

An overview of design, construction, and installation of gravity offshore platforms

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ABSTRACT

The offshore structures are used worldwide in different ways and for different purposes in a variety of weather conditions and water depths. The main aim of these structures is to explore and extract the gas and oil and they should work safely for approximately 25 years or more against some conditions. These structures play a vital role in developing the economic level of the country and it is essential to be accurate in all of their planning, designing, manufacturing, transporting, and installing processes. There are many types of platforms that differ according to their function and the needed water depth. Gravity platform or ConDeep platform is one of these platforms that is fixed offshore platform, made by concrete. The purpose of this paper is to give an informative overview of the advantages, disadvantages, materials used, design, construction, transportation, and installation of gravity platforms.

1. INTRODUCTION

The demand for energy, gas and oil is always increases and this is the main reason for creating and developing offshore structures. The offshore structures are mostly built in areas where there is gas and oil at a certain distance from the shoreline. The aim of these structures is to explore and extract gas and oil and sometimes for electric purposes. The offshore structures are used worldwide in different ways and for different purposes in a variety of weather conditions and water depths. Oil exploration, ship loading and unloading, navigation and bridges support are all uses of the offshore platforms in which oil production is considered as one of the most important uses (Sadeghi, 2007). The offshore structures must function safely for 25 years or more against some conditions. It is essential to be accurate in planning, fabricating, designing, transporting, installing, and selecting the type of offshore platform (Sadeghi, 2008). Offshore structures are very important because of their great influence on the economic development of the countries and they are relying on different conditions like structural and ecological conditions (Sadeghi & Bichi, 2018). Offshore structures are very significant and considered among the tallest structures all over the world. They should be well operated because of the environmental challenges (Nouban

et al., 2017). Offshore structures are so complicated structures that require many aspects in the design and construction processes. In the case of deepwater and harsh environmental conditions, the fixed platforms are used to obtain the stiffness and strength needed for the structures (Sadeghi & Guvensoy, 2018).

1.1. Types of offshore platforms

The offshore platforms can be categorized into three main categories which are fixed platforms, compliant platforms and floating platforms. These main categories can also be further categorized as follows:

1.1.1. Fixed platforms

- Jack-up rigs (when drilling),
- Gravity-based structures,
- Jacket platforms.

1.1.2. Compliant platforms

- Tension leg platform,
- Articulated tower,
- Guyed tower.

1.1.3. Floating platforms

- Floating production unit,
- Spar,
- Semisubmersible,
- Floating production, storage, and offloading system,
- Floating storage and offloading.

(Chandrasekaran, 2018).

2. GRAVITY PLATFORMS

Gravity platforms are fixed offshore platforms which are made of concrete (Fig.1.). ConDeep platforms are the other name of gravity platforms and they are mostly used in the side of Brazilian water and the North Sea (Nouban et al., 2016). Gravity platforms are used in the North Sea because their foundations are large and have long height so no additional fixing and also because the sea bed materials are consolidated in the North Sea (Clauss et al., 1992). The gravity platform contains 24 cylindrical cells located at the caisson (the lower part). The approximate diameter and height of cells are 24 m and 77 m respectively. In order to carry the deck, four of these cells are elongated. Moreover, some of these cells are extended downward and penetrate the seabed to form the skirts (Langena et al., 1998). Table 1 shows the gravity offshore platforms constructed worldwide.

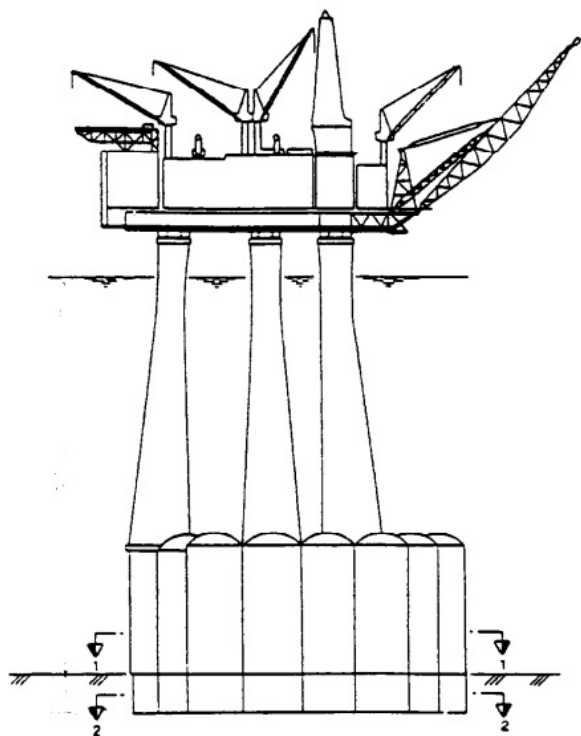


Fig. 1. Gravity platform (Langena et al., 1998)

Table 1. Gravity offshore platforms constructed worldwide (Chandrasekaran, 2018)

Name of platform	Water depth (m)
Troll	330
Draugen	280
Heidrun	280
Slebner	80
Oseberg	100
Maureen	95.6
Ekofisk 1	70
Osberg north	100
Cormorant	149
Ninian	136
Dunlin A	153
Frig TP 1	104
Frig CDP1	98
Frig MCP01	94
Frig TCP2	103
Gulfaks a	133.4
Gulfaks b	133.4
Gulfaks C	214
Beryl A	119
Brent B	140
Brent C	141
Brent D	142
Statfjord A	145
Statfjord B	145
Statfjord C	145

2.1. Advantages of gravity offshore platforms

Advantages of gravity offshore platforms are as follows:

- Safe for the people working on it,
- Possibility of towing to the site with the deck,
- Less time in installation and less cost,
- Less maintenance cost because the concrete in water has lesser problems than the steel,
- Crude oil capacity can be adjusted,
- Can support large areas of decks,
- Healthy monitoring because there is an excess to the seabed from the cell in the foundation.

2.2. Disadvantages of gravity offshore structures

Disadvantages of gravity offshore platforms are as follows:

- Inappropriate for the sites with poor soil conditions,
- Construction process takes a long time which leads to delay in production,
- Falling of the natural frequencies during the range of power of the wave spectrum (Chandrasekaran, 2018).

2.3. Materials

- The requirements for the materials are as follows:
- Compressive concrete strength 65 Mpa,
- Maximum water-cement ratio 0.4,
- Cement material content 360-450 kg/m³,
- Maximum silica fume content 8%,
- Maximum fly ash content 30%,
- Slump 240 mm,
- Coefficient of chloride diffusion 4×10^{-12} m²/s,
- Freezing and thawing are resistant to splash zone 2-4% air entrainment (Widianto et al., 2016).

2.4. Design considerations

Gravity offshore platforms are giant structures and according to the different loads that are imposed on them, there are some considerations that should not be overlooked which are:

- The oil storage must be accurately designed and it should be tight with respect to the oil leakage which means that there should be no cracks and only very limited cracks are accepted,
- The internal pressure of the oil must be less than the external pressure of water,
- Temperature stresses caused by hot oil,
- Instability of the walls and columns of the caisson,
- Local earth pressure,
- Fatigue damage at the bases of columns (Otunyo, 2011).

2.5. Loads considered in the design

The gravity offshore platforms are exposed to many horizontal and vertical loads that should be taken into consideration in the design process. The loads are as follows.

2.5.1. Dead loads

The dead loads are the weights of the structure that include deck, jacket, piping, anodes, boat landing, grating,

and all the equipment which are fixed and permanent (Al-Sharif, 1995).

2.5.2. Live loads

The live loads are the loads that are not permanent on the platform and may change in the different steps of operation. They include the weight of workers working on the platform, impact loads, helicopter loads, and the crane operation (Al-Sharif, 1995).

2.5.3. Ice and snow loads

When the structures are located in the Polar Regions or in the side of cold countries the ice and snow loads must be taken into consideration because their high intensity can create a big load on the structure and it may happen suddenly to the structure. An empirical formula can be used in order to calculate the ice force (Kharade & Kapadiya, 2014).

$$F_{ice} = C f A \quad (1)$$

where:

C: the coefficient of ice force which varies between 0.3 and 0.7,

f: the ice crushing strength which varies between 1.5 and 3.5 Mpa,

A: the area struck by ice which equals to diameter times the thickness.

2.5.4. Wind forces

For the design of the gravity offshore platform, the wind-induced loading which can also be called as drag force should be evaluated. During the estimation of the wind-induced loading, some predictions are used for instance neglecting higher-order wind-induced loading and by using turbulent wind spectral formulations. The drag force can be evaluated by applying the following equation (Jang & Jyh-Shinn, 1999).

$$F_D = 1/2 \rho C_D A U^2 (t) \quad (2)$$

where:

F_D: the drag force,

ρ: the density of air,

A: the area of the structure,

U (t): incident wind speed.

2.5.5. Wave forces

Evaluation of the wave slamming and slap forces on the structure is necessary and it can be included in the equation of motion if warranted. The wave forces that are imposed on the columns are the source of tendon responses and

should be calculated in order to design (Sadeghi & Tozan, 2018). In order to analyze and indicate the wave data sensing by satellites, measuring devices and simulation models are used. The simulation models are mostly used in the world because it is simple and can be applied for most of the geographical areas while the two other methods are not widely used because they consume a long time, are expensive and not available for all regions (Sadeghi, 2007). The wave loads that are imposed on the structure create an overturning moment on the structure. In the design, the maximum wave height has to be used and it has a relationship with the significant wave height which is shown below (Kharade & Kapadiya, 2014).

$$H_{max} = 1.86 H_s \quad (3)$$

where:

H_{max} : the maximum wave height,

H_s : the significant wave height.

2.5.6. Earthquake loads

The offshore structures are exposed sometimes to lateral loads that may exceed their elastic limit. In some regions, the seismic loads are higher than other regions so the regions where the seismic loads are more active should be accurately designed against these loads in order to prevent any failure (Bargie et al., 2011).

2.5.7. Current loads

The currents in oceans create a drag loading on the offshore structures and they consist of tidal and wind-driven currents. The tidal currents vary with the change of depth but non-linearly on the contrary of wind-driven currents that vary linearly with the water depth. These currents can be expressed as follows (Kharade & Kapadiya, 2014).

$$V_T = V_{OT} y^{1/7} / h \quad (4)$$

$$V_W = V_{OW} y / h \quad (5)$$

where:

V_T : the tidal current at any height,

V_{OT} : the tidal current at the surface,

V_W : the wind-driven current at any height,

V_{OW} : the wind-driven current at the surface,

y : the distance from the seabed,

h : the water depth.

2.5.8. Fabrication, transportation, load out and installation forces

The procedures and guidelines for fabrication must be followed and done as recommended to reduce the concentration of stress upon welding and misalignment and to deprive the cracks in the welds. Furthermore, the barge

motion and the forces that may occur upon lifting or loadout with not equally slings must be considered in the design to make sure that the structure can resist these forces (Al-Sharif, 1995).

2.6. Construction and fabrication

The supports of the gravity-based structure can be categorized into three generations and each generation can be constructed in a different place. The dry dock is the first place where the construction of supports can occur and it is used in the first generation of gravity-based structures. The dry dock is flooded when the supports are ready to be floated out Fig.2. Floating pontoons is another place where the construction of supports can occur in which the supports are constructed on semisubmersible barge or floating pontoons and it is used in the second generation. The advantages of this method are no need for a large area for construction in the port and there is no need for operation of floating and loading out in which the supports can be directly transported to the final destination Fig.3. Moreover, onshore can be another choice of supports construction in which the supports are constructed in the port and it is used in the third generation. The quayside may have to be reinforced because of the high requirements of the supports Fig.4 (Esteban et al., 2015).



Fig. 2. Construction of supports in dry dock (Ruiz de Temino Alonso, 2013)



Fig. 3. Construction of supports on semisubmersible barge (Ruiz de Temino Alonso, 2013)



Fig. 4. Construction of supports on the quayside (Ruiz de Temino Alonso, 2013)

2.7. Transportation

For the cases of the first generation which are constructed on the dry dock, after building the structure and floating it out, the heavy-lift vessel barge is used for transporting and installing the supports. It should be modified to achieve the member's weights of structure and water depth requirements. Moreover, it should fit the shapes and sizes of supports. For the cases of the second generation which are constructed on the floating pontoon, after finishing the construction of the supports, they can be transported by the barge. In this case, the barge must follow the requirements of the international maritime organization IMO or any International Association of Classification Societies IACS members. For the cases of the third generation which are constructed on the onshore, a floating pontoon is used for transporting the supports. (Esteban et al., 2015).

2.8. Installation

The installation process is positioning and levelling of the offshore platform according to the design drawings and assembling the different components of the structure in order to make it a stable structure (Muyiwa & Sadeghi, 2007). There are two techniques for installation of the structures which are an individual installation by using the heavy left vessel and installation of several supports by loading them on semisubmersible barges. The first technique is used when the construction occurred on the onshore and dry dock while the second technique is used when the construction occurred on the semisubmersible or floating barge. In all cases, the supports are lowered and installed to the seabed by heavy lift vessel Fig. 5. The advantages of the second technique are transferring the supports by one trip, faster in towing, safer, and easier if any problem occurred due to the weather conditions (Esteban et al., 2015). In some situations, the seabed under the structure

may need some preparations so in this case the preparation process should be started before the arrival of foundations. The backhoe on a pontoon prepares the seabed by installing and levelling a layer of gravel. After preparation of the seabed and arrival of foundations to the location, the heavy-lift vessel lifts the foundations and lowers them to their final destination. Then in order to withstand the applied loads, the foundations are ballasted. The next step is the installation of the quarry stone layer in order to prevent the erosion of the gravel layer (Ruiz de Temino Alonso, 2013).



Fig. 5. Installation of the supports (Ruiz de Temino Alonso, 2013)

3. CONCLUSION

In this paper, some information about the advantages, disadvantages, materials used, design, construction, transportation and installation of gravity platforms has been described. Gravity platforms differ from the other offshore structures in the design, construction and installation processes. This type of fixed offshore structure is worldwide used because of its advantages at special water depths.

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