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Investigation of Steel Building Structures with References to Pushover Analysis

Er. ANSHUL UMREDAKR*, Prof. SANDEEP GAIKWAD**
*(Civil Engineering, TulsiramjiGaikwad-Patil College of Engineering and Technology, Nagpur,)
** (Civil Engineering, TulsiramjiGaikwad-Patil College of Engineering and Technology, Nagpur)

Abstract:

In last decades Steel structure has played an important role in construction Industry. It is necessary to design a structure to perform well under seismic loads. To model the behavior of steel structure analytically in its non-linear zone is difficult. For structural design and assessment of steel section's for member, the non-linear Pushover analysis has become an important tool. Nonlinear static pushover analysis provides a better view on the performance of the structures during seismic events. The seismic performance of a multi-story steel frame building is designed according to the provisions of IS 800 -2007. This analysis of the nonlinear response of steel frame structures carried out to help in the investigation of the behavior of the structure under different loading conditions, its load deflection behavior and the cracks pattern. The non-linear response of steel frame using SAP2000 under the loading has been carried out to investigate the relative importance of several factors in the non-linear analysis of steel frames. Performance of frame is studied through nonlinear static analysis.

Keywords — **Pushover analysis, Steel frames, Behavior factor, etc.**

I. INTRODUCTION

Steel structure has played an important role in construction Industry. It is necessary to design a structure to perform well under seismic loads. To model the behavior of steel structure analytically in its non-linear zone is difficult. For structural design and assessment of steel section's for member, the non-linear Pushover analysis has become an important tool. Nonlinear static pushover analysis provides a better view on the performance of the structures during seismic events.The seismic performance of a multi-story steel frame building is designed according to the provisions of IS 800 - 2007. This analysis of the nonlinear response of steel frame structures carried out to help in the investigation of the behavior of the structure under different loading conditions, its load deflection behavior and the cracks pattern. The non-linear response of steel frame using SAP2000 under the loading has been carried out to investigate the relative importance of several factors in the non-linear analysis of steel frames. Performance of frame is studied through nonlinear static analysis.

A simple computer-based push-over analysis is a technique for performance-based design of building frameworks subject to earthquake loading. Push over analysis attains much importance in the past decades due to its simplicity and the effectiveness of the results. The present study develops a push-over analysis for different eccentric steel frames designed according to IS-800 (2007) and ductility behaviour of each frame.

Pushover analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure. **(girgin. et., 2007)**

II. PUSHOVER ANALYSIS

The analysis accounts for material inelasticity, geometrical nonlinearity and the redistribution of internal forces. Response characteristics that can be obtained from the pushover analysis are summarized as follows:

a) Estimates of force and displacement capacities of the structure. Sequence of the member yielding and the progress of the overall capacity curve.
b) Estimates of force (axial, shear and moment) demands on potentially brittle elements and deformation demands on ductile elements.
c) Estimates of global displacement demand, corresponding inter-storey drifts and damages on structural and non-structural elements expected under the 20 earthquake ground motion considered.
d) Sequences of the failure of elements and the consequent effect on the overall structural stability.
e) Identification of the critical regions, when the inelastic deformations are expected to be high and identification of strength irregularities of the building. Pushover analysis delivers all these benefits for an additional computational effort (modelling nonlinearity and change in analysis algorithm) over the linear static analysis.

Pushover analysis can be performed as either force-controlled or displacement controlled depending on the physical nature of the load and the behavior expected from the structure.Lateral loads are increased until some member(s) yield under the combined effects of gravity and lateral loads some computer programs (e.g. Seismostruct, DRAIN-2DX, nonlinear version of SAP2000, ANSYS) can model nonlinear behavior and perform pushover analysis directly to obtain capacity curve for two and/or three dimensional models of the structure. When such programs are not available or the available computer programs could not perform pushover analysis directly (e.g. ETABS, RISA, SAP90), a series of sequential elastic analyses are performed and superimposed to determine a force displacement curve of the overall structure. A displacement-controlled pushover analysis is basically composed of the following steps:

1. A two or three dimensional model that represents the overall structural behavior is created.
2. Bilinear or tri-linear load-deformation diagrams of all important members that affect lateral response are defined.
3. Gravity loads composed of dead loads and a specified portion of live loads are applied to the structural model initially.
4. A pre-defined lateral load pattern which is distributed along the building height is then applied.

Lateral loads are increased until some member(s) yield under the combined effects of gravity and lateral loads.

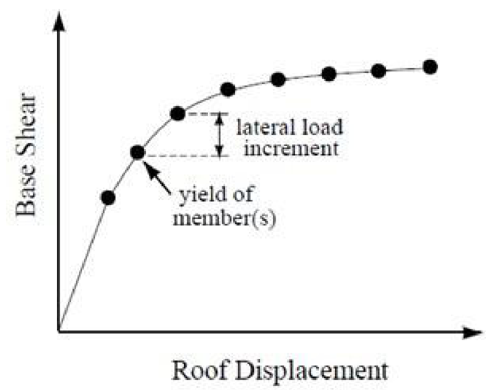


FIGURE1.CAPACITY(PUSHOVER) CURVE OF STRUCTURE

OBJECTIVES OF THIS STUDY:

To study the structural performance of solid and hollow steel frames when subjected to seismic loads.

SCOPE OF THE STUDY:

1. Determination of performance level of different storeyframes
2. To predict peak response of building and components for a given seismic loads.

III.FRAME DESIGNS:

The building frame considered in this study is assumed to be located in Indian seismic zone V with medium soil conditions. The design peak ground acceleration (PGA) of this zone is specified as 0.36*g*. The frame is designed as per prevailing practice in India. Seismic loads are estimated as per

IS 1893 (2002) and the design of the steel elements are carried out as per IS 800 (2007) standards. The characteristic strength of steel is considered 415MPa. The dead load of the slab (6 m x 6 m panel), including floor finishes, is taken as 2.5 kN/m^2, live load as 3 kN/m^2. The design base shear (*VB*) is calculated as per IS 1893 (2002).

$$V = \left(\frac{Z}{2} \frac{I}{R} \frac{S_a}{g} \right) W$$

Where, seismic zone factor, $Z = 0.36$, Importance factor $I = 1.0$, Response reduction factor $R = 4.0$. Estimated Base shear from above formula is found to be 357 kN. Table 4.2, Shows the designed cross section details of steel columns and beams.

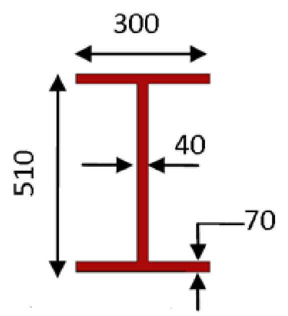
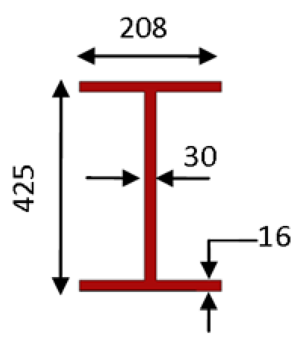
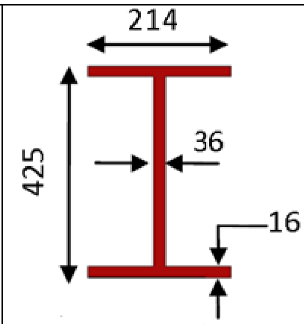
Sr.	Cross section	Used
1		Cross sectional details for ground storey column
2		Cross sectional details for1st to 13th storey column
3		Cross sectional details forbeam in each storey

TABLE 1. CROSS SECTIONAL DETAILS OF THE FRAMES

IV.PUSHOVER ANALYSIS METHODOLOGY:

Figure shows the pushover methodology for both solid and hollow section. In this chart describes the pushover steps and details over the pushover analysis.

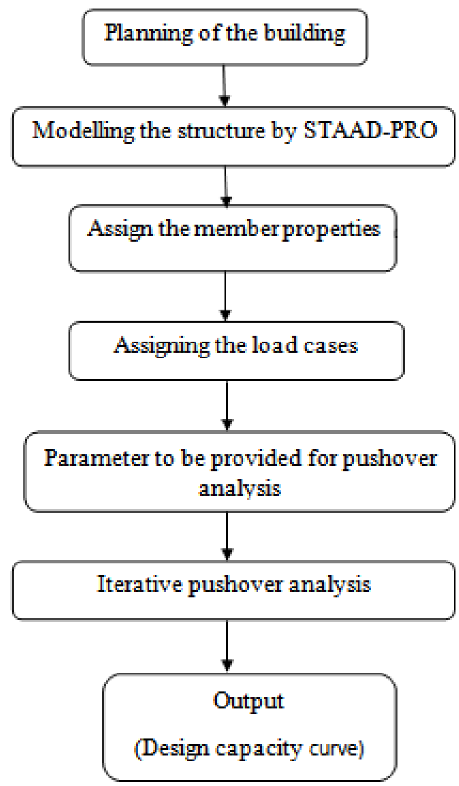


FIGURE 2. PUSHOVER ANALYSIS METHODOLOGY

V. RESULTS AND DISCUSSION:

The capacity (Pushover) curve obtained through the pushover analysis is shown in Figure 4, 5 & 6. In the present study the lateral forces has been estimated by using seismic coefficient method as per IS: 1893-2002. The zone is considered as zone V with medium soil. The analysis carried out by representing the proposed inelastic member behaviour with semi-rigid connection will resemble the most practical case. The sequence of hinge formation observed during the analysis is shown in Figure 11. At the end of interaction severe hinges are observed in first floor beams and ground floor columns and which gives an insight in structural behaviour and understanding. It may be concluded that under a severe earthquake the first floor beams and ground floor columns meet all the structural requirements of the immediate occupancy level. It is observed that inelastic displacement of the structure is within collapse prevention.

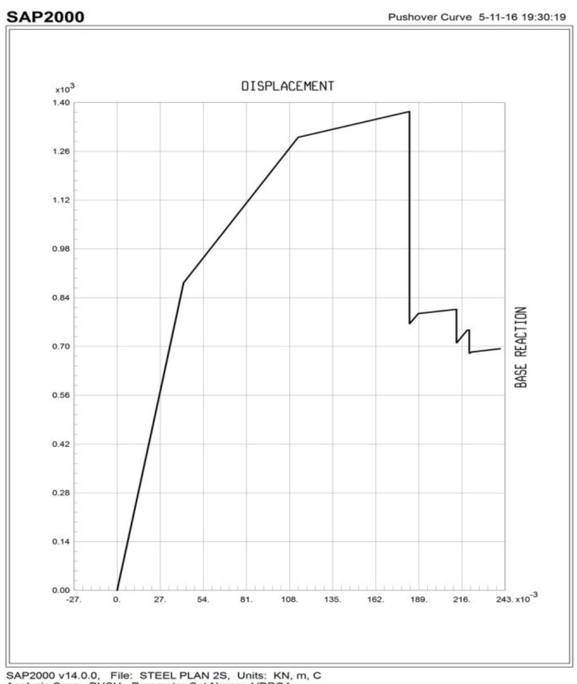


FIGURE 4. PUSHOVER CURVE OF 2 STOREY FRAME

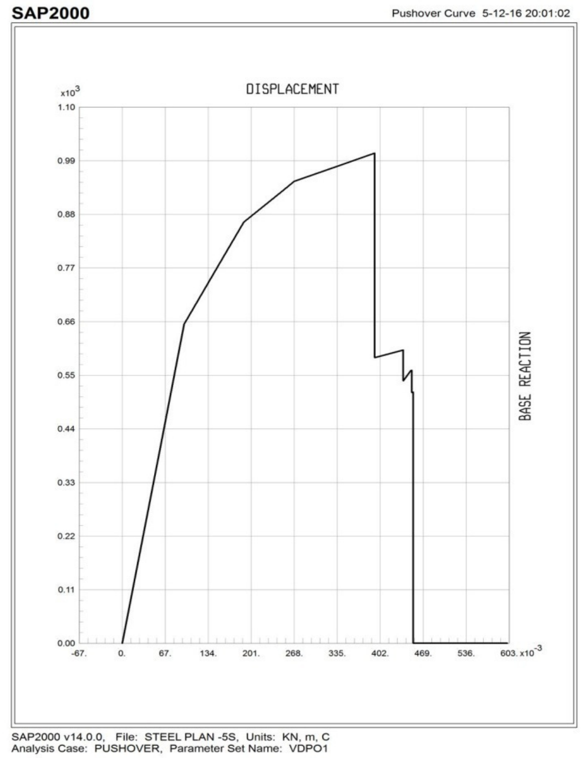


FIGURE5. PUSHOVER CURVE OF 5 STOREY FRAME

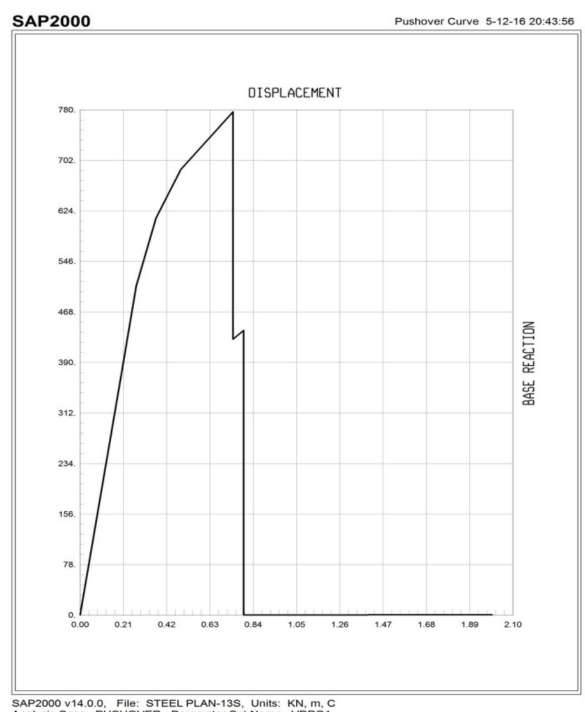


FIGURE6. PUSHOVER CURVE OF 13 STOREY FRAME

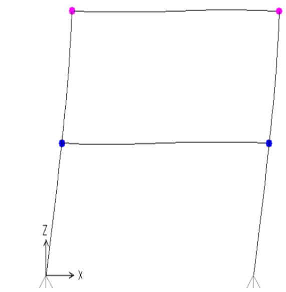


FIGURE 7. IMMEDIATE OCCUPANCY LEVEL FOR 2 STOREYS

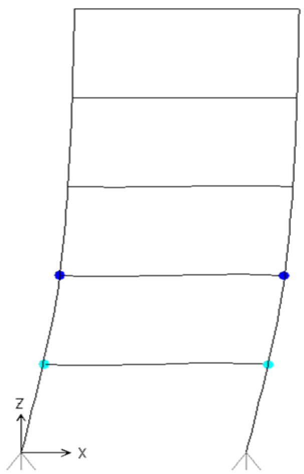


FIGURE 8. IMMEDIATE OCCUPANCY LEVEL FOR 5 STOREYS

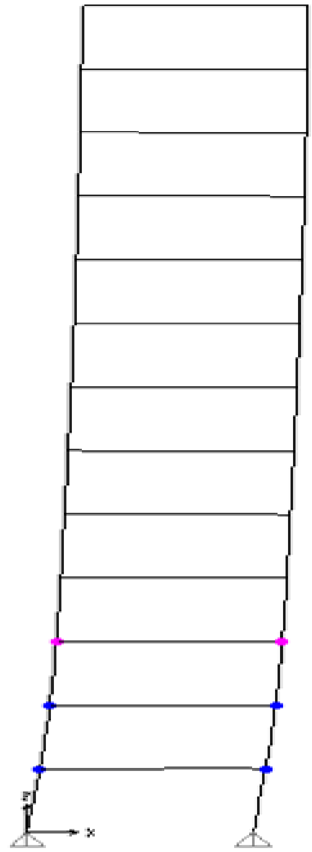


FIGURE 9. IMMEDIATE OCCUPANCY AND LIFE SAFETY LEVEL FOR 13 STOREYS

VI. CONCLUSIONS

In this study, 2-D frames are modelled sections for 2, 5 and 13 stories with constant bay width and storey height which was analysed by pushover analysis using SAP2000.

- From this study, when the number of storey decrease corresponding base shear increases and also number of storeys increases corresponding displacement increases.
- The performances of all section 2-D models are lies in between immediate occupancy, life safety and collapse prevention level. Formations of hinges were maximum when the storey levels are minimum.
- Effect of lateral displacement for 5-storey 2-D frame with hollow section provides 16.73% reduction when compared with the solid sections.
- Maximum deflection for 2-storey steel frame has been found to be 220mm for the base shear value

746.98KN. As the performances point shows immediate occupancy level.

- Maximum deflection for 5-storey steel frame has been found to be 453mm for the base shear value 515.16 KN. As the performances point shows immediate occupancy level.
- When storey level get increased pushover load steps get decreased, so the capacity curve become linear for models corresponding to its storey level.
- The seismic performance evaluation of a steel building frame is carried out by using pushover analysis accounted for user defined inelastic material behaviour and assigning inelastic effects to plastic hinges at member ends.

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