EVALUATION OF SOIL CONDITIONS TO PREDICT OFFSHORE FOUNDATION BEHAVIOR

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Overview

An accurate assessment of offshore soil conditions is required to make reasonable predictions regarding foundation behavior. Predictions of foundation behavior are required to safely and economically install independent leg jack-up rigs, driven pile piles, and suction caissons. Failure to predict foundation behavior can result in punch-through failures (rapid leg penetration) for jack-up rigs and refusal to reach final design penetration depths for piles and caissons. Foundation problems can be catastrophic for the projects, resulting in cost over-runs and pose safety issues for offshore personnel.

One of the first steps to evaluate conditions for an offshore structure is to perform a site investigation. Most offshore projects have geophysical, geotechnical and meteorological ocean (met ocean) investigations to assess potential geohazards, determine the soil conditions, and evaluate the environmental conditions. Usually geophysical data is collected to avoid hazards and select the location where the soil investigation and borings should be performed. Met ocean monitoring may be performed depending on the amount of information available for the location. Government regulatory agencies, insurance underwriters and the experience of the oil and gas companies usually dictate the complexity of these investigations. The collection and use of geophysical and geotechnical data is discussed in this presentation.

Geotechnical parameters are developed from laboratory tests performed on high-quality push soil samples and from in situ test data. Samples are obtained at closely spaced intervals to provide a high density of information. Laboratory tests performed on samples vary from simple hand held devices, such as Torvane and pocket penetrometer; to more complex tests including constant-rate of strain (CRS) consolidation and isotropically consolidated undrained static direct simple shear (CK_0UDSS) tests. The advanced tests are used to determine stress history and adjust for sample disturbance affects using SHANSEP (Ladd & Foott, 1974) and SPW (Quiros, et.al 2000) relationships. In situ test data is obtained from both downhole and mudline suspended piezocone penetrometer test and vane tools.

The laboratory and in situ test data are plotted on the log of boring and test results (borehole log) where the test data are graphically presented for interpretation. These data are used to investigate sample disturbance, determine trends, and assess soil properties. For cohesive soils, the shear strength and the submerged unit weight profiles are required to perform many engineering analyses. Examples of spudcan penetration (Case I) and pile installation (Case II) are presented to demonstrate that the soil conditions and properties can be accurately assessed.

Case I. Jack-up rigs or Mobile Offshore Drilling Units (MODUs) are movable platforms that travel to different location to drill oil and gas wells. Independent-leg jack-up rigs usually have three truss-type legs with foundations. The foundations are inverted cones called spudcans. To prepare to drill a well, a jack-up rig will move onto location, elevate the hull from the water, which applies a load from the rig lightship hull weight and variable deck loads that push the spudcans into the soil. To allow the foundation to withstand environmental (wind, wave and current) loads, seawater is pumped into tanks (preload) to reach a maximum load that provides a factor of safety against foundation failure, once the preload water is dumped. Bearing capacity methods recommended by the SNAME (2008) and ISO 19905-1 (2012) are used with the soil and spudcan properties to develop load penetration curves. These prediction curves are compared to measured values during installation to assess foundation behavior and provide a guide to help safely install the spudcans. An example of predicted and measured spudcan penetration records is presented in Figure 1.

Case II. The installation of platform jackets, installed in shallow water, typically consists of driving open-ended steel pipe piles through the jacket legs. The piles are battered and may be installed 100 to 500 ft below the seabed. The piles can range in size from 24- to 96-in.-diameter, dependent upon design loads. These piles are usually installed with diesel, air-steam, or hydraulically operated hammers. The soil properties are used to develop soil resistance to driving (SRD) curves (Stevens et. al., 1982) and assess soil-damping values. The SRD values, pile dimensions, and hammer properties are used to produce blow-count penetration curves using an iterative finite difference program, such as GRLWEAP (Goble & Rausche, 1986). Predicted and measured blow count data for a 24-in.-diameter caisson installed with a Delmag D-46 hammer are shown in Figure 2.

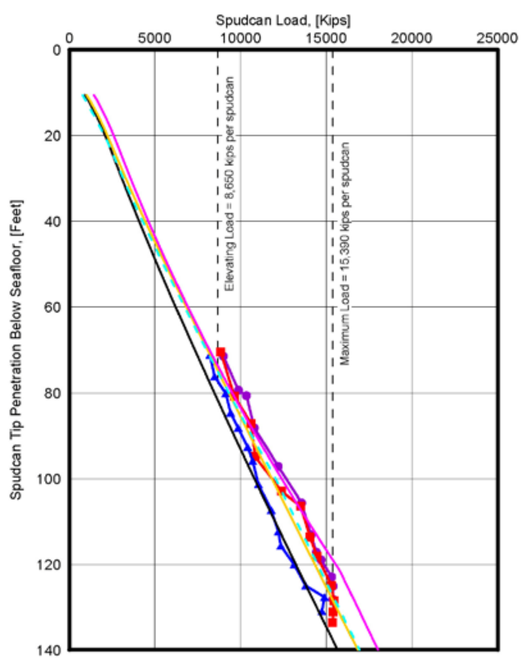

Figure 1. Predicted and Measured Load-Penetration Records Marathon LeTourneau Design, Class 116-C Jack-up Rig

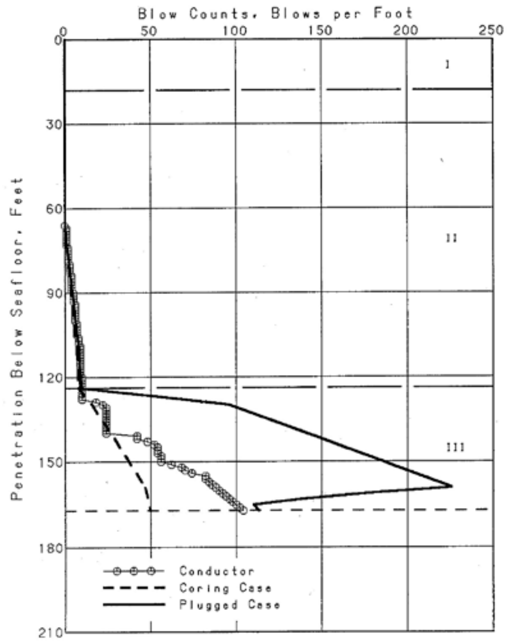

Figure 2. Predicted and Measured Blow Count Data
24-in.-Diameter Caisson, Delmag D-46 Hammer

The case histories of spudcan penetration and pile installation show very good correlation between predicted and measured data. A correlation of predicted and measured spudcan penetration and pile installation data requires accurate in situ soil properties and proven engineering methods. The good correlation between the predicted and measured values indicates that an accurate assessment of the in situ soil conditions was performed.

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