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Pushover Analysis of Plan Irregular RC Buildings with Special Columns

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***Abstract*— Irregular buildings constitute a major portion of the modern urban infrastructure. The group of people involved in constructing the building facilities, including owner, architect, structural engineer, contractor and local authorities, come up with the overall planning, selection of structural system, and its configuration. This may lead to building structures with irregularities in their mass, stiffness and strength along the height of building. When such buildings are located in a seismically active area, the structural engineer's role becomes more challenging. The analysis of the seismic response of irregular buildings is complex due to nonlinear and inelastic response and more difficult than that of regular buildings. Therefore, the structural engineer needs to have a complete understanding of the seismic response of irregular structures. The effect of shape of column and orientation of column will have a major influence on the structure when the structure is subjected to a lateral load such as earthquake load .**

The objective of this study is to carry out nonlinear static analysis of irregular RC frame using special shaped columns with plan irregularity.This study also finds out which plan irregular building is the most effective in resisting lateral loads. The software used for modelling and analysis is ETABS 2015.

Index terms—Special columns, ETABS 2015, Story drift, Base shear

I. INTRODUCTION

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand frequent minor earthquakes and produce enough caution whenever subjected to major earthquakes, so that can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The behavior of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage when compared to buildings with irregular configurations. But nowadays the need and demand of the latest generation and growing population has made the architects and engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in evaluating the role of building configurations. One such development is the provision of special columns in buildings. Some special shapes of columns are L-shaped, Tee- shaped and cross (+) shaped which are not commonly used but gives more indoor space than commonly used shapes of column. Special shaped columns avoid prominent corners in a room which increases the usable floor area.

Research Significance

The plan irregularity can be defined as per IS 1893-2002, that plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction. Buildings with large re-entrant corners, (i.e., plan shapes such as L, V, +,Y, etc.) show poor performance during seismic events. Each wing of such a building tends to vibrate as per its own dynamic characteristics, causing a stress concentration at the junctions of the wings. So these buildings are unsafe in seismically active areas. This study aims to create awareness about these issues in earthquake resistant design of multi-storied buildings.

Special Columns

Special-shaped columns are those in which the column section is L-shaped, Tee-shaped or crisscross-shaped as shown in figure 1.In recent years, special-shaped columns won the national attention and love of the owners and engineers because of its equal thickness of columns and wall, excellent architectural appearance and high room rate. In 2006, Ministry of Construction of the People's Republic of China has issued "Technical specification for concrete structures with specially shaped columns" (JGJ149-2006), which has been implemented since August 1, 2006. Accordingly, there have been a lot of research on ordinary reinforced concrete (RC) frame structure with special-shaped column, and this type of the structure has received quite extensive application because of its great architectural functions and pleasing appearance. Therefore special columns can be provided in re- entrant corners of plan irregular buildings.

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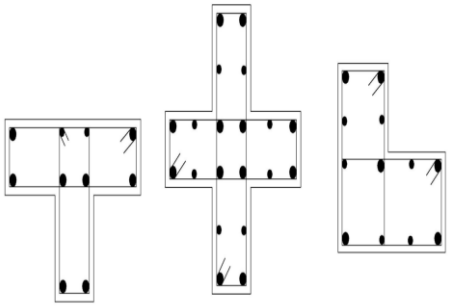


Figure 1: special columns

Nonlinear Static Pushover Analysis

The guidelines and standards mentioned in the introduction include modelling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents explain the force-deformation criteria for potential locations of lumped inelastic behaviour, represented as plastic hinges used in pushover analysis. As shown in Figure 5 below, five points labelled A, B, C, D, and E are used to define the force deformation behaviour of the plastic hinge, and the three points labelled as IO (Immediate Occupancy), LS (Life Safety) and CP (Collapse Prevention) are used to define the acceptance criteria for the hinge. In these documents, if all the members meet the acceptance criteria for a particular performance level, such as Life Safety, then the entire structure is supposed to achieve the Life Safety level of performance. The values given to each of these points vary depending on the type of member as well as many other parameters, such as the expected type of failure, the level of stresses with respect to the strength, and code compliance. Fig-2: Force-Deformation Relation for Plastic Hinge in Pushover Analysis Both ATC-40 and FEMA 356 documents present similar performance-based engineering methods that rely on nonlinear static analysis procedures for prediction of structural demands. While procedures in both documents involve generation of a "pushover" curve to predict the inelastic force-deformation behaviour of the structure, the technique used to calculate the global inelastic displacement demand for a given seismic ground motion differs. The FEMA 356 document uses the Coefficient Method, whereby displacement demand is calculated by modifying elastic predictions of displacement demand.ASCE-41-13 NSP is an improvement over FEMA 356 which is the displacement coefficient method whereas the ATC-40 Report details the Capacity-Spectrum Method, in which the modal displacement demand is determined from the intersection of a capacity curve, derived from the pushover curve, with a demand curve consisting of a smoothed response spectrum representing the design ground motion, modified to account for hysteretic damping effects.

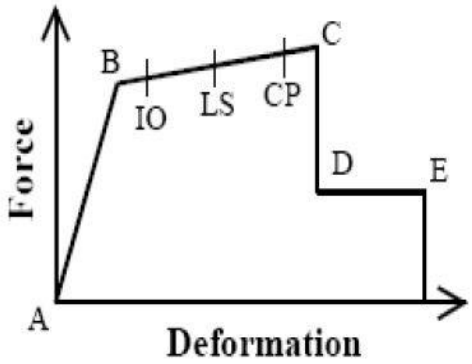


Fig-2: Force-Deformation Relation for Plastic Hinge in Pushover Analysis

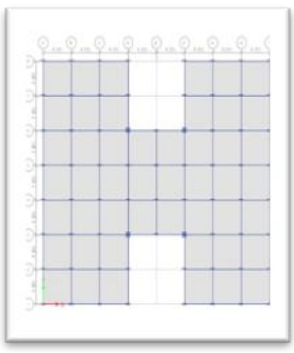
II. OBJECTIVES OF PRESENT STUDY

- To analyse RCC frame with special columns with different irregular configuration.
- To perform nonlinear static analysis of different plan irregular buildings conforming to IS 1893:2001(Part 2).
- To study and compare base shear capacity of different buildings under consideration.
- To find out the best plan irregular configuration and best column which can resist earthquake forces.

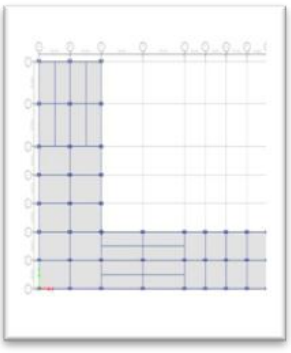
III. MODELLING OF BUILDINGS

The study is carried out on a (G+19) building having different plan irregular configurations. The plan irregularities considered are H, L and Tee shape configurations. The buildings are considered to be located in Zone III as per IS 1893:2002. The building is modeled using the software ETABS 2015. The dimensions of the beams, columns and slabs ,the loads applied and other details are summarized in Table1.

Configurations of Plan Irregularity Chosen



Model 1



Model 2

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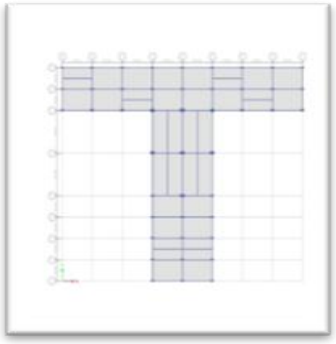


Model 3

Table 1:Details and dimensions of building models

Type of structure	Ordinary moment resisting RC frame
Grade of concrete	M40
Grade of steel	Fe 415
Plan area	896 m^2
Floor height	3 m
Beam size	230x600mm 230x500mm 300x650mm 250x700mm
Column size	230x600mm 600x900mm 450x800mm
Tee shape column	B=D=750mm t_f=t_w=200mm
L shape column	B=D=750mm Thickness-200mm
Cross shape column	B=D=750mm t_f=t_w=200mm
Slab thickness	150 mm
Live load on floor and roof	3kN/$m^2$and 1.5kN/m^2
Plan irregularity	H,L and T

IV. ANALYSIS

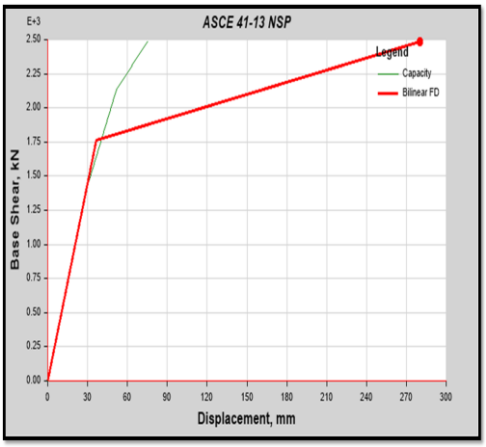
Pushover analysis is carried out on models considering plan irregularity. After assigning the loads to the structure, pushover analysis is done to evaluate the base shear obtained from performance point of pushover curve. After the analysis the behaviour of the buildings are compared in terms of base shear.

Pushover Methodology

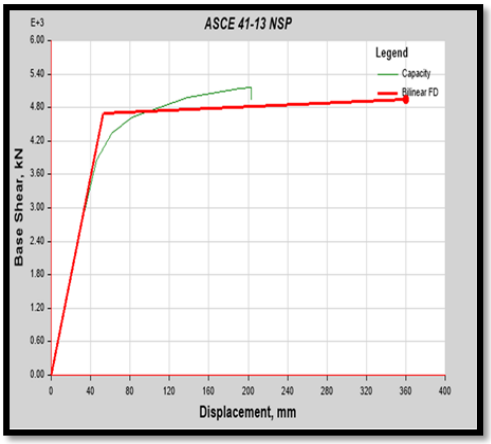
A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads which is representing the inertia forces which would be experienced by the structure when subjected to seismic ground shaking. Under incrementally increasing loads numerous structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using this nonlinear static analysis so called pushover analysis, a characteristic non-linear force displacement relationship can be accurately determined. The maximum base shear that the structure can resist is obtained from the performance point. In this paper ASCE-41-13 displacement coefficient method is used. Analysis were done in X direction.

V. RESULTS AND DISCUSSIONS.

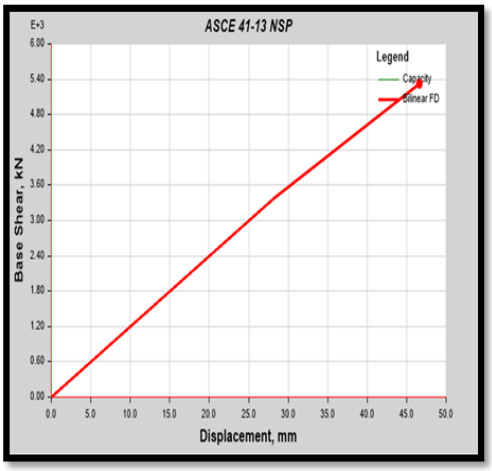
1) Pushover analysis of plan irregularity H shape with special columns are obtained from ETABS 2015 and the pushover curve indicating the performance point are presented below:



H shape model with cross column



H shape model with L column



H shape model with Tee column

2) Pushover analysis of plan irregularity L shape with special columns are obtained from ETABS 2015 and the pushover curve indicating the performance point are presented below:

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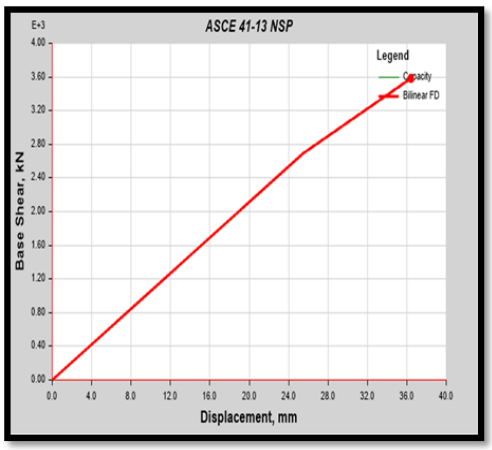
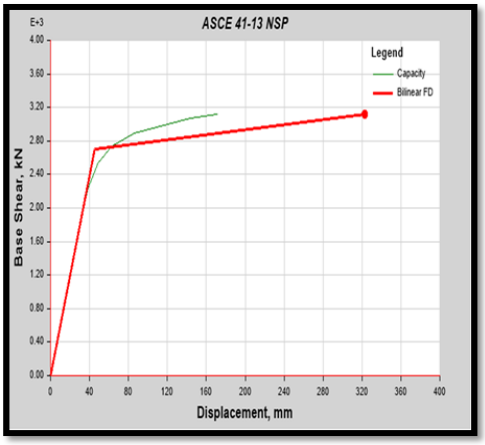
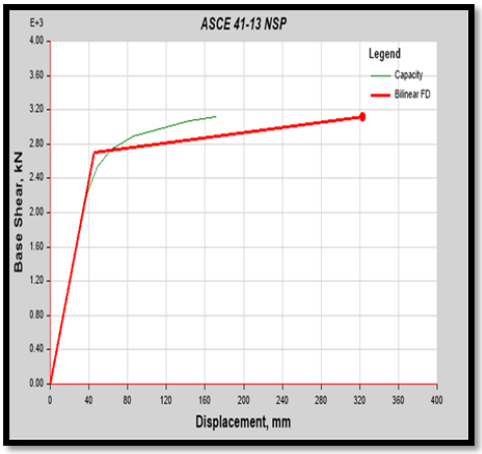


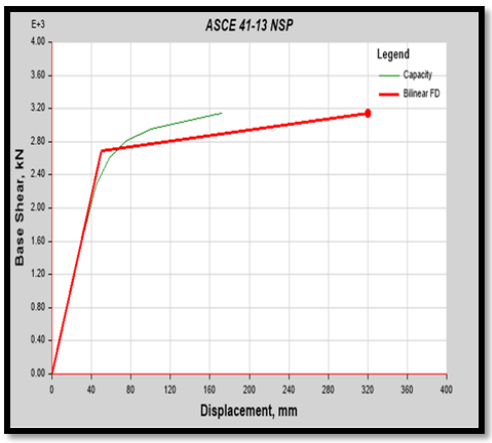
L shape model with cross column



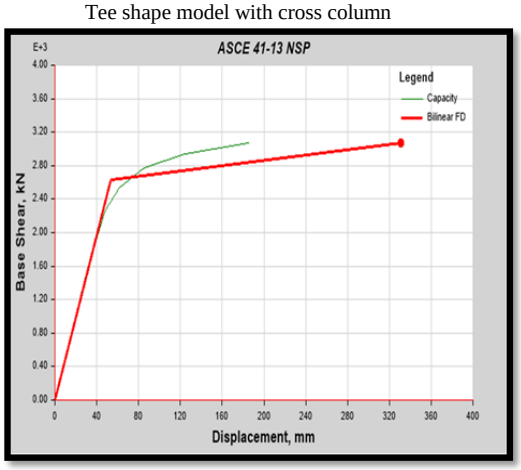
L shape model with L column



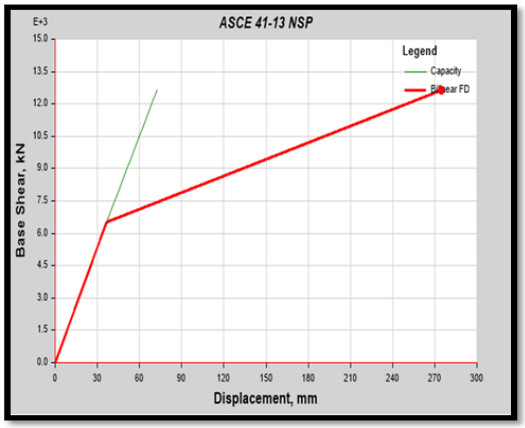
L shape model with Tee column



Tee shape model with cross column



Tee shape model with L column



Tee shape model with Tee column

3) Pushover analysis of plan irregularity Tee shape with special columns are obtained from ETABS 2015 and the pushover curve indicating the performance point are presented below:

Table 2 shows performance point base shears of all models with special shaped columns. Comparison of models were done in terms of base shear in order to determine which model is effective in resisting lateral loads.

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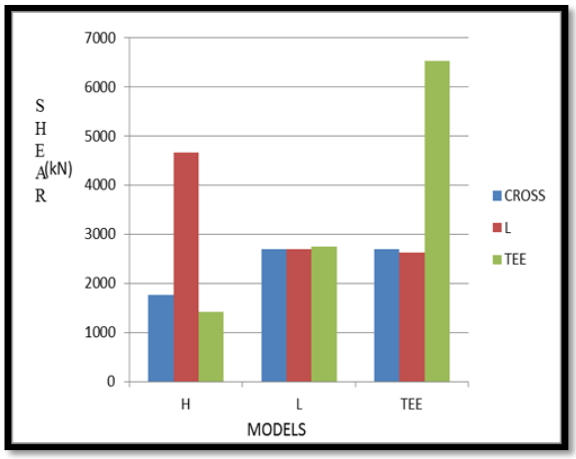
Table 2 : Base shear from Performance Point

PERFORMANCE POINT BASE SHEAR		
H Model	Cross Column	1764.408 kN
	L column	4688.887 kN
	Tee Column	1415.4956 kN
L Model	Cross Column	2691.9567 kN
	L column	2699.274 kN
	Tee Column	2742.0032 kN
Tee Model	Cross Column	2693.4807 kN
	L column	2632.8769 kN
	Tee Column	6529.3623 kN



VI. CONCLUSIONS

The main conclusions obtained from the analysis are summarized below:

1. When earthquake load is applied in X direction the base shear was maximum for H model with L column, i.e L column has 62.37% more base shear capacity than cross and 69.8% than Tee column.

2. Base shear value will be least for L shaped building so this shape of structure should be avoided in earthquake prone areas.

3. The base shear capacity of Tee shaped building is increased by providing Tee shaped column in the re entrant corners , i.e Tee column has 58.7% more base shear capacity than cross column and 59.67% more base shear capacity than L column.

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