Behavior of Swelling Pressure of Expansive Soil within The Active Zone of Surabaya Citraland

Indarto\textsuperscript{1}, Denny Hosen\textsuperscript{2}, Adi Prayitno\textsuperscript{3}

\textsuperscript{1} Civil Engineering Infrastructure Department of Vocation Faculty-ITS, Indonesia
\textsuperscript{2} Master’s Graduate of Post Graduate of Civil Engineering Department of FTSP-ITS, Indonesia
\textsuperscript{3} Graduate of Civil Engineering Infrastructure Department of Vocation Faculty-ITS, Indonesia

Email : indarto@ce.its.ac.id

Abstract. The ability of expansive soils to swell and shrink causes damage to the structures, especially for light buildings and pavements. Generally, swells and shrinks this expansive soil due to changes in water content in the active zone. This paper is a study about behavior of swelling pressure of expansive soil within the active zone. This research using undisturbed samples of soil that was taken from Surabaya Citraland. The experiment of swelling pressure was started from the samples with natural water content, furthermore a series of swelling pressure experiments is performed for a series of samples that was added or subtracted by some water to increase or decrease its water content. Repeated swelling pressure experiments were also performed for a sample that has undergone a drying-wetting cycle repetition. The experiment shows that swelling pressure decrease with increasing of water content of soil, in other side the swelling pressure of expansive soil remain constant after sixth repetition of swelling pressure experiment.

Keywords : Expansive Soil; Swelling Pressure; Active Zone

1. Introduction

Several countries have summarized the expansive soil problem in the Internal Panel Review during the first expansive soil conference in Texas A & M in 1965 (Chen 1975). In the conference stated that the main problem of expansive soil is the foundation damage caused by shrink-swell of expansive soil. In Indonesia, damages due to behavior of expansive soil not recorded properly. But Indarto (2012) estimates that one house damage due to expansive soil requires a cost of a repair around 500-1000 million rupiah.

The uniqueness of expansive soil, especially swell-shrink ability when the water content in this soil increase or decrease due to climate change. If the water content of expansive soil increases, the soil will expand which will put upward pressure on the foundation or building on it, besides that due to the wetting of this soil also decrease the shear stress (Alwan & Indarto 2010). The other side, Holtz and Kovacks (1981) state that when capillary pressure exceeded the cohesion of the expansive soil, crack will occur during desiccation, where the moisture content in the soil decreases.

Nelson and Miller (1992), say that the zone where the water content of soil could be increase or decrease due to climatic environmental factors is located at few upper meters. This zone is generally either the zone of seasonal fluctuation or the active zone.
Badawi and Indarto (2010) show that during drying - wetting cycle the strength of remolded slurry soil was found approximately near to that of undisturbed soil. This may be due the intensity of remolded dry density.

This paper presents the behavior of swelling pressure of expansive soil in the active zone. The term of active zone means that there is variation of water content due to the climate change. Then in this research was conducted on undisturbed sample that was taken from the zone active approximately. The experiments of swelling pressure and swelling potential are started from natural water content. At the same time, the other samples of experiment were conducted after reduction and addition of moisture content of undisturbed sample. The objective of these experiments is to know the effect of moisture content variations to swelling characteristics the expansive soil in the active zone due to variation of climate.

The other experiment has the purpose to know the effect of repetition of swelling to the same soil sample after every experiment of swelling.

2. Methodology

As mentioned before that the material of expansive soil was taken from Citraland that was located at West of Surabaya. The physics characteristic of this soil in the active zone approximately could be seen in the Table 1.

| Soil content (%) | ɣD (kN/m³) | Gs (%) | W L (%) | Wp (%) | IP (%) |
|------------------|------------|--------|---------|--------|--------|
| Sand             | 0.5        | 16.02  | 81.46   | 11.9-13.4 | 2.61   | 101-104 | 31-51   | 69-74  |
| Silt             |            |        |         |        |        |        |
| Clay             |            |        |         |        |        |        |

Table 1 shows that that plasticity index of soil in the range between 69-74 %. According to Chen (1988) this soil could be classified as the soil expansive that has a very high swelling potential.

The prediction of swelling potential and swelling pressure are conducted by using an oedometer apparatus. Measurement of swelling pressure started from unsaturated of undisturbed sample which is placed in the ring of oedometer apparatus. Then after added water sample is allowed swell under the initial load. The initial load could represent overburden surcharge, overburden surcharge with structural load or another load. After swelling, then the sample loaded and unloaded as conventional matter. Usually, swelling defined as the pressure required to recompress the fully swollen sample back to initial volume. Swelling potential is relative capacity for expansion of expansive soil.

The first series of experiments of swelling pressure prediction wa started from undisturbed sample with initial natural moisture content. In this series, prediction of swelling pressure also conducted for a series of initial undisturbed samples after added or subtracted some water. The undisturbed sample for these experiments taken from the depth of 1m, 3m and 5m.

The second series of experiments of swelling pressure prediction also started from undisturbed sample with natural water content. But after the first swelling pressure experiment is completed, the sample is
then dried with dry air, before then a second swelling pressure prediction is performed. This swelling pressure prediction experiment, repeated until the seventh cycle.

Experimental results of swelling pressure and potential predictions are presented in the function of moisture content, and dry densities.

3. Results and Discussion

3.1. Behavior swelling pressure in the active zone

Based on the observation of moisture content in the depth function during the rainy and dry seasons, Hosen and Indarto (2013) say that the active zone of soil expansive in Surabaya Citraland is at a range of depth of 0 to 5 m. This statement is the reason why research on swelling pressure in this paper is used on that depth. The initial condition of moisture content and dry density for each depth of this soil as seen in Table 2.

Table 2. Initial condition of undisturbed sample

| Depth (m) | 1  | 3  | 5  |
|-----------|----|----|----|
| $w_c$ (%) | 53 | 48 | 47 |
| $\gamma_0$ (kN/m$^3$) | 11.9 | 12.6 | 13.1 |

Table 2. show that in the active zone, moisture content and dry density values of the undisturbed samples are not significantly different.

In Figure 1. shows the relationship of swelling pressure in the function of variation of water content. In the figure shows that the curves for the three different depths in the active zone are almost coincidental. This condition is likely due to the condition of the initial samples are almost the same. For all three curves shows that swelling pressure decreases with increasing moisture content. On the contrary, swelling pressure increases with decreasing water content.

Chen (1975) said that the initial water content condition of an expansive soil will affect the amount of swelling. Then he says that the water content below 15%, usually indicates the danger because swelling pressure will be high.
Otherwise clays that have moisture content above 30% indicate that swelling has already started, so the next swelling will be small. In the Figure 1, show that at a depth of 1m it appears that when the initial water content is 53%, the swelling pressure is about 145 kPa, its swelling pressure value increases to 195 kPa when its initial water content drops to 40% due to drying. This increase of swelling pressure due to the softer water content expansive soil, the easier it is to absorb water, thus causing an increase of swelling pressure. Chen (1975), said that if the expansive soil could absorb water equal to 35 %, the expansion could cause structural damage.

Conversely, if the initial water content increases due to the wetting process up to 85%, the swelling pressure decreases to 95 kPa. As mention before, when the initial water content increased due to wetting, this soil indicate that swelling pressure already started.

Identical condition also occurs at the depths of 3 m and 5 m.

Figure 2. show the relation between swelling potential with water content variation, these three curves of different depth have the same behavior with the curves of swelling pressure in Figure 1. Swelling potential increase when water content decreased, conversely swelling potential decrease, when the water content increased.

When swelling pressure and potential were related to dry densities, their relationship could be look at Figure 3 and Figure 4. Dry density is an importance factor that affects the character of swelling of expansive soil.
3. Increased of dry densities accompanied by increased of swelling pressure and potential. This relationship is reversed by the relationship between water content with swelling pressure and potential, where swelling pressure and potential decreases with increasing water content. This inverse state is because the amount of dry density is highly depended on the amount of moisture content in the expansive soil.

3.2. Behavior swelling pressure in the active zone

An expansive soil could potentially shrink and swell. The second experiment presents in this paper is repetition of the test of swelling on the same sample.
In this experiment, an expansive soil sample is subjected to full swelling, allowed to desiccate to initial its water content, then is saturated again. This experiment is repeated a number cycles. The undisturbed samples were taken at the depth of 3m and 5m. Each depth, carried out two experiments.

The Figure 5, shows the result of this experiment. The curves in this figure give the swelling potential value of each cycle of the test.

The swelling potential value decreases with the increase of the experimental cycle, but this value becomes constant after the sixth cycle. This happens in all experiments with two different depths.

This results in accordance with what Chen (1975) obtained using claystone samples, where swelling will decrease with increasing number of experimental cycles, until it becomes constant in the sixth cycle. Chu (1973) and then Chen call this phenomenon as the fatigue of swelling. Chu believe that swelling of the first cycle will be higher than the next cycle that follows during repetition of wetting-drying cycles.

4. Conclusions
Based on the results of study behavior of swelling pressure of Citraland expansive soil in the active zone, can be concluded that:
• Base on identification physic of soil, initial condition of the samples of different depth in the active zone is almost the same or little different.
• Swelling pressure and potential decrease when its water content initial increased, conversely these swellings increase with decreasing initial water content
• Swelling pressure and potential increase with increasing of dry densities initial, conversely, these swellings decrease when dry densities decreased.
• Repetition of swelling potential value decrease with increasing of number of experimental cycle, and the movement due to swelling stay stable after sixth cycle of the test.

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