Comparative Seismic Response of Symmetric and L-Shaped Asymmetric G+10 RCC Buildings in Seismic Zones III and IV Using Staad.Pro

*** B. VENKATA RAMANA MURTY[1], K.DILEEP CHOWDARY[2]**

[1]M.Tech Scholar (Structural Engineering), Department of Civil Engineering,

Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

[2]Assistant Professor, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College,

P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

Abstract

The plan configuration of reinforced concrete (RCC) buildings influences lateral stiffness distribution, seismic-force transfer and torsional response. This study compares a regular rectangular symmetric G+10 RCC frame with an L-shaped asymmetric G+10 frame under earthquake loading corresponding to Seismic Zones III and IV. Both models have a nominal plan envelope of 24 m × 18 m, the same storey arrangement, material grades and support assumptions. The comparison considers roof displacement, inter-storey drift, base shear, support reactions, column axial force, beam and column bending moments, and qualitative torsional behavior. In the principal result set, the maximum roof displacements in the X direction are 34.6 and 51.7 mm for the symmetric building in Zones III and IV, respectively, compared with 43.8 and 65.4 mm for the asymmetric building. Maximum storey drift increases from 3.36 to 4.32 mm in Zone III and from 5.04 to 6.51 mm in Zone IV when the plan configuration changes from symmetric to asymmetric. Beam and column moments are also higher in the asymmetric model, with the largest reported values of 296 kN·m and 508 kN·m in Zone IV. The results indicate that plan asymmetry is associated with greater deformation and local member-force concentration. For several response parameters, the Zone IV values are approximately 50% higher than the corresponding Zone III values. The numerical response quantities are representative estimates based on assumed building models and require replacement or confirmation using final STAAD.Pro analysis outputs. The findings are therefore interpreted as indicative comparative results rather than validated design outputs.

Keywords—Seismic analysis, plan irregularity, symmetric building, L-shaped building, torsional response, storey drift, STAAD.Pro, RCC frame.

1. INTRODUCTION

Earthquake ground motion induces inertia forces in buildings, resulting in lateral displacement, inter-storey drift, base shear and internal member forces. The magnitude and distribution of these effects depend on seismic hazard, building mass, stiffness, ductility, structural system and plan configuration. In multistorey RCC frames, the arrangement of beams and columns and the distribution of mass and stiffness influence the transfer of lateral forces from floor diaphragms to the foundation.

Regular and symmetric plans generally provide a more balanced distribution of stiffness and mass. In contrast, plan-irregular buildings may exhibit eccentricity between the centres of mass and stiffness. The resulting torsional response can increase displacement at exterior edges and concentrate demand near re-entrant corners. L-shaped buildings are a common example of plan irregularity.

This study compares a rectangular symmetric G+10 RCC frame with an L-shaped asymmetric G+10 RCC frame under Zone III and Zone IV earthquake loading using STAAD.Pro. The comparison examines displacement, drift, base shear, support reactions, column axial force, bending moments and torsional response. The analysis is intended to assess the influence of plan configuration under the adopted modelling assumptions.

2. OBJECTIVES AND SCOPE

The objectives are: (i) to develop models of symmetric and asymmetric G+10 RCC buildings; (ii) to compare their responses in Seismic Zones III and IV; (iii) to evaluate roof and storey-wise displacement, storey drift and base shear; (iv) to examine support reactions and member-force demands; and (v) to assess the implications of torsional response in irregular buildings.

The scope is limited to two plan configurations and two seismic zones. Soil–structure interaction, infill-wall stiffness, nonlinear pushover analysis, time-history analysis, detailed foundation design and detailed reinforcement and ductile-detailing design are outside the scope of the reported analysis.

3. BUILDING CONFIGURATION AND ANALYTICAL PARAMETERS

Both structures are modelled as G+10 RCC moment-resisting frames. The common nominal plan envelope is 24 m × 18 m, with a rectangular configuration for the symmetric model and an L-shaped configuration for the asymmetric model. The ground-storey height is 3.60 m, the typical storey height is 3.00 m and the approximate roof elevation is 33.60 m. The typical beam and column dimensions are 300 × 500 mm and 500 × 500 mm, respectively. The slab thickness is 125 mm and the wall thickness is 230 mm.

Table 1. Adopted building and seismic parameters

Parameter	Adopted value
Structural system	G+10 RCC moment-resisting frame
Plan envelope	24 m × 18 m
Plan configurations	Rectangular symmetric; L-shaped asymmetric
Ground / typical storey height	3.60 m / 3.00 m
Approximate roof elevation	33.60 m
Typical beam / column	300 × 500 mm / 500 × 500 mm
Slab / wall thickness	125 mm / 230 mm
Concrete / reinforcement	M30 / Fe500
Soil / base condition	Medium soil / fixed supports
Importance factor / response reduction factor	1.0 / 5.0
Zone factors	Zone III: 0.16; Zone IV: 0.24
Software	STAAD.Pro

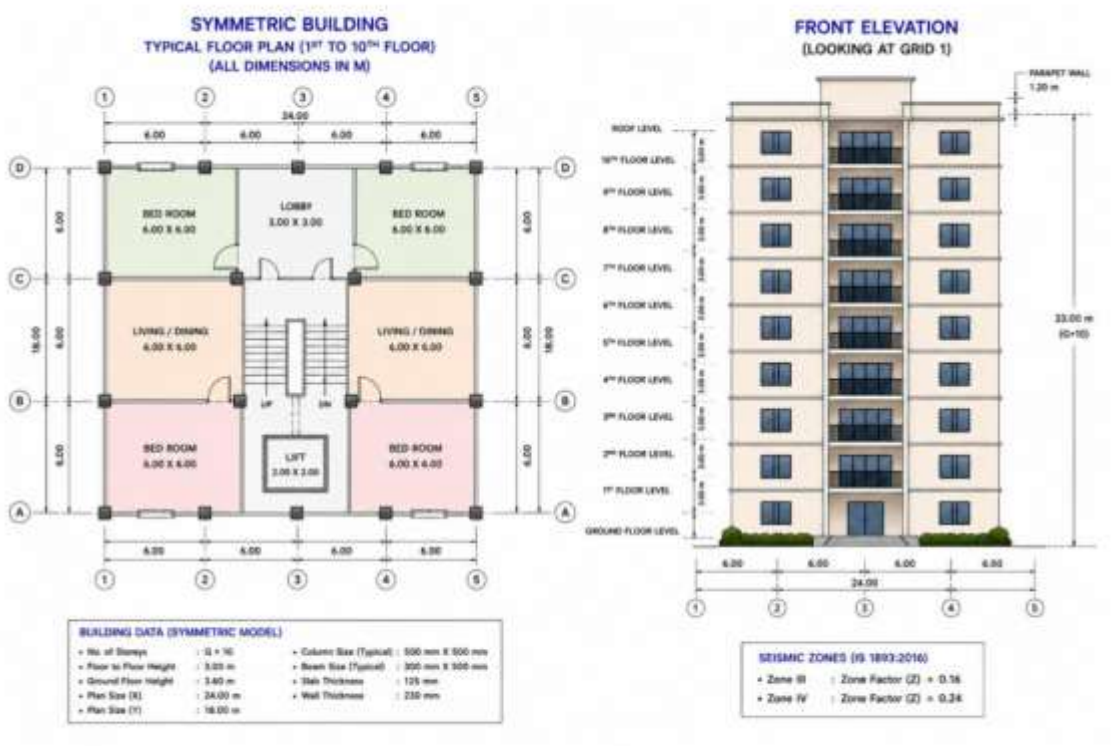


Fig. 1. Typical floor plan and front elevation of the symmetric rectangular building

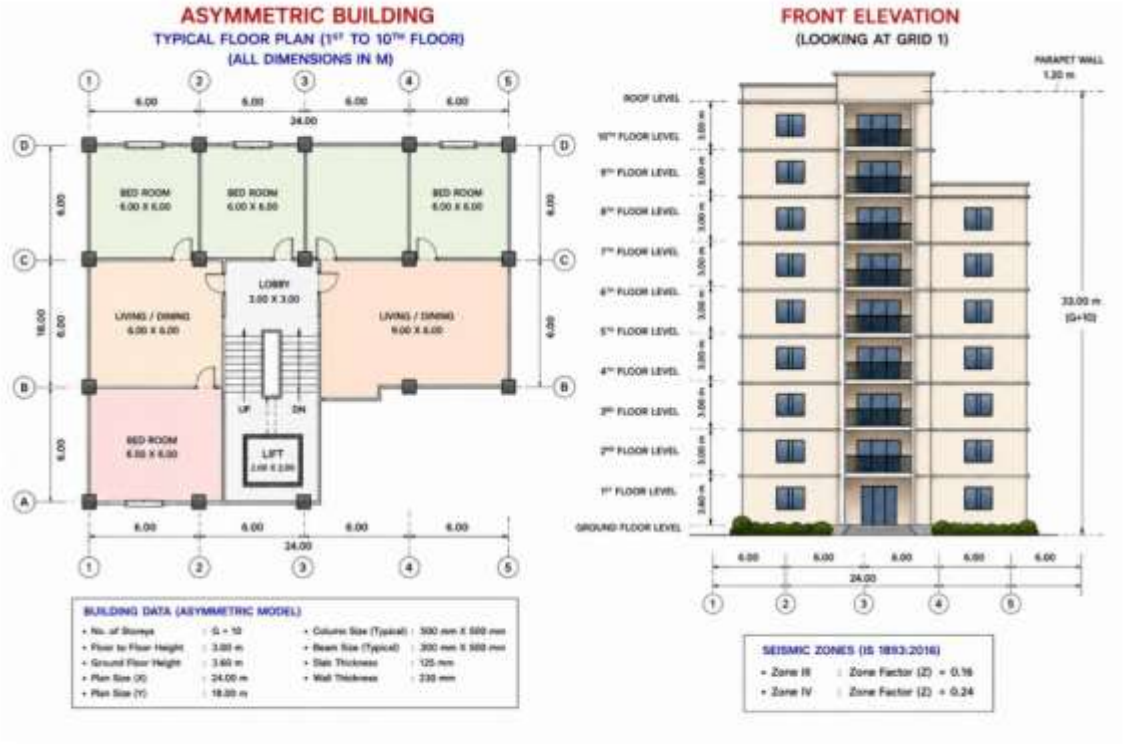


Fig. 2. Typical floor plan and front elevation of the asymmetric L-shaped building

The building drawings show the rectangular and L-shaped floor plans and their corresponding elevations. The L-shaped configuration is formed by omitting selected corner bays, resulting in re-entrant geometry and a less uniform plan distribution of stiffness.

4. SEISMIC LOADING AND ANALYSIS PROCEDURE

The adopted zone factors are 0.16 for Zone III and 0.24 for Zone IV. The importance factor is 1.0, the response reduction factor is 5.0, the soil category is medium and the damping ratio is 5%. The seismic coefficient is expressed as Ah = (Z/2)(I/R)(Sa/g), and the base shear is expressed as VB = AhW. Dead-load, live-load and earthquake actions are considered in the principal X and Z directions, with fixed supports at the column bases.

Table 2. Principal load combinations reported in the dissertation

Combination	Load combination
101	1.5 DL
102	1.5 DL + 1.5 LL
103–106	1.2 DL + 1.2 LL ± 1.2 EQX / EQZ
107–110	1.5 DL ± 1.5 EQX / EQZ
111–114	0.9 DL ± 1.5 EQX / EQZ

The four comparison cases are symmetric–Zone III, symmetric–Zone IV, asymmetric–Zone III and asymmetric–Zone IV. The analysis procedure considers displacement, drift, base shear, support reactions, member forces and torsional response from the STAAD.Pro models. The numerical values presented in Section 5 are representative estimates based on assumed building models; they require confirmation or replacement using the final STAAD.Pro analysis outputs. This qualification applies to all numerical comparisons in the following sections.

5. RESULTS AND DISCUSSION

5.1 Roof and storey-wise displacement

Table 3. Maximum roof displacement estimates for the four building–zone cases

Building configuration	Zone	X displacement (mm)	Z displacement (mm)	Critical location
Symmetric	III	34.6	31.8	Roof
Symmetric	IV	51.7	47.5	Roof
Asymmetric	III	43.8	39.6	Re-entrant / corner region
Asymmetric	IV	65.4	59.2	Re-entrant / corner region

The asymmetric frame has greater reported roof displacement in both principal directions. In the X direction, the increase relative to the symmetric frame is approximately 26.6% in Zone III and 26.5% in Zone IV. The increase from Zone III to Zone IV is approximately 49.4% for the symmetric frame and 49.3% for the asymmetric frame. These comparisons describe the representative values listed in Table 3 and should be verified against the final analytical output.

Table 4. Storey-wise displacement estimates in the X direction

Storey	Sym. ZIII (mm)	Sym. ZIV (mm)	Asym. ZIII (mm)	Asym. ZIV (mm)
Base	0	0	0	0
1st	3.2	4.8	4.1	6.2
2nd	6.5	9.7	8.4	12.5
3rd	10.1	15.1	12.9	19.4
4th	13.8	20.6	17.5	26.2

5th	17.3	25.9	22.0	33.0
6th	20.7	31.0	26.6	39.7
7th	24.1	36.1	31.0	46.3
8th	27.6	41.3	35.5	53.1
9th	31.0	46.4	39.8	59.5
Roof	34.6	51.7	43.8	65.4

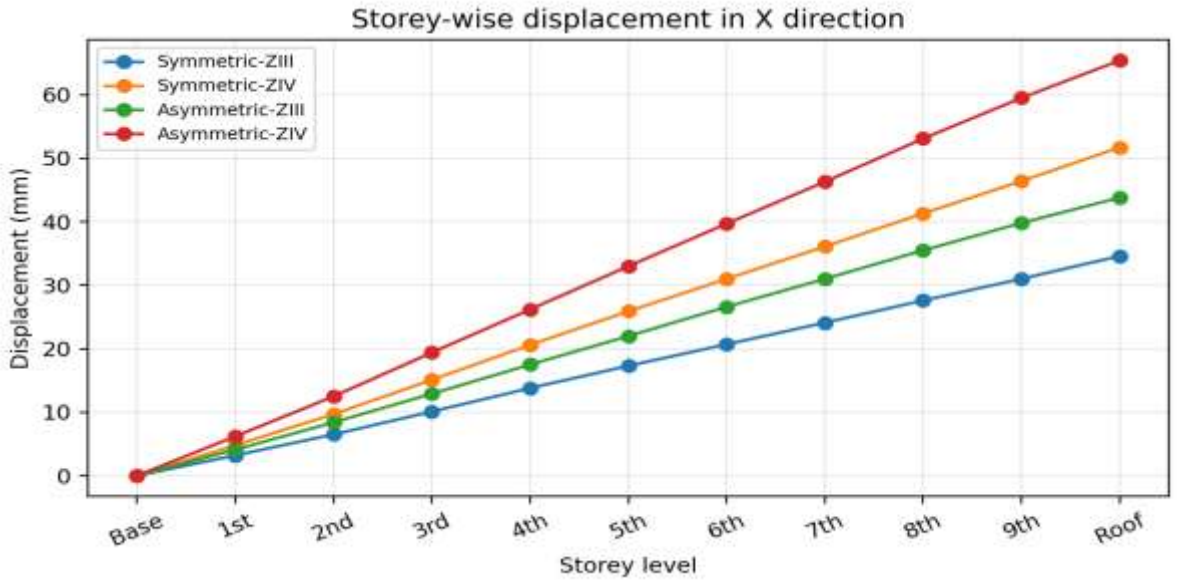


Fig. 3. Storey-wise displacement profiles in the X direction for the four building–zone cases

5.2 Storey drift and base shear

Table 5. Maximum storey drift and drift ratio estimates

Configuration	Zone	Maximum drift (mm)	Drift ratio	Critical storeys
Symmetric	III	3.36	0.00112	5th–6th
Symmetric	IV	5.04	0.00168	5th–6th
Asymmetric	III	4.32	0.00144	4th–6th
Asymmetric	IV	6.51	0.00217	4th–6th

The reported drift values are below the criterion of 0.004 times the storey height cited in the study. For a 3.0 m storey, this corresponds to 12 mm. The asymmetric model nevertheless has higher reported drift: approximately 28.6% greater in Zone III and 29.2% greater in Zone IV than the symmetric model. Compliance should be confirmed using validated storey-wise displacement results and the applicable code provisions.

Table 6. Base shear estimates in the principal directions

Configuration	Zone	X direction (kN)	Z direction (kN)
Symmetric	III	2110	2050
Symmetric	IV	3165	3075
Asymmetric	III	1880	1825
Asymmetric	IV	2820	2738

The reported Zone IV base shear is 1.5 times the Zone III value for both configurations, consistent with the increase in zone factor from 0.16 to 0.24. The asymmetric model has a lower reported total base shear, attributed to its reduced effective floor area and seismic weight. This lower total base shear does not indicate lower local seismic demand: the asymmetric model also exhibits higher displacement, drift and member-force concentration in the representative results.

5.3 Support reactions and member forces

Table 7. Maximum support-reaction and column axial-force estimates

Configuration	Zone	Vertical reaction (kN)	Horizontal reaction (kN)	Maximum column axial force (kN)
Symmetric	III	4260	410	3620
Symmetric	IV	4385	615	3815
Asymmetric	III	3890	462	3950
Asymmetric	IV	4025	690	4210

The maximum vertical support reaction is higher in the symmetric cases, whereas the maximum horizontal reaction is higher in the asymmetric cases. The maximum column axial force is also greater in the asymmetric building, reaching 4210 kN in Zone IV. The critical location is identified near the re-entrant or inner-corner region.

Table 8. Maximum beam and column bending-moment estimates

Configuration	Zone	Beam moment (kN·m)	Column moment (kN·m)	Critical location
Symmetric	III	185	276	Middle-storey beam / lower-storey column
Symmetric	IV	238	415	Middle-storey beam / lower-storey column
Asymmetric	III	224	338	Re-entrant beam / corner column
Asymmetric	IV	296	508	Re-entrant beam / corner column

Compared with the symmetric frame, the asymmetric frame has 21.1% and 24.4% higher maximum beam moments in Zones III and IV, respectively. The corresponding increases in column moment are 22.5% and 22.4%. These representative comparisons indicate greater local member demand near irregular regions, even though the total base shear is lower.

5.4 Torsional response and overall comparison

Table 9. Qualitative comparison of torsional response

Configuration	Zone	Reported observation
Symmetric	III	Low; nearly uniform displacement
Symmetric	IV	Low to moderate
Asymmetric	III	Moderate; corner displacement observed
Asymmetric	IV	High; significant response at re-entrant corner

The L-shaped plan may undergo rotation in addition to lateral translation. The reported observations indicate greater displacement at outer corners and re-entrant regions, with the most pronounced qualitative torsional response in the asymmetric Zone IV case.

Table 10. Overall comparison of representative response values

Parameter	Sym. ZIII	Sym. ZIV	Asym. ZIII	Asym. ZIV
Maximum displacement (mm)	34.6	51.7	43.8	65.4
Maximum storey drift (mm)	3.36	5.04	4.32	6.51
Base shear X (kN)	2110	3165	1880	2820
Maximum support reaction (kN)	4260	4385	3890	4025
Maximum column axial force (kN)	3620	3815	3950	4210
Maximum beam moment (kN·m)	185	238	224	296
Maximum column moment (kN·m)	276	415	338	508
Torsional response	Low	Low–moderate	Moderate	High

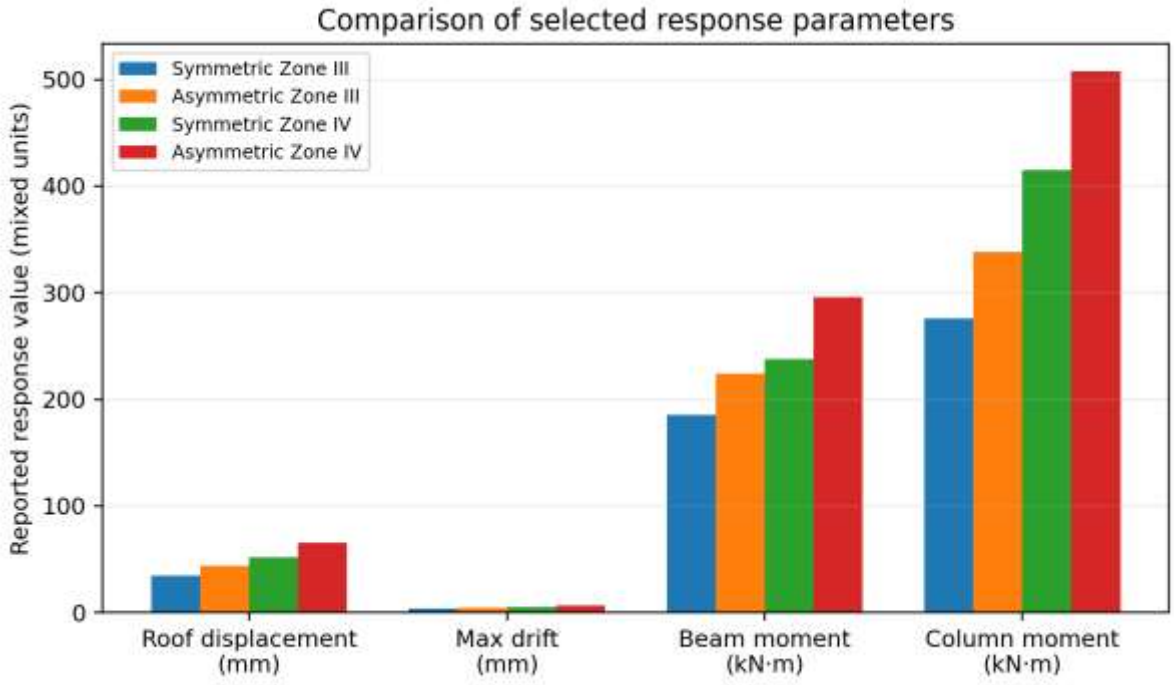


Fig. 4. Comparison of selected response parameters. The vertical axis contains mixed engineering units; comparisons should be made only within each response parameter.

6. KEY FINDINGS

1) The representative results show higher roof displacement and storey drift for the asymmetric L-shaped model than for the symmetric rectangular model in both seismic zones.

2) The asymmetric model has higher reported beam moments, column moments and maximum column axial force, with critical demand located near re-entrant and corner regions.

3) The reported Zone IV base shear is approximately 50% higher than the Zone III value for both configurations, consistent with the adopted zone-factor ratio.

4) The asymmetric Zone IV case is the most critical combination for the reported displacement, drift, member moments and qualitative torsional response.

5) Base shear alone is insufficient to assess the seismic performance of an irregular building; displacement, drift, torsion and local member demands should also be examined.

6) The reported maximum storey drift values are below the limit cited in the study, but the asymmetric model remains comparatively more critical. Final compliance requires verification using validated analysis results.

7. CONCLUSIONS

The comparative results indicate that plan configuration is an important factor governing the seismic response of G+10 RCC frames. Under the adopted assumptions and representative response values, the symmetric rectangular building exhibits a more uniform response, whereas the L-shaped asymmetric building shows higher displacement, drift, member moments and torsional demand. The differences are most pronounced in Zone IV.

The lower reported base shear of the asymmetric building should not be interpreted as evidence of superior seismic performance because its local force demands and deformation measures are higher. Where an irregular plan is unavoidable, design attention should be directed to torsion, re-entrant corners, corner columns, beam–column joints, stiffness distribution and ductile detailing. The comparative results support the preference for regular plans where architectural and functional requirements permit.

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