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Comparative Analysis of Wind Effects on High-Rise Structures Across Diverse Terrain Categories Using STAAD Pro

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ABSTRACT

STAAD Pro is a widely used structural design software that plays a crucial role in analyzing and designing buildings under various loading conditions. This study focuses on a comparative analysis of wind loads on a high-rise structure (G+15) subjected to different terrain categories (3 & 4) using STAAD Pro V8i. The primary objective of this research is to evaluate the impact of wind loads on the structural integrity and safety of buildings situated in different terrain conditions. Wind loads vary based on geographical location, terrain type, and wind velocity, which is inherently stochastic and time-dependent. In this study, wind loads are estimated for a specific zone using the basic wind speed and other influencing factors defined by the region's wind load parameters. Since buildings experience both static and dynamic forces, the combination of these loads is considered in the analysis to determine the overall structural response. The post-processing results include a detailed study of bending moments, shear forces, axial forces, and support reactions. A comparative study is conducted to understand the story-wise variation of these structural parameters under different terrain conditions. The findings of this research provide insights into how terrain category influences wind pressure distribution and structural response. Additionally, a detailed reinforcement design is carried out to ensure the structural safety and stability of the building. The results of this study are essential for structural engineers to optimize designs based on terrain-specific wind effects, thereby enhancing the resilience and efficiency of tall buildings. This research contributes to the development of safer and more reliable structural designs by considering the impact of varying wind loads in different environmental conditions.

Key Word: STAAD Pro, Wind Load Analysis, High-Rise Buildings, Terrain Categories, Structural Design, Bending Moment.

1. INTRODUCTION

The importance of wind engineering is emerging in India ever since the need for taller and slender buildings is coming forth. Considering the ever increasing population as well as limited space, horizontal expansion is no more a viable solution especially in metropolitan cities. There is enough technology to build super-tall buildings today, but in India we are yet to catch up with the technology which is already established in other parts of the world. Nowadays, Construction of high rise building is a basic need because of scarcity of land. Conventional method of manual design of high rise building is time consuming as well as possibility of human errors. So it is necessary to use some computer based software which gives more accurate results and reduce the time.

STAAD-PRO is the structural software is nowadays accepted by structural engineers which can solve typical problem like static analysis, wind analysis, using various load combination to confirm various codes. Many times, wind engineering is being misunderstood as wind energy in India. On the other hand, wind engineering is unique part of engineering where the impact of wind on structures and its environment being studied. More specifically related to buildings, wind loads on claddings are required for the selection of the cladding systems and wind loads on the structural frames are required for the design of beams, columns, lateral bracing and foundations. Wind in general governs the design when buildings are above 150 m height. However the other force which effect most on high rise building are the lateral forces caused by earthquakes. When buildings grow taller, they become flexible and they are moving away from the high frequency earthquake waves. This paper describes wind and seismic analysis of high-rise building in various zones of Indian subcontinent. For the analysis purpose a twelve story reinforced concrete framed structure is selected. The wind loads are estimated by Indian code IS: 875 (Part-3)-1987.

2. LITRATURE REVIEW

Heiza KM, et al.., (2012) The height of a building is relative and cannot be defined in absolute terms based solely on its height or the number of stories. However, from a structural engineering perspective, tall buildings or multistory buildings are characterized by their susceptibility to lateral forces, such as wind or earthquakes.

Ajitha B, Naik MN (2016) These lateral forces significantly influence the structural design of the building. A building is subjected to gravity loads, such as dead loads, live loads, and lateral loads, such as wind or earthquake loads.

Kalra M, Bajpai P, Singh D (2016) These loads are safely transferred to the earth below ground level through a system of interconnected structural members referred to as the structural system. In addition to gravity forces, lateral forces due to wind or seismic activity must be taken into account for tall buildings. The design of tall buildings is often dictated by the need to resist these lateral loads in conjunction with gravity loads.

Okafor CV, Okolie KC, Cyril ME, (2017) These oscillations are in the direction of ground motions in the case of earthquake loading and along the wind, across the wind under the influence of strong winds. As the height of the structure increases, the wind intensity also increases. At a particular height, the wind force is the governing factor in the design of the structure against lateral loading.

Raju KR, Shereef MI, Iyer NR, (2013) Many of these high-rise structures are needed in regions where wind intensity is higher. Also, in coastal regions where tornados and hurricanes are active, there is a need for wind design structures. So in this project, a wind study is done and finds the effect of wind forces on the structures for different terrain categories and zones.

K. Vishnu Haritha, Dr. I. Yamini Srivallie (2015) According to them wind effect is predominant on tall structures depending on location of the structure, height of the structure. Further they discussed their paper is equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carried out using STAAD PRO.

Kiran Kamath, Shruthi (2013) They explain the effect of different aspect ratios on the seismic performance of the steel frame structure with and without infill. Here, height of the building is kept constant and the base width is varied. Two types of frames are considered for the study, one with similar steel sections for maximum strength required for beam and column and the other with varying steel sections conforming to the strength and serviceability requirements to withstand the specified loading. ETABS is used for analysis and the comparison between the performances of frames with different aspect ratios is made using pushover curves and performance point. It is found that the presence of infill stiffness contributes significantly to the performance of the structure compared to bare frame.

D.R. Deshmukh, A.K. Yadav (2016) They explain about High-rise structures which need more time for its time consuming and cumbersome calculations using conventional manual methods. Further they used software i.e. STAAD-Pro which provides a fast, efficient, easy to use and accurate platform for analyzing and designing structures. Their main principle of this project is to analysis and design a multi-storied building G+19 (3-dimensional frame) using STAAD Pro software. The design involves analyzing the whole structure by STAAD Pro. The design methods used in STAAD-Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. They conclude that STAAD-PRO is a very powerful tool which can save much time and is very accurate in designs.

3. PROPOSED SYSTEM

The ims to analyze the impact of wind loads on a high-rise building (G+15) subjected to different terrain categories (3 & 4) using STAAD Pro V8i. The proposed system involves a systematic approach to model, analyze, and compare the structural response of the building under varying wind conditions. The analysis begins with defining the building geometry, material properties, and loading conditions in STAAD Pro. The structure is modeled as a reinforced concrete framed building, following IS 456:2000 for design parameters and IS 875 (Part-3)-1987 for wind load calculations. Two different terrain categories—Terrain Category 3 (open terrain with scattered obstructions) and Terrain Category 4 (highly dense urban areas)—are considered to understand their effect on wind-induced forces. The wind loads are applied to the structure based on the basic wind speed and terrain roughness. The study takes into account both static and dynamic load combinations to determine the overall structural response. The key structural parameters, including bending moments, shear forces, axial forces, support reactions, and story displacement, are analyzed and compared for both terrain categories. Additionally, the required reinforcement is calculated to ensure the structural stability and safety of the building under wind loads. The proposed system also includes a comparative evaluation of the total steel and concrete required for each terrain category, helping engineers optimize material usage. The final results will provide insights into how terrain variations influence wind pressure distribution and overall building behavior. By utilizing STAAD Pro for analysis and design, this study aims to enhance structural safety and efficiency while minimizing manual errors and design uncertainties in high-rise buildings.

4. RESULTS AND DISCUSSIONS

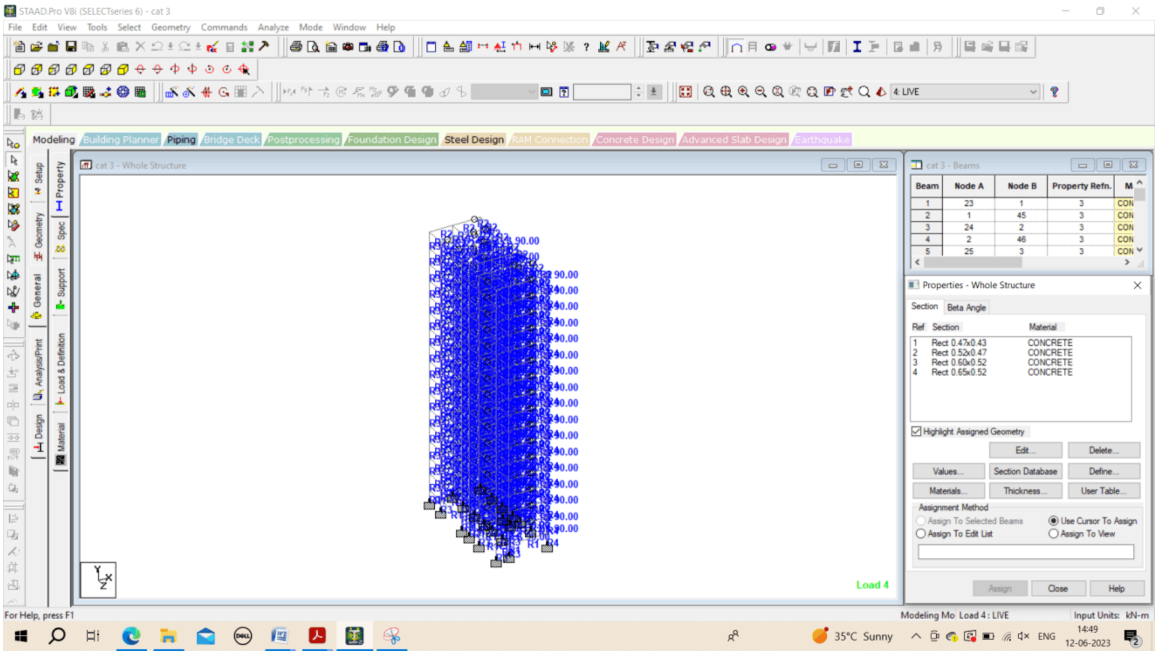

Fig 4.1: Generation of member property

Generation of member property can be done in STAAD.Pro by using the window as shown above.

4.2 SPECIFICATION

Releasing end moments to the secondary beams both at starting and end of the beams.

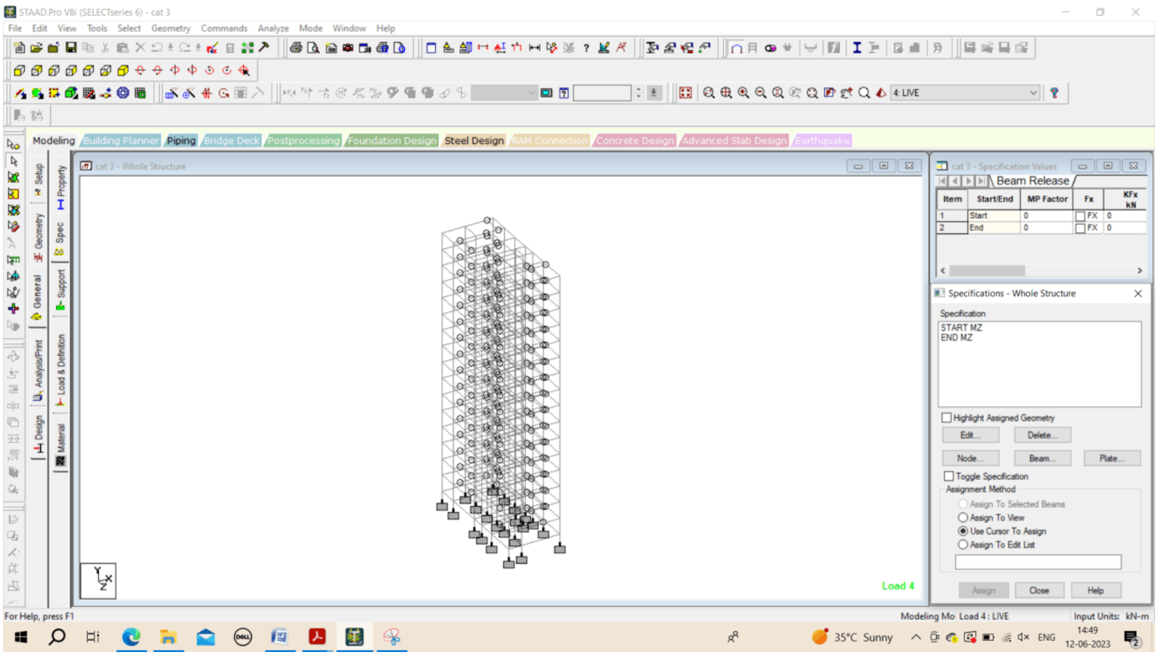

Fig 4.2: Specification (movement release)

4.3 SUPPORT

The base support of the structure was assigned as Fixed. The support was generated using the STAAD.Pro support generator

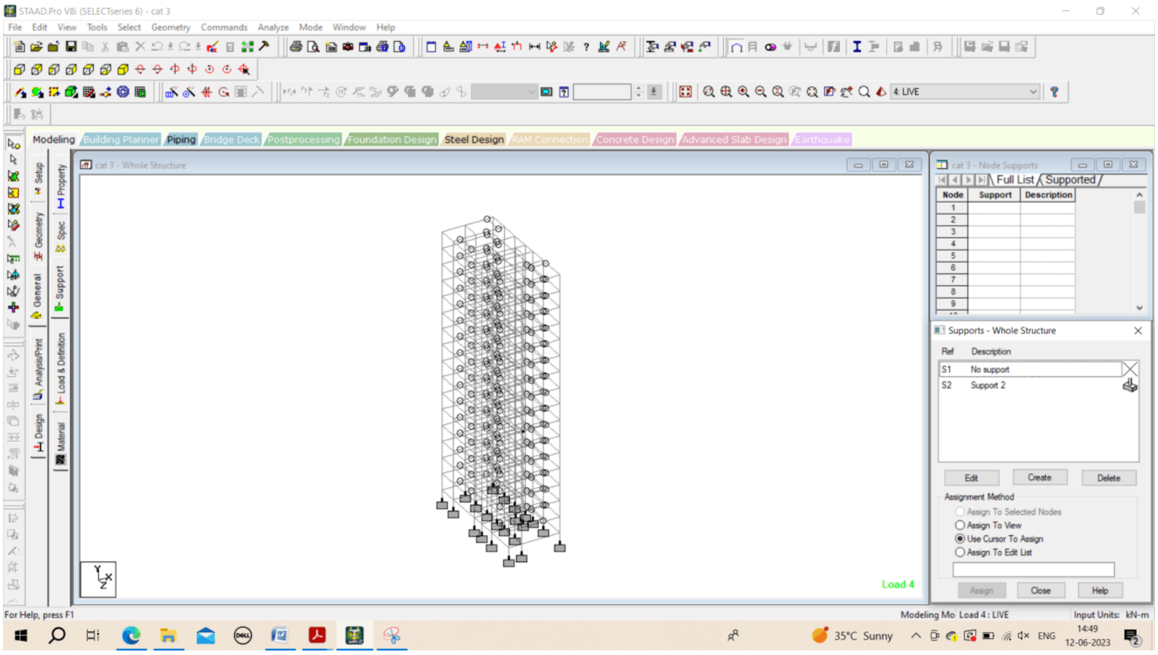

Fig: 4.3 Releasing end moments with supports

4.3 MATERIALS FOR THE STRUCTRE

The materials for the structure were specified as concrete with their various constants as per standard IS code of practice.

4.4 LOADING

The loadings were calculated partially manually and rest was generated using STAAD.Pro generator.

The loading cases were categorized as:

- ✓ Self-weight
- ✓ Dead load
- ✓ Live load
- ✓ Wind load
- ✓ Load combinations

4.4.1 SELF-WEIGHT

The self weight of the structure can be generated by STAAD.Pro itself with the self weight command in the load case column.

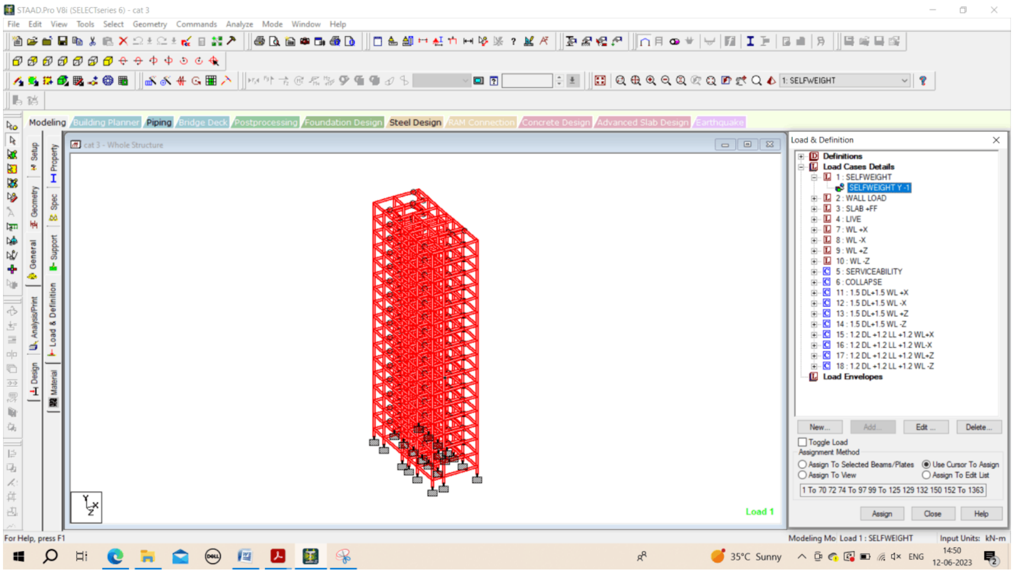

Fig. 4.4: Self weight

4.4.2 DEAD LOAD

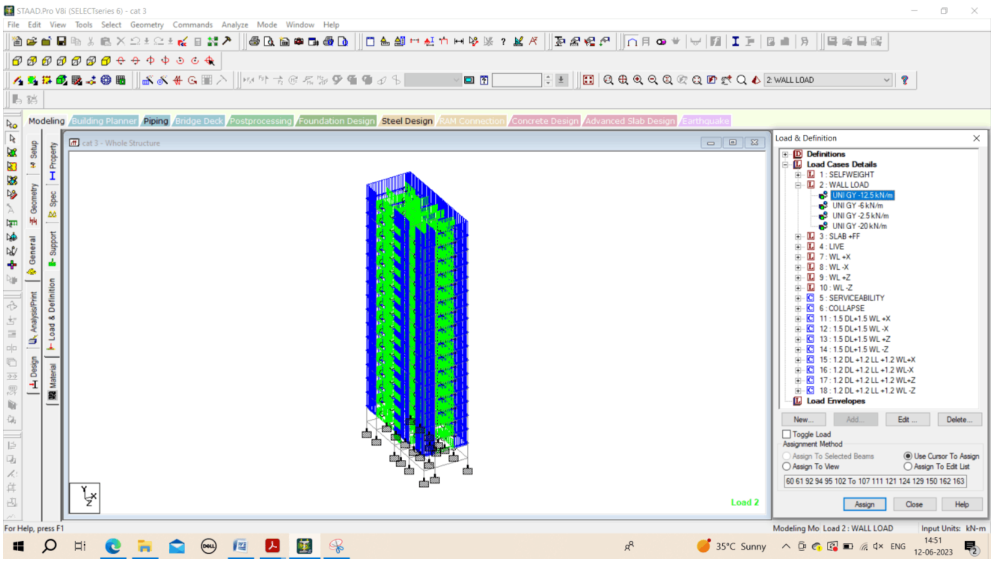

Fig 4.5: external wall load

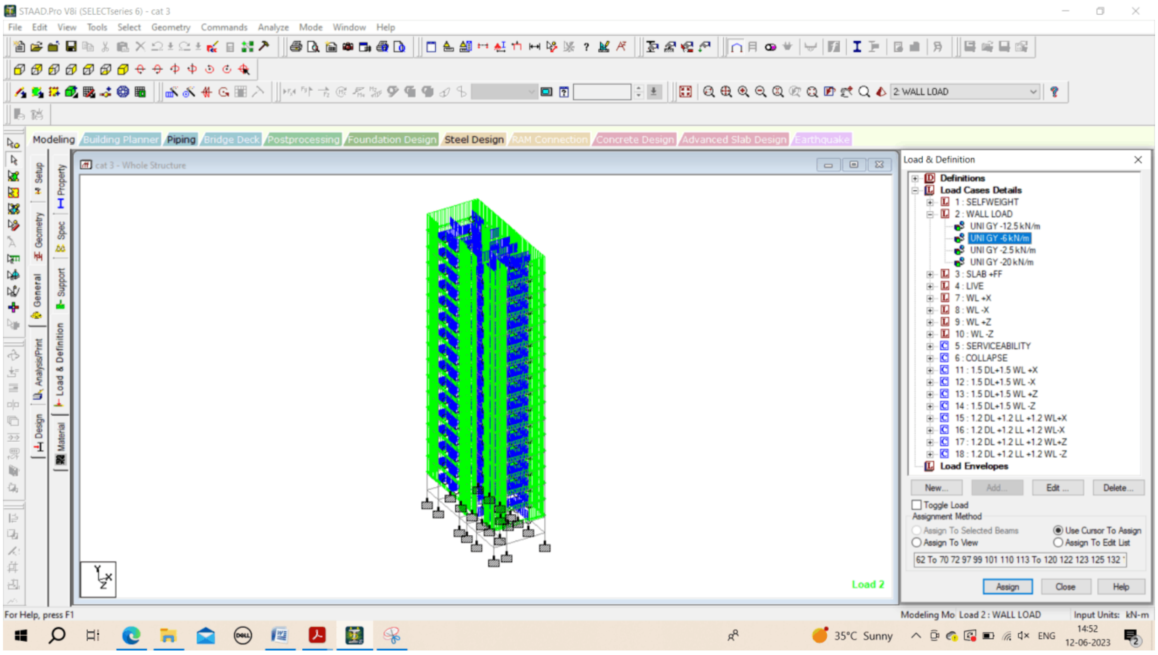

Fig 4.6: Internal wall load

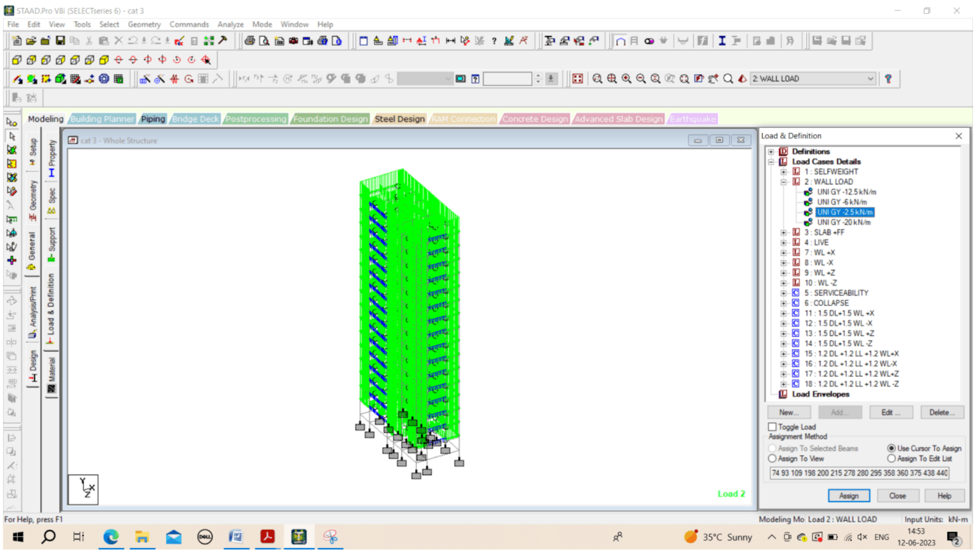

Fig 4.7: Parapet wall load

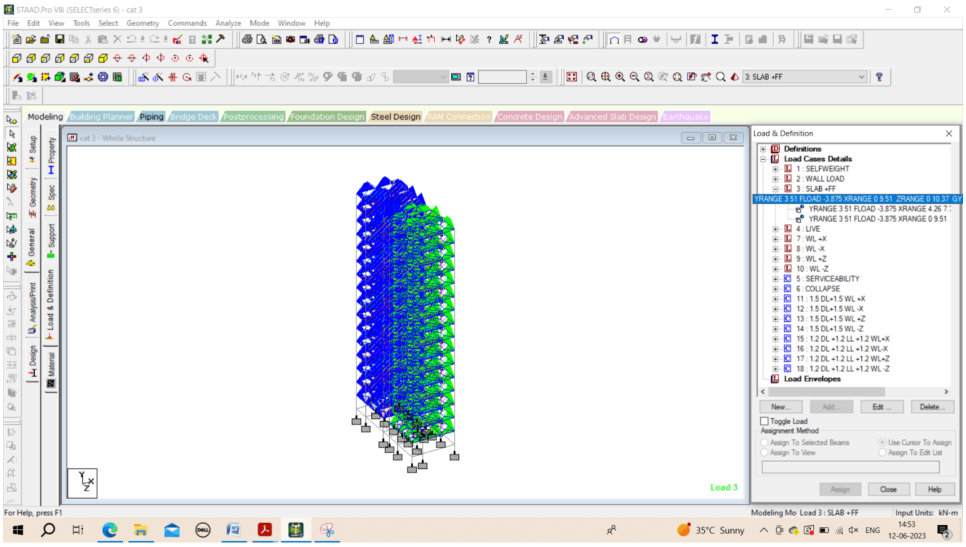

Fig 4.8: Slab + ff

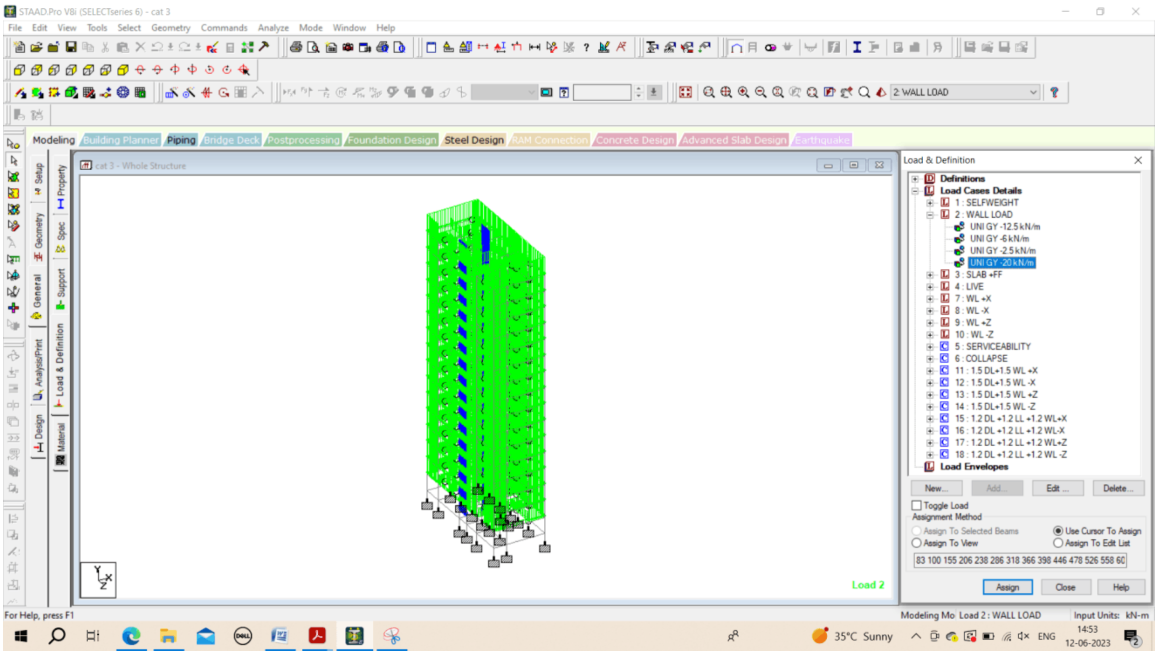

Fig 4.9: Stair case load

4.10 LIVE LOAD

The live load considered in each floor & terrace was 2 kN/sq m. The live loads were generated in similar manners as done in the earlier case dead load in floor. This may be done from the member load button from the load case column.

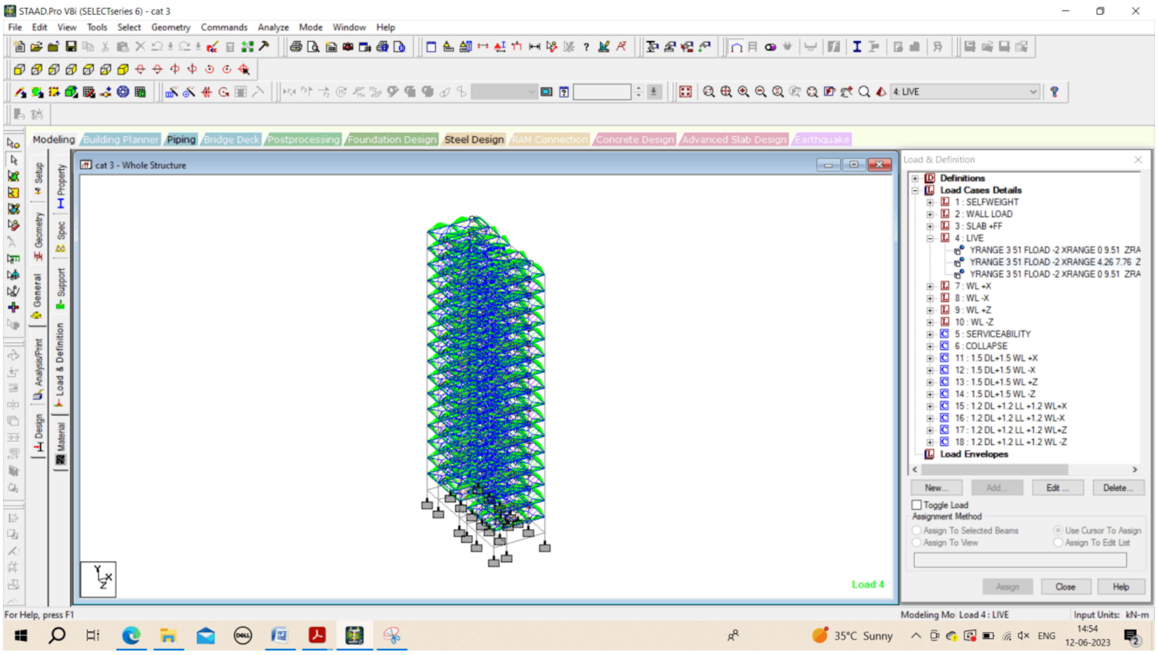

Fig 4.10: Live load

5. CONCLUSIONS

STAAD Pro has the capability to calculate the reinforcement required for any concrete section, incorporating a range of design parameters based on IS 456 (2000). In this study, the beams of the structure were designed considering flexure, shear, and torsion to ensure structural stability under varying wind conditions. The analysis reveals that the height of a structure is directly proportional to its displacement, meaning that as the building height increases, the displacement also increases. Among the different terrain categories, story displacement is found to be the greatest in Terrain Category 1 and the lowest in Terrain Category 4, indicating that rougher terrains help in reducing structural movement caused by wind forces. Furthermore, the study shows that the total steel reinforcement required for Terrain Category 4 is higher than that for Terrain Category 3, with an approximate difference of 2%. However, the volume of concrete required remains the same for both categories, and factors such as bending moment, deflection, and overall concrete design exhibit similar trends across both terrains.

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