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Pushover Analysis of RCC structure with different shape of column having constant cross-sectional area:- A review

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ABSTRACT

In India, seismic study of Reinforced concrete structure couldn't be done because of lack of theoretical and practical studies in engineers and researchers. So, in this review paper we studied about the performance based analysis of reinforced concrete structure according to IS 1893:2002. We studied the RCC structure with constant cross-sectional area of column with different shape in horizontal direction using SAP 2000 software. The behaviour of RCC structure under the action of seismic effect, could suffer a considerable degree of freedom in the direction of Seismic load.

The performance based (pushover analysis) study of RCC structure shows more accurate result against the lateral loading based on ATC-40 and FEMA-356 depends on ductility of steel confinement in column and non-linear performance of material to show plastic rotation of components of the structure.

Keywords: Pushover analysis, RCC structure, seismic effect, plastic rotation etc.

INTRODUCTION

EARTHQUAKE can cause greatest damages to humanity among all the natural hazards. Since earthquake forces are unpredictable and random in nature, proper analysis of the structures must be ensured to withstand such loads. The recent developments in the performance-based engineering design have brought the non-linear static (NSP) or pushover analysis to the forefront. It has replaced the conventional analysis procedures due to its simplicity and proved to be a useful and effective tool for assessing the real strength of structures. Pushover analysis can be either force controlled or displacement controlled. The pushover analysis can provide significant perception and understanding about the weak links in the structure. SAP 2000 can perform static or dynamic, linear or nonlinear analysis of structural systems. To perform pushover analyses in SAP 2000, users can create and apply hinge properties. SAP 2000 is fully equipped with US, Canadian and International Design standards and codes like ACI concrete code, AISC building codes and AASHTO specifications. These integrated design code features can easily generate wind, wave and seismic loads with comprehensive automatic steel and concrete design checks. Pushover analysis is a static non-linear technique in which the magnitude of the structural loading is incremented in the lateral direction of the structure according to a certain pre-defined pattern. Generally, it is assumed that the behaviour of the structure is controlled by its fundamental mode and the predefined pattern is expressed in terms of either story shear or fundamental mode shape. FEMA-273 and its successor FEMA-356 describe about the non-linear static procedure (NSP) or pushover analysis and its uses in the structural engineering field. It is recommended as a standard tool for estimating seismic demands for buildings. In SAP 2000, a frame element is modelled as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are modelled as hinges represented by a series of straight line segments. There are three types of hinge properties in SAP 2000. They are default hinge properties, user-defined hinge properties and generated hinge properties. Studies show that user defined hinge model gives better results than default hinge model. Moment-curvature relationship is used to model plastic hinge behaviour in non-linear analysis. The seismic performance of a structure can be evaluated in terms of pushover curve, plastic hinge formation etc. The maximum base shear

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capacity of structure can be obtained from base shear versus roof displacement curve.

NON-LINEAR STATIC ANALYSIS (PUSHOVER METHOD)

In elastic analysis procedures for the seismic evaluation and design of upgrades of structure as well as design of new construction. The generic process of inelastic analysis is similar to conventional linear procedure in that the engineer develops a model of the structure in which is then subjected to a representation of the anticipated seismic ground motion. The coefficient method is fundamentally a displacement modification procedure that is presented in FEMA -356.

The coefficient method of displacement modification from FEMA- 356: -

The coefficient method is the primary non-linear static procedure presented in FEMA-356. This approach modifies the linear elastic response of the equivalent SDOF system.

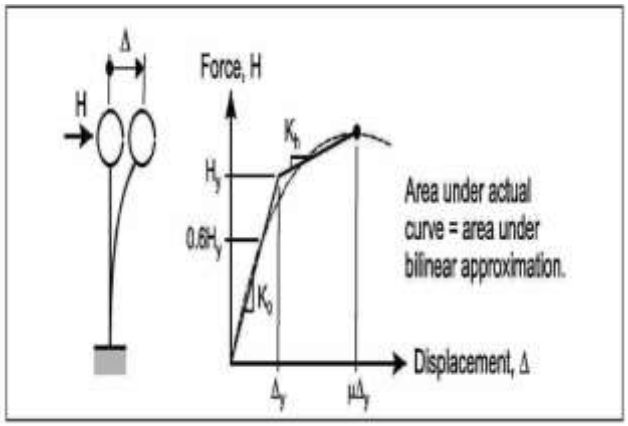

Figure: Bilinear approximation of push-over curve

The peak elastic spectral displacement is directly related to the spectral acceleration by the relation.

$S_d = (T_{eff})^2/4\pi^2 x S_a$

Where,

S_d = spectral displacement.

S_a = spectral acceleration.

T_{eff} = effective time period depends upon the relative stiffness of structure.

The NSP may be used for any structure and any Rehabilitation Objective, with the following exceptions and limitations.

• The NSP should not be used for structures in which higher mode effects are significant, unless an LDP evaluation is also performed. To determine if higher modes are significant, a modal response spectrum analysis should be performed for the structure using sufficient modes to capture 90% mass participation, and a second response spectrum analysis should be performed considering only the first mode participation. Higher mode effects should be considered significant if the shear in any story calculated from the modal analysis considering all modes required obtaining 90% mass participation exceeds 130% of the corresponding story shear resulting from the analysis considering only the first mode response. When an LDP is performed to supplement an NSP for a structure with significant higher mode effects, the acceptance criteria values for deformation controlled actions (m values).

2. LITERATURE REVIEW

A brief review of previous studies on the application of the tubular structure. This literature review also includes previous studies on different application of tube in tube structure. This literature review on recent contribution related to nonlinear static pushover analysis of building structure with tubular tall structure.

Neethu K. N. in his research paper Pushover analysis is one of the most-used nonlinear static procedures for the seismic assessment of structures, due to its simplicity, efficiency in modelling and low computational time. The previous studies about pushover analysis are almost based on symmetric building structures and unidirectional earthquake excitation. This analysis is conducted to evaluate the seismic capacities of an existing asymmetric-plan

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building. The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi storey building frame with the help of pushover analysis is carried out in this paper. In the present study the building frame is designed as per IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis and design software SAP 2000 (version 15).

Navin R. Amin in his study to define general procedures for design of multiple framed tube high rise steel structures in seismic region. The analytical methods and design procedures are outlined special considerations such as beam/column joints and member's proportions are discussed. Three recent high rise projects completed using the multiple tubular concepts are presented followed by the discussion relative merits of multiple tubular systems.

M.L. Gambher in his paper presented a qualitative study of the behaviour of some of the commonly used structural systems for the high rise building subjected to earthquake forces the system analysed are frame-shear core interactive system, framed-tube system and tube-in-tube system. The percentage of lateral load resisted by each of the constituent systems has been determined for buildings of various heights. The characteristics of the core as a load carrying element and its efficiency as a bracing element have own studied. Recommendations are made regarding the stability of a system for building of various heights.

3. MODELLING AND MATERIAL

G+15 building with rectangular shape column frame structure, circular shape column frame structure, square shape column frame structure, hexagonal shape column frame structure was taken for the study. Four different building models with bay width of 4m in X-direction, 4m in Y-direction and story height equal to 3.5m were considered for this study. The structures modelled by using computer software SAP 2000. The column section defined for the frame satisfies both the requirement for strength and stiffness. All the selected models designed with M-25, M-30 grade of concrete are used and Fe-415 grade of reinforcing steel as per Indian standards.

3.1 Material properties

In analysis procedure of pushover method nonlinear properties of concrete and steel material are defined according to Mender confined concrete theory, in which su (ultimate strain of concrete) is a function of the confinement steel. The following figure shows the stress-strain curves for confined concrete. The tensile yield stress for the Mender confined curves is taken as $7.5(fck)^{0.5}$ in psi.

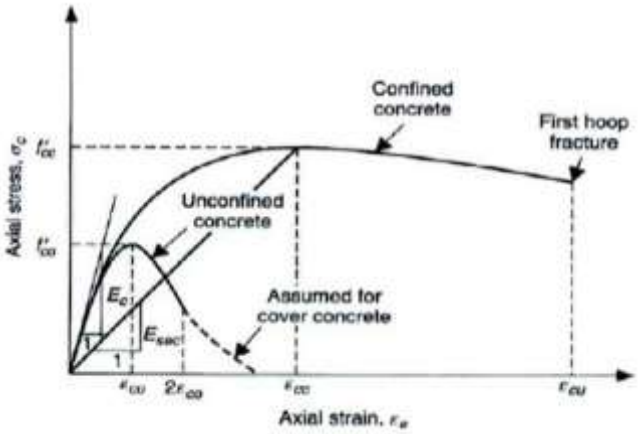

Figure: Stress-strain curve of concrete (non-linear).

3.2 Methodology

A performance (pushover analysis) having an objective specifies the desired seismic performance of the building. Seismic performance is described by designating the maximum allowable damage state

for an identified seismic hazard. A performance objective may include consideration of damage states for several level of ground motion would then be termed a dual or multiple-level performance objective. A performance level describes a limiting damage condition which may be considered satisfactory for a given building and a given ground motion. The limiting condition is described by the physical damage within the building. The threat to life safety of the building's occupants created by the damage, and the post-earthquake serviceability of the building.

3.3 Structural performance levels and Ranges

Structural performance levels and Ranges are assigned a title and, for case of reference, a number. The number is called structural performance number and is abbreviated SP-n (where n is the designated number).

Structural performance levels-

- Immediate occupancy
- Life safety
- Structural stability (damage control)

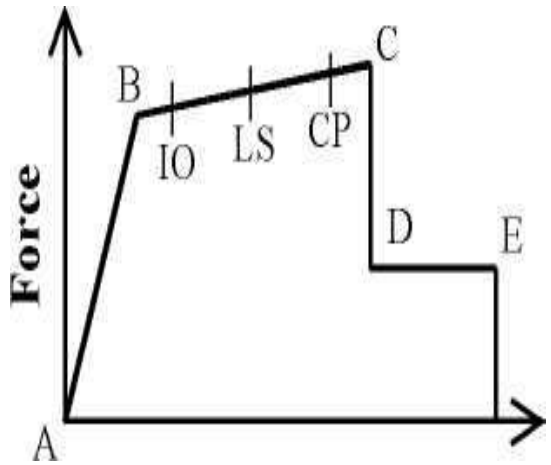

Figure: Performance levels in pushover analysis

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