The Investigations to Improvement performance of Non-displacement pile at Southern part of Bandung area

Agus Sulaeman, Muhamad Agung* and Regi Fasya Septrian

Civil Engineering Study Program, Fakultas sains dan Teknik, Universitas Faletehan, Serang, Indonesia

*muhamadagunghermawanputra@gmail.com

Abstract. In an ordinary theory mentioning that Bored pile type is non-displacement pile instead of driven pile as displacement type. To change the bored pile become displacement type, need an effort to displace surrounding soil in the vicinity of bored pile, the compaction of concrete during installation is one of the solution. During compaction, the soil displaced and excess pore water pressure increase, then by allowing pore water pressure to dissipate, the ground improvement is happening. The modelling of pile loading test (PLT) were carried out in various w/c ratio in ambient condition on first liquidity index (LI_1), LI_2 and LI_3 , The direct shear test (DST) of clay soil (at LI_1 , LI_2 and LI_3) and at combination of clay + cement mortar at various w/c ratio were also carried out to encourage and endorse the simulation work. The ground improvement occurs as a results of : 1. Chemical reaction between cement and clay, 2. Enlargement of slip surface diameter at the interface between soil – soil cement mix hardened, 3. Increasing effective stress as an effect of allowing pore water pressure dissipation after compaction. This stabilization produce increasing strength properties up to 75 % at the optimum w/c ratio 0,4. Based on this findings, it recommends to include the ground improvement effect to bored pile foundation.

1. Introduction

Bandung city is underlain by soft ground deposit, the type of deposit is caused by its geological history and the fact that Bandung clay is a lake deposit. The Bandung city is surrounded by a number of volcanic ridges with some volcanoes which are still in the active condition, also present. The materials comprising soft clay have resulted from eruptions of Tangkuban Perahu, situated some 25 km to the north of the city (van Bemmelen, 1949). Bandung soft clay is a freshwater deposit which is formed in a Quartemary-period lake. The sedimentary deposit it came from the surrounding volcanic andesits [11,12].

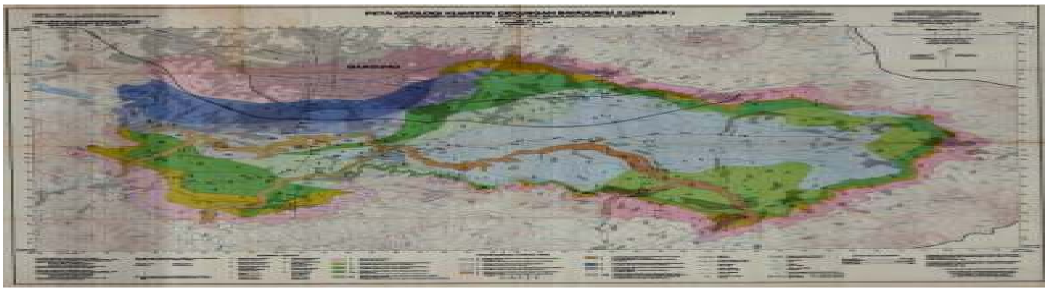

Figure 1. Geological map of Bandung

Figure 1 shows the geological map of the Bandung plain (Directorate of Environmental Geology Bandung). Based on the geological map the area of studies is a flood plain deposit (F) over lake deposit (Lp/L). The lake deposit can be classified as Lacustrine Deposits. Most clay soil found in this area have the characteristic as shown in Figure 2, majority high plasticity of either clay or silt. In the practice of ground improvement, ground improvement to clay soil is satisfied by chemical method or hydraulic modification method. The phenomena of improvement inside the bored pile in clay soil is very rare to discuss [11].

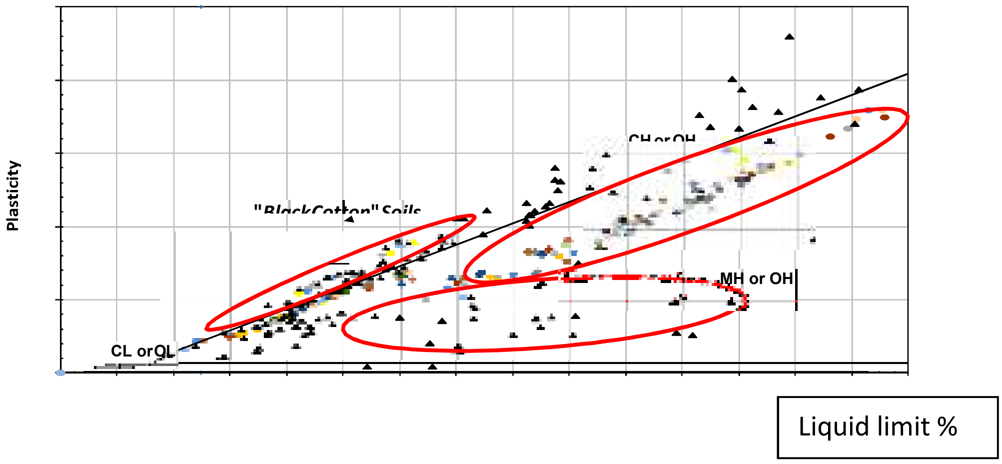

Figure 2. Plasticity condition of clay in Bandung

1.1 Background:

Current practice of bored pile technology, in calculation bearing capacity either in clay or sand, doesn't include ground improvement effect. Plasticity of soil, w/c of concrete and compaction effect are not considered.

1.2 Problem Statement:

How to impart ground improvement effect into Bored pile and what elements in construction of bored pile to trigger ground improvement effect?

1.3 Scope:

The research is in laboratorium basis focused on bored pile in clay at southern part of Bandung area.

1.4 Objectives:

The objectives to do this research are:

- To determine engineering properties of Bandung clay soil
- To determine optimum w/c ratio which provides maximum Bored pile capacity in model simulation basis
- To simulate the failure condition in Direct shear test in the area of soil cement interface.
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1.5 The aim:

The aim of this research is to investigate the optimum water cement ratio in the installation of bored pile in clay soil in various Liquidity Index, which provide maximum capacity.

2. Literature

In an ordinary bored pile design, the effect of ground improvement is neglected for the sake of high safetyness. However, there is possibility to include ground improvement effect both in sand or clay soil. The grouted pile or compacted pile or other method which can displace original soil are among the method to get improvement [3]. The following are some consideration:

2.1 Ultimate Pile capacity

The ultimate capacity Q_u of bored pile can be described in eq 1,

$$Q_u = Q_p + Q_f \quad (1)$$

where, Q_p and Q_f are Point capacity and friction resistance respectively. The term Q_p consists of Ap 9 Cu and p L α Cu for friction capacity as in eq (2).

$$Q_u = Ap\ 9\ Cu + p\ L\ \alpha\ Cu \quad (2)$$

The term **α Cu** is unit friction resistance q_f, Cu is undrained shear strength and α is adhesion factor. According to many references, the value of adhesion factor, α normally in the range of 0.3 to 0.8 to original sub-soil of undrained shear strength [7].

2.2 Effort of soil improvement

Due to small shear strength, the pile capacity in this area without improvement is small and pile length should penetrate to reach rock or hard layer. To gain a benefit in construction of deep pile foundation, the pile should contribute to increasing properties as stabilization of soil surrounding pile.

In an ordinary theory mentioning that Bored pile type is non-displacement pile instead of driven pile as displacement type. To change the bored pile become displacement type, it needs an effort to displace surrounding soil in the vicinity of bored pile, the compaction of concrete during installation is one of the solution. During compaction, the soil displaced and excess pore water pressure increase, then by allowing pore water pressure to dissipate, the ground improvement is happening.

By the improvement, the impact of those improved sub-soil can be as high as two fold to original shear strength even some reported higher. The improvement of properties Su after grouting pile can be in the range of 2 fold of Su before grouting [6].

2.3 Mechanism of improvement inside bored pile installation

Installation of displacement types of pile by driving or by compaction on concrete, causes stress changes in the surrounding soil. The properties will decrease in surrounding soil, recover, and increase after pile column installation. The mechanisms of ground improvement methods involving large lateral soil displacements are similar to that of a laterally expanded cavity in soil [6]. The installation of this type of compaction pile will result in a large radial displacement in the surrounding soil and non-uniformly distributed excess pore water pressure, pwp inside the soil also. If sufficient time is allowed for the excess pore water pressure to dissipate, effective stress increase continued with shear strength increase in the surrounding soil is expected. This in turn affects the contribution to increase in-situ clay to the overall undrained shear strength of ground improvement piles reinforced clay [4,7,10].

2.4 Moisture migration

Majority the causes of improvement in this category closely related with moisture migration, Since either concrete or grouted concrete made of cast-in-place concrete, a certain amount of water will migrate into the surrounding soil from the fresh concrete. The amount of water that migrates between concrete and soil is not well known. Meyerhof and Murdock and Skempton , who studied bored piles in London Clay, concluded that the water migrated from fresh concrete into the surrounding soil to a distance of 2-1/2 to 3 inches. Meyerhof found that the water migration caused the clay next to the pile wall to have a moisture content from 6 to 7 percent higher than the original moisture content for London Clay. Skempton found further that the increase of water content in the soil surrounding the shaft caused a decrease in the soil strength along the shaft surface [2].

2.5 Effect of w/c ratio

Cement mortar is formed by certain amount of sand and cement milk, cement milk is formed by pouring water into cement powder with certain ratio of water over cement. Water – cement ratio is the one to contribute in moisture migration, it is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers [8,9].

For a soil with pores larger than cement particles, both cement and water will penetrate into the soil. The cement that penetrates into the soil will form a layer of cement soil at the interface, which will increase the shearing strength of the soil. For soil such as clay, with pores smaller than the cement particles, there will be only water migration (no cement penetration) with a consequent decrease in shear strength [2].

2.6 Chemical reaction between soil with cement mortar

Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.35 pounds (or 0.35 kg or corresponding unit) of water is needed to fully complete hydration reactions. However, a mix with a ratio of 0.35 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than is technically necessary to react with cement. Water–cement ratios of 0.40 to 0.60 are more typically used. For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flow-ability [9].

Based on the review of the literature, to find solution on the problem statement, the aim of this study is to investigate the optimum water cement ratio in the installation of bored pile in clay soil in various Liquidity Index, LI (different water content) after compaction by hammer blow which is simulated in small scale drum lab. model as shown in Figure 3.

3. Methodology

The main activity of this research are:

Preparing drum model for simulation works, Simulation of pile loading tests to bored pile and direct shear test to simulate slip failure on the interface between clay soil and hardened cement-soil mix.

First steps:

1). Obtaining the parameter of original clay
2). Preparing clay in LI-1 (Pouring in some water to original soil)
3). Installation of 8 bored pile models under 2 nos. of w/c-1; 2 nos. of w/c-2 ; 2 nos. of w/c-3 ; 2 nos. of w/c-4.
During concreting, every pile model was compacted in similar energy (10 blows each)
4). Allowing 3 day curing time then load test to 4 model piles with w/c-1 until w/c-4 as mentioned in Fig.2
5). Allowing 7 days curing time then load test to 4 model piles similar as 3 days curing.

The next steps was to obtain LI_2 , The clay soil was surcharged then consolidated under certain loading and drainage valve was opened in a couple of days as shown in figure 4 and 5. Then do the similar steps as no.3 to 5. Third and Fourth stages were done with different surcharge loading and consolidation time to obtain LI_3 and LI_4. To synergize the above work, direct shear test was performed to original clay soil and to a combination of w/c ratio of cement and clay as mentioned in figure 6 and 7.

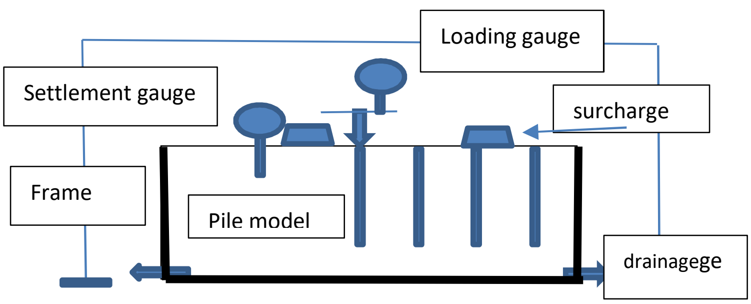

Figure 3.Drum mdel to simulate PLT

Figure 4. Simulation of PLT was being undertaken

Figure 5. Surcharging and consolidation

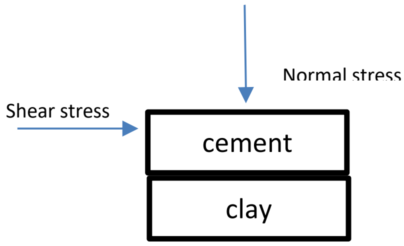

Figure 6. Simulation model of Direct shear test on interface

Figure 7. Preparation of Sample of clay – cement mortar

4. Data and Analysis

From the concept of small scale modelling in normal gravity, the scaling factors is neglected. Instead, in the modelling with enhanced gravity, the scaling factors is a must. So, the result from this data can be used directly in the analysis and calculation without applying correction by scaling factors [10].. Result of physical properties of Southern Bandung clay soil was as follows :

LL = 141 ; PL = 48 ; PI = 93

Classification soil as clay high placticity, CH. Cu from Unconfined Compressive Test, UCT = 3.7 kPa

Data for bored pile model simulation is shown in table 1:

Diameter of bored pile model = 21 mm

Pile length model = 114 mm

L/D = 113/21 = 5 – 6

Table 1 Data for bored pile simulation

Soil condition Liquidity Index, LI	Cement mortar w/c-ratio
w_1 = 83 %	w/c-1 = 0.36
LI-1 = 0.38	w/c-2 = 0.52
	w/c-3 = 0.73
	w/c-4 = 0.92
w_2 = 62	w/c-1 = 0.36
LI-2 = 0.15	w/c-2 = 0.52
	w/c-3 = 0.73
	w/c-4 = 0.92
w_3 = 55	w/c-1 = 0.36
LI-3 = 0.08	w/c-2 = 0.52
	w/c-3 = 0.73
	w/c-4 = 0.92

The load settlement curve of 3 days curing periode from pile loading test were plotted in the Fig. 8, Fig.9 and Fig.10. The curves show that failure occur on 7 – 11 % of pile diameter as mentioned by Terzaghi. At the w/c = 0.42 the pile capacity is the highest, as the low w/c ratio, only small water migrate from cement to surrounding soil to change properties of clay.

Application of compaction with 11 blows to each piles were effective by small w/c ratio to improve clay, and it can be monitored during observation in installation. In higher w/c ratio local softening is high as water migrate from cement mortar, compaction showed cement mortar spilled out because of too much water in it.

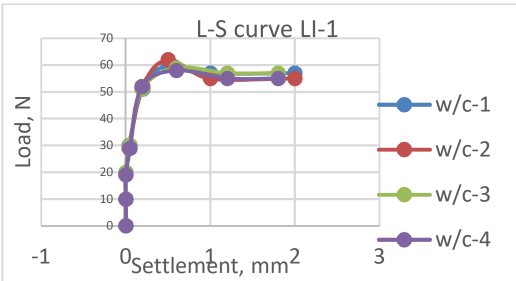

Figure 8. Pile capacity after 3 days on various w/c ratio

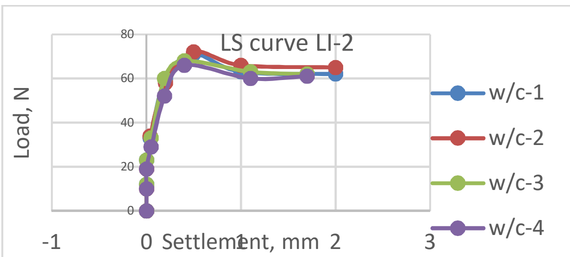

Figure 9. Pile capacity after 3 days on various w/c ratio

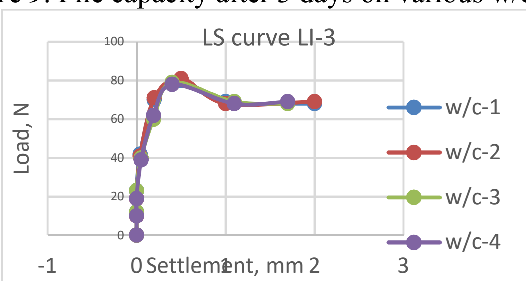

Figure 10. Pile capacity after 3 days on various w/c ratio

The similar result in 7 days curing periode reveals the slight increasing of pile capacity. Eventhough slightly increases, this is an indicator that chemical reaction occurs in there due to some portion of cement pasta concentration penetrates into surrounding clay soil.

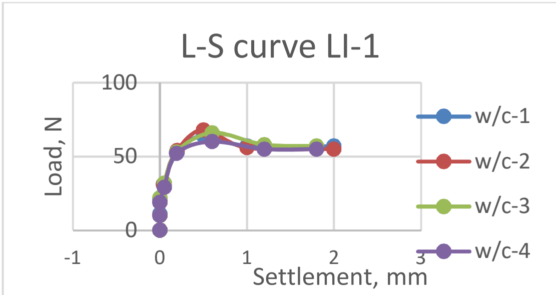

Figure 11. Pile capacity after 7 days on various w/c ratio

This investigation is also agreeable with the findings by Reese [2], He found that by w/c = 0.2 the local softening of the soil had been avoided. The L-S result of original clay soil with high water content which is soft indicates low pile capacity compared with less water content as can be seen in Fig.12. This is due to migration of water from cement mortar leads to worsen soil condition.

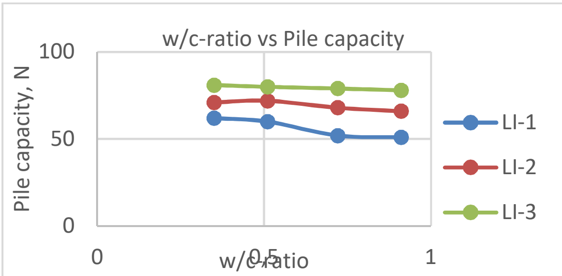

Figure 12. Correlation between w/c ratio with Pile capacity

DST result on Fig.13 showed confirmation and support the pile simulation test. Under LI-1 , strength parameter of original clay without cement mortar c = 3.6 kPa and Ø=5° almost similar with UCT result. As layer of mortar with w/c ratio decrease, strength increase. It was comparable with simulation.

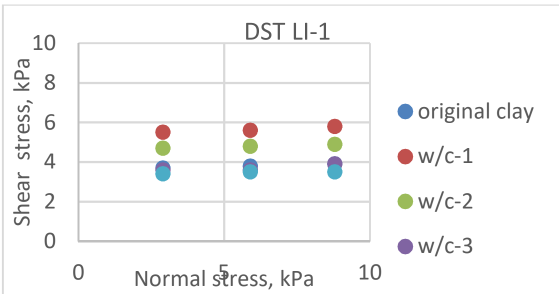

Figure 13. Direct shear test of LI_1 to original clay-mortar in corresponding w/c ratio

To encourage this compaction pile has an element of ground improvement, Let analyze the observation result. Data of pile model : Pile diameter = 2,1 cm ; Area of base, Ap = 0.000296 m^2 ; perimeter,p = 0.068 m ; Pile length = 11,4 cm
Loading test result in capacity = 6.2 N ; 0.062 kN = Cu (0.002682 + 0.007925), So
Cu = 0.062 / 0.00903 = 6.65 kPa

Meanwhile, original clay soil has strength properties of Cu = 3.8 kPa from UCT and C = 3.6 kPa ; Ø = 5° from DST. The increasing strength properties is 74 % to original clay, so the improvement is happening. The increasing capacity of compaction is smaller than grouting (almost 200 % increase), this can be explained that pressure during grouting installation can be setting to reach desired pressure instead of compaction type. By observation the slip surface in Figure 14 and 15, it is some thickness of hardened soil-cement mix attached to concrete in bored pile as a result of compaction and chemical reaction. This leads to increasing diameter of failure slip surface , which in turn increasing pile capacity.

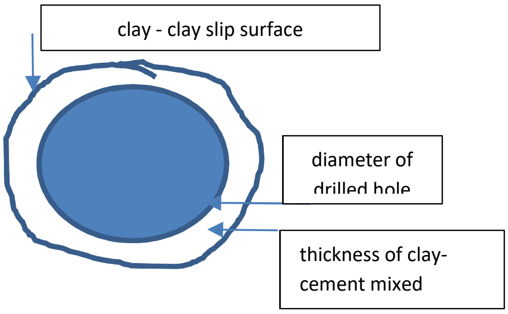

Figure 14. The enlargement of slip surface diameter after concrete hardening

Figure 15. Comparison of with and without compaction on bored pile.

Clay in this sample is Clay with very High plasticity (CH), and particle size is smaller than cement particle. so water migrate to surrounding clay seems to bring small portion of cement particle. Based on this fact, it is another element of action which contribute to improvement effect, that is increasing effective stress as a results of compaction effort and pwp dissipation. The increasing capacity in this clay is dominantly due to this compaction effort which turn the non-displacement type become displacement type. It is recommended to do further research in the application this compaction into bored pile.

5. Conclusion
Non displacement pile in clay soil is capable to perform as displacement pile to behave as ground improvement pile by application a numbers of hammer blow during installation, use the measured water cement ratio of concrete mix (w/c of 0.42 in this case) as well as allowing pore water pressure to dissipate. The average increasing capacity is 74 % higher than those without compaction. There are another aspects should be considered in compaction bored pile on clay : 1. Liquidity index of original soil, 2. time for pore water dissipation and concrete hardening.

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