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LARGE SPAN STEEL ROOF STRUCTURES OF INDUSTRIAL BUILDINGS SEISMIC EVALUATION USING CIRCULAR AND RECTANGULAR STEEL PIPE

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Abstract

Low ceiling heights, a lack of interior partitions, and the presence of factories or workshops are all characteristics of industrial building structures. These buildings frequently have low-rise steel frames and might incorporate gantry girders, which help support enormous loads. This study examines the structural behavior of industrial structures subjected to lateral loads like wind and seismic stresses using equivalent static analysis using ETABS v17.0.1. With regard to long-span roof structures in industrial buildings, the study specifically examines the performance of circular and square or rectangular steel tubes employed in truss formations.

Key Words: Industrial Building Structures, Low-rise stell frames, girders

1.INTRODUCTION

Steel is a popular choice for structural purposes because of its great ductility, strength, and homogeneity. Due to its light weight, simplicity of usage, and numerous physical qualities, it is especially favored in earthquake-prone areas. Tall and wide-span steel constructions are less expensive than concrete ones. Steel construction is quick, and with the right design and detailing, these buildings are capable of withstanding significant lateral stresses. Steel production is subject to rigorous quality control, which guarantees uniform physical qualities and trustworthy connections for increased safety.

1.1 Major components of Industrial Buildings

- Roof Truss
- Bracket Column
- Gable Rafter
- Gable column
- Girts
- Main Column
- Purlins
- Eave Truss

1.2 ROOF TRUSS

Trusses are triangular frameworks composed of members that primarily carry axial loads. Their efficiency in resisting external loads stems from the nearly uniform stress distribution across the cross-section of all the members. As a result, trusses are widely employed in structures with larger spans.

1.3 TYPES OF ROOF

The sawtooth kind of roof is a particular style that comprises of ridges with two pitches on each side. The steeper portions of the roof on one side are glazed and point away from the equator. The objective of this arrangement is to protect equipment and personnel from direct sunlight. Deep plan buildings or industries can get a lot of natural light thanks to the shape of the sawtooth roof, which improves the lighting conditions there. It is especially useful for creating a bright and cosy working atmosphere while reducing the need for artificial lighting.

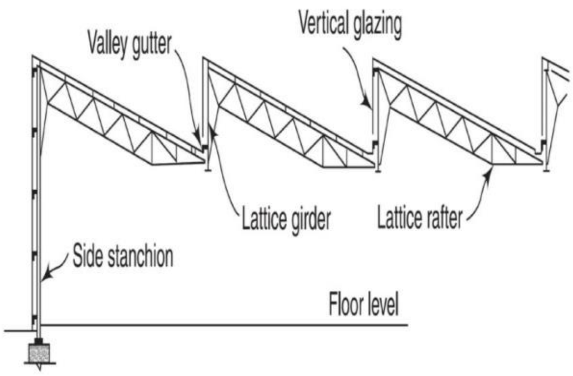


Fig.1.3:Sawtooth Type

The umbrella type is a specific design of roof that resembles the shape of an umbrella. This type of roof truss is commonly utilized in small-scale industrial buildings with spans that are less than 10 meters. The umbrella design provides a simple and efficient solution for covering such structures, offering adequate support and protection. It is a practical choice for smaller industrial buildings where cost-effectiveness and ease of construction are key considerations.

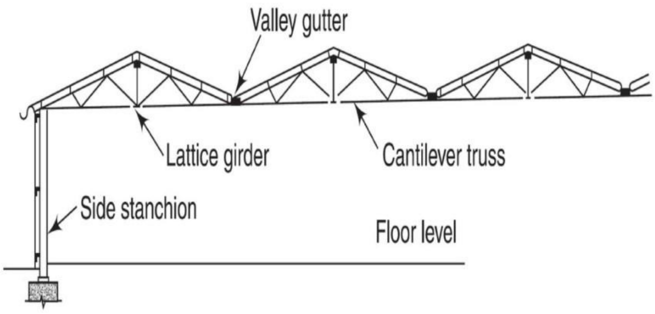


Fig.1.4:Umbrella Type

The butterfly type of roof, commonly known as a V roof, is a distinctive roof style. In an inverted variant of the conventional roof design, two roof surfaces slope downward from opposite edges towards a valley near to the center of the roof. The fact that its roof design mimics a butterfly's wings is where the word "butterfly" originates. In the US, butterfly roofs are frequently used in architectural designs. They allow for more natural light and the possibility of collecting rainwater, and they also give a distinctive and striking look.

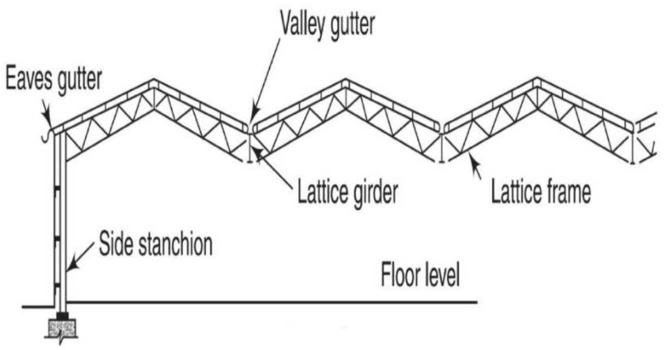


Fig.1.5:ButterflyType

1.4 ANALYSIS OF ROOF TRUSS

The analysis of trusses to determine secondary moments and stresses can be conducted using indeterminate structural analysis methods, typically utilizing computer software such as E Tab, Staad Pro, etc.

- The magnitude of secondary stresses resulting from joint rigidity is influenced by the stiffness of the joint and the stiffness of the members connected at the joint.
- If the chord members' and web members' slenderness ratios are greater than 50 and 100, respectively, secondary stresses in roof trusses may be deemed negligible.

However, the presence of secondary stresses cannot be ignored in the following cases:

- When members are linked eccentrically or when loads are given to the members between nodes, which causes secondary stresses.
- Furthermore, it is impossible to ignore the secondary stresses brought on by joint rigidity.
- In the case of bridge trusses, where it is necessary to take into account the higher stiffness of the members and the effect of secondary stresses on the fatigue strength of members.

1.5 FACTORS CONSIDERED WHILE SELECTING SITE FOR INDUSTRIA BUILDING

When selecting a site for an industrial building, several factors should be considered, including:

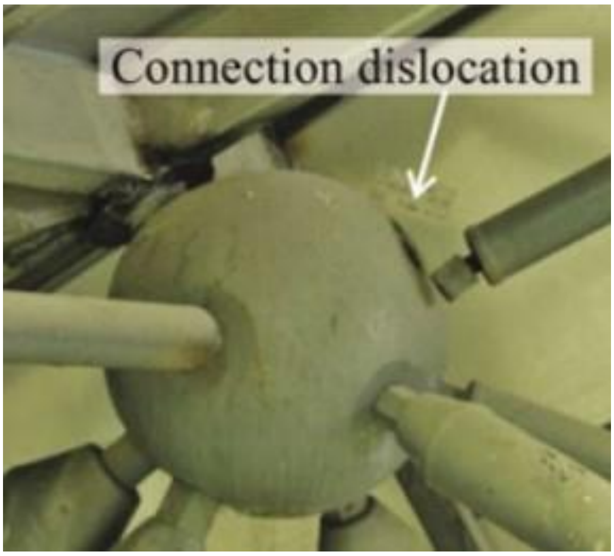
- Location on an arterial road to ensure easy access and transportation connectivity.
- Availability of raw materials required for the industrial process.
- Access to necessary utilities such as water supply and electricity.
- Consideration of the site's topography to determine suitability for construction. Assessment of soil conditions to ensure proper foundation design and stability.
- Adequate waste disposal facilities to comply with environmental regulations. Availability of transportation facilities to facilitate the movement of goods and materials. Accessibility of the site for employees, clients, and suppliers.
- Sufficient space for the storage of raw materials and finished products.
- Provision for future expansion if the need arises.

1.6 TYPICAL DAMAGES CAUSED TOTRUSS

- **Global Buckling or Member Buckling**

- **Member fracture**

- **Failure of the bolted connections**



2. METHODOLOGY

The methodology employed in this study includes the following steps:

- The following steps make up the approach used in this study:
- Literature Review: To investigate prior research and gain understanding of the pertinent theories and methods linked to seismic analysis and industrial building design, a thorough literature review was carried out. This review helped to comprehend the current status of the field's knowledge and served as a foundation for the study.
- Code Consideration: The industrial building's study was performed in compliance with particular codes and regulations. IS 1893:2016 (Part-1), IS 1893, and IS Code 875 (Part-3)-1987 were the codes utilized as references. These rules offer principles and restrictions for seismic analysis and design, guaranteeing that the research complies with the standards and specifications of the industry.
- Seismic Analysis: E-tab v17.0.1 software was used to conduct a seismic analysis of the industrial building. The simulation of seismic forces and their consequences on the building is possible with this program, which is extensively used for structural analysis. The software assists in assessing the structural response to seismic loads, including deformations, stresses, and displacements.
- Graphical Representation: As required to show and illustrate the collected results, graphic representations were produced. These graphical depictions aid in effectively explaining the results of the investigation and give a visual comprehension of the findings.

2.1 SCOPE

The scope of this research is focused on the seismic analysis of industrial buildings using circular and rectangular (square) steel tubes. The primary objective is to assess and compare the performance of these two types of tubes in terms of various parameters such as deflection, displacement, drift, bending moment, and shear moment. The analysis will be conducted separately for each type of industrial building, considering the specific characteristics and dimensions of the circular and rectangular tube structures.

2.2 GENERALDATA

2.2.1 MASS SUMMARY DETAIL

Story	UX kg	UY kg	UZ kg
Story2	5287.28	5287.28	0
Story1	15375.41	15375.41	0
Base	4724.03	4724.03	0

MassSummary(Rectangular)

2.2.2 MASS SUMMARY(CIRCULAR)

Story	UX kg	UY kg	UZ kg
Story2	7732.25	7732.25	0
Story1	16309.3	16309.3	0
Base	4724.03	4724.03	0

MassSummary(Circular)

2.2.3 BASE SHEAR

CALCULATEDBASESHEAR(RECTANGULAR)

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	0.157	202.6318	18.2369

Table1.5–CalculatedBaseShear(Rectangular)

CALCULATEDBASESHEAR(CIRCULAR)

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	0.168	235.7671	21.219

Table1.6–Calculated Base Shear(Circular)

3. MODELLING

For this study, modeling and analysis of an industrial building were done using E-tab Ultimate software version 17.0.1. The size and material qualities of the building were determined using past research as a foundation.

- To simulate the effects of seismic activity, the earthquake load was defined as part of the seismic load. Various load cases and patterns were defined, and these loads were combined according to the relevant IS codes to accurately represent the expected loading conditions.
- The material properties, frame sections, and other elements of the building were defined in the software. The modelling process involved drawing both the geometric representation of the building and assigning the corresponding loads to the relevant elements.
- Following the completion of the modeling process,

the analysis and design of the industrial building model were performed using the E-tab ultimate V17.0.1 software. This allowed for a comprehensive assessment of the structural response and the determination of critical parameters such as deflection, displacement, bending moment, and shear forces.

- By utilizing advanced software and incorporating relevant design codes, this study aimed to evaluate the behaviour and performance of the industrial building under various loading conditions. The analysis and design process facilitated the identification of potential structural weaknesses and the implementation of appropriate measures to ensure the integrity and safety of the building.

- **Material Properties**

Material properties are same in both the cases i.e.,

- Industrial building using rectangular purlins and rafter.
- Industrial building using circular purlins and rafter.

TYPE	E(MPA)	V	UNITWEIGHT (kN/m^3)	DESIGNSTRENGTHS(MPa)
CONCRETE	24855.58	0.2	23.5631	Fc=27.58
TENDON	196500.6	0	76.9729	Fy=1689.91,Fu=1861.58
REBAR	199947.98	0.3	76.9729	Fy=413.69,Fu=620.53
STEEL	199947.98	0.3	76.9729	Fy=344.74,Fu=448.16

MaterialProperties

PLAN DETAILS

This study analyzes long span roof structures measuring 24m x 12m with a height of 7.5m using ETABS 2017 software. The buildings are subjected to seismic zone IV conditions to evaluate their structural performance and ensure compliance with design codes.

MODEL DETAILS

1.	Industrial Building Size	24x12m
2.	Height of Building	7.5m
3.	Slab	4000psi
4.	Slab Thickness	5.5mm
5.	Steel Angle	ISA200X200X25
6.	Section property of Rafter	ISNB90L
7.	Section property of Purlin	ISNB80L
8.	Flange Beam	ISWB550

Model Parameters (Circularr after and purlin)

1.	Industrial Building Size	24x12m
2.	Height of Building	7.5m
3.	Slab	4000psi
4.	Slab Thickness	5.5mm
5.	Steel Angle	ISA200X200X25
6.	Section property of Rafter	ISB66X33X3.6
7.	Section property of Purlin	ISB96X48X3.2
8.	Flange Beam	ISWB550

Model Parameters (Rectangularr after and purlin)

In this research work, the analysis of an industrial building is performed using ETABS Ultimate v17.0.1 software. The building is located in Zone 4, which represents a high seismicity area. Two models were designed and analyzed: one with rectangular purlins and rafters, and the other with circular purlins and rafters.

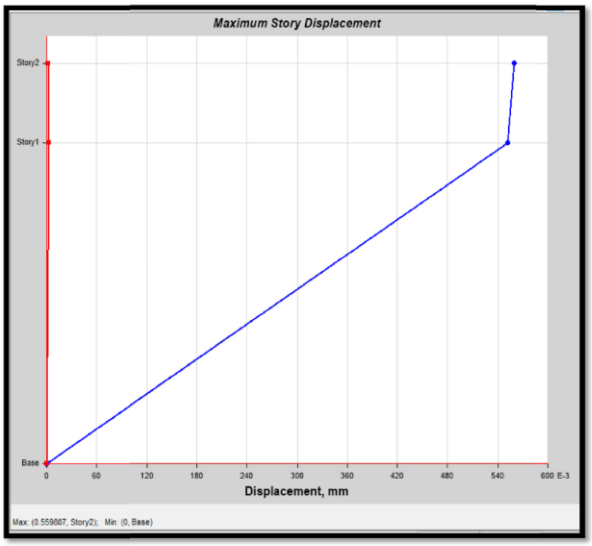
The objective of the analysis is to determine which design performs better in terms of structural behavior and performance under seismic loads. By evaluating factors such as deflection, displacement, bending moment, and shear forces, the study aims to identify the design that exhibits superior structural performance and can withstand the seismic forces prevalent in Zone 4.

Through this comparative analysis, the research aims to provide insights into the effectiveness and efficiency of different purlin and rafter designs for industrial buildings in high seismic zones. The findings will contribute to informing future design decisions and improving the seismic resilience of industrial structures.

3. CONCLUSIONS

3.1 MAXIMUM STOREY DISPLACEMENT

3.1.1 RECTANGULAR SECTION



Maximum Storey Displacement (RECTANGULAR)

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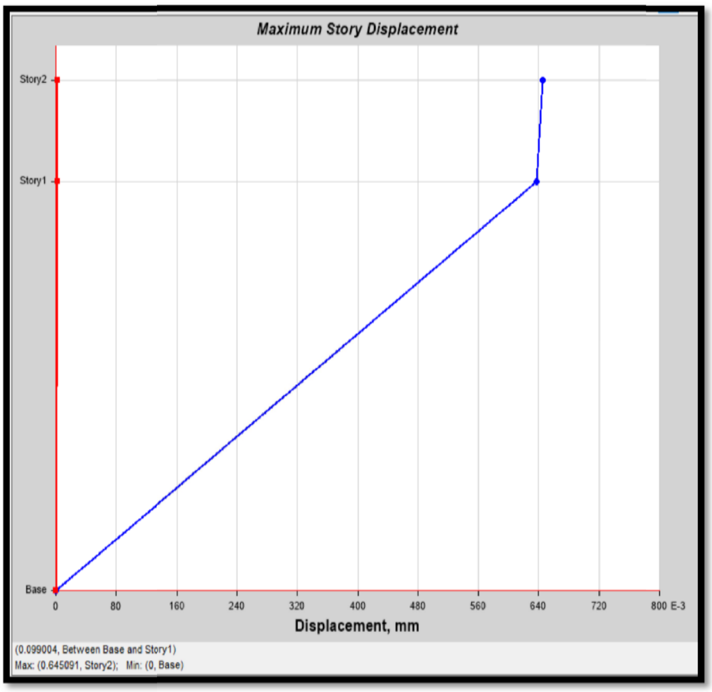
Storey	Elevation	Location	X-Dir	Y-Dir
	m		mm	m
Storey2	7.5	Top	0.202	0.067
Storey1	6	Top	0.122	1.939
Base	0	Top	0	0

3.1.2 CIRCULAR SECTION

Storey	Elevation	Location	X-Dir	Y-Dir
	m		kN/m	kN/m
Storey2	7.5	Top	0.196	0.067
Storey1	6	Top	0.158	0.728
Base	0	Top	0	0



Maximum Storey Displacement (CIRCULAR)

CONCLUSION

On observing the data, graphs and results, we found that:-

- **MAXIMUM STOREY DISPLACEMENT**

Regarding the maximum storey displacement, it was observed that the circular model exhibited higher displacement compared to the rectangular model when subjected to seismic loading as per the provisions of IS 1893:2016 (Part-1). The maximum storey displacement for the circular model ranged between 600-640 (E-3) mm, whereas for the rectangular model, it ranged between 540-560 (E-3) mm. This indicates that the rectangular model performs better in terms of maximum storey displacement compared to the circular model.

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