Pushover Analysis of 4 Storey's Reinforced Concrete Building

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Abstract- The earthquakes in the Indian subcontinent have led to an increase in the seismic zoning factor over many parts of the country. Also, ductility has become an issue for all building that was designed and detailed using earlier versions of the codes. Under such circumstances, seismic qualification of building has become extremely important. The structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis. Modeling for such analysis requires the determination of the nonlinear properties of each component in the structure, quantified by strength and deformation capacities, which depend on the modeling assumptions. Pushover analysis is carried out for either user-defined nonlinear hinge properties or default-hinge properties, available in some programs based on the FEMA-356 and ATC-40 guidelines. This paper aims to evaluate the zone –IV selected reinforced concrete building to conduct the non-linear static analysis (Pushover Analysis). The pushover analysis shows the pushover curves, capacity spectrum, plastic hinges and performance level of the building. The non-linear static analysis gives better understanding and more accurate seismic performance of buildings of the damage or failure element.

I. INTRODUCTION

The nonlinear static analysis where the lateral loads is increased, to maintaining a predefined distribution pattern along the height of the building, until a collapse mechanism develops [9].
The performance based approach requires a lateral loads versus deformation analysis. The pushover analysis is a static method of nonlinear analysis .The pushover analysis is a method to observe the successive damage states of a building. The deficiency of an elastic analysis by the following features.

1. The analysis considers the inelastic deformation and ductility of the members.
2. The sequence of yielding of sections in members and redistribution of loads in the building are observed.

To perform a pushover analysis, a lateral load versus deformation curves for the member is required. The results from a pushover analysis will give the load versus deformation curves. Moreover, the pushover analysis gives only curve of the base shear versus roof displacement behavior of a building. The actual performance of a building may differ from the calculated performance, since the load versus deformation curves and the earthquake levels used in the analysis are estimates.

The structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis described in FEMA-356 and ATC-40, when pushover analysis is used carefully it provides useful information that cannot be obtained by linear static or dynamic analysis procedure [5].

Seismic codes are unique to a particular region or country. These take into account the local seismology, accepted level of seismic risk, building typologies, and materials and methods used in construction. Further, they are indicative of the level of progress a country has made in the field of earthquake engineering.

The codes in India are developed by the Bureau of Indian Standards (BIS). BIS is responsible for developing standards not just for the Civil Engineering industry, but also for a very wide range of other products and processes. The Civil Engineering division at BIS acts as a secretariat and the actual work is carried out by committees consisting of professionals who serve on a voluntary basis.

II. PUSHOVER ANALYSIS OF STRUCTURE

A. Research Significance

The present study is to evaluate the behavior of G+3 reinforced concrete frame structure subjected to earthquake forces in zone IV. The reinforced concrete structures are analyzed by nonlinear static analysis (Pushover Analysis) using SAP2000 software. It shows the performance levels, behavior of the components and failure mechanism in a building. It also shows the types of hinge formation, the strength and capacity of the weakest components.

B. Performance Based Design for Nonlinear Static Pushover Analysis

Create the basic computer model of four storey building frame structure. Define properties and acceptance criteria for the pushover hinges .The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members. These built in properties can be useful for preliminary analyses, but user defined properties are recommended for final analyses [2]. Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties. Define the pushover load cases. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover. Pushover load cases can be force controlled, that is, pushed to a certain defined force level, or they can be displacement controlled, that is, pushed to a specified displacement.

The numbers of hinges are shown in the fig.1 (a) and fig.1 (b). In each member showing the hinges in beams the immediate occupancy, life safety, collapse prevention and some limited hinges are shown in column to define the force deflection behavior of the hinge. The lateral load is applied on the frame, which when deflected forms hinges. Frame is estimating the plastic hinge formation at the yielding and significant difference in the hinging patterns at the ultimate state. The hinge locations are shown in the frame. In frame hinges shows a ductile beam mechanism in which the columns are stronger than the beam. Damage or failure occurs at the beam.

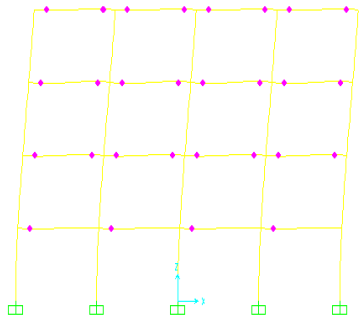

Figure 1: (a) Hinge Model at Yielding

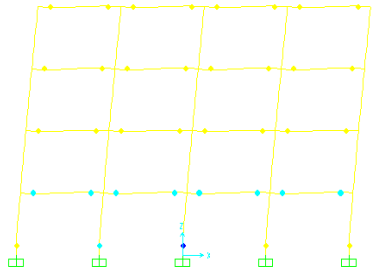

Figure 1: (b) Hinge Model at Ultimate state

Table-1: Plastic hinge Pattern for pushover analysis at different damage level

Hinge damage states			A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
IV Zone	Yielding	Default	36	36	0	0	0	0	0	0	72
	Ultimate	Default	35	0	0	36	0	1	0	0	72

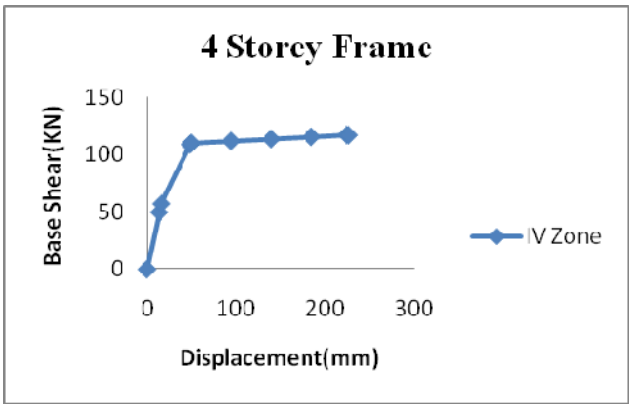

Figure 2: Pushover Curve of a Building for Four Storey IV Zone

The curve shows spectral displacement and spectral acceleration. The performance point for a given set of values is defined by the intersection of the capacity curve (green) and the single demand spectrum curve (yellow).

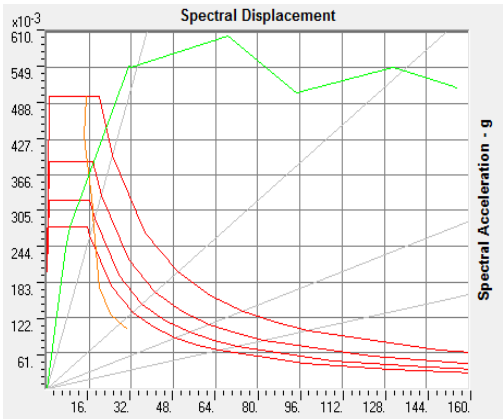

Figure 3: Capacity Spectrum 4Storey IV Zone

C. Pushover Methodology

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building [9]. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modeled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building.

D. Nonlinear Plastic Hinges Properties

The building has to be modeled to carry out nonlinear static pushover analysis. This requires the development of the force - deformation curve for the critical sections of beams, columns. The force deformation curves in flexure were obtained from the reinforcement details and were assigned for all the beams and columns. The Nonlinear properties of beams and columns have been evaluated using the section designer and have been assigned to the computer model in SAP2000. The flexural default hinges (M3) and shear hinges (V2) were assigned to the beams at two ends. The interacting (P-M2-M3) frame hinges type a coupled hinge property was also assigned for all the columns at upper and lower ends [2].

E. Nonlinear Static Pushover Analysis

The model frame used in the static nonlinear pushover analysis is based on the procedures of the material, defining force – deformation criteria for the hinges used in the pushover analysis. Figure 4 describes the typical force-deformation relation proposed by those documents. Five points labeled A, B, C, D and E are used to define the force deflection behavior of the hinge and these points labeled A to B – Elastic state, B to IO- below immediate occupancy, IO to LS – between immediate occupancy and life safety, LS to CP- between life safety to collapse prevention, CP to C – between collapse prevention and ultimate capacity, C to D- between C and residual strength, D to E- between D and collapse >E – collapse[2].

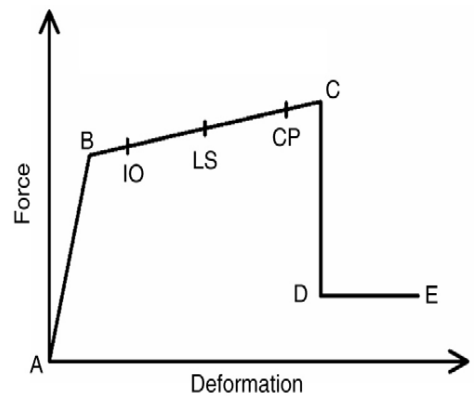

Figure 4: Force-Deformation for Pushover Analysis

III. RESULT AND DISCUSSION

A Four storied reinforced concrete frame structure of building was taken to analysis. The frame was subjected to design earthquake forces as specified in the IS code for zone IV along X directions. Bare frame pushover curves for the building in X directions as shown in Figure 2. These curves show the behavior of the frame in terms of its stiffness and ductility. For bare frame average base shear from pushover analysis is 109.39 KN and average displacement of 49.83mm in X direction. Capacity spectrum is the capacity curve spectral acceleration Vs spectral displacement (Sa Vs Sd) co-ordinates. The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates. The frame shows the performance of the on the spectral acceleration corresponding to the performance point. The performance point is obtained at a base shear level of 61.75KN and displacement of 17.77mm in the X direction.

IV. CONCLUSION

The pushover analysis is a simple way to explore the nonlinear behavior of the buildings. The results obtained in terms of pushover demand, capacity spectrum and plastic hinges the real behavior of structures. In a four storey building seismic zone –IV is designed and constructed using IS-456-1978 and the revised code IS-1893-2000 provisions. Hinges have developed in the beams and columns showing the three stages immediate occupancy, Life safety, Collapse prevention. The column hinges have limited the damage.

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