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Two-Dimensional Bearing Capacity of a Spudcan in Clay After Penetrating Through Top Sand

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This paper presents a series of numerical investigations of the capacity of the foundations of a spudcan in clay after it penetrates through a sand layer and under planar combined loading. The model is validated against available relationships for uniaxial capacity of spudcan foundations on clay soils. The model is then used to investigate the uniaxial capacity and combined VH, VM, and HM capacity of spudcan foundations in the underlying clay of sand overlying clay soils. The results are presented in the form of failure envelopes. The effects of the embedment depth, undrained shear strength of clay, and sand plug thickness on the uniaxial and combined capacity are investigated and discussed.

INTRODUCTION

In the offshore oil and gas and renewable energy industry, a jack-up platform is a mobile structure used for exploration and production and construction of the offshore wind farms. As shown in Fig. 1, it comprises a hull supported by legs (generally three or four) with foundations called spudcans that bear on the seabed. Before installation of a jack-up at a site, the penetration of the spudcan into the seabed and the corresponding ultimate bearing capacities (i.e., the loads above which the soil starts to fail) have to be assessed in order to determine whether the seabed is sufficiently strong to support the platform during installation and environmental storm conditions. This requires understanding of the bearing capacity of each spudcan under combined vertical (V), horizontal (H), and moment (M) loading, as well as their interaction with the jack-up structure.

Three-dimensional bearing capacity envelopes with approximating expressions for combined vertical, horizontal, and/or moment loading are well-documented in the literature for the case of a footing resting on uniform sand (e.g., Gottardi et al., 1999; Houlsby and Cassidy, 2002; Byron and Houlsby, 2004; Andersen et al., 2008; Park et al., 2016) or clay (e.g., Martin and Houlsby, 2000; Gourvenec and Randolph, 2003; Cassidy et al., 2004; Yun and Bransby, 2007; Zhang et al., 2011, 2012, 2014; Bienen et al., 2012) soil.

Soils are often layered, therefore it is important to consider the nonhomogeneity and stratigraphy of the soil. Only a few investigations were carried out for spudcan foundations on layered soils, particularly on sand over clay, which is commonly encountered in some petroleum and renewable energy active regions, e.g., in the North Sea, Gulf of Mexico, South China Sea, and offshore India. Poirriez and Edwards (2013) carried out a series of finite element (FE) analyses to investigate the combined vertical–horizontal capacity envelopes of circular footings resting on the top sand layer of sand over clay. It is found that the ultimate vertical bearing capacity of such a layered soil lies between the maximum vertical bearing capacity obtained for homogeneous clay and sand, while the corresponding ultimate horizontal bearing capacity can be lower than that for homogeneous clay. A simplified method was proposed for estimating the combined vertical–horizontal bearing capacity envelope when the thickness of the sand layer is greater than half of the footing radius. Hu et al. (2017) conducted a series of geotechnical centrifuge model tests involving combined loading of circular footings to establish the VHM yield surface of a spudcan that has been installed through a layer of sand into underlying clay. The testing results at two typical penetration depths on sand over clay are interpreted to provide empirical expressions with best-fit parameters for the combined

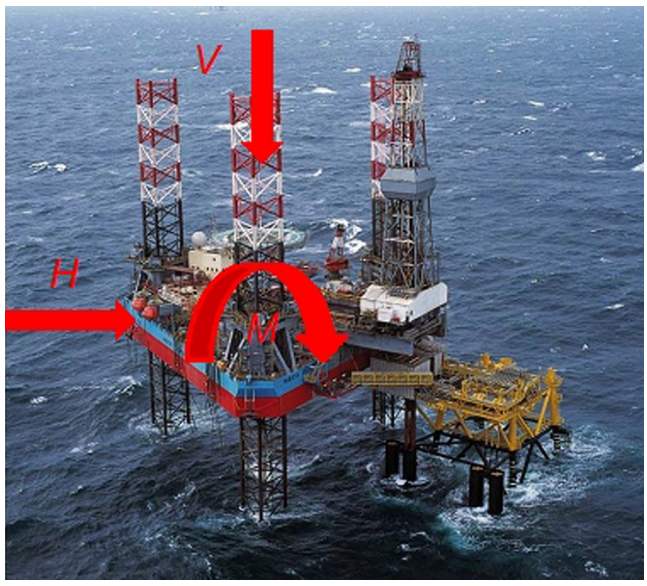

Fig. 1 A typical jack-up platform and the loading conditions

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KEY WORDS: Bearing capacity, combined loading, clay, sand, spudcan foundation.