Stress Analysis of RCC Framed Multistoried Building For Temperature Forces

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Abstract - *Multistory buildings are subjected to various environmental factors, among which thermal loads play a significant role. Changes in temperature can induce stress, strain, and deformation in structural elements, potentially compromising the integrity and safety of the building. Despite the growing construction of high-rise buildings in urban areas, there is limited understanding of how varying and uniform thermal loads affect different building heights. This research aims to address the structural response of multistory buildings subjected to thermal loads by using Staad Pro simulation software. Specifically, it focuses on the thermal analysis of G+10, G+15, and G+20 buildings under different temperature load conditions, examining the impact of both varying and uniform thermal loads on the structural behavior. Moreover, it seeks to analyze the influence of uniform temperature forces on buildings of varying heights in compliance with Indian codal provisions. Identifying the critical thermal responses in these buildings will help in designing safer and more resilient structures. The objectives of current research are to evaluate the structural response of multistory building subjected to thermal loads using Staad Pro simulation software. The thermal analysis of G+10 building is conducted with varying temperature loads. The thermal analysis of G+15 building is conducted with uniform temperature loads. The thermal analysis of G+20 building with uniform temperature loads. The story drifts at G+10, G+15, and G+20 levels are significantly within the permissible limits set by IS 1893:2016.*

Key Words: *Thermal analysis, story drift, multi-story*

1.INTRODUCTION

Reinforced concrete structures possess inherent vulnerability to thermal loads caused by factors such as fire, heat of hydration, service function, and other unavoidable conditions. The design of the structure must consider these loadings, as they may sometimes act as the main loading condition [1]. The prolonged duration of the construction process leads to the exposure of different structural components to varying temperatures. The thermal variations that cause displacements and stresses in a structure are separate from the temperatures experienced during installation and construction, which are outside the control of the designer. The design temperature change is a variable that can potentially impact temperature fluctuations within buildings. This refers to the temperature difference between the construction phase and the highest or lowest temperature of the summer or winter [2, 3]. The second element that is accessible is temperature control [1, 3]. The third component refers to the geometric system, proportions, and type of foundation connection of the buildings [1, 3]. The ultimate factor to be taken into account during the construction of the structure is the choice of construction materials [1, 3]. Multiple factors contribute to the fluctuations in temperature change and temperature gradient observed among different countries. Consequently, the use of different codes leads to variations in temperature gradients across different countries [4-7].

2. LITERATURE REVIEW

Prakarsh et. al. [8] In certain countries, steel buildings are not frequently employed. Steel-concrete composite constructions are required in major urban centers such as Delhi, Mumbai, and Bangalore due to the absence of horizontal expansion. Composite construction is extensively employed, and the steel industry is experiencing accelerated growth in nearly every country on the planet. The three primary factors of uttermost importance from a structural perspective are financial resources, construction duration, and structural integrity. In comparison to RCC structures, steel frameworks with infill demonstrate an 8% increase in maximum storey displacement.

Sattainathan et. al. [9] In contrast to RCC constructions, the steel-concrete composite technology has gained popularity in this investigation. Several engineers find the complexity of analysis and design to be a challenge. Steel-concrete composite construction is the preferred method due to its numerous benefits over traditional building methods. Steel-concrete systems offer cost-effective structural solutions that are highly durable, efficient to construct, and exhibit exceptional seismic performance, as indicated by the findings. The utilization of steel-to-concrete ratios is advantageous for composite structures.

Bhavin et. al. [10] Concrete is a prevalent construction material in India, particularly for medium- and low-rise projects. In addition, steel is frequently employed in the construction of lofty structures. Although composite construction is less common, it is feasible that it will offer supplementary advantages for medium- and high-rise structures. It is feasible to implement steel-concrete composite construction as an alternative to RCC constructions in order to optimize the benefits of steel and concrete and establish cost-effective and efficient structures. The contractor or owner is responsible for determining the essential attributes in the field, and they may subsequently select the appropriate material.

Mohd Amir Khan [11] This study investigates the advantages and characteristics of structural steel-concrete composites, which offer a more cost-effective alternative to reinforced concrete buildings and facilitate the construction of foundations. Structural frameworks that exhibit exceptional combinations of properties demonstrate increased levels of strength. In comparison to RCC frames, composite structural frames exhibit superior resistance to lateral stresses. Compared to an RCC frame, the Steel-Concrete Composite frame demonstrates a reduced overturning moment and less lateral displacement.

Gorakh Vinit [12] This article explores the methodology of designing and analyzing multistory structures using the widely acknowledged STAAD.pro software. ISMB sections are utilized to construct the joists in this case. The system creates a strong and long-lasting network that can efficiently bear the load of the slab. Wide flange sections are utilized in column design because of their superior load transformation capabilities and their strong resistance to buckling and warping.

Jyothi et. al. [13] The steel construction exhibits higher resistance compared to the RCC structure, as evidenced by the findings of the paper. When comparing steel constructions to RCC structures, it can be observed that steel constructions have a reduced dead weight. This reduction in dead weight results in a decrease in shear force and bending moment. Steel structural members demonstrate a favorable strength-to-mass ratio. Steel structural components possess a high level of density, resulting in an enhanced aesthetic appeal for tall structures and a reduction in the necessary construction area.

Paulo et. al. [14] The thermal performance of steel-decked composite pavers is examined in this study under controlled test conditions that simulate a fire starting at the base. A layer of concrete is applied onto the surface of a steel structure in this solution. Steel mesh or individual reinforcing bars, commonly known as rebars, are commonly used to enhance the strength and durability of concrete structures. Furthermore, the deck is susceptible to unintentional ignition originating from the lower region. All varieties of structures require the implementation of this composite solution to achieve fire resistance and adhere to regulatory and specification requirements.

Pallavi et. al. [15] According to research, steel is a commonly used construction material in the building of multi-level commercial structures, factories, and bridges. Both steel and concrete possess excellent adhesive properties and provide rapid construction. The two materials, which exhibit distinct differences, function synergistically and enhance each other. An object consisting of a composite structure made of steel and concrete exhibits nearly identical thermal expansion when in transit. Compared to structures that consist solely of steel or reinforced concrete, this approach is more economically efficient. The total weight of the concrete and steel structure is lower compared to that of the reinforced concrete construction due to the reduced amount of structural steel used.

3. OBJECTIVES

The objectives of current research are to evaluate the structural response of multistory building subjected to thermal loads using Staad Pro simulation software. Thermal analysis of G+10 building with varying temperature loads. Thermal analysis of G+15 building with uniform temperature loads. Thermal analysis of G+20 building with uniform temperature loads.

4. METHODOLOGY

Define the coordinate system and input the node coordinates that represent the joints of the structure. Connect these nodes with members to form beams, columns, and other structural elements. Assign the correct cross-sectional and material properties, ensuring the model accurately reflects the physical characteristics of the structure.

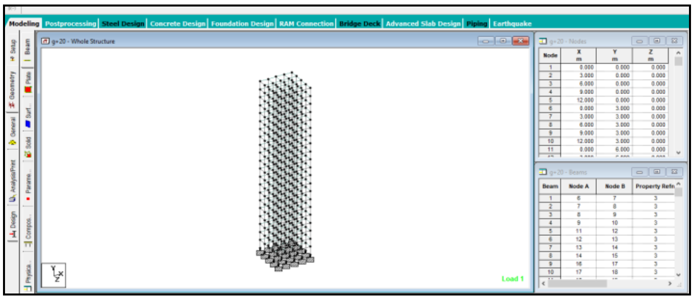

Figure 1: Modeling of nodes and wireframe model

Identify and define various load cases that the structure will encounter. These include dead loads such as the self-weight of structural elements and fixed equipment, live loads like occupancy and movable furniture, and environmental loads such as wind, seismic, and snow loads. Each load case should be defined separately to accurately reflect its impact on the structure.

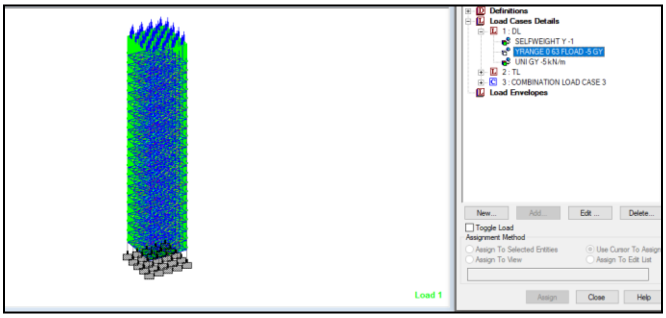

Figure 2: Floor load applied on the structure

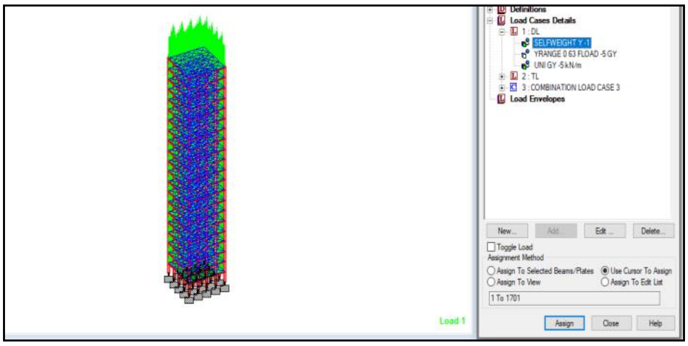

Figure 3: Self weight applied on the structure

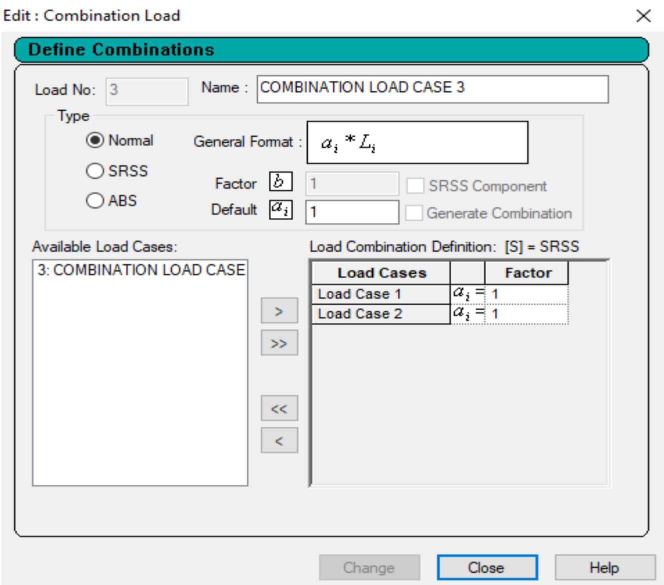

Figure 4: Load combination

Create load combinations to simulate realistic scenarios where multiple loads act simultaneously. These combinations should adhere to design codes (e.g., AISC, Eurocode) and consider the most unfavorable conditions the structure might face. Proper load combinations are vital for assessing the structure's safety and performance. In the 2nd case, all the stories of building are applied with 10^{0}C temperature magnitude as shown by figure 5.

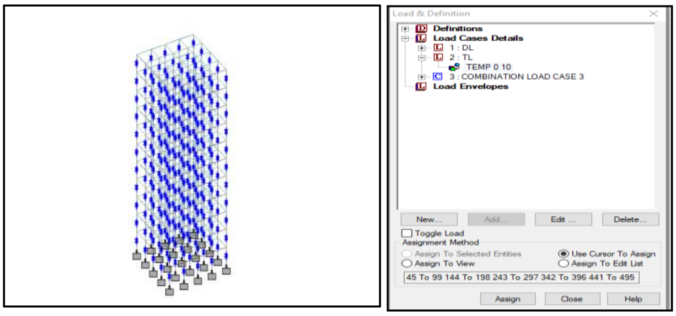

Figure 5: Applied thermal load on G+10 building

5. RESULTS AND DISCUSSION

The results of deformation, floor stresses and bending moment are obtained for G+10 building wherein all the stories are applied with 10^{0}C temperature. For determining deformation, the topmost node is selected as shown in figure 6

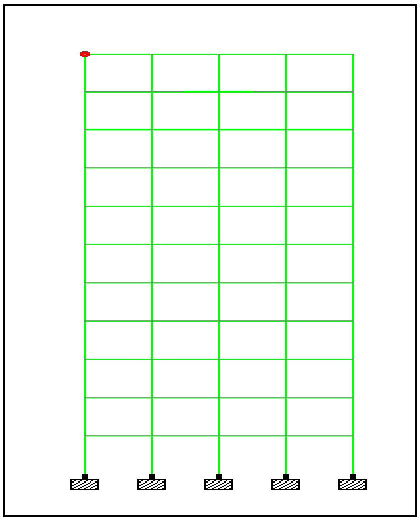

Figure 6: Top node deformation

Table 1: Nodal deformation data

Node Number	Load Condition	Horizontal disp (mm)	Vertical disp (mm)	Resultant (mm)
56	2 TL	0	0.015	0.078
	3 COMBINATION LOAD CASE 3	-0.002	-11.026	11.026

With the thermal loads applied on all the floors, the maximum induced deformation is 11.041mm. The beam deformation is obtained as shown in figure 7. The 1st floor beam is selected and the maximum deformation obtained is 0.188m.

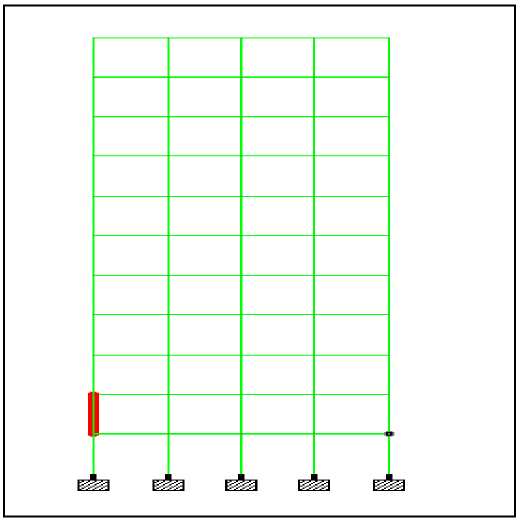

Figure 7: Column selection at the base

From the analysis, the maximum deformation on selected beam is 0.221mm. The parabolic deflection shape confirms that the beam is experiencing bending due to a symmetrical load. The maximum deflection at the mid-span (0.002 mm) is minimal, indicating that the beam is designed to be very stiff and capable of handling the applied load with minimal deformation. The equal deflection at the supports (0.001 mm) indicates symmetrical loading and possibly equal support stiffness. This symmetry and minimal deflection also suggest that the load is uniformly distributed or centrally placed, which is a typical scenario for structural analysis.

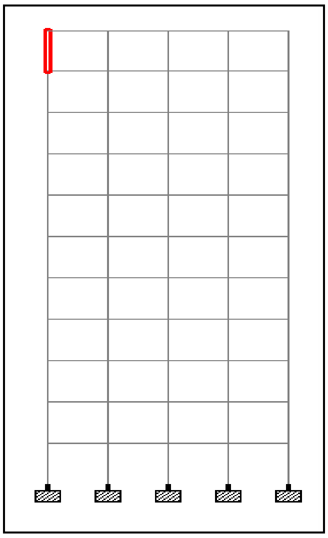

Figure 8: Column selection at the top

The deflection shape confirms that the beam is experiencing bending due to a symmetrical thermal load. The maximum deflection at the mid-span (0.234 mm) is minimal, indicating that the beam is designed to be very stiff and capable of handling the applied load with minimal deformation at the given thermal loads.

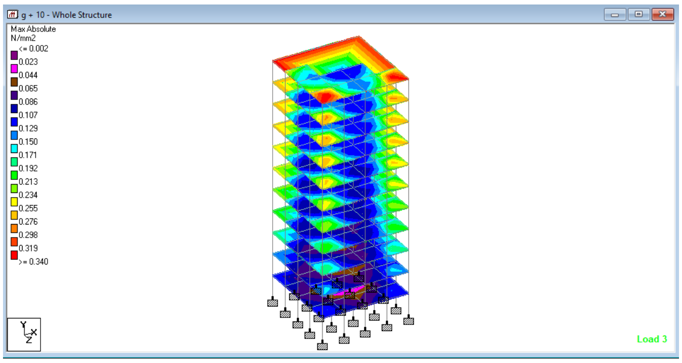

Figure 9: load combination (DL+Tl)

The lower stress distribution around the central core suggests it plays a crucial role in the overall stability of the building. The core likely houses essential structural elements like shear walls or elevator shafts, contributing significantly to the building's lateral stability. The lower stress levels in the bottom floors are typical, as these floors are closer to the foundation and primarily carry compressive loads from the upper structure. This indicates that the foundation and lower floors are well-designed to handle the cumulative loads without experiencing high stress concentrations. The plot shows higher absolute pressure at the corners of each plate with magnitude of more than 0.319N/mm^2.

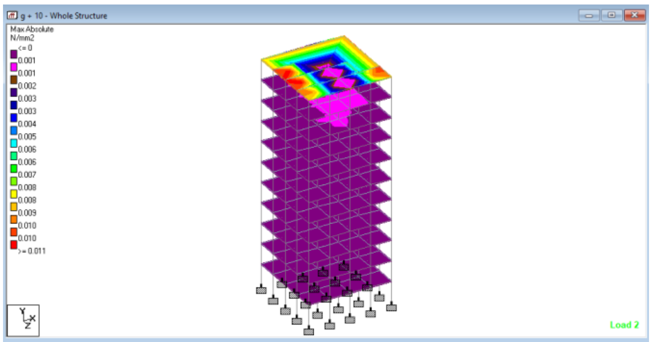

Figure 10: load combination (TL)

The maximum absolute pressure plot on building is shown in figure 10. Due to thermal load, the maximum pressure is induced on top plate with magnitude of more than .010 N/mm^2. The maximum deformation is obtained at the top of G+15 building wherein the maximum induced deformation is nearly 11.163mm. The combination of load has 11.119mm deformation.

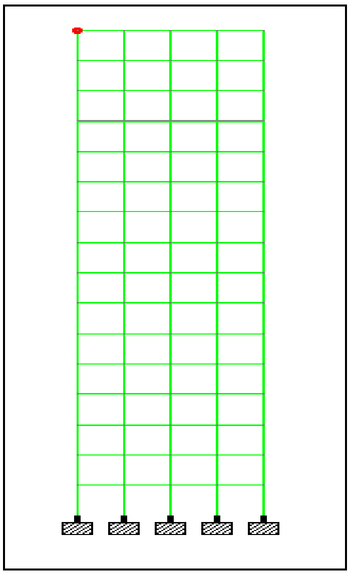

Figure 11: Nodal deformation of G+15 building

The topmost beam is selected for determining beam parameters as shown in figure 11. The maximum deformation on topmost beam element is 0.622. The induced deformation at the 1st point of beam is 0.182mm and at the end point is 0.273mm.

Table 2: Nodal deformation data

Node Number	Load Condition	Horizontal disp (mm)	Vertical Displacement (mm)	Resultant disp (mm)
81	1 DL	0.008	-11.163	11.163
	2 TL	0.273	0.048	0.277

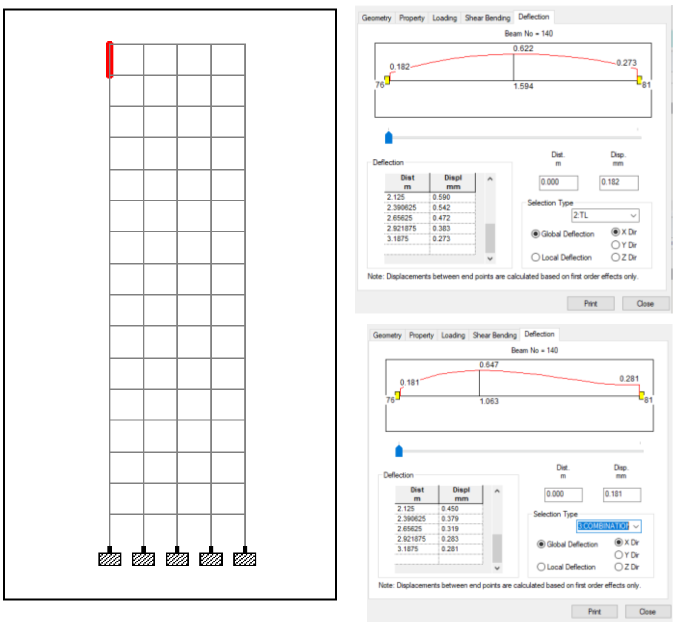

Figure 12: Topmost floor beam deformation

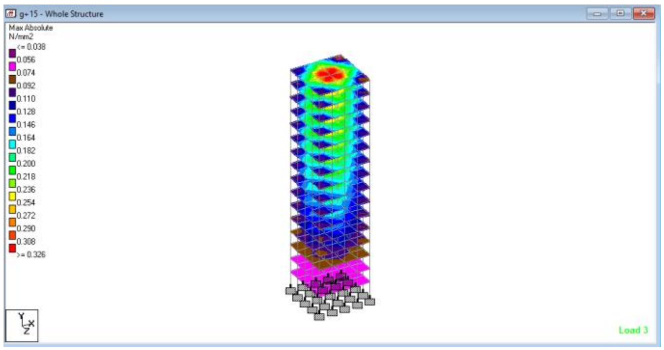

Figure 13: max absolute pressure plot

The maximum absolute pressure on plate is generated as shown in figure 13 above. The plot shows higher normal stress induced on top center plate with magnitude of .308N/mm^2. The absolute pressure is lower on other floors as represented in green and yellow colored plots. The lower stress distribution around the central core suggests it plays a crucial role in the overall stability of the building. The core likely houses essential structural elements like shear walls or elevator shafts, contributing significantly to the building's lateral stability. The lower stress levels in the bottom floors are typical, as these floors are closer to the foundation and primarily carry compressive loads from the upper structure. This indicates that the foundation and lower floors are well-designed to handle the cumulative loads without experiencing high stress concentrations.

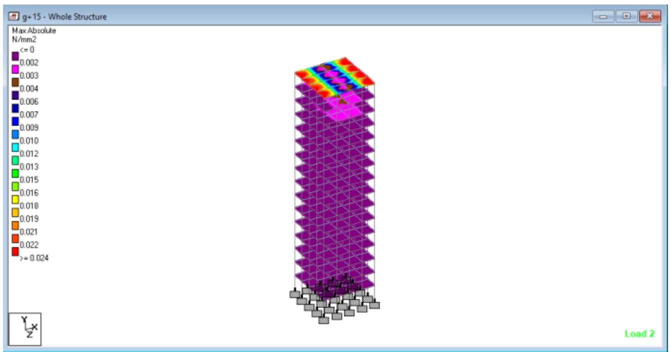

Figure 14: max absolute pressure plot for Thermal loading

The absolute pressure plot on plates due to thermal loading is shown in figure 14 which shows higher absolute pressure at the topmost plate wherein the magnitude is nearly .022N/mm^2.

6. CONCLUSIONS

When story changes from G+10 to G+15, the story drift increases by approximately 259.2%. This substantial increase indicates a significant rise in lateral deformation as the building height increases from G+10 to G+15. When number of stories changes from G+15 to G+20, the story drift increases by approximately 33.0%. The rate of increase in lateral deformation is slower compared to the increase from

G+10 to G+15 but still significant. When number of stories G+10 to G+20, overall, the story drift increases by approximately 377.6%. This highlights the progressive increase in lateral deformation as the building height increases from G+10 to G+20. These findings indicate that lateral deformation becomes more pronounced as the building height increases. The significant increase in story drift, especially between G+10 and G+15, suggests that structural design considerations need to account for increased lateral forces and potential deformations at higher elevations to ensure stability and safety.

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