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Comparative Study Of Industrial Building With Steel Bracings And Sma Bracings

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Abstract: This project presents a comparative study of an industrial steel building using two types of bracing systems: conventional steel bracings and advanced Shape Memory Alloy (SMA) bracings. The aim is to understand how each system performs under various loading conditions, especially seismic loads. The structural models were created and analyzed using software. Key performance parameters such as lateral displacement, roof deflection, base shear, axial forces in bracings, and member utilization ratios were evaluated. The results showed that SMA bracings significantly reduce lateral displacement and residual deformation compared to steel bracings. Though SMA is more expensive, it provides better performance in terms of seismic resistance and structural recovery after an earthquake. Steel bracings, on the other hand, are cost-effective and perform well under normal conditions but may lead to higher post-earthquake damage. This study helps in understanding the potential of using SMA in industrial buildings and guides structural engineers in selecting suitable bracing systems based on performance, cost, and safety considerations.

Index Terms **-**SMA (Shape Memory Alloy), Industrial Building, Steel and SMA Bra**cings.**

I. INTRODUCTION

Industrial buildings, which are made to support a variety of production, storage, and operating operations, are crucial parts of contemporary infrastructure. Usually huge, open-span buildings, these structures need appropriate structural solutions to guarantee cost-effectiveness, usefulness, and safety. Providing sufficient lateral stability to withstand pressures from wind, seismic activity, and other dynamic loads is a crucial component of industrial structure design. In order to increase the lateral stiffness and strength of steel constructions, bracing systems are essential. Bracings decrease lateral displacements and increase overall stability by supplying diagonal elements that create a triangulated structure. Steel bracings like X, V, and K-bracings are often utilized among the many bracing configurations because of their ease of use, accessibility, and efficiency. Nevertheless, there are several drawbacks to conventional steel bracings, especially with regard to their post-yield behavior. They may experience irreversible deformation, buckling, or even failure during strong seismic events, which might impair the structure's capacity to recover. Innovative materials such as Shape Memory Alloys (SMAs) have been developed into structural applications in order to overcome these issues. Super elasticity and the shape memory effect are two special qualities of SMAs that enable them to regain their original shape even after severe deformation. Because of these characteristics, SMA bracings are ideal for applications that call for energy dissipation and self-centering, particularly in earthquake-resistant construction.

II. STRUCTURE DETAILS

The structure modelled is an industrial building with steel truss roofing supported on steel columns and braced laterally. The geometric and design details of the structure are as follows:

- **Location:** Guwahati
- **Span of Roof Truss:** 20 m
- **Spacing between Trusses:** 8 m center-to-center
- **Rise of Truss:** 3 m
- **Height of Truss above Ground Level:** 9 m
- **Total Panel Points in Truss:** 10
- **Number of Bays:** 8 bays are modelled longitudinally
- **Roofing Material:** Asbestos Cement (ACC) sheets with a weight of 150 N/m^2
- **Purlins and Truss Self-weight Assumption:** 120 N/m^2
- **Building Class:** A – Industrial Building (as per IS 875)
- A 3D model of the structure is created in STAAD.Pro with appropriate members, supports, and bracing configurations.

Materials Used -Two separate models were created using different bracing materials for comparison. One is with steel bracings and other is with SMA bracings.

Steel bracing material properties:

- Material: Mild Steel (Fe250)
- Density: 7850 kg/m^3
- Modulus of Elasticity: 2.0×10^5 MPa
- Yield Strength: 250 MPa

SMA bracing material properties [4]:

- Material: Nickel-Titanium (NiTi) based Shape Memory Alloy

Bracing Configuration:

- Bracing Type: **X-type bracings** are used in both transverse and longitudinal frames.
- Placement: Bracings are provided in selected bays at both ends.

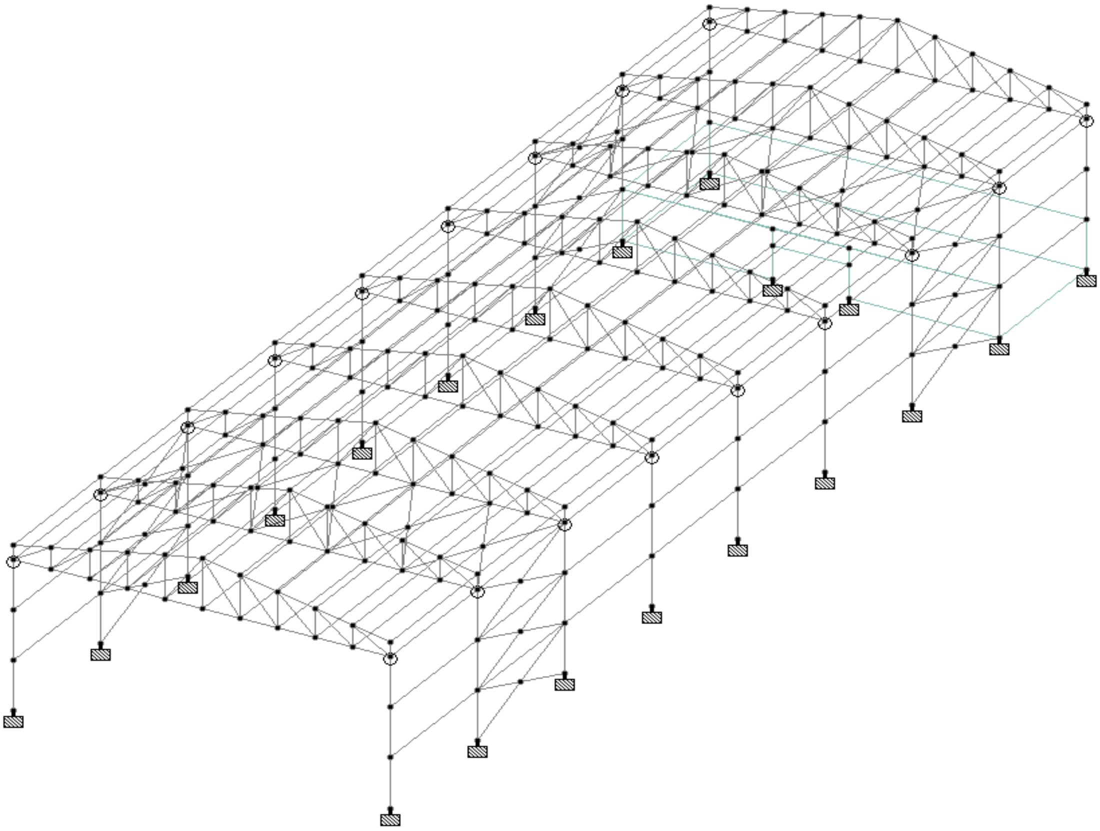


FIG.1 – Model of Industrial Building

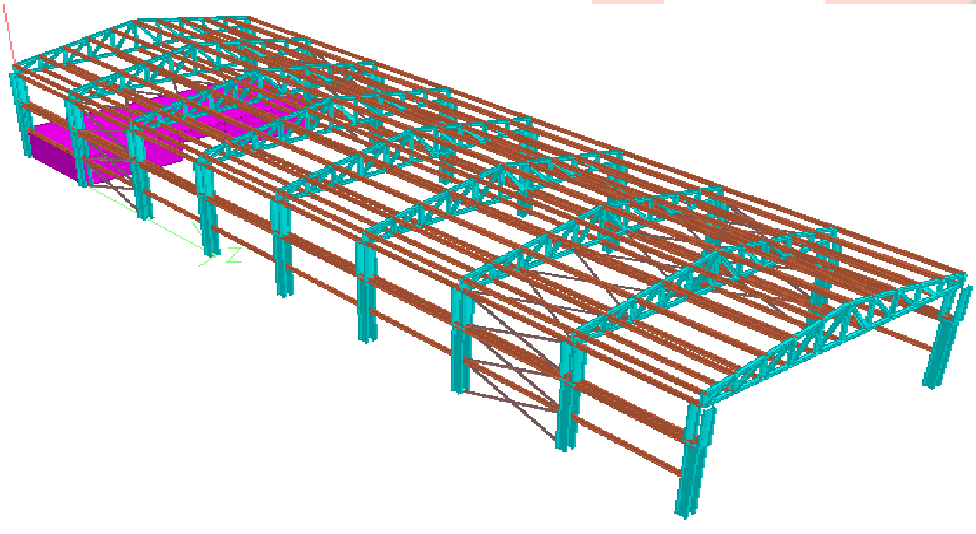


FIG.2- Rendered View

III. Load calculations

All loads are calculated based on IS 875 and IS 1893 (Part 1):2016 standards. The following loads are considered:

3.1 Dead Load (DL)

- Roofing (ACC Sheets): 150 N/m²
- Self-weight of truss and purlins: 120 N/m²
- Automatically calculated by STAAD based on assigned section properties

3.2 Live Load (LL)

- As per IS 875 Part 2, considering roof slope > 10°, live load = 0.75 kN/m²

3.3 Wind Load (WL)

- Code: IS 875 Part 3
- Basic Wind Speed for Guwahati: 50 m/s
- Terrain Category: 2
- Class: A
- Risk Coefficient (k1): 1.0
- Topography factor (k3): 1.0
- Structure height: 9 m
- Wind load applied on windward and leeward roof and walls
- Pressure coefficients as per IS 875 Part 3

3.4 Seismic Load (EQ)

- Code: IS 1893 (Part 1): 2016
- Zone: V (Z = 0.36)
- Importance Factor (I): 1.0 (Industrial use)
- Response Reduction Factor (R): 5.0 (SMRF system)
- Soil Type: Type II – Medium Soil
- Time Period: Calculated based on empirical formula for industrial buildings

3.5 Crane Load (CL)

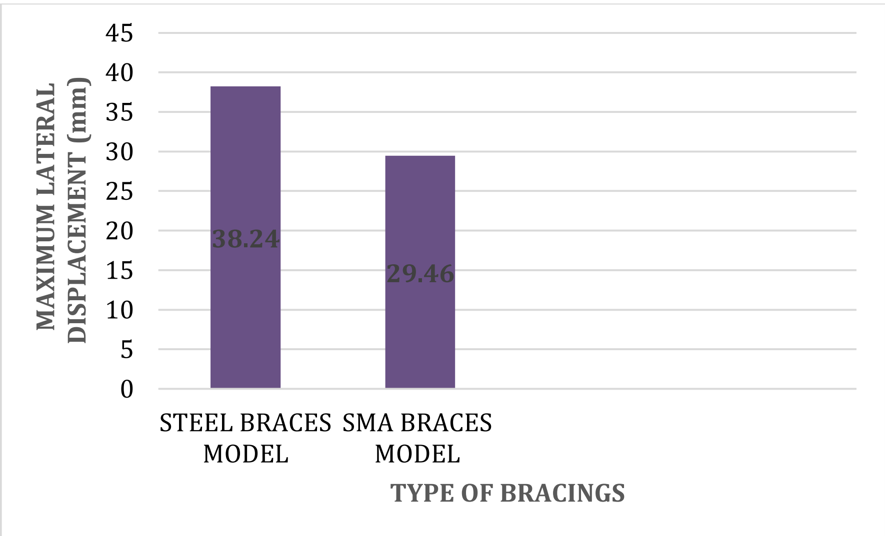
As per SP: 38-1987, the reactions, movements and surge force due to crane are calculated,

Crane capacity: 70 tones

IV. RESULTS AND DISCUSSION

All the above-mentioned loads were applied to the STAAD model as per the study conducted. The structural response parameters, including lateral displacement, axial forces, base shear and roof deflection were evaluated for both types of bracing systems. The results obtained from this analysis are presented and discussed in the following sections.

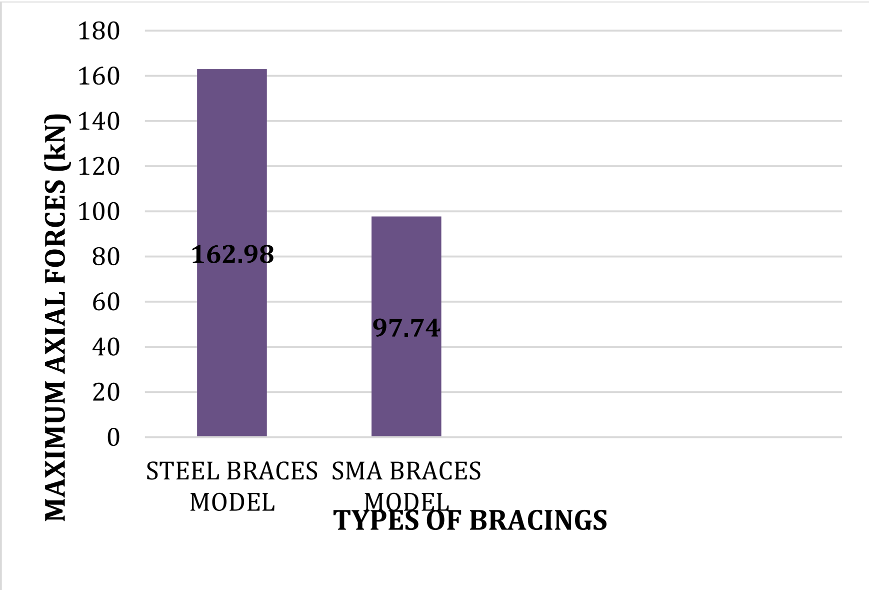
4.1 The graph compares the maximum lateral displacement values for the steel bracing model and the SMA bracing model.



GRAPH-1: MAXIMUM LATERAL DISPLACEMENT vs TYPE OF BRACINGS

The steel bracing system recorded a maximum lateral displacement of 38.24 mm, whereas the SMA bracing system exhibited a significantly lower displacement of 29.46 mm. This reduction in displacement by the SMA bracings indicates improved lateral stiffness and structural stability under applied loads. Lower lateral displacement is a desirable characteristic, as it reduces the potential for structural and non-structural damage, ensuring better serviceability and safety of the structure. Therefore, SMA bracings offer a promising alternative to conventional steel bracings, especially in regions prone to dynamic loading conditions.

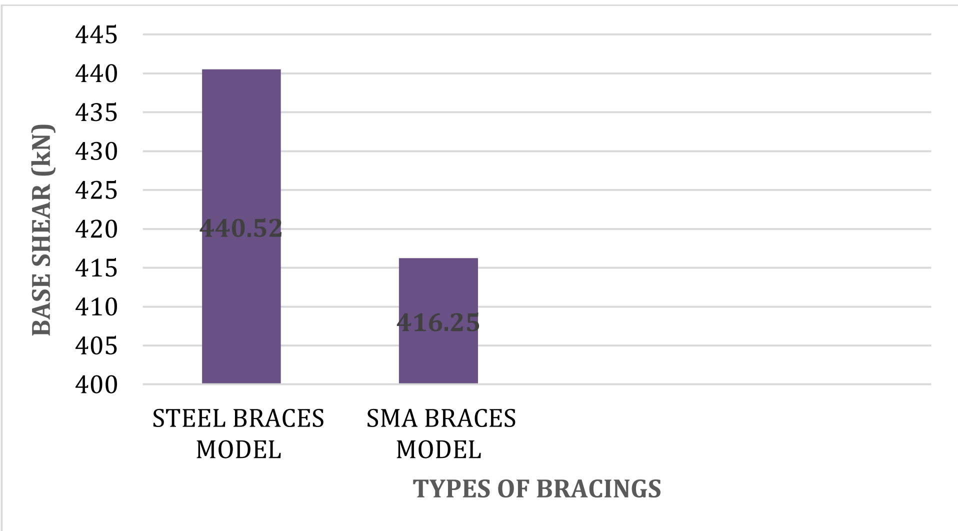
4.2 The graph illustrates the maximum axial forces developed in the bracings for both the steel and SMA bracing models.



GRAPH-2: MAXIMUM AXIAL FORCE IN BRACINGS vs TYPE OF BRACINGS

The steel bracing model experienced a maximum axial force of 162.98 kN, while the SMA bracing model recorded a significantly lower value of 97.74 kN. In practical applications, reduced axial forces in bracings not only enhance the durability and safety of the structure but also contribute to minimizing potential damage during events such as earthquakes. This finding further reinforces the superiority of SMA bracings over conventional steel bracings in improving the seismic resilience of industrial structure.

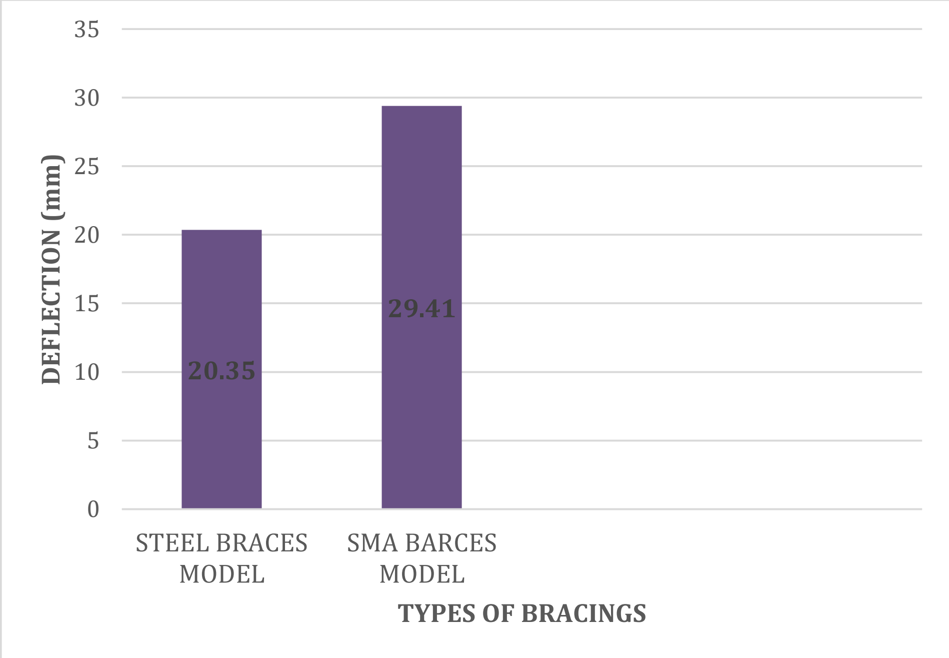
4.3 The graph presents the comparison of base shear values for the steel bracing and SMA bracing models.



GRAPH-3: BASE SHEAR vs TYPE OF BRACINGS

The steel bracing model recorded a base shear of 440.52 kN, while the SMA bracing model showed a slightly lower value of 416.25 kN. The reduction in base shear for the SMA bracing model indicates that it is more effective in dissipating seismic or lateral loads before they are transferred to the foundation. Lower base shear values are advantageous as they reduce the forces acting on the structural base, thereby minimizing potential foundation damage and enhancing overall structural safety during seismic events.

4.4 The graph compares the roof deflection values for the steel bracing and SMA bracing models.



GRAPH-4: ROOF DEFLECTION vs TYPE OF BRACINGS

The steel bracing model exhibited a maximum roof deflection of 20.35 mm, whereas the SMA bracing model showed a slightly higher deflection of 29.41 mm. Although higher deflection values might initially appear unfavorable, in seismic-resistant design, a certain degree of ductility is desirable as it enables the structure to absorb and dissipate energy without significant damage. Thus, the SMA bracing system achieves a balance between flexibility and stability, contributing to better seismic performance compared to conventional steel bracings

V. CONCLUSIONS

The following key observations and conclusions were drawn from the results:

- The Lateral Displacement of structure with SMA bracings is 23% lower compared to the structure with steel bracings.
- Axial forces in SMA bracings were 40% lower than those in steel bracings.
- The SMA-braced structure exhibited a 5.5% reduction in base shear compared to the steel-braced model.
- The roof deflection in the SMA-braced structure was 31% lower compared to the steel-braced structure.

In conclusion, SMA bracings performed better under earthquake loads. SMA systems are more costly than traditional steel, but they are appropriate for essential and seismically vulnerable structures due to their long-term performance benefits and lower post-earthquake repair costs.

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