Shear Strength Reduction of Tertiary Jatiluhur-Subang Claystones Due to Swelling Processes

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Abstract

Swelling processes of Tertiary Jatiluhur-Subang claystones have been received an extensive attention since numerous engineering problems were found recently, such as along the Cipularang toll road and in the development area of Sport Training Facility and Education Centre (P3SON) Hambalang, West Java, Indonesia. Accordingly, this research was carried out to deal with the swelling characterization of these claystones by means of an unconfined swelling test. A series of mineralogical analysis using X-ray diffraction (XRD) were also performed. Furthermore, in order to know how the swelling processes give effects to the decrease in shear strength of the claystones, a series of direct shear test was done for some samples having different immersion time. The claystone commonly has a greenish gray to dark gray color, non-calcareous and massive/monotone (not showing layering structures). The unconfined swelling test indicates unrestricted swelling in all directions and results indicate a swelling strain magnitude as a function of time. The results for selected representative specimens of the claystone show nonlinear relationships between axial swelling strain buildups and time during immersion. The swelling strain magnitude seemed significantly close relations to the occurrence of montmorillonite and the ratio of clay/non-clay minerals. The shear strength reductions of the claystones after 25 days immersion which occurs along with the changes in swelling strain are quite varied, reaching up to 57%.

Keywords: Tertiary claystones, swelling, strain, montmorillonite, shear strength

1. Introduction

Swelling and slaking processes of claystones are generally strongly influenced by changes in natural conditions, such as changes in water content and/or in-situ stress conditions (Sadisun et al., 2002; Sadisun et al., 2005; Czerewko and Cripps, 2006). These changes will result in further rock deteriorations, of which mostly characterized by strength degradation and/or fracturing. Accordingly, swelling and slaking processes have been received an extensive attention since numerous engineering problems were found recently, such as along the Cipularang toll road, in the development area of Sport Training Facility and Education Centre (P3SON) Hambalang and along the Semarang-Bawen toll road.

This research was carried out to deal with the detailed characterization of swelling by means of an unconfined swelling test (Fig. 1), while doing visual observation of slaking process that occurs during the test (Table 1). As a case study, some claystones were collected from some areas of the northern part of West Java Province, Indonesia. A series of laboratory test of physical properties, including mineralogical analysis using X-ray diffraction (XRD) were also performed. Furthermore, how the swelling and slaking processes give effects to the decrease in shear strength of the claystones, a series of direct shear test was done for some samples having different immersion time. In general, the results of this research will be very useful for determining the appropriate solution to anticipate problems dealing with swelling and slaking processes.

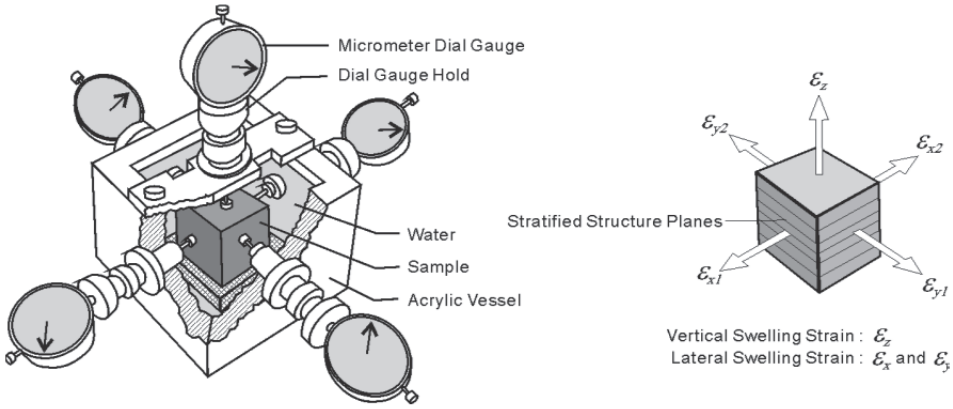

Fig. 1 A schematic device of unconfined swelling test and structural coordinate of dial gauge position

Table 1 Criteria for visually classifying claystones to slaking (Sadisun et al., 2005).

Class	Criteria
0	No visible change or change can be allowable as only very minor hairline cracking
1	Severe hairline cracking without spalling, and/or mud-sand particles starting to breakaway from the rock surface
2	Crack opening with minor spalling and/or little suspended mud-sand particles
3	Further process of crack opening with major spalling and/or suspended mud-sand particles
4	Complete disintegration to a mound of chips and/or remarkable portion of suspended mud-sand particles

Note: Classes correspondingly denote the degree of disintegration.

2. Petrographical characteristics of the claystones

The claystone samples used in this study were then called as Jatiluhur-Subang Claystones; a soft rock formation of Miocene to Pliocene ages within the Bogor-Kendeng trough in the northern West Java area. There were six samples used in this study, which taken by cutting blocks of rock outcrops. In this case, sample 1 was in the most weathered condition, on the contrary to the sample 6 having the freshest condition.

Generally, the claystone has a greenish gray to dark gray color, non-calcareous, massive/monotone (not showing layering structures), and is relatively impermeable, with some thin intercalations of fine-grained sandstone. The results from XRD analysis have shown the composition of plagioclase, quartz, montmorillonite, Illite and kaolinite with some occasional muscovite and siderite. Porosity and water content were tend to increase in weathered claystones than in fresh claystones, however unit weight was tend to decrease. Atterberg limits analyses showed that all claystones can be categorized as CH (clay high plasticity).

3. Results and discussions: Swelling processes and shear strength reductions

The unconfined swelling test indicates unrestricted swelling in all directions and results indicate a swelling strain magnitude as a function of time. The results for selected representative specimens of Subang claystone are presented in the graphs showing the axial swelling strain buildup versus time relationships in two different plotting methods (Fig. 2). The relationships between axial swelling strain buildups versus time exhibited the non-linear swelling strain process during immersion. The swelling strains seemed significantly influenced by occurrence of montmorillonite (widely known as expansive clay mineral) and the ratio of clay/non-clay minerals. Swelling strains in the vertical direction were most likely to be higher than in the horizontal direction, therefore it can be inferred that swelling strains of the claystones are anisotropy.

It was also evident that swelling strain could be generally divided into three distinct stages representing the instantaneous, primary and secondary swelling processes. The distinction on the stage of swelling strain also indicated that there was likewise distinction in rate of swelling strain. The increasing rate in swelling strain was commonly somewhat rapid in the beginning, becoming slower at a moment and then faster until it eventually slows down to a relatively steady state.

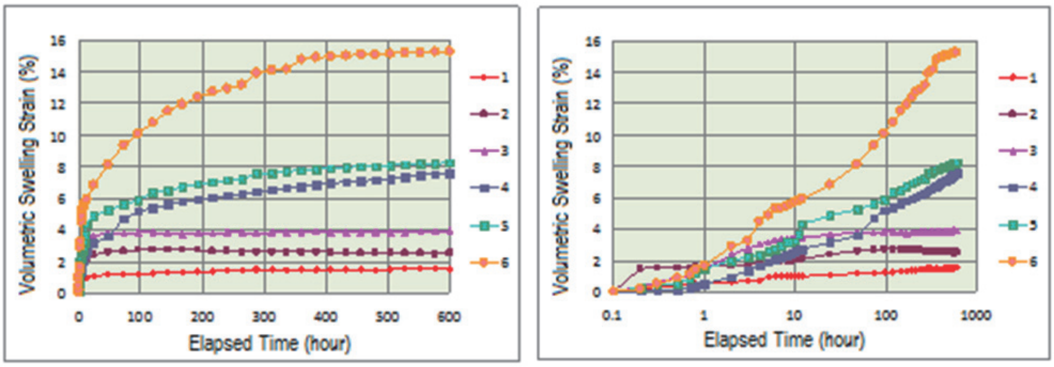

Fig. 2 Volumetric swelling strain indexes of Subang claystones for each different sampel

The rapid rate of strain at early stages of swelling process revealed that rapid increase of specimen volume was occurs at the first minutes after immersion of the specimen into water, which was visually indicated by the initial development of hairline cracks or visible traces of fissility (slaking class 1). This process was might be caused by entrapped air pressure, which existed on dependent of initial rock water content, wetting or water uptake rates, and air thrust. The rate of water uptake was accelerated by the occurrence of capillary effect in where the water was forcedly moved towards capillary paths.

The rate of swelling strain turned into slower at a moment usually showing very low gradual increase of strain magnitude which was considered as the absorption process of water into hairline cracks and specimen itself without much increase of volume. After the absorbed water began to open the hairline cracks, it was then initially generated reaction between the water and any expandable clay minerals present, which in turn gave the highest rate of volume increase. In this case, the highest rates of swelling strain take place at 2-8 hours from the time the specimen was immersed. Since it is widely known that smectite is the main expandable clay mineral, it is interesting to evaluate the variation of swelling strain as a function of smectite content (Yevnin and Zaslavsky, 1970; Moghal and Al-Shamrani, 2011).

At the latest stage and after most cracks had been opened and filled with water (slaking class 3), the rate of displacement due to swelling strain slowed down gradually until it reached a relatively steady state at which no change in axial swelling strain could be observed by the dial gauges. Based on these results, it was important to be noted that owing to the surface (< 3 m) and more weathered condition of claystones, volume changes due to swelling process had a tendency to decrease.

The decrease in shear strength of the claystones after immersion occurs along with the changes in swelling strain and its accompanying slaking processes. The relationship between the magnitude of decrease in shear strength and increase in swelling strain after 25 days immersion quite varied (Fig. 3). Experimental results showed important reduction in both cohesion and internal friction angle, but at different rates, with the application of different length of immersion time. In general, the decreases in shear strengths of the claystone are entirely ranging from 45 % to 57 %.

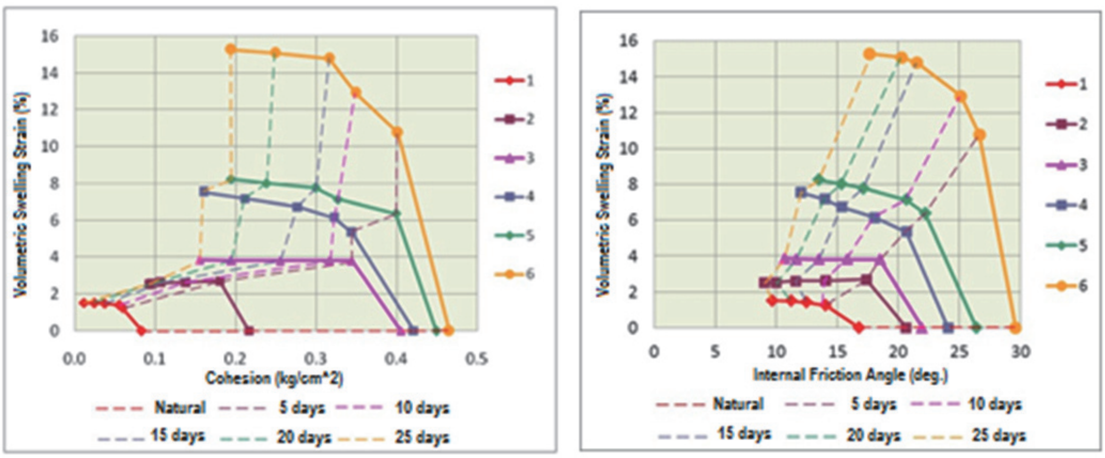

Fig. 3 The relationship between swelling strain and shear strength for each different sampel

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