Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-7, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Pushover Analysis of R/C Setback Building

Deepanjali Sahu
P.G. Student, Department Of Civil Engineering, Kalinga University Raipur, C.G., India

***Abstract**: Pushover analysis is a nonlinear static analysis used mainly for seismic evaluation of framed building. The behaviour of a multi-storey framed building during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. In multi-storeyed framed buildings, damage from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. Further, these weaknesses tend to accentuate and concentrate the structural damage through plastification that eventually leads to complete collapse. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height.*

There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities. Irregular configurations either in plan or elevation were often recognised as one of the main causes of failure during past earthquakes. A common type of vertical geometrical irregularity in building structures arises from abrupt reduction of the lateral dimension of the building at specific levels of the elevation. This building category is known as the setback building.

***Keywords:** setback building; pushover analysis; irregularity; target displacement; lateral load profile; time history analysis.*

INTRODUCTION

i BACKGROUND AND MOTIVATION

This behaviour of multi-storey framed buildings during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of buildings. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height. There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities.

A common type of vertical geometrical irregularity in building structures arises is the presence of setbacks, *i.e.* the presence of abrupt reduction of the lateral dimension of the building at specific levels of the elevation. This building category is known as ‘setback building’. This building form is becoming increasingly popular in modern multi-storey building construction mainly because of its functional and aesthetic architecture. In particular, such a setback form provides for adequate daylight and ventilation for the lower storeys in an urban locality with closely spaced tall buildings. This type of building form also provides for compliance with building bye-law restrictions related to ‘floor area ratio’ (practice in India). Figs 1.2 show typical examples of setback buildings.

Fig. 1.2: Typical Setback building at India

ii SCOPE OF THE STUDY

The plan asymmetry arising out of the vertical geometric irregularity strictly calls for three-dimensional analysis to account properly for torsion effects. This is not considered in the present study, which is limited to analysis of plane setback frames. Although different storey numbers (up to 20 storeys), bay numbers (up to 12 bays) and irregularity are considered, the bay width is restricted, to 6m and storey height to 3m.

PUSHOVER ANALYSIS

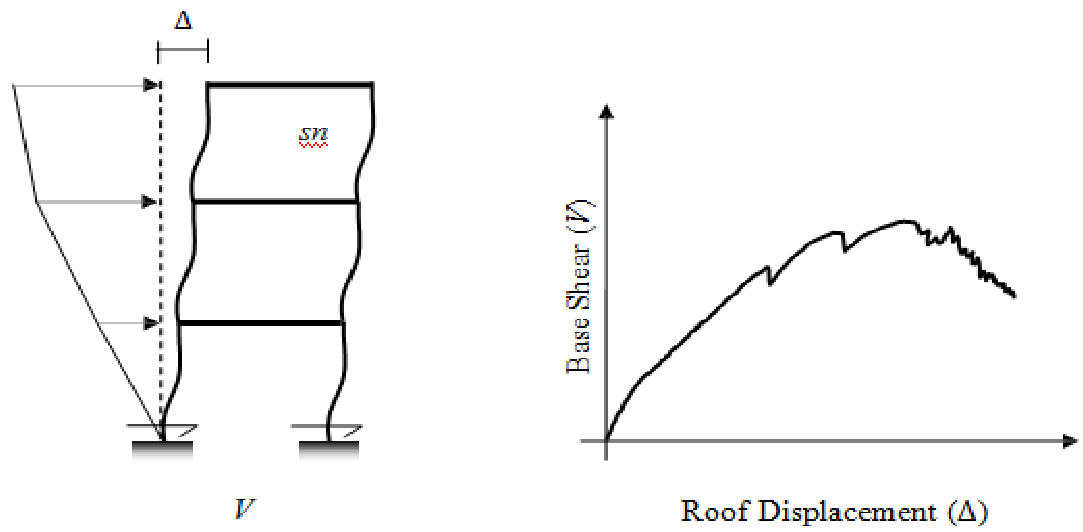
i. PUSHOVER ANALYSIS – AN OVERVIEW

This procedure is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake. Pushover analysis is defined as an analysis wherein a mathematical model directly incorporating the nonlinear load-deformation characteristics of individual components and elements of the building shall be subjected to monotonically increasing lateral loads representing inertia forces in an earthquake until a 'target displacement' is exceeded. Target displacement is the maximum displacement (elastic plus inelastic) of the building at roof expected under selected earthquake ground motion. The analysis accounts for geometrical nonlinearity, material inelasticity and the redistribution of internal forces. Response characteristics that can be obtained from the pushover analysis are summarised 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 earthquake ground motion considered.
d) Sequences of the failure of elements and the consequent effect on the overall structural stability.

ii. PUSHOVER ANALYSIS PROCEDURE

Pushover analysis is a static nonlinear procedure in which the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern along the height of the building (Fig. 2.1a). Building is displaced till the 'control node' reaches 'target displacement' or building collapses. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed. The relation between base shear and control node displacement is plotted for all the pushover analysis (Fig. 2.1b). Generation of base shear– control node displacement curve is single most important part of pushover analysis. This curve is conventionally called as pushover curve or capacity curve. The capacity curve is the basis of 'target displacement'. So the pushover analysis may be carried out twice: (a) first time till the collapse of the building to estimate target displacement and (b) next time till the target displacement to estimate the seismic demand.



a) Building model b) Pushover curve

Fig. 2.1: Schematic representation of pushover analysis procedure

Linear And Nonlinear Dynamic Analyses Results For 20-Storey Building Variants

B.1 NATURAL MODE SHAPES OF 20-STOREY BUILDING VARIANTS

Figs B.1 to B.5 present the elastic mode shapes of the four 20-storey building models considered in the present study (namely R-20-4, S1-20-4, S2-20-4 and S3-20-4). All of these four building models have four bays.

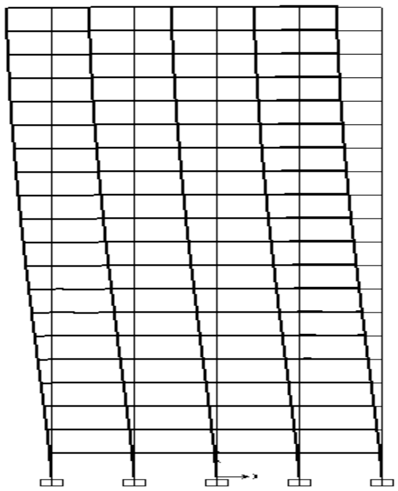


Fig. B.1: First mode shape of R-20-4 building model

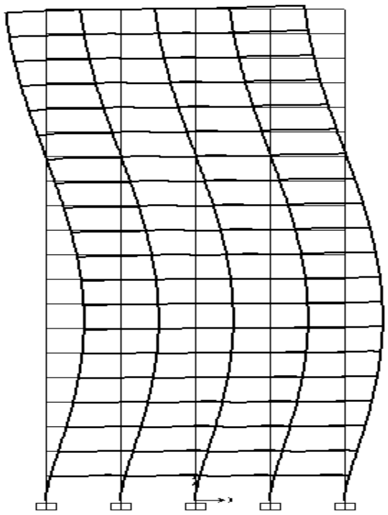


Fig. B.2: Second mode shape of R-20-4 building model

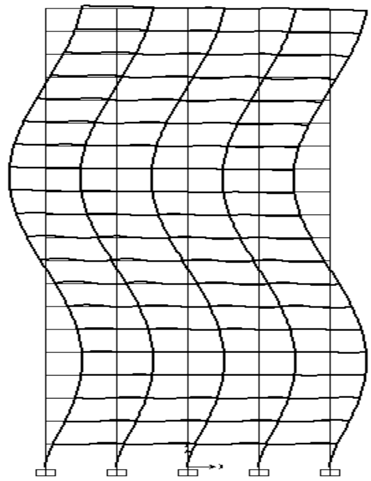


Fig. B.3: Third mode shape of R-20-4 building model

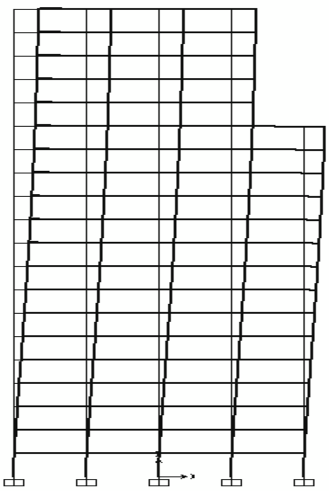


Fig. B.4: First mode shape of S1-20-4 building model

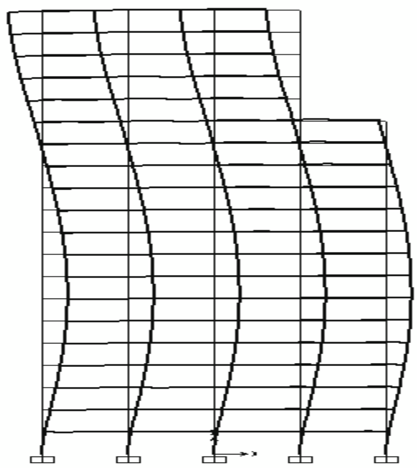


Fig. B.5: Second mode shape of S1-20-4 building model

B.2 DISTRIBUTION OF HINGES

Figs. B.13 to B.14 presents the distribution of hinges at collapse for an eight-storey four- bay setback building (S2-8-4) as obtained from pushover analysis using five different load patterns. It is found from these figures that distribution of hinges, and thereby collapse mechanism, of the building are identical for triangular and Mode-1 load pattern. This correlates the pushover curve of the building under these two load patterns (refer Fig.).

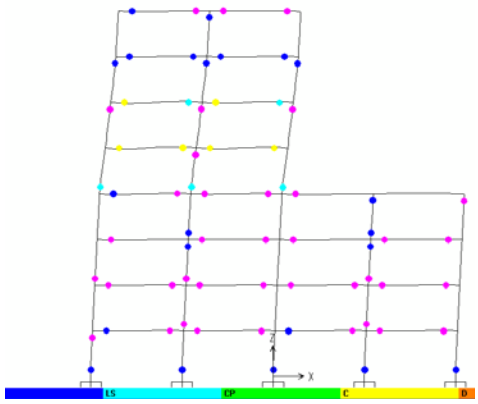


Fig. B.13: Distribution of hinges in S2-8-4 model by triangular load pattern

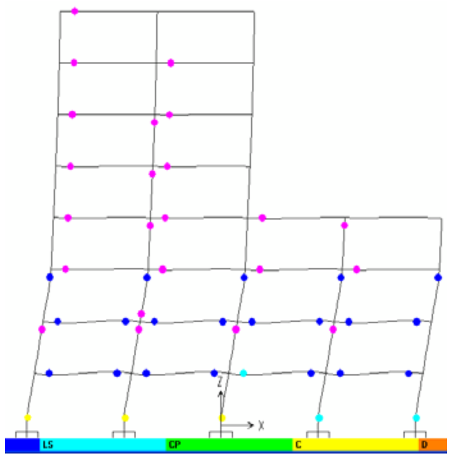


Fig. B.14: Distribution of hinges in S2-8-4 model by uniform load pattern

CONCLUSIONS

Based on the work presented in this thesis following point-wise conclusions can be drawn:

i) A detailed literature review on setback buildings conclude that the displacement demand is dependent on the geometrical configuration of frame and concentrated in the neighbourhood of the setbacks for setback structures

The higher modes significantly contribute to the response quantities of setback structure.

ii) As the shape of the triangular load pattern and first mode shape are similar for mid-rise regular buildings and close for high-rise and setback buildings, the resulting pushover curves are found to be similar for almost all the building studied here.

iii) FEMA 356 suggests that pushover analyses with uniform and triangular load pattern will bind all the solutions related to base shear versus roof displacement of regular buildings. Results presented here support this statement for regular buildings. However, this is not true for setback buildings especially for high-rise buildings with higher irregularity (S3-type).

iv) Mass proportional uniform load pattern found to be suitable for carrying out pushover analysis of Setback buildings as the capacity curve obtained using this load pattern closely matches the response envelop obtained from nonlinear dynamic analyses.

v) Upper bound pushover analysis severely underestimates base shear capacities of setback as well as regular building frames.

REFERENCES

1. **Chopra, A.K.**, and **Goel, R.K.** (2000). Evaluation of NSP to estimate seismic deformation: SDF systems. *Journal of Structural Engineering*, ASCE, **126**(4), 482–490.

2. **Chintanapakdee, C.** and **Chopra, A.K.** (2004) Seismic response of vertically irregular

frames: Response history and modal pushover analyses. *ASCE Journal of Structural Engineering*. **130**(8), 1177-1185.

3. **Chopra, A.K.**, and **Chintanapakdee, C.** (2001). Comparing response of SDF systems to near-fault and far-fault earthquake motions in the context of spectral regions. *Earthquake Engineering and Structural Dynamics*, **30**(10), 375–388.

4. **IS 456** (2000). Indian Standard for Plain and Reinforced Concrete - Code of Practice, Bureau of Indian Standards, New Delhi.

5. **Gupta, A.**, and **Krawinkler, H.** (2000). Estimation of seismic drift demand for frame structures. *Earthquake Engineering and Structural Dynamics*, **29**(9), 1287–1305.

6. **Chopra, A.** and **Chintanapakdee, C.** (2004). Inelastic deformation ratios for design and evaluation of structures: Single degree of freedom bilinear systems. *ASCE Journal of Structural Engineering.* **130**(9), 1309-1319.