Geotechnical failures due to excavation in consolidating soft soils deposit

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ABSTRACT

In most cases, the design of excavation does not consider existing excess pore pressure in consolidating soil. Nevertheless, the movements of the retaining structure and its stability are significantly influenced by the excess pore pressure. This paper presents a case history of geotechnical failures due to excavation in consolidating soft soils deposit. The retaining wall system was contiguous bored pile with three levels of ground anchors as the support. The excavation depth was 18.0 m, but it failed when the excavation reached about 12.0 below the ground surface. The destruction area is about 50 m wide along a section of the four-lane road, causing terrible traffic in the area.

Keywords: Failure; Excavation; Consolidating Soil

1 INTRODUCTION

In past decades, several major excavation failures were reported in the literature, such as Nicoll Highway excavation in Singapore (Whittle and Davis, 2006), two cases of excavation failure in Taipei (Do et al, 2013), and a case of excessive deformations induced by excavation in Jakarta (Lim, 2018). The failure of excavations definitely would cause major economic losses and sometimes, casualties have also been reported. The objective of this article is to present a case history of geotechnical failures due to excavation in consolidating soft soils deposit, where it rarely occurred or been reported.

2 RESIDUAL EXCESS PORE PRESSURE IN CONSOLIDATING SOILS

As widely known, clay soil could be distinguished between Normally Consolidated (NC) Clay and Overly Consolidated (OC) Clay. Nowadays, some researchers also found that the soil was under consolidating. Mostly, the under consolidating soil was found in the bay and/or reclaimed area, such as the Osaka Bay (Tanaka and Sakagami 1989), the Craney Island reclaimed area (Karakouzian et al. 2003), the North Jakarta (Setionegoro 2013; Cox 1970), and the Gwangyang Bay (Lim et al. 2014). According to Rahardjo (2008), the under consolidating soils is the existence of residual pore pressure in the soil layer which could be detected by Piezocone test (CPTu). In this method, the dissipation test is extrapolated using hyperbolic curves and then the result will be U_f or final pore pressure at a time equal to infinity. In Normally Consolidated soil, U_f will be equal to hydrostatic pressure (U_0). But, If Uf is higher than U0, it means that the difference (U_f-U_0) is the residual excess pore pressure. Near the study area, the measured pore pressure (U2) consists of the hydrostatic pore pressure and the excess pore pressure, as shown in Fig 1. As for the under consolidating clay, the excess pore pressure consists of the excess pore pressure caused by the cone penetration and the residual excess pore pressure. It should be noted that, for the normally consolidate soils, the residual excess pore pressure is zero.

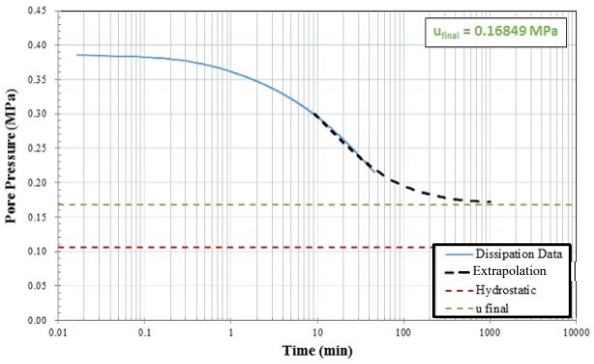
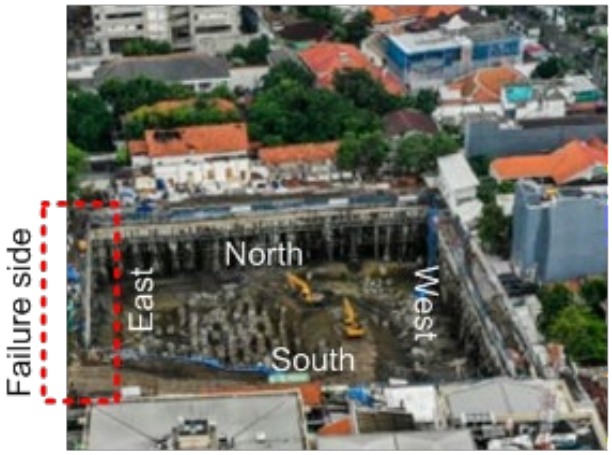


Fig. 1. The result of the dissipation test result of under consolidating the soil

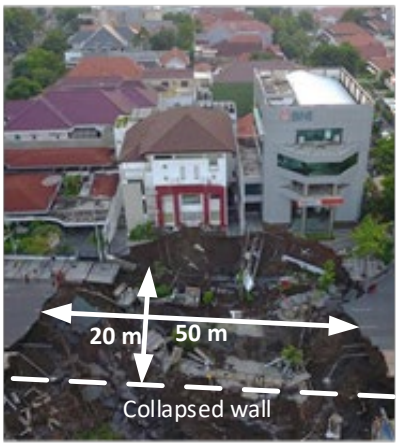
3 PROJECT DESCRIPTION

The project is the development of mixed-use high-rise buildings consisting of one tower 22-story with three levels of basement. The excavation project was located in Surabaya, the capital city of East Java and it was surrounded by Gubeng road at East, and some low to medium-rise buildings (Fig 2(a)). Fig 2(a) depicts the aerial photo before the failure occurred. The photo was taken two days before the failure. The failure happened around 9 pm on December 18, 2018. Before the failure, in the afternoon, water was leak out from some holes of ground anchors. The water could not be stopped. At that time, the progress of excavation was

around -12 m. After the failure occurred (see Fig 2(b)), it destroyed about 50 meters along a section of Gubeng road, causing terrible traffic in the area. Also, a commercial store and a Bank are close because the access road to those buildings was collapsed.



(a). Before failures



(b). After failures

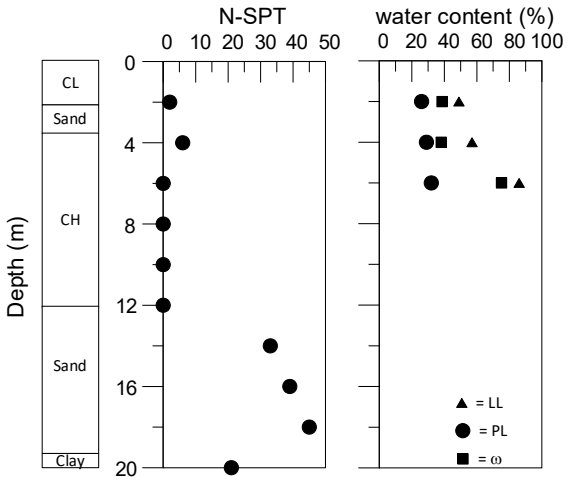
Fig. 2. Photo of the excavation site

4 SOIL CONDITION AND EXCAVATION PLANNING

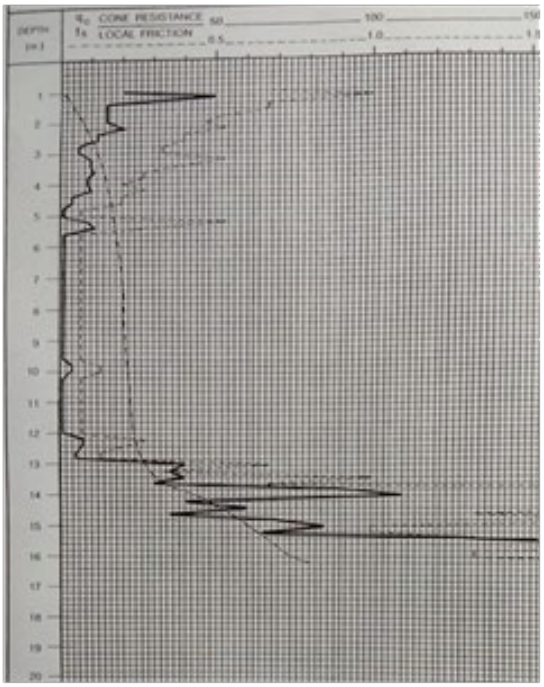
The excavation site mainly comprises of soft clay and sand layers. The in situ testing data was shown in Fig 3. The groundwater level observed during boring was located about -1.5 m below the ground surface. The soft clay with N-SPT = 0 was found from -4 m to -12 m. The data was consistent with the CPT data result (Fig 3b). The excavation depth was -18.0 m. For the protection of the excavation, two types of contiguous bored piles were used, and they are listed in Table 1. The and it was supported by contiguous bored pile combined (L= 32 m) with three levels of ground anchor. The illustration of the overall retaining wall system is shown in Fig 4. The length of ground anchors are varied from 28 to 35 m, and they were penetrated into the neighborhood area.

Table 1. The type of contiguous bored pile

Type	Bored Pile Dimension	Ground Anchors
I	Diameter 0.8 m, spacing 1.2 m (center-to-center), L=22 m	3 layers, spacing 2.4 m (center-to-center)
II	Diameter 0.8 m, spacing 1.2 m (center-to-center), L=32 m	3 layers, spacing 3.6 m (center-to-center)



(a).The N-value and Atterberg limit of the project



(b).The CPT reading

Fig 3. The result of in-situ testing

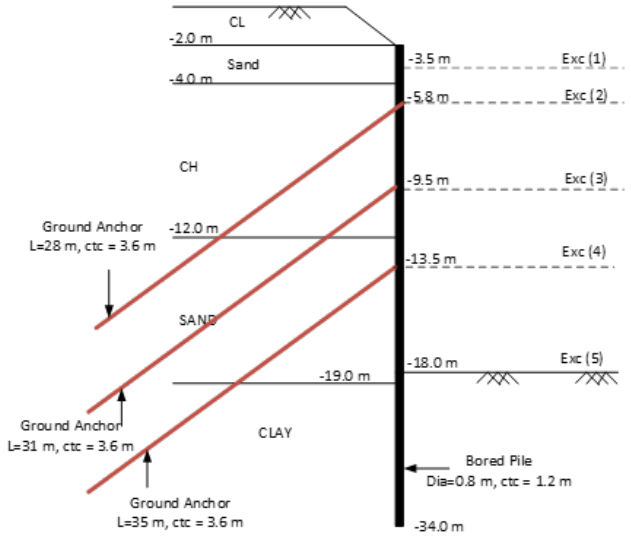


Fig 4. The excavation profile and soil stratification

4 MEASURED DATA

The data measured including piezometer, inclinometers, and settlement markers. Fig 5. shows the elevation of the water table at the dewatering well and at a specific location. The difference of water table is an important factor in the stability of the retaining structures.

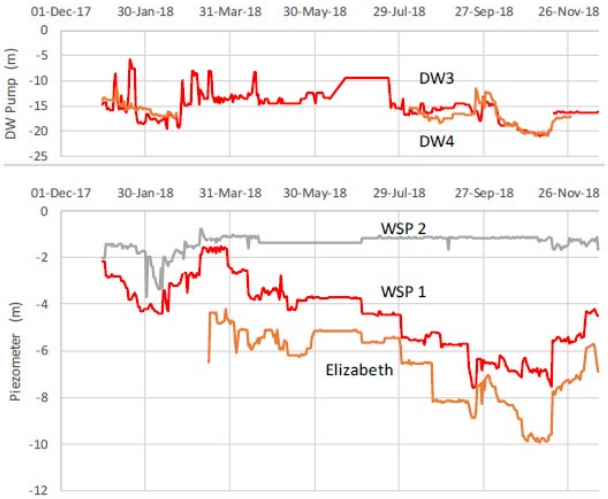


Fig 5. The monitoring of groundwater level

Fig 6 shows the record of inclinometer at the nearest section to the failure wall. The latest reading was taken about 4 months before the failure occurred. As shown in Fig 4, the maximum wall displacement was around 200 mm. This movement was considered very large. If the excavation depth was about 6 m at that time, then the δ_{hmax}/H_e=3.33%. According to Indonesian Geotechnical Code, the maximum movement of the wall should be limited on 0.5%. Hence, the large movement was one indication that the retaining wall system has a problem from the beginning of construction.

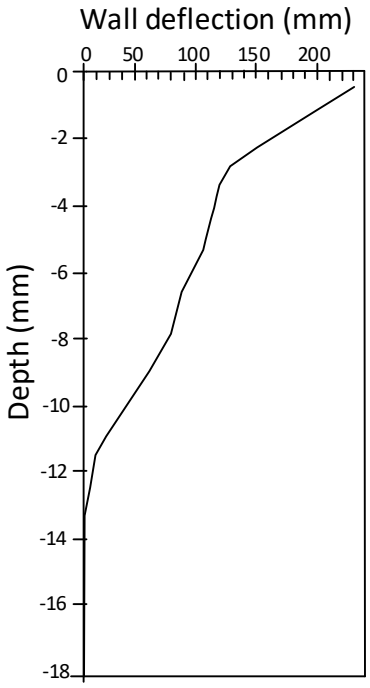


Fig 6. The reading of inclinometer at 4 months before failure

Other data that is of main concern is the settlement of the pedestrian adjacent to the project as shown in Fig 7. The maximum ground settlement is about 90 mm before the accident occurred.

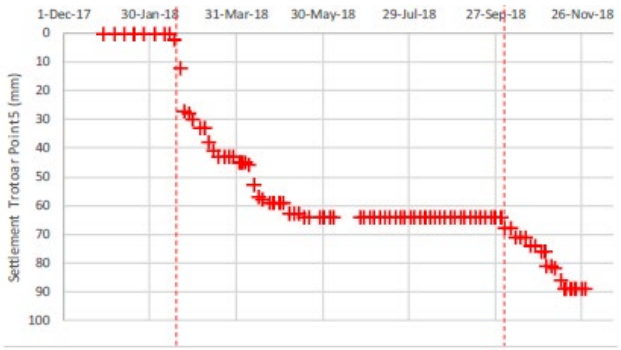


Fig 7. The ground settlement measurement data

5 DISCUSSIONS

Based on the previous data, the excavation has been done in consolidating soft soil where excess pore pressure is still high. This uncovered excess pore pressure may be the cause of the failure. The seepage has occurred continuously bringing soil particles and causing internal erosions of the soils, which further loosening the anchor.

The under consolidation is a serious matter. The evidence commonly not realized by most engineers. A method based on CPTu data can lead to the conclusion that excess pore pressure still exists.

6 CONCLUSIONS AND SUMMARY

1. The excavation in soft soils is a common problem, however, the residual excess pore pressure is seldom detected. Subsequently, if samples were taken for laboratory tests, the excess pore pressure will disappear.

2. Extra measurement or monitoring the excavation is very important. Consequently, deformation will be higher and failure may occur in a sudden manner

3. The use of CPTu to detect consolidating soil layer is very effective.

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