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Effect of Irregularities in Buildings and their Consequences

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Abstract - Many buildings in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. In case, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure and mechanical properties of the structural materials. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. The current version of the IS: 1893 (part I) -2002 requires that practically all multistoried buildings be analyzed as three-dimensional systems. This is due to the irregularities in plan or elevation or in both. The paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with irregularity. Structural irregularities are important factors which decrease the seismic performance of the structures. The study as a whole makes an effort to evaluate the effect of vertical irregularity on RC buildings, in terms of dynamic characteristics and the influencing parameters which can regulate the effect on Story Displacement, Drifts of adjacent stories, Excessive Torsion, Base Shear, etc.

Keywords: Lateral Deflections, Seismic Performance, RC Building, Vertical Irregularity, Dynamic Characteristics.

I. 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 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 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.

II. STRUCTURAL IRREGULARITIES

There are various types of irregularities in the buildings depending upon their location and scope, but mainly, they are divided into two groups―plan irregularities and vertical irregularities. In the present paper, the irregularities are considered and described as follows.

A. Vertical irregularities:

a. Stiffness Irregularity

Soft storey: A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above.

***Extreme Soft Storey*:** An extreme soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storeys above. For example, buildings on stilts will fall under this category.

b. Mass Irregularity

Mass irregularities are considered to exist where the effective mass of any storey is more than 150% of effective mass of an adjacent storey.

c. Vertical Geometric Irregularity

Geometric irregularity exists, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in an adjacent storey.

d. Discontinuity in capacity - Weak Storey

A weak storey is one in which the storey lateral strength is less than 80% of that in the storey above, the storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.

e. **In-Plane Discontinuity in Vertical Elements Resisting Lateral Force**

An in-plane offset of the lateral force resisting elements greater than the length of those elements.

B. Plan irregularities:

a. Torsion Irregularity:

Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure.

b. Re-entrant Corners:

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.

c. Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storeyto the next

d. Out-of-Plane Offsets

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements

e. Non-parallel Systems

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

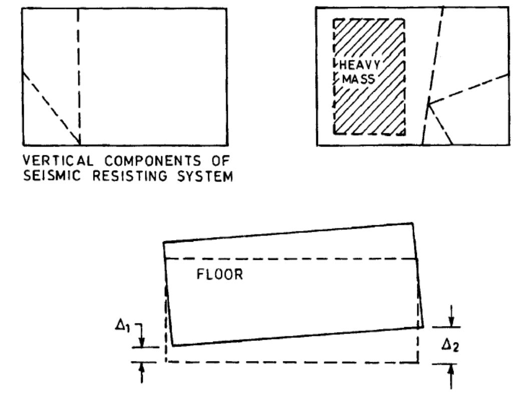

Fig. Torsional Irregularities

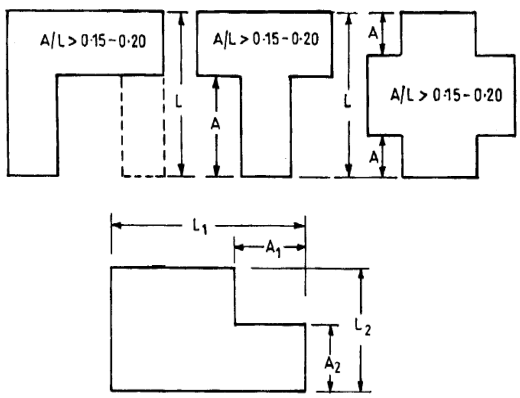

Fig. Re-Entrant Corners

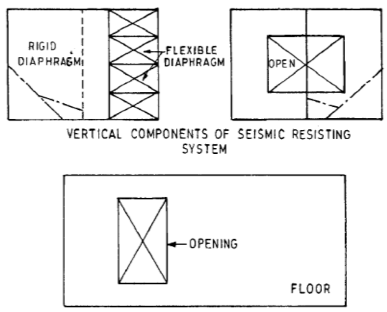

Fig. Diaphragm Discontinuity

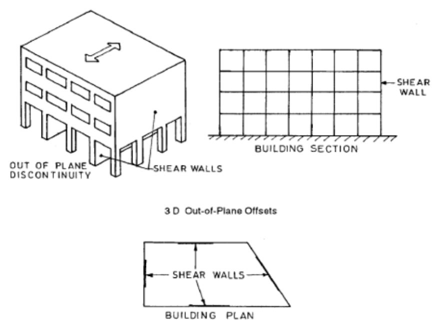

Fig. Non-Parallel System

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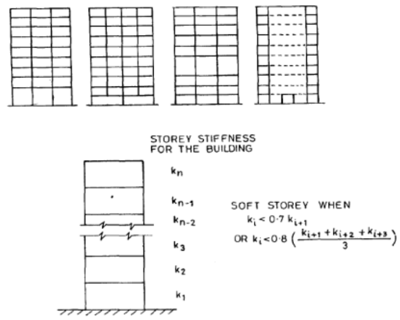


Fig. Stiffness Irregularity

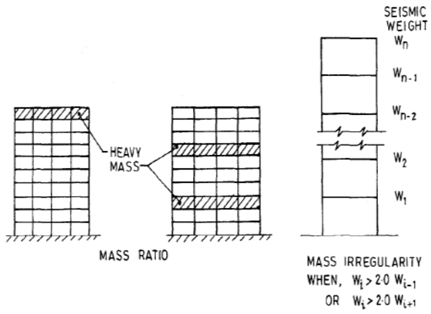
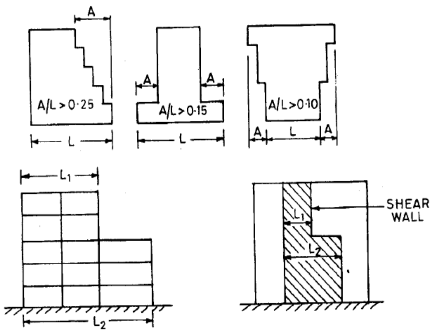


Fig. Mass Irregularity



4 C Vertical Geometric Irregularity when $L_2 > 1.5\ L_1$

Fig. Vertical geometry irregularity

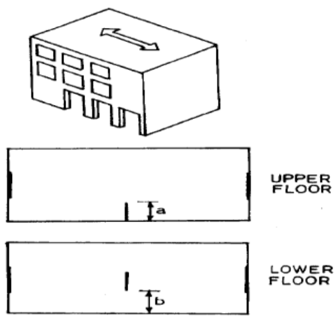


Fig. In-Plane Discontinuity in Vertical Elements Resisting Lateral Force

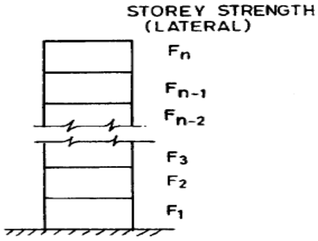


Fig. Weak storey

[All figures are taken from IS 1893:2002 (Part I)]

III. PROBLEM FORMULATION

The problem considered for the study is taken from one of the exiting plans. This 10-storey building frame is considered with two different irregularity as taken from IS 1893(part I): 2002. Thus, we have five frames including the base frame. These five frames have been analyzed using equivalent static method of IS 1893-part 1: 2002 while assuming seismic zone IV, and importance factor 1.5. Analysis has been carried out using CSI-ETABS program. Configuration of frames is as given below and shown in Fig. 1.

Frame-1**:** This is the regular plan of the building with no irregularities and ten storeys, with a storey height of 3 m. The specifications of the building are:
Dimensions of the beam = 0.45 m × 0.25 m; Column size = 0.30 m × 0.30 m; Column length = 3 m; Load combination = DL + LL + EQL; Dead Load = 8.5 kN/m; Live Load = 10 kN/m.

Frame-2**:** This frame carries heavier loading on the top storey, e.g., in the top storey swimming pool has been introduced hence making the top storey heavy, and the building becomes irregular.

Frame3**:** Frame with heavy loading on 4th and 7th storeys. Two storeys of the building, i.e., 4th and 7th storeys, carry heavier loads, hence making the building irregular.

Frame-4**:** Frame having 1st and 2nd storeys soft. No floor slab has been provided which makes these two storeys less stiff, i.e., softer.

Frame5**:** This frame has its 4th and 5th storeys soft. No floor slabs have been provided which makes these two storeys soft.

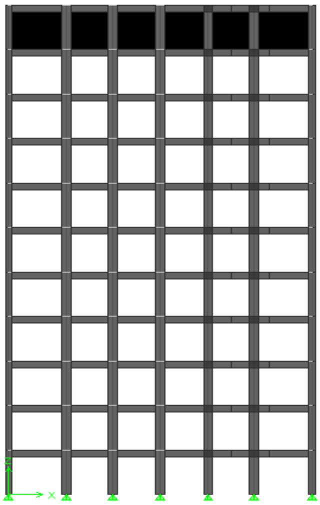


Fig. a

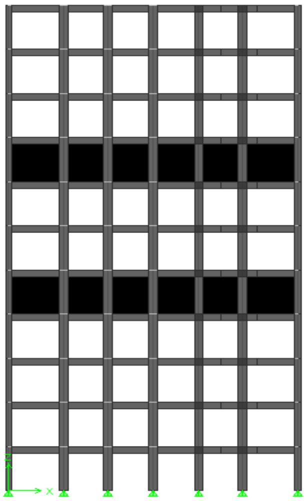


Fig. b

Figure: a] Heavy load at top level (mass irregularity). b] Heavy load at 4th & 7th storey (mass irregularity)

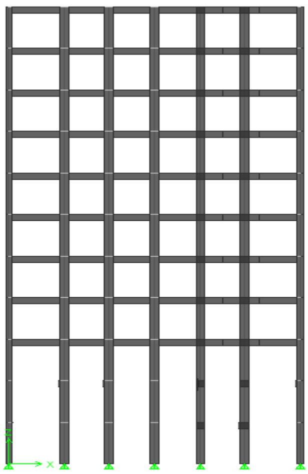


Fig. c

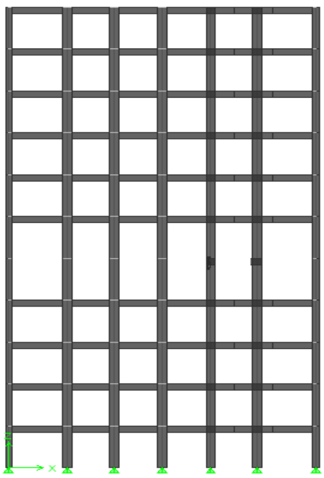


Fig. d

Figure: c] 1st and 2nd storey soft. d] 4th and 5th storeys soft.

IV. ANALYSIS RESULTS

The five frames have been analyzed and their lateral storey-displacements, storey drifts and base shears have been computed to study the effects of irregularities on the frames. The results are presented and discussed hereafter. Table-1 shows displacement of storeys of various frames in X-direction which is horizontal. These have been plotted and shown in Fig. e.

Table No. 1: Displacement in X (mm)

STOREY	frame 1	frame 2	frame 3	frame 4	frame 5
STOREY1	3.2694	5.8	9.74	6.2545	3.45
STOREY2	7.441	11.2	21.151	15.16	7.156
STOREY3	11.6717	18.523	26.325	24.454	11.15
STOREY4	15.83	25.879	30.25	32.11	15.974
STOREY5	19.84	31.23	34.9894	32.2654	27.645
STOREY6	23.58	38.256	37.545	38.3115	37.654
STOREY7	26.92	44.21	41.246	43.651	41.561
STOREY8	29.7106	50.17	43.9465	43.546	42.3545
STOREY9	31.77	54.68	45.325	45.9789	46.755
STOREY10	32.8944	54.7926	46.3254	46.21	47.75

Storey-drifts for all the frames are presented in Table-2 while plotted as Fig. f. Frame-3, Frame-4 and frame-5 are seen to exhibit abrupt changes in storey drifts, which is highly undesirable.

Table no. 2: storey drift in X (mm)

STOREY	frame 1	frame 2	frame 3	frame 4	frame 5
STOREY1	3.2	5.113	9.74	6.99	3.128
STOREY2	4.17	6.56	11.99	8.93	4.01
STOREY3	4.22	6.69	4.43	8.9	4.03
STOREY4	4.16	6.69	4.05	7.2	4.54
STOREY5	4	6.62	3.91	0.09	11.33
STOREY6	3.7	6.49	3.64	5.75	10.88
STOREY7	3.3	6.2	3.25	5.601	3.602
STOREY8	2.7	5.8	2.71	0.108	2.75
STOREY9	2	4.51	2.06	1.76	2.212
STOREY10	1.11	0.15	0.75	1.18	0.765

V. GRAPHS

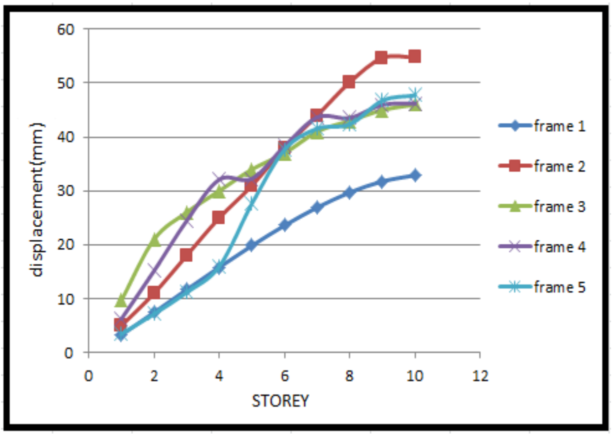


Fig. e

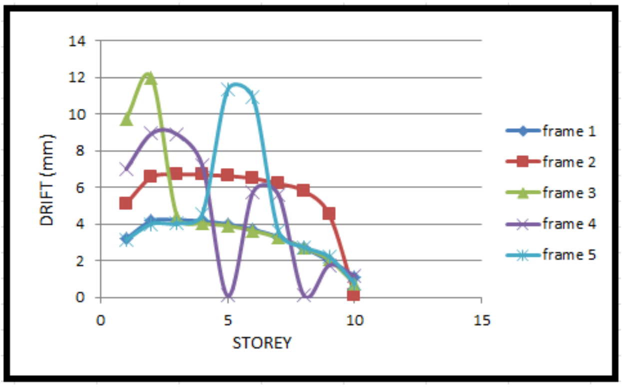


Fig. f

Figure: Response of various frames with irregularities

VI. DISCUSSION AND CONCLUSION

Considering the storey displacement, the frame with frame carries heavier loading on the top storey (frame-2) & frame has its 4th and 5th storeys soft (frame-5) is the weakest since it suffers the maximum displacement while the base frame exhibits the least displacement.

As far as storey drift is concerned, frame-3 (with heavy loading on 4th and 7th storeys) is the weakest since it has the maximum storey drift which changes abruptly. Frame-4 & Frame-5 also shows similar pattern for bottom two storeys & middle stories.

In this paper, various frames with different irregularities, but with same dimensions have been analyzed to study their behavior when subjected to lateral loads. All the frames were analyzed with the same method as stated in IS 1893 (part-I):2002. The base frame (regular) develops least storey drifts while the building with heavy loading on 4th and 7th storeys shows maximum storey drifts on the storey levels. Hence, this is the most vulnerable to damages under this kind of loading. The buildings with irregularities also showed unsatisfactory results to some extent.

This proves that irregularities in buildings are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution of load around the building.

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