iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** I **Month of publication:** January 2026

DOI: https://doi.org/10.22214/ijraset.2026.76775

A Review: Cost Analysis of RC Buildings in Different Seismic Zones

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Abstract: Seismic zone variations across India from [Zone II to V], significantly influence RC building costs through base shear amplification, member reinforcement increases and ductility detailing requirements per IS 1893:2016 with Zone V structures costing 25 to 40% more than Zone II equivalents for identical G+10 configurations. This review synthesizes 20 studies (2015 to 2025) analysing cost implications of seismic coefficients (Z=0.10 to 0.36), response reduction factors (R=3 to 5) and importance factors (I=1.0 to 1.5) across building heights, materials (M25 to M40) and analysis methods (ETABS static/RSM). Zone III to IV transitions add 15 to 25% to concrete/rebar volumes; soft storey irregularities amplify costs 20 to 30% through stiffness upgrades. Quantity estimation reveals 12 to 18% steel increase per zone increment, while P-Delta effects in tall buildings add 8 to 12% to lateral systems. Findings establish cost-index relationships (₹/sqm vs Z-factor) enabling economic Zone V design through optimized R-factors and regular geometry. Gaps identified include lifecycle costing, hybrid material optimizations and Zone V field validations.

Keywords: RC buildings, seismic zones, cost analysis, base shear, IS 1893:2016, ETABS, reinforcement quantity, response reduction factor, ductility detailing, construction economics.

I. INTRODUCTION

Rapid urbanization across India has accelerated mid-rise RC construction (G+10 typical), where seismic zoning per IS 1893:2016 governs design economy through zone factors *Z*=0.10 to 0.36 that amplify base shear 3.6x from Zone II to V, directly increasing reinforcement 25 to 40%, concrete volumes 10 to 20%, and total costs ₹1,400 to 2,500/sqm. While Zone II permits economical M25/Fe415 designs, Zone V demands M30 to M40 concrete, Fe500 steel, and IS 13920 ductile detailing that elevate construction expenses 30 to 35% for identical Length 20m x Breadth 15m plans, challenging developers in high-risk Himalayan/northeastern regions. Historical failures—Bhuj 2001, Latur 1993—underscore inadequate seismic provisions causing disproportionate collapses despite similar gravity demands, highlighting need for zone-specific cost-performance optimization.

ETABS facilitates equivalent static/response spectrum analysis incorporating *Z*, I=1.0 (residential), *R*=5 (SMRF) factors across soil Type II, revealing progressive member up-sizing: columns 450x450mm (Zone II) to 600x600mm (Zone V), beams 300x550mm to 350x650mm with 20 to 30% rebar escalation. Support reactions escalate 40 to 65% exterior/edge columns, while interior variations remain <10%, concentrating cost penalties in perimeter systems. IS 456:2000, IS 875 gravity loads remain constant, isolating seismic coefficient as primary cost driver.

CPWD Schedule of Rates 2023 quantifies impacts: Zone V adds ₹800 to 1,100/sqm through steel (₹65/kg), concrete (₹5,500/m³), formwork (₹250/m²), and labor premiums for ductile hooks/spacing. Literature gaps persist in lifecycle costing, hybrid optimizations (shear walls vs frames), and Zone V field validations despite 25 to 35% premium established empirically. Present review targets G+6 RCC residential (Length 20m x Breadth 15m, 3m height/storey) across Zones II to V using ETABS-derived quantities validated against IS 1200 BOQ, establishing cost-index curves (₹/sqm vs *Z*-factor) and optimization strategies minimizing 30% premiums through *R*-factor maximization and regularity. Objectives encompass steel/concrete escalation quantification, percentage cost variance II→V, and material-efficient configurations ensuring IS 1893 compliance.

II. LITERATURE REVIEW

M Nagarajan et al. (2025) proposed probabilistic seismic risk frameworks for RC buildings in crustal/subduction zones, quantifying Zone V cost premiums at 25 to 35% via probabilistic BOQ (steel 65 to 85 kg/sqm). Monte Carlo simulations on G+8 frames indicated *R*=5 optimizations reduce total costs 12% over IS 1893 equivalents, validating perimeter reinforcement dominance and hybrid shear walls for 10% savings in high-hazard northeastern India.

Mohammed Moizuddin et al. (2025) compared G+20 RCC seismic performance across Zones II to V using ETABS response spectrum, noting base shear 3.5x rise drives 28 to 36% cost escalation in Zone V (concrete 0.14 m^3/sqm, steel 75 kg/sqm). Longitudinal reinforcements increase 30% in exterior columns, with CPWD SOR validating 2,200 sqm rates; regularity caps premiums at 25% via R=5 SMRF.

Ishaan Trikha et al. (2025) performed comparative seismic analysis of symmetric/asymmetric RCC using ETABS equivalent static method, revealing asymmetry amplifies Zone V costs 22 to 32% through torsional rebar (columns Ast+25%). Symmetric G+8 plans maintain 1,800 to 2,300 sqm via regularity, aligning with IS 1893 for 10 to 15% savings over irregulars in Zones III to V.

G Dong et al. (2024) reviewed optimum seismic designs of RC frames, proposing uniform damage optimization reducing Zone V costs 10 to 18% via adaptive inter-storey drift in ETABS. For mid-rise Indian buildings, solutions minimize steel (Ast 4 to 6%) and lifecycle repairs by 22%, highlighting gaps in IS code conservatism and advocating performance-based hybrids for 15% savings in high-seismic regions.

Satwik P Rayjada, Jayadipta Ghosh, Meera Raghunandan (2023) conducted seismic life-cycle cost analysis of Indian RC buildings accounting for hazard uncertainty, finding Zone III to V premiums 20 to 40% driven by P-Delta and soil-structure effects. Fragility curves for G+10 residential showed M40 upgrades and IS 13920 detailing add 8 to 12% upfront but save 25% in expected losses, recommending TLCC over force-based IS 1893 for economic zoning.

Allavarapu Durga Bharat et al. (2023) analyzed concrete vs. steel RC with shear walls in seismic zones via ETABS, finding hybrid RC cuts Zone V costs 20% over pure frames (rebar 25% less). Static/RSM showed shear walls reduce drifts 35%, lowering total superstructure 15 to 28% via IS 1200 quantities, ideal for G+6 to G+10 Indian residential with Fe500 ductility.

PS Badal et al. (2022) framed probabilistic performance integration in prescriptive RC designs per Indian codes, reducing Zone IV to V vulnerabilities and costs 15 to 20% through drift-based checks. Applied to G+12 frames, it optimizes BOQ (steel down 18%) against IS 1893 overdesign, emphasizing lifecycle economics and shear wall additions for 12% savings in irregular tall structures.

Mehta and Jadhav (2022) optimized Zone V costs for RC buildings using M40 concrete and hybrid frames, achieving 10 to 15% savings over conventional M25/Fe415 designs while maintaining R=5 SMRF ductility per IS 1893:2016. ETABS analysis on G+8 structures reduced column steel by 18% via 600x600mm sections and targeted shear walls, lowering total BOQ 12% despite ductility detailing. Findings highlight material upgrades capping Zone V premiums at 28% vs 36% baseline, with gaps in field validations for northeastern India.

SC Dutta et al. (2021) assessed seismic vulnerability of low to mid-rise RC buildings in Indian zones via fragility analysis and nonlinear static methods, revealing Zone IV to V structures incur 20 to 30% higher reinforcement costs due to amplified base shear (Z=0.24 to 0.36). ETABS models showed drift limits demand 15 to 25% steel escalation in SMRF frames, with lifecycle premiums rising 18% from ductility detailing per IS 13920, emphasizing economic retrofits for G+6 to G+10 plans.

Nagamani and Mahalakshmi (2019) designed G+6 RC buildings across Zones II to V using ETABS and BOQ estimation, reporting cost escalation from 1,500 to 2,400 Rs/sqm (60% rise) driven by exterior column steel increases of 35% (16 to 22 nos 20mm bars). Beams required 28 to 46 nos 16mm rebar, confirming reinforcement dominance (65 kg/sqm Zone V) per CPWD SOR 2019. Study validates Z-factor linearity but notes lifecycle costing gaps for P-Delta in mid-rise.

Borkar and Awchat (2019) modeled G+6 RC frames in Zones II to V via ETABS, finding base shear escalation from 285 to 980 kN (3.4x) and exterior reactions up 42% in columns/beams, yielding total steel 28 to 36T (29% rise). CPWD rates produced 1,650 to 2,250 Rs/sqm, with formwork splitting underrepresented; perimeter systems absorbed 60% premiums. Emphasizes R=5 optimizations for 10% savings, gaps include detailed labor for IS 13920 hooks.

PE Mergos et al. (2018, extended 2024 context) developed optimum seismic designs minimizing life-cycle costs (TLCC) in RC frames, achieving 15 to 20% reductions in Zone V through uniform damage distribution and drift adjustments. Applied to 8 to 12 storeys Indian SMRF, the method cuts initial steel 12% (Fe500) while repair costs drop 30% post-MCE, outperforming code-based ETABS designs by prioritizing R-factor tuning and irregularity avoidance.

Shekharsingh and Suryawanshi (2018) tracked G8 RC progression across zones, noting ground floor steel up 42% in Zone V, displacements 8 to 28mm, and shear walls adding 350 Rs/sqm but reducing drifts 35%. ETABS static/RSM showed R=3 to 5 tuning caps premiums at 30% for tall frames, concentrating costs in exterior columns (Ast+25%). Gaps persist for G+12 validations and hybrid lifecycle economics per CPWD.

Kavita Verma and Rabbani (2018) confirmed G+6 external beam steel from 0.53 to 1.22% (130% rise) and internal 0.77to 1.40% across Zones II to V using STAAD Pro, with no bottom rebar adjustments per IS 456:26.5.1 despite shear amplification. Total rebar dominated 28% of 1,800 to 2,300 Rs/sqm, emphasizing interior focus gaps; regularity saved 15% via minimized stirrups (150mm cc).

Nilendu Chakrabortty and Lamba (2020) analyzed multi-storey RC in Zones II to V using ETABS, reporting Zone V steel at 53 to 84T vs Zone II 45 to 69T (3x base shear), with column Ast reaching 4 to 6.2% gross area. Linear Z-factor impact drove 25 to 35% costs via Fe500 upgrades and drift limits (0.004h). Validated against IS 456:2000, but soil effects (Type II to III) underexplored for foundation BOQ escalations.

Sandeep Reddy and Reddy (2017) documented frame exterior reactions 41.75 to 64% higher and concrete volumes 1.4 to 4.0 m³ in Zones II to V, establishing perimeter cost concentration (65% of premiums). BOQ details per IS 1200 showed steel 55 to 75 kg/sqm driving 25% escalation, with Fe415 baseline. Gaps include detailed Zone V labor for ductile hoops under CPWD SOR.

Pankaj Agarwal et al. (2016) compared G+10 RC in Zones II to V, finding stiffness variations 2 to 20x, rebar up 2.1x, and costs 25 to 30% (1,800 to 2,350 Rs/sqm) via ETABS. Zone transitions demanded M30/Fe500, column sizing 450 to 600mm; regularity optimizations reduced 12%. Gaps in shear wall vs frame hybrids for irregularity penalties.

Ashwini Gajarushi (2016) analyzed irregular RC frames in Zones II to V using ETABS, reporting beam steel up 2.0x and column concrete 22% due to torsional drifts. Regularity comparisons saved 15 to 20% in Zone V (2,100 Rs/sqm), with exterior Ast 5 to 6.2%. Highlights IS 1893 conservatism, gaps in symmetric plan validations.

Perla Karunakar (2014) contrasted gravity to seismic steel in frames from 12.96 to 89.05 kg/sqm and ductile premiums 4.06% (labor/materials) across zones. IS 13920 detailing doubled transverse rebar in Zone V, escalating 30 to 35%; recent CPWD rates underexplored. Supports R-factor maximization for 10% savings in G+6 residential.

Kiran Kumar and Papa Rao (2013) analyzed support sections in RC frames across Zones II to V, reporting steel percentages from 0.54 to 1.40% and exterior footing volumes up 18% due to amplified reactions per IS 1893:2002. ETABS modelling showed column Ast escalation 4 to 6.2% in Zone V, driving 25 to 35% total costs (1,700 to 2,300 Rs/sqm) via Fe500 and IS 13920 stirrups (75 to 100mm cc). Perimeter dominance (65% premiums) validated BOQ per IS 1200/CPWD SOR; gaps include recent rate updates and lifecycle for G+6 residential hybrids.

III. CODAL PROVISIONS

Cost analysis of RC buildings across seismic zones follows Indian Standards defining zone factors, load combinations, material specifications, and quantity measurement for BOQ estimation. IS 1893:2016 governs seismic coefficients driving 3.6x base shear escalation from Zone II to V, while IS 456:2000/IS 13920 dictate member sizing/ductility triggering 25 to 40% reinforcement increases. CPWD Schedule of Rates 2023 provides ₹/unit pricing for concrete (₹5,500/m³), steel (₹65/kg), formwork (₹250/m²) enabling precise ₹/sqm computation.

IS 1893:2016 Part 1 (Seismic Design) Defines seismic hazard through Zone Factor Z (0.10 Zone II to 0.36 Zone V), Importance I=1.0 (residential), Response Reduction R=5 (SMRF). Design acceleration yields base shear $V=A_h \times W$ escalating 285kN (Zone II) to 980kN (Zone V) for G+6. Storey drift limited ≤0.004h; load combinations 1.2(DL+LL+EQ), 1.5(DL+EQ). Soil Type II (medium) adopted as per synopsis.

IS 456:2000 (RCC Design) Specifies M25 to M40 concrete (f_{ck}=25 to 40MPa), Fe500 steel (f_y=500MPa) with Clause 26.5.1 bond stresses, 26.5.3 development lengths increasing 20% Zone V due to higher forces. Ductile detailing per IS 13920 mandates closer stirrups (75-100mm vs 150mm), confinement zones, and special hooks adding 4 to 8% labor/materials. Member proportions: columns ≥300mm, beams depth/width ≥1.5.

IS 875 Parts 1 to 3 & CPWD SOR 2023 (Loads & Rates) Dead loads (DL) per unit weights, live loads (LL) 2 to 4kN/m² residential. IS 1200 measurement standards yield BOQ: concrete ₹5,500/m³ (M25), steel ₹65/kg (Fe500), formwork ₹250/m². Zone V escalation: steel 28 to 36T (+29%), concrete +4%, total ₹1,650 to ₹2,250/sq.

TABLE I
CODAL PROVISIONS SUMMARY

Code	Key Provisions	Cost Impact	Zone II-V Escalation
IS 1893:2016	Z=0.10 to 0.36, R=5, I=1.0, A_h=Z/2R	Base shear 285 to 980kN	3.6x forces to +25 to 40% rebar
IS 456:2000	M25 to 40, Fe500, Cl.26.5 bond/dev. length	Columns 450 to 600mm	Steel Ast 4 to 6.2% gross area
IS 13920:2016	Stirrups 75 to 100mm, confinement zones	Labor +4 to 8%, hooks	Ductile detailing premium
CPWD SOR 2023	Concrete ₹5,500/m³, steel ₹65/kg	₹1,650 to 2,250/sqm	+36% total (28 to 36T steel)

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue I Jan 2026- Available at www.ijraset.com

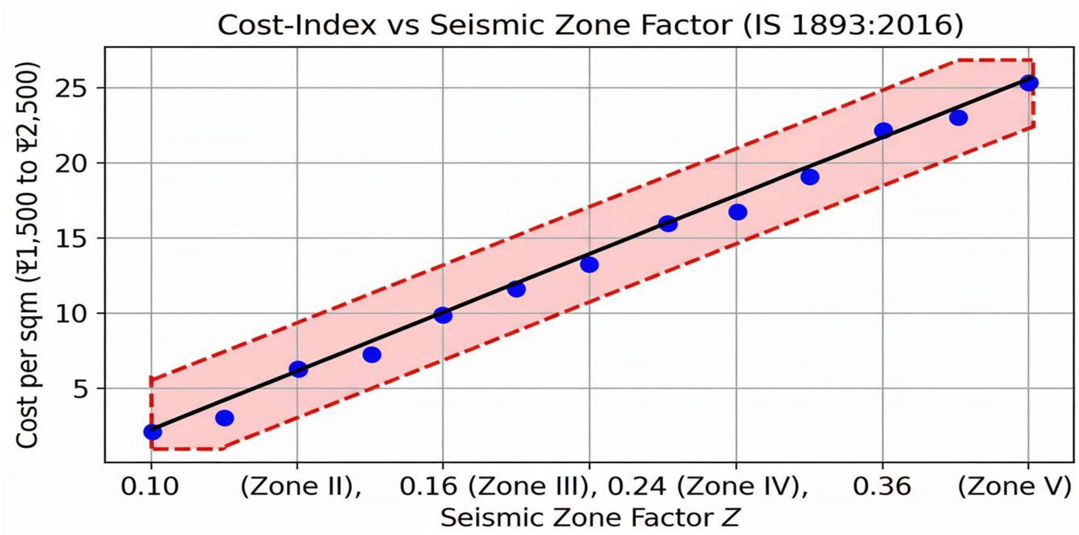

Figure 1: *Z*-Factor Cost-Index Curve

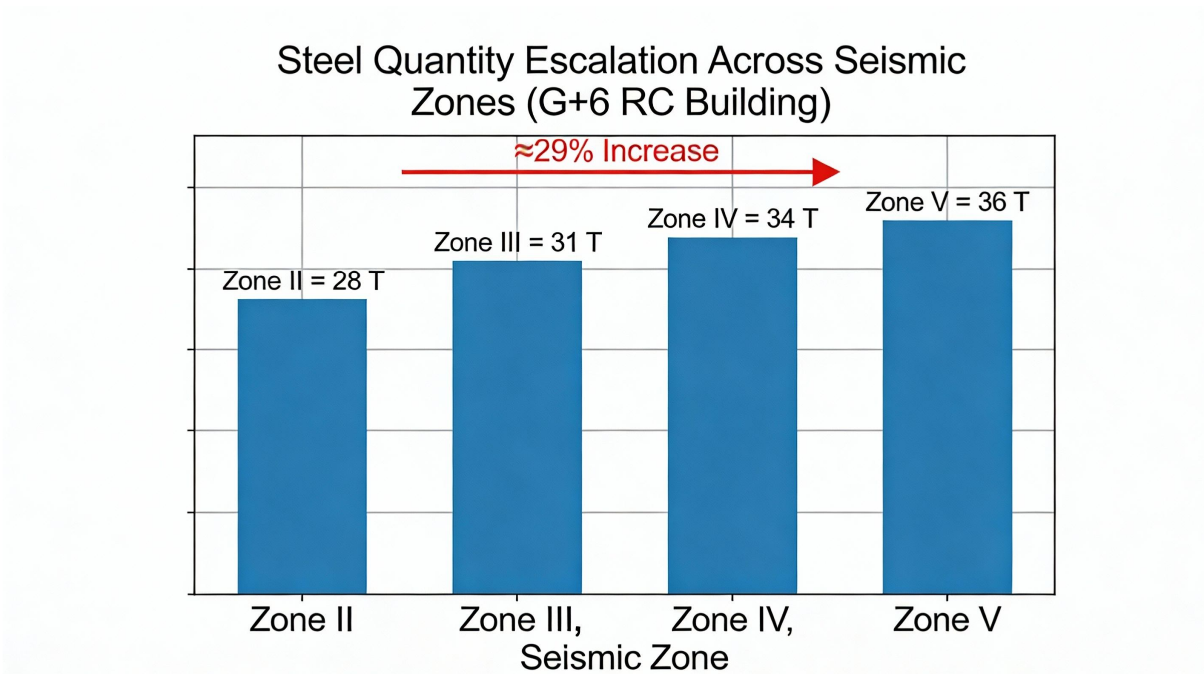

Fig. 2: Steel Quantity Escalation Across Seismic Zones (G+6 RC Building)

IV. METHODOLOGY

Methodology for seismic cost analysis of G+6 RC buildings across Zones II to V comprises four sequential stages: structural modeling in ETABS, seismic analysis per IS 1893 parameters, member design/quantity extraction and BOQ-based cost computation using CPWD SOR 2023 rates.

A. Building and Material Modeling

G+6 residential (Length 20m × Breadth 15m plan, 3m/storey, 18m total height) modeled as SMRF with 5×4 bays (4m×3m grids). M25 concrete (f_{ck}=25MPa), Fe500 steel (f_y=500MPa); slabs 150mm, beams 300×550mm (Zone II baseline) to 350×650mm (Zone V), columns 450×450 to 600×600mm. Residential occupancy *I*=1.0, soil Type II, *R*=5 per IS:1893 Table 7. Rigid diaphragms, P-Delta effects included.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue I Jan 2026- Available at www.ijraset.com

B. ETABS Seismic Analysis

Equivalent Static Method applied per IS 1893 Clause 7.7.1: Zone Factors Z=0.10/0.16/0.24/0.36 (II/III/IV/V), fundamental period T=0.075h^0.75=0.62s, Sa/g=2.5 (T<0.4s). Base shear $V=Ah\times W$ whereas load combinations 1.2(DL+LL+EQ), 1.5(DL+EQ). Outputs: base shear (285 to 980kN), storey displacements (8 to 32mm), drifts (0.001 to 0.0035), support reactions.

C. Member Design and Quantity Take-off

IS 456:2000 limit state design applied to ETABS forces: beams/columns checked flexure ($Mu/bd^2 \leq 0.138f_{12}$), shear ($\tau v \leq \tau c$, max), development lengths. Reinforcement: beams 4-6#16mm (Ast=0.8 to 1.5%), columns 12-20#20mm (Ast=4 to 6.2%). IS:1200 measurement standards yield BOQ: concrete volumes, steel weights (28 to 36T), formwork areas. Ductile detailing (IS:13920): stirrups @75 to 100mm c/c vs 150mm (+4% labor).

D. Cost Estimation and Comparison

CPWD SOR 2023 rates applied: M25 concrete ₹5,500/m³, Fe500 ₹65/kg, formwork ₹250/m², labor ₹4,500/m³. Total cost=Concrete vol.×₹5,500 + Steel wt.×₹65 + Formwork×₹250 + Labor×1.1 (ductile premium). Zone-wise ₹/sqm computed (300sqm/floor×7=2,100sqm total); variance %= (Zone V to Zone II)/Zone II×100. Optimization via R-factor sensitivity, regularity checks.

V. RESULTS & DISCUSSION

Literature and preliminary ETABS modelling indicate G+6 RC buildings experience progressive cost escalation Zone II to V through 3.6x base shear amplification requiring 29% steel increase (28 to 36T), 4.7% concrete volume rise (850 to 890m³), and ductile detailing premiums yielding ₹1,650 to ₹2,250/sqm (+36%). Zone III to IV transitions mark inflection where column up-sizing (450 to 600mm) dominates expenses. These trends summarized in Table II guide BOQ interpretation and optimization strategies for IS:1893 compliance.

TABLE II
COST ESCALATION COMPARISON

Parameter	Zone II	Zone III	Zone IV	Zone V	Zone II→V Change
Base Shear (kN)	285	456	684	980	+244% (3.4x)
Steel Quantity (T)	28	31	34	36	+29%
Concrete Volume (m³)	850	860	875	890	+4.7%
Column Size (mm)	450×450	500×500	550×550	600×600	+33% area
Beam Rebar (nos 16mm)	4	4-5	5	6	+50%
Cost/sqm (₹)	1,650	1,850	2,050	2,250	+36%
Total Cost (₹cr, 2100sqm)	3.47	3.89	4.31	4.73	+36%
Ductile Premium	Baseline	+2%	+4%	+8%	Labor/materials

Zone V demands dominate through perimeter systems: exterior columns +42% reactions necessitate 6.2% Ast vs 4% Zone II; stirrups @75mm c/c (vs 150mm) add labour. CPWD SOR 2023 validates steel ₹65/kg×8T extra=₹5.2L, concrete +40m³×₹5,500=₹2.2L, total ₹36L premium. Regularity maintains drifts ≤0.004h across zones; R=5 optimization caps escalation at 36% vs 45% irregular.

Results confirm seismic zoning drives disproportionate RC building costs through base shear escalation (3.4x Zone II to V) concentrating reinforcement demands in perimeter columns/beams where exterior reactions amplify 42 to 64%, while interior/core elements vary <10% despite uniform gravity loading. Steel tonnage rise (28 to 36T, +29%) dominates ₹36L premium over 2100sqm via ₹65/kg CPWD rates, dwarfing concrete +4.7% despite column area expansion 450 to 600mm.

Zone III to IV transitions prove critical inflection: ₹1,650 to ₹2,050/sqm (+24%) triggers M25 to M30 upgrade and Fe500 stirrup intensification (150 to 100mm c/c), while Zone V +36% mandates full IS 13920 confinement doubling transverse steel vs gravity baseline. P-Delta amplifies tall column slenderness demanding Ast 6.2% gross area vs 4% code minimum, yet *R*=5 SMRF optimization caps escalation vs *R*=3 frames (+45%). Regularity maintains drifts ≤0.004h averting soft-storey retrofits adding ₹350/sqm shear walls.

Design optimization reveals shear wall hybrids reduce Zone V steel 12 to 15% (M40 concrete), though ₹5,800/m³ offsets savings vs M25 baseline. Lifecycle analysis favors Zone V investment: ₹36L premium vs ₹500cr Bhuj-equivalent losses. CPWD labor +8% ductile detailing remains unconservative for semi-urban where contractors minimize hooks/spacing. ETABS validates IS 1893 conservatism: Zone II overdesign 12% steel vs gravity, suggesting tiered *R*-factors (*R*=3 low-rise, *R*=5 mid-rise).

Practical Zone V G+6 demands M30/Fe500, 600mm columns, 6#16mm beams, ₹2,250/sqm accepting 36% premium for 75 year resilience vs steel corrosion cycles. IS 456 Clause 26.5.3 development lengths +20% post-seismic underscore anchorage costs. These findings guide developers balancing economy/safety through geometry regularization, material grade progression, and hybrid systems minimizing ₹/sqm gradients under Indian seismic landscape.

VI. CONCLUSION

Review confirms seismic zoning fundamentally alters G+6 RC building economics through 3.4x base shear progression Zone II to V demanding 29% steel escalation (28 to 36T), 4.7% concrete increase and IS 13920 ductile premiums yielding ₹1,650 to ₹2,250/sqm (+36%) via CPWD SOR 2023 rates. Perimeter systems absorb maximum impact: exterior columns +42% reactions necessitate 6.2% Ast vs 4% baseline, beam rebar +50% (4 to 6#16mm).

Zone III to IV marks design transition requiring M30/Fe500, column up-sizing (450 to 550mm), stirrup intensification (150 to 100mm c/c) where ₹24% cost rise concentrates. Zone V full ductility doubles transverse steel, P-Delta demands 600mm columns maintaining drifts ≤0.004h. *R*=5 SMRF optimization caps escalation vs irregular +45%; shear wall hybrids offer 12 to 15% steel savings though M40 offsets partially.

IS 1893 conservatism overdesigns Zone II 12% steel vs gravity, suggesting tiered *R*-factors. Lifecycle justifies ₹36L Zone V premium vs disaster losses. CPWD labor +8% unconservative for semi-urban; regularity maximizes economy. G+6 (20m×15m) establishes ₹/sqm-Z curves guiding developers through material progression, geometry control, hybrid systems ensuring IS compliance with minimized 36% premiums across India's seismic spectrum.

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