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NON-LINEAR STATIC PUSHOVER ANALYSIS OF FRAMED STRUCTURE BY SAP2000

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Abstract - *In last decade, four devastating earthquakes of world have been occurred in India, and low to mild intensities earthquakes are shaking our land frequently. It has raised the questions about the adequacy of framed structures to resist strong motions, since many buildings suffered great damage or collapsed. To evaluate the performance of framed buildings under future expected earthquakes, a non-linear static pushover analysis has been conducted. To achieve this objective, 4 storied building is analyzed. The results obtained from this study show that properly designed frame will perform well under seismic loads. Elastic method of analysis indicates elastic capacity of structures and tells us about location of first yielding but it cannot capture important phenomena that control seismic performance of structures during severe ground shaking.*

Thus, for design and evaluation of structures, inelastic procedures are being used by engineers to understand structural behavior during earthquakes with the assumption that elastic capacity of structure will be exceeded.

To identify the nonlinear behavior of frame elements in the structure, Pushover analysis is performed using SAP 2000.

***Key Words*: Yielding, Seismic Performance, Pushover Analysis, Elastic Capacity, SAP 2000**

1. INTRODUCTION

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approx. 47 mm/year. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version, which consisted of five or six zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity. Modelling Non-linear behavior in SAP2000 by Pushover Analysis is limited to Framed Structures. Therefore, this thesis is to analyze 4 storied RC framed structure.

1.1 PUSHOVER ANALYSIS

Pushover analysis is a static non-linear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with a certain pre-defined pattern by applying monotonically increasing lateral loads to the structure representing the inertial forces that would be experienced by the structure during severe earthquakes. Magnitude of lateral load increases until the structure reaches target displacement. Target displacement represents the top deformation that the structure will be subjected during earthquake. Various structural elements yield during load increment. Loss in stiffness occurs at each event subsequent to yielding of structural members, etc.

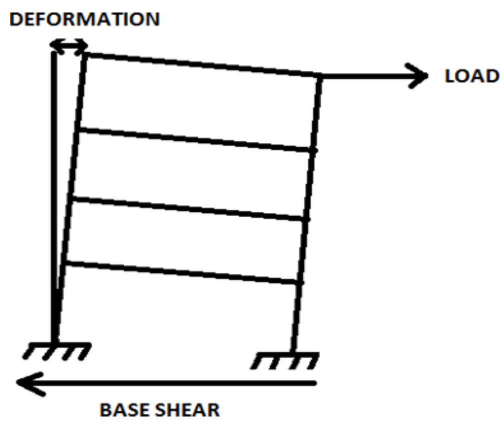

Fig. 1.1 Pushover Mechanism

Capacity curve (Pushover curve) is generated during pushover analysis which shows the relationship between base shear force and roof top displacement. Capacity curve is dependent on strength and deformation capacities of the structure. It enables us to understand the behavior of the structure beyond elastic limit. Because of the complex nature of the structural properties, structural response cannot be adequately predicted during ground shaking. Displacement values give an estimate of the maximum expected response of the structure during earthquakes.

1.2 PURPOSE OF DOING NON-LINEAR STATIC ANALYSIS

The purpose of 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. This method considers the nonlinear behavior of the structure which increases the load taking capacity of the building. It also focuses on ductility of the structure by providing plastic hinges. Pushover analysis is applicable to new and existing structures which can be a good method for retrofitting of structures after its design life is over. It considers target displacement and defining objectives whenever the performance meets the objectives then the damage at that performance level is acceptable.

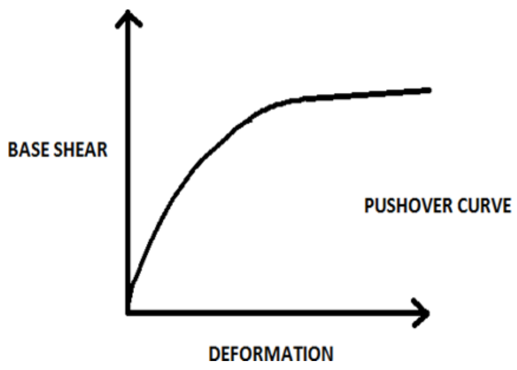

Fig. 1.2 Pushover Curve

2. OBJECTIVE

- Estimate of force and displacement capacity of structure.
- Sequence of members yielding and the progress of overall capacity curve.
- Load demand of the structure.
- Sequence of failure of element and the consequent effect on the overall structure (by hinge mechanism).
- Estimation of performance point of structure for a given earthquake ground motion.
- Identification of critical region where the inelastic deformations are expected to be high.
- Calculation of target displacement.
- Study the behavior of symmetric or asymmetric structure using different seismic zone.

3. METHODOLOGY

Initially, a 4 storied building plan has been selected for modelling with basic material properties, i.e. the properties that generally happen in basic building materials. Then, modelling using SAP 2000 software is done by applying different load combinations and thus, results are analyzed by running the model and results are obtained.

The total design lateral force or design seismic base shear (Vb) along any principal direction shall be determined by the following expression:

Vb = Ah.W

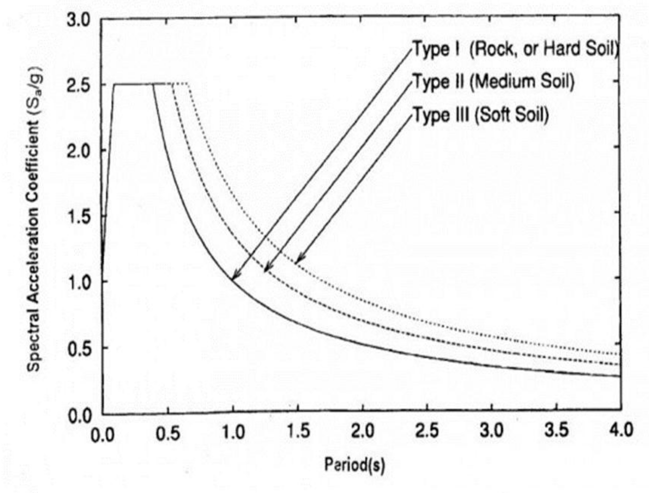

Fig. 3.1 Response Spectra for Rock and Soil sites for 5% Damping

4. SAP 2000

SAP 2000 is a general-purpose civil-engineering software ideal for the analysis and design of any type of structural system. Basic and advanced systems, ranging from 2D to 3D, of simple geometry to complex, may be modeled, analyzed, designed, and optimized using a practical and intuitive object-based modeling environment that simplifies and streamlines the engineering process.

Although quick and easy for simple structures, SAP 2000 can also handle the largest and most complex building models, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineers in the building industry.

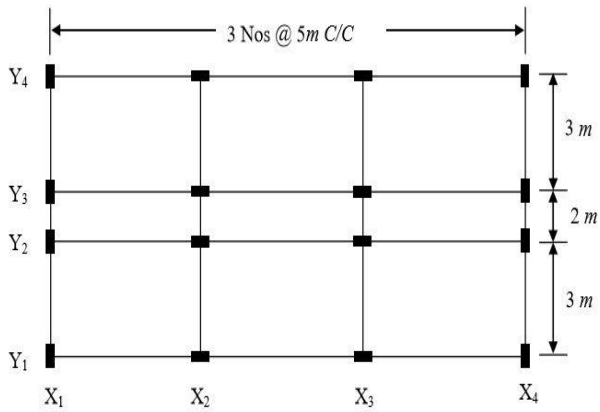

Fig. 4.1 Plan of the RC Framed building

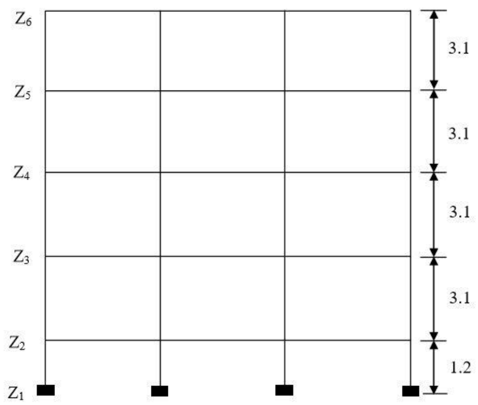

Fig. 4.2 Elevation of the RC Framed Building

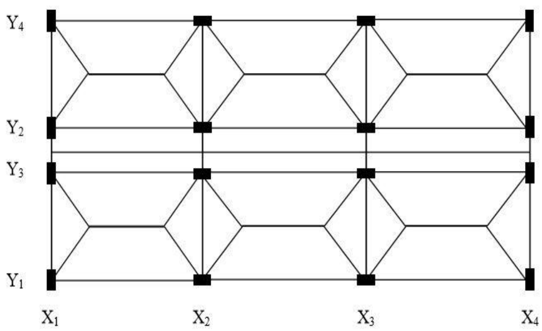

Fig. 4.3 Yield Pattern of the Model

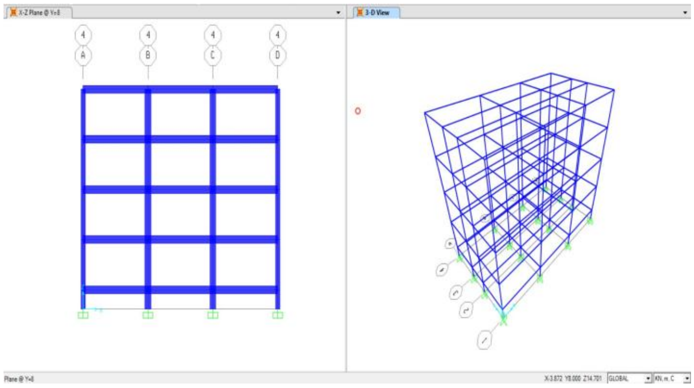

Fig. 4.4 Windows 3D View

5. RESULT

Plastic hinges formation for the building mechanisms have been obtained at different displacement levels. Plastic hinge formations start with beam ends and base columns of lower storeys, then propagates to upper stories and continue with yielding of interior intermediate columns in the upper stories. But since yielding occurs at events B, IO and LS respectively, the amount of damage in the building will be limited. After assigning all properties of the model, the displacement –controlled pushover analysis of the model is carried out. The model is pushed in monotonically increasing order until target displacement is reached or structure loses equilibrium; whichever occurs first. For this purpose, target displacement at roof level and number of steps in which this displacement must be defined.

In this study, target displacement is taken 4% of building height. Pushover curve is a base shear force versus roof displacement curve. The peak of this curve represents maximum lateral load carrying capacity of the structure. The initial stiffness of the structure is obtained from the tangent at pushover curve at zero load level. The collapse is assumed when structure losses its 75% strength and corresponding roof displacement is called “maximum roof displacement”.

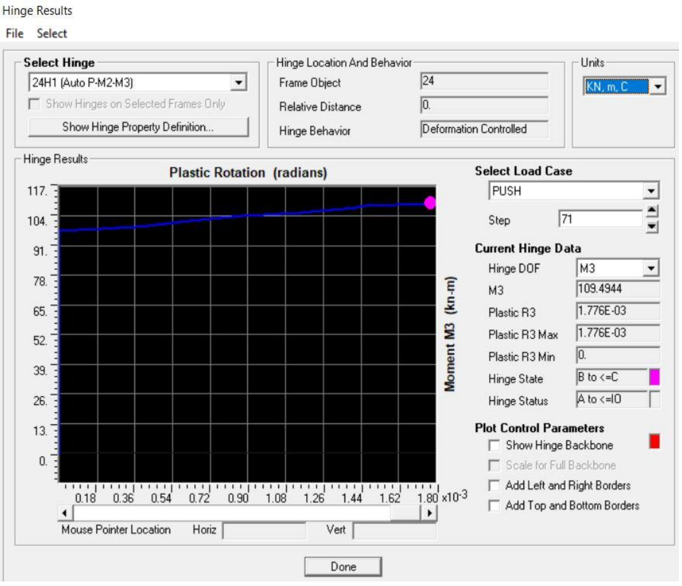

Fig. 5.1 Hinge Graph

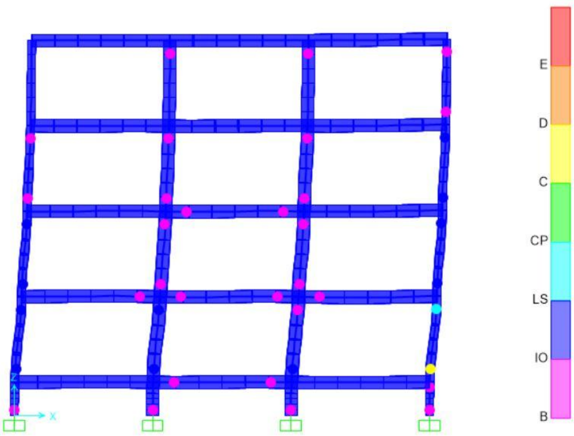

Fig 5.2 Deformed Shape and Hinge Formation after Pushover Analysis

The values obtained as result by modelling are approximately equal to those obtained by manual calculation.

S. No.	Particulars	Calculated Value	Value by Modeling
1	Total Dead Wall	3660.64 kN	3641.56 kN
2	Total Dead Slab	2280 kN	1800 kN
3	Total Dead Floor Finish	480 kN	333 kN
4	Total Dead Roof Treatment	180 kN	180 kN
5	Total Live Load	1440 kN	1080 kN
6	Base Shear in X-direction	755.173 kN	755.148 kN
7	Base Shear in Y-direction	755.173 kN	755.281 kN

Table 5.3 Manual and Software Calculation

6. CONCLUSIONS

The pushover analysis is a relatively simple way to explore the non-linear behavior of Buildings.

- The behavior of properly detailed reinforced concrete frame building is adequate as Indicated by the intersection of the demand and capacity curves and the distribution of Hinges in the beams and the columns. Most of the hinges developed in the beams and few in the columns but with limited damage.
- The causes of failure of reinforced concrete during the earthquake may be attributed to the quality of the materials.
- The results obtained in terms of demand, capacity and plastic hinges gave an insight into the real behavior of structures.
- It must be emphasized that 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 may occur in a structure subjected to severe earthquakes, and it may exaggerate others. Inelastic dynamic response may differ significantly from predictions based on invariant or adaptive static load patterns, particularly if higher mode effects become important.
- Thus, performance of pushover analysis primarily depends upon choice of material models included in the study.

- It would be desirable to study more cases before reaching definite conclusions about the behavior of reinforced concrete frame buildings.
- Weak elements in the structure can be identified with the help of pushover analysis However, Pushover analysis may not accurately represent dynamic behavior of the structure as it is an approximate method based on static loading.
- Formation of the hinges starts at the supports and progressively moves towards the upper stories with the increment of load. Step by step development of hinges is observed in results.
- Nonlinear behavior of base shear vs displacement curve of all three building is semi- ductile and it gives information about yielding of structure, due to this sudden collapse of building is avoided.

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