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EFFECT OF SMA FOR COMBINED WIND AND WAVE LOAD BEHAVIOR OF OFFSHORE STRUCTURE

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Abstract

The offshore jacket structure plays a crucial role in supporting various industries, including offshore oil and gas exploration, wind energy generation, and marine transportation. The primary objective is to calculate the base shear and displacement of the structure under combined wave load and wind load. To achieve this objective, a comprehensive finite element model of the offshore jacket structure is developed in SAP2000, considering the structural geometry, material properties, and boundary conditions. The wave load is simulated using Airys wave theory, accounting for the low and high wave conditions. Similarly, wind load is incorporated based on wind velocity profiles from API 4F 2013. The calculated base shear and displacement of the offshore jacket structure provide valuable insights into its structural integrity and performance under different environmental scenarios. Comparisons are made between the two conditions to understand the varying responses of the structure.

Keywords: offshore jacket structure, SAP2000, base shear, displacement, wave load, wind load, low wave height, high wave period, high wave height, low wave period.

I. Introduction

Offshore jacket structures are vital components of offshore industries, serving as essential supports for offshore oil and gas platforms, wind turbines, and various marine infrastructure. These structures are subjected to complex environmental loads, including waves and wind, which necessitate accurate analysis and design to ensure their structural integrity and stability. In this research paper, the focus is on developing a model using SAP2000 software and conducting load analysis of an offshore jacket structure under combined wave and wind loads.

The behavior of offshore jacket structures under different wave and wind conditions is of significant interest to engineers and designers. The magnitude and characteristics of waves, such as wave height and wave period, greatly influence the dynamic response of the structure. Similarly, wind loads, including wind speed and turbulence, can impose considerable forces on the structure, further affecting its overall performance. Understanding the effects of these combined loads is crucial for designing structures that can withstand the demanding offshore environment.

In conclusion, this research paper aims to provide valuable insights into the behavior of offshore jacket structures subjected to combined wave and wind loads. The utilization of SAP2000 software allows for accurate modelling and analysis, while the consideration of distinct wave and wind conditions enhances the understanding of structural responses. The obtained results will support informed decision-making processes related to the design, construction, and maintenance of offshore jacket structures, ultimately contributing to the safety and efficiency of offshore operations.

II. Literature Review

Harish N and Shanthala B,[1] study encompasses a comprehensive assessment of the platform's structural behavior under various loading conditions, including environmental forces such as waves, currents, wind, and seismic events. The findings contribute to enhancing the overall efficiency, reliability, and safety of offshore structures, thereby supporting sustainable and resilient offshore operations.

Anis A. Mohamad Ali and Jaffar A.[4]Kadim conducted the study, focuses on the assessment of offshore structures subjected to wind and wave forces. The findings facilitate the identification of critical areas prone to excessive displacements or stresses, allowing for design modifications and reinforcement strategies. Additionally, the dynamic analysis helps in evaluating the platform's dynamic behavior during extreme events, such as hurricanes or rogue waves.

Mohammad Aghajani D., Mahsa Pahlavikhah V., *et.al*. [5] conducted the research, focuses on the application of SMA elements as a means to enhance the seismic performance of offshore platforms. The SMA-equipped platform exhibits reduced displacements, improved energy dissipation, and enhanced damping characteristics compared to the conventional platform. The SMA elements effectively mitigate the occurrence of plastic deformations and limit the development of residual displacements, contributing to the structural resilience and post-earthquake functionality of the platform.

Shahin Zareie, M. Shahria Alam, *et.al.* [11] conducted the research which employs numerical modelling and simulation techniques to evaluate the performance of the SMA-based element in offshore structures. The results demonstrate the potential benefits of the proposed SMA-based element in offshore structures subjected to cyclic loading. The element effectively controls structural stability by actively adapting to changing loading conditions, minimizing excessive deformations, and maintaining the integrity of the structure.

Dutta, S.C. and Majumder, R.[19] focuses on utilizing SMAs as an innovative and effective means of mitigating structural vibrations. The SMA dampers exhibit high energy dissipation capabilities, enabling them to absorb and dissipate vibration-induced energy, thereby reducing the amplitude and duration of vibrations. The SMA dampers also provide adaptive control, as their stiffness and damping properties can be tailored to the specific vibration characteristics of the structure.

II. Methodology

The 3D model of offshore structure in SAP2000 involves defining the geometry, material properties, and support conditions of the structure. Wind load applied is as per API 4F 2013 and wave load applied as per API WSD2000. The wave load is considered from API WSD2000

3.1 Model Drafting

The platform considered in the study is a four-legged production platform water depth at the location is 200 m. The platform is designed based on API recommended criteria for 50 years return period. In the study structure made of SMA bracings is used with fixed base for calculation.

Total height of structure = 250 m

Bottom dimension 110 * 70 m

At height 200 m = 50 * 30 m

At top deck = 60 * 40 m.

All the vertical legs and diagonal bracings are 1.5 m diameter and wall thickness are 0.2 m. The horizontal bracing are 1.25 m diameter and wall thickness is 0.15m.

Wind speed = 41.67 m/s

Wave height = 14.86 m

Wave period = 21.66 m

For the analysis different wave heights and wave periods are considered

- Low wave height and high wave period = 2m and 2.5 s
- High wave height and low wave period = 20m and 10 s.

The computer 3D model of the structure is shown in Figure 1.

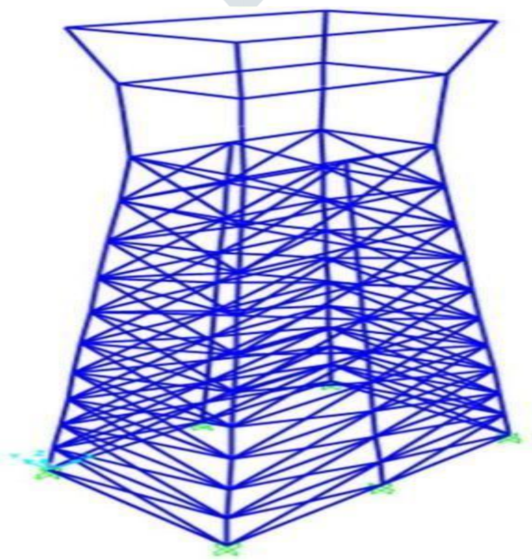

Figure 1: Modelling for SMA Bracing in SAP 2000.

3.2 Loading Conditions

Wind loads are considered as dynamic loads, and the software allows for the specification of wind direction, speed, and turbulence parameters. The 2013 edition of API 4F provides guidelines for determining wind loads on offshore structures. Basic Wind Speed is determined based on the location and is usually obtained from meteorological data or wind maps specific to the region. Basic Wind velocity of 81 knots is taken in the problem. The exposure category (Kz) is determined based on the structure's location and the height above ground level (HAGL). The categories range from A to D, with A representing the most sheltered locations and D representing open sea locations. The exposure category is used to calculate the gust factor. The windward and leeward sides of the structure are considered for the variation in wind pressure distribution.

The API recommended default wave load pattern is described in API RP 2A-WSD (Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms Working Stress Design). The API default wave load pattern assumes a constant wave height (H) throughout the design life of the structure. The API default wave load pattern assumes a simplified wave profile known as the "sine wave" or "crest to trough" profile. In this profile, the wave elevation varies sinusoidally with respect to the still water level.

IV.Results

- **Base shear of low wave height and high wave period**

The base shear according to low wave height of 2m and high wave period of 2.5 s is prescribed in table 1 and separated by base shear for steel bracing and SMA bracing with full bracing provide over structure.

Table 1: Base shear of low wave height and high wave period for full storey SMA

Results	Base shear (Peak) X	Base shear (Peak) Y
SMA bracing	730.812 kN	895.754 kN
Steel bracing	821.777 kN	1054.385 kN

- **Base shear for High wave height and low wave period**

The base shear according to High wave height of 20m and low wave period of 10 s is prescribed in table 2 and separated by base shear for steel bracing and SMA bracing with full bracing provide over structure.

Table 2: Base shear of High wave height and low wave period

Results	Base shear (Peak) X	Base shear (Peak) Y
SMA bracing	950.249 kN	1123.327 kN
Steel bracing	1154.259 kN	1458.924 kN

- **Displacement for low wave height and high wave period**

The Displacement according to low wave height of 2m and high wave period of 2.5 s is prescribed in table 3 and separated by base shear for steel bracing and SMA bracing with full bracing provide over structure.

Table 3: Displacement for low wave height and high wave period

Results	Displacement (X)	Displacement (Y)
SMA bracing	43mm	32mm
Steel bracing	45mm	41mm

- **Displacement for High wave height and low wave period**

The Displacement according to High wave height of 20m and low wave period of 10 s is prescribed in table 4 and separated by base shear for steel bracing and SMA bracing with full bracing provide over structure.

Table 4: Displacement for High wave height and low wave period

Results	Displacement (X)	Displacement (Y)
SMA bracing	42mm	50mm
Steel bracing	54mm	58mm

- **Distribution of base shear**

The base shear along X and Y for both cases is shown below in figure 1 which clearly prescribed the comparison between base shear of steel and SMA braced structure

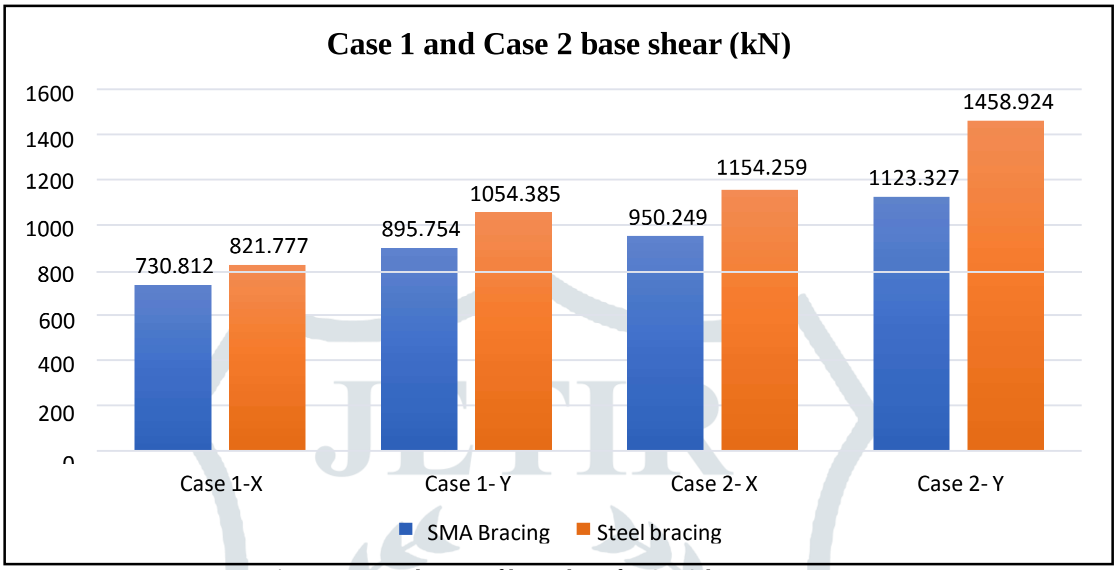

Figure 1: Distribution of base shear for SMA bracing

- **Distribution of displacement**

The Displacement along X and Y for both cases is shown below in figure 2 which clearly prescribed the comparison between base shear of steel and SMA braced structure.

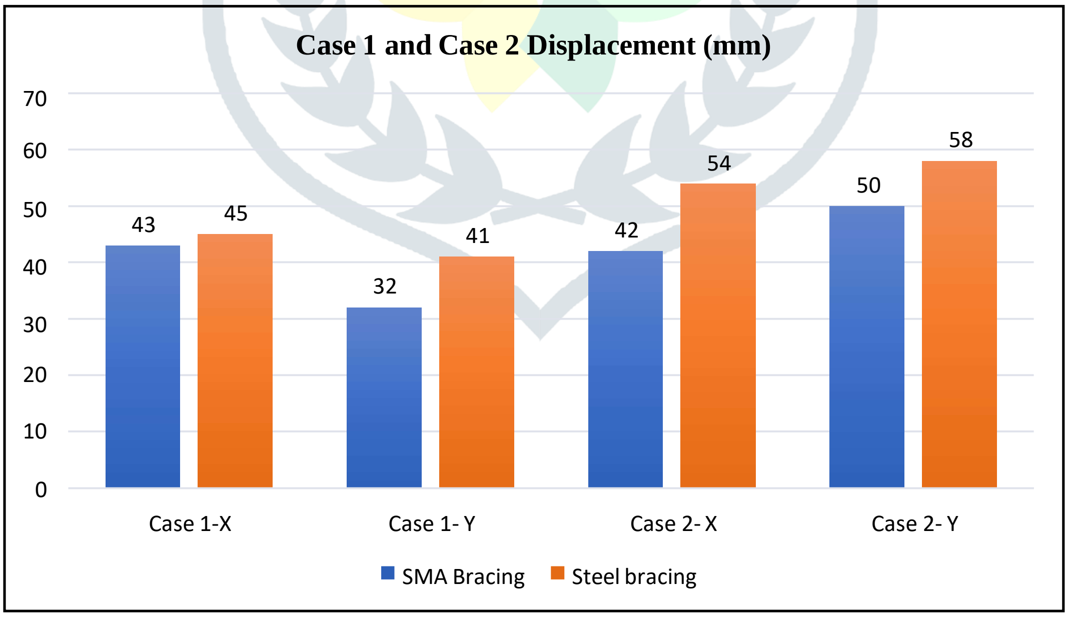

Figure 2: Distribution of displacement for SMA bracing

The SAP analysis was conducted for a 200m water depth to get wave response parameter for the maximum wind and wave forces that are taken. The deflection response to the wind and wave force is shown in figure 3. The responses considered are deflection in global Y- direction.

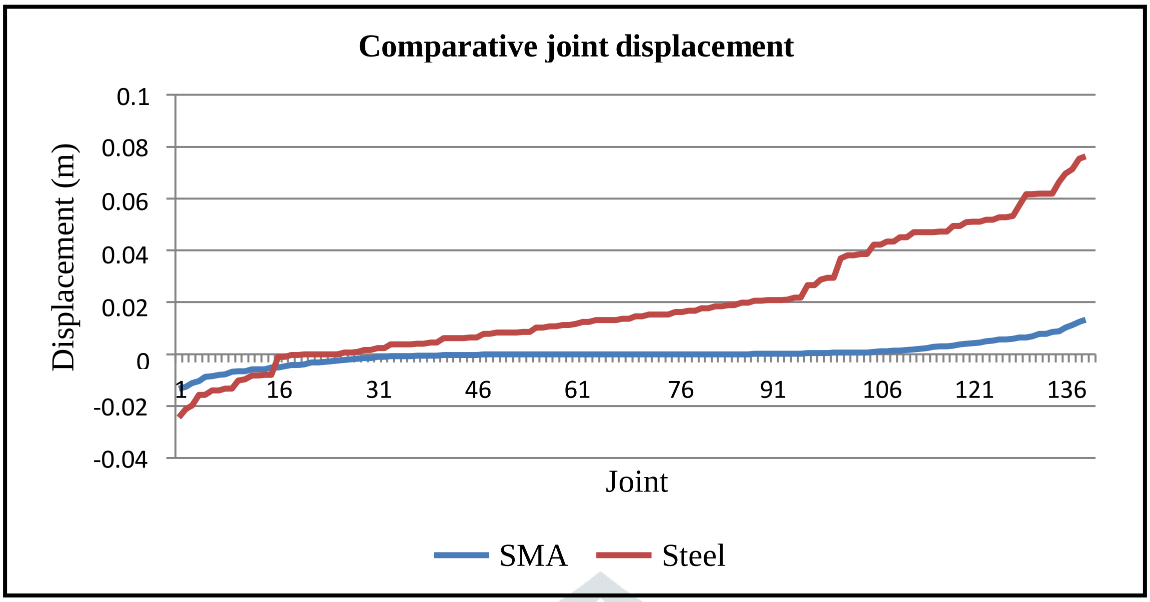

Figure 3: Comparative joint displacement

Form figures it is seen that the platform deflection for SMA bracing is proportional to the wind and wave loadings. The maximum platform deflection is 13.29 cm is SMA bracing structure and 76.29 cm in Steel braced structure at top side of the deck for a wave height of 14.86 m and wind speed of 41.67 m/sec.

V.Conclusion

- By creating a 3D model of the offshore structure and incorporating the appropriate wind and wave loading conditions, the analysis captures the dynamic response of the system. The combined analysis accounts for the interaction between wind and wave forces, providing a comprehensive understanding of the structural response.
- The incorporation of SMA bracket behavior adds an additional layer of complexity to the analysis. This allows for a more accurate assessment of the system's behavior, considering the unique properties of SMA such as shape memory effect, super elasticity, and temperature-dependent behavior.
- For the low wave height and high wave period scenario, the structural displacements and base shear are relatively small.
- The longer wave period resulted in a slower build-up of wave-induced forces on the structure, leading to lower displacements and base shear.
- The high wave height and low wave period scenario poses a greater challenge to the structure.
- The larger wave height and shorter wave period resulted in more significant wave- induced forces acting on the offshore structure. As a consequence, the displacements and base shear are increased.

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