RESPONSE OF MONOPOD PLATFORM UNDER EXTREME WAVE IN MALAYSIAN WATER

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Keywords: monopod platform, response, displacement, environmental loads

Abstract. This paper investigated the structural response of an existing monopod platform under extreme wave condition in Malaysian water. The estimation of the response plays an important role in the design of offshore structure. In this investigation, in-place analysis is performed to measure the reliability of monopod structure owing to the extreme environmental load condition in Malaysian water. The response of the structure to the varying conditions of the structure and varying environmental loads directions are analysed using well defined in-place analysis method[1]. In the present analysis, the deflection of the structure is studied for the number of guyed wires supporting the structure and multi-direction of environmental loads applied onto the structure.

Introduction

The basic information underlying in this monopod platform is a small deck sustained by a single caisson, which contains the wells, or by a braced sub-structure. Monopod platform implement tarpon system which consists of a central caisson stabilized by three cable guys located about 120 degree apart, composed of two cables each, pinned to an anchor pile at or below the mudline and pinned to the central caisson below the water level as shown in Figure 1.1.

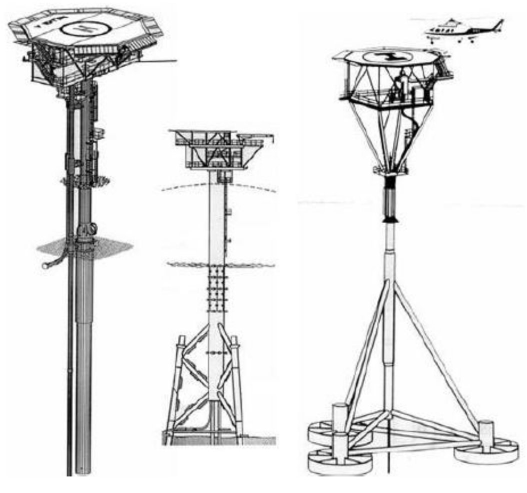

Figure 1: Typical monopod platforms used in shallow water

The first monopods were installed on the North West Shelf (NWS) in 1986, just 2 years after offshore production commenced in the region. Monopods have since become the dominant NWS platform selection, as they have cost advantages for exploiting small, shallow water fields and can be fabricated in Western Australia[2]. The tarpon system has been existence for almost 30 years but the system was widely used in the North Sea by oil major players with over 20 installations to-date. However in Malaysia, this system is still new. The system was first installed at Semarang Kecil oil field in year 200 and was later applied at the North Lukut and Penara oilfields in 2002 and Ledang Anoa in 2006.

Structural behaviour of monopod platforms designs under wave loading platform quite complex due to several factors. Firstly, monopods are installed in shallow water, where non-linear wave kinematics is important especially in harsh environments. Secondly, unlike the larger platforms, the platform's configuration is such that the fundamental dynamic bending behaviour is concentrated in the wave zone, rather than throughout the water column. Studies have proved that the wave zone is the most sensitive region in which the failure of a braced monopod on the North West Shelf during a tropical cyclone was localized in the wave zone[3][6].

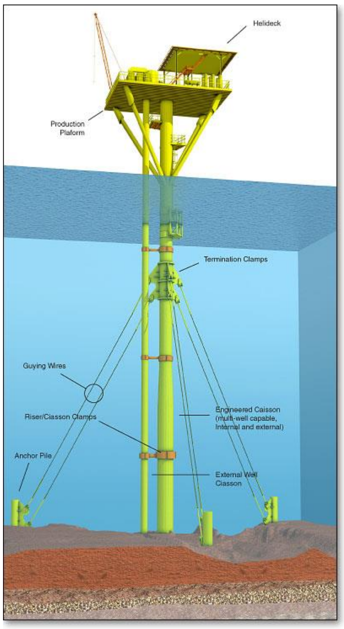

Figure 2: Typical designs for Tarpon system

Platform Configurations

A specific configuration of minimum monopod platforms is used as a reference to study its reliability under harsh environmental loads condition in Malaysian water. The platform is located on the South China Sea, namely Peninsular Malaysia Ocean (PMO) in water depth of 60 meter. The self-weight of the topsides is to be approximated of 200 tonnes. All other external loads such as secondary structures, appurtenances and live load are defined as individual load in the analysis. The central caisson's outer diameter is 2.13 meter (84 inches) with varying thickness throughout the caisson. Each guying wire fixed to the caisson which has a pretension of 355.86 kN (80 kips) to provide external support to the platform.

The computer 3-D model of monopod platform is shown in Figure 3. As per requirement of inputs to SACS, the structural members and environmental loads are defined. All the designs of its members and materials properties are based on PETRONAS Technical Standard (PTS). All loads required for the analysis are included in the program.

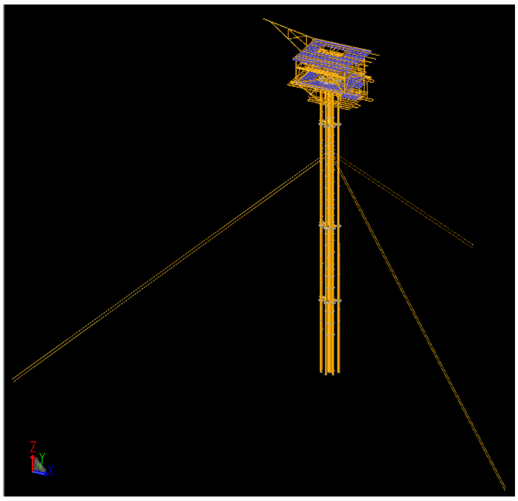

Figure 3: Computer 3-D Modelling for Monopod Platform Model

Loads Configuration

For the present analysis, wind speed that will be used is 39.97 m/s. The determination of wave forces exerted on offshore platform is very complex. Wave theory can be divided into three categories which are sinusoidal waves, cnoidal waves and solitary waves. Wave theory should be understood before one can properly calculate the wave forces[4]. In this analysis, Stokes theory is used to perform the analysis.

Pierson-Moskowitz Spectrum was proposed in 1964 for new formula for an energy spectrum distribution of a wind generated sea state[5]. PM Spectrum describes a fully-developed sea determined by one parameter, namely, wind speed and is widely accepted in the whole world. PM Spectrum can be describes as:

$$S(\varpi) = (A/\varpi^5)*e^{(-B/\varpi 4)} \quad (2)$$

Where,

$A = 0.0082g^2$

$B = 0.74(g/u)^4$

$\varpi = 2\pi f$

Where,

u = wind speed (m/s)

g = gravitational acceleration (m/s)

f = frequency (Hz)

The statistical parameters were evaluated using the spectral moments as follows:

$$\text{Significant wave height, } H_s = 4\sqrt{m_0} \quad (3)$$

$$\text{Zero crossing wave period, } T_z = \sqrt{\frac{m_0}{m_2}} \quad (4)$$

For this present analysis, the value for wind speed, wave height and wave period is 39.97 m/s (77.7 knots), 13.29 m and 11.10 s respectively.

Result and Discussion

The static analysis of Monopod Platform is carried out for 60 m water depth with different several conditions. The overall topside member's weight is designed for 200 tonnes. The topsides design is as illustrated in Figure 3.

The platform will be analysed for load combination of dead load, live load and environmental loads to provide real life situations. The platform will be firstly analysed for eight different directions (omni-direction) of environmental loads with the three wired guys are attached to the caisson. The platform then will be analysed for free standing platform where all the wired guys are removed to compare the deflection between these two conditions.

The caisson displacements to the combined load cases and number of wired guys attached to the platform are studied.

Displacement of the Platform

Figure below illustrated one of the directions of the wind force, wave force and current when subjected to the platform.

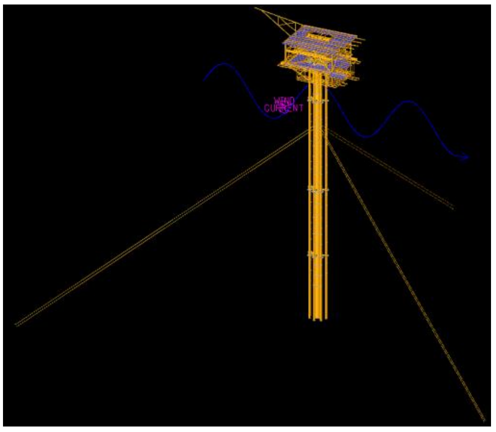

Figure 4: Environmental Loads from 0°

It should be noted that deflections are considered in the total of global X-direction and global Y-direction. The deflections observed are based on the deflections of the caisson of the platform from the mudline level to the top of the caisson excluding the topside.

Figure 4 illustrated the environmental loads when subjected from 0° direction of the platform. The estimated deflection due to the environmental loads from each direction is illustrated in the Figure 5-12 below.

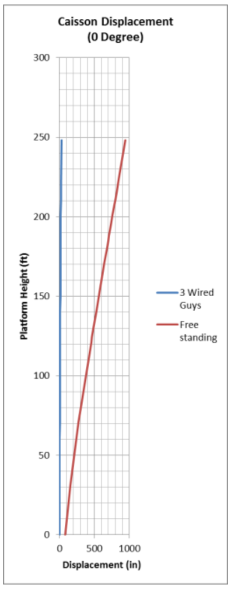

Figure 5: Caisson Displacement at 0° Direction

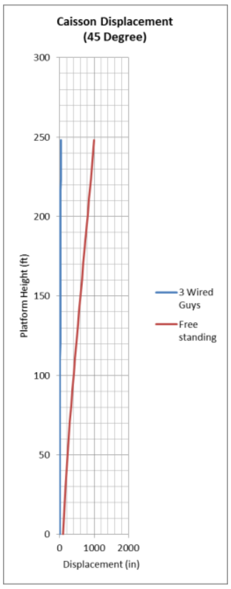

Figure 6: Caisson Displacement at 45° Direction

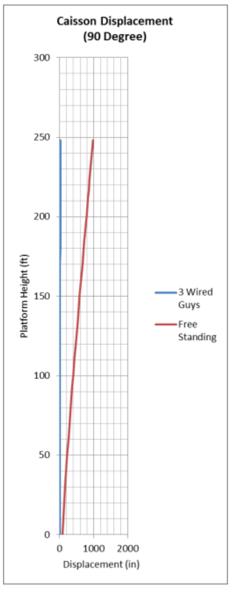

Figure 7: Caisson Displacement at 90° Direction

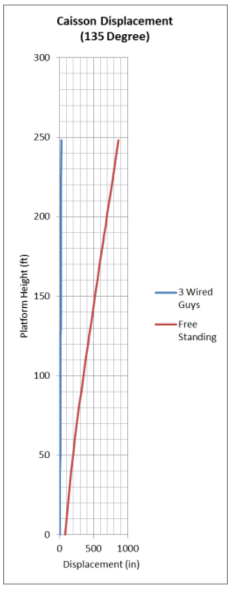

Figure 8: Caisson Displacement at 135° Direction

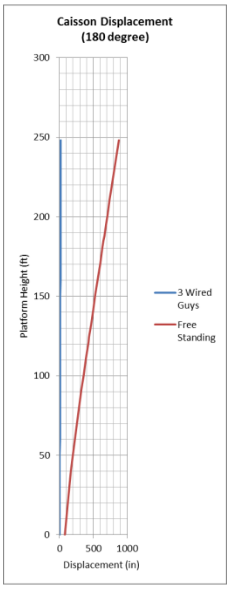

Figure 9: Caisson Displacement at 180° Direction

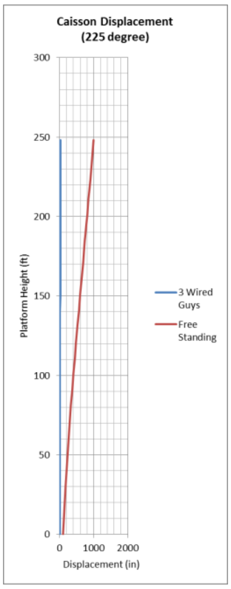

Figure 10: Caisson Displacement at 225° Direction

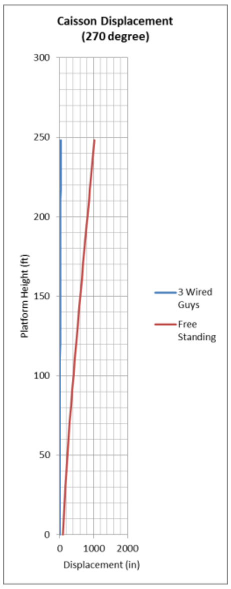

Figure 11: Caisson Displacement at 270° Direction

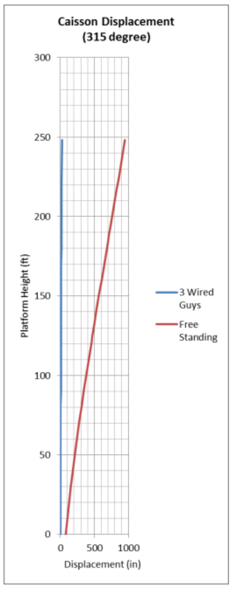

Figure 12: Caisson Displacement at 315° Direction

From the figures above, we observed that the pattern for caisson displacement is alike for all environmental loads directions. When the wired guys are removed from the caisson, the deflection of the caisson is much greater than the deflection of the caisson when supported by wired guys. In the design, the platform will be considered as collapsed when the deflection of the members of the caisson is greater than 1 meter. In this analysis, we can observe that the platform is collapsing in all environmental loads direction during free standing condition.

The maximum displacement of the caisson when supported by 3 wired guys is 89.53 cm (35.25 in) when subjected to environmental loads from 270° direction. Meanwhile, the maximum displacement of the caisson during free standing condition is 2598.12 cm (1022.88 in) when subjected to the environmental loads from the same direction.

From the analysis, we observed that displacement of the caisson also occurred at the mudline level. The maximum caisson displacement is 4.45 cm when subjected from 135º direction environmental loads for 3 wired guys condition. The displacement of the caisson during free standing condition is 224.78 cm when subject to the environmental loads from 270º direction. The displacement occurrence is based on the strength of the soil during the analysis which will not be discussed in this present analysis.

Conclusions

In this present analysis, the deflection of the caisson is studied for omni-direction when subjected to environmental loads. From the analysis, the maximum displacement of the caisson is 89.53 cm and 2598.12 cm for 3 wired guys and free standing condition, respectively. Additionally, we can observe that the critical condition is when the environmental loads are coming from 270º for both conditions.

The platform is considered as collapsed when the caisson has a displacement more than 1 m. In this case, it is noted that the platform is collapsing when the wired guys are removed from the platform. We can conclude that the importance of the wired guys to the monopod platform in structural reliability which provides the stability of the platform during extreme conditions.

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