

Design and Analysis of a Transfer Truss System in High-rise Building

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Abstract:

The rapid growth of high-rise buildings has introduced several structural challenges, particularly due to the mismatch of column layouts between upper and lower floors. To overcome this issue, transfer truss systems are widely used as an efficient structural solution.

This project deals with the design and analysis of a steel transfer truss system for a high-rise building, which facilitates the transfer of loads from upper storeys to a different column arrangement at lower levels. The structural analysis was performed using finite element modeling under various loading conditions such as dead load, live load, wind load, and seismic load, in accordance with Indian Standard codes. The behavior of the truss was studied in terms of axial forces, bending stress, and deflection.

The results indicate that the truss system efficiently transfers loads through axial action. The top chord members are subjected to compression, while bottom chord members are subjected to tension.

The obtained stresses and deflections are within permissible limits, confirming the structural safety and serviceability of the system. The study concludes that transfer truss systems are highly effective in providing large column-free spaces in modern high-rise construction.

1. INTRODUCTION:

Modern high-rise construction involves complex structural and architectural requirements. One of the key challenges is the discontinuity of vertical load paths caused by different column layouts between upper floors and lower podium levels.

To overcome this issue, transfer truss systems are used. A transfer truss acts as a structural bridge that transfers loads from upper columns to a different support system below.

Steel trusses are preferred due to:

- High strength-to-weight ratio
- Efficiency in axial load transfer
- Ease of fabrication and erection

Transfer trusses allow:

- Large column-free spaces
- Efficient load redistribution

- Improved architectural flexibility.

KEYWORDS:

Transfer Truss, High-Rise Building, STAAD Pro, Structural Analysis, Deflection, Axial Force, Steel Structure.

2. LITERATURE REVIEW:

Steel transfer truss systems are essential structural components in high-rise buildings, primarily used to resolve column discontinuities and accommodate large-span requirements at podium or transfer levels. The design of these mega-trusses is typically governed by serviceability criteria, where high stiffness is required to control vertical deflection under massive gravity loads. Research indicates that deep Pratt Truss configurations are most effective for managing high shear forces and optimizing material efficiency through axial load resistance. Furthermore, the structural integrity of these systems depends on the use of heavy built-up steel sections and robust steel-to-concrete interface connections at corbels to handle concentrated reaction forces. Finally, engineers must perform construction-stage analysis to address temporary instabilities during erection, ensuring the truss remains stable from assembly through to the final occupancy phase.

1. Seismic Behaviour of Steel Staggered Truss in Building.

International Journal for Research in Applied Science and Engineering Technology

M.S Sayali Sastre, July 2021

The Staggered-Truss System (STS) is an efficient steel framing method for multi-story buildings that utilizes story-high trusses spanning the full width of the structure in an alternating pattern between exterior columns. By eliminating interior columns, it creates large, versatile clear-span areas ideal for residential and commercial spaces while achieving high structural rigidity through the integrated action of floors, trusses, and columns. The floor system serves a dual purpose as a diaphragm to transfer lateral loads, making the STS highly resistant to wind and seismic forces and more material-efficient than conventional beam-column frames.

2. Comparative Study of Different Structural System with Steel Staggered Truss System.

International Conference on Research and Innovations in Science, Engineering and Technology.

Viral H Sheth, Varsha Panchal, May 2019

The Staggered Truss System (STS) is a highly efficient steel framing technique that significantly reduces steel tonnage and project costs compared to traditional methods. Comparative analysis using SAP2000 reveals that STS drastically outperforms standard moment-resisting systems, reducing transverse displacement by 28% to 76%. When integrated with shear walls, the system becomes even more robust, achieving displacement reductions of up to 77% in both longitudinal and transverse directions under seismic loads. Ultimately, the combination of a staggered truss with shear walls emerges as the most efficient configuration for managing lateral drift and ensuring structural stability in high-rise buildings.

3. Seismic retrofit schemes for staggered truss structures.

Engineering Structures 102:93-107

Jinkoo Kim, Joonho Lee, November 2015

This research evaluates the seismic performance of Staggered Truss Systems (STS), specifically focusing on the impact of Vierendeel panels—the rectangular openings often required for central hallways. The study demonstrates that while these panels can be structural weak points, their performance is significantly enhanced by retrofitting with interior columns, which improve the force-displacement relationship and reduce seismic fragility. Additionally, implementing end bracing, vertical cables, or Buckling-Restrained Braces (BRB) effectively increases structural strength and ductility while minimizing inter-story drifts and residual displacements, ensuring greater stability during seismic events.

4. Construction Simulation and Monitoring of the Jacking Steel Truss and Main Column of a Seismic Design of Large-Span, Heavy-Load Transfer Truss for Zhanjiang Bay R&D Building.

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5. Comparison and Selection of Multiple Construction Schemes for the Large-Span and Heavy-Load Transfer Truss.

Tao Lan, Guangjie Xing, Guangchong Qin, Zexu Li, December 2023.

The construction of the Zhanjiang Bay Laboratory R&D Building highlights a strategic approach to managing a 53.4 m large-span, heavy-load transfer truss. Researchers compared two installation methods: Scheme 1, which utilized a continuous rigid connection to the side towers from the outset, and Scheme 2, which employed a staged approach using elastic-to-rigid transitions and large diagonal tie rods.

The results demonstrated that Scheme 2 is superior, as it allows the structure to form a cohesive unit with the upper floors before final rigid connections are established. This staged method optimizes stress distribution within the core barrel shear walls and the truss itself, ensuring that deflection remains within safe limits and significantly enhancing the overall structural reliability of the super high-rise system.

3. OBJECTIVES:

- To develop an optimized, safe, and code-compliant structural design of a steel transfer truss system capable of effectively resolving column grid discontinuity between the upper tower floors and lower podium or lobby levels, while safely transferring cumulative gravity loads, wind loads, and seismic forces.
- To analyse the structural behaviour of the steel transfer truss using appropriate analytical and numerical methods, in order to evaluate axial forces, stresses, deflections, and overall loadtransfer mechanisms under various loading combinations.
- To ensure adequate strength, stability, and serviceability of all truss members by checking them against ultimate limit state and serviceability limit state requirements, with particular emphasis on controlling vertical deflection and preventing buckling of compression members.
- To study and design efficient truss member sections and connections, including built-up steel sections, gusset plates, and bolted or welded joints, ensuring sufficient strength, stiffness, and ductility.
- To understand the role of steel transfer truss systems in modern high-rise buildings and evaluate their effectiveness in creating large column-free spaces without compromising structural performance.

4. METHODOLOGY:

The project followed a systematic approach:

1. Identification of column discontinuity
2. Selection of truss configuration (Pratt Type)
3. Load calculation (DL, LL, Wind, Seismic)
4. 3D modelling using STAAD Pro
5. Structural analysis
6. Design of members (as per IS 800:2007)
7. Connection design
8. Deflection and stability checks
9. Fabrication and erection planning

5. EXPERIMENTAL PROGRAM:

5.1 Geometry and Support Condition of Transfer Truss:

- Span on truss = 18.6m
- Depth Of truss = 3.4 m
- Brace to Brace = 1.75 m
- Member –Hollow Rectangular Section
- Grade of Material = 310 Mpa
- Support Condition = Simply Supported and Rollers

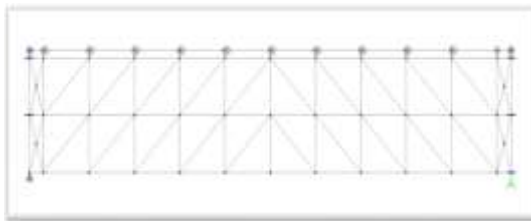


Figure No.01: Geometry of Truss



Figure No.02: Geometry of Truss

5.2 Loading on Transfer Truss:

- Self-weight of truss -Y-1
- Platform load /Sheeting /Covering plate -2KN/M
- Connection load includes Bolt, Gusset and Plates and Miscellaneous finishes load -1KN/M.
- Load Acting on single truss -70 KN/M.

- Live Load on Platform – 5 KN/M² including Material Movement with spacing of truss 1.25 m



Figure No.03: Loading on Truss

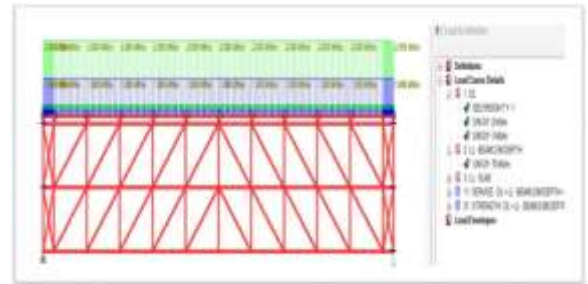


Figure No.04: Loading on Truss

5.3 Structural Behaviour, Forces & Deflection:

Axial force:

The analysis results indicate that the axial force distribution along the truss span follows the expected structural behaviour, with the top chord predominantly in compression and bottom chord in tension.

This confirms efficient load transfer and proper shear interaction at the support connections.

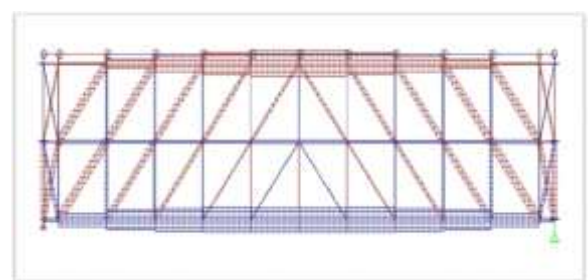


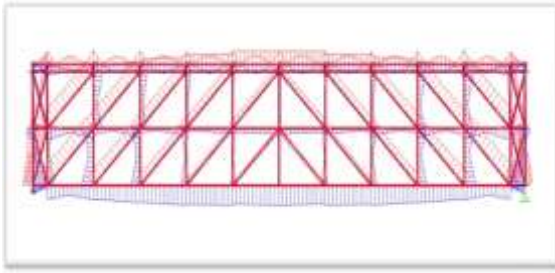
Figure No.05: Axial Force

5.4 Bending Stress:

The stress distribution in the beam is found to be satisfactory, with higher stresses near supports and mid-span regions, indicating proper bending and shear behavior under applied loads.

Design bending stress $\leq f_y / \gamma_{m0}$

Allowable bending stress $\approx 310 / 1.1 = 281 \text{ Mpa} > 148 \text{ Mpa}$.



Figure

No.06: Bending stress

5.5 Structural Behavior, Forces & Deflection Axial Force:

The analysis results indicate that the axial force distribution along the truss span follows the expected structural behavior, with the top chord predominantly in compression and the bottom chord in tension.

Deflection:

Deflection refers to the displacement or bending of a structural element when subjected to a load, such as Platform, Equipment, wind, or vibrations.

Vertical Deflection:

Occurs mainly in bridge spans under platform loads.

Measured at midspan (typically the maximum point of deflection).

Lateral Deflection:

Side-to-side movement, often caused by wind or horizontal movement.

DEFLECTION CHECK (Clause 5.6 –IS800:2007)

Allowable deflection = $\text{span} / 250 = 18600 / 250 = 74.4 \text{ mm}$

Deflection arrived due to loading = 27.253 mm

Hence Safe in Deflection.

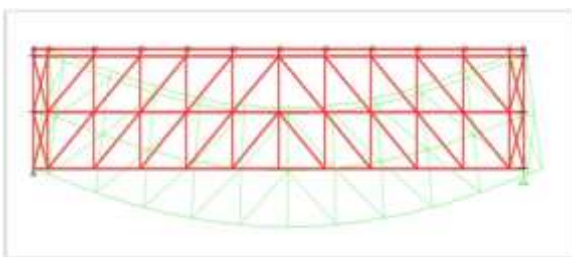


Figure No.07: Deflection

5.6 Design Check:

The design check confirms that all truss members are within permissible limits as per the applicable design codes. The utilization ratios for both tension and compression members are below unity, indicating adequate strength. Compression members show relatively higher utilization due to buckling considerations, which has been duly accounted for in the design.

Below the results indicate that the utilization ratio for tension members is 0.69, while for compression members it is 0.78. Both values are below unity, confirming that the members are adequately designed. The higher value in compression members is expected due to additional buckling effects.

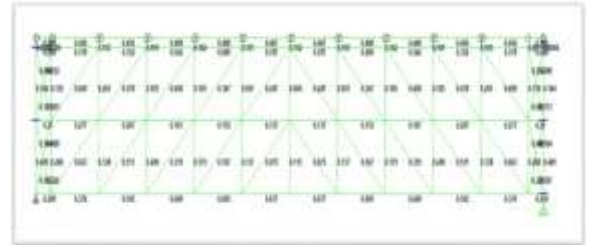


Figure No.08: Design check

6. DESIGN RESULTS OF TRUSS ELEMENTS:

The design check confirms that all truss members are within permissible limits as per the applicable design codes. The utilization ratios for both tension and compression members are below unity, indicating adequate strength. Compression members show relatively higher utilization due to buckling considerations, which has been duly accounted for in the design.

6.1 Observation and Conclusion:

Deflection:

Observation: The permissible deflection calculated based on $\text{span} / 250$ is 74 mm. The analytical deflection obtained from STAAD Pro is 27 mm, while the field test recorded a deflection of 22 mm.

Discussion: Both analytical and experimental deflection values are significantly lower than the allowable limit, indicating good stiffness of the structure. The slight variation between analytical and field results may be due to material properties, construction tolerances, and boundary conditions. Overall, the structure satisfies serviceability requirements and performs as expected.

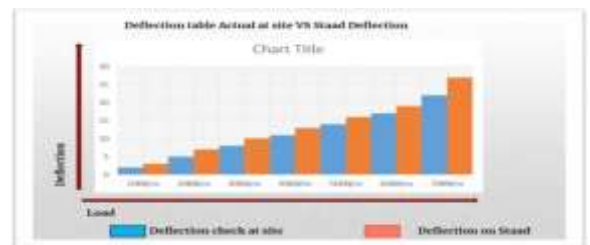


Figure No.09: Observation

6.2 Axial Force Distribution in Transfer Truss:

Observation: The axial force diagram of the transfer truss shows a proper distribution of forces, with members effectively carrying compression and tension as intended.

Discussion: The top chord members are predominantly in compression, while the bottom chord members are in tension, confirming expected truss behavior. This indicates

that the load is transferred efficiently through axial action, validating the structural modeling and design assumptions.

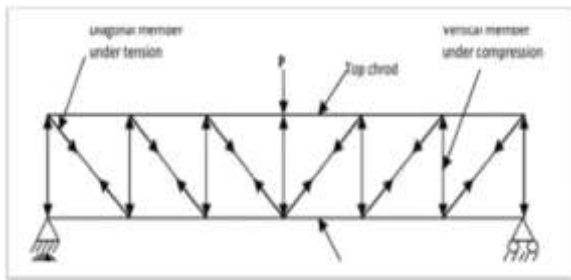


Figure No.10: Force distribution

6.3 Beam Stress Distribution:

Observation: The stress distribution in the beam is found to be satisfactory, with higher stresses observed near supports and mid-span regions.

Discussion: This pattern is consistent with expected bending and shear behavior, where maximum bending moments occur at mid-span and higher shear near supports. The stress values remain within permissible limits, confirming that the beam is performing safely under the given loading conditions.

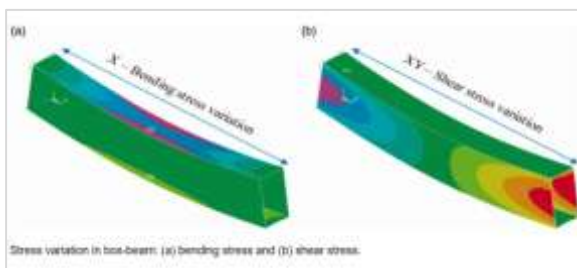


Figure No.11: Beam stress distribution

6.4 Utilization Ratio:

- Tension members ≈ 0.69
- Compression members ≈ 0.78

All $< 1 \rightarrow$ Safe design

This validates practical feasibility of design.

6.5. Execution Process:

The project included real site execution:

1. Fabrication at yard
2. Insert Plate
3. Corbel erection
4. Truss lifting using tower crane
5. Installation and bracing
6. Connection testing (DPT)
7. Final Installation

Stage I: Fabrication at yard



Stage II: Insert plate



Stage III: Corbel erection & Lifting



Stage IV: Truss lifting using tower crane



Stage V: Installation and bracing



Stage VI: Connection testing (DPT)

Stage VII: Final Installation



6.6 Discussion:

The structural analysis of the transfer truss system produced the following results: Axial Force Distribution: The truss shows proper force distribution, with compression in the top chord and tension in the bottom chord, confirming expected structural behaviour.

Stress Analysis:

The maximum bending stress is within allowable limits, ensuring safe design as per codal provisions.

Deflection Check:

The allowable deflection (span/250) is 74.4 mm, whereas the obtained deflection is 27.25 mm, which is significantly lower and hence safe.

Utilization Ratio:

The utilization ratio for tension members is approximately 0.69 and for compression members is 0.78, both less than 1.0, indicating safe design.

The results clearly demonstrate that the transfer truss system performs efficiently under applied loads. The axial force-dominated behaviour ensures that the structure utilizes material efficiently with minimal bending effects. The deflection is well within permissible limits, indicating adequate stiffness of the system, which is essential to prevent serviceability issues such as Cracking or Misalignment.

Compression members exhibit slightly higher utilization due to buckling effects, which is expected in truss systems. However, proper design and member selection ensure stability and safety. The close agreement between theoretical expectations and analysis results validates the Modelling approach.

Overall, the transfer truss system satisfies both strength and serviceability requirements, making it a reliable solution for high-rise structures with column discontinuity.

7. CONCLUSION & FUTURE SCOPE:**7.1 Overview of the Project:**

This study confirms that transfer truss systems are indispensable for high-rise buildings with irregular layouts, as they efficiently redistribute massive loads from upper columns to lower supports. By optimizing truss configuration and connection detailing, these systems effectively minimize deflection and stress concentrations while enabling valuable column-free architectural spaces. However, due to their high load density and structural complexity, they require precision engineering and

meticulous construction-stage analysis to mitigate sensitivity to errors and ensure overall safety.

Transfer truss is a reliable and efficient solution for high-rise structures.

7.2 Future Scope:

- Nonlinear and dynamic analysis
- Use of high-strength steel
- BIM integration
- Structural health monitoring
- Optimization techniques

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