Investigation of enhancing industrial waste as a soft soil stabilizer

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Abstract. This study compares two methods in enhancing fly ash as a soft-soil stabilizer. The first is using fly ash with mixing proportion varies from 10%, 15%, and 20%. In the second method, 10% cement combines with fly ash mixing proportion in the first method. Based on CBR test results, the fly-ash effectively increases the soft soil capacity with a CBR maximum of 9.31% at 20% fly ash in the first method. The second method enhances more impact than the first method with a CBR maximum of 49.36% at 20% fly ash. The swelling value keeps decreasing with the increase of fly ash content, and adding cement to fly ash-soft soil mixture can further minimize the swelling value by two times compared to only fly ash as the stabilizing agent.
Keywords: soft soil, fly ash, cement, CBR, swelling

1. Introduction

Indonesia has a soft soil type for approximately 20 million hectares of land [1]. Building construction on soft soils is vulnerable to hazards in terms of the foundations, the structure, and construction work in general. In Banjarmasin, South Kalimantan Province of Indonesia, many buildings have problems during or after construction. The distribution of hard soil in Banjarmasin City is at a depth of 28 m to 42.4 m [2]. So that the construction of a building requires various handling to make sure there will be no problem in the project.

To stabilize and to improve soft soil bearing capacity falls into two categories, mechanical and chemical. The mechanical method uses soil reinforcement elements such as geotextile [3], while the chemical method involves chemical admixtures such as cement and other viscoelastic materials. This study will focus on chemical admixtures as soil stabilizers such as fly ash as one of an industrial waste and cement.

Fly-ash is one industrial waste that comes in large quantities and is easy to find since there is a power plant in South Kalimantan Province. Fly-ash is an industrial waste from a steam-powered electric plant furnace burning coal that is smooth, round, and pozzolanic [4]. It contains silica or silica and alumina with very little or no binding ability (non-cementitious), and if it reacts with calcium hydroxide, it forms a material with cementitious properties [5]. Fly-ash as admixtures in concrete can enhance concrete performance by improving durability, increasing workability, and reducing heat hydration [6].

This research investigates fly-ash's performance when mixed with cement for soft soil stabilization and compares both options. California Bearing Ratio (CBR) and free swell test result will represent the performance of fly-ash and fly-ash with cement. CBR value relates to the soft soil bearing capacity while swelling value corresponds to the expansion behavior of the soft soil sample.

2. Materials and methods

Soft soil extractions (the sample is shown in Figure 1a) were carried out at a depth of 1 m to 2 m in the area of Engineering Faculty of Lambung Mangkurat University-Banjarmasin Campus. The soft soil samples are tested to find their characteristics. The soft soil samples fall into the high plasticity silts category based on the Unified Soil Classification System (USCS). The soil sample properties are presented in Table 1.

Table 1. Soft soil sample engineering properties [7]

Liquid limit (LL)	Plasticity Index (PI)	Shrinkage limit (SL)	Plastic limit (PL)	Sand	Silt and Clay	Water content	Unconfined compression test (q_u)	Specific gravity (G_s)
68%	26%	72.49%	42%	14.3 %	85.7 %	269.64 %	0.101 kg/cm^2	2.636

This study uses Ordinary Portland Cement (OPC) Type I as a complement and additive to increase soft soil bearing capacity together with fly-ash as shown in Figure 1b. When cement is mixed with soil, cement will bind the soil grain during the cement hydrolysis [8]. Cement consists of CaO, Al_2O_3, SiO_3, Fe_2O_3, and other components.

(a) (b) (c)

Figure 1. Material (a) soil sample (b) OPC, and (c) Fly Ash Type C

Fly ash in this study as shown in Figure 1(c) is collected from Asam-asam Power Plant, Tanah Laut District of South Kalimantan Province, Indonesia. Major chemical components of fly ash are SiO2 of 49.65%, Fe_2O_3 of 19.63%, Al_2O_3 of 12.91%, CaO of 8.07%, MgO of 5.9%, K_2O of 0.77, SO_3 of 0.15%, and LOI of 1.35% [9]. From that major components, it is concluded that the fly ash used in this study is categorized as Type C fly ash. This is based on ASTM C618 criteria of CaO higher than 8% and SiO2 from 30% to 50% falls to Type C.
Four samples adding fly ash vary from 0%, 10%, 15%, and 20%. These four samples will be compared to three samples containing cement and fly ash. The last three samples consist of fly ash 10%, 15%, and 20% while keeping cement constant at 10% [7]. The soft soil and stabilizing agents, fly ash and cement, will be mixed and cured for seven days. All samples are presented in Table 2.

Table 2. Composition of additives and curing time of the samples

Sample	*Additives*		Curing time (day)
	Fly Ash (%)	Cement (%)	
FA0%	0	0	7
FA10%	10	0	7
FA15%	15	0	7
FA20%	20	0	7
CFA10%[7]	10	10	7
CFA15%[7]	15	10	7
CFA20%[7]	20	10	7

California Bearing Ratio (CBR) test is used to obtain the soft soil bearing capacity, and the laboratory CBR test method is based on SNI 1744:2012 [10]. The treatment of samples is, all the same, using the proctor compaction method with five layers, and each layer undergoes 56 blows. It is assumed that the samples reached their maximum dry density and optimum moisture content after the blows. A free swell test is also delivered to investigate the expansion behavior of soft soil-admixture. The test is based on ASTM D4546- 90, which provides a way of measuring free swell, percentage expands (percent swell), and pressure expands (swelling pressure) using the Oedometer [11]. The CBR and free swell test results of soft soil-fly ash and soft soil-fly ash-cement will be compared and discussed.

3. Results and discussions

3.1 California Bearing Ratio (CBR) test results

Based on Figure 2, CBR test results on samples with only fly ash as the stabilizing agent show a constant increase from 3,25% of FA0% to 9,31% of FA20%. The percentage difference increase from FA0% to FA10% is 40%, FA10% to FA15% is 47%, and FA15% to FA20% is 38%. These constant increases may be due to changes in cations in the soft soil which are replaced by calcium in the chemical composition of fly ash, thereby stabilizing the soft soil and increasing the CBR value. Similar trends have been shown in research by Kumar et al. [12] , Rajak and Pal [13], and Hangge et al. [14].

Compared CBR value to the stabilizing agent with only fly ash, when the fly ash mixes with a cement of 10%, the CBR values increase significantly. Figure 3 shows the CBR value of FA10% to CFA10% has an almost 230% increase while the maximum CBR value from all combinations is given by soil-admixture CFA20% of 49,36% [7]. The increase in CBR value caused by mixing fly ash and cement is also shown in the research done by Binal [15], KW et al. [16], and Rai et al [17].

In the Pavement Design Manual 2017 [18], increasing the CBR value in the soil subgrade can reduce the pavement layer thickness. The soil subgrade with a CBR value of more than 10% is categorized as high bearing capacity index, while the soil subgrade with a CBR value of 3%-10% is categorized as moderate bearing capacity index. Based on this result, the soil can be categorized as high bearing capacity by adding 10% cement to the admixture of soft soil and fly ash.

3.2 Free swell test results

Based on Pratiwi et al. [7], the degree of expansion of the soft soil falls into medium to a very high degree category with swelling potential being from 1,5% to 25%.

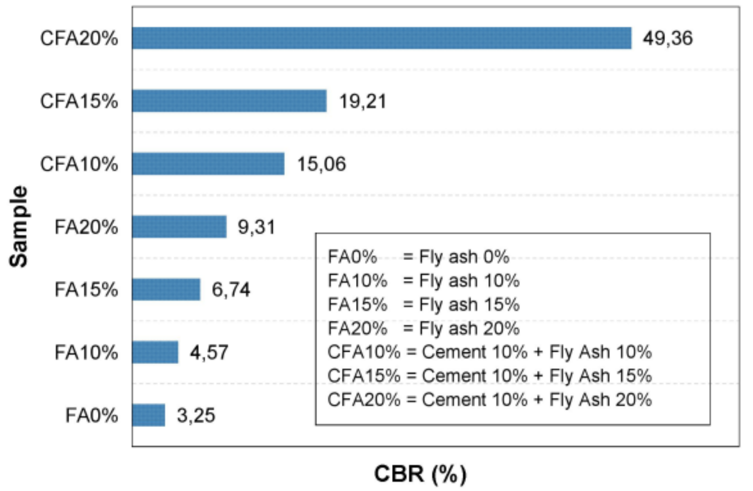

Figure 2. CBR test result

To investigate the effect of stabilizing agents on the soft soil to reduce its expansive behavior, the free swell test results are observed. From Figure 3, generally, the increase of fly ash content will decrease the swelling value. The swelling value of CFA 10% was twice that of FA10%, while CFA 15% and CFA20%, which had close swelling values, had a swelling value that was two times smaller than FA15% and FA20%. It means that adding cement to fly ash and soft soil can further minimize the swelling value of the soft soil by two times compared to only fly ash as the stabilizing agent. The reason is that cement contains calcium hydroxide, which can react with fly ash to form a cementitious material. Cementitious material can bind the soil grain nearby and increase its properties. t is also observed that after 20 hours, the change of swelling value becomes almost constant for CFA samples while for FA samples are still increasing but not significant.

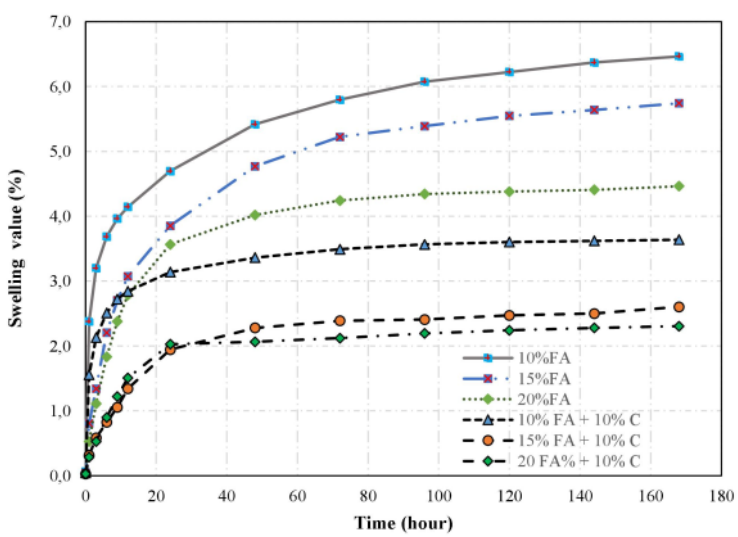

Figure 3. Swelling value versus time

4. Conclusions

From the discussion above, it can be concluded that the CBR value of soft soil steadily increases with the increase of fly ash content. In addition to that, the CBR value further increases to 2,85-5,30 times when fly ash is combined with 10% cement. As for the swelling value, it keeps decreasing with the increase of fly ash content, and adding cement to fly ash-soft soil mixture can further minimize the swelling value by two times compared to only fly ash as the stabilizing agent.

5. Acknowledgement

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