Soil Plug Effect on Driving Piles of Offshore Oil Platform

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ABSTRACT

Foundation piles of the offshore oil platforms in Bohai Bay are usually longer than 100m with a diameter larger than 2m. Driving such long and large size piles into the ground is a difficult task. It needs a comprehensive consideration of the pile dimensions, soil properties and the hammer energy. Thoughtful drivability analysis has to be performed in the design stage. It has been shown that to judge if the soil column inside the pile is fully plugged, which will make the pile behave as close-ended, strongly influences the accuracy of drivability analysis. Engineering practice repeatedly indicates that the currently widely used methods for soil plug judgment often give incorrect results, leading the designers to make a wrong decision. It has been found that this problem is caused by the ignorance of the bearing capacity provided by the soil surrounding the pile. Based on the Terzaghi’s bearing capacity calculation method for deep foundation, a new approach for judging soil plug status is put forward, in which the surcharge effect has been considered and the dynamic effect coefficient is included. This approach has been applied to some practical engineering projects successfully, which may give more reasonable results than the currently used method.

KEY WORDS: soil mechanics; static equilibrium theory; soil plug; pile drive ability; large diameter pile; Terzaghi’s theory; deep foundation.

GENERAL INTRODUCTION

It has been proved that using longer and larger diameter piles as the foundation of ocean platform are more economic. In Bohai Bay, the length of commonly used piles is more than 100m with a diameter of over 2m. Driving such long and large size piles into the ground is a difficult task. It needs a comprehensive consideration of the pile dimensions, soil properties and the hammer energy. Thoughtful drivability analysis has to be performed in the design stage, because of the high cost and time limitation for pile driving. When an open-ended pile is driven into the ground, a body of soil will crowd inside the pile to form a soil column (the plug). It has been shown that to judge if the soil column inside the pile is fully plugged, which will make the pile behaves as close-ended, strongly influences the accuracy of drivability analysis. If the pile is judged to be fully plugged, larger energy hammer has to be used or more blows are expected for driving the pile to a certain penetration, which will considerably increase the driving cost and the risk of damaging the pile body. The static equilibrium method (Randolph M.F., 1987, Tatsunori, 1991, Paikowsky, 1990) is usually adopted for judging the plugging status. Based on this method, as long as the bearing capacity at the tip of the pile is greater than the inside shaft friction force plus the weight of the plug, the plug keeps moving up into the pile during pile driving. Otherwise, the plug no longer moves into the pile, and the pile will act as a close-ended. Up to know, research work on judging the plug status is concentrated on the behavior of soil forming the plug and less attention is paid to estimate the bearing capacity at the tip of the pile. It has been found that with the larger size pile being used, the current plug status judgment method often gave too conservative results, which always suggest to use larger hammers to drive a pile (Dong, 2009).

According to soil mechanics, the bearing capacity at the tip of the pile is provided by three components, i.e., the soil unit weight, soil cohesion and the surcharge. For pile foundation, the surcharge is induced by the soil weight around the pile. The surcharge contribution is ignored in the API Codes (1993) in estimating the total bearing capacity of the pile in use. This is quite reasonable. Considering the platform has to be working in such severe environmental conditions, larger safety reservation should be given in design. But on the other hand, in the drivability analysis, the surcharge effect has to be considered in bearing capacity calculation for judging the soil plug status. Practice has proved that ignorance of surcharge effect on the bearing capacity will lead to wrong judgment of drivability (Dong, 2009). Therefore, in order to carry out reasonable drivability analysis, more precise method for calculating bearing capacity at the tip of the pile has to be involved. In this paper, the Terzaghi’s bearing capacity calculation method for deep foundation is applied in pile drivability analysis.

CURRENT METHOD FOR JUDGING THE STATUS OF THE SOIL PLUG

Mechanism of Soil Plugging

When open-ended piles are driven into the soil, a soil column is formed