GENERAL GUIDANCE FOR DESIGN AND CONSTRUCTION OF GRAVITY PLATFORMS

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ABSTRACT

Among the different types of offshore platforms which are mainly categorized according to waterdepth of the installation location, the gravity platforms have different type of construction and installation. The platforms are generally made of steel, built onshore, and then transported to the installation locations. For some cases of sea waterdepths and aggressive environments like the condition of the North Sea, the heaviest type of platform, called gravity platform, having enormous mass, is used. Gravity platforms have their own special requirements and fabrication/installation procedures. They need special types of construction materials to resist the environmental conditions imposed by the aggressive environmental loads. The construction, transportation, installation and the operation processes, kinds and specifications of used materials in the gravity platforms are presented in this paper.

Keywords: Construction, Installation, Offshore, Gravity platforms, Condeep, Concrete platforms.

INTRODUCTION

As the competition in the offshore production market rises, the demand for offshore structures also increases, specifically in the North Sea along with some other places that invest in the production of offshore oil/gas. In Norway, the inlets played a major role in facilitating the process of offshore construction due to the possibility of submerging the structures in those areas, making the transportation process less difficult by the means of barges. Offshore substructures have proved to be highly endurance to the harsh marine conditions, this is due to the strength of the reinforced concrete that can be further reinforced on demand to meet the requirements of several sites (Chakrabarti, 2005). Condeep (gravity) platforms that are essentially made of reinforced concrete, fixing it rigidly to the seabed and giving it more resistance to the sea waves (Sadeghi, 2008; Sadeghi, 2001 and Tianwei, 2010).

Types of Offshore Concrete Structures

The three main types of offshore concrete structures are as follows (Atkins Process Limited and Olav Olsen, 2003):

i. Tower and caisson types with circular caisson cells (Condeep),
ii. Tower and caisson types with rectangular caisson cells,
iii. Jarlan wall types (Doris).

Advantages of Gravity Platforms

i. Built on an onshore site,
ii. Ease of transportation,
iii. Conveniently installed by means of submerging,

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iv. The simplicity of installation methods (Chandrasekaran, 2015).

Drawbacks of Gravity Platforms

i. Requires significantly high soil standards,
ii. Additional labor for the pre-construction phases,
iii. Prolonging the production as it commences after the construction competition. (Chandrasekaran, 2015).

Design Requirements

Especial attention should be paid to overcome the obstacles that may be faced when designing of such type of platform, which are listed as follows (Hsai, 1991):

i. A reasonable safety factor is required to prevent the structure from sliding and to obtain more rigidness to the foundation when subjected to harsh environmental conditions,
ii. The plastic rotation that occurs in the structure when facing the previously mentioned conditions should not reach an endangering level,
iii. The endurance of the structure should also be taken into consideration when the structure is subjected to oscillating forces,
iv. Altering the design of the structure does not have a natural frequency that could be affected by oscillating forces,
v. The effect resulting from the constant motion of the seafloor is to be minimized in the design, keeping in mind that the structure should stand rigidly on the seafloor despite the unsteadiness caused by the waves,
vi. Finally, ease of access and renovation is essential, as the structure underlies several factors of erosion.

Geotechnical Design Of Foundation System

A number of points should be taken into consideration in order to construct an ideal structure, such as (Hsai, 1991):

i. Pre-construction phases,
ii. Structure analysis,
iii. The degree of plastic rotation,
iv. Distortion and disruption of the structure,
v. Short-term cyclic displacements,
vi. Dynamic analysis of the soil structure system for wave loads and earthquakes,
vii. Analysis of conductors and risers under external forces caused by the unstable nature of the environment,
viii. Decommissioning issues.

Pre-Constructional Operations

Normally, a pre-construction phase consists of numerous known points. However, additional obstacles take contractor's attention when executing an offshore structure, generally revolving around two points:

i. A geotechnical analysis of the soil,
ii. Seabed leveling work before placing the gravity-based structure.

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Primarily, the soil on which the construction work is to be performed must undergo a careful study, then determine whether the soil is fitting to the standards required to accommodate the structure. In the case of the presence of any impurities that rupture the implementation of the project, further treatment is performed to the sand. However, in order that the process of sand treatment not to exceed its assigned budget, the depth of sand removal reaches only 10 m, with the aid of offshore tools and ships to carry them along with labor workers, this is due to the nature of the site (Esteban, 2015 and Bai, 2012).

MATERIALS

The quality requirements for concrete in the North Sea platforms are given in the regulations and codes and are essential as following:

i. High-quality materials,
ii. The compressive strength of concrete at least 40 MPa,
iii. Maximum water/cement ratio of 0.45 or 0.40 in the splash zone.

Table 3 presents the comparison of two different mixture types of concrete used in two platforms (Kato, 1985). As mentioned above, the enhancement is obtained by improving the quality of the materials used in the mixture of concrete and by altering the aggregation and mixing processes (Kato, 1985).

Table 4. Comparison of two different mixtures of concrete (Kato, 1985).

Condeep Beryl A (1973-75)		*Condeep Statfjord C (1981)*	
Cement (SP 30)	*430 kg*	*Cement (SP 30-4A)*	*380 kg*
Sand, Ardal 0-10 mm	*900 kg*	*Sand, Tytlandsvik 0-5 mm*	*1030 kg*
Coarse aggregate, Ardal, 10-32 mm	*900 kg*	*Coarse aggregate, Tytlandsvik, 5-20 mm*	*485 kg*
Water	*175 L*	*Water*	*160 L*
Betokem LP	*4 L*	*Betokem PA (B)*	*4 L*
Slump	*120 mm*	*Slump*	*220 mm*
w/c ratio	*0.41*	*w/c ratio*	*0.42*
Obtained mean 28-day compressive strength	*55 N/mm^2*	*Obtained mean 28-day compressive strength*	*62 N/mm^2*

SITE SELECTION

It's a fact that the choice of location plays a major role in the success of the project. However, what is meant by a proper site location, here is one that will minimize the costs of transportation, along with construction assembly (Esteban, 2015).

Facilities

i. Drydock (1st generation): The main principle that dry dock construction relies on is basically utilizing the dock as a building ground, then loading the gravity based structures (GBS) structure by means of flooding it, as it will naturally float when the water reaches a certain height. This method is considered to be the oldest in the construction of GBS.
ii. Floating pontoons (2nd generation): a floating pontoon (semisubmersible barge) is used to both support the structure, and to load it to its destination, reducing the labor

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required to transport the structure once the construction has been finalized, and not having to dedicate site space to the construction process onshore.

iii. Onshore (3rd generation): creating an issue once the construction reached the final stage of loading, the construction is carried out on the docks, reinforced on the seafront. The issue here is the transportation of the reinforced structure (Sadeghi, 2001 and Esteban, 2015).

RELOCATION OF SUPPORTING STRUCTURE

After the primary stage of fabricating the supporting structure, and setting up the seabed, the supporting structure needs to be relocated to the target location to be installed, the relocating process consists of a critical step called "load-out", and the procedures differ according to the specifications of the target site, where supporting GBS will finally settle.

That's why relocation methods are categorized, taking into consideration the specifications of each participating facilities, such as dry docks, pontoons, and onshore facilities.

Firstly, a clear way of using GBS would be the "Middelgrunden" offshore wind farm, the method used to construct the facility was the Dry Dock. As explained before, it was relocated and installed by means of a special type of vessels. However, additional modifications were made to the vessel in order to support the weight of the structure and withstand the depth of the water, and a boat was used as a support to the structure.

Secondly, post to the production of all the required items in the pontoon, they are transported via same pontoon as illustrated in the method of floating pontoons. However, the pontoon undergoes strict analysis, and evaluation by international institutes in order to assure its compatibility with the required standards. External forces exerted by the weather conditions are also taken into consideration prior to sailing, in addition to the analysis done to the structure itself to ensure the completion of successful construction, installment processes, and lower the hazardous risks of uncalculated failures.

Thirdly, in the 3rd generation construction method, the pontoon serves as a base for the construction, and as a means of transportation after the completion of the construction. This was performed in the Bank of Thornton with the selection of a "Rambiz" heavy lifting vessel. The modifications done to the vessel, to enhance its performance consisted of equipping it with stronger lifting tools, all in compliance with the dimensions of the structure to be loaded. A simple yet smart method was used to reduce the weight of the structure, which was partially sinking the structure in the seawater throughout the lifting process, hence reducing the load carried by the vessel. The submerged mass created the problem of drag resistance to the towing vessel that had a loading capacity that goes up to 3300 tons, although it was only carrying loads ranging from 2800 to 3000 tons. As a remedy to the extra drag force, the vessel was lowered 10 meters below sea level, substantially reducing the drag force caused by the submerged structure mass (Esteban, 2015).

GBS SUPPORT STRUCTURE INSTALLATION

Given the offshore wind farms already at hand, the installation process of the structure follows its transportation, which is done by one of two methods:

i. Singular installation of structures carried out by a heavy lifting vessel, this method is chosen when the process of construction followed is either the onshore or the dry dock method.

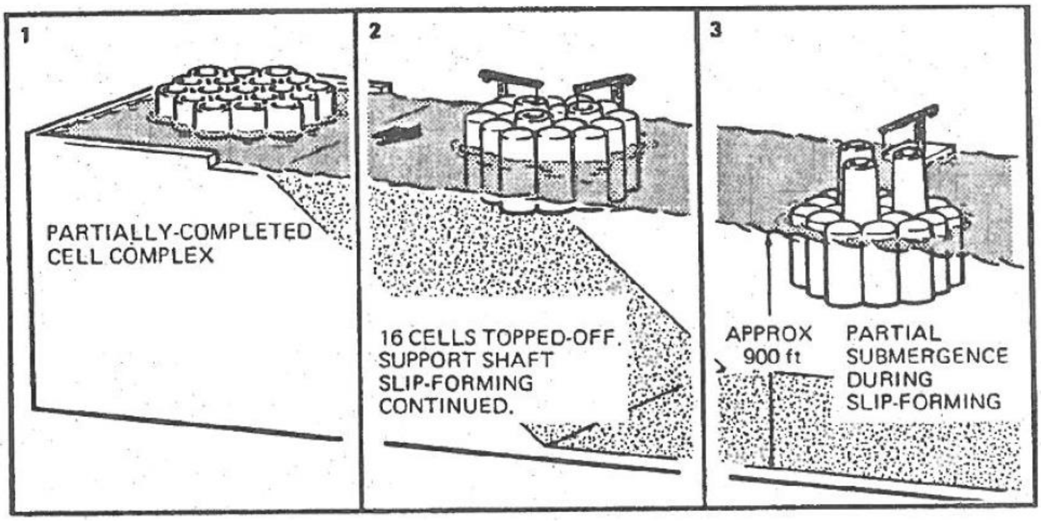
ii. Mass transportation and installation of several structures instantaneously, loaded on pontoons.

A good example of a singular HLV aided installation would be Middleground Offshore Wind Farm, which was performed with an "Eide V" type vessel, which placed the structure in its current location on the seabed.

The case of relocating of a supporting structures group on semisubmersible barges, it corresponds to the "pontoon" GBS support structure manufacturing method. In these cases, supporting structures are relocated to the offshore site by the use of the same method. The setup process is carried out by a special type of vessels, which lifts each support structure and then lays the unit over the pre-cured seabed. The main benefits of this process are the relocation of several supporting structures in a single cruise; the higher towing velocity; the higher safety while relocating; the higher frequency of operations made taking an advantage of the unrestricted weather. Therefore, long distance relocating through the ocean is feasible and the project will not be constrained, and open to logistics factors such as the capability of yard facilities and setup methods. However, some differences could occur in the mentioned type of offshore wind farms, illustrated as following (Esteban, 2015).

To execute the offshore "Condeep" platform of the oil and gas industry, the following steps were followed (Sadeghi, 2001 and Esteban, 2015):

i. Construction process carried out in the dock,
ii. Loading by means of floating the structure,
iii. Anchoring at the offshore site,
iv. Offshore building,
v. Caisson chamber finalization,
vi. Construction of the shaft,
vii. Transporting to the offshore coupling location,
viii. Erection of the platform's deck,
ix. Transporting the deck,
x. Partially submerging the structure for deck coupling,
xi. Deck coupling,
xii. Fastening,
xiii. Loading into the offshore location,
xiv. Setup.



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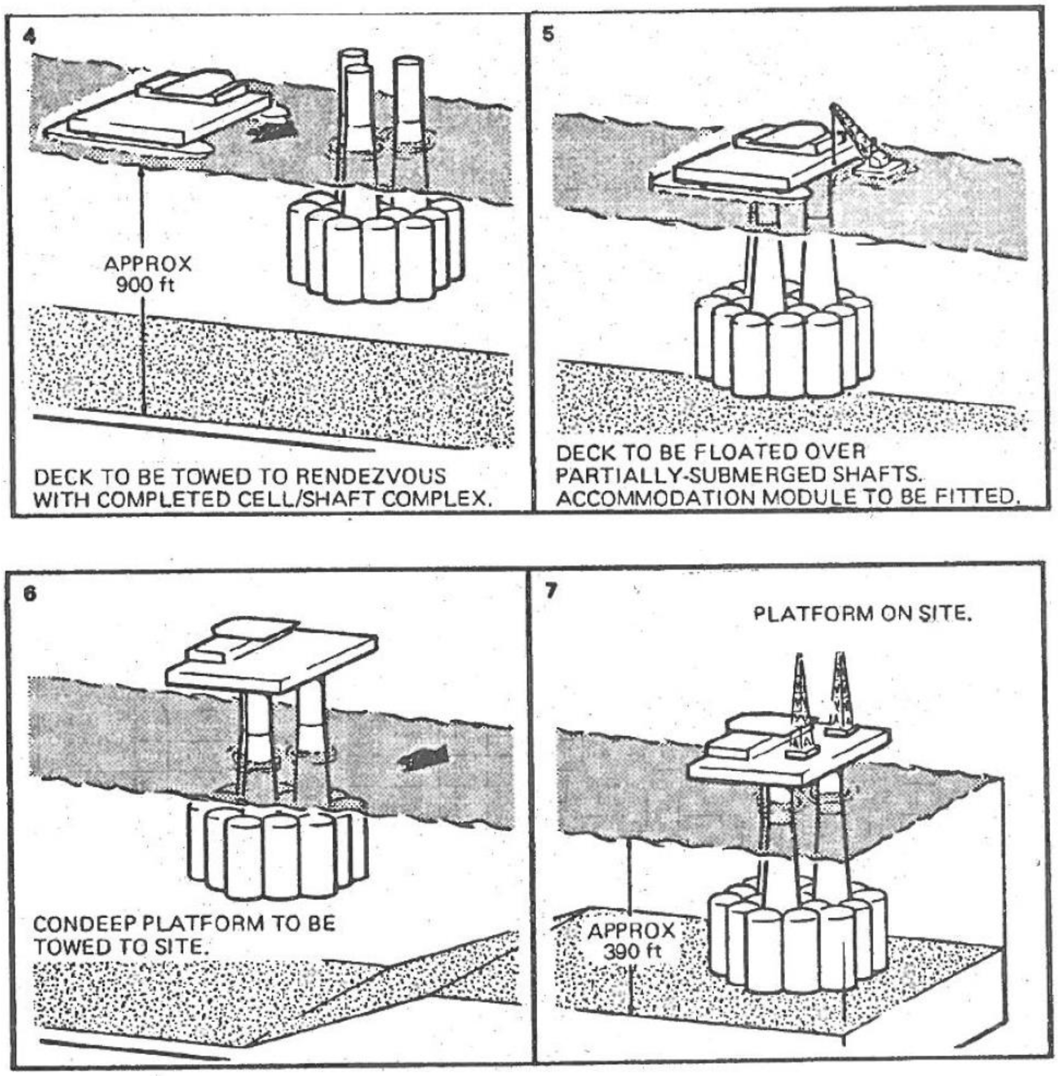

Figure 1. Illustration of construction and installation procedures for concrete gravity platforms (Sadeghi, 2001).

BALLASTING AND ANTI-EROSION PROTECTION

Ballasting and anti-erosion protection is a part of the installation process. However, they were separated in this steady to emphasize on the later one for its importance.

The ballasting process takes place after the GBS has been installed on the seabed. The importance of ballasting increases with respect to the generation of the GBS. While it is not required at all for the first generation GBSs, only the holes of the weakest links of the slap and the core of the structure need ballasting. The third generation, however, requires more complex ballasting operations both externally and externally, Due to its rigidity, ballasting is as essential to the support structure as the anti-scouring. As for the materials used for ballasting, Olivine was found to be the best choice, and for anti-scouring, rip-rap rocks were used, such as concrete or sandbags (Esteban, 2015 and Widianto, 2016).

REFLOAT

The pros of the reversed installation method revolve around the platform having sufficient float rigidity to carry the structure to its offshore destination. The minimization of offshore labor is also an essential advantage of refloating, as the disassembling of the deck can take place onshore.

The usual steps followed to perform refloating operations are:

i. Sufficient removal of topside facilities, easing the refloating process and making it safer.
ii. Seal holes in all sections to obtain sufficient resilience for the following processes.
iii. Mechanical tools used to perform the task must undergo strict quality control procedures.
iv. Pump air in the shaft and caisson chambers.
v. Ballasting should not exceed the allowable weight limit, which might reduce the resilience of the platform.
vi. Generate a hydraulic lifting force by injecting water under the base slap, pulling the skirt out of the subsoil.
vii. At the point, where the hydraulic force is less than the required force to lift the platform, the shafts are to undergo further deballast, in order to pull the skirts and dowels out (Atkins Process Limited and Olav Olsen, 2003).

TOW ASHORE

Ashore towing is merely reversing the offshore towing process, performed to install the structure. After refloating, to reach a suitable towing draft, the substructure will be deballasted. The buckling used for towing can be reused if left undamaged. Otherwise, a replacement of the brackets is needed. Similar to refloating, when towing ashore, the platform is labor free.

Despite the flooding of caisson cells, deep structures normally remain floating as a characteristic gained by its design. Shafts must remain afloat at all times, as sinking it will cause damage to the structure. However, poor designs of offshore structures result in its sinking after the cells have been flooded.

The mechanical tools and systems used in towing process are to be maintained in a sound condition. Failure to do so may result in serious damage to the structure.

Analysis and studies are to be carried out to the structures, in order to reach an endurance level for at least 100 years of summer storms (Atkins Process Limited and Olav Olsen, 2003 and Ben, 2007).

DISMANTLING OF PLATFORM

First, the topside facilities and the mechanical outfitting are to be internally and externally removed from the structure. The aid of HLVs is required in this case. The removal process is carried out onshore as the structure normally has the adequate floating rigidity to enable it to refloat.

An adequate water depth is a necessity in the characteristics of the location on which the platform is to be fixed. A good example to this would be the Norwegian “Hanøytangen” yard located on the western coast. HLVs are replaced with 600t floating cranes along with pontoons to transport the cranes.

Dissembling the shafts is done by cutting them horizontally into 600t pieces using a diamond headed saws, or by means of drilling and pressing the parts along the cutting line. Slices are

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then loaded onto a pontoon to be carried to an onshore site, undergoing further cutting to reach the required dimensions.

The cleaning process of the caisson cells is performed using pressurized water applied to the top of the caisson. The wastewater is then collected in barges and carried ashore for decontamination treatment.

The same cutting process applied to the shaft to transport it ashore is applied to the walls of the caisson cell. Ballasted parts are carried ashore by means of conveying techniques. Upon reaching a weight that can be handled without further cutting, the substructure is then transported ashore for finishing processes. The remaining of the cutout pieces may be used for other industrial purposes (Atkins Process Limited and Olav Olsen, 2003).

For additional information on the environmental data together with necessary formulas of wave and wave hydrodynamic loading, the following references: (Kaiser et al., 2013), (API, 2010), (Sadeghi, 2004, 2007a, 2007b, 2008 and 2013), (US Army Coastal Engineering Research Center, 1980), (Nouban and Sadeghi, 2013 and 2014), (US Army Corps of Engineers, 2011), (Nouban, 2016), (Nouban et al., 2016) and (Nouban et al., 2017) can be used.

CONCLUSION

In this paper, a special type of offshore marine structures, called the gravity platform has been described. Distinct considerations for using such a huge type of structures have been emphasized. Also, its benefits and drawbacks, as well as design requirements are described. Since for such a structure, a special type of foundation is needed, so foundation performing procedures are illustrated. Like the other structures, the construction process of this type has its own special stages, such as pre-construction, construction, maintenance after construction and operation.

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