AN INTRODUCTION TO THE DESIGN OF OFFSHORE STRUCTURES

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ABSTRACT

This paper deals with an overview of the key aspects in the design of offshore structures. The paper covers the design of two types of offshore structures; fixed and floating structures. The main aim of this review paper is introducing the different types of offshore platforms and submitting the main design aspects for different types of platforms, as well as platforms' parts, platforms' installation, corrosion protection, platforms' foundations, hydrostatics and stability, structural analysis, acceptance criteria, and different applicable codes in design.

Keywords: Offshore structures, platforms, design, criteria, codes.

1. INTRODUCTION

Gas and oil are detected under seabeds to start proceeding by using offshore platforms. The offshore platform which reaches to 6 m depth off the coast of Louisiana was set up for the first time in 1947. Nowadays, numbers of the offshore platform around the world are over 7000 and they can also reach to the 1850 m depth of water thanks to the advanced offshore structure technology. Moreover, platform size is determined by loading condition because oil rig, living quarters and helipad are loaded to the topside of the offshore platform so the size of an offshore platform is determined according to the amount of loading. Waters, where the platform is on, are classified by their depths. Therefore, waters which had less than 350 m, less than 1500 m and more than 1500 m depths, are defined as shallow water, deep water, and ultra-deepwater, respectively. However, according to the US Mineral Management Service (MMS), more than 1300 ft and more than 5000 ft waterdepths are categorized as deepwater and ultra-deepwater. In the meantime, there are two main types of offshore platforms such as fixed and floater structures. The fixed structure includes steel jacket, concrete gravity structure, and compliant tower. The other type is floater structures which contain Semisubmersible, Spar, Tension Leg Platforms and Ship Shaped Vessel (King, 2012).

2. DIFFERENT TYPES OF PLATFORMS

2.1. Fixed Platforms

2.1.1. Jacket Platform

The jacket platforms are fixed platforms in form of space frame structures, which are composed of tubular members, and are supported on piled foundations to safely establish construction of the jacket platform. The jacket platforms are in general suitable for the moderate waterdepths, which have less than 400 m depths. In addition, the jackets ensure the protective coating surrounding the piles. There are three parts of a classic offshore structure such as a cellar deck, main deck, and a helideck. The deck legs which are linked to the peak of the piles support the deck structure. The piles go over to the seabed and into the soil from above the mean low water level. The legs of jacket structure which resist against lateral loads to keep up the platform include the piles which are generally underwater. As the jacket is

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used as a template, the piles which are parts of the jacket platform initiate to drive from the top side jacket. About ninety-five percentages of the offshore platforms that are around the earth are sustained by jackets (El-Reedy, 2012).

2.1.2. Compliant Tower

The compliant tower is another member of fixed platforms. The compliant tower is a narrow and flexible framed structure which is supported by a piled foundation. There isn't oil storage capacity in this type of platforms so produced oil is transported to the topside of the platform by stiff risers as well as the elastic or catenary steel pipe is used to export oil. However, the platforms are exposed to wave loading so large that the lateral deflections more 10 ft are applied on them. Additively, the platforms are appropriate for moderate water depths which have more than 600 m depths (King, 2012).

2.1.3. Concrete Gravity Structures

The concrete gravity structures are another type of fixed platforms. The concrete gravity structures are made of concrete, so these structures which are very heavy remain stable on the seabed and using piles isn't necessary. Concrete gravity structures are suitable for moderate water which has more than 300 m waterdepths. The platform becomes are constructed bottom-up design like an onshore structure. In addition, it's belowside is next to the surface of the sea, while a certain part of the dock is flooded, some parts of the dock floats. The remaining construction is finished in deeper sheltered water where the dock is towed to. The dock is sunk on the seabed through being filled with water, its base then by towing to the field. The concrete gravity has an important advantage that they are in need of less maintenance. (King, 2012), (Sadeghi, 2008).

2.2 Floater and Movable Platforms

2.2.1. *Tension Leg Platform (TLP)*

Tension Leg Platforms are one type of floater platforms that are connected to the seabed by tethers, which are vertical steel tubes. The connection immobilizes the structure in the vertical direction, but it leads to being very elastic in the horizontal direction. The oil wells are connected to the structure for manufacturing to thanks to the vertical rigidity. Moreover, horizontal flexibility protects the structure against the primary effect of waves. Large pontoons, wide columns and a fairly deep draught are used to construct the structure. Thanks to keeping tethers in tension, Tension Leg Platform has extreme unsinkability. Topside facilities which have not risers must be immobilized at the predesign stage. Tension Leg Platform is suitable for moderate water which has more than 1200 m depths. However, the platforms haven't integral storage and the tether tensions are affected sensitively by topside load and draught variations (Chakrabarti, 1994).

2.2.2. *Semi-Sub Platform*

The Semi-Submersible (Semi-Sub) Platform is a floater platform. As the platform has a small waterplane field, they are very sensitive. Therefore, flood alarm systems are needed to be on site. Upper edge facilities which have not risers must be immobilized at predesign stage. Furthermore, the Semi-Sub Platform is convenient for ultra-deepwater. Thanks to anchors which are joined to a catenary mooring system, Semi-Submersibles are kept on site. As column pontoon joints and connections suffer from large loads, seasonal checks and maintenances are required because of the probability of fatigue fracture of braces (King, 2012).

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2.2.3. *SPAR*

Spar is another member of flouter platforms. The deck is supported by a single vertical cylinder having a large diameter. The concept is very new because it is improved recently. The preliminary spar platform was set up in 1997 in the USA coasts. As Spar platforms contain deep draught and taut catenary moorings, the natural periods of Spar platforms are approximately about 30 seconds. Spar is suitable for ultra-deepwater which has more than 2300m depths. Spar is quite steady because the center of gravity is highly below the center of unsinkability. Because of space limitation in the core, the number of risers must be predetermined (Chandrasekaran, 2015).

2.2.4. *Ship Shaped Vessel (FPSO)*

Ship Shaped Vessel is another member of flouter platforms. The platform is known as Floating, Production, Storage, and Offloading (FPSO) plants. The hull of the platform is used as integral oil storage so construction of a costly and long pipeline isn't necessary for transportation to coast. The platform is a ship so it can move. Moreover, it detects marginal wells under the water and deep water in the remote. The platform is more economical, feasible and technical than other types of platforms. As the Ship Shaped Vessel platform explores reservoir, it goes to hold in position over the reservoir. However, the platforms can weathervane around the mooring area so it is subjected to prevailing weather (King, 2012).

2.2.5. *Jack-up*

Jack-ups are endued which are able to be jacked up upon the sea utilization legs which are able to be degraded, vary such as jacks. They are characteristically utilized in water deepness less than one hundred twenty meters, though some designs are able to reach to one hundred seventy meters depths. They are planned to go from place to place, as well as anchor themselves with emanation their legs to the ocean below utilizing a rack as well as pinion gear system on every leg.

3. **FLOATER PLATFORMS' PARTS**

3.1. **Topside**

The topside includes different utility equipment and incorporating process such as injection compressors, gas turbine generators, gas compressors, piping, HVAC, drilling rig, instrumentation. In addition, the topside part of the platforms contains accommodation for staff, crane to handle equipment and helipad (King, 2012).

3.2. **Moorings and Anchors**

Moorings and anchors hold platforms at the intended point. Steel chain or steel wire rope which has a catenary shape because of heavyweight and synthetic fiber rope is used to form moorings and anchors. For example, synthetic fiber rope which is required less rope length is not subjected to corrosion and it has stretched shape because of fraught less weight than steel rope (King, 2012).

3.3. **Riser**

The riser system is designed according to ship interfaces, filed layout, environmental condition, and fluid properties. There are two riser types in platforms such as rigid and flexible. When flexible riser is used, the vessel can move with compensates heave movements and the effect of wave loading. In other words, simple catenary risers having a flexible pipe can act freely between the surface vessel and the seabed. Other catenary variants may be used in special conditions (King, 2012).

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4. PLATFORM INSTALLATION

According to structure size and usage of resources, different methods are applied for installation. There is a crane barge to install jackets on the topside. In addition, floating vessels with cranes are used to lift up smaller jackets. Large deck barges carry up to 12000 tons of weight (King, 2012).

5. CORROSION PROTECTION

There is a usual occurrence of corrosion conservation on the subaqueous section of the jacket. Moreover, the upper section of the piles has a usual occurrence of corrosion protection. These conditions occur with cathodic protection making use sacrificial anodes which are made from zinc and aluminum bar cast like a steel tube so they are welded on the structures. Almost five percentages of the jacket weight are used as anodes (D.N.V., 2011). The allowance thickness is added to the members' thicknesses which are used to protect the steel in the splash zone.

6. PLATFORM FOUNDATION

Onboard equipment and environmental conditions cause generating loads on the platform so the piles at the seabed and below withstand to the loads. The soil exploratory is important for designing of the offshore structure. In other words, it is vital. Doing soil borings at the intended location improve geotech report which is performed insitu and laboratory tests. Pile penetrations are affected by size and loads of platform and also soil characteristics (D.N.V., 2011).

7. HYDROSTATICS AND STABILITY

Due to the stability, the platforms don't capsize. As the center of mass of the displaced water locates at the center of Buoyancy, there is under no external force to become the center of gravity as well as buoyancy on the same vertical plane. For example, the upward force of water, the weight of the floating vessel and displaced water are equal. Center of Buoyancy moves under wind load vessels heels to ensure stabilizing which is defined as the righting moment. Center of Gravity which is known as metacenter will intersect with a vertical line along the new center of buoyancy. There are two stability types such as intact stability resisting to wind moment with sufficient righting moment and damage stability needing vessel resistance inundating of designated volume with wind moments. Heeling causes alteration on the center of gravity of partly filled vessels. That outcomes lead to decreasing instability. The formation is defined as a free surface correction (FSC). Terminally, there are six rigid body motions such as transitional motion including surge, sway and heave and rotational motion containing roll, pitch, and yaw. Therefore, the result of these motions causes involving structural deformations (Biran, 2003).

8. STRUCTURAL DESIGN

8.1. Loads

The dead, operating (live), environment (wind, wave, and earthquake), construction, installation, fatigue and accidental loads are applied to platforms. (Nouban et al., 2016)

8.1.1. Permanent (Dead) Loads

Permanent loads are dead loads which are self-weight of structure in the air and includes the marine grought weight. The loads contain the weight of ballast. Compounded structures indelibly and weights of equipment are assembled on the platform. Buoyancy and hydrostatic pressures are on the members below the waterline. (Nallayarasu, 2012).

8.1.2. Operating (Live) Loads

Operating loads are live loads. They contain the weight of movable material, equipment, and forces such as the weight of consumable supplies, life support systems, drilling, living quarters, liquids, heliport, furniture, and production facilities so the loads are perceived on the platform during using the equipment. Drilling, helicopter landing, vessel mooring, and crane operations are forces being formed during the operations. According to BS6235 the live loads, for working areas and all of the crew quarters and passageways are 3.2 kN/m2 and 8.5 kN/m2, respectively.

8.1.3. Wind Loads

The upper part of the platform staying above the water level such as housing, derrick is affected by wind loads. Used codes which help to combinative wind loads with wave loads don't suggest two loading conditions. One of them is along 1 minute continued wind speeds with extreme waves. The other of them is 3 seconds gusts. When the height of the structure is 5 times smaller than the horizontal dimension of the structure, API-RP2A needs the dynamic effects of the wind which is kept in mind and the flow which causes cyclic wind loads has to be considered because of vortex shedding. (El-Reedy, 2012).

8.1.4. Wave Loads

Design wave concept defines a regular wave of given height and period. In addition, a high-order wave theory is used to determine the forces because of this wave. Maximum wave is always determined by using a return period of 100 years and the structure has no dynamic behavior. As the dominant wave periods are above the period of the structure, this static analysis is suitable. This case is extreme storm waves behaving on shallow water structures. The kinematics of waves of water is defined by wave theories used to compute the particle velocities and accelerations as well as the dynamic pressure as functions of the surface elevation of the waves. The waves are supposed to be long-crested such as described by a two-dimensional flow field and characterized by the parameters which are wave height (H), period (T) and water depth (d). Large volume bodies which affect the wave area with diffraction and reflection are categorized as hydrodynamic compact structures. Then, calculations of diffraction theory determine the forces on the forces. Hydro-dynamically transparent structures which are slender don't have an important influence on the wave area. Using of Morison's equation helps to properly compute the forces. The proportion of the member diameter to the wavelength should be less than 2 to apply the Morison's equation. (Haritos, 2007).

8.1.5. Earthquake Load

There are two levels of earthquake intensity which offshore structures are designed for. One of them is strength level that earthquake recognized as having a "reasonable possibility of not being exceeded during the platform's life which is mean recurrence interval between 200 and 500 years". That is to say, the structure is designed to elastically answer. Second of them is ductility level that earthquake is identified as close to the "maximum credible earthquake" at the locations. That is to say, the designed structure responses non-elastically and for having suitable reserve strength to avoid collapse (King, 2012).

8.1.6. Ice and Snow Loads

Ice is one of the most problems for marine structures which is in sub-arctic and the arctic regions. Large pressures which cause horizontal and vertical forces are generated by ice formation and expansion. Moreover, winds and waves with speeds up to 0.5 to 1 m/s drive large ice blocks can hit the structure so they manufacture impact loads. (Nallayarasu, 2012).

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8.1.7. Temperature Load

Thermal stresses are generated by temperature gradients. Extreme values of the sea and air temperature tending to occur during the life of the structure should be forecasted. Then, environmental sources and the accidental release of cryogenic material cause increasing temperature. Therefore, the condition has to be calculated as accidental loads. In addition, the temperature of the gas and oil generated has to be taken into account.

8.1.8 Marine Growth

Marine growth is supported with submerging members, but the effect of wave forces rises on the members by rising subjected zones and drag coefficient because of higher surface roughness. The diameters should increase proportionally with masses of submerged members (Nallayarasu, 2012).

8.1.9. Installation Load

The installation loads are temporary and increase during fabrication and installation of the platform or components. For example, lifting forces are produced by installation lifts of different structural components. During transportation to the site, launching and upending/lifts related to installation as well as platform loadout. The forces which cause static equilibrium of the lifted weight and the sling tensions are important factors to be designed all members and connections of a lifted component. At all stages of jacket loadout and transportation to the fabrication, all forces are to be calculated and the stresses to be verified.

8.1.9. Accidental Load

Accidental loads such as fire, explosion, dropped objects, collision with vessels and done without flooding of buoyancy tanks originate as a consequence of an accident or exceptional circumstances. Specific calculations are done normally to decrease the risk of accidental loads (D.N.V., 2011).

8.1.10. Load Combinations

There are two loads of combination suggested for use with allowable stresses for normal and extreme operations. For normal operations, DL (Dead loads) + managing environmental loads (EL) + max LL (maximum live loads) and DL + managing EL + min LL. For extreme operations, DL + extreme EL + max LL and DL + extreme EL + min LL, EL should be associated in a manner steady with their connection probability of occurrence. However, earthquake loads are forced as an especial EL such as not for combined with waves, wind etc. (D.N.V., 2011). Fatigue loading also is considered to check the strength of the welds against the repeating wave action.

9. ANALYTICAL MODELS

The same analytical models used in onshore engineering are employed in offshore engineering. In other words, the same models are used in both type structures except for supports locations. Stick models are used commonly for tubular structures which are flare booms, bridges and jackets and lattice trusses which are modules and decks. Then, every structure members are connected to each other from its ends to other structural elements in the model. Every member in the structure is classified according to geometrical and material properties and hydrodynamic coefficients such as relating to marine growth, inertia, and drag as well as allowing wave forces to be automatically produced. Then, plate elements define large bulkheads which are involved by integrated decks and hulls of floating platforms. A deck can withstand crane's highest roll moments with resembling highest recline on weights for at least eight conditions of the crane boom around 360-degree paths. A structural analysis

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is going to be a static linear analysis of the structure above the sea bed above the seabed combined with a static non-linear analysis of the soil with the piles. In addition, installation, as well as transportation of the structure, maybe needs extra analyses. Detailed fatigue analysis shall be done to indicate overall fatigue damage. Wide flange beams or Pipe for whole first structural members are used generally in the offshore platform designs (Nallayarasu, 2012).

10. VERIFICATION AND TOLERANCES

The confirmation of a member includes a comparison of its characteristic resistance to stress or design force. It contains strength checking where the characteristic resistance is dependent on the yield strength of the element, stability checking for elements in compression dependent on the buckling limit of the element, a member is checked at typical sections which are at least both ends and mid-span towards to buckling and resistance. Then, tabular joints are checked against to punching. The checks might show the requirement for local chord reinforcement which uses internal ring-stiffeners or larger thickness. In addition, elements shall be approved against temperature, fatigue, durability or corrosion wherever relevant (D.N.V., 2011).

11. STRUCTURAL DESIGN

There are three project given circumstances such as transit, operation as well as survival. The project given circumstances for durability should be depended on intact as well as damage is given circumstances which can be supportiveness or link has done impotent, the main beam in deck done impotent, heeled given circumstances because of lack of buoyancy etc. (Nallayarasu, 2012).

For extra information on design and data on the ecological information together with important equations and the information required for the design of offshore structures, the guidelines and information given in references [8] to[13] and [16] to [34] may be utilized.

12. CODES

There are three codes such as Offshore Standards (OS) providing technical necessaries and admission criteria for overall appeal by the offshore industry like DNV-OSC101, Advised Practices (RP) providing showed technology and voice engineering practice and inducement for the greater level launchings like API-RP-WSD and BS6235: Code of practice for fixed offshore structures like British Standards.

13. CONCLUSION

The paper has ensured a wide of some of the key aspect in the analysis, design, construction, and installation of offshore structures. Moreover, the paper has emphasized introducing types of platform, platform parts, platform installation, corrosion protection, platform foundation, naval architecture, structural design, structural analysis, acceptance criteria, and structural design and different codes. Finally, the reference list of the paper gives to interested readers many paper lists about offshore structure so they can investigate the topic more detailed if they want.

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