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Settlement of residential houses supported by piled foundation embedded in expansive soil

Gogot Setyo Budi[a,*]

[a]*Civil Engineering Department, Petra Christian University, Surabaya 60236, Indonesia*

Abstract

The damage has occurred on residential houses built on expansive soils. The weight of the walls and roof of the houses is transferred onto pile foundations through suspended tie beams and columns, respectively. The typical pile used to support the house was 30 cm in diameter and it was penetrated into the depth of 600 cm. The slabs or floors were rested on the fills. This study was conducted to determine all potential sources that initiated the settlement and damages to the houses. Site investigation to each and every houses that experienced settlement and damages was conducted to gather and inventory the pattern of the cracks or damages. The result of site investigation showed that there were no damages induced by swelling, but the settlements and cracks were triggered by settlement, instead. It was also noticed that the settlement of piled foundations located on the area that susceptible to the water infiltration relatively larger than those piled foundation in the covered area. Therefore, it was concluded that, based on the analysis, the damages which occurred on the residential ordinary houses were mainly caused by the settlement of the piled foundations and the fills due to the soil softening.

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Keywords: expansive soils; settlement; crack; soil softening; residential houses.

1. Introduction

The demand of housing in urban area has been increasing in the last few decades. Accordingly, it requires large area of land for residentials and infrastructures. Several Real estates in Surabaya, the second largest city in Indonesia, have been expanding to the areas that consist of expansive soil formation.

The ordinary low rise housing, which is built on expansive soils require better and more comprehensive design

* Corresponding author. Tel.: +62-31-2983397; fax: +62-31-2983392.
E-mail address: gogot@petra.ac.id

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due to its swell and shrink behavior. The expansive soil will swell when contact with water, and shrink when lose its moisture content. Due to seasonal climate change, the moisture content of soil at the upper layer changes. The depth of expansive soil to which its moisture content changes periodically by the seasonal climate change, is called active zone [1]. Based on the soil investigation in Surabaya – Indonesia reported by Testana Engineering, the thickness of active zone is about 5 m [2]. When the weight of a structure rested on the active zone is less than the swelling pressure of soil, the structure will heave and may experience differential deformation.

The consistency of expansive soil will soften when its moisture content increases and harden with losing its water content. In their research focusing on expansive soil in Surabaya – Indonesia, Tjandra et al. [3] stated that the seasonal wetting and drying cycles affects the undrained shear strength of soils, and furthermore it has an impact to the friction capacity and adhesion factor of pile foundation.

2. Wetting behavior of unsaturated soils

The wetting-induced softening behavior of the unsaturated expansive clay is crucial to understanding the rain-induced settlement of foundation and progressive slope failure in unsaturated of expansive soils.

Zhan et al. [4] investigated the softening characteristics of unsaturated recompacted and natural soils using suction-controlled triaxial tests. It was found that the wetting process for recompacted specimen generally showed ductile failure, while for the natural specimens exhibited a brittle failure similar to a heavily over consolidated soils, which is caused by the cementation effect of iron and manganese oxides. It was also stated that dilative behavior developed only for the natural specimen during wetting process. Ye et al. [5] identified that the magnitude of shear dilation of the unsaturated specimen depends on the confining pressure or suction, i.e. the dilation decreases with the increase of confining pressure and suction. It is also mentioned that, in low suction state, the cohesion of the specimen increases linearly with the applied suction.

Upon wetting, the failure of soil specimen was indicated by development of rapid shear strain in soil when the suction was reduced to certain threshold value. Along the wetting path, an increase in degree of saturation is related to the decreasing suction is associated with the flooding of soil voids with water. As a result, the normal forces at interparticle contacts decrease, thereby reducing the overall stability of soil skeleton. From the macroscopic viewpoint, both yield stress and shear strength of the soil specimen decrease Wheleer et al. [6].

According to Melinda et al. [7], at the beginning of the infiltration process, the soil deformation was small but matric suction decreased rapidly. When failure approaches, soil deformation increases sharply.

3. Typical ordinary houses

The typical low rise houses, which were studied, consisted of brick walls confined by reinforced concrete columns and beams. The weight of the walls was transferred onto pile foundations through suspended beam, which was supported by the piles. The floor was laid on the approximately 80 cm thick fill material. The schematic of cross section of the house is presented on Fig. 1. Typical diameter of pile foundation was 30 cm in diameter and it was penetrated into the depth of 600 cm (Fig. 2).

4. Soil data

Soil profile of the housing area is presented on Fig. 3. The soil formation is dominated by unsaturated clay layer. Based on the soil investigation report conducted by Testana Engineering, the existing soil layer consists of expansive soil with the active zone of 5 m (Fig. 4). The properties of soil is presented in Table 1.

Table 1. Soil Properties

Depth (m)	Classification	Wc (%)	Gs	γt (t/m^3)	Deg. of saturation S (%)	e_o	LL	PL	Cohesion (kg/cm^2)
2.5 – 3.0	CH	35	2.60	1.63	79	1.15	76	24	0.24
6.5 – 7.0	CH	32	2.60	1.68	80	1.04	87	26	0.55
10.5 – 11.0	CH	29	2.56	1.74	83	0.90	82	25	0.76
16.5 – 17.0	CH	30	2.60	1.74	83	0.94	66	23	0.78