



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VIII **Month of publication:** August 2026

DOI: <https://doi.org/10.22214/ijraset.2026.84735>

www.ijraset.com

Call: ☎ 08813907089

E-mail ID: ijraset@gmail.com

Structural Behaviour of Multi-Storey Buildings with Circular and Rectangular Columns under Earthquake Loads

Shahnavaj¹, Mrs. Ankita Singhai², Dr. Rahul Kumar Satbhayia³

¹Research Scholar, Civil Department, Infinity Management & Engineering College, Sagar

²Asst. Prof. and Guide, Civil Department, Infinity Management & Engineering College, Sagar

³HOD, Civil Department, Infinity Management & Engineering College, Sagar

Abstract: Moment-resisting frames (MRF) of reinforced concrete (RC) are the most popular structural system for multi-storey construction in seismically active zones and the size and shape of the columns have significant impact on the seismic performance of the MRF structure. The paper presents a comparative nonlinear static (pushover) analysis of a ten-storey (G+9) RC moment-resisting frame with six different types of cross-sectional area of the columns, three rectangular cross sections (450×600 mm, 500×600 mm and 550×600 mm), and three circular cross sections (250 mm, 300 mm and 350 mm). All the other geometric and material parameters were kept constant and shape and size of the columns were the only variables. The nonlinear static pushover analysis was performed based on the Indian seismic design provisions in ETABS, and seismic demand parameters were estimated by equivalent linearisation method developed by FEMA-440. The results of the Storey shear, Storey drift and Storey displacement indicate that the circular column configurations always have lower base shears than the rectangular column configurations of similar size, and storey drift and storey displacement are marginal, while equivalent-linearization performance points are more favourable. The six base-shear and storey-shear profiles in the above comparison confirm this tendency at all three size pairings, and show that circular columns have a slight seismic performance benefit over the rectangular columns in multi-storey RC frames.

Keywords: pushover analysis; nonlinear static procedure; reinforced concrete frame; circular column; rectangular column; performance point; FEMA-440; capacity spectrum; storey drift; earthquake-resistant design.

I. INTRODUCTION

A. Background

Ground shaking during an earthquake causes transient lateral forces on buildings that are resisted mainly by the lateral load path of the structural system [1]. Based on seismicity observations and the tectonic context in the Indian subcontinent, four seismic zones (II to V) are classified by the Bureau of Indian Standards [2]. Many structures in seismically active areas, such as those designed before seismic codes were established and/or revised, do not meet current detailing and capacity requirements [3] and therefore, the seismic performance assessment of existing and new buildings is a critical challenge for structural earthquake engineering.

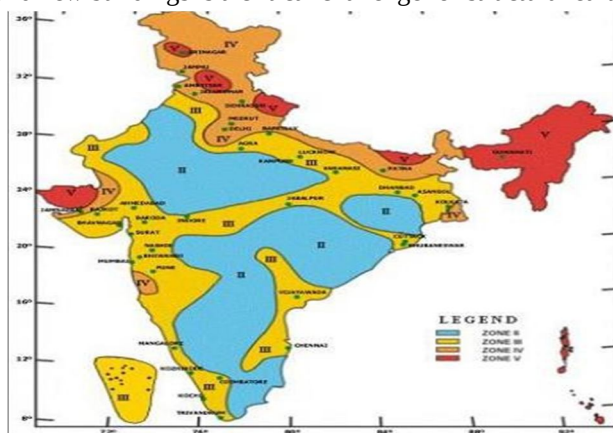


Fig. 1. Seismic zoning map of India, showing Zones II–V as defined by the Bureau of Indian Standards [2].

In a RC moment-resisting frame, the columns carry the axial gravity load and also resist the axial load from earthquake loads in addition to the lateral loads which result in biaxial bending and shear stresses. The shape and size of the cross section of a column thus have an important effect on the seismic behaviour of the building, being a first-order effect. Circular columns are under close confinement by circular ties or a spiral and offer more uniform triaxial confinement for the concrete core, and an isotropic second moment of area about any bending axis [4, 5] compared to rectangular and square columns. The key question addressed in this paper is whether this member-level benefit of circular sections is apparent at the level of the entire multi-storey building under earthquake loading. Such buildings are increasingly evaluated on a performance basis using nonlinear static procedures, frequently referred to as pushover analysis, which involve the application of a lateral load pattern that is monotonically increased to a structural model simulated using a nonlinear structural model until a target displacement is achieved. The analytical framework employed in this study was defined in guidance documents from Applied Technology Council (ATC-40 [6] and FEMA-356 [7]) and subsequently developed in the FEMA-440 report [8] which used an equivalent linearization method to define the performance point of each column configuration considered.

B. Objectives of the Study

The specific objectives of this paper are as follows: (i) to evaluate the seismic behaviour of a ten-storey RC moment-resisting frame with rectangular columns of three different sizes; (ii) to evaluate the seismic behaviour of the same building provided with circular columns of three different radii, each having a cross sectional area and reinforcement ratio similar to one of the rectangular sets; and (iii) compare the resulting storey shear, storey drift, storey displacement and FEMA-440 equivalent-linearization performance points across all six configurations to identify which shape of column allows for the most favourable seismic performance for a building of this configuration. The geometry, storey height, and bay layout, beam sizes, slab thickness, material grades, and seismic zone were kept constant for all six models, leaving column cross-section as the only independent variable.

II. LITERATURE REVIEW

Griffith and Pinto [9] studied a four-storey infilled RC frame, and they showed that the bare frame drift capacity is about two per cent, while the infill cracking drift capacity is only 0.3 per cent, demonstrating the sensitivity to the secondary elements in the system. Otani [10] studied the evolution of the earthquake-resistant RC design and related the damage statistics of the earthquake in Kobe with the design period of the earthquake-damaged buildings. Faella et al. [11] recommended that a displacement-based procedure is more relevant in comparison seismic demand to seismic capacity for retrofit of an existing building rather than a force-based procedure. Oğuz [12] compared invariant pushover load pattern results with the nonlinear time-history results for RC and steel frames and found that the accuracy of the pushover is dependent on the load pattern, the characteristics of the ground-motion, and the dynamic properties of the structure, while Rai [13] presented guidelines for the seismic assessment and strengthening of the existing building stock in India.

Kadid and Boumrkik [14] used pushover analysis on an Algerian code RC building and showed the need to have realistic hinge modelling for buildings with highly inelastic response. In the present study, the FEMA-440 procedure was chosen for Section 3.3 to be evaluated against the roof displacements measured during instrumented earthquakes, following Goel [15] who compared the FEMA-356, ASCE/SEI 41-06, ATC-40 and FEMA-440 nonlinear static procedures with measured roof displacements of instrumented earthquakes. Sattar and Liel [16] have demonstrated that fully infilled frames have less collapse risk than bare frames, Tamboli and Karadi [17] have demonstrated that open-ground-storey configurations lead to much higher ground-storey drift, and Bodige and Ramancharla [18] have compared the Applied Element Method with the conventional pushover analysis and shown that ductile detailing matters more than material grade in determining capacity.

A more focused strand of research focuses directly on column cross-sectional geometry. Chrysanidis and Tegos [19] examined circular RC columns that were steel and hybrid jacketed, and found that confinement efficiency was one of the geometry-dependent variables that significantly affected the columns. Kim, Kim and Chang [20] studied the retrofitting with three dimensional textile-reinforced mortar panels of rectangular RC columns and found that the strength, ductility and energy dissipation properties of the columns improved significantly. At the building scale, Wulandari and Wardi [22] applied pushover analysis to a three-storey RC building and reported that increasing the base-shear demand in the same building by about twenty per cent was achieved by a revised seismic code, which means that the storey nonlinear static performance characteristics are also different. Lee, Han and Kim [23] then used finite-element modeling of RC column specimens strengthened with polyurea coatings to show that the reinforcing effect was greater for the circular specimens than the rectangular ones, which they attributed to the continuous, curvature-free geometry of the former. Montes Rodriguez, Angarita Trillos and Arroyo Amell [24] developed machine-learning surrogate models to predict the parameters of pushover curves directly from the design parameters for RC column specimens in which the columns

were strengthened with polymer coatings; and Anjum et al. [25] integrated pushover analysis with response-spectrum analysis on a ten-storey reinforced concrete building to conclude that pushover analysis can be used to identify failure mechanisms that are not captured by response-spectrum analysis. The reviewed literature provides further confirmation that pushover analysis, enhanced by ATC-40, FEMA-356, and FEMA-440, is currently the most prevalent nonlinear static analysis method for performance-based seismic evaluation, and that circular RC columns typically provide better member-scale confinement and retrofit effectiveness. This paper directly tackles the same issue, however, as few studies focus on column shape when considering a full-multistorey building analysed by pushover methods, the authors compare six different column configurations of a ten storey RC frame, all otherwise identical.

III. METHODOLOGY

A. Description of the Building Model

The idealised building model was created in ETABS, which consisted of a ten-storey RC structure (G+9). Six sets of columns, all identical in every detail except for the cross sections, were prepared: three sets of rectangular cross sections having dimensions of 450 x 600 mm, 500 x 600 mm and 550 x 600 mm and three sets of circular cross sections with a radius of 250 mm, 300 mm and 350 mm, all with the same cross sectional area and reinforcement ratio. That all beams in the models were of the same section 450 × 600 mm, and slab thickness, storey heights, material grades and seismic parameters were kept constant throughout all six models, as summarised in Table 1.

Table 1. Summary of geometric, material and seismic parameters adopted for the G+9 RC building models.

S. No.	Parameter	Description
1	Structural system	RC moment-resisting frame
2	Seismic zone (IS 1893)	Zone V, zone factor 0.36
3	Number of storeys	G + 9
4	Typical / ground storey height	3.00 m / 3.30 m
5	Concrete grade	M25 (beams); M30 (columns)
6	Reinforcement grade	Fe415
7	Rectangular columns — Sets 1/2/3	450×600 / 500×600 / 550×600 mm
8	Circular columns — Sets 4/5/6	Radius 250 / 300 / 350 mm
9	Beam size (all floors)	450×600 mm
10	Slab thickness	125 mm
11	Soil type	Medium (Type II)

The design of the Building has been carried out for combined gravity and seismic loading according to IS 456:2000 [26] for reinforced concrete design and IS 1893 (Part 1):2002 [2] for seismic base shear and distribution of seismic base shear over height with taking ductile detailing according to IS 13920:1993 [27] and other design loads as per IS 875 (Part 5):1987 [28]. The three dimensional ETABS model of the building is shown in fig. 2.

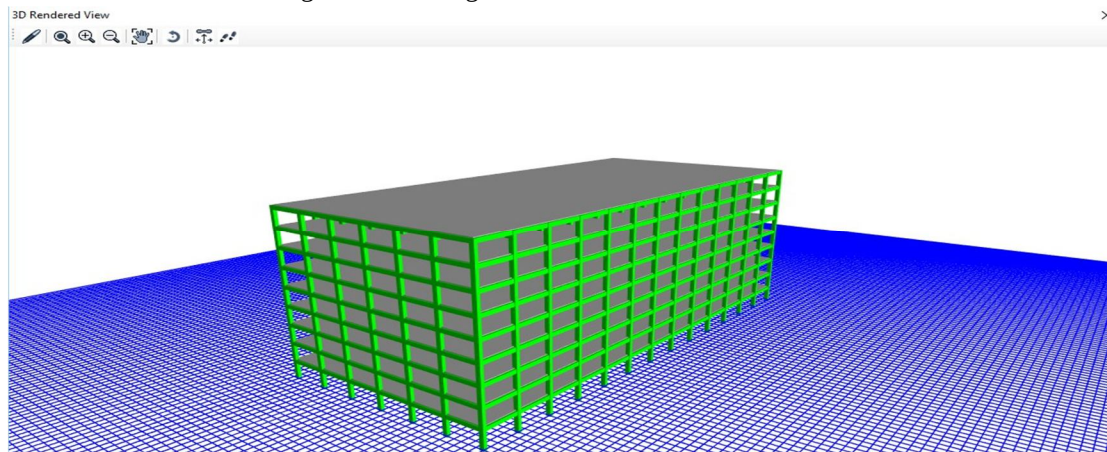


Fig. 2. Three-dimensional ETABS model of the G+9 building used for the pushover analysis.

B. Nonlinear Static (Pushover) Procedure

The pushover sequence was: (a) a force-controlled pushover for gravity loads followed by displacement-controlled pushover for lateral loads in the X-direction with results recorded at progressive load steps; (b) the base-shear versus roof-displacement relationship; and (c) storey shear, storey drift and storey displacement were obtained at each storey and load step. The idealised capacity curve is depicted in Fig. 3 which shows the Immediate Occupancy (IO), Life Safety (LS) and Collapse Prevention (CP) performance levels referred to in Section 4.

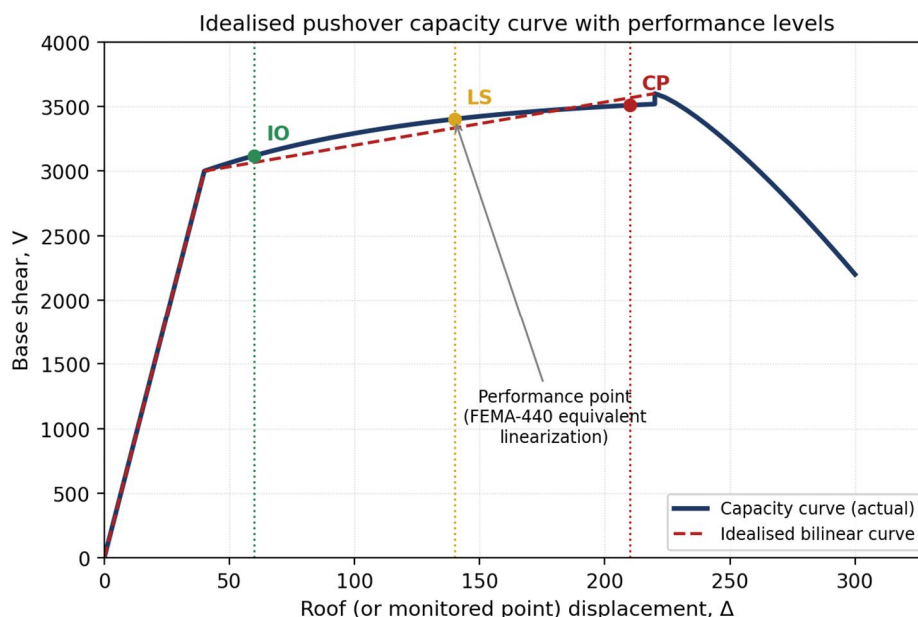


Fig. 3. Idealised pushover capacity curve showing the IO, LS and CP performance levels and the FEMA-440 performance point used to interpret the results of Section 4.

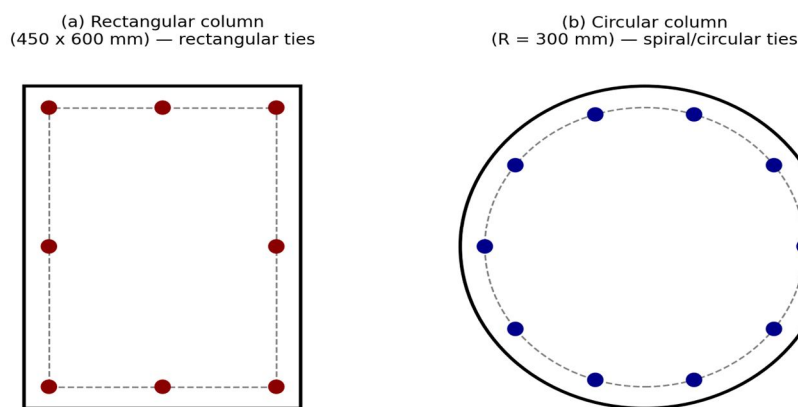


Fig. 4. Schematic cross-sections of (a) a rectangular column with rectangular ties and (b) a circular column with circular/spiral ties, illustrating the more uniform confinement geometry of the circular sections compared in this study [4], [5].

C. FEMA-440 Equivalent Linearization

The seismic demands were calculated from each pushover capacity curve by the FEMA-440 equivalent linearization procedure [8] that represents the inelastic single-degree-of-freedom system as an equivalent linear oscillator with an equivalent viscous damping ratio and a secant (effective) period, both of which are functions of the ductility demand.

$$\frac{\mu = \Delta_{max}}{\Delta_y} \quad (1)$$

The capacity spectrum and a family of damped, reduced demand spectra intersect to produce a spectrum that is implied. This process is repeated until the guessed and calculated ductility values become the same, which sets the performance point for the assumed spectral displacement (S_d), the computed spectral acceleration (S_a) and the computed effective period. The original approach was to use the ATC-40 capacity spectrum method, but Goel [15] noted that the FEMA-440 formulation gave better estimates of displacement than the recorded strong-motion response when compared to the ATC-40 method.

IV. RESULTS AND DISCUSSION

Nonlinear static pushover analysis was carried out independently for each of the six column configurations. The results are shown as storey shear, storey drift, storey displacement, and FEMA-440 capacity spectra and then a comparative synthesis of all six configurations is presented.

A. Storey Shear

The representative storey-shear results for the rectangular configuration (450x600 mm) and the circular configuration (250 mm radius) are shown in Fig. 5 and Fig. 6 respectively; with these results, the expected monotonic increase of storey shear from the roof to the base of the regular frame was observed for the two case-studies under the same lateral loading pattern over the storey-height.

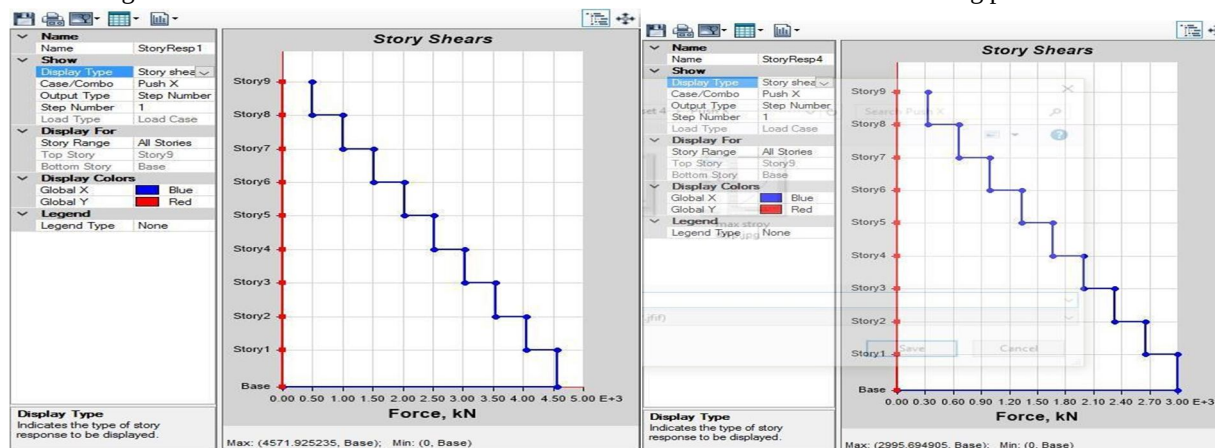


Fig. 5–6. Storey shear obtained from pushover analysis for (left) the 450×600 mm rectangular column and (right) the 250 mm radius circular column.

The results for the storey shear (in the X-direction) for all six configurations are summarised in Table 2, and all the profiles are plotted in Fig. 7. The base storey shear increases with the size of the column in both families, but for a similar increase in cross-sectional area, the rectangular sets generate much greater base shear than the circular sets: 15,598 kN, 16,169 kN for the two 500×600 mm and 550×600 mm columns respectively, compared with 2,996 kN, 5,542 kN and 7,193 kN for the two 250 mm, 300 mm and 350 mm radius columns.

Table 2. Storey shear (X-direction) at every level for the six column configurations.

Storey	Elev. (m)	R-450×600 (kN)	R-500×600 (kN)	R-550×600 (kN)	C-R250 (kN)	C-R300 (kN)	C-R350 (kN)
9	27.3	489.0	1651.2	1704.0	330.1	608.8	786.1
8	24.3	999.1	3393.5	3510.8	663.3	1225.3	1586.8
7	21.3	1509.2	5135.7	5317.7	996.4	1841.8	2387.4
6	18.3	2019.3	6878.0	7124.6	1329.6	2458.3	3188.1
5	15.3	2529.4	8620.2	8931.5	1662.7	3074.8	3988.7
4	12.3	3039.5	10362.5	10738.4	1995.9	3691.3	4789.4
3	9.3	3549.6	12104.7	12545.2	2329.1	4307.8	5590.0
2	6.3	4059.7	13847.0	14352.1	2662.2	4924.4	6390.6
1	3.3	4571.9	15598.3	16169.3	2995.7	5541.6	7192.8

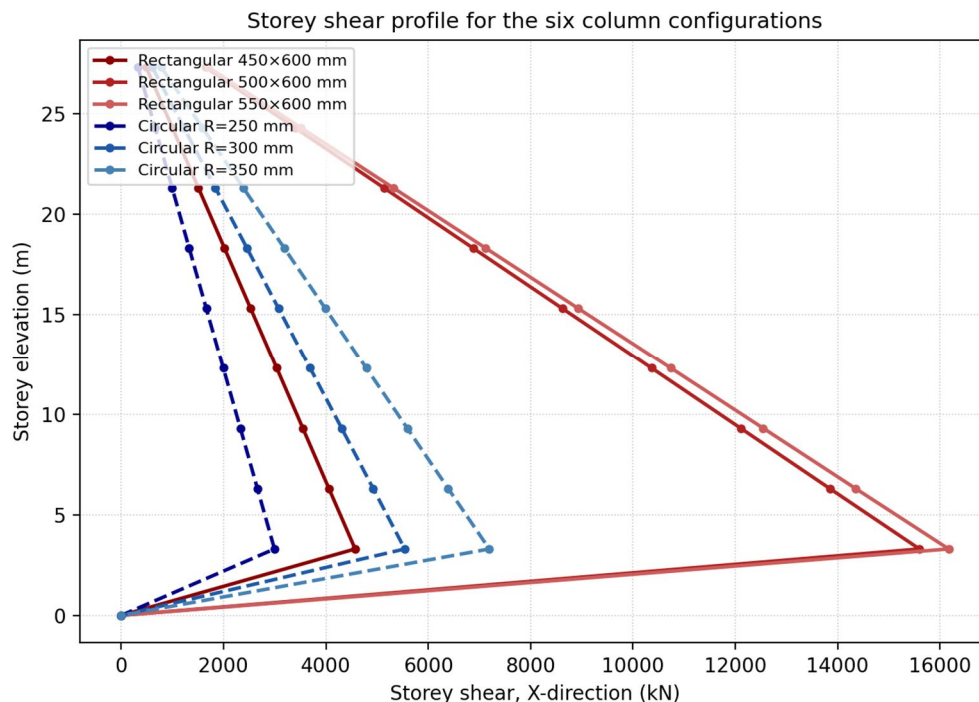


Fig. 7. Storey shear profile (elevation versus storey shear, X-direction) for the six column configurations, plotted from Table 2.

B. Storey Drift

Results of representative storey-drift are given for the rectangular configuration in Fig. 8, and for the circular configuration in Fig. 9. Drift is greatest in the lower levels of both families and diminishes progressively up the levels, reflecting a moment resisting frame where the drift demand in the columns is greatest at the ground and first floor. In comparing the two configurations, the rectangular column seems to have a slightly higher peak storey drift for a similar size than the circular configuration, which is consistent with the more uniform distribution of second moment of area in a circular section compared to a section of rectangular shape with similar area.

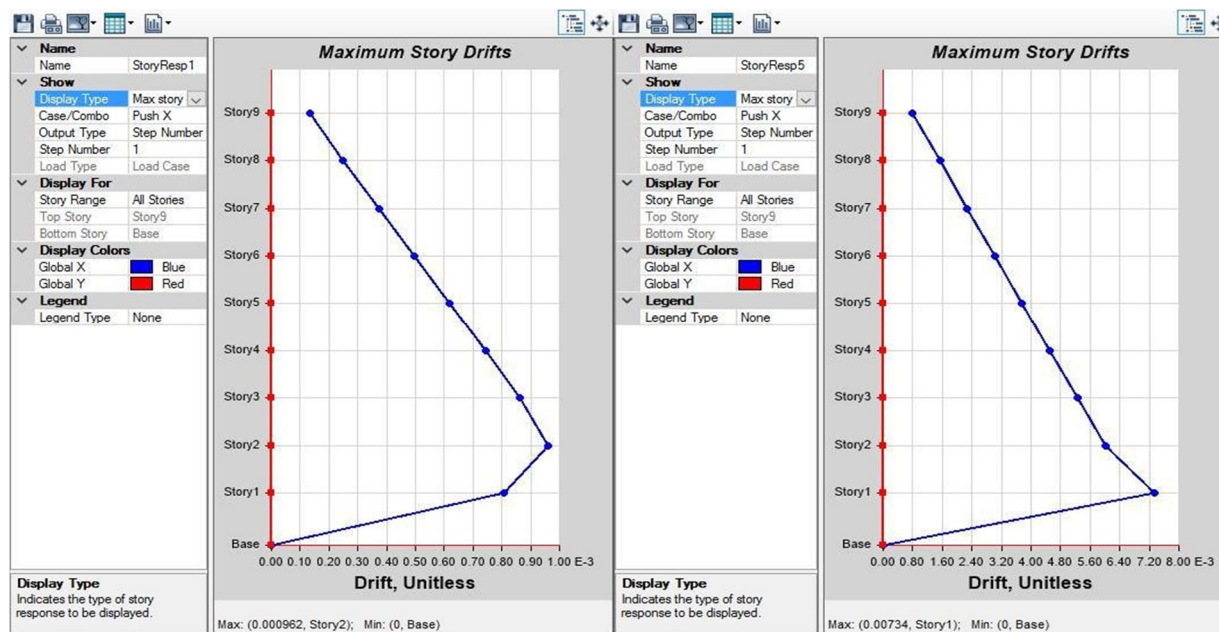


Fig. 8–9. Storey drift obtained from pushover analysis for (left) a rectangular column configuration and (right) a circular column configuration.

C. Storey Displacement

Cumulative storey displacement for typical rectangular and circular configurations is shown in Fig. 10 and Fig. 11 respectively. In a similar manner to the storey drift, for the rectangular column sets, roof level displacement recorded at each load step is generally, although slightly, higher than that recorded for the circular sets of similar size, suggesting that the circular sets are able to provide adequate lateral stiffness at a lower level of base-shear loads.

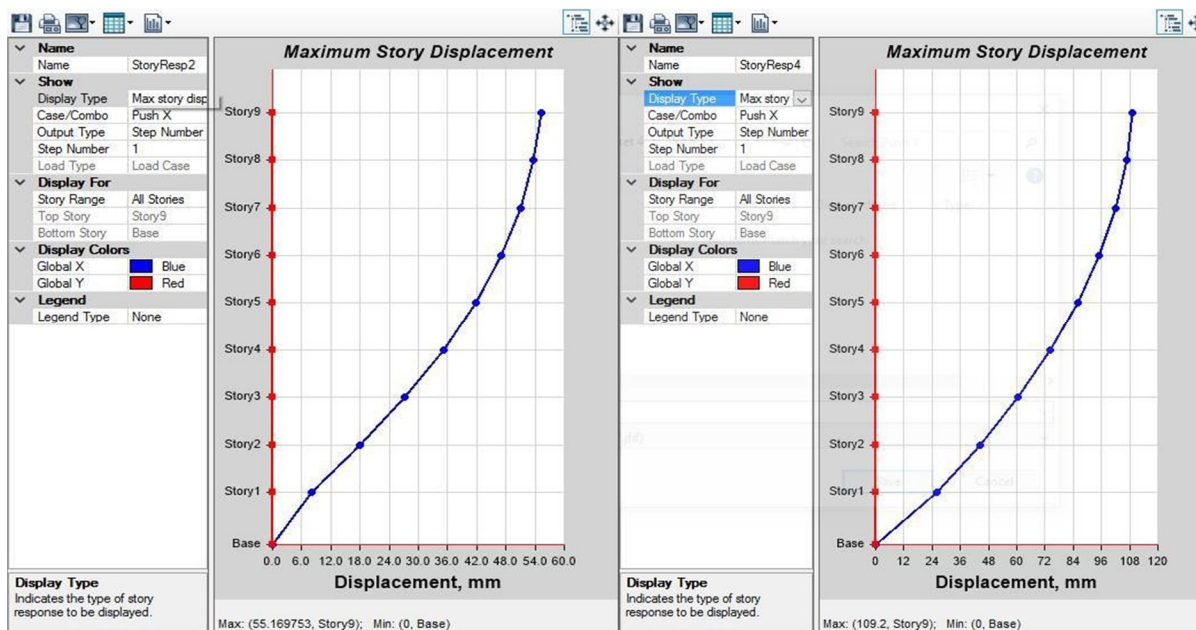


Fig. 10–11. Storey displacement obtained from pushover analysis for (left) a rectangular column configuration and (right) a circular column configuration.

D. Capacity Spectra and FEMA-440 Equivalent Linearization

The pushover capacity curve for each configuration was transformed to a capacity spectrum and then analyzed using the FEMA-440 equivalent linearization procedure of Section 3.3 to obtain relationships between the peak spectral displacement, T ; peak spectral acceleration, S_a ; and spectral acceleration, S_a and the spectral displacement, S_d . The performance point sequence shown in Table 3 is reproduced for the rectangular configuration of 450×600 mm, where the performance point is refined in each iteration, the effective period becomes longer as the secant stiffness decreases with increasing ductility, and the final iteration is at the equilibrium performance point.

Table 3. FEMA-440 equivalent linearization sequence for the 450×600 mm rectangular column configuration.

Sd (mm)	Sa (g)	Teff (s)
0	0	0
12.767	0.024856	1.438
52.775	0.092292	1.517
71.567	0.107625	1.636
74.896	0.108768	1.665
144.511	0.060643	3.097

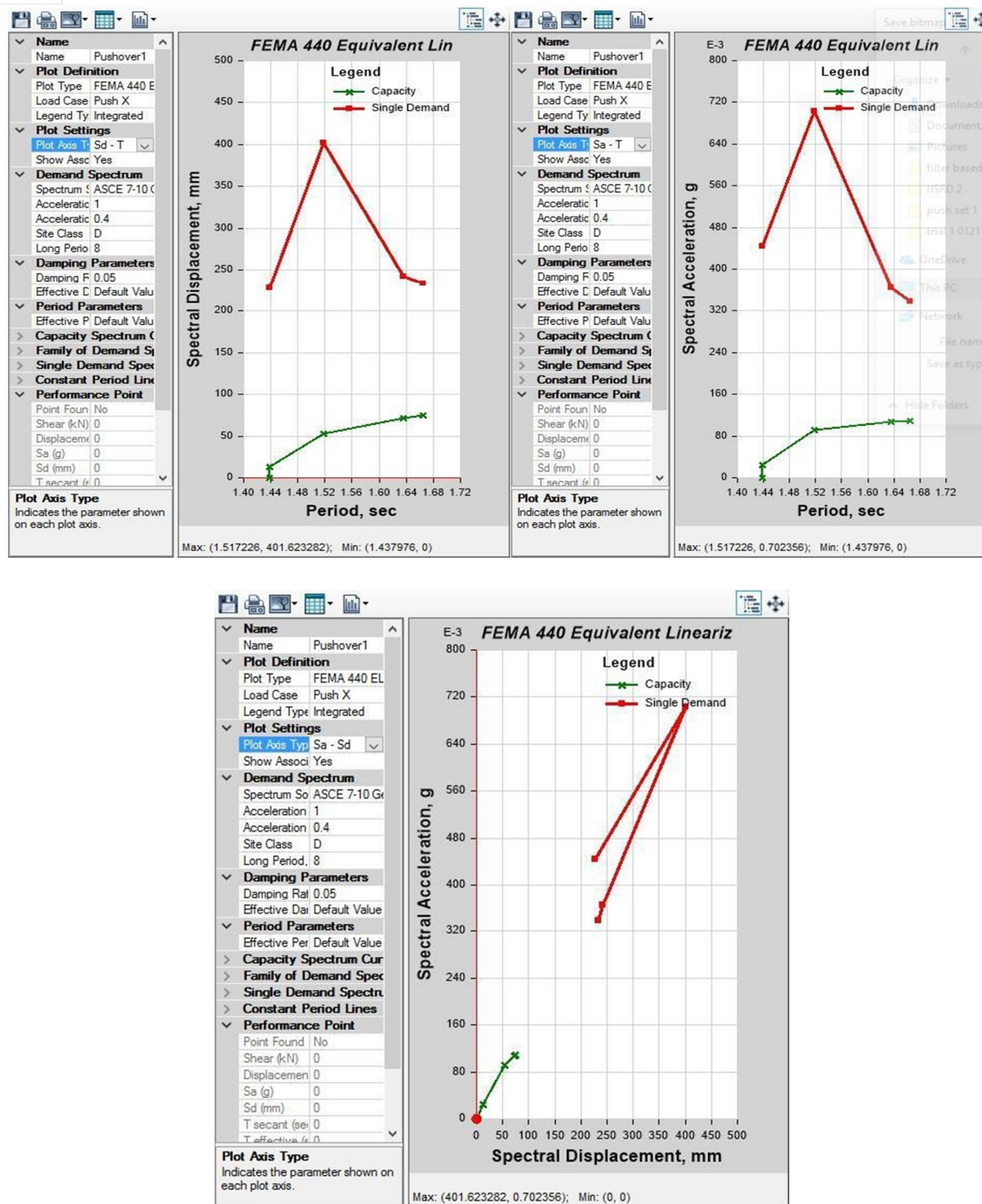


Fig. 12. (a) Sd-T, (b) Sa-T and (c) Sa-Sd plots for the 450x600 mm rectangular column configuration.

As observed in Sections 4.2 and 4.3, the performance point in all six configurations is found to be lower for the circular column sets compared with the rectangular sets of similar size. The effective duration at the performance point is also slightly shorter for the circular configurations, suggesting a stiffer linear system given the same ductility required.

E. Comparative Synthesis

The base storey shear (X-direction, storey 1) of all six configurations is summarised in Fig. 13. The three circular configurations scale more gradually with radius, and the rectangular column of 500×600 mm and 550×600 mm have a base shear about three times that of the 450×600 mm rectangular column. Overall, the pattern, along with the drift, displacement and performance-point outcomes from the sections 4.2 through 4.4, suggests that for a given lateral increase in cross-sectional area, circular columns exhibit a similar or better performance in lateral resistance, and a lower proportion of total seismic base shear.

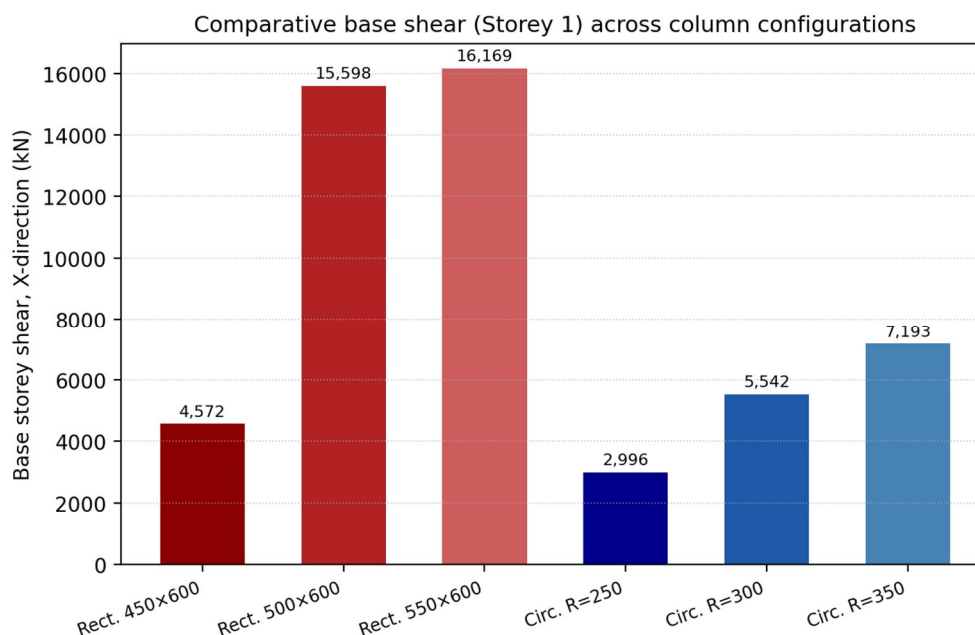


Fig. 13. Comparative base storey shear (storey 1, X-direction) for the six column configurations, synthesised from Table 2.

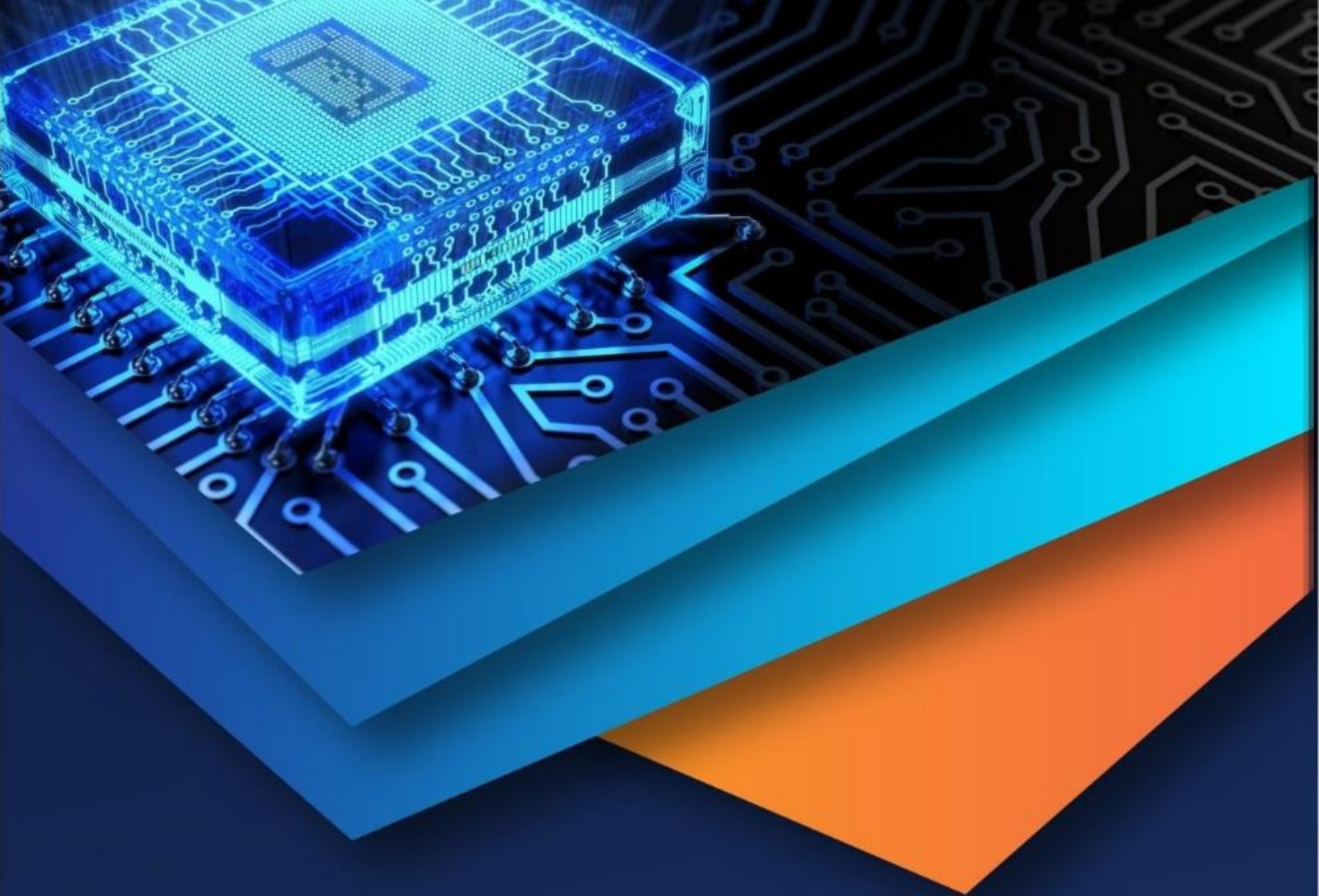
V. CONCLUSION

For this purpose, 6 different configurations of a 10-storey RC moment-resisting frame (MRF) with comparable cross sectional areas of columns—(450 x 600 mm), (500 x 600 mm), (550 x 600 mm), (radius 250 mm), (radius 300 mm), and (radius 350 mm)—were selected and evaluated using a comparative nonlinear static (pushover) approach. The following conclusions are drawn based on the storey shear, storey drift, storey displacement and FEMA-440 equivalent-linearization results:

- 1) As the variation in cross-sectional shape of the column is the only variable used to differentiate between the two column families, the resulting effect is not primary, but measurable and is felt globally in the seismic response of the building being studied.
- 2) At all of the size pairs compared, 2. storey drift and 2. storey displacement are consistently (but not so significantly) greater for the rectangular column configurations than for the circular column configurations of comparable size.
- 3) In comparison, the FEMA-440 performance point achieved for these circular column configurations is associated with a reduced spectral displacement demand and a slightly reduced effective period in comparison with the corresponding rectangular column configurations, suggesting a slightly superior overall seismic performance for these circular column configurations.
- 4) In comparison to the gradual increase in seismic base shear with increasing cross-sectional area of the circular column sets, the larger rectangular column sets (500×600 mm and 550×600 mm) share a disproportionately larger portion of the seismic base shear.
- 5) These findings are aligned with member-level studies that show good confinement and retrofit performance for circular RC columns, [4, 5, 19, 23], and are expanded from the level of a single member to the level of a full-scale multi-storey building analysed using pushover analysis.
- 6) It would be useful for future work to incorporate explicit shear and joint failure criteria, to confirm the conclusions drawn from the pushover analysis using nonlinear time-history analysis, and to broaden the range of column configurations for machine-learning-based surrogate modelling (as presented by Montes Rodriguez et al. [24]).

REFERENCES

- [1] P. Agarwal and M. Shrikhande, *Earthquake Resistant Design of Structures*. New Delhi, India: PHI Learning, 2004.
- [2] Bureau of Indian Standards, IS 1893 (Part 1): Criteria for Earthquake Resistant Design of Structures — General Provisions and Buildings, 5th rev. New Delhi, India: BIS, 2002.
- [3] A. Agarwal, "Seismic evaluation of institute building," B.Tech. thesis, Nat. Inst. Technol. Rourkela, India, 2012.
- [4] J. B. Mander, M. J. N. Priestley, and R. Park, "Theoretical stress-strain model for confined concrete," *J. Struct. Eng.*, vol. 114, no. 8, pp. 1804–1826, 1988, doi: [10.1061/\(ASCE\)0733-9445\(1988\)114:8\(1804\)](https://doi.org/10.1061/(ASCE)0733-9445(1988)114:8(1804)).
- [5] S. Rocca, N. Galati, and A. Nanni, "Interaction diagram methodology for design of FRP-confined reinforced concrete columns," *Constr. Build. Mater.*, vol. 23, no. 4, pp. 1508–1520, 2009, doi: [10.1016/j.conbuildmat.2008.06.010](https://doi.org/10.1016/j.conbuildmat.2008.06.010).
- [6] Applied Technology Council, ATC-40: Seismic Evaluation and Retrofit of Concrete Buildings, vol. 1. Redwood City, CA, USA: ATC, 1996.
- [7] Federal Emergency Management Agency, FEMA-356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings. Washington, DC, USA: FEMA, 2000.
- [8] Applied Technology Council / Federal Emergency Management Agency, FEMA-440: Improvement of Nonlinear Static Seismic Analysis Procedures. Washington, DC, USA: FEMA, 2005.
- [9] M. C. Griffith and A. V. Pinto, "Seismic retrofit of RC buildings — A review and case study," Univ. of Adelaide, Australia and European Commission Joint Research Centre, Ispra, Italy, 2000.
- [10] S. Otani, "Seismic vulnerability assessment of reinforced concrete buildings," *Faculty Eng. Univ. Tokyo, Ser. B*, vol. 47, pp. 5–28, 2000.
- [11] C. Faella, E. Martinelli, and E. Nigro, "Displacement-based assessment and retrofit of existing reinforced concrete framed buildings," *Comput. Struct.*, vol. 80, no. 11, pp. 1001–1009, 2002.
- [12] S. Oğuz, "Evaluation of pushover analysis procedures for frame structures," M.S. thesis, Middle East Technical Univ., Ankara, Turkey, 2005.
- [13] D. C. Rai, "Seismic evaluation and strengthening of existing buildings," IIT Kanpur and Gujarat State Disaster Management Authority, Gandhinagar, India, 2005.
- [14] A. Kadid and A. Boumrkik, "Pushover analysis of reinforced concrete frame structures," *Asian J. Civ. Eng. (Build. Hous.)*, vol. 9, no. 1, pp. 75–83, 2008.
- [15] R. K. Goel, "Evaluation of current nonlinear static procedures for reinforced concrete buildings," in *Proc. 14th World Conf. Earthq. Eng.*, Beijing, China, 2008.
- [16] S. Sattar and A. B. Liel, "Seismic performance of reinforced concrete frame structures with and without masonry infill walls," in *Proc. 9th U.S. Nat. / 10th Can. Conf. Earthq. Eng.*, Toronto, Canada, 2010.
- [17] H. R. Tamboli and U. N. Karadi, "Seismic analysis of RC frame structure with and without masonry infill walls," *Indian J. Nat. Sci.*, vol. 3, no. 14, pp. 1137–1147, 2012.
- [18] N. Bodge and P. K. Ramancharla, "Pushover analysis of RC bare frame: Performance comparison between ductile and non-ductile detailing," *Int. Inst. Inf. Technol. Hyderabad, Rep. IIIT/TR/2012/-1*, 2012.
- [19] T. Chrysanidis and I. Tegos, "Axial and transverse strengthening of R/C circular columns: Conventional and new type of steel and hybrid jackets using high-strength mortar," *J. Build. Eng.*, vol. 30, p. 101236, 2020, doi: [10.1016/j.job.2020.101236](https://doi.org/10.1016/j.job.2020.101236).
- [20] S. Kim, S. J. Kim, and C. Chang, "Seismic performance evaluation of RC columns retrofitted by 3D textile reinforced mortars," *Materials*, vol. 15, no. 2, p. 592, 2022, doi: [10.3390/ma15020592](https://doi.org/10.3390/ma15020592).
- [21] M. Shi, M. Choi, Y. Choi, and S. Kang, "Influences of column orientations and story levels of the RC frames under nonlinear static analysis," *Archit. Res.*, vol. 26, no. 4, pp. 127–138, 2024, doi: [10.5659/AIKAR.2024.26.4.127](https://doi.org/10.5659/AIKAR.2024.26.4.127).
- [22] W. Wulandari and S. Wardi, "Seismic performance of an RC building using pushover analysis (case study: Three-storey flat house building in Padang City)," *J. Civ. Eng. Build. Transp.*, vol. 7, no. 1, pp. 18–23, 2023, doi: [10.31289/jcebt.v7i1.8564](https://doi.org/10.31289/jcebt.v7i1.8564).
- [23] T.-H. Lee, S.-H. Han, and J.-H. J. Kim, "Numerical evaluation of seismic performance of RC columns strengthened with stiff-type polyurea," *Materials*, vol. 18, no. 8, p. 1839, 2025, doi: [10.3390/ma18081839](https://doi.org/10.3390/ma18081839).
- [24] C. D. Montes Rodriguez, C. E. Angarita Trillos, and O. D. Arroyo Amell, "Machine learning-based approach for predicting pushover curves of low-rise reinforced concrete frame buildings," *Structures*, vol. 70, p. 107694, 2024, doi: [10.1016/j.istruc.2024.107694](https://doi.org/10.1016/j.istruc.2024.107694).
- [25] N. Anjum, M. S. Rana, F. Islam, and M. A. Rahman, "Seismic performance evaluation of a 10-story RC building using pushover analysis & response spectrum analysis," *Am. J. Civ. Eng.*, vol. 14, no. 1, pp. 20–38, 2026, doi: [10.11648/j.ajce.20261401.13](https://doi.org/10.11648/j.ajce.20261401.13).
- [26] Bureau of Indian Standards, IS 456: Plain and Reinforced Concrete — Code of Practice, 4th rev. New Delhi, India: BIS, 2000.
- [27] Bureau of Indian Standards, IS 13920: Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces — Code of Practice, 2nd rev. New Delhi, India: BIS, 1993.
- [28] Bureau of Indian Standards, IS 875 (Part 5): Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, 2nd rev. New Delhi, India: BIS, 1987.



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)