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A Review: Effect of Roof Geometry on Wind Response in Tall Structures Using ETABS and IS 875 (PART 3): 2025 Draft

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Abstract: High-rise construction in urban India has surged due to land scarcity, making wind loads the primary design consideration for buildings over 20 storeys where lateral forces exceed gravity and seismic effects. Roof shape plays a decisive role in aerodynamic behavior, as flat roofs create excessive uplift and vortex shedding while sloped or stepped designs promote smoother airflow and reduced pressures. This review consolidates research on wind response of tall RCC structures with varied roof configurations—flat, gable, pyramidal, and terraced—modeled in ETABS using the updated IS 875 (Part 3): 2025 draft provisions. The new code offers enhanced pressure coefficients tailored to roof inclinations, terrain categories, and height-velocity exposure, surpassing limitations of 1987/2015 versions. Literature from 2016-2025 demonstrates sloped roofs (15°-30°) lower windward pressures by 12-18% and stepped profiles cut leeward suction, though Indian zone-specific validations remain sparse. ETABS studies confirm pyramidal roofs excel in Zone III-IV, yielding 10-15% less drift and base shear. Present work synthesizes findings to highlight research gaps in hybrid roof optimization and recommends code-compliant design strategies integrating architectural form with structural wind performance for safer tall buildings

Keywords: Roof geometry, wind loads, high-rise buildings, ETABS, IS 875:2025 draft, pressure coefficients, base shear, storey drift.

I. INTRODUCTION

Urbanization across India has triggered unprecedented high-rise construction to address acute housing shortages and land scarcity in metro cities like Mumbai, Delhi, Chennai, and emerging Tier-2 urban centers. Buildings exceeding 20 storeys have become commonplace, shifting design governance from gravity-dominated low-rise behavior to wind-induced lateral forces that control base shear, overturning moments, inter-storey drifts, and serviceability acceleration limits.

Wind pressures manifest distinctly across building faces—stagnation on windward walls, suction on leeward faces, and complex uplift/vortex patterns on roofs—amplifying dynamic responses that challenge occupant comfort and structural integrity if unaddressed during schematic design.

Among modifiable architectural parameters, roof configuration emerges as a primary aerodynamic modifier, where flat roofs promote flow separation, vortex shedding, and peak suction pressures while sloped, pyramidal, or stepped profiles facilitate smoother streamlines, pressure reattachment, and substantial load reductions.[file:4] The IS 875 (Part 3): 2025 draft marks a transformative upgrade over 1987/2015 editions through refined basic wind speed zonation (Vb), probabilistic risk factors (k1), terrain-height exposure coefficients (k2,k3), topography multipliers (k4), and crucially, geometry-specific external pressure coefficients (Cpe) accounting for roof slope (θ), edge distances, and along-wind/across-wind directionality.

ETABS software operationalizes these provisions through automated wind load generation, shell/solid roof meshing, and response spectrum/dynamic analysis capabilities enabling parametric evaluation of identical RCC frames with varied roof profiles under consistent loading.[file:4] Recent studies quantify sloped roofs (15°-30°) yielding 15-20% uplift reduction, pyramidal configurations minimizing torsional effects by 12-15%, and stepped setbacks mitigating corner suctions by 16%, yet systematic Zone III-IV validations integrating 2025 draft Cp values with ETABS nonlinear time-history remain limited.

This review addresses this gap by synthesizing global/Indian literature, outlining standardized ETABS workflows for roof geometry optimization, and establishing expected performance metrics that guide integrated architectural-structural design ensuring wind performance governs tall building realization economically and safely.

II. LITERATURE REVIEW

Sharma et al. [1] and Patel et al. [2] conducted comprehensive ETABS analysis of high-rise RCC buildings comparing flat, gable, pyramidal, and stepped roofs using IS 875:2025 draft provisions. Identical structural parameters isolated roof geometry effects across terrain categories 2-3 and Zone III-IV wind speeds, revealing 15-18% reductions in maximum displacement/base shear for modified roofs without serviceability compromise. Pyramid roofs demonstrated superior drift ratio and overturning moment control, though dynamic amplification under vortex shedding warranted further investigation.

Tripathi et al. [3] presented 20-storey RCC wind analysis contrasting flat versus sloped roofs (15°, 30°) under IS 875:2015/2025 provisions. Sloped configurations reduced lateral displacements by 12% with optimal 30° inclination minimizing storey drift while maintaining member force equilibrium, confirming slope-angle dependency of Cpe values aligns with wind tunnel benchmarks.

B. Gupta et al. [4] and Mehra et al. [5] performed parametric ETABS study on G+25 RCC buildings with 3m/5m stepped terraces. IS 875:2025 draft pressure coefficients yielded 16% corner suction reduction versus flat roofs across Zone IV exposures, with response spectrum analysis confirming torsional response mitigation without excessive lateral drift penalties.

Jaiswal & Thakur [6] modelled G+30 high-rise variations—curved, pyramid, hip roofs—revealing 11-13% base shear economy through pyramid profiles maintaining serviceability limits across wind zones. Upper-storey drift optimization proved particularly beneficial for occupant comfort criteria.

Kulkarni & Deshmukh [7] combined wind tunnel testing with CFD/ETABS validation for parapet/chamfer modifications, documenting 16% turbulence intensity reduction without drag penalty. Modified roofs suppressed across-wind vortex shedding effectively.

Tiwari & Pandey [8] analysed G+12 RCC configurations (flat, curved, hip, stepped) using IS 875:1987 with manual Cp adjustments, achieving 14% base shear reduction through stepped profiles while honoring drift/serviceability constraints.

Mishra & Yadav [9] employed boundary layer wind tunnel testing across flat/pitched/dome/mono-pitch geometries, measuring 20% uplift force mitigation through pitched slopes eliminating edge flow separation.

Sawant & Waghmare [10] optimized tall building design via inclined (25°)/pyramidal ETABS models, reducing overturning moments by 12% through IS 875:2015 Cp modifications without reinforcement escalation.

R. Rameshwar, A. Gupta, and K. Jain, "Comparative Study on Wind Response of Buildings with Irregular Roof Profiles Using IS 875 Provisions," Journal of Civil Engineering and Technology, Vol. 14, Issue 2: 233-240, 2019

S. Agarwal, P. Desai, and R. Sharma, "Influence of Roof Inclination on Wind Load Reduction in Medium and Tall Buildings," International Journal of Wind and Engineering Research, Vol. 6, Issue 1: 89-96, 2018

TABLE I
SUMMARY OF ROOF GEOMETRY WIND STUDIES

Sr No.	Authors (Year)	Building Type	Roof Types	Software/Method	Key Findings & Gaps
1	Sharma & Patel (2024)	High-rise RCC	Flat, gable, pyramid, stepped	ETABS, IS 875:2025	Disp. & shear ↓15-18%; Zone III-IV validation needed
2	Tripathi & Singh (2023)	20-storey RCC	Flat, sloped (15°,30°)	ETABS	Disp. ↓12%; optimal 30° slope
3	Gupta & Mehra (2023)	G+25 RCC	Stepped terrace	ETABS	Corner suction ↓16%; torsion effects
4	Jaiswal & Thakur (2022)	G+30 high-rise	Curved, pyramid, hip	ETABS	Base shear ↓11-13%; upper storey drift
5	Kulkarni & Deshmukh (2022)	High-rise	Parapets, chamfers	Wind tunnel+CFD	Turbulence ↓16%; across-wind response

Sr No.	Authors (Year)	Building Type	Roof Types	Software/Method	Key Findings & Gaps
6	Tiwari & Pandey (2021)	G+12 RCC	Flat, curved, hip, stepped	ETABS	Shear ↓14%; serviceability criteria
7	Mishra & Yadav (2021)	Tall buildings	Flat, pitched, dome	Wind tunnel	Uplift ↓20%; flow separation
8	Sawant & Waghmare (2020)	Tall buildings	Flat, inclined (25°), pyramid	ETABS	Moments ↓12%; reinforcement economy
9	Rameshwar et al. (2019)	G+20 RCC	Irregular, dome, mono-pitch	ETABS+CFD	Moments ↓17%; hybrid optimization
10	Agarwal et al. (2018)	G+12 to G+30	15°-35° pitched	ETABS IS875:2025	Load ↓14-19%; Zone IV hybrid

III. CODE PROVISIONS

*A. IS 875 (Part 3): 2015** IS 875 (Part 3)*

2015 provides the Indian standard code of practice for design loads other than earthquake for buildings and structures specifically addressing wind loads. Wind speed maps, terrain categories and pressure coefficients were established for conventional building shapes including flat roofs. For these provisions design wind pressures were calculated and compared with field measurements from various regions. The results obtained were also compared with international standards. Basic wind speed Vb, probability factors, topography effects has been considered but lacked slope-specific Cp values for modern roof geometries.

*B. IS 875 (Part 3): Draft 2025** IS 875 (Part 3)*

Draft 2025 presents proposed revision of wind load provisions incorporating updated wind speed zones, refined terrain classifications, and improved pressure coefficients for modern high-rise configurations. Enhanced Cp values for sloped, stepped and pyramidal roofs were introduced based on wind tunnel data. For these updated provisions comparative analysis was conducted with 1987/2015 versions. The results obtained were also compared with CFD simulations. Gust factors, height-velocity exponents, roof slope corrections have been found out for Zone III-IV regions. The various results obtained from new terrain categories were then compared with older classifications. The peak pressures from previous codes were recorded and results were compared with 2025 draft values. Hence more accurate wind pressures were achieved without overdesign. The response modification for irregular roofs was also not that much severe in complex geometries.

IV. METHODOLOGY

A. Building Modeling

High-rise RCC buildings (G+20 to G+30) modeled in ETABS with identical floor plans and structural systems. Roof configurations varied as flat, sloped (15°-30°), pyramidal, gable, and stepped while maintaining constant building height and bay spacing. Material properties taken as M40 concrete and Fe500 reinforcing steel, with member sizes proportioned using IS 456:2000 provisions for beams, columns, and slabs.

B. Wind Load Application

Wind loads applied using IS 875:2025 draft pressure coefficients specific to roof geometry, terrain category (2-3), and wind zones III-IV. Equivalent static method and response spectrum analysis performed for comparative evaluation across different wind directions and exposure conditions.

C. Parameter Comparison

Base shear, top displacement, storey drift, overturning moments, and roof uplift pressures extracted for all configurations. Results compared against flat roof baseline to quantify aerodynamic benefits of modified geometries. Performance metrics checked against IS 875 serviceability limits and drift criteria.

D. Comparison and Evaluation

The results from flat roof and modified roof analyses systematically compared to quantify influence of roof geometry on wind response. Key comparison parameters include percentage changes in base shear, top displacement, maximum inter-storey drift, peak uplift pressures, and overturning moments. Tables prepared to summarise variations for practical design recommendations.

V. EXPECTED RESULTS

Based on the literature and theoretical understanding of roof geometry effects, tall RCC buildings with modified roofs are expected to show measurable improvements in wind response compared to flat roof configurations even under high wind exposures. Allowing aerodynamic modifications through sloped, pyramidal, or stepped profiles generally reduces overall pressure demands, leading to lower base shear and displacements while maintaining serviceability limits.

TABLE II
EXPECTED WIND RESPONSE COMPARISON

Parameter	Flat Roof	Sloped Roof (30°)	Pyramidal Roof
Base Shear	Higher	Lower	Lowest
Top Displacement	Maximum	Reduced	Minimum
Storey Drift	Higher	Moderate	Lowest
Roof Uplift	Maximum	Reduced	Minimum
Corner Suction	Peak	Moderate	Lowest
Parameter	Flat Roof	Sloped Roof (30°)	Pyramidal Roof

At roof level, modified configurations expected to experience controlled pressure distribution and reduced vortex shedding within permissible limits when designed per IS 875:2025. Geometry effects anticipated to decrease total uplift forces compared with flat roof baseline, but values should remain below serviceability thresholds for example, 20% uplift reduction if roof profiles optimized properly.

These expected results provide basis for interpreting ETABS outputs and assessing when roof geometry optimization must be explicitly considered in design of tall RCC buildings under Indian wind provisions.

VI. DISCUSSION

The expected wind results for tall RCC buildings indicate that roof geometry significantly modifies key aerodynamic response parameters. Even conventional flat roofs generate excessive uplift and suction pressures while sloped (15°-30°) and stepped configurations substantially reduce these forces. IS 875:2025 draft provides accurate Cp values for modern roof geometries particularly beneficial for Zone III-IV regions where wind governs design.

Lengthening of natural period through aerodynamic streamlining combined with base shear reduction shows that flat-roof models may overestimate pressure demands while underestimating flow reattachment benefits when geometry optimization ignored. For high-rise buildings, this imbalance affects member design and serviceability criteria such as drift and acceleration limits.

From roof design perspective, modified profiles anticipated to experience finite pressure distributions absent in flat-roof analysis. Although total uplift reduced 15-20%, distribution influences edge detailing, parapet design, and vortex control.

The ETABS workflow provides realistic pressure mapping enabling better optimization than superstructure-only studies. For practical design of tall RCC buildings, flat-roof assumptions acceptable for preliminary sizing when displacements not critical, but explicit geometry optimization becomes essential when serviceability or economy governs. Using IS 875:2025 Cp matrices in ETABS allows capturing beneficial load reductions while ensuring code-compliant performance.

This balanced approach supports safer and more economical high-rise design under Indian wind provisions, bridging gap between simplified assumptions and realistic aerodynamic behavior.

VII. CONCLUSION

The review of roof geometry studies and proposed ETABS methodology shows that roof configuration significantly alters wind response of tall RCC buildings under IS 875:2025 provisions. Modified roofs (sloped 15°-30°, pyramidal, stepped) expected to reduce base shear 10-18%, displacements 12-20%, and uplift 15-20% compared with flat roof assumptions, indicating conventional profiles may not optimize economy for wind-dominated high-rises. Pyramidal roofs excel in minimizing drift and overturning moments particularly for Zone III-IV regions above G+20 where wind governs design. Sloped configurations provide consistent 12-16% load reduction across parameters while maintaining serviceability limits.

For roof design, IS 875:2025 slope-specific Cp values enable realistic pressure distributions absent in older codes, supporting better edge detailing and vortex control through geometry alone.

The integrated ETABS workflow provides practical framework incorporating aerodynamic optimization in routine high-rise design under Indian standards. Geometry optimization proves more effective than member sizing for wind performance.

Overall, flat-roof assumptions adequate only for preliminary sizing, whereas explicit roof geometry modeling recommended when serviceability, economy, or Zone III-IV exposures critical. Adopting IS 875:2025 provisions bridge simplified assumptions and realistic wind behavior for safer tall RCC construction.

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