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To Study the Effect of Re-entrant Corner RC Framed Building under Seismic Load and Strengthening it by Bracing

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***Abstract*: Nowadays building with irregular configuration is more prone to seismic action. Previous earthquake experiences have demonstrated that buildings with plan irregularity suffer significant damages. Hence it is necessary to identify the performance of the structure to withstand against disaster for both new and existing one. The present paper made an attempt to study the vulnerability of re-entrant corners in a building. Variety of cases of re-entrant corners has been considered for the parametric study. In this regard, different shapes of building of four storey and eight storey have been considered and analyzed using equivalent static method. In order to understand the performance, this model has been compared with a box shaped building. Critical structure is identified and checks the efficiency of providing bracing.**

***Keywords*: Bracing, Equivalent static method, Re-entrant corner, Seismic action.**

1. Introduction

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. 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 during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that we can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The analysis procedure quantifying the earthquake forces and its demand depending on the importance and cost, the method of analysing the structure varies from linear to nonlinear. The behaviour of a building during an earthquake depends on several factors, stiffness, adequate Lateral strength, 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 compared to irregular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in understanding the role of building configurations.

A. Objectives

- To understand the behaviour of regular and irregular building subjected to lateral loading.
- To describe the importance of equivalent static method in seismic analysis of regular and irregular structures.
- To evaluate the effect of plan irregularity in the form of re-entrant corners on the seismic behavior of RC structures.
- To study the feasibility of strengthening the buildings with re-entrant corners by the introduction of bracings.

2. Literature review

- Kusuma B studied the effect of seismic responses such as the storey lateral displacement, storey drift, storey shear, storey stiffness by considering irregularities like re-entrant corner, diaphragm and compared the result.
- Anjana. A et. al considered linear static analysis method to study the behaviour of building with horizontal irregularity with and without shear wall and concluded that building with shear wall is an efficient structure than without shear wall.
- Shivkumar Hallale, H Sharada Bai studied the behaviour of plan irregular buildings using response spectrum method and analysed the results in Etabs.
- Komal R Btele, S B Borghate focused on irregularity in plan due to re-entrant corner and concluded that building with large projections of re- entrants result in torsion.
- Divyashree M, Gopisiddappa summarized that re-entrant corner experienced about 12% more lateral drift and 22% reduction in base shear capacity compared to regular and building with retrofitted showed improvement in shear carrying capacity.
- Subbaiah Venkatesh Rajeeva conducted the study of irregular building subjected to lateral loading and to determine the optimum position of shear wall by taking irregular building plan and concluded that keeping shear wall in proper places significantly minimize the displacement caused by earthquake.

3. Methods of analysis

Seismic analysis is a subset of structural analysis and is the calculation of the response of the building structure to earthquake and is a relevant part of structural design where earthquakes are prevalent. The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behaviour of the overall structure. The analysis may be static or dynamic in approach as per the code provisions. Thus broadly we can say that linear analysis of structures to compute the earthquake forces is commonly based on one of the following three approaches.

1. An equivalent lateral procedure in which dynamic effects are approximated by horizontal static forces applied to the structure. This method is quasi-dynamic in nature and is termed as the Seismic Coefficient.

A. Method in the IS code

- The Response Spectrum Approach in which the effects on the structure are related to the response of simple, single degree of freedom oscillators of varying natural periods to earthquake shaking.
- Response History Method or Time History Method in which direct input of the time history of a designed earthquake into a mathematical model of the structure using computer analyses.

One of the above three methods of analysis, equivalent static method is considered for the analysis of building studied here. Details of these models are described in following section. The seismic of analysis based on Indian standard 1893:2002 (part-1) is described as follows.

B. Equivalent static method

This is a linear static analysis. This approach defines a way to represent the effect of earthquake ground motion when series of forces are act on a building, through a seismic design response spectrum. This method assumes that the building responds in its fundamental mode. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces. In the equivalent static method, the lateral force equivalent to the design basis earthquake is applied statically. The equivalent lateral forces at each storey level are applied at the design 'centre of mass' locations. It is located at the design eccentricity from the calculated 'centre of rigidity (or stiffness)'. The base dimension of the building at the plinth level along the direction of lateral forces is represented as *d* (in meters) and height of the building from the support is represented as *h* (in meters). For the purpose of determining the design seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I and II are merged into Zone II in fifth revision of code. The design horizontal seismic forces coefficient Ah for a structure shall be determined by following expression,

$$A_h = \frac{Z\ I\ S}{2Rg}$$

Z = zone factor for the maximum considerable earthquake (MCE) and service life of the structure in a zone. Factor 2 in denominator is to reduce the MCE to design basis earthquake (DBE).

I = importance factor, depending on the functional purpose of the building, characterized by hazardous

Consequences of its failure, post-earth quake functional needs, historical value, or economic importance.

R = response reduction factor, depending upon the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations however the ratio *I/R* shall not be greater than 1.

Sa /g = average response spectrum

C. Design of lateral force

The total design lateral force or design seismic base shear (Vb) along any principal direction of the building shall be determined by the following expression,

$$V_b = A_h W$$

Where, Ah = horizontal seismic forces coefficient

W = seismic weight of building.

D. Fundamental design period

The fundamental natural time period as mentioned in *clause 7.6 IS 1893 (part 1): 2002* for moment resisting RC frame building without brick infill walls and moment resisting steel frame building without brick infill walls, respectively is given by

$$T_a = 0.075h^{0.75}$$

Where, h= height of the building in m.

E. Distribution of design force

The design base shear, *Vb* computed above shall be distributed along the height of the building as per the following expression,

$$Q_i = V_b \frac{W_i h_i^2}{\sum W_i h_i^2}$$

Where, Qi = design lateral force at i_{th} floor.

Wi = seismic weight of i_{th} floor

Hi = height of i_{th} floor measured from base, and

n = numbers of storey in the building is the number of the levels at which the masses are located.

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4. Structural Modelling

In the present work we have considered typical four and eight story buildings with regular and irregular (with re-entrant corners of L, T, PLUS and U shape) configuration for the comparison of their Seismic performance. The configurations of building adopted for the present study are described below.

- Model 1: Regular building
- Model 2: L shape building
- Mosel 3: T shape building
- Model 3: U shape building
- Model 4: plus, shape building.

Table 1
Data of modeled structure considered for the study

No of stories	5
Storey type	Moment resisting frame
Typical storey height	3.5
Grade of concrete	M30
Grade of steel	Fe 500
Size of beam	300X450mm
Size of column	450X450mm
Thickness of slab	150mm
Seismic zone	III (Z=0.36)
Importance factor	1
Soil type	medium

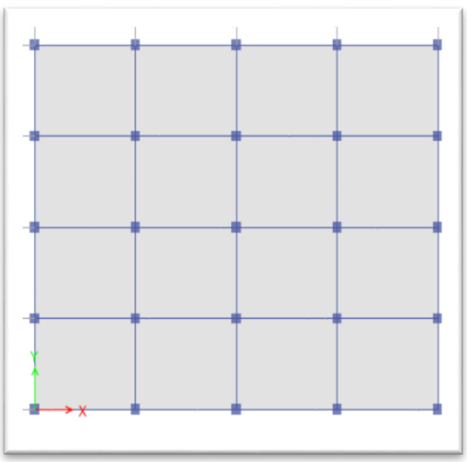

Fig. 1. Plan of regular building

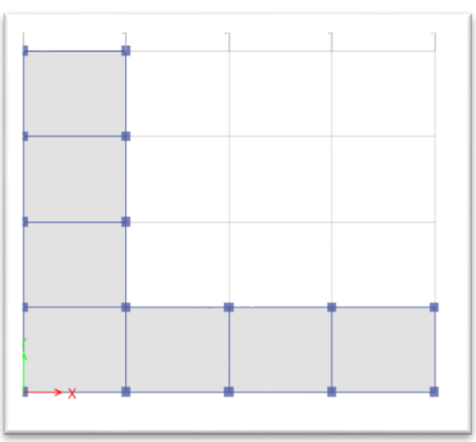

Fig. 2. Plan of L shape building

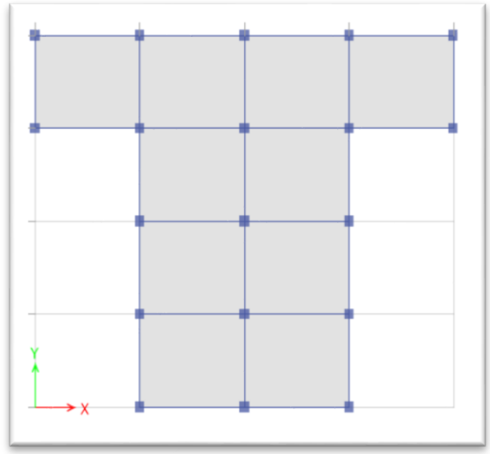

Fig. 3. Plan of T shape building

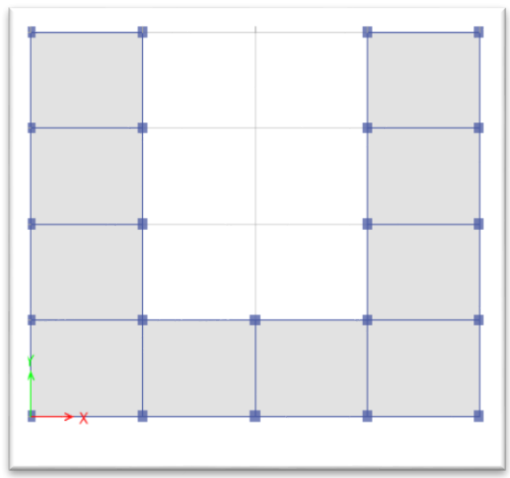

Fig. 4. Plan of U shape building

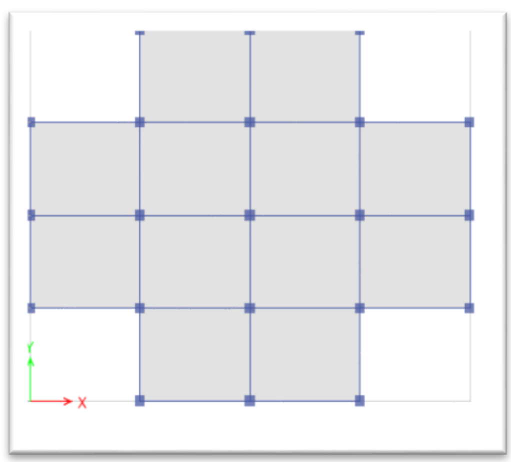

Fig. 5. Plan of plus shape building

5. Results and discussion

The following parameters of the results obtained from analysis are considered for the study. The results obtained in terms of base shear, storey shear and displacement for different

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building models considered for analysis and carried out using equivalent static method and gravity analysis also presented. An effort has made to study the behaviour of regular and irregular RC framed building

A. Base shear

Table 2
Base shear obtained for regular and irregular 4 – storey building

Models	Base shear (KN)
Regular	583.89
Plus shape	466.86
U shape	461.5
T shape	408.22
L shape	312.96

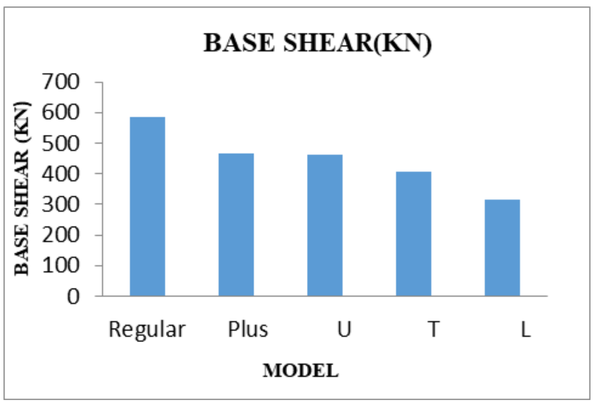

Fig. 6. Base shear diagram for regular and Irregular building of four storey building

B. Displacement

Table 3
Displacement obtained for regular and irregular 4 – storey building.

Models	Displacement (mm)
Regular	10.765
Plus shape	11.111
U shape	10.82
T shape	11.251
L shape	10.785

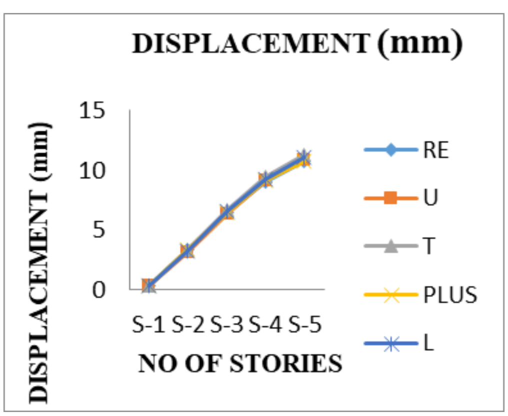

Fig. 7. Displacement diagram for regular and irregular 4-storey building

C. Storey shear

From the results it is clear that L and Plus shape building show more displacement than the other two shape and storey shear is more at the top of the building. Hence building with more re-entrant corner is more vulnerable to earthquake waves.

Table 4
Storey shear obtained for regular and irregular 4-storey building

Storey Shear (KN)					
No. of Stories	RE	U	T	PLUS	L
S-1	0.52	0.45	0.398	0.439	0.34
S-2	28.072	21.114	19.71	22.54	15.84
S-3	85.446	64.269	60.019	68.612	47.26
S-4	173.95	130.84	122.18	139.68	96.113
S-5	263.90	193.21	182.60	210.09	141.47

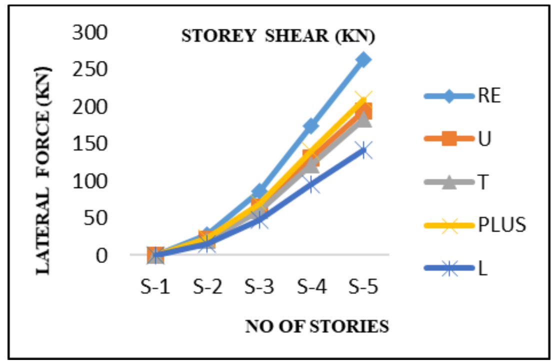

Fig. 8. Storey shear diagram for regular and irregular 4-storey building

6. Strengthening by bracing

One of the simplest methods of relieving the structures of the deficiencies caused by the re-entrants corners is to separate the structures at the notches and converting them into smaller blocks of regular configurations. Separation of buildings needs to take into account the functional requirements. The separated structures should be located far apart so as to avoid ponding effects during earthquakes.

For an existing structure, there are many possible options of strengthening the structure to overcome the ill effects of irregularities. One of the viable.

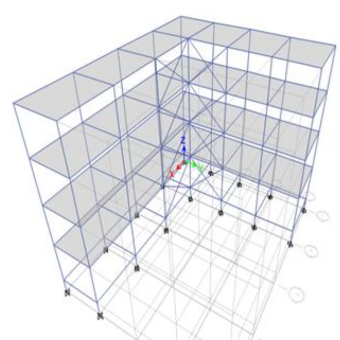

Fig. 9. Bracing provided for L- shape building

Table 5
Displacement values obtained for L- shape 4-storey building with and without bracing

Storey	Without Bracings	With Bracings		
		150X150mm	250x250mm	350x350mm
S-1	0.337	0.259	0.252	0.247
S-2	3.275	2.082	1.99	1.931
S-3	6.528	4.154	3.99	3.889
S-4	9.295	6.057	5.848	5.716
S-5	11.111	7.458	7.23	7.097

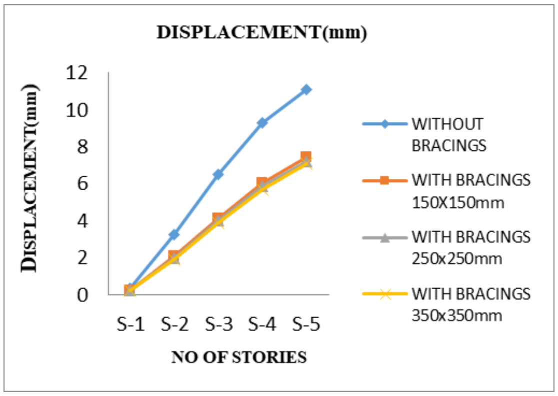

Fig. 10. Displacement diagram of L-shape 4-storey building with and without bracings

The data shows the displacement of L shape building after providing bracing. Different angles of bracing are provided to the same building to check the efficiency. It is observed that after providing bracing the displacement is almost reduced and also as the size of bracing increased displacement decreases. Hence the method of strengthening the building using bracing is effective

7. Conclusion

From the above results it is clear that the regular structure with RC moment resisting frame perform better under the action of seismic load, compared to irregular structure. The irregular structure especially the re-entrant corner structure shows worst performance when subjected to seismic excitation. Using these result following conclusions were drawn

- Buildings with higher percentage of re-entrant corner are susceptible to more seismic damages particularly in high seismic zones.
- Building with re-entrant corner shows more displacement at the notches than the regular building.
- Structure strengthened by bracing at the re-entrant corner showed better performance than the building without bracing

Considering the analysis of irregular structures, we got to know that simple attracts less force and perform well during the effect of earthquake. Hence it is inevitable to reduce complex building.

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