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Use of PIV to Investigate Spudcan-Pile Interaction

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ABSTRACT

Centrifuge model tests have been conducted on half-cut model jack-up spudcans to investigate the soil flow mechanism and the free field soil movements at the location of adjacent piles during spudcan penetration in soft clay. From the high resolution photographs taken during spudcan penetration, the resulting soil movements were evaluated using Particle Image Velocimetry (PIV) technique. The measured induced responses of an adjacent free head pile were then correlated with the measured free field soil movements at the pile location.

KEY WORDS: Spudcan; pile; soil movement; PIV; image processing; bending moment; axial force.

INTRODUCTION

There is potential adverse interaction when a jack-up rig is installed close to the piles supporting the adjacent permanent jacket platform for the drilling of new wells or working over old wells. The penetration of the spudcan foundation of the jack-up rig may cause significant soil movements and hence induce high stresses to the piles nearby.

The effects of spudcan penetration on adjacent piles have been studied experimentally since 1990s (e.g. Siciliano et al., 1990; Craig, 1998; Xie et al., 2006; Leung et al., 2006b). These studies are mainly related to the induced pile responses, but the corresponding soil flow mechanism still remains unknown. The soil flow pattern surrounding the spudcan during spudcan penetration has been investigated in different types of soils, e.g. soft clay (Hossain et al., 2005) and dense sand (Teh et al., 2006). As these studies mainly concentrated on the bearing capacity aspect, the focus was on the soil flow surrounding the spudcan. The free field soil movement patterns at the location of adjacent piles have not been thoroughly investigated. This information is necessary in order to get a better understanding of the spudcan-pile interaction problem and also to facilitate the subsequent numerical analysis.

In view of this, centrifuge model tests with half-cut model spudcans have been carried out at the National University of Singapore (NUS) to evaluate the free field soil movements and investigate the corresponding soil movement patterns at the location of nearby piles.

EXPERIMENTAL MODELING AND PROCEDURE

Image Processing Technique

The image processing technique employed in the present study is the Particle Image Velocimetry (PIV), which was firstly employed in geotechnical research studies by White et al. (2002). This technique is able to monitor the soil deformation and quantify the soil movements, by tracking the texture of a particular patch within an image of soil through a series of sequential images. Since 2003, PIV has being successfully applied in the study of many geotechnical problems at NUS, e.g. excavation (Zhang, 2005), spudcan in soft clay (Purwana et al., 2006) and spudcan in dense sand (Teh et al., 2006).

Centrifuge Model Setup

All the centrifuge model tests were conducted at 100g. A photograph of the experimental setup is shown in Fig. 1. The dimensions of the stainless model container are 410 × 200 × 410 mm (length × width × height). The front of the container is made of transparent perspex to facilitate observations of soil flow. As shown in Fig. 2, the model spudcan made of aluminum has a diameter of 100 mm with an 11^o base angle and an 80^o conical tip, simulating a 10-m diameter prototype spudcan at 100g. The half-spudcan is fabricated by cutting a full-spudcan into two identical parts. Above the spudcan is the load cell, which is connected with the spudcan via a stainless rod, to measure the spudcan load during its penetration. The rod is weld slightly away from the centre of the full-spudcan so that only the half-spudcan is in contact with the plate of perspex. At around 500 mm away from the centre of the perspex, a JAI-A2 progressive scan camera with a maximum grabbing speed of 15 fps was installed to capture continuous images of the soil field during spudcan penetration. The process of the image capturing with desired speed can be remotely controlled through wireless mode outside the centrifuge.

For the test reported in this paper, the aim is to obtain the free field soil movement at the location of adjacent piles during spudcan penetration. Hence no pile was placed in the model setup. As the soil strains at the model container boundary were measured to be less than 0.1%, the container boundary effect is deemed to be insignificant.