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Technical note

A pilot test on a membraneless vacuum preloading method

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ABSTRACT

A membraneless vacuum preloading method is proposed in this paper for soft soil improvement. The method offers several advantages over the conventional vacuum preloading in which membrane is used to create the airtight condition and sand blanket layer to distribute vacuum. To assess the effectiveness of the proposed method, a pilot test was conducted at a land reclamation site in Tianjin, China. The ground settlement and the pore water pressure (PWP) at different elevations in soil were measured. After vacuum preloading, the average water content of the soft soils reduced by approximately 12% and the undrained shear strength increased twofold. The average degree of consolidation at the end of the vacuum preloading achieved 85.1% based on the settlement data and 84.5% based on the PWP data. The pilot test data have shown that the proposed method exhibits similar efficiencies to the conventional vacuum preloading method.

1. Introduction

Vacuum preloading is one of the common methods used for the improvement of engineering properties of soft soil (Holtan, 1965; Chu et al., 2000,2004, 2006, 2009; Wang et al., 2016; Bergado et al., 2002; Seah, 2006; Doyle and Qiu, 2016; Indraratna et al., 2011, 2015, 2016a, 2016b; Yan and Chu, 2005). The conventional vacuum preloading system consists prefabricated vertical drains (PVDs), horizontal pipes embedded in a layer of sand blanket, membranes, and vacuum pumps (Qian et al., 1992; Chu et al., 2000). The sand blanket acts as a drainage layer and distributes the vacuum pressure from the horizontal pipes to PVDs. The sand blanket also contributes to the formation of a working platform in soft clay soils (Chu et al., 2013). The membranes are used to seal the whole area to create an airtight condition. As only a limited size of membranes can be placed at one time, subsection of the site is required for a large land reclamation project. In this case, internal dikes may have to be used for partition and anchoring of membranes. Construction of the internal dikes on soft clay is expensive and time consuming. Furthermore, clean sand is required for the sand blanket and it may not be available. In this case, it will be desirable to have an alternative vacuum preloading method that does not required the use of sand blanket and membranes. When membranes are not used, internal dikes are not required either.

In the past, a similar approach to use clay slurry as the sealing layer for vacuum preloading was proposed, see Chu et al. (2008) for detail. However, this method can be affected by the formation of tension cracks in the clay layer due to desiccation effect. Once the cracks connect with the horizontal pipes or PVDs, the vacuum pressure will leak. It should be mentioned that there is another membraneless method to use airtight tubing system to connect PVDs directly with vacuum lines as presented by Bergado et al. (2002), Seah (2006), Chai et al. (2008) and Chu et al. (2008). However, the membraneless method proposed in this paper is different. The proposed method uses special couplings to connect vacuum pipes directly with PVDs so to remove the need for a sand blanket. It uses a layer of clay instead of membranes to cover the horizontal pipes. A similar method of using horizontal band drains (HBDs) to connect with PVDs loosely was also adopted in China in the past (Long et al., 2015). However, the vacuum pressure transmission was not effective in this case (Long et al., 2015).

In this paper, a membraneless vacuum preloading method is proposed in which the airtight condition is provided by a layer of

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clay slurry pumped on the top of the horizontal vacuum pipes. PVDs are connected directly to the horizontal vacuum pipes using special designed connectors to act in lieu of the sand blanket. To evaluate the performance of the proposed method, a pilot test was conducted at a land reclamation site in Tianjin, China. The ground settlement, the vacuum pressure in PVDs and the pore water pressure (PWP) in the soil were monitored during vacuum preloading. The average degree of consolidation (DOC) was calculated based on both settlement and PWP data.

2. Membraneless vacuum preloading system

The proposed membraneless vacuum preloading method is schematically shown in Fig. 1a. The horizontal vacuum pipes are placed in the middle of two-adjacent rows of PVDs. Each PVD is then connected to the horizontal vacuum pipes through a special couplings system in a way as shown in Fig. 1b. After connecting all the PVDs with the horizontal vacuum pipes, an approximately 1.0-m-thick clay slurry is placed by pumping to cover all the horizontal vacuum pipes. If the ground is too soft, one or two layers of light-weight nonwoven geotextile can be laid to form a working platform (Chu et al., 2013) for PVDs installation.

3. Pilot test

To access the efficiency of the proposed method, a pilot test was conducted at a land reclamation site in Tianjin, China. The pilot test area covers the northeast corner of a land reclamation project as shown in Fig. 2. Four sides of the diamond-shaped test area were of equal length of 40 *m*. The site investigations for the land reclamation site included borehole sampling and vane shear tests that were conducted before and after vacuum preloading. The field instruments included PWP transducers, surface settlement plates, and multi-level settlement gauges. The layout of the instruments and locations of the site investigation tests are shown in Fig. 2. Data were recorded at frequent intervals during the entire consolidation process.

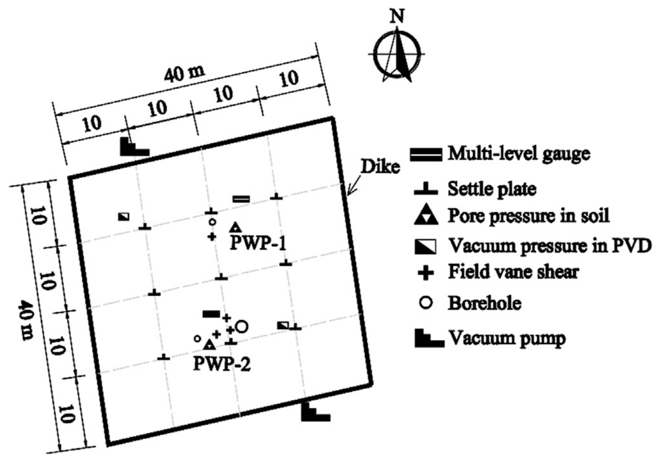

Fig. 2. Layout of field test and plan view of test instrumentations.

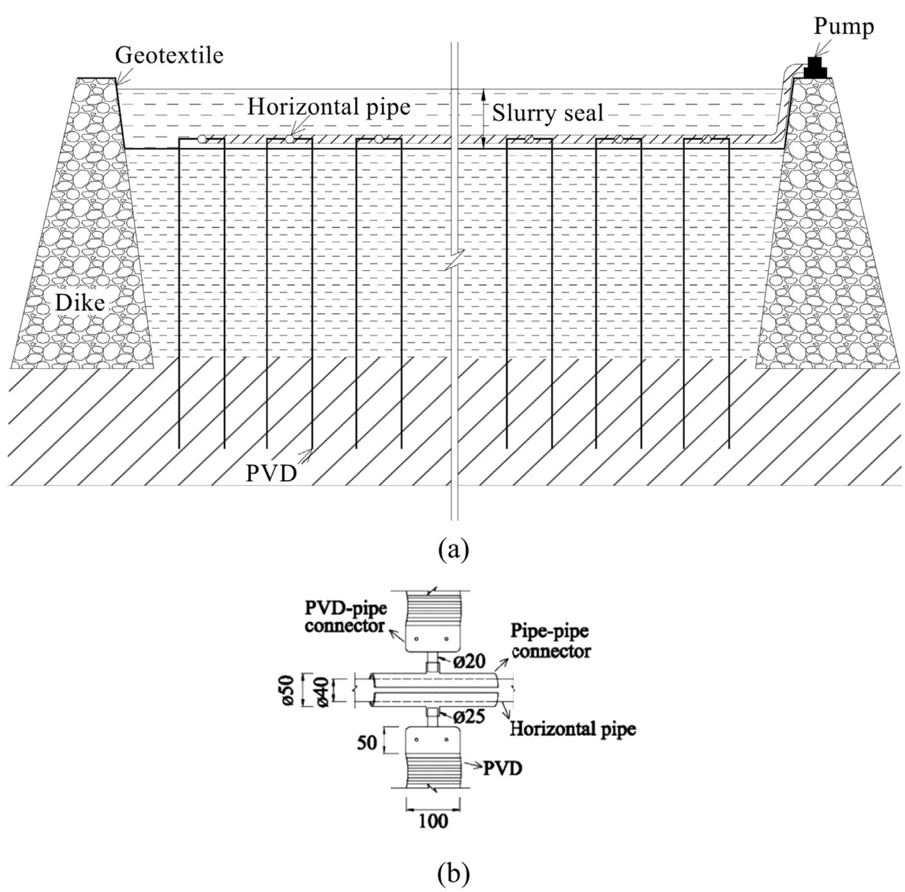

Fig. 1. Schematic arrangements of the proposed membraneless vacuum preloading method using slurry as sealing cap (a) the whole system and (b) the tubing connectors.