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Comparative Study on Seismic Performance of Regular and Irregular RC Multi-Storied Building

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***Abstract*— In modern structural engineering, lateral resilience of multistoried RC building is significantly affected by structural geometry. Structural irregularities in plan or elevation often led to non uniform distribution of mass, stiffness & strength which results in significant damage during earthquakes.**
This study presents comparative analysis of seismic performance of regular building (Rectangular shape building) and irregular building with different types of plan geometry (H, Plus, T, U and L shape building). The models consist of G + 12 storey consisting of same floor area of 720m2 analysed in accordance with IS 1893 (Part 1): 2016, IS 456:2000, and IS 13920:2016 and IS 875 (Part 1&2). Method used is response spectrum for zone III, IV & V with soil type II using etabs software. A comprehensive study is conducted to examine storey drift, storey displacement & base shear. Results indicate that corner re-entrant plan irregularities cause higher lateral displacement and drift compared to regular configuration. This demonstrates that plan irregularity significantly affects seismic stiffness and overall stability of RC structures.

***Index Term*— Multistoried building, regular, irregular building, seismic analysis, response spectrum analysis, re-entrant corner, storey drift, storey displacement, base shear.**

I. INTRODUCTION

A. General

While designing reinforced concrete multistoried building, seismic resistance is a critical requirement specially in medium to high seismic zone. Rapid urban growth and architectural constraint have led to accepting of irregular building configurations which often lead to uneven distribution of mass and stiffness. These plan irregularities introduce torsional effects and complex dynamic responses during earthquake excitation which increases the susceptibility of structures to damage. The influence of plan geometry on seismic performance becomes more significant as building height and seismic intensity increases.

Previous studies have enlightened the adverse effects of plan irregularity. Shaikh & Upase (2021) analyzed regular and irregular G+11 building using staad.pro for zones III & IV who reported that regular buildings attract higher base shear but experience lower drift and displacement compared to irregular configuration [1].

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Mohd Abdul & Bommisetty (2019) investigated RC building of varying heights using Etabs and observed that plan irregular structure causes higher displacement & drift due to torsional effect caused by asymmetry with seismic demand increasing significantly with building height and zone [2]. Jayakrishna et al. (2018) studied G+7 RC building using response Spectrum Analysis and concluded that irregular configurations experience higher shear forces and bending moments, particularly in higher seismic zones [3]. Ref .[4] and ref. [6] studied inclusion of vertical irregularities can also alter the response behavior. Mohaiminul Haque & Sourav Ray presents the plan irregularities in building but floor area kept on changing with influence the seismic behavior [5]. Ref. [7], ref. [8] & ref. [9] highlights irregularities significantly changes the behavior of multistoried building with changing soil factor and geometric configuration plays major role in stability of structure. Although these studies confirm the vulnerability of irregular buildings, limited research is available on higher-rise buildings with different plan irregularities under much higher seismic zones using a uniform modeling approach.

In the present study, a comparative seismic evaluation is carried out on G+12 building. Six type of plan configuration are modelled, comprising one regular rectangular building and five plan-irregular building namely H, Plus, T, U and L shape building. All models are configured with same floor area of 720 m², identical storey height, material properties and loading conditions to ensure uniformity in comparison. Analysis performed in zone III, IV & V using IS 1893 (Part 1): 2016 with RSA method. Seismic response parameters like storey displacement, drift & base shear are obtained to find influence of plan irregularity with higher seismic zone. Equation (1) is design horizontal seismic coefficient (AH) depends on various factors such as zone factor (Z), importance factor (I), response reduction factor (R) & avg response acceleration coefficient (S_a/g) given as [12],

$$A_H = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} \qquad (1)$$

Total design base shear depends on building weight (W) obtained as in (2),

$$V_B = A_H \, x \, W \qquad (2)$$

Storey drift represents difference in lateral displacement between two consecutive floor and as per codal provision this value should not exceed 0.004 times floor height [12]. These codal provisions gives the basic idea to compare structural performance of different types of model in present study.

B. Objective of Research

Objective of study is to model and analyse G+12 regular and plan irregular building with different shape which includes rectangular, L, T, U, H and plus shape plan using etabs software. The study also involves reviewing and applying the relevant codal provisions of IS 1893 (Part 1): 2016, IS 456:2000 and IS 875 (Part 1 and Part 2) that are applicable for analysis of RC building using response spectrum method is performed for zone III, IV & V considering soil type II. Behaviour of regular and irregular buildings will be studied and compared based on key response parameters.

II. METHODOLOGY

A. General

Process begins with setting up the structural model by creating a new project and defining grid lines, storey levels, and overall building geometry. After this material properties as concrete and steel grades and section sizes of beams, columns, slabs, and walls are assigned so the structure behaves realistically during analysis. Once the properties are defined, six different building models both regular and irregular are drawn on the software to study variations in structural behaviour.

All relevant loads, including dead, live, wall, floor finished, seismic and wind load are then applied to each model as per IS codes to simulate actual conditions. Load combinations are made following IS 456 & IS 1893 to ensure every model is checked under the most critical loading scenarios [12]. Support conditions as fixed are assigned at the foundation level to define how the structure interacts with the ground. After all this analysis is run & software compute internal forces, reactions, displacements and other structural responses. Results are carefully checked for drift, bending moments, displacement, base shear and axial forces to verify code compliance and structural safety.

Finally performance of regular & irregular building is compared based on mentioned parameter to understand how building configuration influences structural behaviour.

B. Design parameter

The present study considers six different RC building models with G+12 storey configuration. Each building model is developed with same floor area 720m² & typical floor height 4.0m resulting in total building height of 42.0m. All structures are modelled as reinforced concrete moment resisting frame systems. The slab thickness is taken as 125mm while external wall and internal wall thickness are assumed 230mm and 150mm respectively. Concrete grade M30 and reinforcing steel fe500 are used throughout analysis. The beam sections are modelled with dimension 300 mm × 450 mm and the column sections are modelled as 600 mm × 600 mm for all storeys to maintain uniformity across all model. The superimposed dead load on floor slab taken as 1.5KN/m². Load due to external walls considered to be 13.0 KN/m² while the internal wall load as 9.0KN/m² [10]. Live load of 3.0KN/m² is applied on typical floor and 1.5KN/m² is considered on roof slab [11]. Seismic analysis carried out for zone III, IV & V using Z values as 0.16, 0.24 & 0.36 respectively followed with I value as 1.2 and R value as 5.0 for soil type II [12]. These modelling parameters form basis for calculating and comparing performance of regular and plan irregular G+12 RC building using etabs software in consideration to earthquake forces.

C. Model Configurations

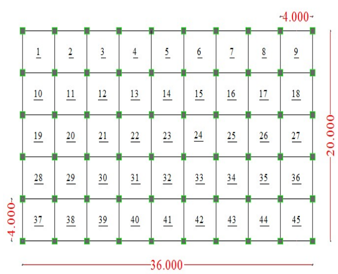

Figure 1. Regular shape model-1

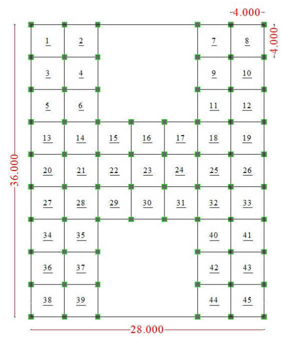

Figure 2. H shape model-2

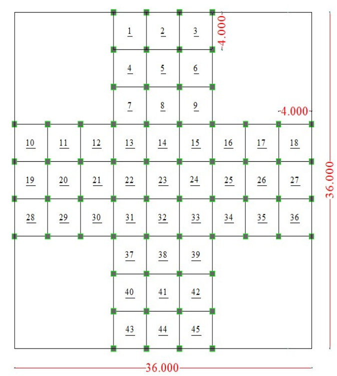

Figure 3. Plus shape model-3

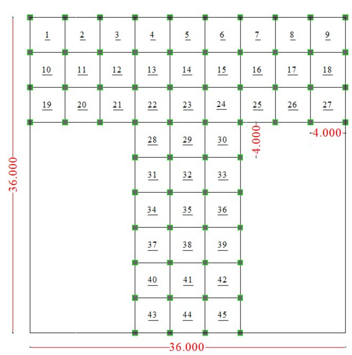

Figure 4. T shape model-4

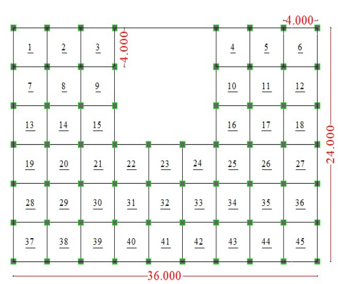

Figure 5. U shape model-5

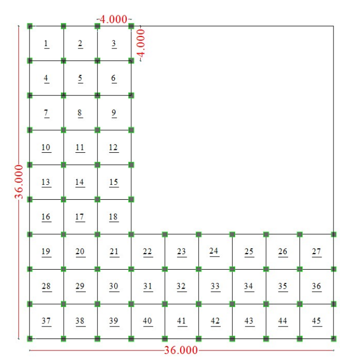

Figure 6. L shape model-6

The plan configurations as shown in figure 1-6 are adopted for the present study, representing one regular and five plan-irregular reinforced concrete building models. The regular model of a rectangular plan with uniformly spacing between columns arranged in an orthogonal grid as shown in figure 1 ensuring symmetrical distribution of mass and stiffness along both principal directions. Plan-irregular models include H, plus, T, U and L shape configurations which are developed by adding re-entrant corners and varying projections while maintaining the same overall floor area of 720 m². All models are analysed with identical bay spacing of 4.0m in both direction & column locations are kept consistent within each configuration to maintain structural continuity. Figure 2 H shape model made by two parallel wings connected by central web resulting in stiffness irregularity along the transverse direction. Figure 3 Plus shape model consists of intersecting orthogonal arms extending from central core creating symmetry in geometry but inducing stress concentration at junctions. Figure 4 T shape and figure 5

U shape model introduced significant re-entrant corners which lead to plan asymmetry and potential torsional effects under seismic loading. Figure 6 L shape model exhibits highest degree of plan irregularity due to its asymmetric geometry and discontinuity in load paths. With all geometric variations all models are assigned the same storey height, structural member properties & loading conditions. This type of modelling approach ensures that observed variation in seismic response are primarily due to differences in plan geometry instead of other influencing parameters.

IV. RESULTS

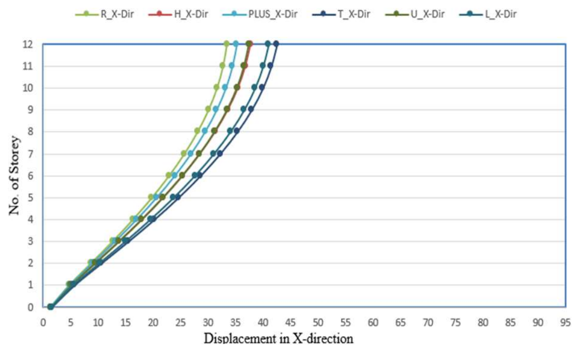

Figure 7. Maximum storey displacement for zone III in X direction

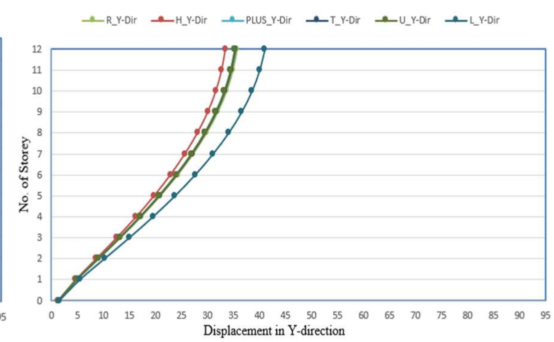

Figure 8. Maximum storey displacement for zone III in Y direction

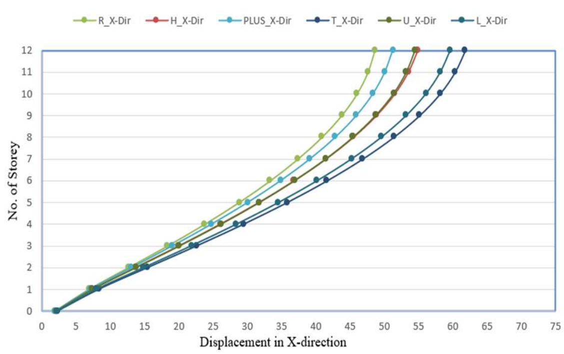

Figure 9. Maximum storey displacement for zone IV in X direction

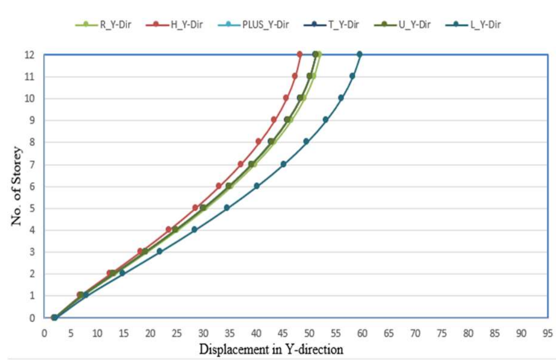

Figure 10. Maximum storey displacement for zone IV in Y direction

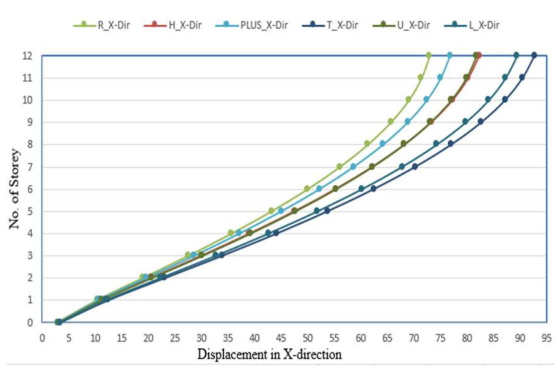

Figure 11. Maximum storey displacement for zone V in X direction

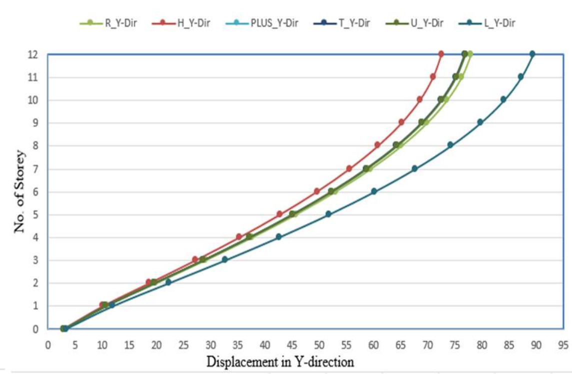

Figure 12. Maximum storey displacement for zone V in Y direction

The analysis of all building configurations was carried out by evaluating base shear, storey displacement & drift with zones III, IV & V. Base shear represents total horizontal seismic force transferred to foundation. In figure 19 when compared with rectangular model in all zones, H shape building consistently showed highest base shear recording about 7–8% more than rectangular frame. Remaining model are closest to rectangular model with only about 3–4% higher base shear. Storey displacement represents lateral movement of each floor under seismic loading. In both X & Y directions, storey displacement increased with seismic zone & rectangular model consistently recorded lowest roof movement. In X direction as shown in figure7, figure 9 & figure 11, T shape model was most critical showing highest top storey displacement of 42.504 mm, 61.818 mm and 92.743 mm across all zone. While other irregular models remained only slightly higher than rectangular frame. In Y direction as shown in figure 8, figure 10 & figure 12, L shape building emerged as most critical recording 40.989 mm, 59.622 mm and 89.433 mm across three zones whereas all remaining models showed values closely grouped near rectangular configuration. Overall T shape governed maximum displacement in X direction while L shape dominates in Y direction where other models displaying comparatively minor variations. Storey drift represents relative lateral displacement between two consecutive floor showed its maximum value at mid height level for all configurations. At floor level three it shows maximum value. In X direction as shown in figure 13, figure 15 & figure 17, T shape building consistently showed highest drift values across all zone making it most critical configuration while remaining irregular models stayed close to rectangular frame with only minor differences. In Y direction as shown in figure 14, figure 16 & figure 18, L shape structure recorded maximum drift in every seismic zone clearly emerging as critical model whereas other configurations produced drift values that were closely grouped and only slightly above regular model. Overall T shape governs drift demand in X direction & L shape governs in Y direction while other building shapes exhibit comparatively small variations.

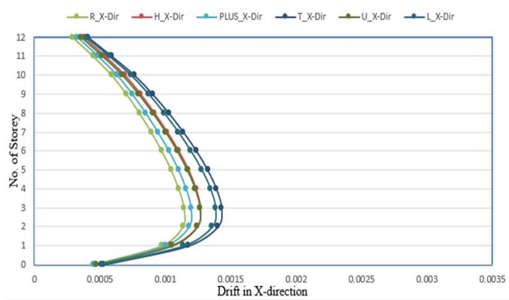

Figure 13. Maximum storey drift for zone III in X direction

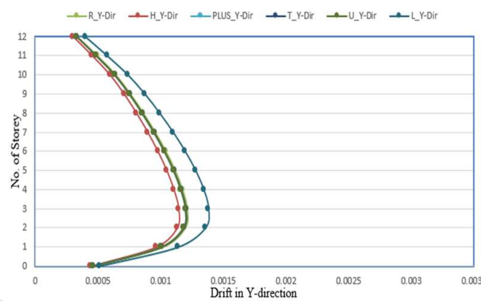

Figure 14. Maximum storey drift for zone III in Y direction

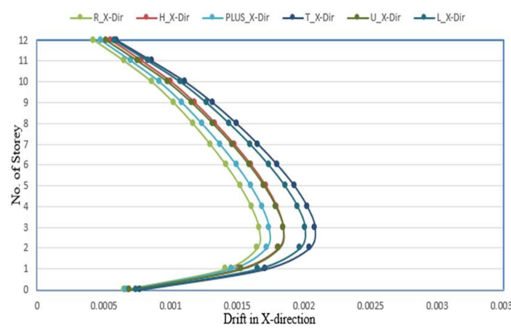

Figure 15. Maximum storey drift for zone IV in X direction

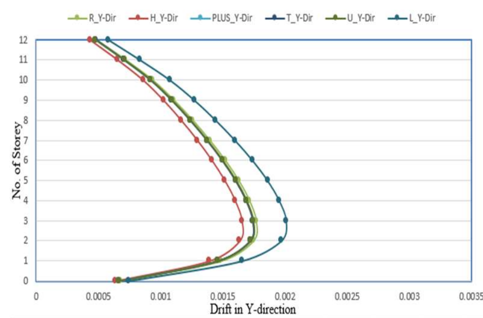

Figure 16. Maximum storey drift for zone IV in Y direction

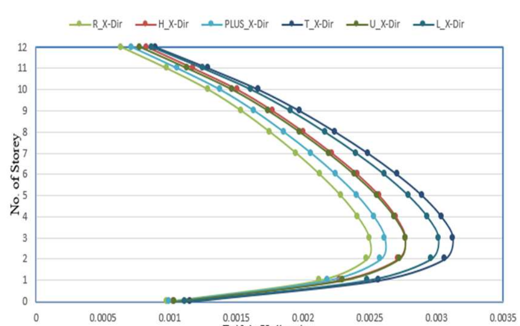

Figure 17. Maximum storey drift for zone V in X direction

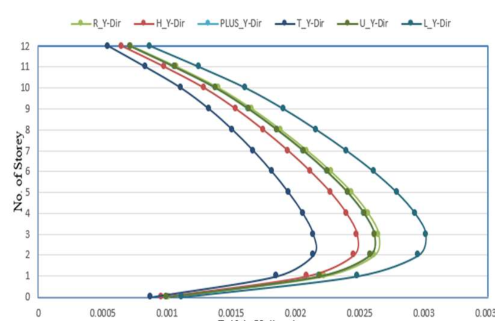

Figure 18. Maximum storey drift for zone V in Y direction

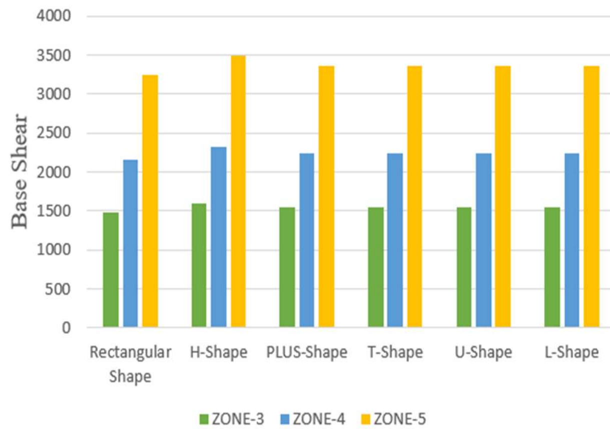

Figure 19. Maximum base shear

A. Discussion of Results

Behaviour of regular and irregular RC building was evaluated using response spectrum method [12] for zones III, IV & V. Comparison was carried out in terms of storey displacement, storey drift & base shear in both principal direction as shown in figure 7-18. Results show that storey displacement & storey drift increase with zone for all building configuration. Regular rectangular building exhibits lower displacement and drift while plan irregular buildings i.e. L, U, and T shape configuration show higher values due to re-entrant corners and torsional effects. Difference between regular and irregular buildings becomes more significant in Zone V indicating higher vulnerability of irregular buildings in severe seismic regions. Storey drift is generally observed to be maximum at intermediate storey levels which is characteristic of moment resisting frame building subjected to dynamic loading. Higher drift demand in irregular buildings indicates greater possibility of structural & non-structural damage during earthquake. Base shear response shows noticeable variation with building configuration and zone. In present study it is clearly observed that certain plan irregular building attract higher base shear compared to regular rectangular building but difference is very comparative hence base shear alone should not be considered as sole indicator of seismic safety and it must be evaluated along with deformation based parameters.

V. Conclusion

Analysis was carried out on G+12 building with one regular rectangular and five plan irregular configurations (L, T, U, H, and Plus shape) using etabs software. All models are assigned with identical floor area, storey height, material properties & loading condition to ensure consistent and reliable comparison. Response spectrum analysis was performed for zones III, IV & V considering medium soil condition. Model 1 shows the most uniform seismic response with comparatively lower storey displacement & storey drift indicating better seismic performance due to its regular configuration. Models 4 followed with 5 and 6 exhibit higher storey displacement & storey drift due to plan irregularity & torsional effects. Model 3 performs better among the irregular configurations showing relatively controlled displacement and drift. Models 4 and 6 show maximum storey displacement and storey drift making these configurations more susceptible to seismic hazards. Storey drift is generally observed to be maximum at lower storey levels three. For Model 6 storey displacement increases by approximately 46.45% in zone IV and 118.19% in zone V when compared to zone III showing strong influence of seismic zone intensity. Base shear values vary with building configuration and Model 2 shows maximum base shear among all models. Base shear in zone V observed to be significantly higher than zone III highlighting increased seismic demand in higher seismic zones. The study indicates that increase in severity of plan irregularity leads to increase seismic demand particularly in terms of storey displacement & storey drift. Seismic response parameter found to be vary in X and Y directions depending on plan dimension and stiffness distribution of each building configuration. Plan irregular buildings require special attention during analysis and design including stiffness and strict ductile detailing to achieve acceptable seismic performance. Present study is limited to moment resisting frame building and inclusion of elements such as shear walls or bracings may further influence seismic response.

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