this analysis which are described below:

- Pushover analysis is a static non linear analysis which gives the non linear behaviour of the structure, which is the real behaviour of the structure.
- It is concluded that building frame is seismically safe, because the base shear of performance point is greater than the design base shear.
- Since the capacity curve intersects demand curve within the elastic range, the structure has good bearing resistance and safety.
- All concrete frames passed the stress/capacity check.
- Pushover analysis can identify weak elements by predicting the failure mechanism and account for the redistribution of forces during progressive yielding. It may help engineers take action for rehabilitation work.

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