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SEISMIC PERFORMANCES OF REINFORCED CONCRETE FRAMES WITH STRUCTURAL IRREGULARITIES

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Abstract— **An earthquake is a natural phenomenon associated with the violent shaking of the ground which cause damages to the buildings due to the presence of structural irregularities. These irregularities are unavoidable but its behaviour can be studied for the analysis of seismic response of structures. In this study, both horizontal irregularities and vertical irregularities are considered.**

Reinforced concrete frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi-family residential uses in seismic-prone regions worldwide. The masonry walls has a significant impact on the seismic response of an Reinforced Concrete frame building, increasing structural strength and stiffness and also results in brittle failure mechanisms.

The objective of this study is to understand the importance of irregularities, behavior of different irregularity of reinforced concrete structure to seismic forces, its failure pattern during earthquake, to suggest safe performance level for various types of irregularities and to study the short column and long column behavior to earthquake.

Index terms- **Earthquake, structural Irregularities, Seismic Performances, Short-Long Column.**

I. INTRODUCTION

A. General

An earthquake is a sudden release of energy in the Earth’s crust that creates seismic waves. The earthquake occurrence can neither be predicted nor prevented but structures can be built to resist these seismic forces using quality material and skilled workmanship. The damages caused due to the seismic forces depends on the type of materials used in the building, type of seismic waves, ground on which the structure is built. During earthquake, damages to the structure start from the weakest structural member due to the presence of irregularity such as discontinuities in stiffness, diaphragm, strength or mass between adjacent stories. Considering horizontal irregularity and vertical irregularity, main reason for the structure failure during earthquake is vertical irregularities.

In order to construct a earthquake resistant structure, seismic codes are available that are usually revised, which includes proper design and detailing of structures against earthquake. For the purpose of revising the seismic codes and also to improve the construction techniques in earthquake prone region, damage patterns in reinforced concrete frames are studied thoroughly from the past earthquake. To minimize the failure of structures in earthquake prone regions, the concerned authorities should develop an awareness programs related to earthquake, good construction practice methods, role of building configurations, use of good quality materials, need for skilled workmanship.

B. Structural Irregularity

The irregularities are broadly classified as vertical irregularity and horizontal irregularity.

1) Vertical Irregularity

Vertical irregularity is further classified as Mass Irregularity, Stiffness Irregularity and Strength Irregularity. If the seismic weight of a storey is more than 200 percent than the adjacent storey then mass irregularity exists. In case, if lateral stiffness is less than 70 percent than the storey above then it is considered as stiffness irregularity and that storey is referred as soft storey. Similarly, if storey strength is less than 80 percent than the storey above then it is considered as strength irregularity and that storey as weak storey.

2) Horizontal Irregularity

Horizontal Irregularity is further classified as Asymmetrical Plan Shapes, Re-Entrant Corners and Diaphragm Discontinuity. A regular structure may actually be asymmetrical if the structure has masonry infill walls or stiffer lateral resisting systems on one side of the structure that has not been taken into consideration in the analysis. Re-Entrant corner irregularity exists if the projection of the structure is more than 15 percent than the plan dimensions. Diaphragm Discontinuity is the one where there are variations in the stiffness of one storey being more than 50 percent than the next one.

II. SCOPE AND OBJECTIVES

- To study the importance of irregularity of RC Structure to seismic forces.
- To study the behavior of RC Structure to earthquake forces using performance based analysis.
- To study the failure pattern of structure with structural irregularity during earthquake.
- To suggest the safe performance level for various types of irregularities.

III. LITERATURE REVIEW

A. General

There are many study papers on Seismic Performances of Reinforced Concrete Frames with Structural Irregularities using different software. Accordingly, different conclusions were drawn for each study after the analysis. The present section shows some research work done by some researchers regarding the above topic.

B. Reviews on the Literature

Neha Modakwar et al (2014) : The study is based on the behavior of structure with re-entrant corner by choosing a realistic structure with shapes cross shape and L-shape. The analysis was carried out and concluded that re-entrant corner columns are to be stiffened for shear force.

Madhusudan et al (2014) : The present study focuses on Seismic Performances of RC frames in elevation using ETABS software. Study concluded that with increase in vertical irregularity, percentage of plastic hinges crossing elastic limit increases, rendering the structure more vulnerable.

Ravikumar et al (2012): The study has made an effort to evaluate the effect of vertical irregularities of different models for different zones and soil types with various parameters. Many conclusions were drawn such as time period does not change as zone and soil type changes. As vertical irregularities increases, storey drift and story displacement also increases.

IV. MODELLING

A. Building Parameters

The frames are designed according to the Indian standard Code IS-456:2000 and IS-1893:2002. The model is designed using Software – SAP2000 v 17.2.0. The structure is located at Zone V for the analysis and design of this study. SAP facilitates the plastic hinge properties which are described in ATC-40. Auto hinge properties are also included. Finally, Push over Analysis was carried out. The model is designed for special moment resisting frame with storey height of 4m. Beam size and column size are taken as 0.45m X 0.3m and 0.6m X 0.3m respectively. M25 grade of concrete is used.

B. Model Design

The model designed for the present study is of G+7 floors. For this model, a slab thickness of 0.2m is designed. To study different types of irregularities, the model is designed in such a way that the internal columns in first floor and third floor are deleted and the imposed load is also doubled for that floor. In this prepared model, the height of the column differs from each other for ground floor based on design for short column and long column. This model also includes irregularities such as shape irregularity, mass irregularity, stiffness irregularity, strength irregularity. After slab design, the model is designed for loading with two way distribution of the uniform loads. Then hinge properties are assigned for columns and beams in the model. Since Non Linear Static Analysis i.e. Pushover Analysis is adopted, Pushover parameters are also designed. The complete model is as shown in the below Figure 1.

V. PERFORMANCE BASED ANALYSIS

A. Pushover Analysis

Push over Analysis is a non-linear static analysis which is used widely nowadays. This analysis is used to determine some parameters like maximum base shear and displacement, yield load and yield displacement. After the analysis, a push over curve is drawn by considering base shear along vertical axis and displacement along horizontal axis.

B. Analysis Results

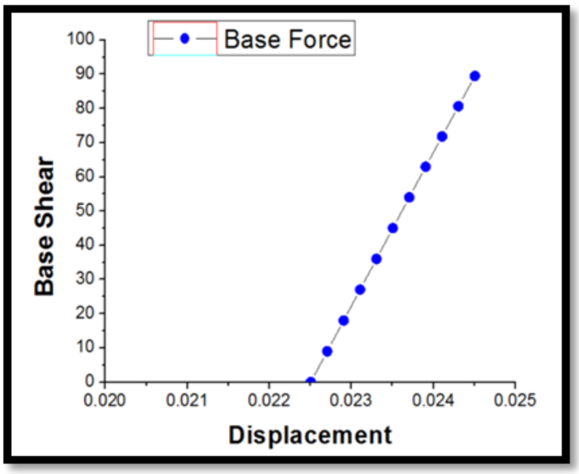

Figure 2 Capacity Curve for Push X

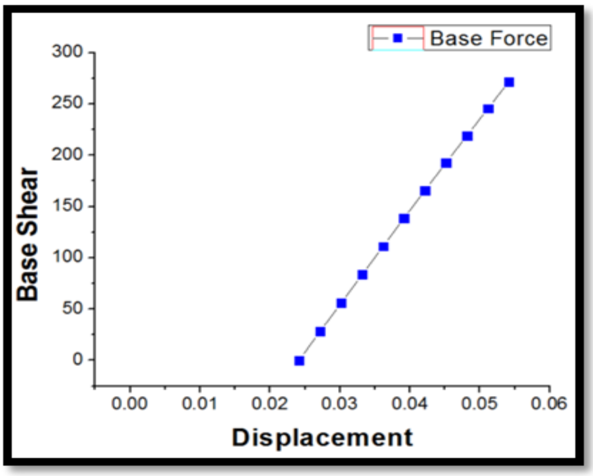

Figure 3 Capacity Curve for Push Y

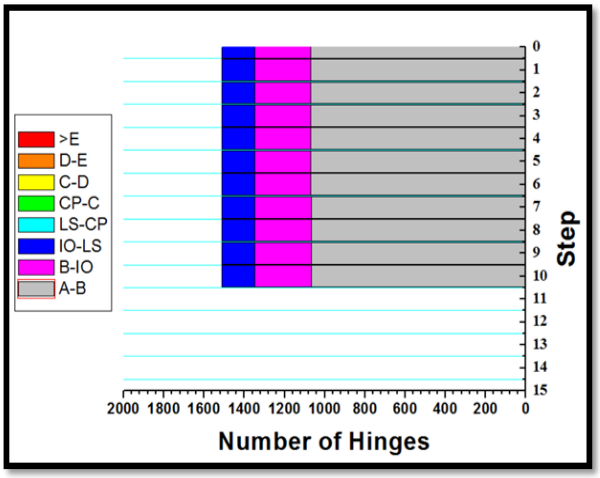

Figure 4 Hinges for Push X

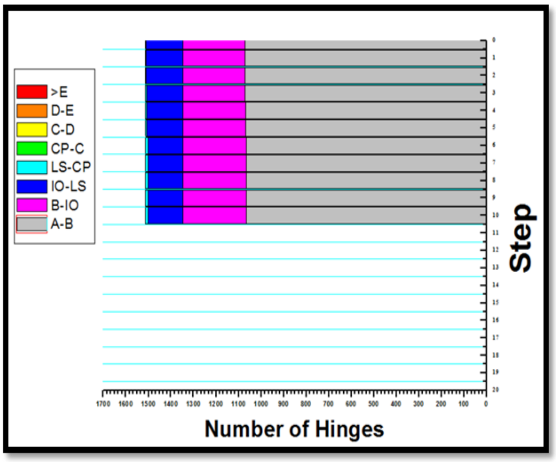

Figure 5 Hinges for Push Y

VI. CONCLUSIONS

A study on seismic performances of reinforced concrete frames with structural irregularity is presented. Following conclusions were drawn from the push-over analysis;

- Referring to graphs of push-over curves, X-axis represents displacement in m and Y-axis represents Base shear in kN. Initial displacement is similar in both directions whereas comparatively the structure on Y-direction displaces more and also the base shear carrying capacity along Y-direction is more than X-direction. This shows that the stiffness along Y-direction is higher compared to X-direction. Hence, for semi-circular type of structures it's better to increase the stiffness in particular direction where structure is not spreaded and where the built-up area is less.
- In capacity versus demand graph, since the structural stiffness is very high, the number of hinges versus steps curve it was found that the number of failure hinges formation is more along Y-direction which shows the structural stability for deformation. Along X-direction, there is no formation of vulnerable hinges. The structure still remains in immediate occupancy state because the built-up area is more along X-direction.
- Compared to semi-circular structures, rectangular structures perform better both in case of displacement and base sear carrying capacity. And also the hinges are in immediate occupancy condition, hence rectangular structure is in more stable condition when compared to semi-circular structure.
- Hence better to avoid structural irregularities for important public building in earthquake prone areas.

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