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Time development of scour around pile groups in tidal currents

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ABSTRACT

Local scour around pile foundations is a major factor affecting the foundation stability in ocean engineering. A series of experiments has been conducted to study the time development of scour around pile groups under the unidirectional and tidal currents. 49 cylindrical model piles were arranged in a typical dumbbell-shaped configuration, and 20 micro-cameras as well as a 3D laser scanner were used to capture the local scour topography. In the unidirectional current test, the scour pit was spoon-shaped, and the maximum scour depth was located in the central part of upstream pile group. In the tidal tests, two similar shallow scour pits existed in the upstream and downstream pile group. During the initial stage of tide-induced local scour, the increase of scour depth was similar to that under unidirectional current. But, the repetitive scour and backfill process led to obvious fluctuations of scour depth, especially for the piles at the rear of upstream pile group and in the front of downstream pile group. It was found that the tidal cycle number had obvious effect on the scour depth development. The final scour depth after sufficient tidal cycles could reach up to 77.1% of the maximum scour depth under unidirectional current.

1. Introduction

Piles are commonly used as the foundations of marine structures, such as sea-crossing bridges and offshore platforms. In ocean environment, the stability of pile foundation is mainly threatened by the phenomenon of local scour. Local scour around a single pile, which is caused by the downflow in pile front along with horseshoe vortex shedding in the lee wake, has attracted numerous attentions in the last decades. For the pile group, the development of local scour becomes quite complicated. Sumer and Fredsøe (2002) pointed out that due to the flow interference between adjacent piles, the scour around pile group obviously differed from that occurring around a single pile. Exposed to continuous water flow, two kinds of scour will take place around the pile group: one is local scour around each individual pile, and the other is global scour around the whole pile group in the form of a bowl-shaped depression. To assess the effect of pile arrangements on the scour depth, some studies have been conducted by Hannah (1978), Breusers (1972), Salim and Jones (1996) and Sumer et al. (2005). Richardson and Davis (2001) modified the empirical formula for a single pile to predict the scour depth around pile group. The effects of other factors, such as pile diameter, spacing, submergence ratio, flow rate and skew-angle were studied by Ataie-Ashtiani and Beheshti (2006), Amini et al. (2012) and Lança et al. (2013). Successful application of GMDH (group method of data handing) has been introduced in the works of Najafzadeh and Barani (2011), Najafzadeh and Azamathulla (2013), Najafzadeh (2015) and Najafzadeh et al. (2016). It was found that GMDH showed more accurate prediction than traditional equations. Recently, Solaimani et al. (2017) studied the local scour around pile group by experimentally investigating the effect of the various pile spacing on the bed formation, area and volume of the scour pit.

Previous studies focused mainly on some simple pile arrangements (mostly in matrix configurations) and unidirectional current conditions. Moreover, some studies on local scour around a single pile under tidal current have been performed. Escarameia and May (1999) found that the scour depth under a square tide (velocity was equal and opposite for each half cycle) was smaller than that under unidirectional current due to the backfilling of the scour hole during flow reversals, which was opposite to the works by Jensen et al. (2006) and Margheritini et al. (2006), but supported by McGovern et al. (2014). Porter et al. (2014) conducted a series of experiments to investigate the scour characteristics around a circular pile under unidirectional current, a square tide and a spring-neap tide, respectively. It was found that the scour depth under a spring-neap tidal cycle was considerably less than that under the unidirectional current.

In fact, the pile foundations for the sea-crossing bridges are usually arranged in complex configurations (typically dumbbell-shaped), and the piles are often subjected to strong tidal currents in ocean

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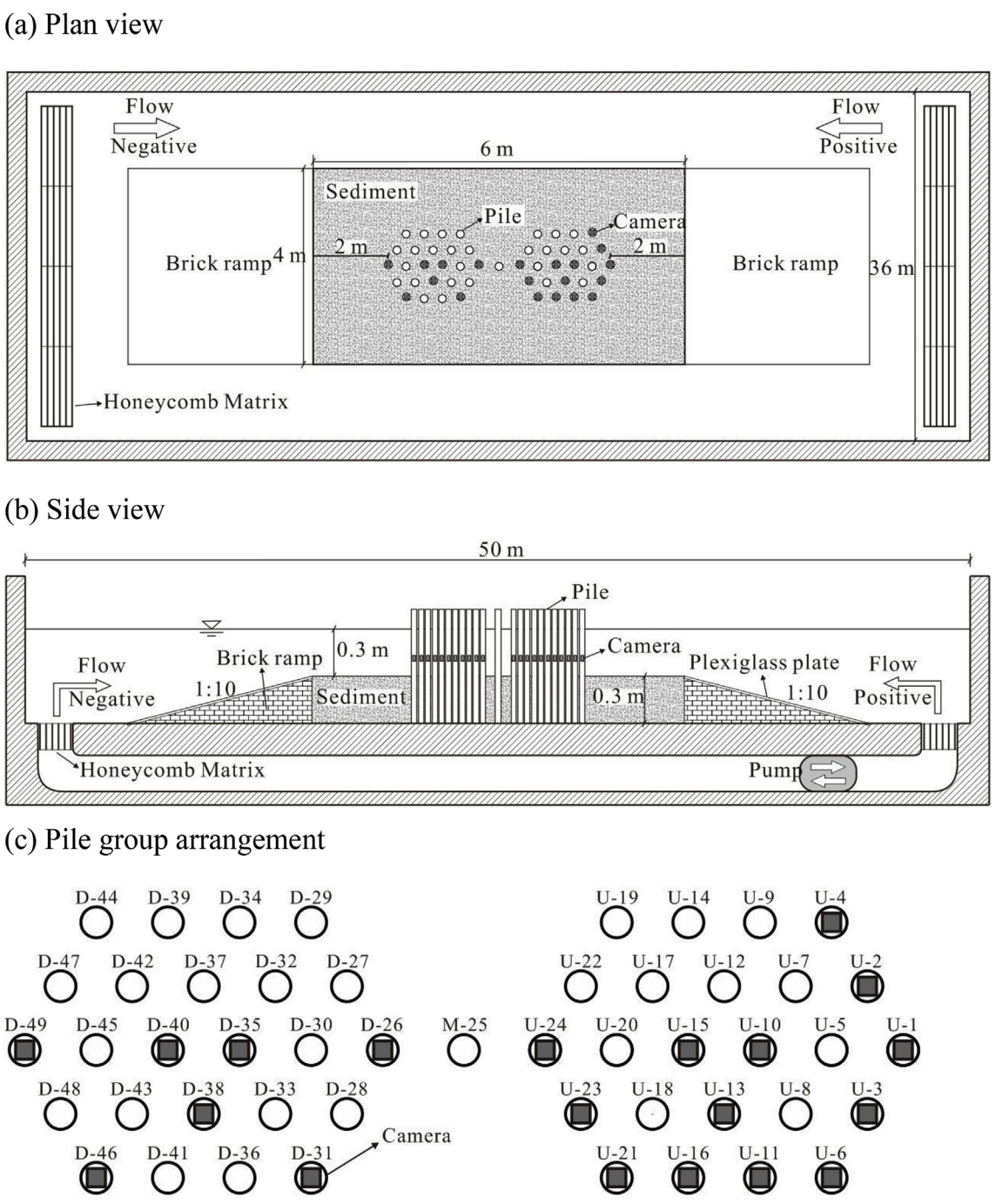

Fig. 1. Schematic diagram of experimental set-up.
(a) Plan view.
(b) Side view.
(c) Pile group arrangement.

environments. So far, the influences of complex configurations and tidal currents have not been well understood. The objective of this study is to provide an insight of the characteristics of local scour around a typical dumbbell-shaped pile group under unidirectional and tidal currents based on a series of experimental studies.

2. Laboratory tests

2.1. Experimental set-up

The experiments were conducted in a pool (50.0 m in length, 30.0 m in width and 1.0 m in height) at Zhejiang University. The pool is