EFFECT OF PLAN IRREGULARITY IN HIGH SEISMIC ZONE

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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. During strong earthquake motions the performance of a high rise building depends on the distribution of stiffness, strength and mass along both the vertical and horizontal directions. If there is discontinuity in stiffness, strength and mass between adjoining storeys of a building then such a building is known as irregular building. The present study focuses on the performance and behaviour of regular and Plan irregular G+24 reinforced concrete (RC) buildings under seismic loading. Total Six buildings are modelled and seismic analysis is carried out using Equivalent static method in seismic zone-V. Different seismic responses like storey displacement, storey drift, time period and base shear are obtained. By using these responses, a comparative study has been made between different irregular buildings. The result remarks the conclusion that, a building structure with different plan irregularity provides instability during seismic loading. To control the instability, a proportionate amount of stiffness is beneficial in RC building.

Keywords: Plan irregularity, Seismic forces, displacement, drift, base shear.

1. INTRODUCTION

The weakest points in a building are usually the first to suffer earthquake damage. Having holes in the slab might cause load distribution inconsistencies. These holes, however, may protect the building from harm if placed strategically. Structural engineers now have faith in their ability to create safe and sound structures. Specifically, this research looks at how the positioning of slab apertures influences the seismic response of a multi-story structure. Stiffness, appropriate lateral strength, ductility, and simple and regular layouts all contribute to how a structure behaves in an earthquake. Structures with regular geometries and evenly distributed mass and stiffness in plan and elevation are far less likely to sustain damage than those with non-uniform layouts. Vibrations caused by powerful earthquakes have been responsible for the deaths of millions of people. Many architects and engineers are searching for the most effective approach to lessen the seismic impact on buildings and thereby preserve lives in the event of an earthquake. Indian standards divide buildings into two categories: regular and irregular. There are no major breaks in the plan, vertical or lateral force resisting systems of a regular building. Uneven structures are more likely to sustain harm. It's distribution of mass, stiffness, in horizontal & vertical planes of structures that determines how they behave during powerful earthquakes. Inconsistencies in the diaphragm's stiffness, mass, or strength may be to blame for the building's fragility. Structures' structural safety during large earth tremors is the primary issue of seismic load structural design, although structures' serviceability and the possibility for economic loss are also important considerations. Understanding how a structure will respond to massive inelastic deformations is crucial when dealing with seismic loads. Openings that account for more than half of the total diaphragm area or variations in the effective diaphragm stiffness that account for more than half of the total between stories are considered diaphragm discontinuities. Openings, cut outs, neighbouring floors at various levels, and variations in diaphragm thickness all contribute to a loss of lateral stiffness. Stairways, shafts, and other architectural elements are the traditional users of floor diaphragm holes.

Disruptions in mass, stiffness, strength, geometry, and the diaphragm all contribute to a lopsided floor plan. Though originally regular, structures may become irregular after extensive remodelling in response to changing needs. As a result, irregularities may become more pronounced with time. Possible future severe earthquakes might occur here. Stiffness, appropriate lateral strength, ductility, and simple and regular layouts all contribute to how a structure behaves in an earthquake. Structures with regular geometries and evenly distributed mass and stiffness in plan and elevation are far less likely to sustain damage than those with non-uniform layouts. However, because to the increasing population and modern demands, architects and engineers today must inevitably prepare for unconventional layouts. Excessive strains or forces occur in certain parts of an irregularly shaped structure, causing severe damage. It is important to evaluate the ability of both new and existing buildings to endure natural disasters.

2. LITERATURE REVIEW

2.1 Amin Alavi, et.al: Learning how a building reacts in a highly seismic area is the primary focus of this research. For this, researchers first looked at the effects of a five-story structure with re-entrant corners in eight distinct configurations, beside a standard layout for reference. IS 1893 (Part I): 2002, the Indian standard code, has these discrepancies accounted for under clause 7.1. To analyze the whole models, we used ETABS 9.7. The present investigation additionally took into account the possibility of intentional or unintentional twisting in X & Y axes. The Ends Justify Means The findings demonstrated that, in high seismic zones in particular, buildings with significant irregularity are more susceptible than those with less irregularity. Even without the dual system, the eccentricity between a structure's centre of mass & resistance has a major effect on its seismic reaction.

2.2 Komal R. Bele, et.al: According to paragraph 7.1 of IS 1893 (part1):2002, irregular structures should undergo dynamic analysis using either THA or RSA. It is advised that for Regular construction, an ESA based on an empirical time period be used. Previous studies have shown that uneven building behaviour during earthquakes is more prone to damage. Severe damage may occur during earthquakes due to the uneven distribution of stresses and forces in irregular buildings. Knowing how such a structure would fare in an earthquake is essential for improving its design. The study focuses on the deviation from the intended layout that occurs at the Re-entrant corner. Torsion occurs in buildings with protruding re-entrant corners.

2.3 Akshay Ahirwal, et.al: To that end, this research aimed to compare the seismic responses of two buildings, one with and one without a diaphragm discontinuity. In this research, we use CSI SAP200 software to simulate a pre existing structure that has an irregularity in its diaphragm and then compare its seismic response to that of a structure without such a disruption. We have performed both static and dynamic linear analysis. We have compared the modal time periods, base shear, storey drift, and joint displacement results between the two buildings.

2.4 Divya Patel, et.al: Earthquakes are a natural disaster that may cause significant damage to buildings. To ensure the safety of its occupants, buildings must be resistant to seismic force via the careful design and detailing of its structural parts. In this research, we apply the seismic coefficient technique to the investigation of the behaviour of multi-storey buildings with irregular floor plans. In order to find the most earthquake-proof design for a home, we evaluate the results of many irregular C, H, T, and L shaped constructions. Each building type (C, H, T, and L) in a given zone has its behaviour evaluated on three distinct soil types (hard, medium, and soft). Structure-after analysis includes the computation and comparison of displacements, storey drift, and base shear.

2.5 Krishna Verma, et.al: Different models of irregular forms, including those having orientation of columns & lateral load resisting components, were developed and evaluated in E-tabs 2018 software to determine torsion-al impact on the structures in this research. Research uses linear dynamic analysis to look at what happens to an L-shaped structure when exposed to gravity loads and seismic stresses throughout its 30 floors.

2.6 Pradeep Pujar1, Amaresh: In this thesis work, we analyze three different building types—an "I" shape, a "L" shape, and a "C" shape—each having ten storeys. We then take six different models, including three bare frame models and three shear wall models. The structures' corners and L-segments serve as shear walls. Use of shear walls is prevalent. The buildings under consideration are located in Seismic Tremor Zone V (severe) and Soil Type II. Equivalent static method, aided by E-tabs V 15.0.0 software, is used to do the necessary structural analysis. From this analysis, we can compare and contrast buildings with and without shear walls based on factors like story displacement, story drift, and base shear of structure. The scope of the endeavour is to zero in on the effects of seismic influence on layout irregularity in those rare re-entrant corner case buildings.

2.7 Prof. Sujeet Patil, et.al: In this study, we use the ETABs 2015 program to assess & comparing seismic performance of a G+14 structure with a 7 bays X 9 bays plan irregular to a regular building. The structure is examined in a medium-soil location that is part of seismic zone IV. It employs the methods of ESA & RSA. As such, we take into account the factors of base shear, storey drift, and storey displacement.

2.8 Pranaybarman: The current research used the Linear Static approach to analyze a 10-story structure in ETABS 2017 and the IS Code 1893:2002(part-1). Linear Static Analysis is capable of analyzing both Regular and Irregular structures up to a height of 31 meters in zone V. To learn how buildings respond to earthquakes, researchers will compare reactions such as base force reaction, storey force reaction, torque, and stiffness. There are now seven models available. All the models are uniquely shaped, with one having a regular structure and the others having irregular ones.

2.9 Aysha S: Reinforced concrete buildings will exhibit nonlinear behaviour due to the development of plastic hinges and a consequential reduction in stiffness when subjected to seismic stresses. The current research applies the IS 1893:2002 push over analysis to a G+4 irregular RCC structure in zone III in Kerala. In ETABS 2018, we modelled the building, and we ran the push over analysis and the time history analysis in the same program. From these calculations, ETABS determines the building's push over curve, response spectrum curve, demand capacity, base reactions, and performance point.

2.10 P A Krishnan, et.al: In event of a major earthquake, any irregularities in structure should be cause for alarm. Modifying a building's vertical or horizontal orientation drastically might cause structural damage. In order to avoid failure and reduce the potential for harm, it is necessary to examine in depth how irregular structures react to lateral loads. This work uses Pushover analysis to investigate the behaviour of nonstandard structures. We examine the impact of 10 different re-entrant corner models in light of the 2016 amendments to IS 1893 (Part 1). We use ETABS v. 16.2.0 and Seismo Match v. 2018.2 as our primary analysis tools. In this analysis, we focus on three key performance indicators: performance levels, stress concentration, and storey displacement. We also cover methods for fortifying weak models. We evaluate our findings against those of a conventional design.

3. OBJECTIVES AND SCOPE OF WORK

3.1 Objectives:

Finding out how different types of RC framed regular & plan irregular structures react to earthquakes is the focus of this study. In order to choose the best layout for a structure, it is necessary to compare several seismic factors. The purpose of this research is to analyze how geometric distortions in the design affect the building's efficiency.

1. A look of how storey drift, base shear, displacement, and time period compare in a regular vs plan irregular frame.
2. 2Seismic performances of structures with varying floor plans and elevations in a very high seismic region (V)
3. Use the suggested multi-scale modelling approach for evaluating seismic safety & collapse susceptibility of existing structures.

3.2 Scope of Work:

1. Modelling for RC framed structure.
2. The mass of infill wall was considered.
3. Applying seismic zone factor with respect to different plan irregular building and comparing the result of base shear, time period, displacement, & storey drifting.
4. Behaviour of modelled is check with respect to base shear, displacement, time period, & storey drifting.
5. The study highlight the effect of plan irregularities subjected to seismic forces under seismic zone-V.

4. METHODOLOGY

For our further work of regular and irregular shape we have taken G+ 24 storeys with storey height of 3.3m provided. Also properties are defined. The seismic zone considered is zone-V. We have adopted 5 cases by assuming different plan. Different irregular buildings are I, T, C, L and Plus-shape. All of our building simulations adhere to the Indian standard (IS-1893:2016) for seismic zone V. Seismic load, dead load, and live load according to IS 875 part I & II and IS 1893/2016 are all part of the applied loading for a specific structure. The Etabs program does the analysis in an equivalent static fashion. Into our research seismic analysis of all the five irregular RC buildings and one regular building has been carried out.

4.1 Analytical Modelling:

1. Seismic effects on RC framed buildings with varying degrees of plan irregularity are the focus of the present study.
2. Using Etabs, we do a full study of a G+24 RC framed structure.
3. Seismic Zone-V, including a variety of layout anomalies, is the setting for this investigation.
4. Parameters such as lateral displacements, base shear, Time period, and inter-storey drifts are recorded after assessing several models in Etabs software.
5. Finally, we compare the outcomes across many models.

4.2 Description of Models:

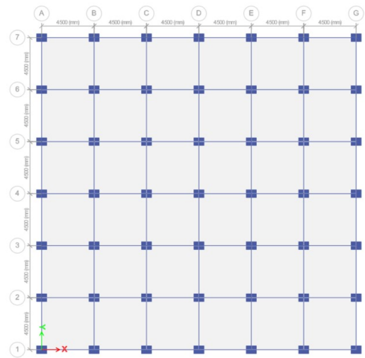
A total of 6 models were prepared for seismic study of RC regular and plan irregular building.

1. A RC framed regular building of G+ 24 storeys
2. A RC framed plan irregular building (I-shape) of G+ 24 storeys
3. A RC framed plan irregular building (T-shape) of G+ 24 storeys

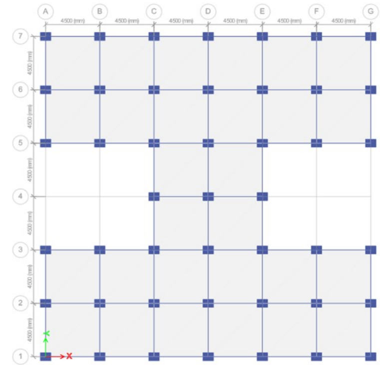
4. A RC framed plan irregular building (C-shape) of G+ 24 storeys
5. A RC framed plan irregular building (L-shape) of G+ 24 storeys
6. A RC framed plan irregular building (Plus-shape) of G+ 24 storeys

Modelling different types of model using Etabs

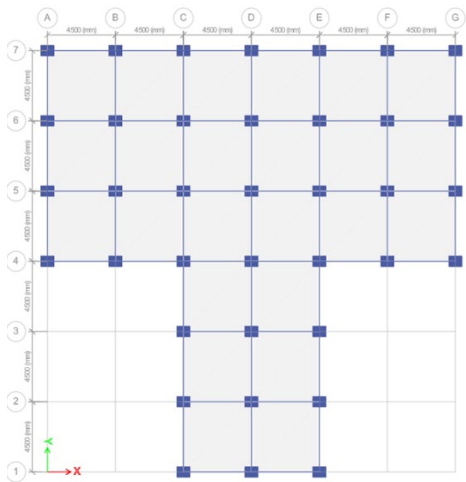
1. Regular building of G+ 24 storeys



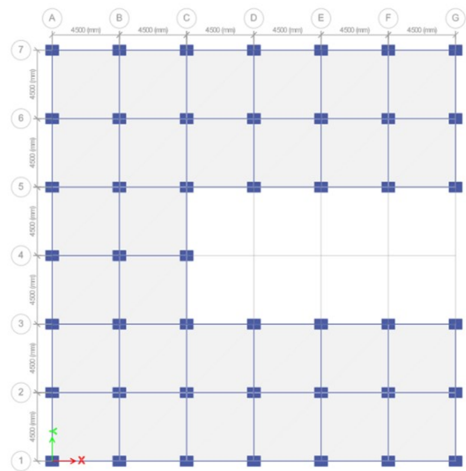
2. I-Shape Building of G+24 storey



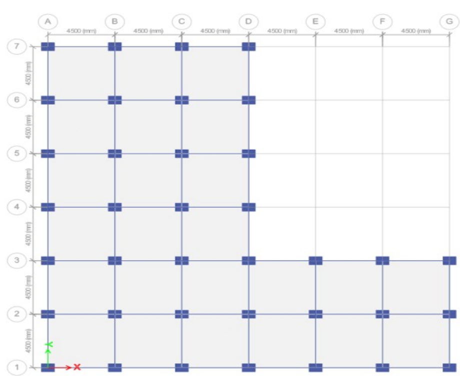
3. T-shape building of G+ 24 storeys



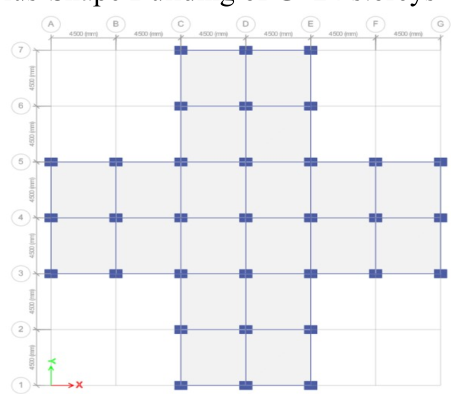
4. I-Shape Building of G+24 storey



5.L-shape building of G+ 24 storeys



6. Plus-Shape Building of G+24 storeys



4.3 Details of Structure:

Building type	Commercial Building
Frame type	Reinforced Concrete moment resisting
Total storey	25 (G+24)
Each storey height	3.3 m
Bottom storey height	2.7m
Total building height	81.60m
Wall thickness	230mm
LL	3KN/m^2 (As per IS-875-Part-II)
FF	1.0 KN/m^2
Wall load	11.80KN/m
Concrete grade	M30
Steel grade	Fe-500N/mm^2
Brick masonry density	18 KN/m^3
Beam size	230mm x 525mm
Size of column	C-700 x 900 mm
Slab thickness	150mm
Seismic Zone	V
Soil type	Medium
Response reduction factor	5 (SMRF)
Importance factor	1.0
Damping ratio	5%

5. METHODS OF SEISMIC ANALYSIS

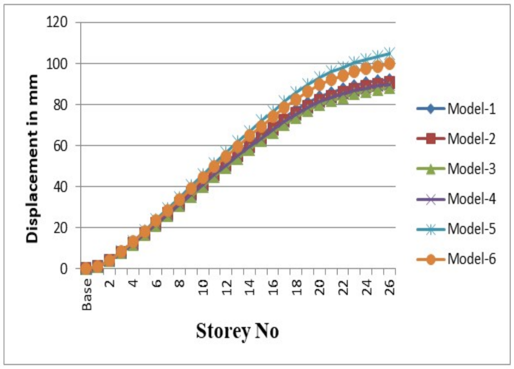
Some of Seismic Analysis Approaches may be categorized according to linear and non-linear methods. Linear methods include linear static and equivalent static force methods & linear dynamic & response spectrum techniques. The following are some examples:

1. Equivalent static Method
2. Response spectrum method
3. Pushover Analysis method
4. Time history analysis

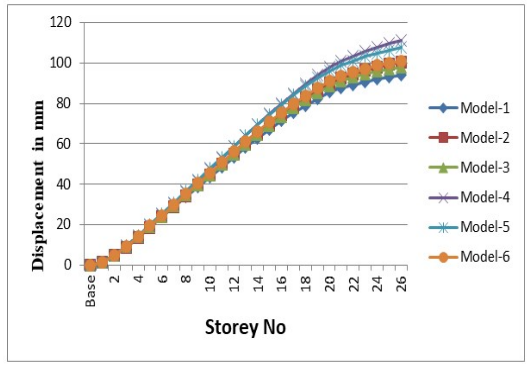
6. RESULT AND DISCUSSION

6.1 GENERAL: Six RC building models in total were built for examination, using the seismic load equivalent static approach. The analysis of every unique building model is completed with the ETAB 2020 software. Plan irregularities of various shapes are examined in relation to displacements, storey drifts, time periods, and base shear; the outcomes are then compared.

6.2 DISPLACEMENT: Storey displacement is termed as its displacement of considered floor with reference to base of building, usually base of a building being a ground. Maximum allowable displacement in any multi-storey structure is hs/500 where hs is structure's height, as stated in clause 7.11.1.2 of IS 1893 Part 1. Allowable deflection is 81.60/500 = 0.1632m=163.20mm

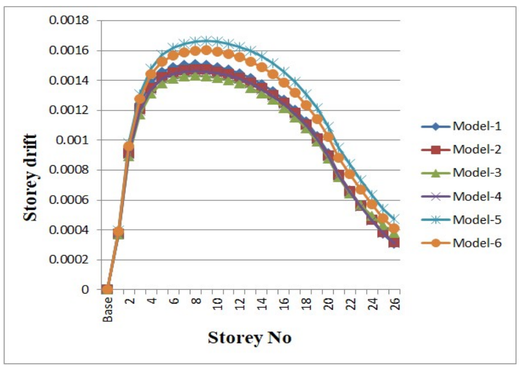


Graph-6.1: Displacement in mm of all models due to ESM along-X direction

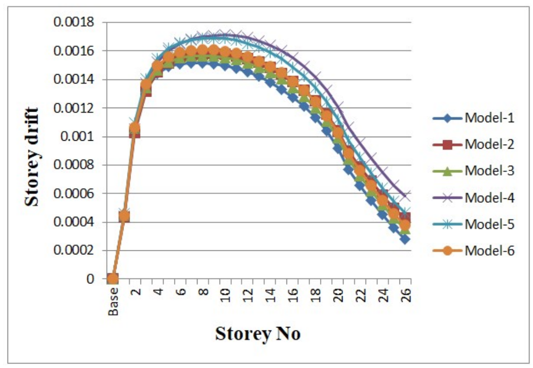


Graph-6.1: Displacement in mm of all models due to ESM along-Y direction

6.3 Storey Drift: Floor to floor movement is known as storey drift, & storey drift to height ratio is amount of storey drift expressed as a percentage of total storey height.

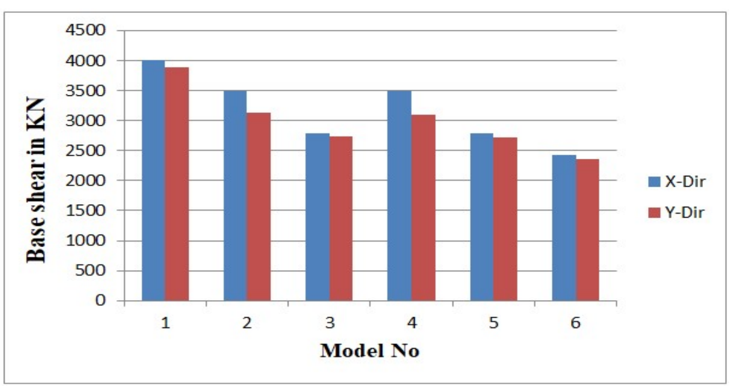


Graph-6.3: Storey drift of all models due to ESM along-X direction



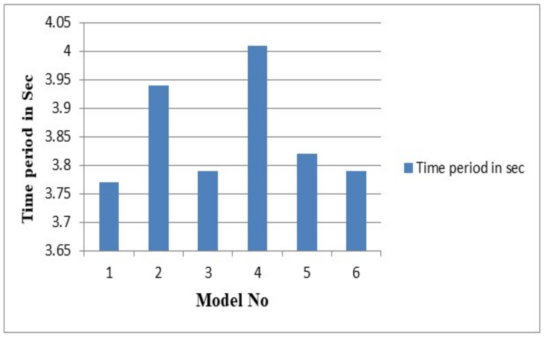
Graph-6.4: Storey drift of all models due to ESM along-Y direction

6.4 Base Shear: It's a calculation of how much pressure will build up at a building's foundation in the event of a major earthquake.



Graph-6.5: Base shear of all models due to ESM along-X and Y-direction

6.5 TIME PERIOD: It is defined as time required for completing one cycle of Vibration to pass in a given point.



Graph 6.6: Time period for all models

7. OBSERVATION AND CONCLUSION

7.1 Observations:

1. Displacement is greatest in the L-shaped irregular structure, increasing by roughly 11.74% compared to the X-shaped regular building.
2. Displacement in the Y-axis is larger for irregular buildings compared to conventional ones.
3. C-shaped irregular buildings show the greatest displacement, which is roughly 15.49% higher than that of normal Y-shaped buildings.
4. Compared to ordinary buildings, L-shaped ones have a much higher drift value.
5. Increases in floor area contribute more to base shear for typical buildings.
6. When compared to conventional construction, the time frame for irregular construction is much longer.
7. T-shaped and Plus-shaped structures take the same amount of time to construct.
8. Plus-shaped structures showed the least amount of base shear.

7.2 Conclusions:

1. The findings also demonstrated that severely irregular structures are more susceptible to earthquake damage, particularly in high seismic zones.
2. The base shear for regular construction is greater than that for irregular construction.
3. The base shear of a regular building is greater than that of an irregular building because dead load is greater for the former.
4. Displacement along the X-axis is less for irregular plan buildings, such as I, T, and C-shaped buildings.
5. Plan irregular construction causes higher Y-axis displacement than conventional construction.
6. The maximum movement in an L-shaped structure is 11.74 percent higher than in a conventional building.
7. Drift values for I-shape, T-shape, and C-shape buildings are lower than those for conventional X-directional buildings.

8. Since plan irregular buildings are less rigid in the Y-direction, their drift values are greater than those of regular buildings.

7.3 Scope for further study:

1. The results of this research provide insight on the functionality of Plan irregular structures.
2. Dynamic analysis of plan irregular buildings will benefit from this research.
3. Push over analysis and Time history analysis is useful tools for evaluating structures with an irregular floor layout.
4. Shear walls with steel bracing systems allow us to perform structural analysis on otherwise unorthodox constructions.
5. Increasing the building's story count is one way to implement an irregular construction design.

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