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Design of FPSO Piles Against Storm Loading

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Abstract

FPSO [Floating Production Storage and Offloading] structures have been accepted as a sustainable economic solution for deepwater development projects. Short to medium length (typically 15 to 25m) large diameter driven piles are often used to anchor FPSOs. The loading in such piles during a storm can be resolved into two components: (a) Lateral load, which is one-way cyclic; (b) Tensile (upward) load, which is typically only a few percentage of the lateral load.

The greatest uncertainty in the analysis is the load carrying capacity of the pile, since the cyclic storm loading results in progressive degradation of the soil (sand or clay) supporting the pile. Thus understanding the degradation of the supporting soil is critical, for a safe, economic design. This paper thus has two aims: (a) to propose criteria and considerations for design of such piles; (b) to set out simple modifications in the p-y formulation that will provide a safe working envelope for the full range of ground conditions likely to be encountered at different sites.

A parallel is also drawn to the approach routinely used by the geotechnical earthquake engineering profession, and reported centrifuge tests have been used to validate the proposed modification.

Introduction

The energy challenge, deepwater oil exploration and the FPSO

It is predicted that the world will need almost 60% more energy in 2030 than in 2002, and fossil fuels will still meet most of this need (IEA, 2005). We shall still depend on petroleum for 90% of our transport needs including aviation, land and sea transport. Hydrocarbons will also be used for agriculture, for electricity generation and for the feedstock of the chemical industry. A prime reason for this enhanced energy demand is the economic growth of developing countries such as China and India. Meeting this energy need is one of the greatest engineering challenges of the next decades.

Though research on alternative sources of sustainable energy such as wind, wave and solar power are continuing, specific challenges in the oil and gas exploration areas need to be addressed, as these will still be a major source of energy.

Much of the world's oil and gas comes from offshore locations such as the North Sea, Middle East, Gulf of Mexico and West Africa. Offshore oil and gas production started with platforms consisting of fixed structures resting on the seabed. Over the years, these have evolved into sophisticated modern steel or concrete structures, which may be located in deep, hostile waters. These fixed structures are typically suitable for water depths up to about 300 m, but the tallest fixed platform is Shell's Bullwinkle structure, located in 412 m of water in the Gulf of Mexico, (Offshore Magazine 2005).

The depletion of oil and gas resources in shallow water, coupled with the increase in energy demand, has forced the petroleum industry to move into deeper water. Today it is common to operate in water depths of more than 1300 m. Shell's Na Kika platform operates in 1920 m of water depth in the Gulf of Mexico and plans are underway to exploit resources in more than 3000 m depth of water.

The lateral extent of oil and gas in deepwater reserves is often much larger than that in shallow water, and the use of fixed structures in such deep water is often impractical, not only due to the areal extent, but also to the large water depth, unfavourable sea conditions and economic constraints. Floating Production Systems (FPS) are therefore becoming the preferred choice for deepwater. An FPS is essentially a floating oil rig, anchored to the seabed, containing all the equipment associated with a fixed installation. A Floating, Production, Storage and Offloading unit [FPSO] is a particular type of production system where the oil produced can be stored temporarily on the vessel, before it is discharged into tankers for transportation to a refinery.

From the sustainability point of view, the FPSO system has benefits, as it is quite easy to move it to a new location when the reserves in a particular field reach a commercially unprofitable level. Current predictions indicate that floating systems will continue to dominate the future development plans of the petroleum industry.

It is simply not possible to extrapolate the shallow water technology into deep waters. To meet the market demand, the petroleum industry is developing and implementing new