Geotextiles and Geomembranes 46 (2018) 575–585

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Preloading using fill surcharge and prefabricated vertical drains for an airport

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ARTICLE INFO

Keywords:
Geosynthetics
Surcharge preloading
Ground treatment
Runway
Consolidation
Field monitoring

ABSTRACT

This paper presents the field measurements and analysis of a preloading project with the installation of prefabricated vertical drains (PVDs) in Wenzhou, China. At the site, PVDs were installed to a depth of 22 m from the ground surface with a spacing of 1.5 m in a triangular pattern. The preloading fill thickness was 6 m with a unit weight of approximately 18 kN/m^3. After a total elapsed time of 310 days, approximately 3 m thick fill was removed. The measured preloading settlement was approximately 1.5 m. The measurements and analytical results indicated that the soil layer with PVD improvement reached almost 100% primary consolidation when part of the fill was removed. After partial unloading, the PVD-improved zone was in an over-consolidated state. After the runway was opened for traffic, a settlement increment of approximately 7 mm was monitored over a period of 11 months. Analysis indicated that the settlement was mainly due to the consolidation of soil layers below the PVD-improved zone and post-surcharge secondary consolidation of the PVD-improved zone. The values of the parameters related to PVD improvement were back-estimated from the field measurements. These findings can be used to guide the design of PVDs improvement along the east coast of China.

1. Introduction

Along the southeast coast of China, thick soft clayey soil layers are widely deposited. These soft soils have high compressibility, high water content, and low strength. Normally, ground improvement is required for the construction of infrastructure, such as highways and airports. Methods of ground improvement generally include replacement, dynamic compaction, surcharge preloading, impact-rolling, and compaction piles. Innovative methods have also been explored to deal with this problem (Cai et al., 2017, 2018; Deng and Zhou, 2016a, b; Fu et al., 2017; Geng et al., 2011, 2012; Indraratna et al., 2010, 2012; Jeyakanthan et al., 2011; Karunaratne, 2011; Mesri and Khan, 2012; Sun et al., 2017; Wang et al., 2016a, 2016b, 2017, 2018). Among these methods, surcharge preloading with prefabricated vertical drain (PVD) improvement is a mature technique that has been shown to be economical and effective (Artidteang et al., 2011; Abuel-Naga et al., 2015; Cascone and Biondi, 2013; Jang and Chung, 2014; Lu et al., 2015; Saowapakpiboon et al., 2011; Zhou and Chai, 2016; Xu and Chai, 2014). Preloading a soft deposit with an effective stress higher than the design load of the superstructure and/or operating load can result in an over-consolidated foundation; this can reduce the amount of deformation induced by the operation load and secondary consolidation (Bo et al., 2007). This method has been widely used in airport construction projects (Bergado et al., 2002; Lam et al., 2015; Morohoshi et al., 2010; Saowapakpiboon et al., 2010; Voottipruex et al., 2014).

To meet the demand of increased traffic, a second runway project was constructed at Wenzhou Longwan International Airport with a flight grade of 4E according to the Chinese airport grade system (i.e. can accommodate a Boeing 747 and Airbus 340). The runway is 3200 m long and 60 m wide. Fig. 1 shows a plan view of the second runway. At the site, the original elevation was lower than the design elevation of the runway. Consequently, a large embankment needed to be construction. In this situation, the embankment construction was combined with surcharge preloading.

This paper presents the results of the surcharge preloading project for the second runway construction at Wenzhou International Airport as

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https://doi.org/10.1016/j.geotexmem.2018.04.013
Received 6 September 2017; Received in revised form 13 April 2018; Accepted 15 April 2018
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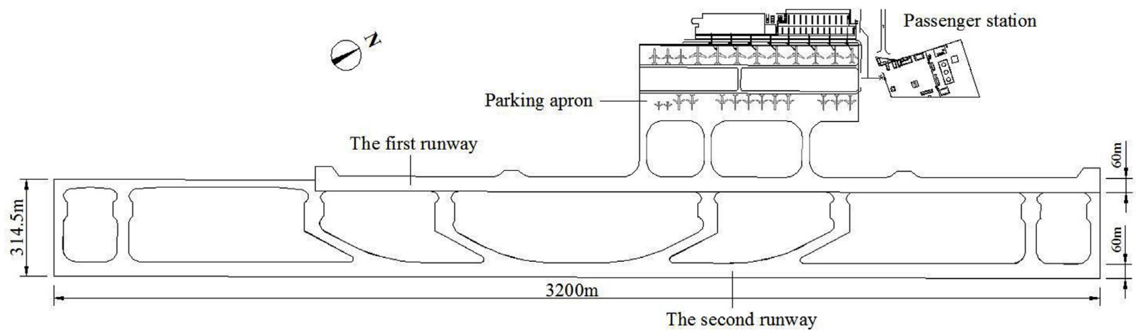

Fig. 1. Plan view of the second runway.

a case study. The settlement during the runway operation was also investigated. The site conditions, ground treatment scheme, and field instruments used are presented first. Then the field monitored data are presented and analysed. The effectiveness of PVD improvement on the Wenzhou clay deposit and a method for deciding design parameters related to PVD-induced consolidation are presented by comparing the measured and calculated settlements.

2. Site conditions

Wenzhou Longwan International Airport is located east of Wenzhou City on the coast of the East China Sea. The elevation of the site ranges from 2.8 m to 3.7 m. At the site, alternating soil layers of clay, mucky silt clay, mud, muddy silt, silty clay, etc. are deposited with a total thickness of more than 50 m. Fig. 2 shows a typical soil profile with some engineering properties. The groundwater level was almost at the ground surface. The natural water content was 40%–60% and slightly higher than the corresponding liquid limit. C_c was approximately 0.2–0.5. The compression index (C_c) for the top 3-m-thick soil layer was back-evaluated by using the measured compressions of the corresponding soil layer. For the coefficient of consolidation c_v and permeability k_v in the vertical direction, the values plotted in Fig. 2 are for a stress range from the initial vertical effective stress σ'_{v0} in the ground to σ'_{v0} + 100 kPa.

3. PVD installation and loading process

3.1. PVD installation

The PVDs used in this project had a cross-section of approximately 100 mm × 5 mm. PVDs were installed in an equilateral triangle pattern with a spacing of 1.5 m to a depth of 22 m from the ground surface. The mandrel used for installing the PVDs was a tube with an outside diameter of 127 mm and inner diameter of 110 mm, and the anchor shoes were discs with a diameter of approximately 127 mm.

3.2. Load scheme

The second runway project was designed for the operation of mostly used Boeing 737–800, consequently, a relevant work load used for the design was 41 kPa based on Zhao et al.'s (2011) simplified methods for calculating aircraft load. For design the total preloading fill height, two factors were considered. The first one is that the removed surcharge load should be larger than the designing work load of 41 kPa, and second is the resulting elevation of the runway should be about 4.5 m (design elevation). With an estimated preloading settlement of about 1.5 m and the two factors considered, a total fill thickness of 6.0 m and removal fill thickness of 3.0 m were design.

To ensure the factor of safety against slip circle failure to be larger

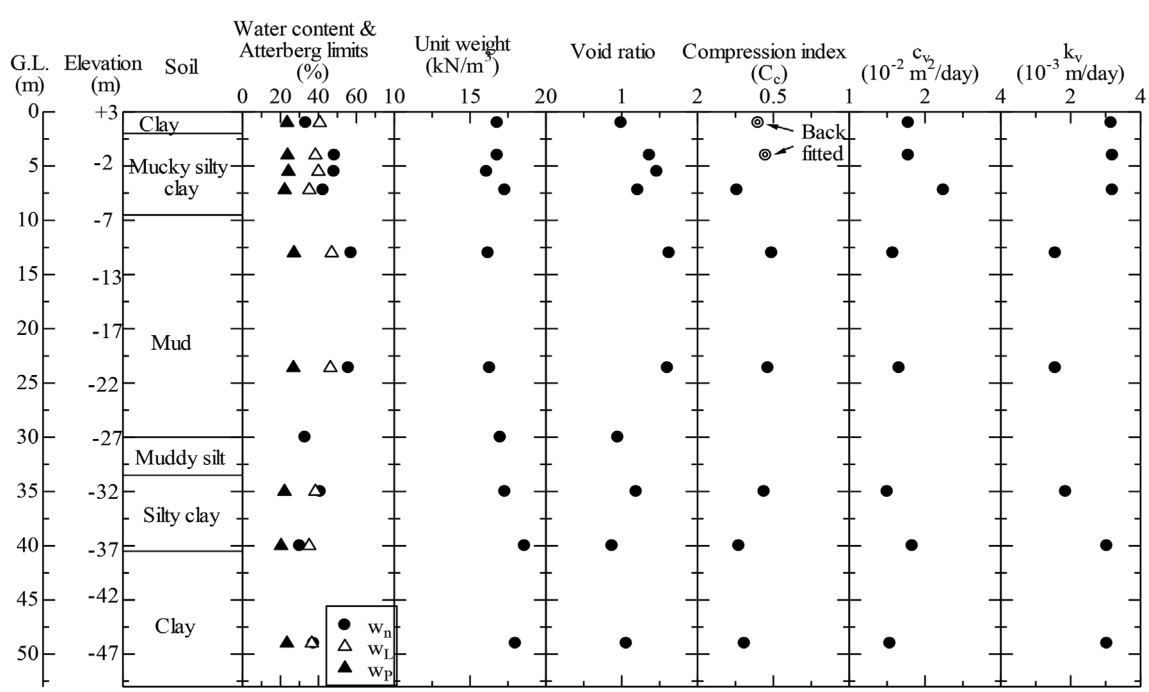

Fig. 2. Typical soil profile and some engineering properties.