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A Study on the Behavior of Symmetrical, L-Shape and T-Shape RC Building during Earthquake

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Abstract: *The occurrence of irregularities in mass, stiffness, strength or geometry along the elevation of the building is classified as vertical irregularity. Torsional irregularity or in-plan irregularity can be regarded to exist if the building possesses non-concurrency in the lines of action of centers of mass and stiffness on a common vertical axis at each floor level. Throughout earthquakes or any other lateral loads, the inertia force acts through the center of mass and resistive force through the center of stiffness or resistance. Irregularities in mass and stiffness along the height of the buildings in combination with torsional irregularities along the plan of the buildings are evaluated. Transient analysis is implemented to analyse the seismic response of the shear wall buildings, mass irregular buildings and stiffness irregular buildings with in-plan eccentricity using Etabs software. The responses of the irregular buildings and the outcome of in-plan eccentricity in terms of variation in natural period, base shear storey drifts, roof deflection, torsional resultant and roof rotations obtained from the analysis due to asymmetry have been calculated in detail. As concerns the seismic responses of the irregular buildings, equations and irregularity coefficients are planned to quantify and compare buildings with of vertical and torsional irregularity in combination. It is also attempted to suggest modification for the approximate natural period expression given in the IS 1893:4016 and ASCE 7-16 to incorporate the in-plan eccentricity and evaluate the natural period of irregular buildings. It is observed that the existence of in-plan eccentricity if present singly or in combination with any other irregularities, determines the overall seismic behavior of a building and tends to modify its response.*

Keywords: RC Building

I. INTRODUCTION

Along with the natural hazards, earthquakes have the capability for causing the greatest damages. Since earthquake forces are haphazard in nature & irregular, the engineering tools needs to be sharpened for analysing structures under the action of these forces. About 60% of the land area of our country is at risk to damaging levels of seismic hazard. In future, earthquakes can't be avoided, but awareness and safe building construction practices can surely decrease the extent of damage and loss. The performance of a structure throughout earthquakes depends significantly on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at various floor levels in a building require to be brought down along the height to the ground by the shortest way; any deviation or discontinuity in this load transfer path results in poor performance of the building. Even if there are so many studies regarding earthquakes but however it has not been likely to calculate when and where earthquake will take place. It has been learned how to identify the locations of earthquakes, how to precisely measure their sizes, and how to build flexible structures that can resist the strong shaking created by earthquakes and protect our loved ones.

Up to date, damaging earthquakes experienced in our country consist of (1) Bihar Nepal earthquake (1988), (2) Uttarkashi earthquake (1991), (3) Killari earthquake (1993), (4) Jabalpur earthquake (1997), (5) Chamoli earthquake (1999) and (6) Bhuj earthquake (2001) and recently occurred (7) West Bengal earthquake (2011). In all of these earthquakes there is massive loss of life and very large destruction of existing reinforced concrete (RC) buildings. The earlier buildings, even if constructed in fulfillment with prevailing standards, may not comply with the more stringent specifications of the latest standards of IS 1893(Part 1):2016, IS 4326:1993 and IS 13920: 1993.

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II. REGULAR AND IRREGULAR STRUCTURES

Buildings with simple regular geometry and uniformly distributed mass and stiffness in plan and in elevation, undergo much less damage, than buildings with irregular configurations. All efforts shall be made to reduce irregularities by modifying architectural planning and structural configurations. Limits on irregularities for Seismic Zones III, IV and V and special requirements are laid out in Tables 5 and 6.

There are basically two types of irregularities in building,

1. Plan irregularity
2. Vertical irregularity

There are again various types plan irregularities such as,

1. Torsional Irregularity
2. Re-entrant Corners
3. Floor slabs having unnecessary cut-off and opening
4. Out-of-plane Offsets in vertical elements
5. Nonparallel lateral force system

2.1 Regularities and Irregularities in Structures

Introduction In this chapter, a brief overview of research into the seismic behaviour of plan irregular Structures are presented. Existing earthquake codes describe structural configuration as either regular or irregular in provisions of size and shape of the building, arrangement of the structural and non-structural elements inside the structure, distribution of mass in the building etc.

2.2 Plan Irregularity

Asymmetric or plan irregular structures are those in which seismic response is not only translational but also torsion, and is a result of stiffness and/or mass eccentricity in the structure. A regular structure may actually be asymmetric 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. Asymmetry may in detail exist in a nominally symmetric structure because of uncertainty in the evaluation of centre of mass and stiffness.

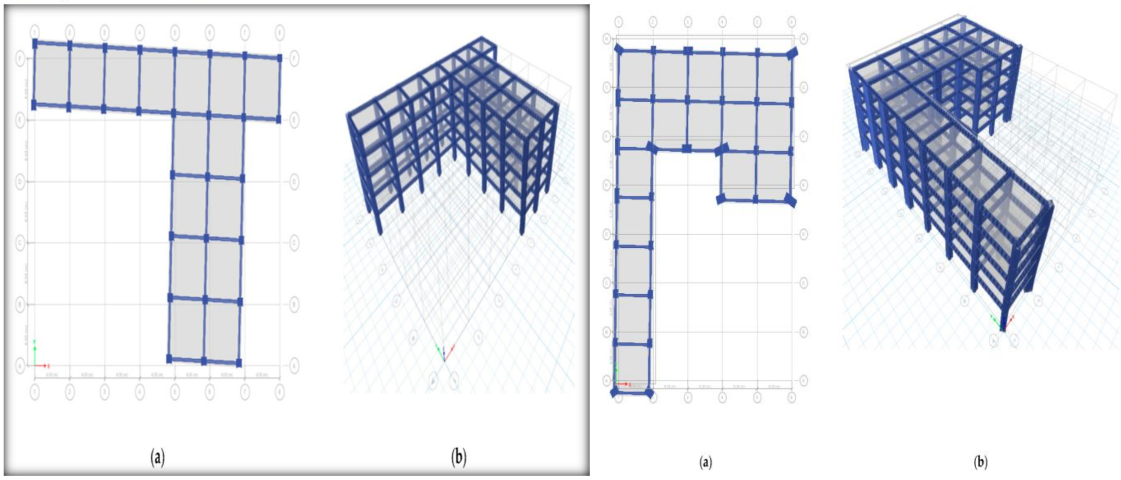

Fig 1: Shows Plan Irregularity

2.3 Vertical Irregularity

Vertical irregularity results from the irregular distribution of mass, strength or stiffness along the elevation of a building structure. Mass irregularity results from a abrupt change in mass between adjoining floors, such as mechanical plant on the roof of a structure. Stiffness irregularity results from a sudden change in stiffness between adjacent floors, such as in the elevation of a building.

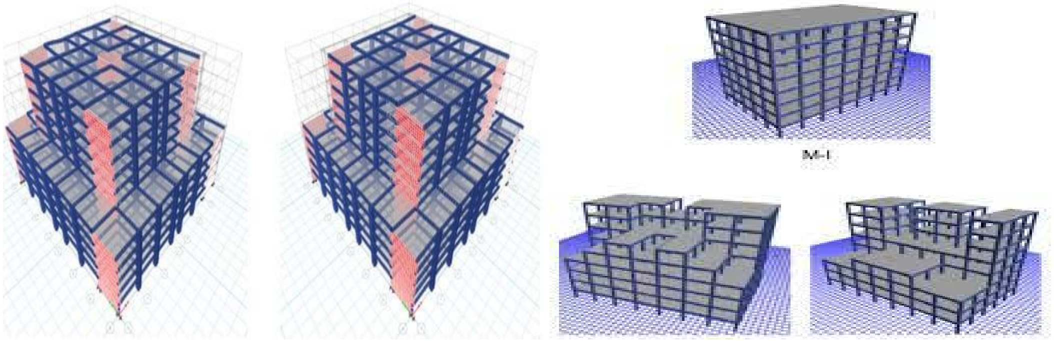

Fig 2: Shows Vertical Irregularity

2.4 Objectives

1. Consequence of seismic load on structure due to plan irregularity.
2. To compute lateral force on each levels due to seismic force.
3. To study behavior of different shaped buildings in plan during earthquake.
4. Calculate the torsional movement in structure due to irregularity in mass and stiffness.
5. To study the software and provide accurate and quicker analysis results by the use of ETABS.

II. REVIEW OF LITERATURE

G. Guruprasad *et al.* (2017)

Performed a dynamic analysis of G+15 storied RC frame building with L, C & rectangular shape in plan with the help of ETABS software. Comparison has been done by taking into account the parameters such as story drift, story shear, support reactions, building mode, and section cut force. It has been concluded that highest value of story shear was observed for L-shape plan than rectangular building and C-shape building. The stories drift values in X direction and Y direction increases for top to base story in all three cases. When earthquake load is applied in Y direction, it was found that irregular plan structure can resist more base shear than rectangular plan structure. Regular building and L-shape buildings are gave good results than C-shaped buildings in all aspect.

Athulya Ullas *et al.* (2017)

Performed wind analysis of buildings having various shapes such as Y, Plus and V. Buildings of plan shapes Y, Plus and V are modeled in ETABS 2016 and analyzed. It is observed that the storey force is equal for all the shapes, i.e. the storey force does not alter with the shape. The lateral displacement is found highest for V shape building. The storey drift is observed maximum for Y shape as compared to that of other shapes and the lateral displacement and the storey drift are observed minimum for Plus shape building as compared to Y and V shape buildings and hence it is the most structurally stable shape among the selected shapes.

III. METHODOLOGY

The buildings considered for the study of irregularities were three-dimensional (3D) idealized frames of 5 storey, 10 storey and 15 storey buildings categorized into group A, group B and group C respectively. The storey height and length of each bay of all the building frames were chosen as 3m and 4m respectively. The thicknesses of floor slab and the raft slab were taken as 0.15m and 0.5m respectively. The beam dimensions of 0.3 x 0.4m and column dimensions of 0.4m x 0.4m, 0.5m x 0.5m and 0.6m x 0.6m were considered for the 5, 10 and 15 storey buildings respectively. The dimensions of building components were adopted based on the structural design as per Indian standard codes for design of reinforced concrete structures IS 456:4000 and IS 13940:4016. Concrete of M45 grade and steel of Fe 415 grade were considered as the material for the structural elements and live loads of 3.0 kN/m4 and 1.5 kN/m4 were provided on floor and roof respectively. The loading for the residential building was considered based on IS 875(Part1):1987.

3.1 Shear Wall Buildings

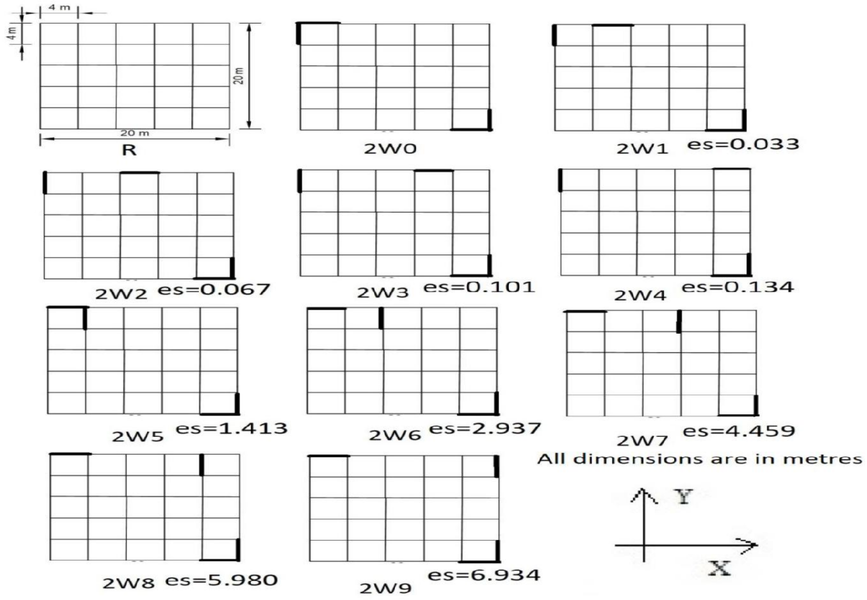

Fig 3: Plan layouts of 4W shear wall buildings

Table 3.1 Dynamic eccentricities of the shear wall building configurations

Building configuration	es (m)	ed (m)	ed/L	Building configuration	es(m)	ed(m)	ed/L
4W0	0.000	1.000	0.050	4W0	0.000	1.000	0.050
4W1	0.033	1.050	0.054	4W1	0.036	1.054	0.053
4W4	0.067	1.101	0.055	4W4	0.110	1.165	0.058
4W3	0.101	1.154	0.058	4W3	0.180	1.470	0.064
4W4	0.134	1.401	0.060	4W4	0.790	4.185	0.109
4W5	1.416	3.144	0.156	4W5	1.580	3.370	0.169
4W6	4.937	5.406	0.470	4W6	1.595	3.393	0.170
4W7	4.459	70689	0.384	4W7	3.463	5.895	0.495
4W8	5.980	9.970	0.499	4W8	4.944	8.383	0.419
4W9	6.934	11.401	0.570	4W9	6.595	10.893	0.545

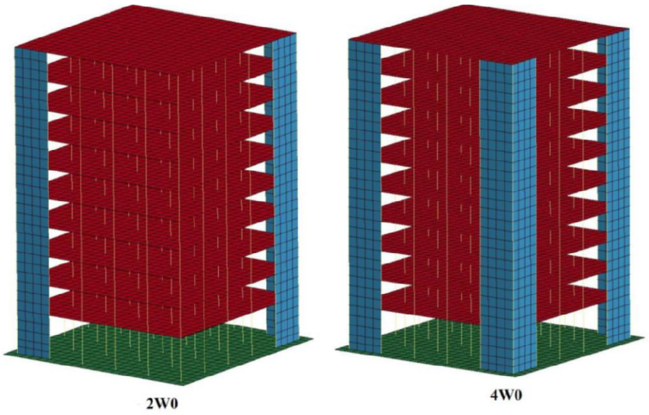

Fig 4: Elevation layouts of shear wall building

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IV. RESULTS AND DISCUSSIONS

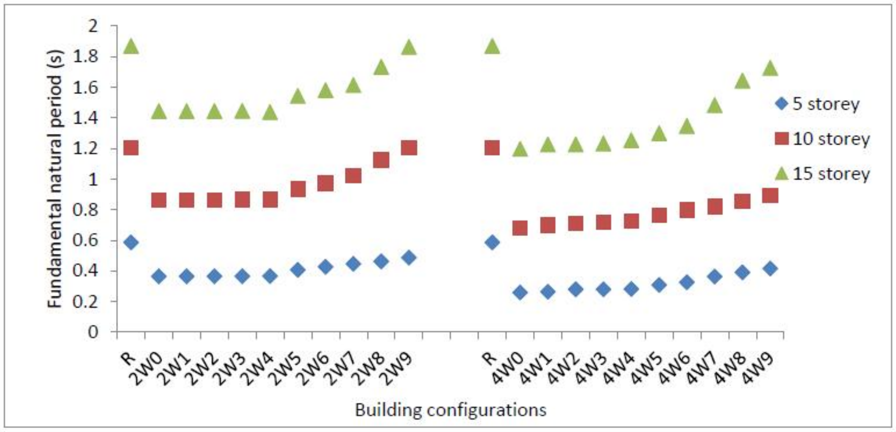

Fig 5: Variation in natural period of group A, group B and group C shear wall buildings

Table 4.1 Frequency ratios of the irregular shear wall building configurations

Building Configuration	Frequency ratio (Ω)			Building Configuration	Frequency ratio (Ω)		
	Group A	Group B	Group C		Group A	Group B	Group C
4W1	1.087	1.068	1.054	4W1	1.036	1.028	1.0185
4W4	0.995	0.986	0.981	4W2	0.984	0.981	0.975
4W3	0.979	0.975	0.969	4W3	0.976	0.973	0.971
4W4	0.962	0.954	0.952	4W4	0.939	0.935	0.931
4W5	0.921	0.918	0.911	4W5	0.903	0.893	0.890
4W6	0.846	0.831	0.822	4W6	0.875	0.872	0.867
4W7	0.812	0.803	0.795	4W7	0.852	0.847	0.841
4W8	0.787	0.785	0.783	4W8	0.824	0.818	0.809
4W9	0.735	0.724	0.716	4W9	0.798	0.781	0.775

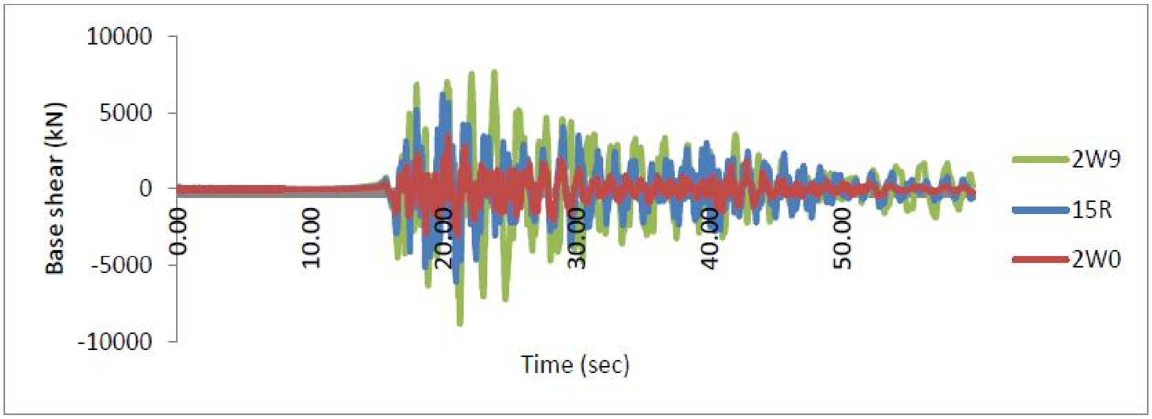

Fig 6 Time history plot of base shear of 2W9, 15R and 2W0 buildings

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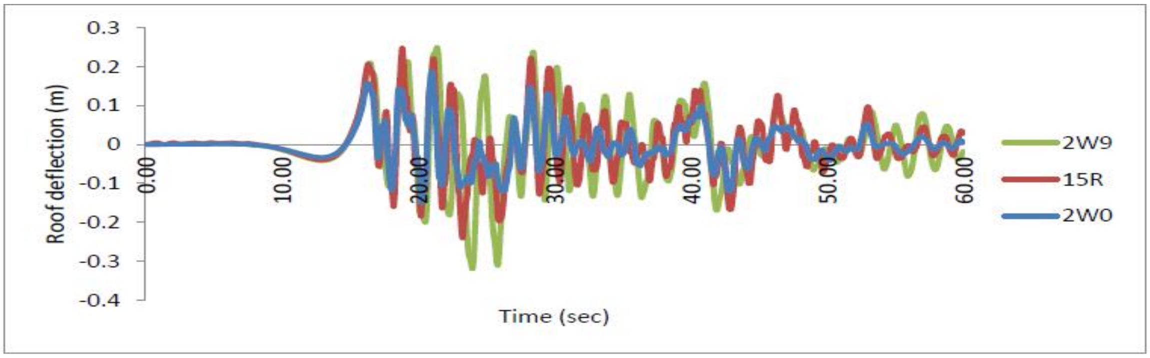

Fig 7 Time history of roof deflection in 2W0, 2W9 and 15R buildings

V. SUMMARY

From the study carried out on shear wall buildings with in-plan irregularity due to change in the symmetrical location of the shear walls, it can be inferred that the in-plan eccentricity plays a major role in determining the seismic behaviour of a building, despite the presence of lateral load resisting elements. Here, the in plan eccentricity incorporated was the highest in 2W9 as 0.57L and the highest variation of the same configuration with respect to the building with symmetrically configured shear walls (2W0) are 60% in natural period, 89% in base shear ratio, 62% in roof deflection ratio and 98% in roof rotations. It is also concluded here that dynamic eccentricity ratio is a good measure of the in-plan torsional irregularity in buildings

VI. CONCLUSION

The seismic responses of the shear wall buildings 2W0-2W9 and 4W0-4W9 with in-plan eccentricity in the range of 0.05L to 0.57L in this study were evaluated and the following conclusions are drawn:

- Shear wall improves the seismic behavior of buildings when symmetrically arranged in plan. However, as eccentricity of the configurations increases, the seismic responses increases and becomes the same or even higher than that of the bare frame buildings.
- The in-plan eccentricity incorporated was the highest in 2W9 as 0.57L and the highest variation of the same configuration with respect to the building with symmetrically configured shear walls (2W0) are 60% in natural period, 89% in base shear ratio, 62% in roof deflection ratio and 98% in roof rotations.
- The eccentricity to the plan width ratio has high compliance to the torsional irregularity coefficient and can be used to represent the torsional irregularity of buildings with irregularity in mass and stiffness.

Considering the mass irregular buildings belonging to group A, group B and group C with different locations of the additional masses along the height of the building and varying in-plan eccentricities from 0.05L to 0.144L, the seismic responses are studied and the following conclusions are made:

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