International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 11 | Nov 2026 www.irjet.net p-ISSN: 2395-0072

COMPARATIVE STUDY ON SEISMIC PERFORMANCE OF RCC BUILDINGS WITH REGULAR AND IRREGULAR CONFIGURATIONS USING STAAD.PRO AND RCDC

KONDAPURAM MANOJ SAI[1], Dr. I. V. RAMANA REDDY[2]

[1]PG Student, Department of Civil Engineering, SV University College of Engineering, Tirupati, Andhra Pradesh, India

[2]Professor, Department of Civil Engineering, SV University College of Engineering, Tirupati, Andhra Pradesh, India

---

ABSTRACT - *Earthquakes load buildings sideways, and how well a reinforced cement concrete (RCC) building copes with that load depends a great deal on its shape. Irregularities in plan or elevation disturb the flow of seismic forces and make a building more vulnerable. This paper compares three G+7 RCC buildings, one regular, one horizontally (plan) irregular and one vertically irregular, under earthquake loading. Each building was modelled in STAAD.Pro 2025 and analysed by the response spectrum method of IS 1893 (Part 1):2016 in both horizontal directions for seismic Zones II, III, IV and V, giving twelve models in all. The buildings were then designed in RCDC 2023 as per IS 456:2000 and IS 13920:2016. The three configurations were compared for natural period, modal mass participation, base shear, storey displacement and storey drift, and also for member sizes, quantities of concrete and steel, and the cost of the structural frame. All twelve models were analysed without errors, captured more than 90 percent of the seismic mass in both directions and stayed within the storey drift limit of 0.004. The highest drift ratio, 0.00303 (76 percent of the limit), occurred in the vertically irregular building in Zone IV. This building also attracted the largest base shear in every zone, and its drift was up to 14 percent higher than that of the regular building in the X direction and 19 to 28 percent higher in the Z direction. The horizontally irregular building drifted less (26 to 42 percent lower in X and 45 to 50 percent lower in Z), but it needed 150 to 250 modes to reach 90 percent mass participation, a clear sign of strong torsional coupling. In Zone V, the column sizes were controlled by the beam–column joint checks of IS 13920:2016 rather than by drift. Taken together, the regular building gave the best balance of seismic behaviour and economy, and it was also the cheapest at Rs. 6,420 per m^2 of floor area, against Rs. 6,970 for the vertically irregular and Rs. 9,034 for the horizontally irregular building.*

Keywords: RCC building, seismic analysis, regular and irregular buildings, response spectrum method, ductile design, STAAD.Pro, RCDC, IS 1893 (Part 1):2016.

1. INTRODUCTION

Earthquakes rank among the most destructive natural hazards. When the geometry, mass or stiffness of a building is irregular, seismic forces are shared unevenly, torsion develops and stresses concentrate at particular locations; such irregularities have been a major cause of damage in past earthquakes. IS 1893 (Part 1):2016 groups them into plan (horizontal) and vertical irregularities and calls for dynamic analysis of irregular buildings. Irregular buildings are nevertheless common in practice, driven by the shape of the plot, architectural intent and functional needs. Designers therefore need a clear picture of how each type of irregularity changes displacement, drift and base shear, and how much it adds to the cost of the structure. This paper addresses that need for a set of G+7 RCC buildings.

2. LITERATURE REVIEW

2.1 Studies on the seismic behaviour of RCC buildings

Yelmeli and Verma (2024) stressed the need for accurate seismic analysis of high-rise RCC buildings. Sharma et al. (2025) developed fragility curves that relate the probability of damage to the intensity of ground motion, while Shendkar et al. (2025) proposed methods for evaluating and retrofitting existing RCC structures. Together, these studies show why seismic analysis and evaluation matter, but none of them links the response of a building to its configuration.

2.2 Studies on irregular buildings and other structural systems

Soni and Mistry (2006) reviewed the seismic response of vertically irregular building frames, and Rathore et al. (2022) and Munni and Chandra Mohan Rao (2022) analysed plan-irregular buildings, including buildings with re-entrant corners

and buildings resting on different soils. For buildings on sloping ground, Parmar et al. (2025) found that unequal column heights increase torsion and that bracing and shear walls improve performance considerably. Patil and Patil (2025) reported that composite buildings behave better than RCC buildings when the plan is irregular, and Gawali et al. (2026) and Zhang and Zhang (2024) reached a similar conclusion for high-rise buildings. These studies confirm that irregularity has a strong influence on seismic response, but each of them covers only a small number of configurations.

2.3 Research gap and objectives

The review points to four gaps: (i) horizontal and vertical irregularity are rarely studied together against a regular reference building in the same investigation; (ii) few studies compare regular and irregular RCC buildings across all the seismic zones; (iii) ductile design of the members is usually left out, so the effect of irregularity on member sizes, material quantities and cost remains unclear; and (iv) results are seldom checked against code requirements for mass participation, base shear and drift.

The objectives of the study are: (i) to model and analyse G+7 RCC buildings with regular, horizontally irregular and vertically irregular configurations by the response spectrum method of IS 1893 (Part 1):2016, and to verify each model for modal mass participation, base shear scaling and storey drift; (ii) to evaluate and compare the natural time period, modal mass participation, base shear, storey displacement and storey drift of the three configurations; (iii) to examine how these responses change from seismic Zone II to Zone V; (iv) to carry out the ductile design of the members in RCDC as per IS 456:2000 and IS 13920:2016 and to compare the member sizes, quantities of concrete and steel, and the cost of the structural frame; and (v) to identify the configuration that offers the best overall seismic performance and economy.

3. METHODOLOGY AND MODELLING

3.1 Description of the buildings

All three buildings are G+7, with a storey height of 3.3 m and the foundation level 1.5 m below the plinth

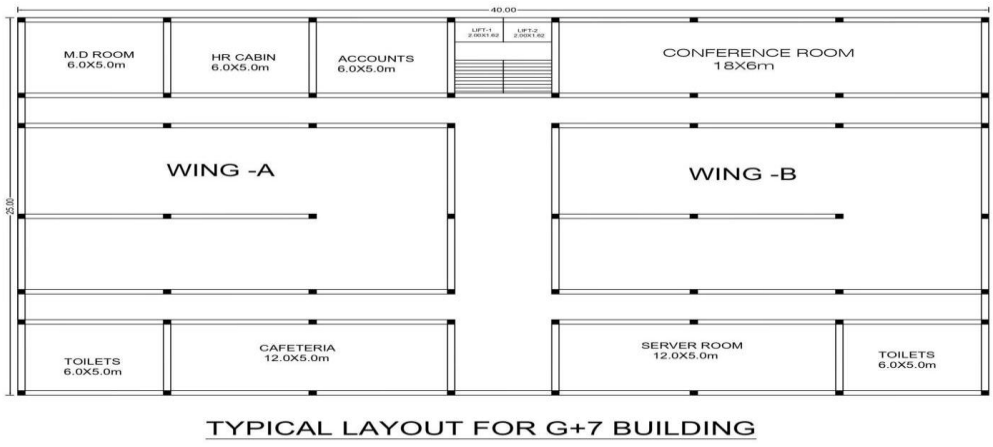

Figure 1. Typical plan of the regular G+7 building

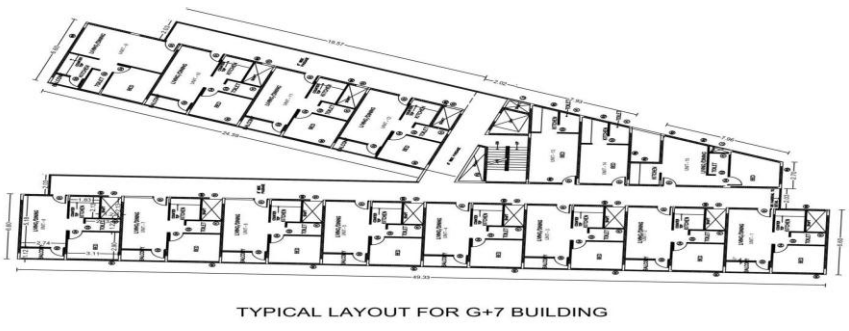

Figure 2. Typical plan of the horizontally irregular building

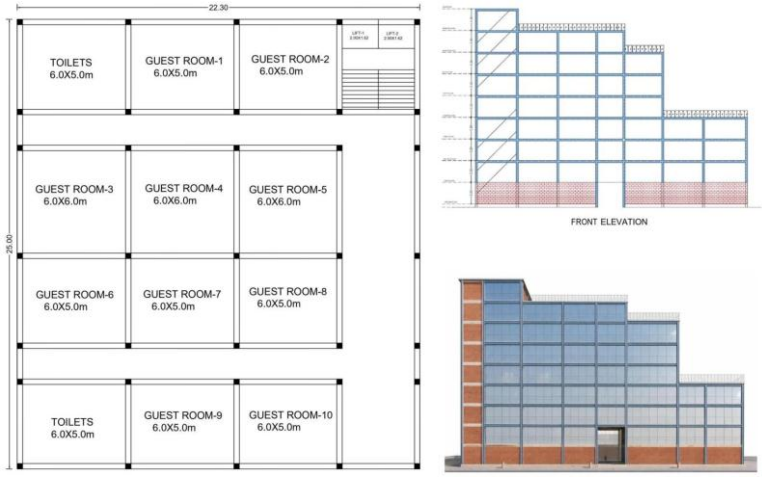

Figure 3. Vertically irregular building: (a) typical plan of the upper levels, (b) front elevation

3.2 Structural system and STAAD.Pro modelling

The three buildings were modelled in STAAD.Pro 2025 as three-dimensional RCC special moment resisting frames, with the beams and columns as frame members (Figure 4). The seismic parameters adopted from IS 1893 (Part 1):2016 are listed in Table 1.

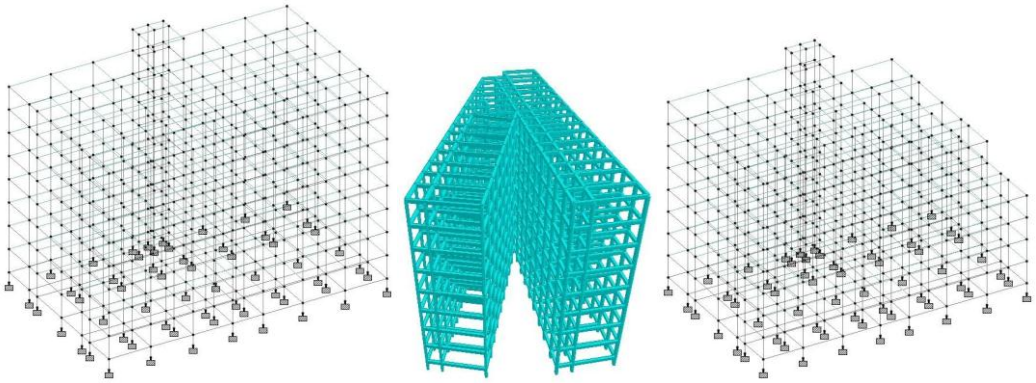

Figure 4. STAAD.Pro models: (a) regular, (b) horizontally irregular, (c) vertically irregular

Table 1. Seismic parameters

Parameter	Value
Zone factor Z	II (0.10), III (0.16), IV (0.24), V (0.36)
Importance factor I	1.2
Response reduction factor R	5.0 (special moment resisting frame)
Soil type / damping	Medium soil (Type II) / 5%
Design coefficient Ah	0.030, 0.048, 0.072, 0.108 (Zones II to V; Sa/g = 2.5)
Method / modal combination	Response spectrum, X and Z directions / CQC
Number of modes	40 (regular and vertically irregular); 150 (horizontally irregular; 250 in Zone II)

4. RESULTS AND DISCUSSION

4.1 Member sizes

Table 2. Final member sizes adopted in the STAAD.Pro models (mm)

Member	Zone II	Zone III	Zone IV	Zone V
Column, −1.5 to 3.3 m	500 × 750	600 × 750	500 × 750	750 × 750
Column, 3.3 to 9.9 m	450 × 700	550 × 700	450 × 700	750 × 750
Column, 9.9 to 16.5 m	450 × 650	550 × 650	450 × 650	650 × 700
Column, 16.5 to 26.4 m	400 × 550	500 × 550	400 × 550	550 × 650
Floor beams (b × D)	230 × 450	300 × 450	300 × 500	300 × 600
Roof beams (b × D)	230 × 400	230 × 450	300 × 450	300 × 500
Plinth beams (b × D)	300 × 600	300 × 600	300 × 700	350 × 750

4.2 Time period and modal mass participation

Table 3. Natural time periods and cumulative modal mass participation

Building	Zone	T1 (s)	Modes	Mass X (%)	Mass Z (%)	> 90 %
Regular	II	1.687	40	93.14	91.53	OK
	III	1.460	40	93.43	91.84	OK
	IV	1.411	40	93.17	91.76	OK
	V	1.040	40	92.08	91.80	OK
Horizontally irregular	II	1.351	250	93.66	92.36	OK
	III	1.183	150	92.13	91.22	OK
	IV	1.169	150	92.18	90.56	OK
	V	0.863	150	91.64	91.16	OK
Vertically irregular	II	1.569	40	93.44	90.50	OK
	III	1.355	40	93.75	91.88	OK
	IV	1.306	40	93.48	91.21	OK
	V	0.932	40	91.13	90.74	OK

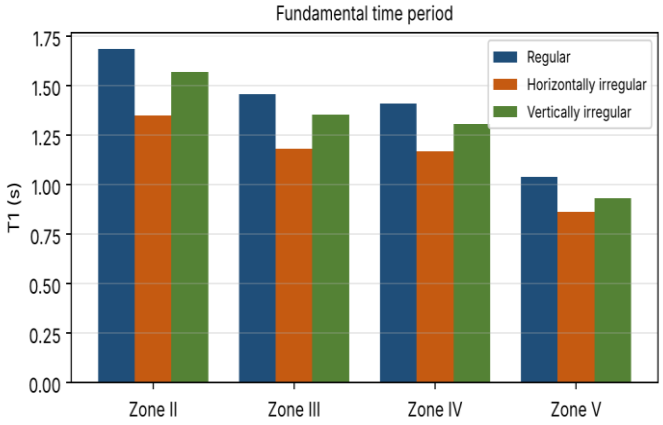

Figure 5. Fundamental time period of the three buildings in Zones II to V

4.3 Seismic weight and base shear

Table 4. Seismic weight and scaled design base shear

Building	Zone	Ah	W (kN)	Scale factor X / Z	Design Vb (kN)
Regular	II	0.030	97,514	3.83 / 3.21	2,925
	III	0.048	103,040	3.33 / 2.92	4,946
	IV	0.072	102,347	3.18 / 2.73	7,369
	V	0.108	113,131	2.43 / 2.25	12,218
Horizontally irregular	II	0.030	100,285	3.16 / 2.45	3,009
	III	0.048	106,997	2.84 / 2.25	5,136
	IV	0.072	105,272	2.79 / 2.03	7,580
	V	0.108	119,245	2.23 / 1.67	12,878
Vertically irregular	II	0.030	106,625	4.17 / 4.23	3,199
	III	0.048	111,737	3.59 / 3.79	5,363
	IV	0.072	111,011	3.42 / 3.54	7,993
	V	0.108	124,809	2.51 / 2.55	13,479

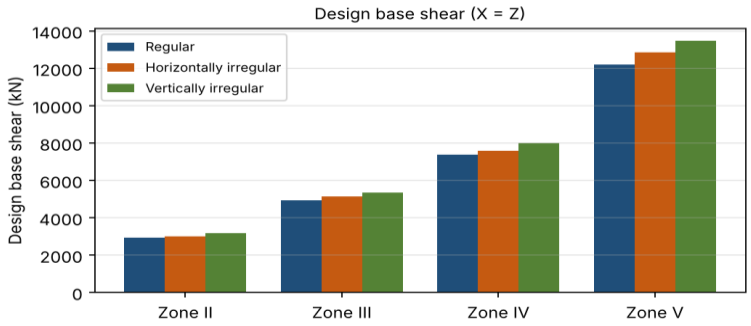

Figure 6. Scaled design base shear of the three buildings in Zones II to V

4.4 Storey displacement

Table 5. Maximum storey displacement in the X direction under 1.0 EQX (cm)

Building	Zone II	Zone III	Zone IV	Zone V
Regular	3.33	4.04	5.64	4.86
Horizontally irregular	2.34	2.93	4.30	3.78
Vertically irregular	3.48	4.18	5.81	4.70

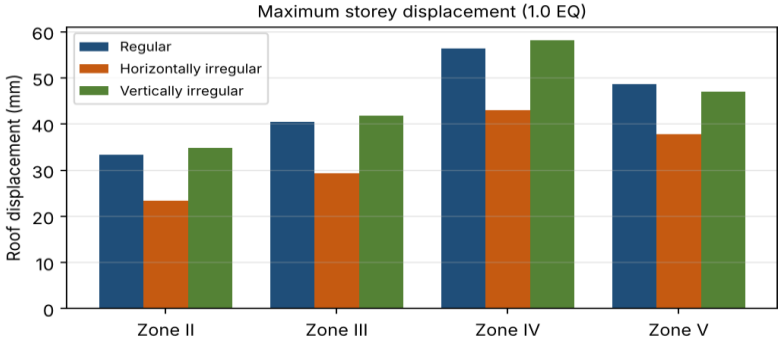

Figure 7. Maximum storey displacement of the three buildings in Zones II to V

The maximum storey displacement ranges from 2.34 cm to 5.81 cm (Table 5). In Zones II to IV the vertically irregular building moves the most and the horizontally irregular building the least. In Zone V the regular building shows the largest displacement (4.86 cm), slightly more than the vertically irregular building (4.70 cm). In all three buildings the displacement peaks in Zone IV and drops in Zone V, where the members are much larger.

4.5 Storey drift

Table 6. Maximum storey drift ratio and status (limit 0.004)

Building	Zone	Max drift X	Max drift Z	Limit used	Status
Regular	II	0.00196	0.00117	49 %	PASS
	III	0.00207	0.00155	52 %	PASS
	IV	0.00289	0.00200	72 %	PASS
	V	0.00239	0.00199	60 %	PASS
Horizontally irregular	II	0.00114	0.00064	28 %	PASS
	III	0.00142	0.00086	35 %	PASS
	IV	0.00204	0.00106	51 %	PASS
	V	0.00176	0.00100	44 %	PASS
Vertically irregular	II	0.00223	0.00146	56 %	PASS
	III	0.00220	0.00199	55 %	PASS
	IV	0.00303	0.00254	76 %	PASS
	V	0.00234	0.00237	59 %	PASS

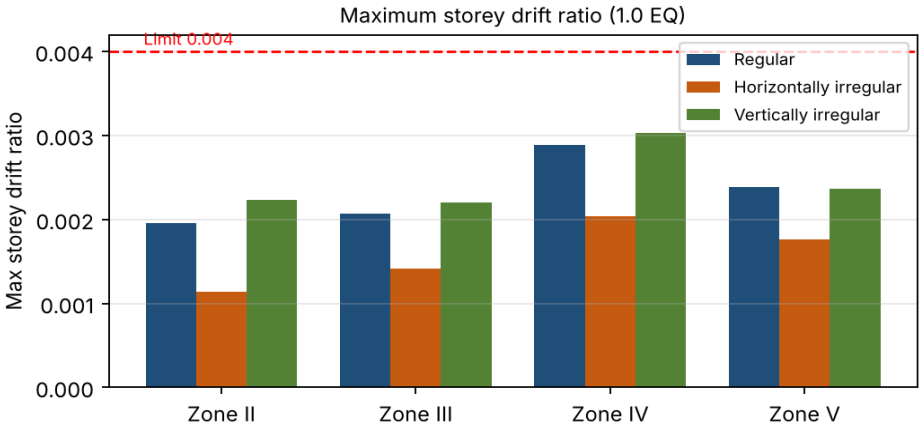

Figure 8. Maximum storey drift ratio of the twelve models and the limit of 0.004

5. CONCLUSIONS

The seismic performance of G+7 RCC buildings with regular, horizontally irregular and vertically irregular configurations was studied for seismic Zones II to V. The main conclusions, which apply to the twelve models analysed, are listed below in the order of the objectives.

1. All twelve models were analysed without errors, captured more than 90 percent of the modal mass in both directions, had their dynamic base shear scaled to the design base shear, and satisfied the drift limit of 0.004 in every storey, meeting the checks required by IS 1893 (Part 1):2016. [Objective (i)]
2. The fundamental period falls from Zone II to Zone V as the members become larger: from 1.687 s to 1.040 s in the regular building, 1.351 s to 0.863 s in the horizontally irregular building and 1.569 s to 0.932 s in the vertically irregular building. The regular and vertically irregular buildings reach 90 percent mass participation within 40 modes, whereas the horizontally irregular building needs 150 modes (250 in Zone II), showing a strongly coupled translational–torsional response. [Objective (ii)]

3. The dynamic base shear had to be scaled up by factors of 1.67 to 4.23. The vertically irregular building, being the heaviest, has the largest design base shear in every zone, from 3,199 kN in Zone II to 13,479 kN in Zone V. [Objective (ii)]
4. The maximum storey displacement varies from 2.34 cm to 5.81 cm. It is largest in the vertically irregular building in Zones II to IV and smallest in the horizontally irregular building in every zone. [Objective (ii)]
5. The largest drift ratio is 0.00303 (76 percent of the limit), in the vertically irregular building in Zone IV. Compared with the regular building, vertical irregularity increases the drift by up to 14 percent in the X direction and by 19 to 28 percent in the Z direction, while horizontal irregularity reduces it by 26 to 42 percent in X and 45 to 50 percent in Z. [Objective (ii)]
6. Moving from Zone II to Zone V increases the design base shear by about 4.2 to 4.3 times. The drift of the regular building rises by 47 percent from Zone II to Zone IV but falls in Zone V, because the Zone V column sizes are governed by the beam–column joint checks of IS 13920:2016, made more demanding by the Fe550 beam bars, and not by drift. [Objective (iii)]
7. From Zone II to Zone V the steel quantity roughly doubles and the frame cost per square metre rises by 41 to 50 percent. In Zone V the frame costs Rs. 6,420 per m^2 for the regular building, Rs. 6,970 per m^2 (9 percent more) for the vertically irregular building and Rs. 9,034 per m^2 (41 percent more) for the horizontally irregular building. [Objective (iv)]
8. Taking seismic response, code compliance and cost together, the regular building performs best. Where an irregular layout cannot be avoided, a vertical setback costs less than a plan irregularity but raises base shear and drift, and both types of irregularity call for careful dynamic analysis. [Objective (v)]

REFERENCES

[1] IS 1893 (Part 1):2016, Criteria for Earthquake Resistant Design of Structures – General Provisions and Buildings, Bureau of Indian Standards, New Delhi.

[2] IS 875 (Part 1):1987, Code of Practice for Design Loads (Dead Loads), Bureau of Indian Standards, New Delhi.

[3] IS 875 (Part 2):1987, Code of Practice for Design Loads (Imposed Loads), Bureau of Indian Standards, New Delhi.

[4] IS 875 (Part 3):2015, Code of Practice for Design Loads (Wind Loads), Bureau of Indian Standards, New Delhi.

[5] IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi.

[6] IS 13920:2016, Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice, Bureau of Indian Standards, New Delhi.

[7] Chopra, A. K., Dynamics of Structures: Theory and Applications to Earthquake Engineering, Pearson.

[8] Paulay, T., and Priestley, M. J. N., Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons.

[9] Agarwal, P., and Shrikhande, M., Earthquake Resistant Design of Structures, PHI Learning Pvt. Ltd.

[10] Duggal, S. K., Earthquake-Resistant Design of Structures, Oxford University Press, New Delhi.

[11] Soni, D. P., and Mistry, B. B. (2006). "Qualitative Review of Seismic Response of Vertically Irregular Building Frames." ISET Journal of Earthquake Technology, 43(4), 121–132.

[12] Rathore, H. S., Mathur, A., and Hussain, S. (2022). "Seismic Analysis of Irregular Buildings with Re-Entrant Corners and Autoclaved Aerated Concrete Blocks." Materials Today: Proceedings, 62(Part 3), 1643–1650.

[13] Munni, V., and Chandra Mohan Rao, B. D. V. (2022). "A Comparative Study on Seismic Analysis of Regular and Plan Irregular Buildings Resting on Different Soils." Materials Today: Proceedings, 71(Part 2), 325–331.