Analysis And Structural Design of a G+2 Pre-Engineered Building with Truss Less Roofing and Peripheral Cantilever System

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***Abstract*—The present study focuses on the analysis and structural design of a G+2 Pre-Engineered Building (PEB) convention centre with truss less roofing, modular expansion concept, and peripheral cantilever system. The proposed structure was modeled and analyses using STAAD Pro V9i software under dead load, live load, wind load, and seismic load conditions as per relevant IS codes. The convention centre consists of parking, dining hall, kitchen, auditorium, and stage facilities with large column-free spaces for improved functionality. A truss less roofing system was adopted to achieve long-span structural performance with reduced self-weight and improved aesthetics. The peripheral cantilever system was introduced to enhance architectural appearance and provide external circulation space. Structural analysis was carried out using appropriate load combinations, and the responses such as displacement, beam reactions, and member forces were evaluated. The study demonstrates that PEB systems provide economical, lightweight, and efficient structural solutions compared to conventional RCC structures.**

***Index Terms*—Pre-Engineered Building, Convention Centre, Truss less Roofing, Peripheral Cantilever System, STAAD.Pro V9i, Seismic Loads, Wind Loads, Structural Analysis, Steel Structure**.

I. INTRODUCTION

Pre-Engineered Buildings (PEB) are modern steel structural systems widely used in commercial, industrial, and public buildings. These structures are preferred because of their lightweight nature, faster construction, and economical design. PEB components are fabricated in factories and assembled at the construction site. Compared to conventional RCC buildings, PEB structures reduce construction time and foundation cost. They provide large column-free spaces suitable for auditoriums, convention Centre, and industrial halls. Steel sections are optimized based on structural requirements, improving efficiency and reducing material wastage. PEB systems also offer flexibility in architectural planning and future expansion. Due to these advantages, PEB systems are increasingly adopted in modern infrastructure projects.

PRE-ENGINEERED BUILDINGS

Pre-Engineered Buildings are steel structures designed using built-up sections according to bending moment and shear force requirements. The structural members are manufactured in factories under controlled conditions and transported to the site for erection. PEB systems provide high structural efficiency with reduced steel consumption. These structures are widely used for warehouses, industrial buildings, auditoriums, and convention halls. The prefabrication process improves quality control and reduces construction errors. PEB systems also minimize construction time and labour requirements. Due to their lightweight nature, they reduce foundation loads and overall project cost. The flexibility and adaptability of PEB systems make them suitable for modern long-span structures.

TRUSSLESS ROOFING SYSTEM

The trussless roofing system is adopted in the present project to achieve large-span coverage without intermediate supports. Curved steel rafters and lightweight roofing sheets are used to reduce structural dead load. The system provides large unobstructed interior spaces suitable for convention halls and auditoriums. Trussless roofs improve the architectural appearance of the structure and provide better interior aesthetics.

The absence of roof trusses simplifies the structural arrangement and improves functional space utilization. Lightweight roofing materials reduce load on columns and foundations. Proper structural analysis is necessary to ensure roof stability and deflection control. The trussless roofing concept is efficient, economical, and suitable for modern steel buildings.

PERIPHERAL CANTILEVER SYSTEM

Peripheral cantilever systems are provided around the building perimeter to improve both functionality and architectural appearance. Cantilever projections provide shading, balcony space, and external circulation areas. Steel cantilever beams are used due to their high strength and lightweight nature. Proper design of cantilever systems is essential to control deflection and ensure structural stability. The cantilever arrangement also enhances the modern appearance of the convention centre. These systems efficiently transfer loads to the main structural frame. Peripheral cantilevers improve usable space without increasing foundation area. The system adopted in the project provides both structural efficiency and aesthetic enhancement.

II. LITERATURE REVIEW

This literature review has been carried out by various books, research papers, journals, and reliable online sources to understand the concepts of PEB.

Syed Firoz (2012) presented a detailed study on the design concept of Pre-Engineered Buildings and their advantages over conventional structures. The study focused on the efficient use of steel sections in industrial and commercial buildings. The author explained that PEB systems reduce construction time due to factory fabrication and quick site erection. The optimized steel sections used in PEB structures help in reducing overall structural weight. The research highlighted the economic benefits achieved through reduced material consumption and labour cost. The study also discussed the suitability of PEB systems for long-span structures such as auditoriums, warehouses, and industrial buildings. The structural performance of PEB systems under various loading conditions was evaluated. The results showed that PEB structures provide better flexibility and adaptability compared to RCC buildings. The study concluded that PEB systems are cost-effective and environmentally sustainable. The research supports the adoption of PEB structures for modern convention centre construction. The findings are useful for understanding lightweight structural systems and efficient steel usage. The study provides a strong foundation for the present project involving a G+2 PEB convention centre.

Maria Subashini and Shamini Valentina (2015) carried out a comparative study between Pre-Engineered Buildings and conventional industrial steel buildings. The research analysed the structural behaviour, material consumption, and construction efficiency of both systems. The study reported that PEB structures require less steel compared to conventional steel buildings due to optimized section design. The authors explained that PEB systems reduce foundation cost because of reduced structural self-weight. The construction time of PEB buildings was found to be significantly lower than traditional construction methods. The study also discussed the flexibility offered by PEB systems for future expansion and modifications. Structural analysis results showed that PEB systems provide satisfactory performance under dead, live, and wind loads. The authors highlighted the economic advantages achieved through reduced fabrication and erection time. The study concluded that PEB structures are suitable for industrial and commercial applications requiring large column-free spaces. The findings support the use of PEB systems in convention centres and assembly buildings. The research is relevant to the present project due to its focus on economical and lightweight steel structures.

Duggal S.K. (2018) discussed the design and behaviour of long-span steel structures used in auditoriums, stadiums, and industrial buildings. The study focused on structural systems capable of covering large areas without intermediate supports. The author explained the advantages of steel structures in achieving long spans with reduced dead load. The research highlighted the importance of trussless roofing systems in improving architectural appearance and interior space utilization. Various steel framing systems and roofing concepts were discussed in detail. The study emphasized the need for proper deflection control and lateral stability in long-span structures. The author explained that rigid steel frames provide efficient load transfer and improved structural performance. The research also discussed the use of lightweight roofing materials to reduce structural loads. The findings indicated that steel structures are highly suitable for convention halls and auditoriums requiring unobstructed spaces. The study supports the trussless roofing concept adopted in the present project. The information provided in the research is useful for understanding long-span structural behaviour and design considerations.

S. Sayyad and A.S. Shaikh (2019) conducted a study on the estimation of deflections in cantilever steel beams subjected to various loading conditions. The research focused on understanding the behaviour of cantilever beams and methods to control excessive deflection. The authors explained that cantilever systems are widely used in balconies, canopies, and peripheral structural extensions. The study discussed the importance of stiffness and proper member sizing in cantilever beam design. Different loading cases and support conditions were analysed to evaluate beam deflection behaviour. The research highlighted that excessive cantilever deflection affects structural safety and serviceability. The study proposed suitable design approaches for improving cantilever performance. The authors concluded that optimized steel sections help in controlling deflection and improving stability. The findings are relevant to the peripheral cantilever system adopted in the present project. The study supports the use of steel cantilever beams for architectural and functional enhancement. The research provides useful guidance for cantilever beam analysis and structural design.

Paul Sherlock (2021) presented a study on the development of affordable steel-framed modular buildings and their advantages in modern construction. The research focused on modular construction techniques and future expansion possibilities in steel structures. The study explained that modular systems improve construction speed and reduce labour requirements. The author discussed the flexibility offered by steel modular buildings for future structural extensions without demolition.

The research highlighted the economic and environmental benefits of modular construction. The study also analysed the structural performance of modular steel systems under different loading conditions. The results showed that steel modular buildings provide improved lifecycle performance and ease of maintenance. The author emphasized the importance of bolted connections in modular structural systems. The findings indicated that modular construction is highly suitable for commercial and public buildings. The study supports the modular expansion concept adopted in the present project. The research provides valuable information regarding expandable steel structural systems and efficient construction practices.

Swetha Pantheeradi and Susan Abraham (2022) carried out a comparative study between Pre-Engineered Buildings and conventional steel buildings. The study focused on analysing structural weight, construction efficiency, and overall project economy. The authors explained that PEB structures are fabricated using optimized built-up sections, which reduce steel consumption. The research highlighted that PEB systems require less construction time due to factory manufacturing and quick assembly at site. Structural analysis was performed under various loading conditions to compare the performance of both systems. The study showed that PEB structures provide better flexibility and adaptability for large-span buildings. The authors discussed the reduced foundation requirements achieved through lightweight steel framing systems. The results indicated that PEB structures are more economical and efficient compared to conventional steel structures. The study concluded that PEB systems are suitable for commercial buildings such as convention centres and industrial halls. The findings support the use of PEB systems in the present project for achieving safe and economical structural performance. The research provides valuable insights into modern steel construction methods and structural optimization.

III. RESEARCH METHODOLOGY

The research methodology involves the structural analysis and design of a G+2 Pre-Engineered Building (PEB) convention centre incorporating a trussless roofing system and a peripheral cantilever arrangement. The proposed building was developed with plan dimensions of 30 m × 72 m, providing a total built-up area suitable for convention, dining, parking, and service facilities. The building consists of three levels (Ground + 2 Floors) with a floor-to-floor height of 4.0 m, resulting in an overall structural height of approximately 12 m. The structural system was designed using optimized built-up steel sections to achieve large column-free spaces while maintaining structural stability and economy. The complete three-dimensional model was developed and analysed using STAAD.ProV9i. Structural analysis and member design were carried out in accordance with IS 800:2007 for steel design, IS 875 (Part 1, Part 2 and Part 3) for dead, live, and wind loads, and IS 1893 (Part 1):2016 for seismic loading. The methodology included geometric modelling, material property assignment, section selection, load application, and generation of critical load combinations. The structure was evaluated under dead load, live load, wind load, and earthquake load to determine structural responses such as nodal displacement, beam forces, support reactions, axial forces, bending moments, and overall stability. Design iterations were performed by optimizing the steel member sections until all members satisfied the strength, serviceability, and stability requirements prescribed by the relevant Indian Standard codes. The final structural configuration demonstrated adequate load-carrying capacity, efficient material utilization, and satisfactory performance under all governing load combinations, confirming the suitability of the proposed Pre-Engineered Building system for modern convention centre applications.

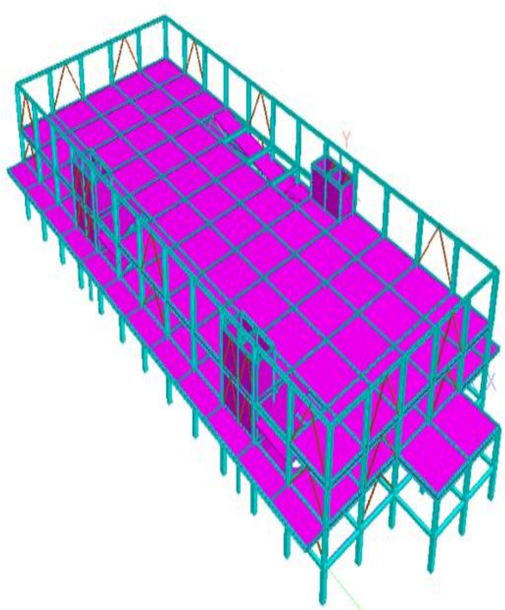

Figure 1: PEB 3D Model

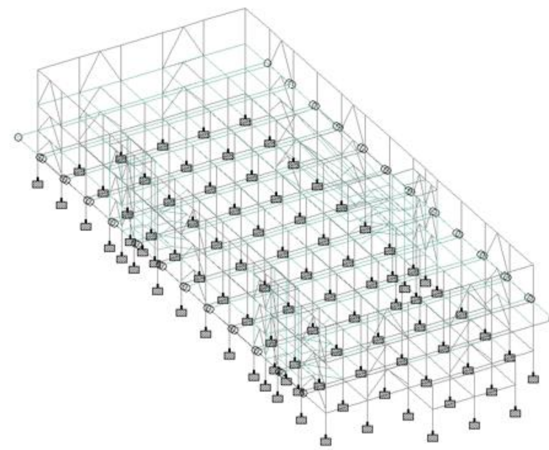

Figure 2: Isometric view

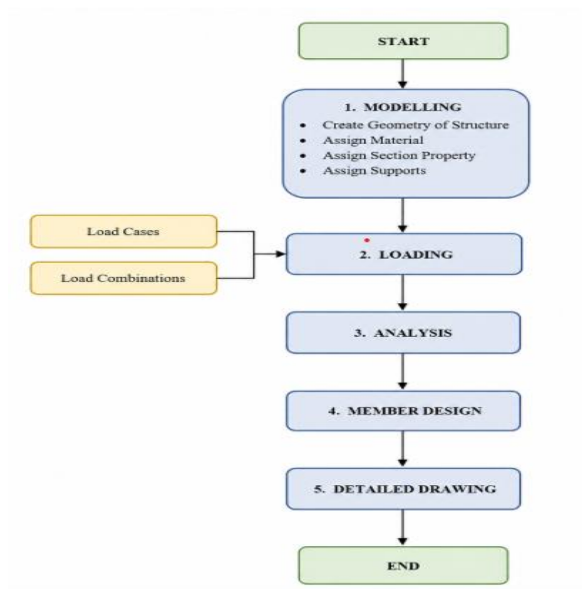

Figure 3: Process of Design

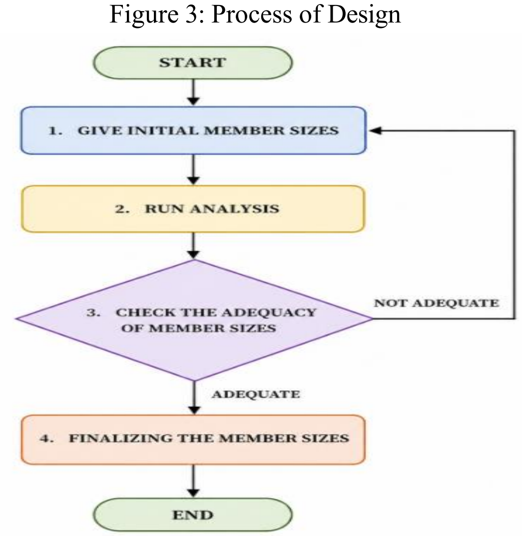

Figure 4: Iterative Process of Member Design

STRUCTURAL PARAMETERS

Table 1: Structural Parameters

Sl. No	Component	Size / Thickness	Remarks
1	Foundation	1.50x1.50x0.40 m 2.70x2.70x0.60 m 3.20x3.20x0.60 m	Main structural member
2	Column	0.50 m × 0.50 m 0.30 m x 0.30 m	Lvl.-3.00m to +0.50m
3	Plinth Beam	0.30 m × 0.30 m	Lvl.0.00m
4	Slab Plate	150 mm	Floor system
5	Lift Plate	10 mm	Steel plate
6	PEB Section	Taper Section	Primary frame

PROPERTY ASSIGNMENT

Table 2: Dead Load Of Components

. No	Component	Size / Thickness	Description / Usage	Remarks
1	Slab Plate	150 mm	Thickness provided for slab	Floor system
2	Lift Plate	10 mm	Plate thickness for lift core	Steel plate
3	Column	0.50 m × 0.50 m	RCC column section	Main structural member
4	Plinth Beam	0.30 m × 0.30 m	Beam at plinth level	Load transfer
5	Taper Section	Sections 1, 2, 3, 4, 5, 6	Built-up tapered sections for PEB	Primary frame
6	Lift Column / Beam	0.30 m × 0.30 m	Structural support for lift shaft	Secondary member

IV. LOAD CALCULATION

DEAD LOAD

Dead loads include self-weight, floor finish, wall loads, roofing loads, and false ceiling loads calculated as per IS 875 Part 1.

Table 3: Dead Load

Sl. No	Component	Load Value (kN/m²)
1	Self-Weight	Auto
2	Brick Wall (230 mm)	5
3	False Ceiling Load	0.5
4	Partition Floor Load	3
5	Roofing Load	0.75
6	Lift Load	5
7	Staircase Load	5
8	Ramp Load	5

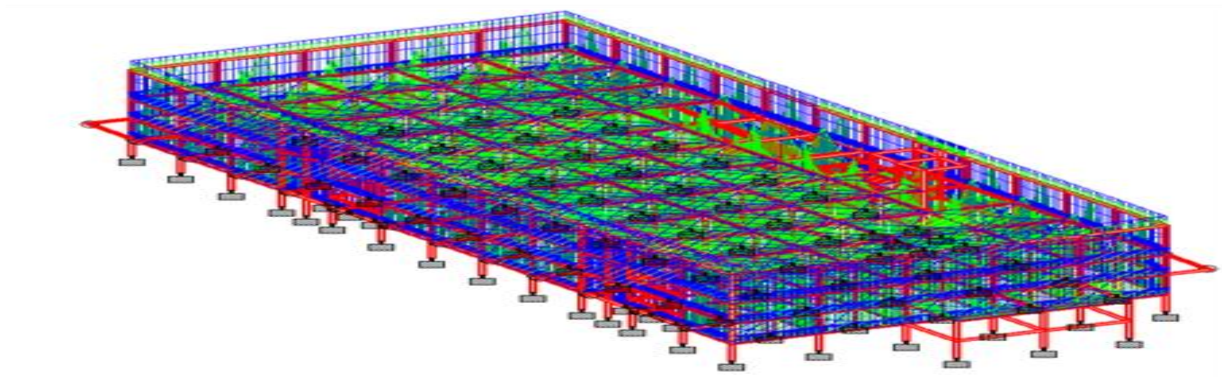

Figure 5: Dead Load Assigned

LIVE LOAD

Live loads were assigned based on occupancy such as dining hall, auditorium, staircase, kitchen, and parking areas as per IS 875 Part 2.

Table 4: Live Load

Sl. No	Area Type	Load Value (kN/m²)
1	Dining Hall	5
2	Kitchen	3
3	Toilet	2
4	Stage	5
5	Auditorium	5
6	Balcony	4
7	Staircase	5
8	Lift	5
9	Roof	3
10	Ramp	5

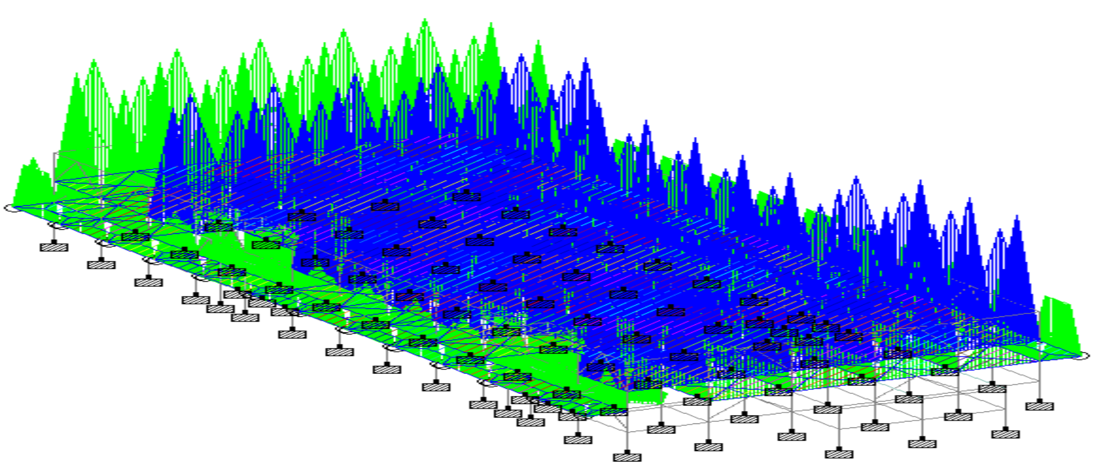

Figure 6: Live Load Assigned

WIND LOAD

Wind load is one of the governing lateral loads for long-span steel structures. The proposed convention centre incorporates a trussless roofing system with a large exposed roof area, making wind loading a critical design consideration.

Wind loads were determined according to IS 875 (Part 3): 2015 by considering.

Table 5: Wind Load

Sl. No	Parameter	Value
1	Basic Wind Speed (Vb)	39 m/s
2	Risk Coefficient (k1)	1.0
3	Terrain Factor (k2)	1.0
4	Topography Factor (k3)	1.0
5	Design Wind Speed (Vz)	39 m/s
6	Wind Pressure (Pz)	0.91 kN/m²
7	Wind Directions	+X, -X, +Z, -Z
8	Critical Effect	Roof uplift
9	Governing Load	Wind load

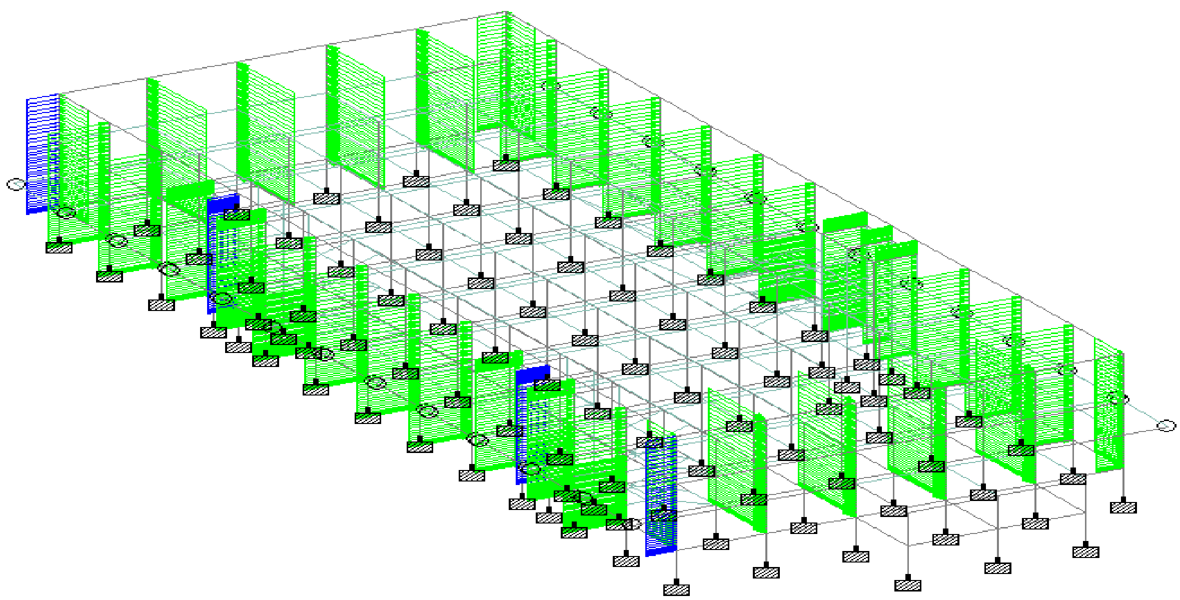

Figure 7: WIND LOAD

SEISMIC LOAD

Seismic loads were calculated as per IS 1893 using Zone Factor = 0.16,
Importance Factor = 1.2,

Response Reduction Factor = 4.

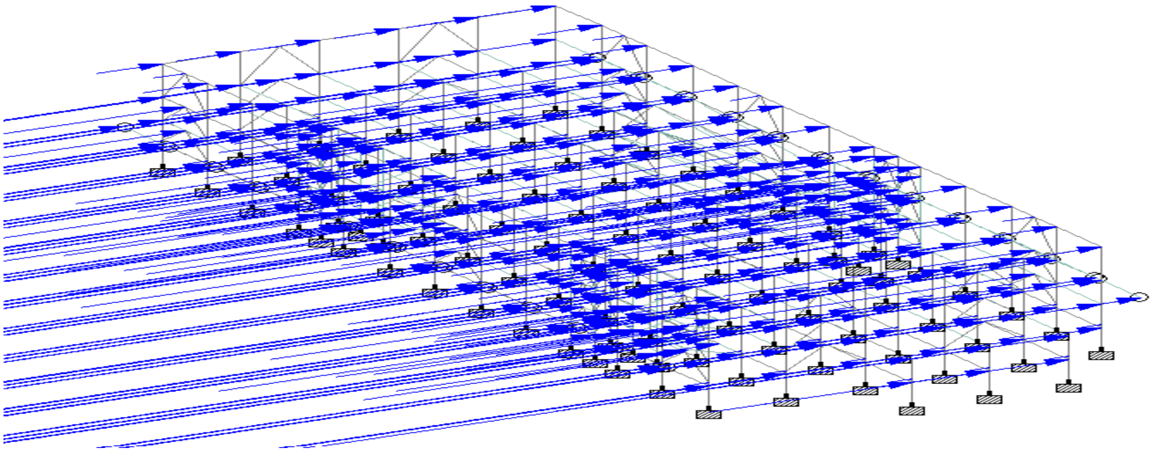

Figure 8: SEISMIC LOAD

LOAD COMBINATIONS

Ultimate Load Combination Factor Loads

Table 6: Ultimate Load Combination

Load Combination	Description	IS Code Reference
1.5 DL	Dead load only	IS 800 Cl. 5.3.3
1.5 DL + 1.5 LL	Dead + Live	IS 800
1.5 DL + 1.5 Wind (+X, -X, +Z, -Z)	Wind cases (both CPI ±)	IS 875 Part 3
1.5 DL + 1.5 EQ (+X, -X, +Z, -Z, +Y, -Y)	Seismic cases	IS 1893
1.2 DL + 1.2 LL + 0.6 Wind (all directions)	Reduced wind combo	IS 800
1.2 DL + 1.2 LL + 0.6 EQ (all directions)	Reduced seismic combo	IS 1893
1.2 DL + 1.2 LL + 1.2 Wind (all directions)	Full wind combination	IS 875
1.2 DL + 1.2 LL + 1.2 EQ (all directions)	Full seismic combination	IS 1893
0.9 DL + 1.5 Wind (all directions)	Uplift (critical for PEB)	IS 800
0.9 DL + 1.5 EQ (all directions)	Seismic uplift	IS 1893

Serviceability Load Combination Factor Loads

Table 7: Serviceability Load Combination

Load Combination	Description	IS Code Reference
1.0 DL	Dead load only	IS 800
1.0 DL + 1.0 LL	Normal service load	IS 875

1.0 DL + 1.0 Wind (all directions)	Wind service case	IS 875
1.0 DL + 1.0 EQ (all directions)	Seismic service case	IS 1893
1.0 DL + 0.8 LL + 0.8 Wind	Reduced service wind	IS 800
1.0 DL + 0.8 LL + 0.8 EQ	Reduced service seismic	IS 1893

CONCRETE DESIGN PARAMETERS

Table 8: Concrete Design Parameters

Parameter	STAAD Value	Meaning	IS Code Reference
Design Code	INDIAN	IS method used	IS 456:2000
Clear Cover	0.03 m	30 mm cover	25–50 mm (IS 456)
Clear Cover	0.05 m	50 mm cover	For columns/exposure
FC	35000 kN/m²	fck = 35 MPa (M35)	≥ M20 required
FYMAIN	550000 kN/m²	Main steel = 550 MPa	Fe500/Fe550
FYSEC	550000 kN/m²	Secondary steel	Fe415–Fe550
MAXMAIN	32 mm	Max main bar dia	≤ 40 mm
MAXSEC	16 mm	Max secondary bar	≤ 16 mm typical
MINMAIN	16 mm	Min main bar	≥ 12 mm (beam)
MINSEC	10 mm	Min secondary bar	≥ 8 mm
RATIO	4%	Max steel ratio	≤ 4% (IS 456)
TRACK	2	Detailed output level	—
Design Type	BEAM	Beam design	IS 456
Design Type	COLUMN	Column design	IS 456
Concrete Take Off	Enabled	Quantity calc	—

STEEL DESIGN PARAMETERS

Table 9: Steel Design Parameters

Parameter	STAAD Value	Meaning	IS Code Reference
Code	INDIAN	IS 800 used	IS 800:2007
BEAM	1	Beam design ON	Steel design
CMY	0.9	Moment factor (Y)	IS 800
CMZ	0.9	Moment factor (Z)	IS 800
DFF	180	Deflection limit	Span/180
DFF	150	Deflection limit	Span/150
FYLD	250000 kN/m²	Fy = 250 MPa	Fe250 steel
LY	1.5 m	Effective length Y	IS 800
LZ	3.5 m	Effective length Z	IS 800
LZ	5 m	Buckling length	IS 800
LZ	6 m	Buckling length	IS 800
LZ	3 m	Buckling length	IS 800

MAIN	180	Slenderness ratio	≤ 180
NSF	1	Net section factor	IS 800
RATIO	1	Unity check limit	≤ 1
TRACK	2	Output detail	—
CHECK CODE	Enabled	Code verification	IS 800
STEEL TAKE OFF	Enabled	Quantity calc	—

V. RESULTS

BEAM REACTIONS SUMMARY

Table 10: Beam Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	714	218 1.0 DL + 0	**11.691**	519.467	47.624	71.310	5.175	-6.547
Min Fx	705	207 1.0 DL + 1	**-122.109**	-443.791	5.296	12.029	-2.308	207.496
Max Fy	728	202 1.0 DL + 1	-78.772	**729.664**	-116.147	-192.485	-1.907	132.045
Min Fy	694	203 1.0 DL + 1	-89.768	**-712.436**	111.034	184.138	-1.361	151.435
Max Fz	680	203 1.0 DL + 1	-84.589	-681.103	**111.274**	184.785	-1.359	142.739
Min Fz	728	202 1.0 DL + 1	-78.772	729.664	**-116.147**	-192.485	-1.907	132.045
Max Mx	680	203 1.0 DL + 1	-84.589	-681.103	111.274	**184.785**	-1.359	142.739
Min Mx	728	202 1.0 DL + 1	-78.772	729.664	-116.147	**-192.485**	-1.907	132.045
Max My	714	204 1.0 DL + 1	-15.806	643.844	56.862	84.766	**9.100**	57.973
Min My	670	202 1.0 DL + 1	-32.931	-19.562	-36.603	-79.877	**-9.448**	73.533
Max Mz	705	207 1.0 DL + 1	-122.109	-443.791	5.296	12.029	-2.308	**207.496**
Min Mz	714	218 1.0 DL + 0	11.691	519.467	47.624	71.310	5.175	**-6.547**

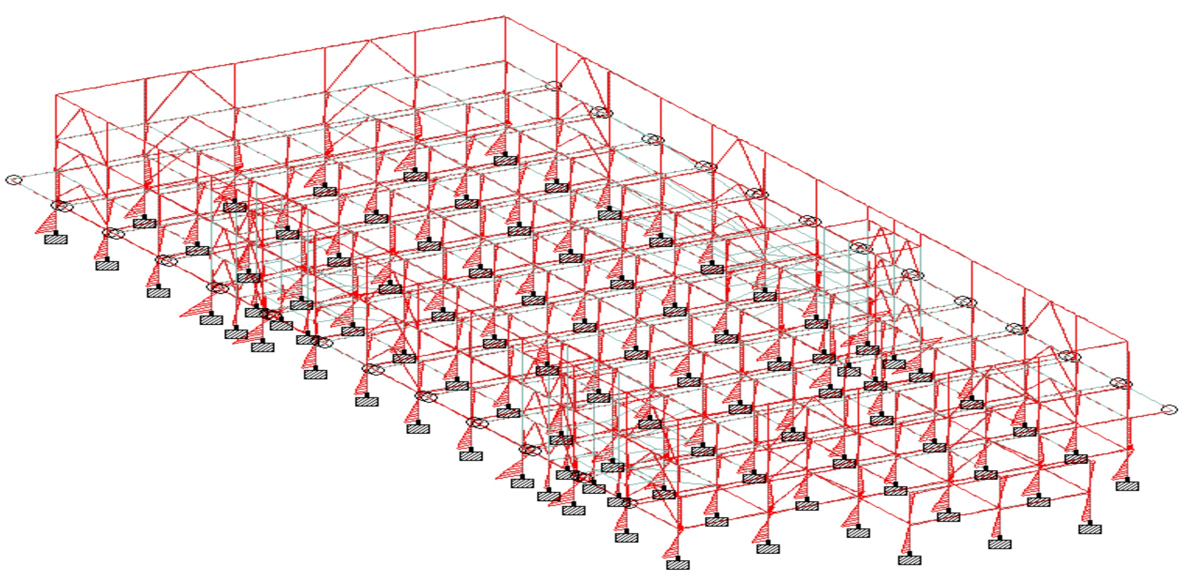

Figure 9:Bending Moment Diagram

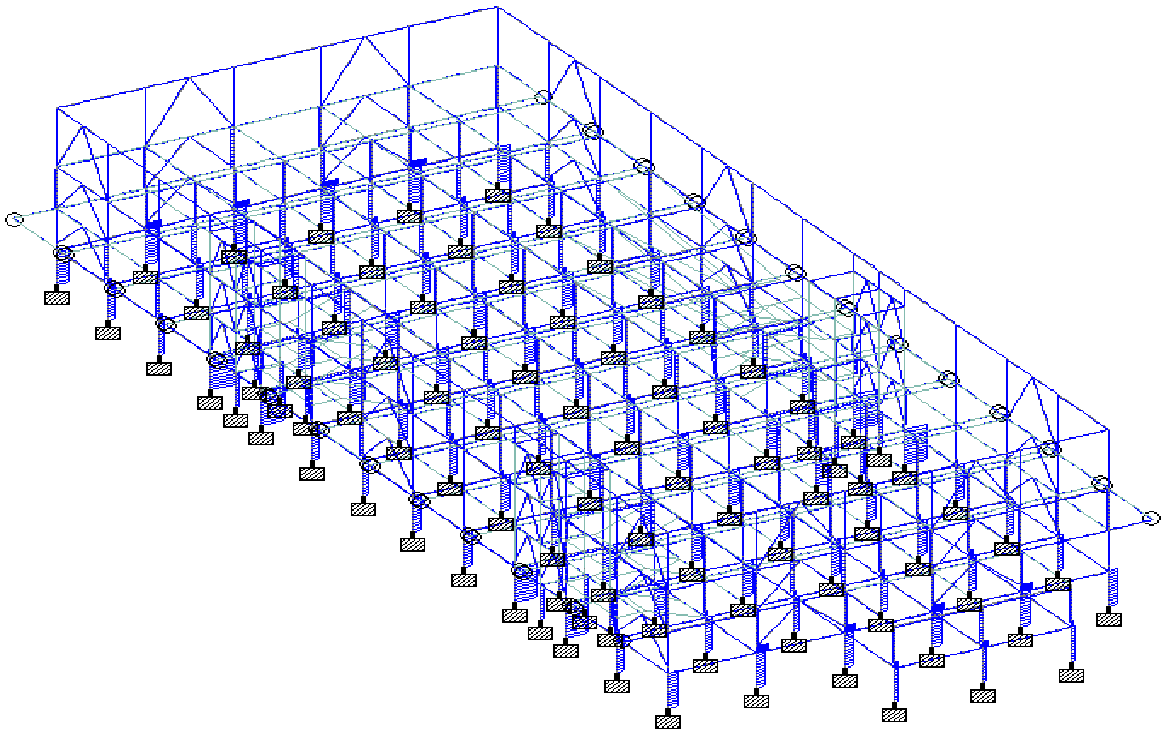

Figure 9:Shear Forcet Diagram

DISPLACEMENT SUMMARY

Table 11: Displacement Summary

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	282	207 1.0 DL + 1	**15.627**	0.079	-0.533	15.637	-0.000	0.001	-0.002
Min X	163	223 1.0 DL + 0	**-6.515**	-0.021	0.027	6.515	0.000	0.000	0.002
Max Y	858	203 1.0 DL + 1	2.678	**5.796**	-3.015	7.061	-0.001	-0.000	-0.000
Min Y	861	204 1.0 DL + 1	4.519	**-17.990**	1.225	18.589	-0.004	0.000	-0.004
Max Z	562	211 1.0 DL + 1	6.195	0.037	**15.309**	16.515	0.004	-0.000	-0.000
Min Z	318	213 1.0 DL + 1	5.887	-0.036	**-15.139**	16.244	-0.004	0.000	-0.000
Max rX	562	211 1.0 DL + 1	6.195	0.037	15.309	16.515	**0.004**	-0.000	-0.000
Min rX	861	204 1.0 DL + 1	4.519	-17.990	1.225	18.589	**-0.004**	0.000	-0.004
Max rY	561	213 1.0 DL + 1	5.875	-0.033	-11.878	13.252	-0.003	**0.002**	-0.000
Min rY	73	206 1.0 DL + 1	6.077	0.044	-0.291	6.084	-0.000	**-0.002**	-0.000
Max rZ	854	204 1.0 DL + 1	3.238	-17.200	-0.105	17.503	-0.004	0.000	**0.004**
Min rZ	340	204 1.0 DL + 1	3.908	-10.380	1.042	11.140	-0.000	-0.000	**-0.005**
Max Rst	861	204 1.0 DL + 1	4.519	-17.990	1.225	**18.589**	-0.004	0.000	-0.004

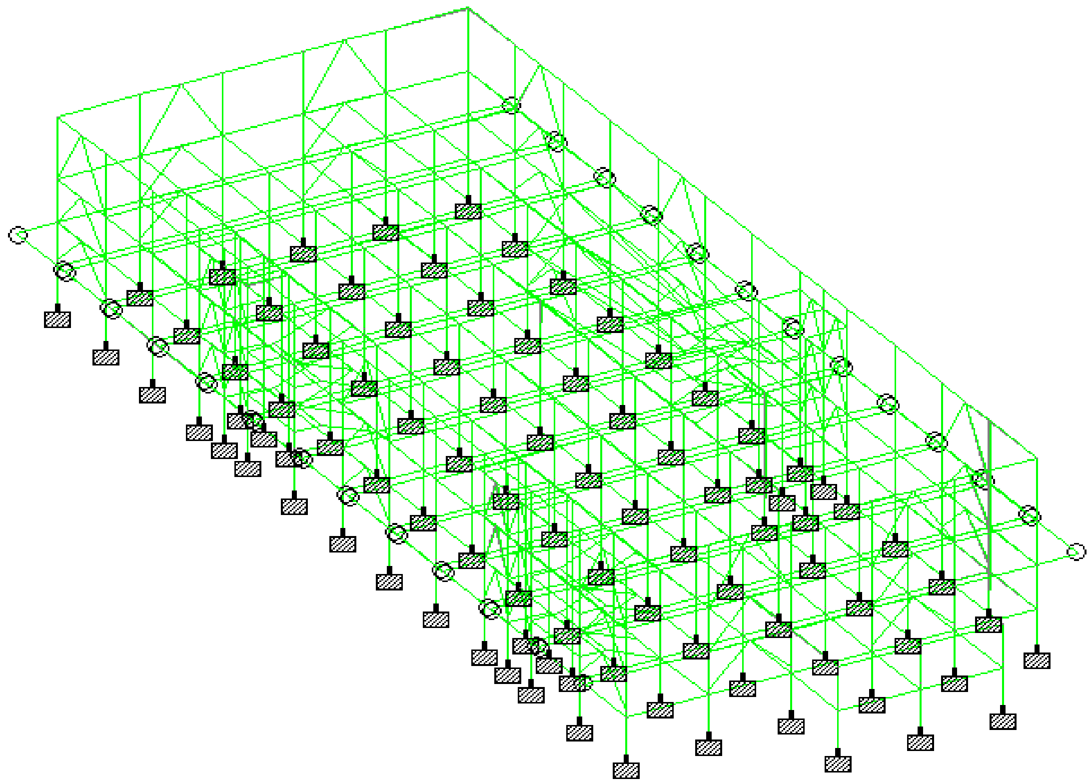

Figure 10:Displacementt Diagram

VI. RESULTS AND DISCUSSION

- The STAAD Pro analysis showed that the proposed PEB structure satisfies strength and serviceability requirements.
- The trussless roofing system successfully provided large column-free spaces suitable for auditorium and dining hall functions.
- The structural self-weight of the PEB system was lower compared to conventional RCC structures.
- Wind load was identified as the governing lateral load condition for roof uplift and cantilever behaviour.
- The peripheral cantilever system improved both architectural appearance and functional circulation space.
- The displacement values obtained from analysis were within permissible limits specified in IS codes.
- The modular expansion concept allows future extension of the building without major demolition work.
- Optimized built-up steel sections reduced steel consumption and improved structural efficiency.
- The structure exhibited satisfactory performance under combined dead, live, wind, and seismic load conditions.
- The project demonstrates that PEB systems are economical, lightweight, and suitable for modern large-span buildings.

VII. CONCLUSION

- A G+2 Pre-Engineered Building convention centre was successfully planned and analysed using STAAD Pro software.
- The trussless roofing system effectively achieved large-span coverage without internal obstructions.
- The peripheral cantilever system enhanced both aesthetics and circulation functionality.
- The modular expansion concept allows future structural extension without reconstruction.
- The optimized steel sections reduced structural weight and improved overall efficiency.

- The structure satisfied stability and serviceability requirements under all critical load combinations.
- The use of PEB systems reduced construction time and foundation requirements.
- Wind and seismic analyses confirmed the safety and performance of the structural system.
- The project demonstrates the advantages of steel construction for commercial and public buildings.
- The project demonstrates the advantages of steel construction for commercial and public buildings.

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