Non Linear Static Analysis of RC Framed Buildings with Setback

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Abstract: **Analysis of the structure shall be conducted to determine the distribution of forces and deformations induced in the structure by the design ground shaking and other seismic hazards corresponding with rehabilitation objectives. The analysis shall address the seismic demands and the capacity to resist these demands for all the elements in the structure that either are essential to the lateral stability of the structure (primary element) or to the vertical load carry in integrity of the building Major structural collapses occur when the building is under the action of dynamic loads which includes earthquake loads. In these modern days most of the structures are involved with architectural importance and hence many structures in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. Hence, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. This study aims at evaluating and comparing the response of G+10, G+15, G+20 systems with vertical irregularities as described by the ATC-40 and the FEMA273 using nonlinear static procedures, with described acceptance criteria. The methodologies are applied to G+10, G+15, G+20 systems with vertical irregularity with bracings and with masonry struts. The non linear response of structure with vertical irregularity has been done using SAP2000 16 with Intent to evaluate importance of several factors in the non linear static analysis which includes time period, displacement, base shear etc. Performance may relate the strength level achieved in certain members to the lateral displacement at the top of the structure, or bending moment may be plotted against plastic rotation. Results provide insight into the ductile capacity of the structural system, and indicate the mechanism, load level, and deflection at which failure occurs.**

I INTRODUCTION
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.

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.

III 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.
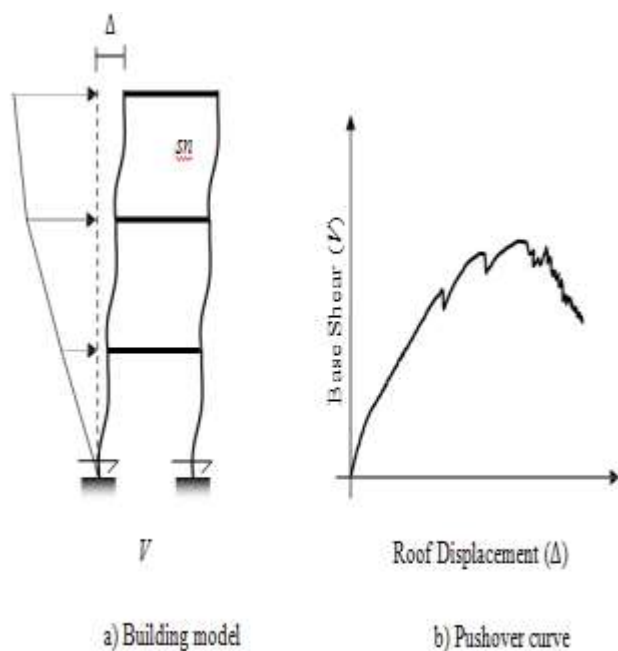

a) Building model   b) Pushover curve

Fig. 2.1: Schematic representation of pushover analysis procedure

IV 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.

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.

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.)

V CONCLUSIONS

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

1) 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.

2) 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.

3) 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).

4) 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.

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