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Comparison of Jackup Rig Spudcan Penetration Methods in Clay

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Abstract

This paper compares four methods that predict jackup rig spudcan penetration with measured load-penetration records at thirteen Gulf of Mexico locations. Predicted load-penetration curves, for the four methods, are determined using site-specfic geotechnical information for normally to slightly over-consolidated clay soil profiles. The four methods include two based on SNAME (2002) recommendations, using bearing capacity formulations as proposed by Skempton (1951) and Hansen (1970), a method recommended by Houlsby & Martin (2003), and a method recommended by Hossain et al. (2006). Detailed spudcan geometries and dimensions from the seven different types of jackup rigs installed at the thirteen locations are also provided. Spudcan diameters of the seven jackup rigs vary from 11.0 to 20.1 meters and spudcan bearing pressures range from 162.8 to 507.4 kPa.

Interpreted soil parameters are presented for all thirteen sites. Boring logs, illustrating the interpretation of parameters from the measured soil properties are presented for two of these locations. The logs present the results of standard laboratory tests typically performed for Gulf of Mexico site investigations: undisturbed undrained shear strength measurements from Torvane, miniature vane, pocket penetrometer and unconsolidated-undrained (UU) triaxial tests; remolded shear strength from miniature vane and UU triaxial tests; submerged unit weights (derived from measured bulk wet unit weight); water content; and Atterberg limits. Theoretical submerged unit weight values, used as an aid in parameter selection, are also plotted on the boring logs.

The results of this study are presented in a series of figures that compare the predicted load-penetration curves based on each of the four methods to the measured load-penetration data recorded during the installation of the jackup rig at each of the thirteen locations. The comparisons indicate that (1) the Houlsby & Martin method provides good lower bound load-penetration predictions, generally predicting a deeper penetration under a given load than measured; (2) the Hossain et al., method provides an upper bound load-penetration prediction, usually predicting a shallower penetration under a given load than that measured, and (3) the modified SNAME methods, with Skempton and Hansen bearing capacity factors, provide reasonable predictions of the average penetration under a given load.

Two factors affecting the predictions are also discussed: spudcan geometry and spudcan cavity depth. The results demonstrate the difficulties all four methods may experience providing accurate load-penetration predictions for jackup rigs with spudcan geometries that do not lend themselves to easy modeling using standard bearing capacity factors and equivalent projected circular bearing areas. At four of the sites, with three different types of jackup rigs, all of the four methods provide more acceptable predictions after application of empirical rig-specific correction factors. The depths of spudcan cavities are examined using the methods presented in SNAME (2002) and recommendations in the Hossain et al. (2006) paper. The effects of spudcan cavity depth on the load-penetration behavior during preload and on the ultimate bearing capacity are discussed in this paper.

Introduction

Ten independent leg jackup rigs in the Gulf of Mexico either sustained severe damage or were completely lost during severe storms of the 2004 and 2005 hurricane seasons (Jack et al., 2007). These losses have been attributed to larger than anticipated storm waves, in some cases placing the jackup rig hulls within the wave zone, and ultimately overloading the foundation and/or structural components of the legs (Morandi, 2007).

The losses have prompted actions, to reduce the chances of future losses, and research to better understand and predict foundation behavior of independent leg jackup rigs. API RP 95J (2006) and the U.S. government Mineral Management Service (MMS) highly recommend that site-specific spudcan penetration assessments be performed and larger jackup rig hull-to-mean-sea-level air gaps be used during hurricane season. A comprehensive joint industry study of jackup rig spudcan