Pushover Analysis of G+4 Reinforced Concrete Building

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Abstract— Many urban multi-storey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. This paper highlights the importance of explicitly recognizing the presence of the open first storey in the analysis of the building and also for immediate measures to prevent the indiscriminate use of soft first storeys in buildings. Alternate measures, involving stiffness balance of the open first storey and the storey above, are proposed to reduce the irregularity introduced by the open first storey. 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 –II 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. This non-linear static analysis gives better understanding and more accurate seismic performance of buildings of the damage or failure element.

Key words: Multi-Storey Buildings, Open First Storey, Performance of Buildings, Pushover Analysis

I. INTRODUCTION

Pushover analysis is stated as a nonlinear analysis in which, the nonlinear load-deformation characteristics are determined directly by incorporating the mathematical model of the building frame. The response of individual components and elements of buildings can be calculated separately. Each element shall be exposed to monotonically increasing lateral loads. During an earthquake, the inertia forces generated act as the lateral loads. As the intensity of the load increases, the structure is pushed. Due this, cracks are generated at various locations. When it exceeds the elastic limit, yielding occurs and it leads to plastic hinge formations along the span of the member. The deformations are recorded as a function of the increasing lateral load up to the failure of various structural components. This load incremental process is discontinued when the target displacement is reached at the roof level. Target displacement is the maximum expected displacement by combining both elastic and inelastic responses of the building under selected earthquake ground motion. Pushover Analysis evaluates the structural performance by computing The force, drift capacity and seismic demand by a nonlinear static analysis algorithm. The analysis accounts for material inelasticity, geometrical nonlinearity and the redistribution of internal forces. The seismic demand parameters are component deformations, component forces, global displacements (at roof or any other reference points), storey drifts and storey forces.

The static pushover analysis is mainly based on the assumption that the response of the structure is regulated by the first mode of vibration and mode shape, or by the first few modes of vibration, and that this shape remains constant throughout the elastic and inelastic response of the structure. This provides the basis for transforming a dynamic problem into a static problem. Capacity spectrum method is another approach for getting the target displacement. The basic assumption is that, for the nonlinear SDOF system, the maximum inelastic deformation can be approximated from corresponding value of the linear elastic SDOF system with an equivalent period and damping, and it is same as the displacement coefficient method. In this method the term ductility is incorporated in calculation of effective period and damping. In the capacity spectrum method the pushover curve is considered in the form of acceleration-displacement response spectrum (ADRS) format, and is termed as capacity spectrum. The Fig. 1 shows the ADRS format for the capacity spectrum method.

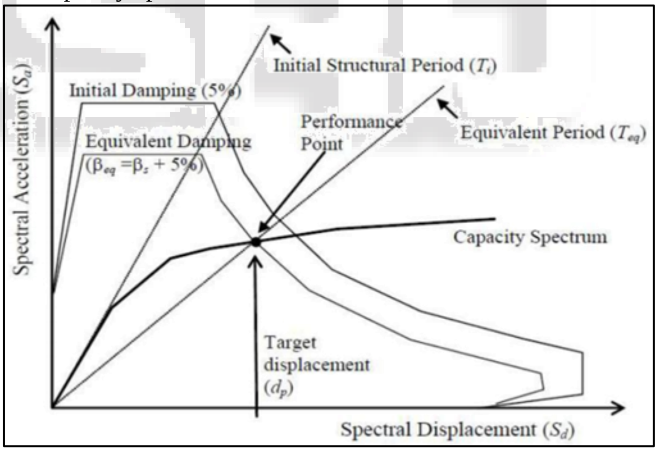

Fig. 1: ADRS Format

A. *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. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behaviour of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modelled 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.

B. Nonlinear Plastic Hinges Properties

The building has to be modelled 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.

C. Performance Level of a Structure

The structural and non- structural components of the buildings together comprise the building performance. The performance levels are the discrete damage states identified from a continuous spectrum of possible damage states. The structural performance levels based on the roof drifts are as follows: Five points labelled A, B, C, D and E are used to define the force deflection behaviour of the hinge and these points labelled as

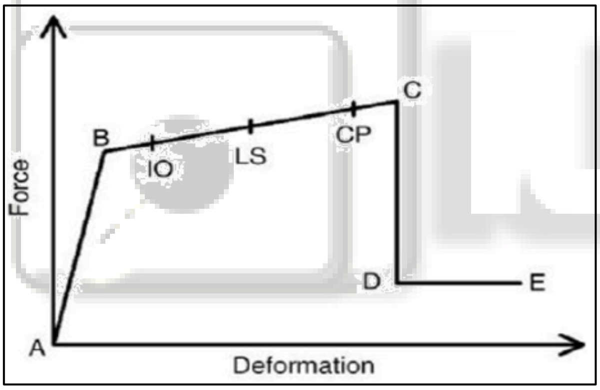

Fig. 2: Showing Force vs. Deformation Curve

The performance levels (IO, LS, and CP) of a structural element are represented in the load versus deformation curve as shown below

1) A to B : Elastic state,
– Point 'A' corresponds to the unloaded condition.
– Point 'B' corresponds to the onset of yielding.
2) B to IO : below immediate occupancy,
3) IO to LS : between immediate occupancy and life safety,
4) LS to CP : between life safety to collapse prevention,
5) CP to C : between collapse prevention and ultimate capacity,
– Point 'C' corresponds to the ultimate strength
6) C to D : between C and residual strength,
– Point 'D' corresponds to the residual strength
7) D to E : between D and collapse
– Point 'E' corresponds to the collapse.

II. STRUCTURAL MODELLING

The (G+4) RCC multi storey building consider for analysis building to know the realistic behaviour during earthquake with the general form of plan shown in figure1.Building is modelled for Indian seismic zone III IS:1893-2002. Plan dimension in X and Y direction is 30 m and 20.0m respectively. The buildings has following dimensions, Columns size 300mm x300mm, All beam size 300mm x 450mm. Floor slabs are taken as 150mm thick. The height of all floors is 3.25m. Soil type is hard. Modal damping 5% is considered. Material concrete grade is M35 Steel Fe500D is used.

For given structure, loading which applied includes live load, earthquake load and dead load are according to IS 875 part I, Part II and IS 1893:2002 respectively. Live load on floor slab – 2.5 kN/m^2, Live load on terrace floor – 3.5 kN/m^2, Floor finish load -1.5 kN/m^2, WC and Bath – 2.5 kN/m^2 Terrace floor slab - 1 kN/m^2 Floor slab – 1.5 kN/m^2.

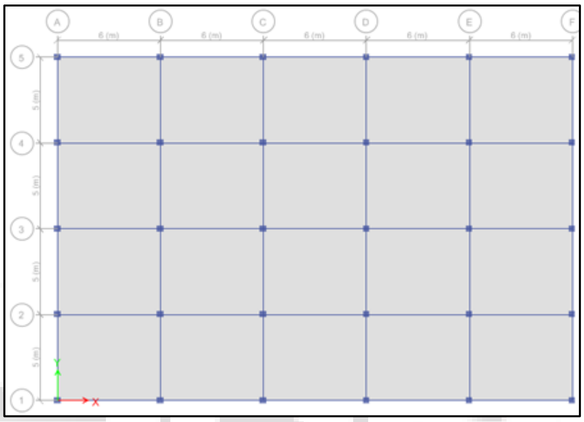

Fig. 3: Plan of G+4 Multi-Storey Building

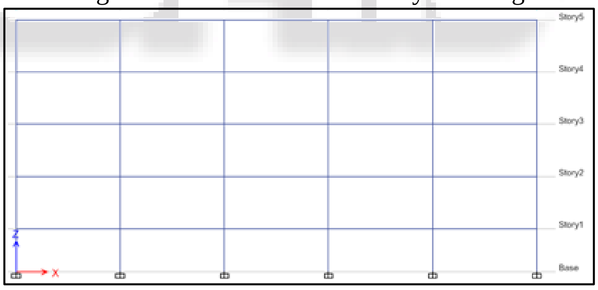

Fig. 4: Elevation of G+4 Multi-Storey Building

III. ANALYSIS RESULTS

The numbers of hinges are shown in the fig.5 and fig.6 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 behaviour 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.

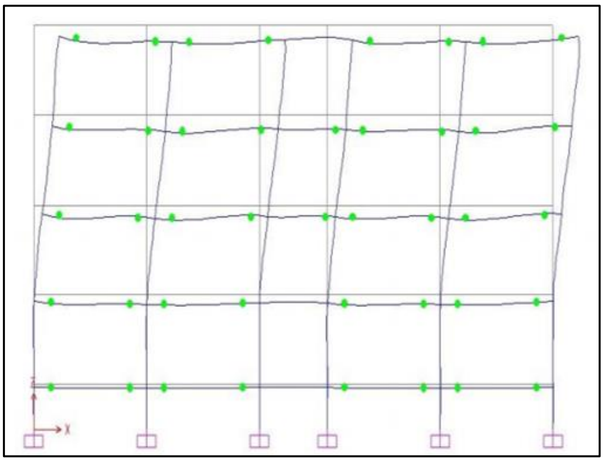

Fig. 5: Showing Hinge Model at Yielding

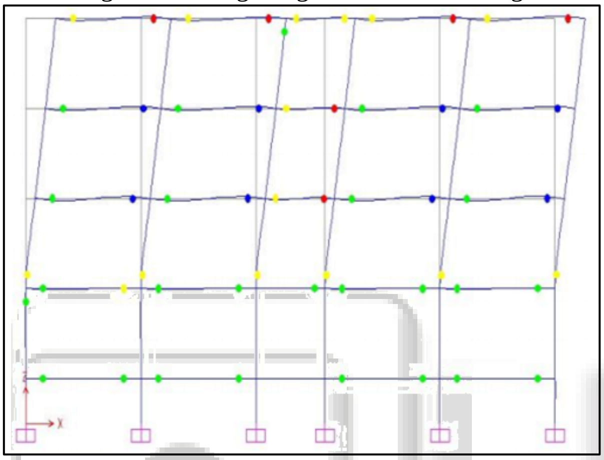

Fig. 6: Showing Hinge Model at Ultimate State

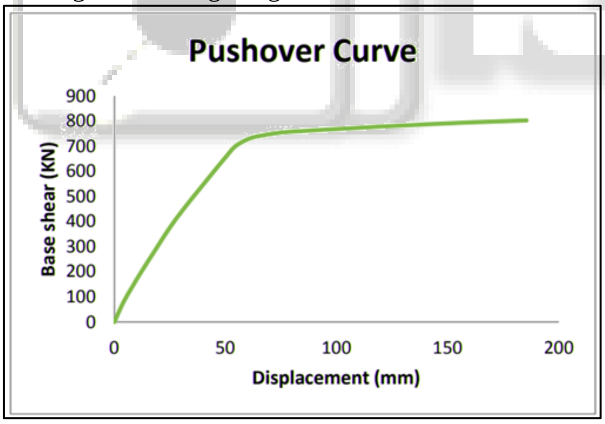

Fig. 7: Showing Pushover Curve of a Building for Five Storeys

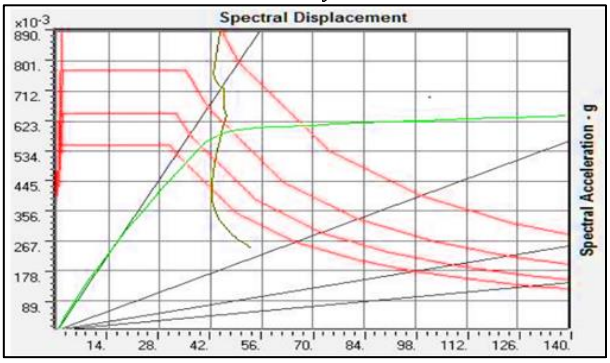

Fig. 8: Showing Capacity Spectrum

A five 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 II along longer directions. Bare frame pushover curves for the building in X directions as shown in Figure 8. These curves show the behaviour of the frame in terms of its stiffness and ductility. For bare frame maximum base shear from pushover analysis is 992 KN and maximum displacement of 223mm 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 533KN and displacement of 43mm in the X direction.

IV. Conclusion

The pushover analysis is a simple way to explore the nonlinear behaviour of the buildings. The results obtained in terms of pushover demand, capacity spectrum and plastic hinges the real behaviour of structures. In a four storey building seismic zone –II 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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