SEISMIC ANALYSIS OF HIGH RISE BUILDING FOR TRANSFER FLOOR SYSTEM WITH TRANSFER SLAB AND TRANSFER GIRDER

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Abstract - *In this study, the research provides a comparative analysis of transfer slab and transfer girder systems in high-rise buildings, focusing on their seismic performance using STAAD Pro. A ten-story building model was analyzed, considering key factors like lateral displacement, bending moment, and shear force. The study followed IS 1893:2016 standards and applied various load combinations to assess the building's seismic response. Findings show that the transfer girder system performs better, with lower lateral displacements (10-28mm) and higher bending moments and shear forces, indicating superior stability under seismic forces. However, the transfer slab system remains a viable option, especially in cases where cost and design considerations are critical. The study emphasizes balancing seismic performance, structural efficiency, and cost-effectiveness when selecting a transfer floor system.*

Key Words: Seismic analysis, High-rise building, Transfer slab, Transfer girder, Comparative analysis, Seismic forces.

1. INTRODUCTION

High-rise buildings are iconic representations of modern urban development, driven by the need to optimize limited horizontal space in cities. While these towering structures showcase architectural innovation and engineering advancements, they also introduce significant challenges in terms of structural integrity and safety, especially in regions prone to seismic activity. Seismic forces, generated by sudden ground movements, induce lateral stresses that can severely impact tall buildings. As these structures grow taller, their interaction with seismic forces becomes more complex, requiring detailed analysis to ensure stability and resilience. Transfer floor systems, often used to redistribute loads or accommodate varying column spacing, further complicate the design. These systems, while essential for structural efficiency, must be carefully integrated into seismic analysis to ensure that high-rise buildings can withstand lateral forces without collapse or excessive damage. Therefore, the incorporation of robust seismic design strategies is crucial to the safe and functional construction of high-rise buildings, especially when transfer floor systems are involved.

1.1 Aim & Objective

To analyze High Rise Building for Transfer Floor System with Transfer Slab and Transfer Girder subjected to Seismic forces.

1) Study of transfer floor system will be carried for transfer slab and transfer girder.
2) Analysis of high-rise building transfer slab and transfer girder system using structural analysis software.
3) Study the feasibility of building at different level for transfer floor system with respect to building height.
4) Comparative study of seismic behavior of two types of transfer floor system with transfer slab and transfer girder.

2. Literature Review

The literature review highlights the effects of a soft storey mechanism forming below the transfer level in high-rise buildings, as well as the impact of abrupt structural changes near the transfer storey. It points out that there is limited research available on the analysis of high-rise buildings incorporating a transfer floor, an important structural element used to distribute loads. The review emphasizes the need for further studies focusing on the vertical placement of the transfer system in relation to the building's overall height. Additionally, it stresses the importance of a comparative analysis between two common types of transfer systems—transfer slabs and transfer girders—to better understand their performance and influence on building stability.

Contributions of researchers are presented as follows,

Prof. P.S. Lande, Parikshit D Takale (2018) [1] "Analysis of high rise building with transfer floor", International Research Journal of Engineering and Technology (IRJET) Introduction of the transfer floor in the lower part of the structure is better than having it is at higher location. For girder type of transfer system there is reduction in storey moment and storey shear values below the transfer level as compared to slab type transfer system. Girder type transfer system improves the global behavior of the structure. The displacement distribution shown in displacement graph reveals that every building has a flexural behavior mode up to its transfer floor level. At this level, a large inertial force hit the building due to the significant mass of the transfer level which results a large displacement.

Mahendra Pratap Singh, et al (2017) [2] "Analysis and Design of Residential Building with Transfer Slab", Journal of Industrial Pollution Control Transfer slab is the kind of frame in which upper storey column are directly supported over the slab or from which picked up columns may be started where there are no columns underneath. By using this technique the overall cost of the building can be reduced and excess stories can be constructed in the same height of the building due to eliminations of beams and same columns in the foundations or upper stories. This technique will allow to use more area with cheaper formwork. The purpose of this paper is to get better understanding about the Transfer slab analysis and design. The residential building model is analyzed using the software STAAD.PRO V8i .IS codes like IS456-2000, ACI-318-08 are used for guidelines. To increase the bearing capacity of the flat-slab structure under horizontal loads, particularly when speaking about seismically prone areas and limitation of deformations, modifications of the system by adding structural elements are necessary.

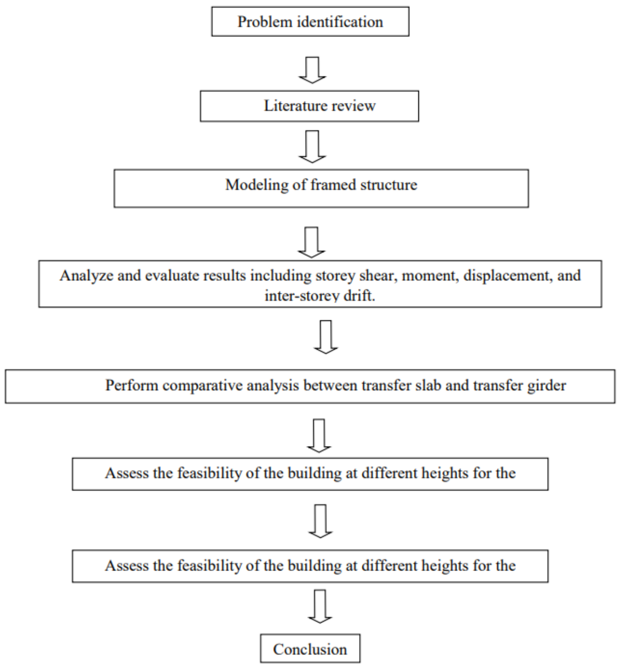
Y.M. Abdlebasset et al (2016) [3] "Seismic Behaviour of High-Rise Buildings with Transfer Floors;state of art of review", Electronic Journal of Structural Engineering eJSE. A state-of-the art review on structural and seismic behavior of high rise buildings with transfer floors is presented. It covers the effect of transfer floor systems types and the structural irregularity classification. It also covers some codes of practice limitations for such irregular buildings. The review discusses the transfer structures local deformations and stresses concentration. The review discusses the effect of the sudden change in the building stiffness on the seismic behavior of the building and outline the story drifts distribution along the building height. The commonly adopted numerical models for these irregular building are briefly outlined and the effect of the vertical location of the transfer floor with respect to the building height is presented. And concluded that irregularity in upper stories would have a little effect on the floor displacements, while, irregularity in lower stories would have a significant effect on the height-wise distribution of floor displacements.

El-Awady et al (2014) [4] "Seismic Behaviour of High-Rise Buildings with Transfer Floors", Electronic Journal of Structural Engineering eJSE. The authors have pointed out to the severity of the drift in the vicinity of the transfer floor on the level of damage occurring to these buildings. This investigation showed the significant effect of the lateral flexure and shear stiffness of the vertical elements above/below the transfer level on the drift values.

Zhang and Ling and Abdelbasset et al (2011) [5] R"Dynamic analysis of elastoplastic performance of tall building with arch transfer floor subjected to severe earthquake [J]". Journal of Beijing Jiaotong University. A major drawback of any transfer floor is the abrupt change in the building's lateral stiffness in the vicinity of its level; a direct consequence of such irregularity is that the deformation of a soft-storey mechanism under moderate to severe earthquakes or lateral wind loads imposes high ductility demands on the elements in the vicinity of the transfer floors. Therefore, if this irregularity is not taken into consideration during the design stages, it becomes a major source of damage during strong earthquakes.

3. METHODOLOGY

3.1 Methodology Flow Chart



3.2 Methodology Steps

The first process involves configuring the unit system to meters in STAAD Pro as a way of standardizing measurements. In the next step of the process, the Structure Wizard option is invoked Once again, the prototype model is selected from the drop-down list as a Bay Frame which comes in handy since it has a pre-defined structural framework for analysis. This selection simplifies the modeling process and sets up the geometry and structure layout for the high-rise building analysis.

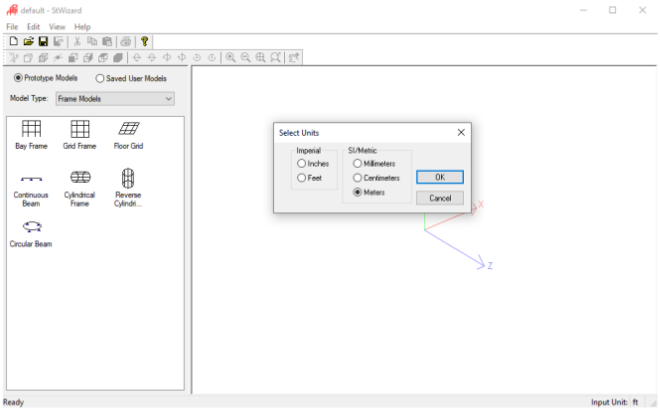


Figure 3.1: Unit Selection

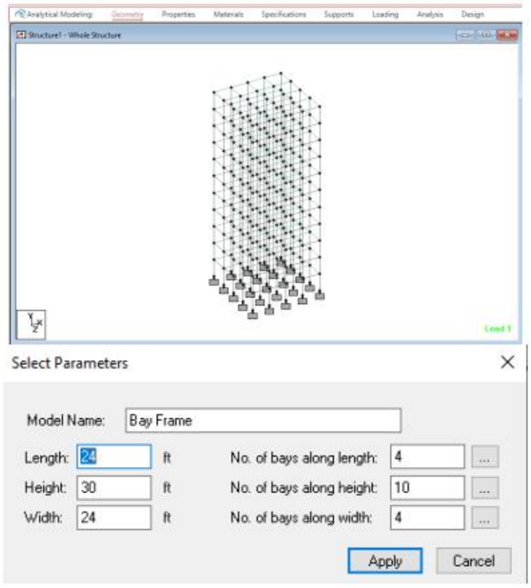


Figure 3.2: Modeling of Building Structure

Table 4.1: Nodes modeling

Node	X (m)	Y (m)	Z (m)
8	3.000	3.000	0.000
9	3.000	3.000	3.000
10	3.000	3.000	6.000
11	3.000	3.000	9.000
12	3.000	3.000	12.000
13	3.000	3.000	15.000
14	3.000	3.000	18.000
15	3.000	3.000	21.000
16	3.000	3.000	24.000
17	3.000	3.000	27.000

Table 3.2: Beam Modeling

Beam	Node A	Node B	Property Ref.
15	17	18	2
16	16	17	2
17	15	16	2
18	14	15	2
19	13	14	2
20	12	13	2
21	11	12	2
22	10	11	2
23	9	10	2
24	8	9	2
25	8	10	2

The building structure in STAAD Pro is developed in such a way that nodes and beams are created using the concept of the Bay Frame prototype. Nodes are introduced at the places where the connectivity of elements occurs in the structure e.g. beam-column joints (Kumar et al., 2020). They are then given between these nodes to create the skeletal system of the building in question. This makes the structural shapes of the building to be modelled accurately, and its behavior under different loading conditions such as earthquake loads to be studied.

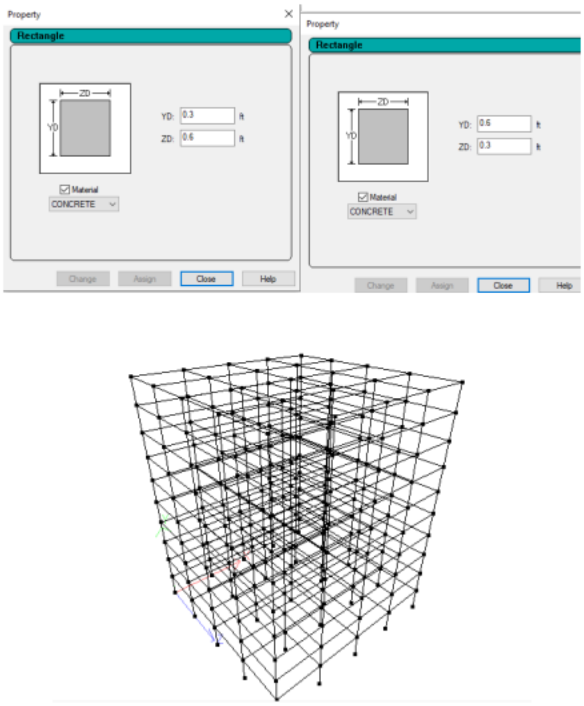


Figure 3.3: Applying Beam Thickness of each frame

The thickness of the beam along the longitudinal, transverse, and vertical direction for each rectangular frame of a 10-story building is input in STAAD Pro. According to the design specifications, a different thickness is given to every frame to provide the necessary strength as well as burden support (Verma et al., 2024). The cross-section of the beam is defined concerning the size and characteristics of the actual framework of the building to produce seismically and otherwise loaded realistic modeling of the building's response.

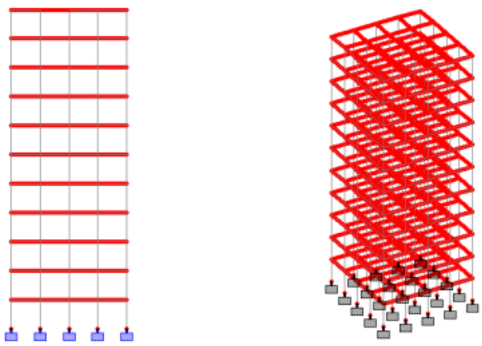


Figure 3.4: Applying Fixed Support

Propped supports are given at the bottom of the building in computer software named STAAD Pro to consider the constraints of the foundation. These supports ensure that no transnational or rotational force can be applied at the base thereby ensuring a firm fixing of the structure on the ground. This setup is quite advantageous in real conditions where the foundation of the building must counteract all vertical and lateral forces at any stage such as during the occurrence of an earthquake or any other form of loads.

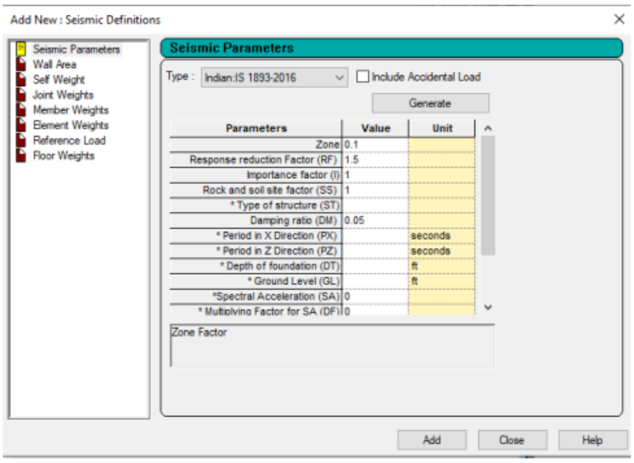


Figure 3.5: Applying seismic Parameter

These parameters are then enforced on the building model under consideration based on the stipulations of the code IS 1893: 2016 depending on a particular seismic zone. This comprises the determination of the zone factor, the type of soil, the importance factor, and the response reduction factor that depends on the structural type of the particular building. These parameters are very important for selecting an appropriate model required to predict the response of the building to seismic actions to ensure that the design of the building meets the safety and performance criteria stipulated in the Indian seismic code.

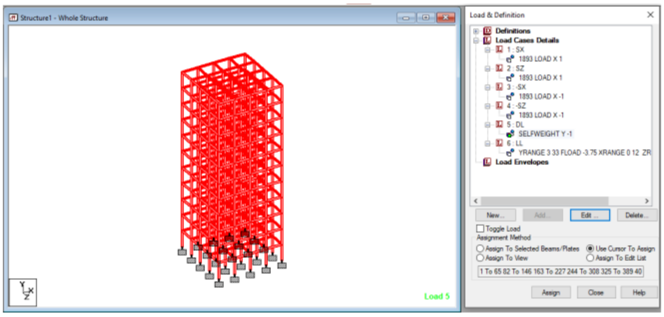


Figure 3.6: Applying various kinds of load

Load combinations consistent with IS 1893:2016 are then applied to the building model for a comprehensive assessment of its structural response. The dead load refers to the permanent load on the structure which constitutes the weight of the structural members namely beams, columns, slabs and walls and fixed loads in terms of installations such as HVAC systems, and partitions among others. This load takes into account the densities and dimensions of the materials so that the correct weight of the building is incorporated into the analysis (Ramesh, 2021). Those that are due to the occupancy and use of the building are also used such as the live loads. Some of these include dead loads from people, movable furniture and equipment, according to loads as provided by codes and standards within usage categories. Roof live loads are designated to roof areas and any probable activities in the roof areas such as maintenance or construction of a temporary structure are taken into consideration to determine the live loads that the roof can bear.

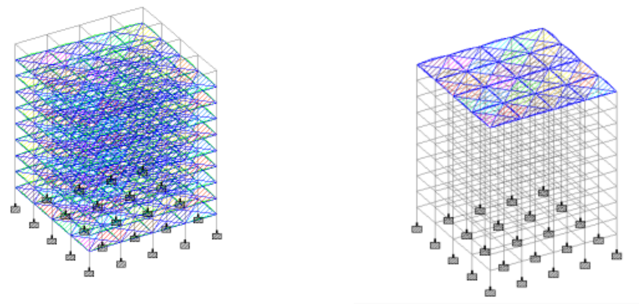


Figure 3.7: Load Visualizations

Earthquake loads are imposed depending upon the relevant parameters of the design code IS 1893:2016. This includes the use of the seismic zone factor, which takes into consideration the earthquake-prone area of the building location, and the nature of the soil under the building structure upon which the building requires different types of response to an earthquake (Uikey and Satbhaiya, 2020). The importance factor involves the use aspect of the building in safety and function while the response reduction factor which is based on the structural system decreases the seismic forces to the capacity of the building in dealing with earthquakes. Such loads are incorporated into the structure to analyze structures as per their performance criteria and safety standards in various conditions.

Table 3.3: Material Properties

Name	E (kip/in²)	Poisson's Ratio	Density (kip/in³)	Alpha (/°F)	Fy (kip/in²)	Fu (kip/in²)	Ry	Rt	Fcu (kip/in²)
ALUMINUM	10000.000	0.330	98E-6	12.8E-6	0.000	0.000	0.000	0.000	0.000
CONCRETE	3150.001	0.170	86.8E-6	5.5E-6	0.000	0.000	0.000	0.000	4.000
STAINLESSSTEEL	29000.000	0.300	283E-6	9.5E-6	0.000	0.000	1.500	1.200	0.000
STEEL	29000.000	0.300	283E-6	6.667E-6	0.000	0.000	1.500	1.200	0.000
STEEL_275_NMM2	29732.736	0.300	283.7E-6	6.667E-6	39.885	59.465	1.500	1.200	0.000
STEEL_355_NMM2	29732.736	0.300	283.7E-6	6.667E-6	51.488	68.168	1.500	1.200	0.000
STEEL_36_KSI	29000.000	0.300	283E-6	6.5E-6	36.000	58.000	1.500	1.200	0.000
STEEL_50_KSI	29000.000	0.300	283E-6	6.5E-6	50.000	62.000	1.500	1.200	0.000

Validation of Overall Methodology

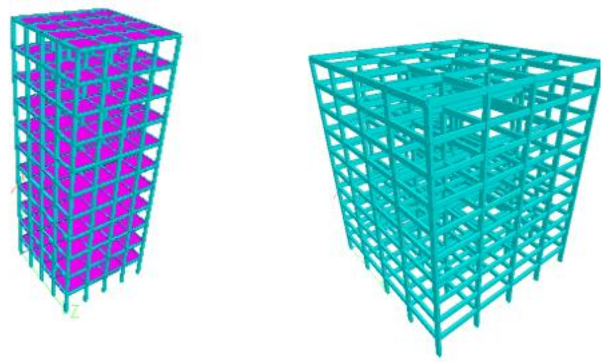


Figure 3.8: 3D rendering Structure of beam and plates

The overall methodology is ensured to be valid by making sure that all these steps follow the generally acceptable standards in structural analysis and design. The process starts with choosing the right type of units and prototype models in STAAD Pro leading to a stable simulation process. A clear model of the structure of the building is created by the use of nodes and beams that are accurately displayed. Thicknesses of beams are installed along the X, Y and Z axes in order to provide durability to the structure. Precise models of real-world constraints at the base provide fixed supports to bring the building into its correct alignment. Seismic parameters conform to the IS 1893:2016 to represent the regional seismicity, site class, and importance level of the structure and enable sound earthquake analysis (Soni and Chandrakar, 2022). Seismic parameters based on IS 1893:2016 are incorporated to consider the zone factor, site class factor and importance factor for accurate earthquake analysis. According to the codes, several loads such as dead load, operational load, roof operational loads, and seismic load are applied to models. This result valuation enhances the concretization of the methodology through a thorough examination of storey shear, storey moment, displacement, and inter-storey drift. A comparative analysis of transfer slab and transfer girder systems allows for an adequate evaluation of the seismic performance. This approach complies with safety and performance standards implying its usefulness in assessing the system of high-rise buildings. The general approach aims to provide a detailed consideration of the seismic performance of high-rise buildings that comprise transfer floor systems with reference made to transfer slabs and transfer girders. The actual nature of the situation is well captured by adopting a 10- storey building model and using structural analysis tools such as the STAAD Pro. The application of dead, live, roof live and seismic loads in compliance with IS 1893:2016 means that the analysis meets safety guidelines and does not depart far from an accurate depiction of the building's behavior under different forms of load (Ramesh, 2021). This approach facilitates the achievement of the research objectives by enabling the comparative assessment of the transfer slab and the transfer girder systems, the determination of the feasibility of the system and the evaluation of the seismic response of the system. Finally, the research approach will provide an understanding of how high-rise buildings should be designed to improve their performance and safety and achieve the aim of the research.

4. PROBLEM IDENTIFICATION

4.1 Research Gap

While existing studies have explored various aspects of high-rise building design and seismic performance, there remains a significant gap in comprehensive analyses specifically focused on the comparative seismic behavior of transfer floor systems utilizing transfer slabs versus transfer girders. Most research to date has either concentrated on individual components of transfer systems or has not adequately addressed the performance differences between these two configurations under seismic forces. Additionally, there is limited understanding of how the feasibility and effectiveness of these transfer systems vary with building height, which is crucial for optimizing structural design in different high-rise contexts. Furthermore, the application of advanced structural analysis software to evaluate and compare the performance of transfer slabs and transfer girders under seismic conditions has not been thoroughly explored. This research aims to fill these gaps by systematically analyzing and comparing the seismic behavior of transfer floor systems with transfer slabs and transfer girders, assessing their feasibility across various building heights, and utilizing structural analysis software to provide detailed insights. This comprehensive approach will contribute to more informed design decisions and enhance the seismic resilience of high-rise buildings.

4.2 Problem Identification

High-rise buildings are inherently complex structures that must effectively manage and redistribute loads to maintain stability and ensure occupant safety, especially when subjected to seismic forces. Transfer floor systems, which include transfer slabs and transfer girders, are pivotal in facilitating the transfer of loads between different structural elements, particularly at points where column layouts change or where there are variations in floor levels. However, the dynamic nature of seismic events poses significant challenges to these transfer systems, potentially leading to structural vulnerabilities, excessive deformations, and even catastrophic failures if not properly designed and analyzed. Current engineering practices may not fully account for the intricate interactions between transfer slabs and transfer girders under seismic loading, resulting in insufficient resilience of high-rise buildings during earthquakes. This underscores the necessity for a detailed investigation into the performance of transfer floor systems, aiming to enhance their design, improve seismic resistance, and ensure the overall safety and feasibility of constructing tall buildings in earthquake-prone regions.

5. RESULTS

5.1 Analysis of various Loads

Comparisons of the maximum shear stress displacements between the transfer girder and transfer slab systems are highlighted for each floor of the 10-story building. In both systems, it is found also that the maximum negative displacements are higher than the positive showing that the building undergoes more downward displacement at maximum shear stress.

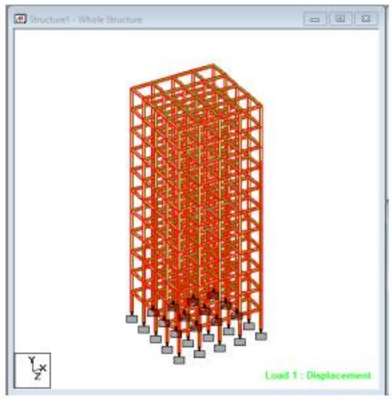


Figure 5.1: Maximum Displacement

Table 5.1: Beam Relative Displacement Details Table:

Beam	L/C	Length (m)	Max x (m)	Dist (m)	Max y (m)	Dist (m)	Max z (m)	Dist (m)
1	SX	3.000	0.000	0.000	-0.031	0.750	0.000	0.000
2	SZ	3.000	1.750	2.750	0.000	0.000	0.000	0.000
3	SX	3.000	1.750	2.750	-0.031	0.750	0.000	0.000
4	SZ	3.000	1.750	2.750	-0.031	0.750	0.000	0.000
5	DL	3.000	0.000	0.000	0.000	0.000	0.000	0.000
6	LL	3.000	0.000	0.000	0.000	0.000	0.000	0.000
7	SX	3.000	1.750	2.750	-0.031	0.750	0.000	0.000

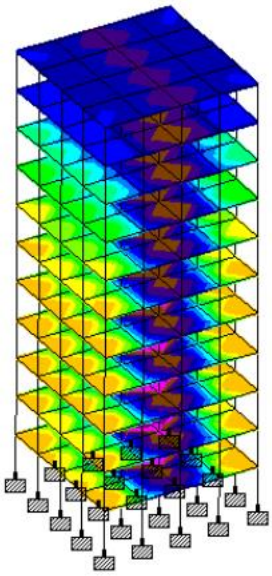


Figure 5.2: Displacement Visualization

The displacement values are also higher in the transfer slab system as compared to the transfer girder system, especially on Floors 5 and 6 which indicated a high displacement value of the building. For example, on Floor 5, the transfer slab system shows a maximum positive displacement of 0.408 meters and a negative displacement of negative 0.490 meters while the transfer girder system shows negligible 0.306 meters positive and -0.365 meters negative displacements. This implies that the transfer slab system could perhaps be undergoing even greater impacts using the shear stress.

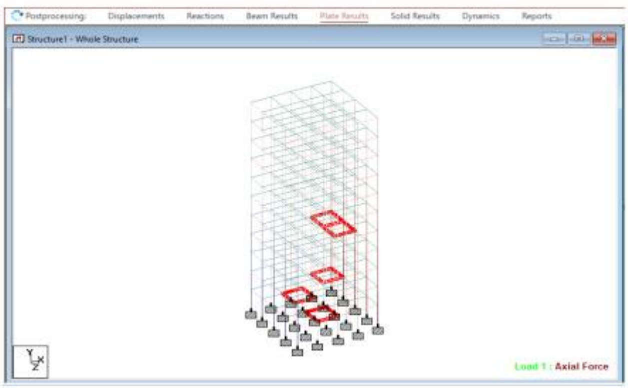


Figure 5.3: Maximum Axial Forces

Table 5.2: Plate Center Stress

Plate	L/C	SMAX Top (psi)	SMAX Bottom (psi)
3-SX	SX	98.663	-17.845
4-SZ	SZ	98.663	-17.845
5-LL	LL	10.927	-3.305
317	SX	98.662	-17.844
2-SX	SX	-17.632	-8.156
5-DL	DL	10.927	-3.305

Table 5.3: Plate Corner Stres

Plate	L/C	Node	SQX (local) psi
316	SX	109	-11.319
1-SX	SX	110	-11.319
2-SZ	SZ	111	-11.319
3-SX	SX	113	-11.319

On the other hand, floors with lower displacement are demonstrated to have constant results in both systems between the displacements such as Floor 1 and Floor 10. Therefore, both transfer girder and transfer slab systems display almost the same displacement patterns with very small maximum displacement values (Abdulnasir Abdullah, 2023). In conclusion, the investigation reveals that both systems perform well with slight variations where the transfer slab system shows slightly high displacement under the maximum shear stress that is likely to affect the structural performance and its design.

5.2 Deflection analysis

From the deflection analysis of the beam, it is found that variation of bending moment in plus and minus direction affects deflection to a considerable extent. Unknown values of the bending moment are observed at points along the beam lengths, with significant values of 627.400 kip-in (positive) & -574.140 kip-in (negative). These values are associated with large deflections suggesting that the beam yields a considerable amount of bend when the load is applied on it (Akhil and Manikanta, 2022). The amount of deflection is proportional to the values of the bending moments; high values of moments cause high deflection. Assessing the deflection factor is concerned with confirming that the deflection is reasonable enough to sustain adequate load-bearing and performance characteristics of the structure in question.

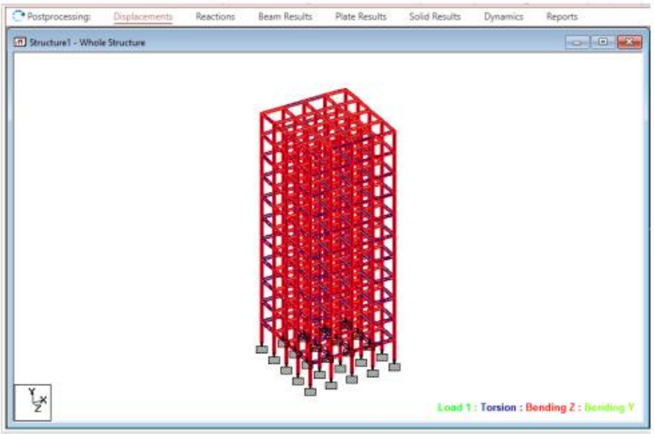


Figure 5.4: Maximum Displacemen

Table 5.4: Plate Center Stress

Plate	L/C	SQX (local) psi	SQY (local) psi
1-SX	SX	-14.869	0.515
2-SX	SX	-14.869	-0.515
3-SX	SX	-14.869	-0.515
5-DL	DL	0.198	0.141
67	LL	-12.263	-0.143
66	SX	-12.263	-0.143

Table 5.5: Plate Corner Stress

Plate	L/C	Node	SQX (local) psi	Shear A
66	SX	6	-12.263	-16.856
1-SX	SX	2	-12.881	-16.856
3-SX	SX	17	-12.881	-12.881
2-SX	SX	7	-16.856	-12.881
67	LL	1	-16.856	-16.856

Table 5.6: Nodal results

	Node	L/C	Horizontal Fx (kN)	Vertical Fy (kN)	Horizontal Fz (kN)	Moment Mx (kip-in)	Moment My (kip-in)	Moment Mz (kip-in)
Max Fx	12	3-sX	45.252	27.708	0.014	0.123	0.007	-627.400
Min Fx	12	1 Sx	-45.252	-27.708	-0.014	-0.123	-0.007	627.400
Max Fy	23	5 DL	0.000	491.577	0.000	0.000	0.000	-0.000
Min Fy	45	3-sX	36.870	-425.612	0.303	2.634	0.040	-554.204
Max Fz	45	3-sX	33.203	-349.974	1.877	16.557	-0.107	-522.045
Min Fz	45	1 Sx	-33.203	-349.974	-1.877	-16.557	0.107	522.045
Max Mx	45	3-sX	33.203	-349.974	1.877	16.557	-0.107	-522.045
Min Mx	45	1 Sx	-33.203	-349.974	-1.877	-16.557	0.107	522.045
Max My	45	3-sX	33.203	-349.974	1.877	16.557	-0.107	-522.045
Min My	45	1 Sx	-33.203	-349.974	-1.877	-16.557	0.107	522.045
Max Mz	12	3-sX	45.252	27.708	0.014	0.123	0.007	-627.400
Min Mz	12	3-sX	45.252	27.708	0.014	0.123	0.007	-627.400

Table 5.7: Results Summary

	Plate	L/C	Principal (Top psi)	Principal (Bottom psi)	Von Mis (Top psi)	Von Mis (Bottom psi)	Tresca (Top psi)	Tresca (Bottom psi)
Max Pri	316	3-sX	98.663	-17.845	91.135	90.785	98.663	98.383
Min Prin	316	1 Sx	-98.663	17.845	91.135	90.785	98.663	98.383
Max Pri	316	1 Sx	-17.632	98.383	91.135	90.785	98.663	98.383
Min Prin	316	3-sX	17.632	-98.383	91.135	90.785	98.663	98.383

Max Von	69	1 Sx	3.295	-91.105	96.405	91.556	98.663	98.383
Min Von	71	6 LL	2.608	-1.978	2.645	1.880	2.680	1.978
Max Vo	312	1 Sx	3.139	-93.927	95.877	95.501	97.408	97.002
Max Tre	71	6 LL	2.608	-1.978	2.645	1.880	2.680	1.978
Max Tre	316	1 Sx	-17.632	98.383	91.135	90.785	98.663	98.383
Min Tre	71	6 LL	2.608	-1.978	2.645	1.880	2.680	1.978

The simulation results provide detailed insights into the structural mechanics of the beam, focusing on principal, von-Mises, and Tresca stresses to evaluate the beam's structural health under different loads. The analysis shows significant stress variations, with maximum internal resistive forces around 98 psi and high deformation observed in certain areas, indicating potential material yielding. The von-Mises and Tresca stress results are consistent, identifying key stress concentrations and possible failure points. These findings align with the research objectives, offering valuable data for reinforcing or modifying the structure to ensure stability and safety under expected loads.

6. CONCLUSIONS

This study compares the seismic performance of transfer slab and transfer girder systems in a ten-story high-rise building. The transfer girder system shows lower lateral displacement, ranging from 10mm to 28mm, indicating better stability under seismic forces compared to the transfer slab system, which ranged from 12mm to 30mm. The transfer girder also exhibited higher bending moments and shear forces, enhancing its ability to handle seismic loads. While the transfer girder offers superior seismic performance, the transfer slab remains a viable option when cost and design constraints are important. The choice between the two depends on seismic performance, structural efficiency, and cost.

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