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# Performance Based Seismic Analysis of Buildings

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**ABSTRACT**

Performance based design explicitly evaluate how a building is likely to perform given the potential hazard it is likely to experience , considering uncertainties inherent in the quantification of potential hazard and uncertainties in assessment of the actual building response.

It is an iterative process that begins with selection of performance objective, followed by the development of a preliminary design assessment as to whether or not the design meets the performance objective and finally redesign and reassessment if required until the desired performance level is achieved.

In present study two R.C. buildings, one rectangular and one square in plan are analyzed using pushover analysis and redesigning by changing the reinforcement in columns. The pushover analysis is carried out using Etabs 2015. A Six storied buildings are considered to be located in Zone IV with Hard soil strata

***Keywords:*** *Performance, Performance Level, Etabs*

## I. INTRODUCTION

The concept of performance based seismic design approach has become the future direction for seismic design codes. In this approach, nonlinear analysis procedures become important in determining the patterns and extent of damage to assess the structure's inelastic behavior and failure pattern in severe seismic events. Static pushover analysis is a simplified nonlinear procedure wherein the pattern of earthquake is applied incrementally to the structural frame until a plastic collapse mechanism is formed. The methodology adopts the lumped plasticity approach, identifying the extent of inelasticity through the formation of nonlinear plastic hinges assigned at the ends of the frame elements while the incremental loading is applied. In other words, determination of desired structural response that satisfies both global level (i.e. system level) and local level (i.e. element level) response is needed.

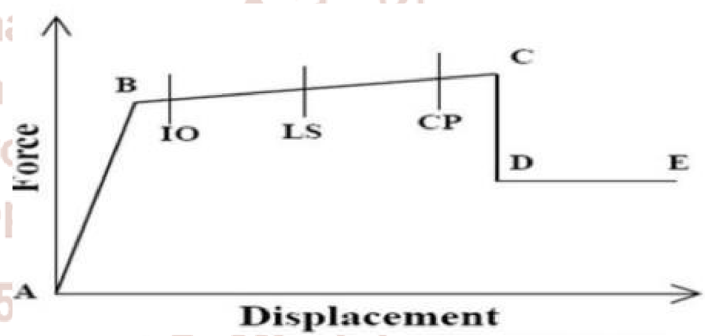


**Fig.1 Structural Performance levels**

## II. PERFORMANCE BASED DESIGN APPROACH:

The performance based design process primarily requires that the expected performance objectives be clearly defined. These objectives correspond to a seismic hazard level and the expected performance levels of the structure. In other words, the level of 'acceptable risk' needs to be well defined. The 'risk' may be expressed in terms of seismic hazard and a susceptibility of structure to damage.

The performances objectives are quantified can be called as 'performance criteria' which means a quantified acceptance criteria necessary to meet the performance objectives. In recent times, the performance objectives other than 'Life Safety', which was the major focus to reduce the threats to the life safety are also being considered. Such performance objectives may vary from 'Collapse Prevention' for the rare event of a large earthquake to an 'Operational Level' for frequent earthquakes of moderate intensities.

## III. ANALYSIS APPROACH:

The inelastic displacements that the structure undergoes truly represent the damage sustained by the structure while dissipating the energy during an earthquake. Thus, the evaluation of displacement parameters for a given structure can provide a realistic evaluation of structural damage during earthquake.

Nonlinear static pushover analysis is a simple tool that can be used for this purpose. It provides a 'capacity curve' of structure and relates the deformation parameters of the system (roof displacement) to the force parameter of the system(base shear). The displacement capacity of the structure goes on increasing with the increase of damage from 'Operational' to 'Collapse Prevention' level of the performance.

## IV. EXISTING CODE BASED APPROACH & PERFORMANCE BASED APPROACH

Initial design procedures considered that the earthquake forces acting on the structure are nothing but the inertial forces developed due to earthquake accelerations and thus would be proportional to the weight of the structure.

Later, with the revolution in the design approach, wide range of studies on the actual behavior of structure resulted in shift to this procedure highlighting the fact that in addition to structure's weight, the structural demands generated during the earthquake are the functions of its strength and stiffness properties. The existing conventional code based procedures are normative in nature. Such codes needs to cover a wide range of structures and thus, such codes usually cannot consider the various expected performance levels and seismic risk levels and are generalized.

Performance based design on the other hand shows a major shift from such conventional normative codes and overcomes their limitations by considering both the performance and risk levels. In conventional code based procedures, design seismic forces for linear design are obtained by reducing an elastic demand by applying reduction factor 'R' which reflects the capacity of structure to dissipate energy through inelastic behavior.

It is a combined effect of over strength, ductility and redundancy. The strength factor is a measure of base shear force at design level and at yielding.

In performance based design on other hand, it is recognized that the inelastic seismic demands are based on the inelastic capacity of structure. As inelastic capacity increase, the period of structure lengthens; damping increases and demand is reduced.

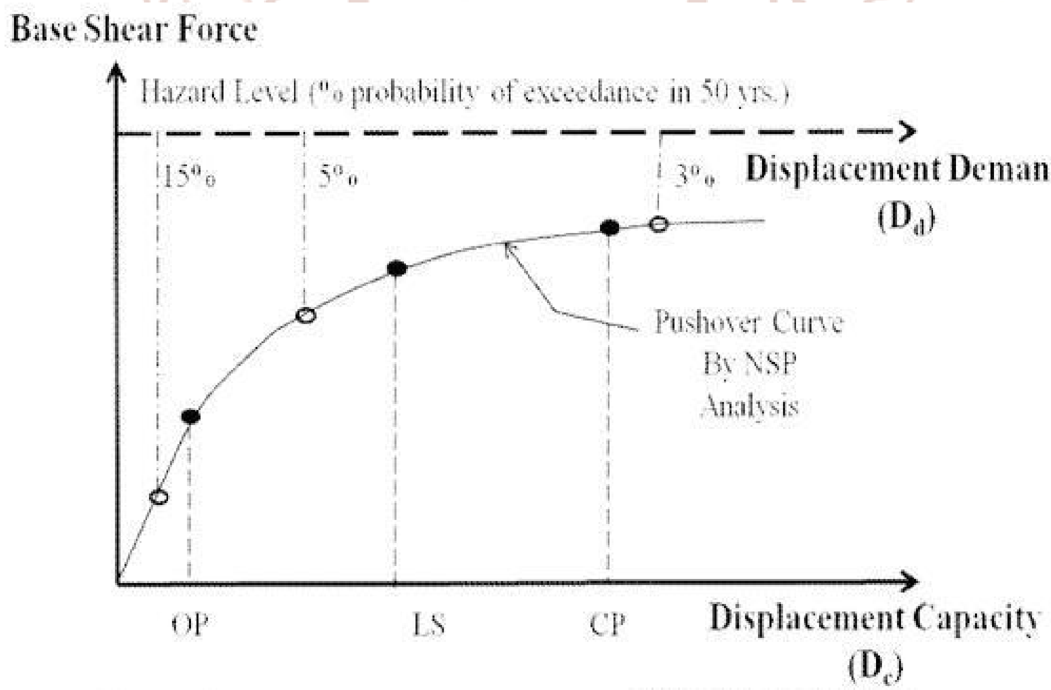


**Fig 4: Displacement & Demand Capacities for different levels of performance.**

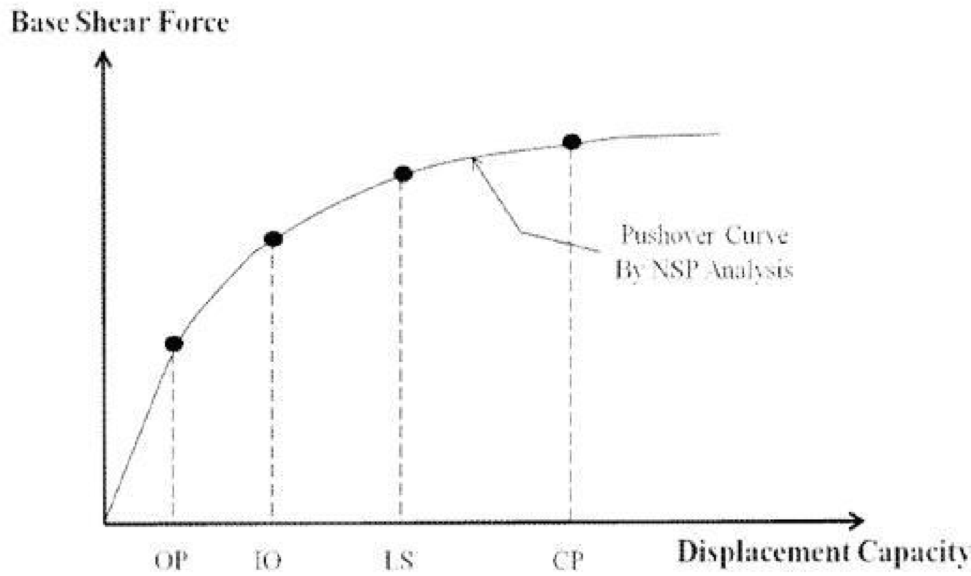


**Fig 5: Displacement capacities for different levels of performance**

## V. ILLUSTRATIVE EXAMPLE:

***General:*** The main objective of performance based seismic design of buildings is to avoid total catastrophic damage and to restrict the structural damages caused, to the performance limit of the building. For this purpose Static pushover analysis is used to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

**Description of structure:**

The building considered for analysis is a typical Ground+6 storey R.C. building designed as per IS 456 – 2000. The plan area of square building is 12 x 12 m with 3.0m as height of each typical storey. It consists of 3 bays of 4 m. each in X-direction and 3 bays of 4 m. each in Y-direction. The plan of rectangular shape building is 4 x 12 m, It consists of 2 bays of 4 m in X-direction and 3 bays in of 4m in Y- direction.

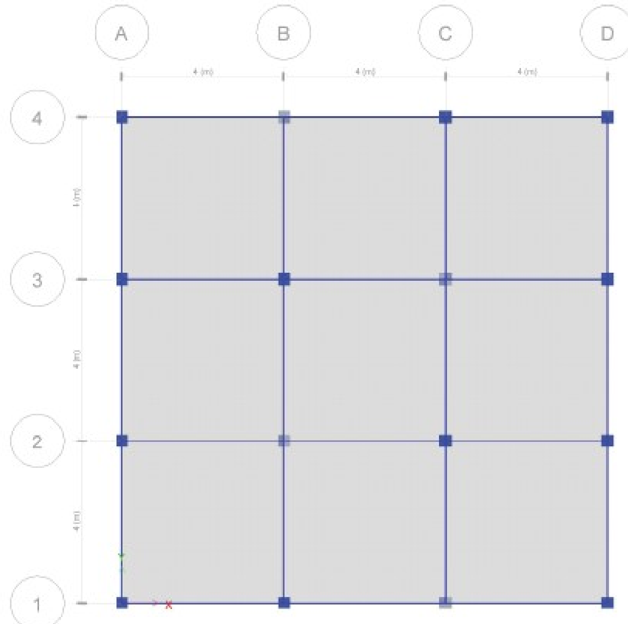


**Fig. 6 Square shape building**

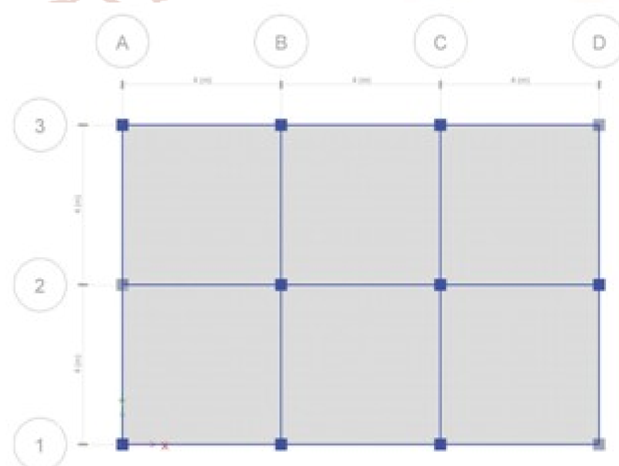


**Fig. 7 Rectangular shaped building**

**Table 1:- Initial sizes considered for analysis**

| Description | Sizes |
|---|---|
| Column | 300 mm x 300 mm |
| Beam | 300 mm x 450 mm |
| Slab | 150 mm |

**Loading considered: -** In present example considered for analysis floor finish of 1.5 kN/m2 , live load of 2 kN/m2, Brick wall 230 mm thick with density 18 kN/m3. Building is situated in zone IV.

**Pushover Analysis:**

Pushover analysis is an efficient way to analyze the behavior of the structure, highlighting the sequence of member cracking and yielding as the base shear value increases. This information then can be used for the evaluation of the performance of the structure and the locations with inelastic deformation. The primary benefit of pushover analysis is to obtain a measure of over strength and to obtain a sense of the general capacity of the structure to sustain inelastic deformation. The loads acting on the structure are contributed from slabs, beams, columns, walls, ceilings and finishes. They are calculated by conventional methods according to IS 456 – 2000 and are applied as gravity loads along with live loads as per IS 875 (Part II) in the structural model. The lateral loads and their vertical distribution on each floor level are determined as per IS 1893 – 2002. These loads are then applied in "PUSH – Analysis case"

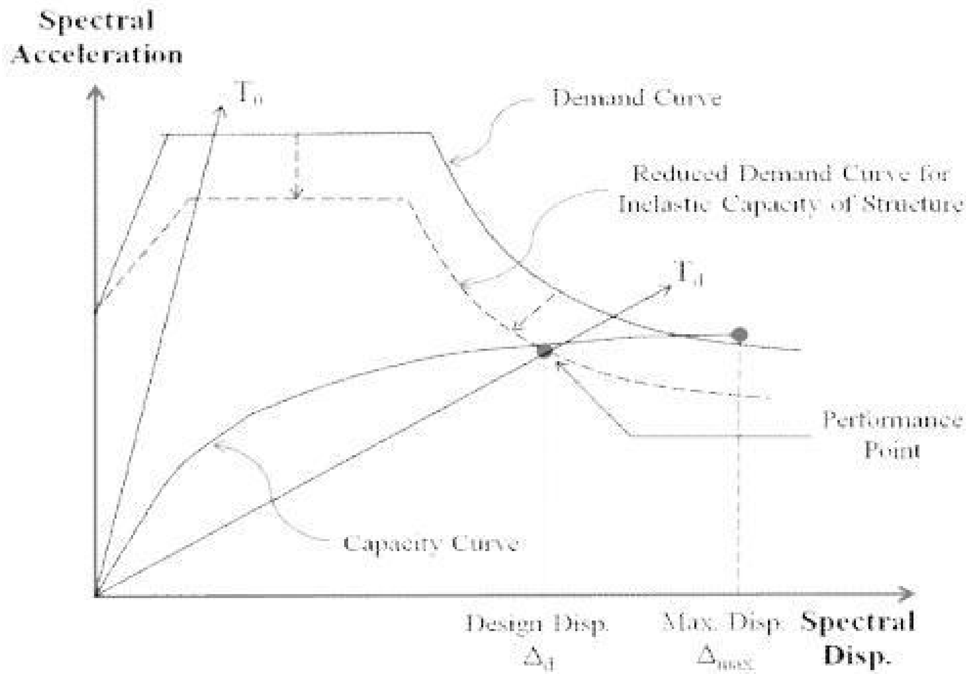


**Fig. 8 Performance based design approach**

## VI. RESULTS

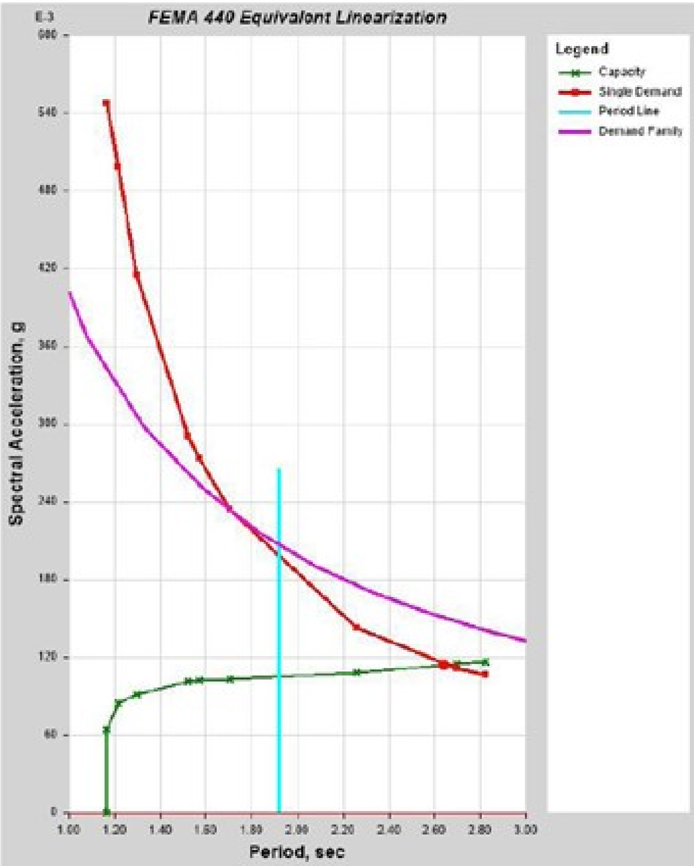


**Fig. 9 Capacity curve for Square Model**

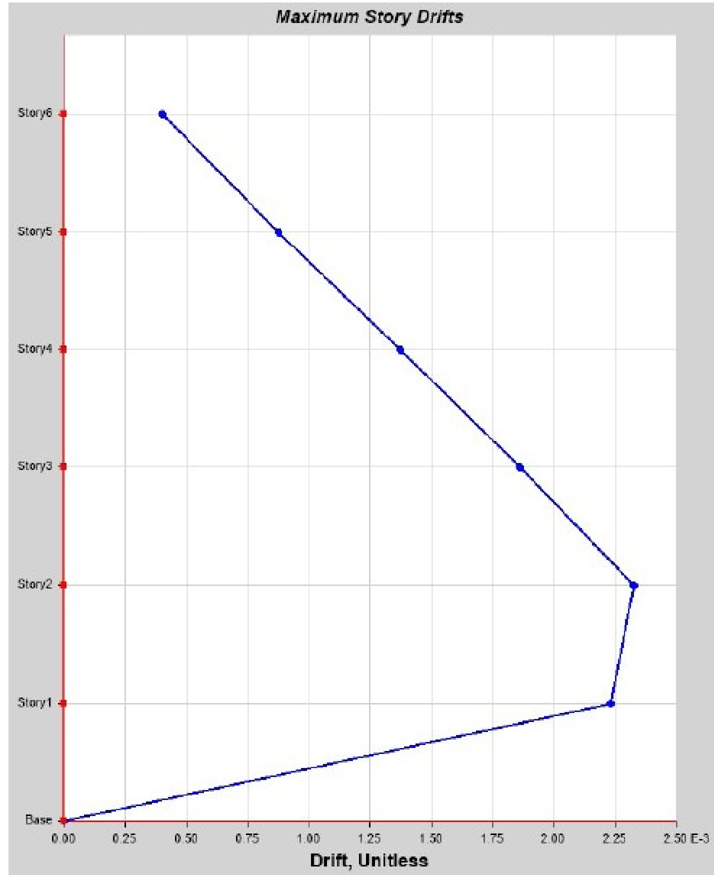


**Fig. 11.Storey drift for square model**

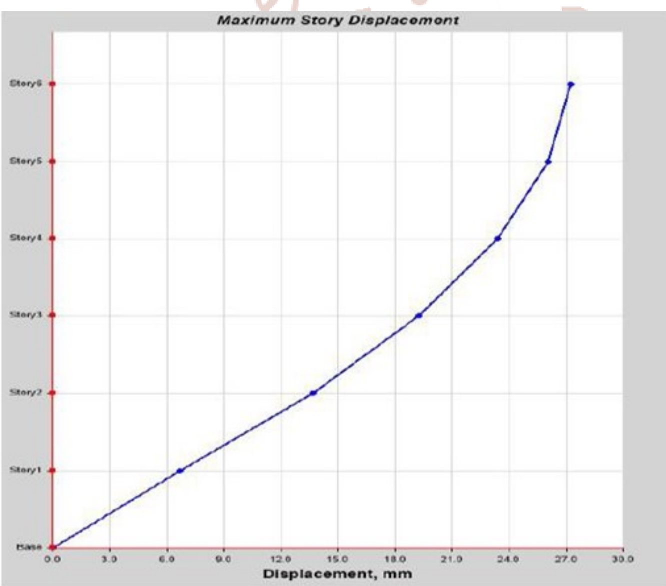


**Fig. 10 Storey displacement for Square Model 4**

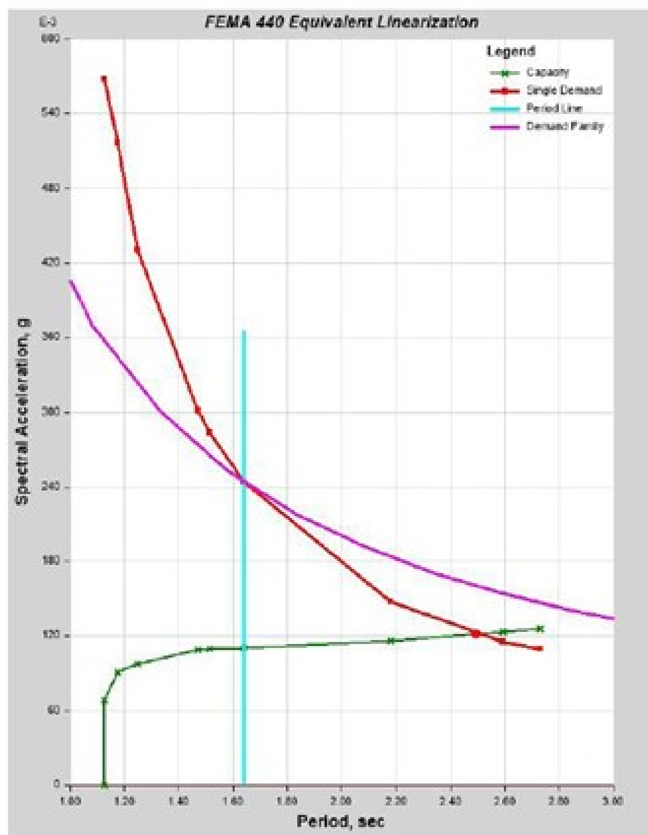


**Fig.12 Capacity curve for Rectangular Model**

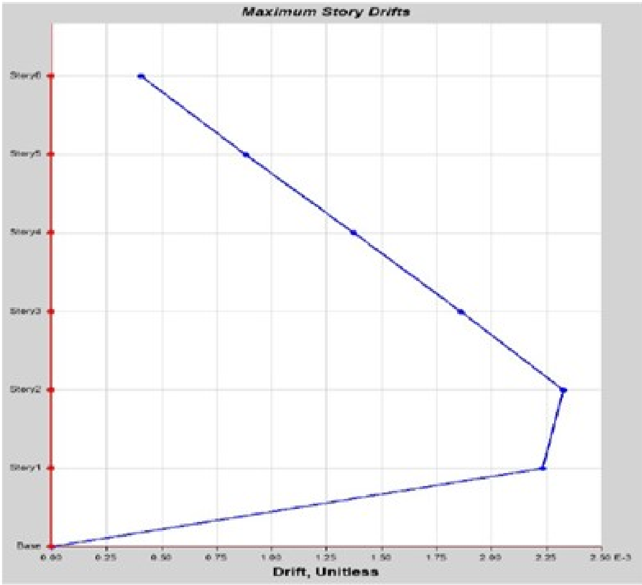


**Fig 13 Storey drift for Rectangular Model**

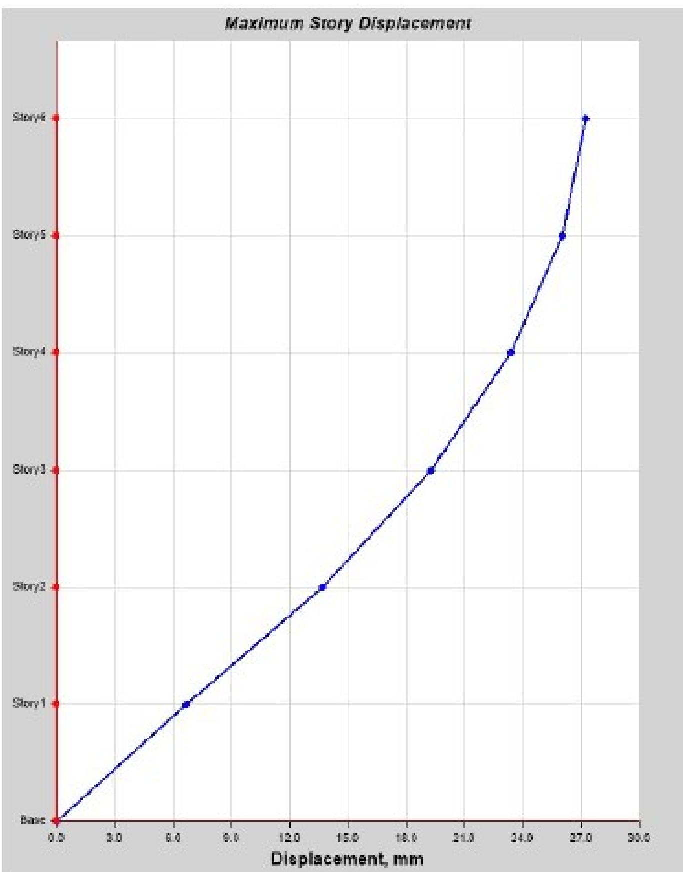


**Fig 14 Storey Displacement for Rectangular Model (X Direction)**

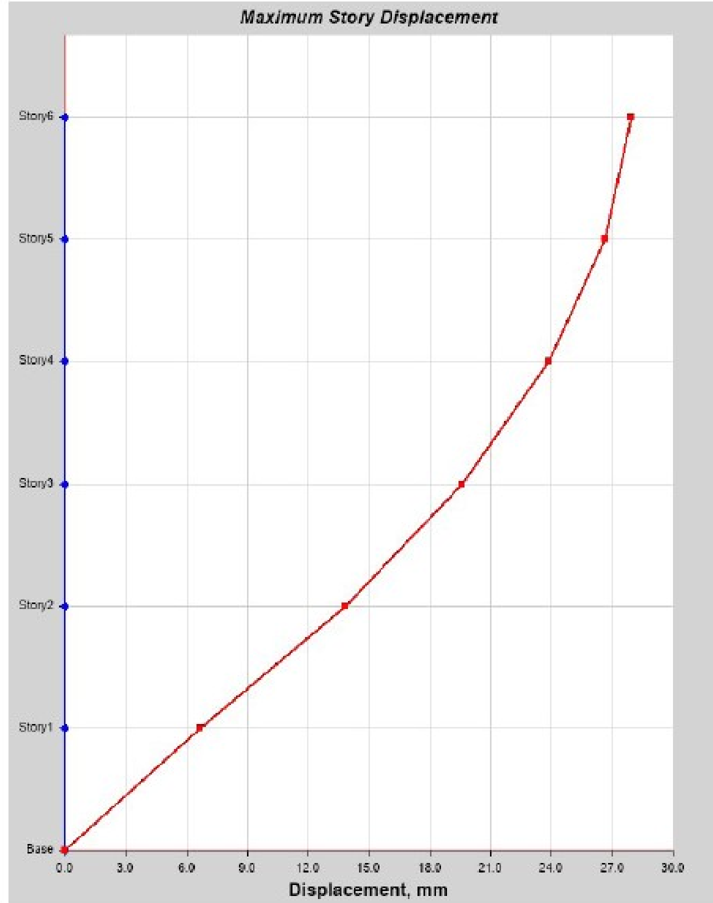


**Fig 15 Storey Displacement for Rectangular Model (Y Direction)**

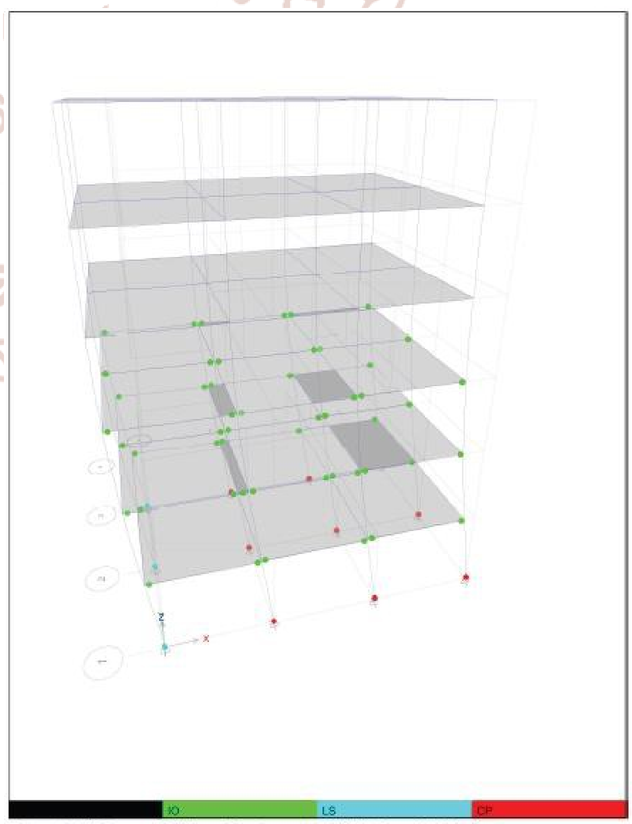


**Fig 16: Hinges formation for Rectangular Model**

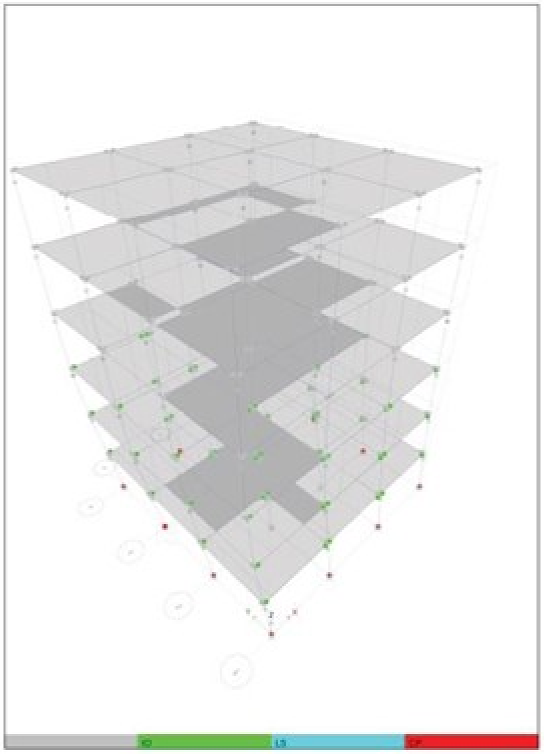

**Fig. 17 Hinges formation for Square Model**

**CONCLUSION:**

The evaluation factors like displacement ductility, inelastic displacement demand ratio etc. justify the ductile detailing of the structure as every parameter associated with it is critically evaluated for the seismic behaviour at each performance level. The determination of plastic rotations and the type of hinge formation for each performance level and their potential locations provides an useful input for providing special confining reinforcement in the structural members. The accuracy of this will depend upon the accuracy of modeling.

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1. ASCE, 2000, Pre-standard and Commentary for the Seismic Rehabilitation of Buildings, FEMA 356 Report, 12/13 prepared by the American Society of Civil Engineers for the Federal Emergency Management Agency, Washington, D.C.