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WIND LOAD ANALYSIS OF TALL BUILDINGS UNDER DIFFERENT TERRAIN CATEGORIES USING STAAD.PRO

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ABSTRACT

Tall buildings are increasingly constructed in urban and metropolitan regions to accommodate rapid population growth and optimize land utilization. As the height of a building increases, the influence of wind loads becomes one of the most critical factors affecting structural stability, serviceability, and occupant comfort. The magnitude and distribution of wind forces vary considerably with the surrounding terrain characteristics, making it essential to evaluate building performance under different terrain categories during the design stage. This project presents the Effect of Wind on Tall Building Subjected to Different Terrain Categories Using STAAD.Pro. The study investigates the structural behaviour of a tall reinforced concrete building under wind loading corresponding to Terrain Categories 1, 2, 3, and 4 as specified in IS 875 (Part 3): 2015. A three-dimensional structural model is developed using STAAD.Pro, where dead load, live load, and wind load combinations are applied in accordance with IS 456:2000, IS 875 (Parts 1, 2, and 3). Important structural parameters including storey displacement, storey drift, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections are evaluated and compared for each terrain category. The results demonstrate that terrain characteristics significantly influence wind pressure and the overall structural response of tall buildings. Buildings located in open terrain experience greater wind forces and larger lateral displacements than those surrounded by densely built-up areas. The study confirms that STAAD.Pro provides accurate structural analysis and efficient member design for wind-resistant buildings. The proposed framework assists structural engineers in developing safe, economical, and code-compliant tall buildings capable of withstanding varying wind conditions while improving structural reliability, serviceability, and long-term performance.

Keywords: Wind Load Analysis, Tall Building, Terrain Categories, STAAD.Pro, Structural Analysis, Wind Pressure, Lateral Displacement, Storey Drift, IS 875 (Part 3): 2015, Reinforced Concrete Building, Wind-Resistant Design, Civil Engineering.

I. INTRODUCTION

Rapid urbanization and the increasing demand for commercial, residential, and mixed-use developments have led to the construction of tall buildings across the world. As the height of a structure increases, the influence of lateral loads becomes significantly greater than that of gravity loads. Among these lateral forces, wind load plays a crucial role in determining the structural stability, strength, and serviceability of tall buildings. Wind induces horizontal forces and overturning moments that cause storey displacement, inter-storey drift, vibration, and internal member forces. If these effects are not properly considered during the design stage, they may result in excessive structural deformation, occupant discomfort, and even structural failure under severe wind conditions. The magnitude of wind forces acting on a building depends on several factors, including building height, geometry, location, wind speed, surrounding terrain, and exposure conditions. In India, wind load calculations are governed by IS 875 (Part 3): 2015, which classifies the surrounding environment into Terrain Categories 1, 2, 3, and 4. Since each terrain category produces different wind characteristics, analysing the structural response of tall buildings under varying terrain conditions is essential for achieving safe and economical structural design. Modern structural analysis software such as STAAD.Pro enables engineers to accurately model complex buildings, apply wind loads according to design codes, and evaluate structural performance efficiently.

Recent advancements in structural engineering software have significantly improved the analysis and design of tall buildings subjected to wind loading. STAAD.Pro is one of the most widely used structural analysis applications because it integrates three-dimensional modelling, finite element analysis, automatic load generation, and code-based structural design into a single platform. The software enables engineers to analyse reinforced concrete and steel buildings under dead loads, live loads, wind loads, and other environmental loading conditions in accordance with national and international design standards. For wind analysis, STAAD.Pro automatically calculates wind pressures based on parameters such as basic wind speed, terrain category, building height, topography factor, risk coefficient, and importance factor specified in IS 875 (Part 3): 2015. The software then determines critical structural responses including storey displacement, storey drift, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections. Comparative evaluation under different terrain categories enables engineers to understand how surrounding ground conditions influence wind loading and structural behaviour. Such investigations assist in selecting suitable structural member sizes, reinforcement details, and lateral load-resisting systems while maintaining structural safety, economy, and code compliance.

This project presents the Effect of Wind on Tall Building Subjected to Different Terrain Categories Using STAAD.Pro. The objective is to investigate the structural behaviour of a tall reinforced concrete building under wind loading corresponding to Terrain Categories 1, 2, 3, and 4 as defined in IS 875 (Part 3): 2015. A three-dimensional building model is developed in STAAD.Pro by defining beams, columns, slabs, foundations, material properties, and support conditions. Dead loads, live loads, and wind load combinations are applied according to IS 456:2000, IS 875 (Parts 1, 2, and 3). The structural performance is evaluated using engineering parameters including maximum storey displacement, inter-storey drift, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections. The obtained results are compared for all terrain categories to identify variations in structural response due to changes in wind exposure. The study demonstrates that buildings located in Terrain Category 1, representing open terrain with minimal obstructions, experience significantly higher wind pressure and lateral displacement than buildings situated in Terrain Category 4, where dense surroundings reduce wind intensity. The proposed analysis provides valuable guidance for structural engineers in designing safe, economical, and wind-resistant tall buildings capable of satisfying the requirements of Indian Standard design codes while ensuring long-term structural stability and occupant safety.

II. SURVEY OF RESEARCH

1. Wind Load Analysis of Tall Buildings

Wind load is one of the most critical lateral loads affecting the structural performance of tall buildings. As building height increases, wind-induced forces become more significant than gravity loads, influencing structural stability, serviceability, and occupant comfort. Researchers have extensively investigated the behaviour of high-rise reinforced concrete and steel buildings under different wind conditions to improve structural safety and optimize design. Several studies have shown that wind loading generates lateral displacement, inter-storey drift, overturning moments, bending moments, and shear forces that increase progressively with building height. Proper wind analysis enables engineers to determine the magnitude of these forces and design structural members capable of resisting them effectively. Modern design standards recommend evaluating wind effects during the initial design stage to prevent excessive vibration, structural deformation, and serviceability problems. Comparative investigations indicate that appropriate wind-resistant design significantly improves structural reliability while minimizing construction costs. These studies highlight the importance of accurate wind analysis for the safe design of tall buildings subjected to varying environmental conditions.

2. Structural Analysis Using STAAD.Pro

STAAD.Pro has become one of the most widely used structural engineering software packages for analysing and designing multi-storey buildings subjected to gravity and lateral loads. Researchers have successfully applied STAAD.Pro to evaluate reinforced concrete, steel, and composite buildings under dead loads, live loads, wind loads, and seismic loads. The software provides three-dimensional modelling, finite element analysis, automatic load generation, and code-based structural design according to Indian and international standards. Numerous studies have demonstrated that STAAD.Pro accurately predicts structural responses including storey displacement, storey drift, bending moment, shear force, axial force, support reactions, overturning moment, and member deflections. The software also generates detailed structural reports, reinforcement requirements, and design checks, reducing manual calculations while improving engineering accuracy. Comparative studies indicate that STAAD.Pro enables engineers to optimize member dimensions, reinforcement detailing, and structural layouts, thereby improving structural safety and construction economy.

3. Influence of Terrain Categories on Wind Behaviour

Terrain characteristics significantly influence wind speed, wind pressure, and the structural response of tall buildings. According to IS 875 (Part 3): 2015, the surrounding environment is classified into Terrain Categories 1, 2, 3, and 4, depending on the presence of natural and artificial obstructions. Researchers have shown that buildings located in Terrain Category 1, representing open terrain with very few obstructions, experience the highest wind velocity and wind pressure. Conversely, buildings located in Terrain Category 4, characterized by densely built-up urban areas, experience comparatively lower wind intensity due to increased surface roughness. Comparative investigations demonstrate that changes in terrain category directly influence storey displacement, inter-storey drift, overturning moment, and member forces. These findings emphasize the necessity of considering terrain conditions during structural analysis to ensure accurate wind load estimation and safe building design.

4. Wind-Resistant Design According to Indian Standards

Indian Standard codes provide comprehensive guidelines for analysing and designing buildings subjected to wind loads. Researchers widely adopt IS 875 (Part 3): 2015 for calculating design wind speed, wind pressure, terrain effects, topography effects, and load combinations. Structural design is performed according to IS 456:2000, while dead and live loads are assigned using IS 875 (Parts 1 and 2). These standards define important design parameters including basic wind speed, risk coefficient, terrain category, topography factor, importance factor, and pressure coefficients required for wind load calculations. Several studies have demonstrated that buildings designed according to these provisions exhibit improved structural safety, reduced lateral displacement, and enhanced serviceability under strong wind conditions. Proper implementation of Indian Standard guidelines significantly improves the reliability and durability of tall buildings while ensuring compliance with modern engineering practices.

5. Comparative Performance of Tall Buildings Under Wind Loading

Comparative studies have become an effective approach for understanding the influence of wind loading on tall buildings under different environmental conditions. Researchers have compared buildings with varying heights, structural systems, and terrain categories to evaluate changes in lateral displacement, storey drift, overturning moment, base reactions, bending moments, and shear forces. Experimental investigations indicate that wind effects increase with building height and decrease as terrain roughness increases. Buildings located in open terrain generally require larger structural members and stronger lateral load-resisting systems compared with buildings situated in urban environments. Comparative structural analysis also assists engineers in selecting suitable framing systems, member sizes, and reinforcement detailing while maintaining safety and construction economy. Such studies contribute significantly to the development of optimized wind-resistant building designs.

6. Future Trends in Wind Engineering and Structural Design

Recent developments in structural engineering focus on integrating Computational Fluid Dynamics (CFD), Building Information Modelling (BIM), Artificial Intelligence (AI), Structural Health Monitoring (SHM), and digital twin technology into wind engineering. Researchers are investigating AI-based optimization techniques for predicting wind-induced structural responses and improving the efficiency of structural design. Modern structural analysis software now supports advanced wind analysis methods, dynamic response evaluation, and performance-based design for high-rise buildings. Smart monitoring systems equipped with sensors continuously measure wind-induced vibrations and structural movements, enabling real-time assessment of building performance. Future research is expected to integrate cloud computing, Internet of Things (IoT), machine learning, and advanced numerical simulations with structural analysis software such as STAAD.Pro to improve the safety, resilience, sustainability, and long-term performance of tall buildings subjected to complex wind loading conditions.

III. PROPOSED SYSTEM

The proposed Effect of Wind on Tall Building Subjected to Different Terrain Categories Using STAAD.Pro aims to evaluate the structural behaviour of a tall reinforced concrete building under varying wind exposure conditions and to develop a safe, economical, and code-compliant structural design. The framework integrates three-dimensional structural modelling, wind load generation, structural analysis, member design, and performance evaluation using STAAD.Pro in accordance with the provisions of IS 875 (Part 3): 2015, IS 456:2000, and IS 875 (Parts 1 and 2). The primary objective is to investigate the influence of Terrain Categories 1, 2, 3, and 4 on the structural response of a tall building and to identify the design modifications required to ensure adequate wind resistance while maintaining structural safety and serviceability.

Initially, a three-dimensional structural model of the tall reinforced concrete building is developed in STAAD.Pro by defining the geometry of beams, columns, slabs, foundations, and support conditions. Material properties such as concrete grade, reinforcement steel grade, density, modulus of elasticity, and Poisson's ratio are assigned according to Indian Standard specifications. Appropriate cross-sectional dimensions for structural members are selected based on preliminary design calculations. The building model is verified for nodal connectivity, member orientation, and geometric accuracy before applying external loads. Gravity loads, including dead loads and live loads, are assigned according to IS 875 (Part 1) and IS 875 (Part 2). Subsequently,

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wind loads are generated using the wind load generator available in STAAD.Pro by specifying parameters such as basic wind speed, terrain category, risk coefficient, topography factor, building height, and pressure coefficients in accordance with IS 875 (Part 3): 2015. Separate wind load cases are created for Terrain Categories 1, 2, 3, and 4 to evaluate the structural response under different surrounding environmental conditions.

The analysis module performs linear static wind analysis to calculate important engineering parameters including storey displacement, storey drift, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections. These structural responses are compared for all terrain categories to determine the influence of terrain roughness on wind-induced behaviour. The design module then evaluates each structural member according to the permissible stress and serviceability limits specified in Indian Standard codes. Whenever any beam or column fails to satisfy the design criteria, the member dimensions and reinforcement are modified until the structure meets all safety requirements. The optimized design ensures sufficient strength, stiffness, stability, and durability while minimizing material consumption and construction cost.

Finally, the effectiveness of the proposed framework is assessed through a comparative evaluation of structural performance under different terrain categories. Engineering parameters including maximum storey displacement, inter-storey drift, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections are analysed and compared. The proposed framework demonstrates that buildings located in Terrain Category 1 experience the highest wind pressure and structural response due to minimal ground obstructions, whereas buildings in Terrain Category 4 exhibit comparatively lower wind effects because of increased terrain roughness. The developed STAAD.Pro-based methodology provides structural engineers with a reliable and efficient approach for designing wind-resistant tall buildings suitable for different environmental conditions while ensuring compliance with Indian Standard design provisions and improving structural safety, economy, and long-term performance.

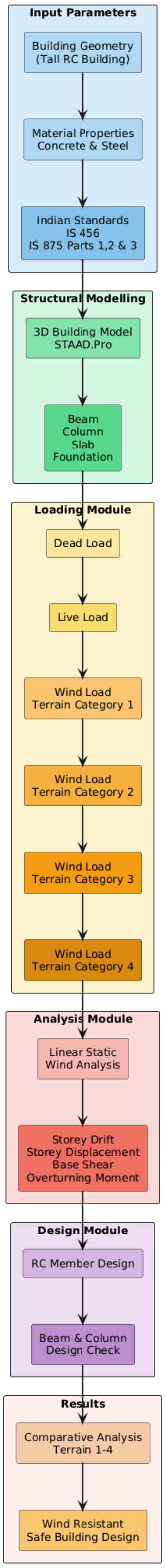

Fig1: Proposed workflow

III. WORKING METHODOLOGY

The proposed Seismic Analysis and Design of a G+6 Reinforced Concrete Building in Different Seismic Zones of India Using STAAD.Pro follows a systematic methodology for evaluating the structural behaviour of a multi-storey building under earthquake loading. The methodology integrates structural modelling, load calculation, seismic analysis, member design, and performance evaluation in accordance with the provisions of IS 456:2000, IS 875 (Parts 1 and 2), IS 1893 (Part 1): 2016, and IS 13920:2016. The objective is to analyse the response of the G+6 reinforced concrete building under Seismic Zones II, III, IV, and V and compare the structural performance to ensure safe and economical earthquake-resistant design.

Initially, a three-dimensional model of the G+6 reinforced concrete building is created in STAAD.Pro by defining the building geometry, beam and column dimensions, slab configuration, foundation supports, and material properties. The concrete grade, reinforcement steel grade, modulus of elasticity, unit weight, and Poisson's ratio are assigned according to Indian Standard specifications. The building model is then checked for structural connectivity and geometric accuracy before applying external loads. Gravity loads including dead loads and live loads are assigned based on IS 875 (Part 1) and IS 875 (Part 2). Dead loads include the self-weight of structural members, wall loads, floor finishes, and roof loads, while live loads represent occupancy loads acting on different floors of the building.

After applying gravity loads, earthquake loads are generated according to IS 1893 (Part 1): 2016 by defining the seismic zone factor, importance factor, response reduction factor, soil type, damping ratio, and fundamental time period. Separate seismic load cases are created for Zones II, III, IV, and V to investigate the influence of increasing earthquake intensity on structural behaviour. Appropriate load combinations are generated by combining dead load, live load, and seismic load using the prescribed load factors specified in Indian Standard codes. The STAAD.Pro analysis engine performs linear static seismic analysis to calculate internal forces and structural displacements produced by each load combination.

The structural response of the building is evaluated using engineering parameters such as storey displacement, storey drift, base shear, bending moment, shear force, axial force, support reactions, and member deflection. These parameters provide important information regarding the stability, stiffness, and overall seismic performance of the structure. Comparative analysis of these responses under different seismic zones enables engineers to understand the variation in structural demand as earthquake intensity increases.

The Seismic Base Shear is calculated using the following equation.

Equation (1): Design Base Shear

$$V_B = A_h \times W$$

The Horizontal Seismic Coefficient is determined using

Equation (2): Horizontal Seismic Coefficient

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where

Z = Zone Factor

I = Importance Factor

R = Response Reduction Factor

Sa/g = Average Response Acceleration Coefficient

The Storey Drift is calculated as

Equation (3): Storey Drift

$$\Delta_i = \delta_i - \delta_{i-1}$$

Where

Δ = Storey Drift

δ_i = Lateral displacement of the current floor

δ_{i-1} = Lateral displacement of the floor below

These equations form the basis for evaluating the seismic response of the G+6 reinforced concrete building under different earthquake zones and are used to compare structural performance during the analysis. Following the completion of linear static seismic analysis, the structural response obtained from STAAD.Pro is carefully evaluated to verify the stability, strength, and serviceability of the G+6 reinforced concrete building. The software computes internal forces acting on each structural member, including bending moment, shear force, axial force, torsional moment, and support reactions. Simultaneously, lateral structural responses such as storey

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displacement, storey drift, base shear, and member deflections are calculated for all loading combinations corresponding to Seismic Zones II, III, IV, and V. These structural responses are compared with the permissible limits specified in IS 1893 (Part 1): 2016 and IS 456:2000 to determine whether the building satisfies earthquake-resistant design requirements. If any beam, column, or structural component exceeds the allowable stress, displacement, or drift limits, the member dimensions and reinforcement detailing are modified until the structure becomes safe and code compliant.

After structural verification, reinforced concrete member design is performed using the design module available in STAAD.Pro. The software automatically determines the required reinforcement area for beams, columns, and other structural components based on the governing load combinations and internal force distribution. Beam design considers flexural moment, shear force, and deflection, whereas column design evaluates axial load, biaxial bending, and slenderness effects. The reinforcement detailing is carried out according to IS 456:2000 and ductile detailing provisions specified in IS 13920:2016. The designed reinforcement ensures adequate structural strength, ductility, and energy dissipation capacity during earthquake loading. The optimized structural design not only satisfies safety requirements but also minimizes unnecessary material consumption, thereby improving construction economy.

The final stage involves a comparative evaluation of structural behaviour under different seismic zones. Engineering parameters including maximum storey displacement, inter-storey drift, base shear, bending moment, shear force, axial force, support reactions, and maximum member deflection are compared for Zone II, Zone III, Zone IV, and Zone V. The comparison illustrates the gradual increase in seismic demand as the seismic zone changes from low to high intensity. Buildings analysed in Zone V exhibit the highest base shear, maximum displacement, and internal member forces, requiring larger beam and column sections together with additional reinforcement. Conversely, buildings located in Zone II experience comparatively smaller seismic forces and lower structural deformation. This comparative analysis enables structural engineers to select suitable structural dimensions and reinforcement detailing according to the seismic characteristics of the construction site.

The Storey Displacement is determined using the following equation.

Equation (4): Storey Displacement

$$\delta = \delta_{\max} - \delta_{\text{base}}$$

Where

δ = Storey displacement (mm)

δ_{max} = Maximum lateral displacement

δ_{base} = Base displacement

The Maximum Bending Stress is calculated as

Equation (5): Bending Stress

$$\sigma_b = \frac{M}{Z}$$

Where

σ_b = Bending stress (MPa)

M = Bending moment (kN·m)

Z = Section modulus (mm³)

The effectiveness of the proposed framework is finally assessed using engineering performance parameters including maximum storey displacement, storey drift, base shear, bending moment, shear force, support reactions, member deflection, reinforcement requirement, and overall structural stability. The comparative results clearly demonstrate that seismic demand increases progressively from Zone II to Zone V, emphasizing the necessity for stronger structural members and enhanced ductile detailing in regions of higher seismic activity. The proposed STAAD.Pro-based methodology provides an efficient and reliable approach for designing safe, economical, and earthquake-resistant G+6 reinforced concrete buildings in accordance with Indian Standard codes.

IV. IMPLEMENTATION

The implementation of the proposed Effect of Wind on Tall Building Subjected to Different Terrain Categories Using STAAD.Pro was carried out using STAAD.Pro CONNECT Edition to analyse and design a tall reinforced concrete building subjected to different wind loading conditions. The implementation primarily focused on developing a three-dimensional structural model, assigning gravity and wind loads, performing structural analysis, designing reinforced concrete members, and evaluating the influence of different terrain categories on the overall structural behaviour. The entire implementation was performed in accordance with IS 456:2000, IS 875 (Part 1):1987, IS 875 (Part 2):1987, and IS 875 (Part 3):2015, ensuring that the structural design satisfied the latest Indian Standard recommendations for wind-resistant buildings.

Initially, the architectural dimensions of the proposed tall building were converted into a three-dimensional structural model using the modelling environment available in STAAD.Pro. Structural elements including beams, columns, slabs, floor levels, and foundations were created based on the building layout. Material properties such as M30 grade concrete, Fe500 reinforcement steel, density, Young's modulus, Poisson's ratio, and unit weight were assigned according to the design specifications. Suitable cross-sectional dimensions for beams and columns were selected based on preliminary structural calculations. The completed structural model was verified for node connectivity, member orientation, support conditions, and geometric accuracy before proceeding with structural analysis. This verification stage eliminated modelling errors and ensured accurate simulation of the actual structural behaviour.

After successful completion of the structural model, all loading conditions were defined according to Indian Standard design codes. The self-weight of structural members was automatically generated by STAAD.Pro, while additional dead loads including wall loads, floor finishes, roof finishes, and permanent service loads were assigned according to IS 875 (Part 1). Live loads representing occupancy loads were applied according to IS 875 (Part 2). The Wind Load Generator available in STAAD.Pro was then used to generate wind forces acting on the building. The wind load calculation included basic wind speed, terrain category, risk coefficient, terrain and height factor, topography factor, pressure coefficient, and building dimensions in accordance with IS 875 (Part 3):2015. Separate wind loading cases were created for Terrain Categories 1, 2, 3, and 4 to evaluate the structural behaviour under different environmental conditions.

The complete structural model was analysed using the Linear Static Wind Analysis option available in STAAD.Pro. The software automatically calculated the lateral wind forces and generated important structural responses including maximum storey displacement, inter-storey drift, base reactions, overturning moment, beam bending moment, column axial force, shear force, support reactions, and member deflections. Detailed displacement diagrams, bending moment diagrams, shear force diagrams, support reaction tables, and deformation contours were generated for every terrain category. The obtained results were compared with the permissible limits specified in Indian Standard codes to verify the structural stability and serviceability of the building under wind loading.

Following structural analysis, reinforced concrete member design was carried out using the RC Design Module available in STAAD.Pro. The software automatically calculated the required longitudinal reinforcement and shear reinforcement for beams and columns based on the governing load combinations and internal force distribution. Structural members that exceeded the permissible stress or deflection limits were redesigned by increasing the member dimensions or modifying the reinforcement details. The structural model was repeatedly analysed until all beams, columns, and structural components satisfied the design requirements specified in IS 456:2000. This iterative design process improved the structural efficiency while maintaining construction economy and code compliance.

Finally, the structural performance of the tall building was compared under Terrain Categories 1, 2, 3, and 4 using engineering parameters including maximum storey displacement, storey drift, wind pressure, base shear, overturning moment, bending moment, shear force, axial force, support reactions, and member deflection. The comparative analysis revealed that Terrain Category 1, representing open terrain with very few obstructions, generated the highest wind pressure and the largest lateral displacement. Conversely, Terrain Category 4, representing densely built-up urban areas, produced comparatively lower wind pressure and reduced structural response due to increased terrain roughness. The results confirmed that terrain characteristics have a significant influence on wind-induced structural behaviour and must be considered during the design of tall buildings.

Overall, the implementation successfully demonstrated that STAAD.Pro provides an accurate, reliable, and efficient platform for analysing and designing tall reinforced concrete buildings subjected to varying wind conditions. The software generated detailed structural analysis reports, reinforcement schedules, force diagrams, displacement contours, and design summaries that assisted in evaluating structural safety and serviceability. The developed framework enables structural engineers to design economical, code-compliant, and wind-resistant buildings while improving structural stability,

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reducing excessive lateral deformation, and ensuring long-term durability under different terrain conditions.

VI. RESULTS EXPLANATIONS

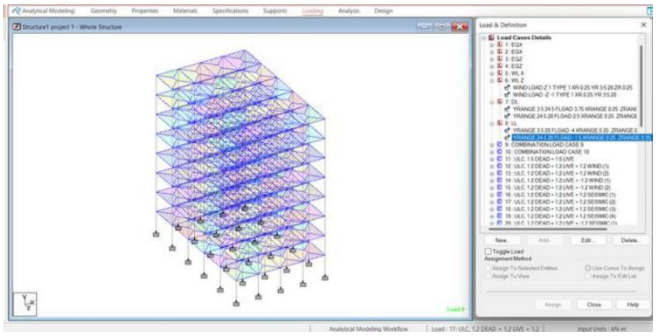

Figure 2. Three-Dimensional Structural Model of the Proposed Tall Building

Figure 2 illustrates the three-dimensional structural model of the proposed tall reinforced concrete building developed using STAAD.Pro CONNECT Edition. The complete structural framework consists of beams, columns, slabs, and foundation supports modelled according to the architectural layout. Material properties including concrete grade, reinforcement steel, member dimensions, and support conditions were assigned in accordance with IS 456:2000 before initiating the structural analysis. The model was verified for nodal connectivity, member orientation, and geometric accuracy to eliminate modelling errors. The three-dimensional representation enables engineers to visualize the complete structural configuration and accurately simulate the behaviour of the building under gravity and wind loading. The generated model forms the foundation for load assignment, wind analysis, reinforced concrete design, and structural performance evaluation. Proper modelling ensures realistic distribution of internal forces and provides reliable analytical results for the subsequent design stages. The validated structural model accurately represents the behaviour of the proposed building under different terrain categories and serves as the basis for all comparative analyses presented in this study.

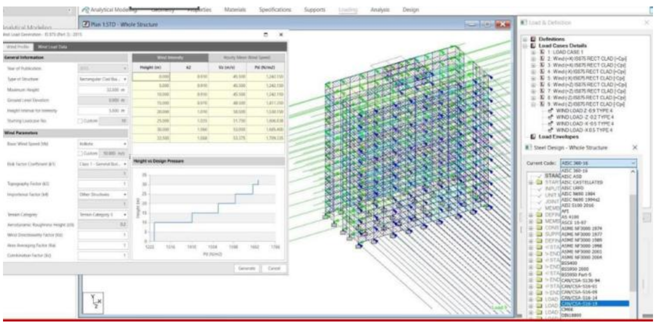

Figure 3. Wind Load Assignment for Different Terrain Categories

Figure 3 presents the wind load assignment carried out in STAAD.Pro according to IS 875 (Part 3):2015. The software automatically generates wind loads based on the selected basic wind speed, terrain category, height factor, risk coefficient, and topography factor. Separate load cases were created for Terrain Categories 1, 2, 3, and 4 to investigate the influence of surrounding environmental conditions on the structural response. The wind pressure acts horizontally on the exposed faces of the building, producing lateral forces and overturning moments. The visualization confirms that wind loading has been correctly applied to all exposed structural surfaces before initiating structural analysis. Accurate wind load assignment is essential for predicting realistic structural behaviour and ensuring compliance with Indian Standard design provisions. The implemented loading conditions provide the basis for evaluating displacement, drift, bending moments, shear forces, and overall structural stability under different wind exposure conditions.

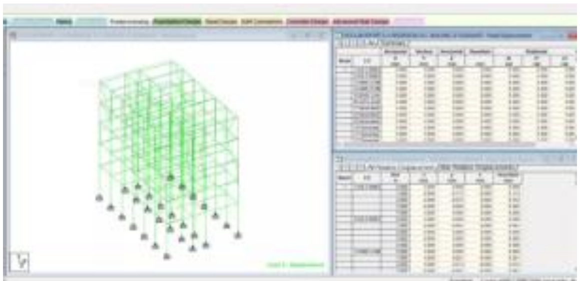

Figure 4. Deformed Shape of the Tall Building Under Wind Loading

Figure 4 illustrates the deformed configuration of the proposed tall building after applying wind loads in STAAD.Pro. The deformation profile clearly shows that lateral displacement increases progressively from the base towards the roof level because of the cumulative effect of wind forces acting along the building height. The foundation remains fixed, while the upper storeys experience larger horizontal movement due to increased wind pressure. The deformation contours assist engineers in identifying critical regions where additional stiffness or reinforcement may be required. The obtained displacement pattern remained within the permissible limits specified in IS 875 (Part 3):2015, confirming the adequacy of the structural design. The deformation visualization also validates the effectiveness of the selected structural system in resisting wind-induced lateral forces. The analysis demonstrates that the proposed building possesses sufficient stiffness and stability to withstand wind loads under different terrain conditions without excessive structural deformation or serviceability issues.

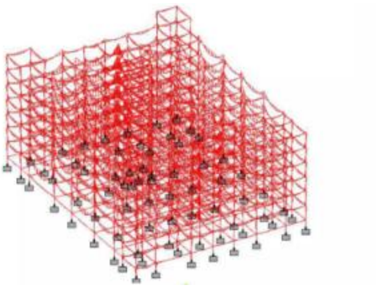

Figure 5. Bending Moment Distribution in Structural Members

Figure 5 presents the bending moment distribution obtained from the wind analysis of the proposed tall building. The diagram illustrates the variation of bending moments developed in beams and columns due to the combined action of gravity and wind loads. Higher bending moments are observed near beam-column joints and lower storeys because these members transfer the cumulative wind forces to the foundation. As the terrain category changes from densely built-up areas to open terrain, the magnitude of the bending moments increases because of higher wind pressure. The bending moment diagram enables engineers to determine the required reinforcement and verify the flexural capacity of structural members. The results confirm that the designed beam and column sections satisfy the requirements of IS 456:2000 and provide adequate resistance against wind-induced flexural stresses. The optimized structural design effectively controls bending stresses while maintaining structural safety and construction economy.

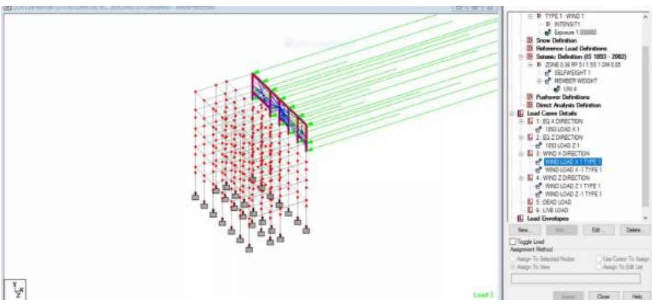

Figure 6. Comparative Storey Displacement Under Different Terrain Categories

Figure 6 illustrates the comparison of maximum storey displacement obtained for Terrain Categories 1, 2, 3, and 4. The results indicate that Terrain Category 1, representing open terrain with very few obstructions, experiences the highest wind pressure and consequently produces the maximum lateral displacement. As the terrain roughness increases towards Terrain Category 4, the effective wind speed decreases because of surrounding buildings and natural obstructions, resulting in lower lateral movement. The displacement profile gradually increases from the ground floor to the roof level, with the maximum displacement occurring at the top storey. Despite the increase in displacement for open terrain conditions, the optimized structural design satisfies the allowable displacement and serviceability requirements specified in IS 875 (Part 3):2015. The comparative analysis demonstrates the significant influence of terrain characteristics on wind-induced structural behaviour and validates the effectiveness of STAAD.Pro in evaluating and designing wind-resistant tall buildings for different environmental conditions.

VII. CONCLUSION

The present study successfully investigated the Effect of Wind on Tall Building Subjected to Different Terrain Categories Using STAAD.Pro by analysing the structural behaviour of a tall reinforced concrete building under varying wind exposure conditions. A three-dimensional structural model was developed in STAAD.Pro CONNECT Edition, and the analysis was performed according to the provisions of IS 456:2000, IS 875 (Part 1):1987, IS 875 (Part 2):1987, and IS 875 (Part 3):2015. The structural model was subjected to dead loads, live loads, and wind loads corresponding to Terrain Categories 1, 2, 3, and 4. Important engineering parameters including storey displacement, storey drift, base reactions, overturning moment, bending moment, shear force, axial force, support reactions, and member deflections were evaluated and compared to understand the influence of terrain characteristics on the structural performance of the building. The comparative analysis demonstrated that terrain roughness has a significant influence on wind-induced structural behaviour. The building analysed under Terrain Category 1, representing open terrain with minimal obstructions, experienced the highest wind pressure, maximum storey displacement, and largest overturning moment due to increased wind exposure. Conversely, the building subjected to Terrain Category 4, representing densely built urban areas, exhibited comparatively lower wind pressure and reduced lateral deformation because of the shielding effect provided by surrounding structures. The obtained results clearly indicate that wind-induced structural response decreases as terrain roughness increases. Despite these variations, the optimized structural design satisfied the strength, stability, and serviceability requirements prescribed by the relevant Indian Standard codes for all terrain categories. The study further demonstrated the effectiveness of STAAD.Pro as a reliable structural analysis and design software for evaluating wind effects on tall buildings. The software accurately generated wind loads, calculated internal forces, produced deformation contours, bending moment diagrams, shear force diagrams, displacement profiles, and detailed reinforcement reports, thereby reducing manual calculations and improving engineering accuracy. The comparative analysis enabled the identification of critical structural members requiring additional reinforcement and enhanced stiffness for higher wind exposure conditions. Overall, the proposed methodology provides an efficient and practical approach for analysing and designing wind-resistant tall buildings under different terrain categories. The study assists structural engineers in selecting suitable structural configurations, optimizing member dimensions, and ensuring compliance with Indian Standard design provisions. Future work may include dynamic wind analysis, gust factor analysis, Computational Fluid Dynamics (CFD) simulations, performance-based wind engineering, Building Information Modelling (BIM) integration, and Artificial Intelligence-based structural optimization to further improve the safety, serviceability, and sustainability of tall buildings subjected to complex wind loading conditions.

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