Structural Analysis And Performance Evaluation Of The G8 Building Under Various Load Cases

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Abstract

It is common knowledge that the principles of civil engineering have been disseminated around the globe. In addition, it has been rapidly spreading over the past few years. The idea of civil engineering is front and centre in India's development efforts at the moment. As Civil Engineers, one of our responsibilities is to be able to study and design different components of buildings, such as beams, columns, slabs, and so on. Within the scope of this term project, STAAD. Pro is utilised for the research and design of a G+8 commercial building. STAAD. Pro and Pro are the two most well-known pieces of design software now on the market, and a large number of design companies make extensive use of them. The findings that were obtained via the process of designing a building utilising the softwares are going to be presented as the primary emphasis of this study. As part of the design phase, you will need to calculate the load (including live load, dead load, and wild load), as well as examine the complete structure. Limit State Designs, which are in accordance with the Indian Standard Code of Practise, are the design methods that are applied while using both of these software packages. The basic objective of a structural engineer is to make use of available technology to build a structure that is not only secure but also economical, with the end goal of gaining the confidence to design structures that are progressively larger and more complicated. STAAD. Pro softwares come equipped with a variety of capabilities, including a contemporary user interface, visualisation tools, and more.

Key word: India's development efforts, Building design, STAAD. Pro software, Commercial building, Load calculation, Structural engineering, Limit State Designs, Structural analysis

Introduction

Human society need order in order to function as a whole. The building's construction should prioritise its functionality as a public service. A building is just an enclosed area with walls and a roof that is meant to provide protection from the elements for humans. "When it comes to public works like roads, bridges, canals, dams, airports, sewage systems, pipelines, structural elements of buildings, and trains, civil engineers use calculus, physics, and mechanics to plan, design, construct, and maintain these infrastructures". Prehistoric peoples sought refuge in caves from the elements and predators alike. Timbers, often known as wood material, became the dominant construction material after that. Newer homes are increasingly standalone or multi-story structures. Indicators of a country's social development include its built environment [4]. There have been several recent advancements in the field of building construction. In order to meet the demands of the people, the structures are constructed cost-effectively. The construction of the structures is very rapid. Structure analysis is the process of determining how a structure will react to imposed forces. The expected external loads are used

to assess the loads delivered to the structure during the preliminary design phases. The size of each member and the amount of reinforcement it needs are calculated. Through structural analysis, a connection is made between the external loads acting on the members and the internal forces and displacements acting within the members to counteract those loads.

Nowadays, a wide variety of structures are analysed and designed using structural engineering software. Structural engineers can easily analyse and design a wide variety of structures using software like STAAD. Pro due to the software's flexible modelling environment, state-of-the-art features, and adaptable data collaboration. This includes, but is not limited to, buildings, bridges, towers, structures for transportation, industry, and utilities. As a result, time-consuming manual labour and mistakes are no longer necessary.

Literature Review

Gupta, N. K., Kashyap et al (2023): To ensure safety, functionality, durability, economy, and aesthetics, structural designers strive for these goals in every project. Designing an entire structure calls for in-depth information, creative thinking, and practical expertise. "Analysis and Design of a G+4-story residential building in STAAD. Pro Software in accordance with the provisions of the Indian Building Code. AutoCAD was used for all the drafting" and detailing, which then allowed the structure to be sent to STAAD. Pro for analysis and design. Beam, column, slab, and foundation designs are initially completed in STAAD. Pro using the "Limit State Method" at a seismic zone-II location. IS: 875-2016 (part 1, part 2) and IS: 1893-2005 (seismic load) are taken into account to account for the various loads placed on the member. The results, such as the bending moment, the drift of the storeys, the displacement of the storeys, the shear at the base, etc., are recorded and evaluated for reliability. Then, using the STAAD. Pro programme, we repeat the process in seismic zone-IV with the same loading circumstances. The project's conclusions are finally validated by comparing the results from the seismic zone-IV design to those from the seismic zone-II design.

Giri, R. A., Khan, A., Shende (2021): In this piece of writing, the Author made an effort to centre their attention on a residential building. The purpose of this project is to conduct research and design for the purpose of building a structure that is capable of withstanding all loads that are applied without breaking down for the duration of its intended life. The process of designing a structure involves a number of steps, some of which are the computation of loads, the design of members, and the detailing of various elements. The usual approach to structural design and analysis results in a great deal of complexity as well as laborious calculations that take up a great deal of time. In today's world, quick software is required in order to successfully complete a design and analysis. Using STAAD. Pro, the computer-aided design process for a residential building includes the following steps: generating a structural frame plan; getting a model; performing an analysis of the structure; and designing the structure. (Wailkar et al., 2021)

Yogesh Solanki, et al. (December 2021): "STAAD. Pro Analysis and Design of a Residential Tower with a Shear Wall: The planning, analysis, and design of a G+16 multi-story building was completed. It was a G+16 building, where G represents the ground level and 16 the number of stories above it, all of which housed apartments". The whole structural elements were created by hand, with AutoCAD only used for the detailing. STAAD. Pro was used for both static and dynamic analysis and design to ensure compliance with industry standards. Members' deflection was measured across a wide range of loading conditions. To address the design problems, this project's primary focus was on the conceptual study and design of a high-rise, multi-story residential complex in STAAD. Pro The necessary amount of reinforcement was determined by testing various active load cases.

Shaikh Ibrahim, et al. (April 2019): "After considering factors including dead load, live load, wind load, and seismic load during the design and analysis of a G+4 residential building, it was determined that the construction was safe". The nature and magnitude of the loads imposed served as inputs towards the sizing of structural members (beams, columns, and slabs). With AutoCAD, you may get exact measurements and count of structural elements. The software is executed by STAAD. Pro Details such as the number of beams, their locations, and their distances apart were planned for flexure, shear, and tension.

Objectives Of Study

- Analysis and designing of a G+8 commercial steel building by STAAD. Pro
- Compare the horizontal displacements, support reactions, axial forces in columns, shear forces and bending moment in beams.

Methodology

- **Step - 1:** Development of points that serve as nodes. The column positioning of the plan served as the basis for our entry of the node points into the STAAD. Pro file.
- **Step 2:** Creating of Rectangle Beam, column and plate. We drew the beams and columns using the add beam command to connect the node points that corresponded to each beam and column.
- **Step 3:** is a 3D visualisation of the structure. In order to obtain a three-dimensional perspective of the construction, we have applied the Transitional repeat command in the Y direction here.
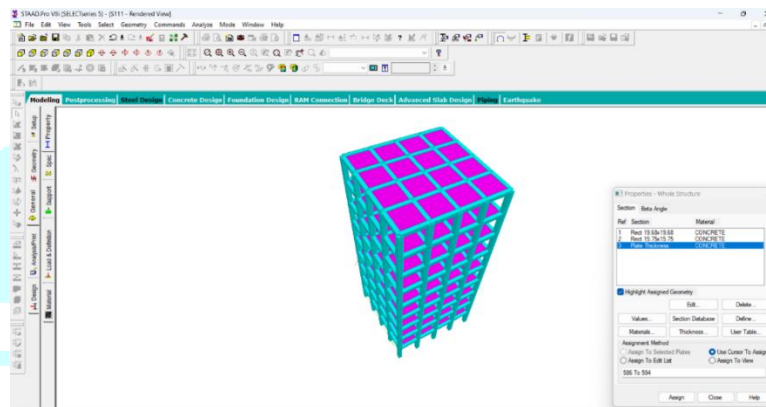

Figure 1: 3D visualisation

- **Step 4:** involves assigning supports and properties. After the structure has been created, the supports that are located at the structure's base are designated as being fixed. In addition, the materials were designated, and the cross sections of the beams, columns, and members were decided upon.
- **Step - 5:** 3D rendering view. The three-dimensional depiction of the construction can be displayed once the property has been assigned.
- **Step 6:** involves the distribution of wind loads. In accordance with IS 875 PART 3, wind loads are established on the basis of the computed intensity and the exposure factor. After that, loads are added in the load case details in the +Z,-Z, and +X -X directions respectively.
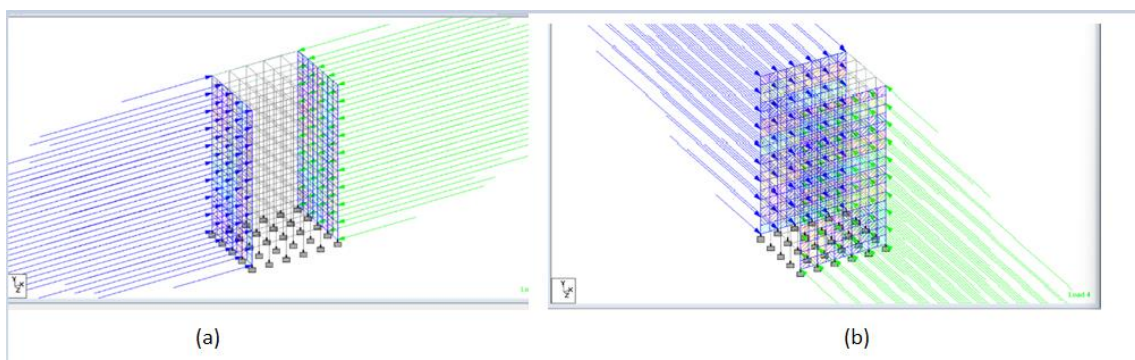

Figure 2: (a) wind loads in X direction (b) wind loads in Z direction

- **Step 7:** assignment of dead loads. Calculations of dead loads are performed these calculations also take into account the structure's own weight.
- **Step 8:** involves the assignment of live loads. the live loads for each level have been determined to be 3 kN/m^2.

- **Step 9:** involves the addition of various load combinations. After all of the loads have been assigned, the load combinations are presented with an appropriate factor of safety.
- **Step - 10:** Analysis Following the completion of all of the Steps that came before it, we carried out the analysis and checked for mistakes.
- **Step - 11:** Design. Last but not least, the design of concrete is carried out in accordance with IS 456: 2000 by specifying appropriate design directives for various structural components. After we had finished assigning commands a second time, we did an analysis to check for problems.
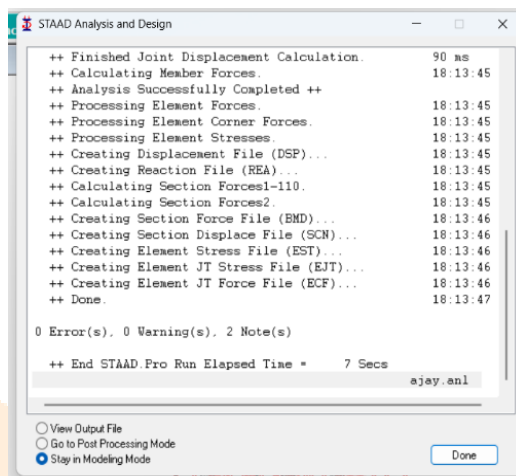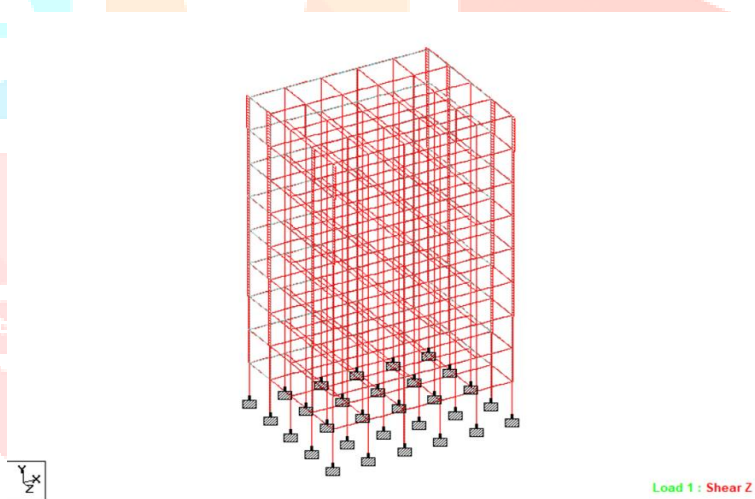

Figure 3: STAAD. Pro Pre processing

Results

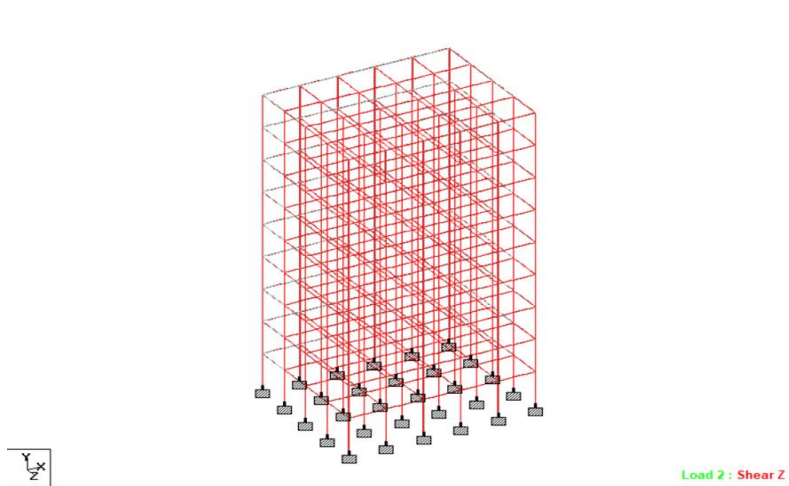Figure 4: Shear force in Z direction due to dead load

Figure 5: Shear force in Z direction due to Live load
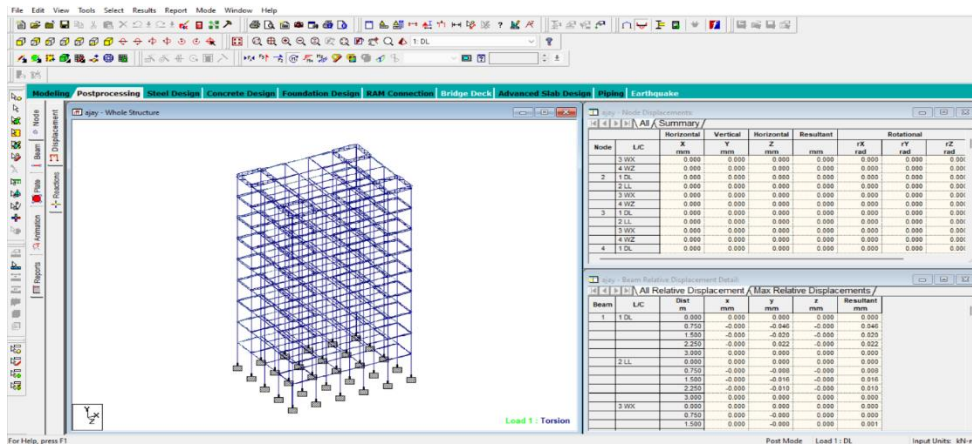
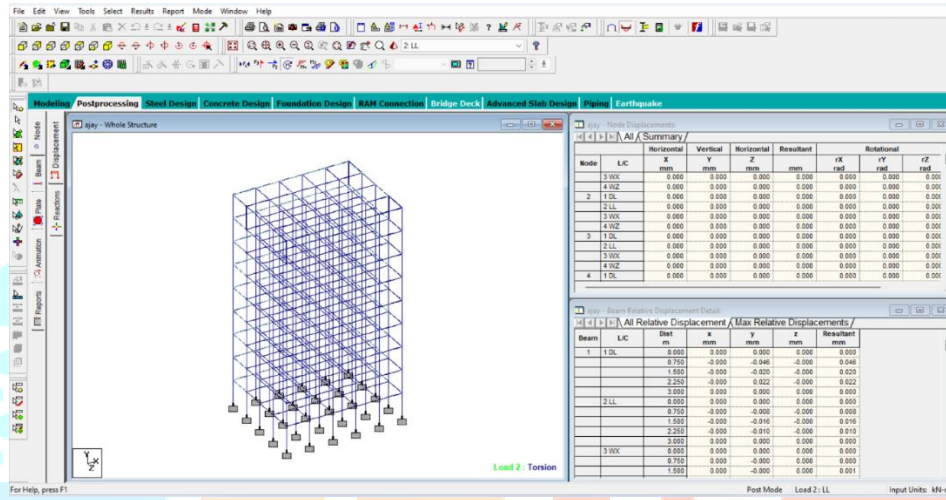Figure 6: Torsion due to dead load
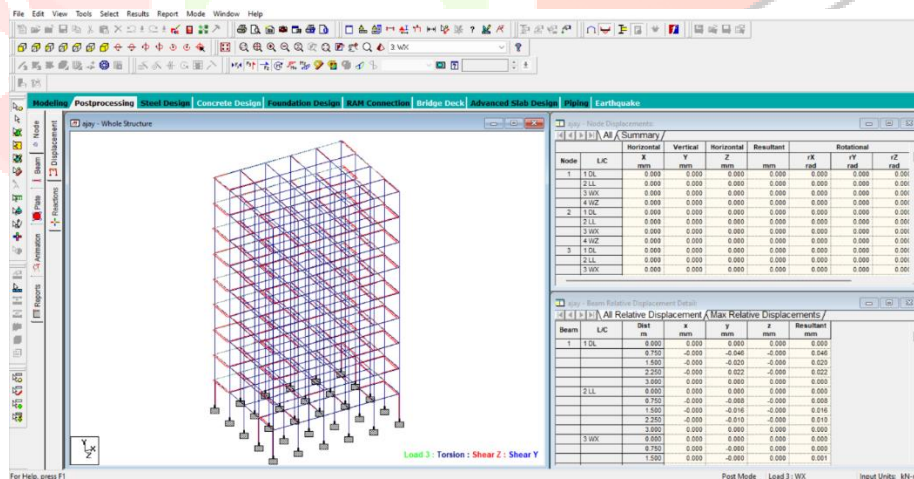

Figure 7: Torsion due to Live load

Figure 8: Torsion, shear force in Z and Y direction due to wind load in X direction
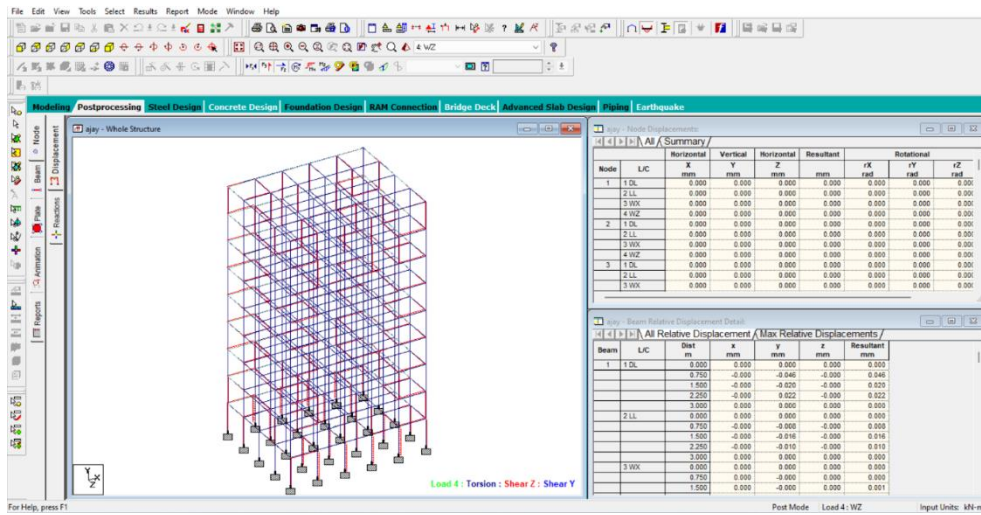
Figure 9: Torsion, shear force in Z and Y direction due to wind load in Z direction
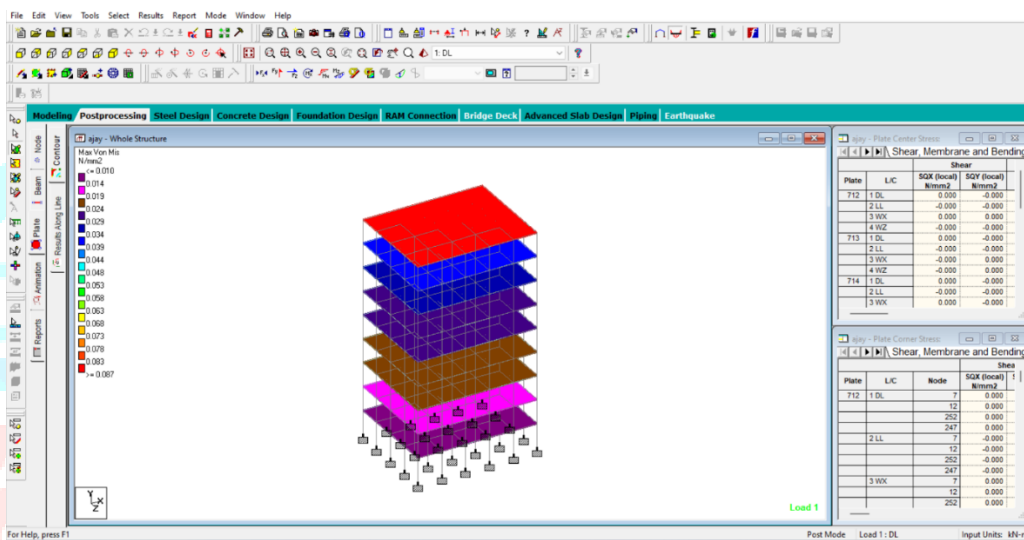

Figure 10: Max Von Miss

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	rX rad	rY rad	rZ rad
Max X	59	1 DL	0.015	-1.326	-0.006	1.327	-0.000	0.000	-0.000
Min X	56	1 DL	-0.015	-1.326	-0.006	1.327	-0.000	-0.000	0.000
Max Y	178	4 WZ	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000
Min Y	55	1 DL	-0.006	-3.314	-0.010	3.314	-0.000	-0.000	0.000
Max Z	240	1 DL	0.009	-1.331	0.014	1.331	0.000	-0.000	-0.000
Min Z	120	1 DL	0.009	-1.331	-0.014	1.331	-0.000	0.000	-0.000
Max rX	240	1 DL	0.009	-1.331	0.014	1.331	0.000	-0.000	-0.000
Min rX	120	1 DL	0.009	-1.331	-0.014	1.331	-0.000	0.000	-0.000
Max rY	60	1 DL	0.006	-3.314	-0.010	3.314	-0.000	0.000	-0.000
Min rY	300	1 DL	0.006	-3.314	0.010	3.314	0.000	-0.000	-0.000
Max rZ	56	1 DL	-0.015	-1.326	-0.006	1.327	-0.000	-0.000	0.000
Min rZ	59	1 DL	0.015	-1.326	-0.006	1.327	-0.000	-0.000	-0.000
Max Rs	55	1 DL	-0.006	-3.314	-0.010	3.314	-0.000	-0.000	0.000

Figure 11: summary of displacement in Node

displacements of different nodes in the G8 building, specifically in the context of their horizontal (X, Y) and vertical (Z) directions. Here is an interpretation of the table:

- Node: The identification number or name assigned to each node in the G8 building.
- L/C: Indicates the load case or condition under which the displacements were measured.
- Horizontal X (Displacement): Represents the displacement in the X-direction (horizontal) for each node. The values indicate the magnitude of displacement measured in millimeters.
- Horizontal Y (Displacement): Represents the displacement in the Y-direction (horizontal) for each node. The values indicate the magnitude of displacement measured in millimeters.
- Horizontal Z (Displacement): Represents the displacement in the Z-direction (vertical) for each node. The values indicate the magnitude of displacement measured in millimeters.
- Resultant (Displacement): Represents the overall or resultant displacement for each node, combining the displacements in all three directions (X, Y, Z). The values indicate the magnitude of displacement measured in millimeters.

Interpreting the values in the table:

- Max X: Node 59 experienced the maximum displacement in the X-direction, with a magnitude of 0.015 mm under load case 1 DL.
- Min X: Node 56 experienced the minimum displacement in the X-direction, with a magnitude of -0.015 mm under load case 1 DL.
- Max Y: Node 178 experienced the maximum displacement in the Y-direction, indicating no displacement (0 mm) under load case 4 WZ.
- Min Y: Node 55 experienced the minimum displacement in the Y-direction, with a magnitude of -3.314 mm under load case 1 DL.
- Max Z: Node 240 experienced the maximum displacement in the Z-direction, with a magnitude of 0.014 mm under load case 1 DL.
- Min Z: Node 120 experienced the minimum displacement in the Z-direction, with a magnitude of -0.014 mm under load case 1 DL.
- Max Rst: Node 55 experienced the maximum resultant displacement, with a magnitude of 3.314 mm under load case 1 DL.

These displacement values provide insight into the structural behaviour of the G8 building under the specified load cases. The displacements can help assess the building's stability, structural integrity, and potential areas of concern that may require further analysis or corrective measures.

	Plate	L/C	Principal		Von Mis		Tresca	
			Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2
Max Pri	720	2 LL	0.005	-0.010	0.005	0.010	0.005	0.010
Min Prin	720	1 DL	-0.042	0.086	0.037	0.087	0.042	0.089
Max Pri	720	1 DL	-0.021	0.089	0.037	0.087	0.042	0.089
Min Prin	720	2 LL	0.003	-0.010	0.005	0.010	0.005	0.010
Max Vo	720	1 DL	-0.021	0.089	0.037	0.087	0.042	0.089
Min Vo	720	4 WZ	-0.001	-0.001	0.001	0.001	0.001	0.001
Max Vo	720	1 DL	-0.021	0.089	0.037	0.087	0.042	0.089
Min Vo	720	4 WZ	-0.001	-0.001	0.001	0.001	0.001	0.001
Max Tr	720	1 DL	-0.021	0.089	0.037	0.087	0.042	0.089
Min Tre	720	4 WZ	-0.001	-0.001	0.001	0.001	0.001	0.001
Max Tr	720	1 DL	-0.021	0.089	0.037	0.087	0.042	0.089
Min Tre	720	4 WZ	-0.001	-0.001	0.001	0.001	0.001	0.001

Figure 12: principle stress, Von Mises stress, and Tresca stress

the principle stress, Von Mises stress, and Tresca stress at different locations (top and bottom) of plates within the G8 building. Here is an interpretation of the table:

- Plate: Represents the identification number or name assigned to each plate within the G8 building.
- L/C: Indicates the load case or condition under which the stresses were measured.
- Principle Stress (Top): Represents the maximum and minimum principle stresses at the top surface of each plate. The values indicate the magnitude of stress measured in Newton per square millimeter (N/mm²).
- Principle Stress (Bottom): Represents the maximum and minimum principle stresses at the bottom surface of each plate. The values indicate the magnitude of stress measured in N/mm².
- Von Mises Stress (Top): Represents the maximum and minimum Von Mises stresses at the top surface of each plate. The values indicate the magnitude of stress measured in N/mm².
- Von Mises Stress (Bottom): Represents the maximum and minimum Von Mises stresses at the bottom surface of each plate. The values indicate the magnitude of stress measured in N/mm².
- Tresca Stress (Top): Represents the maximum and minimum Tresca stresses at the top surface of each plate. The values indicate the magnitude of stress measured in N/mm².
- Tresca Stress (Bottom): Represents the maximum and minimum Tresca stresses at the bottom surface of each plate. The values indicate the magnitude of stress measured in N/mm².

Interpreting the values in the table:

- Max Principal (Top): The plate with an identification number of 720 experienced the maximum principle stress at the top surface, with a magnitude of 0.005 N/mm² under load case 2 LL.
- Min Principal (Top): The plate with an identification number of 720 experienced the minimum principle stress at the top surface, with a magnitude of -0.042 N/mm² under load case 1 DL.
- Max Principal (Bottom): The plate with an identification number of 720 experienced the maximum principle stress at the bottom surface, with a magnitude of 0.089 N/mm² under load case 1 DL.
- Min Principal (Bottom): The plate with an identification number of 720 experienced the minimum principle stress at the bottom surface, with a magnitude of -0.01 N/mm² under load case 2 LL.
- Max Von Mis (Top): The plate with an identification number of 720 experienced the maximum Von Mises stress at the top surface, with a magnitude of 0.037 N/mm² under load case 1 DL.
- Min Von Mis (Top): The plate with an identification number of 720 experienced the minimum Von Mises stress at the top surface, with a magnitude of 0.001 N/mm² under load case 4 WZ.
- Max Von Mis (Bottom): The plate with an identification number of 720 experienced the maximum Von Mises stress at the bottom surface, with a magnitude of 0.087 N/mm² under load case 1 DL.
- Min Von Mis (Bottom): The plate with an identification number of 720 experienced the minimum Von Mises stress at the bottom surface, with a magnitude of 0.001 N/mm² under load case 4 WZ.
- Max Tresca (Top): The plate with an identification number of 720 experienced the maximum Tresca stress at the top surface, with a magnitude of 0.042 N/mm² under load case 1 DL.
- Min Tresca (Top): The plate with an identification number of 720 experienced the minimum Tresca stress at the top surface, with a magnitude of 0.001 N/mm² under load case 4 WZ.

Conclusion

The analysis of the G8 building's displacements and stresses under different load cases has provided valuable information regarding its structural performance. The displacements recorded at various nodes indicate the extent of deformations experienced by the building in the X, Y, and Z directions. These displacements are crucial in understanding the structural response and potential areas of concern.

Additionally, the evaluation of principle stresses, Von Mises stresses, and Tresca stresses at the top and bottom surfaces of different plates within the building has shed light on the magnitude and distribution of internal forces. These stress values allow for a thorough assessment of the structural integrity and strength of the building components.

The identification of specific load cases, such as dead loads (DL), live loads (LL), and wind loads (WZ), has helped in comprehending the building's behavior under various loading conditions. This knowledge is essential for designing structures that can withstand real-world scenarios and ensuring the safety of occupants.

The findings from this analysis contribute to a deeper understanding of the G8 building's structural behavior, aiding in the identification of critical areas that may require further investigation or structural modifications. These insights can inform decision-making processes related to design optimization, maintenance, and potential retrofitting strategies.

Overall, the analysis of the displacements and stresses presented in this study has provided valuable insights into the structural performance of the G8 building. These findings enhance our understanding of the building's behavior under different load cases and contribute to the broader body of knowledge in the field of structural engineering.

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