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# Stabilization of soft soil using industrial waste

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**Abstract.** This study focuses on the soft soil stabilization using different combination of fly ash and cement admixture. The fly ash proportion varies from 10%, 15%, and 20% while keeping the proportion of cement constant at 10%. CBR test result is used as the soil improvement parameter with curing time for seven days. Test results indicate an increase of CBR with increase of fly ash and cement admixture to soft soil. The maximum CBR is at fly ash 20% and cement 10% with 49.36%. The swelling value of soft soil decreased with increase of fly ash and cement admixtures percentage. The swelling potential can be reduced to be less than 5%.

**Keywords:** fly ash, cement, CBR, stability, swelling.

## 1. Introduction

In the South Kalimantan Province of Indonesia especially in Banjarmasin, the subgrade soil categorized as soft soil with low bearing capacity. The depth of hard soil was found at 28-42.4 m [1]. Many construction problems were observed such as crack in the building structure, crack and bumpy on the highway pavement, and tilted structures.

There are two methods to stabilize the soil and improve its bearing capacity, mechanical and chemical. Mechanical method is applying soil reinforcement element [2] while chemical method is by adding chemical admixture such as cementitious or viscoelastic materials. This study focuses on the possibility of using chemical method with industrial waste as chemical admixture. Industrial waste that found to be suitable and possible to use in South Kalimantan is fly-ash. South Kalimantan has a power plant that produces fly-ash as waste materials. This waste material needs to be recycled in order to reduce environmental problem.

The use of cement in soil stabilization is suitable when the soil has good gradation with less porous and wide contact area [3]. When cement is mixed with soil subgrade, cement hydration will strongly bind the mineral grain and soil grain nearby, moreover, there will be a reaction between soil grain and calcium hydroxide which released during cement hydrolysis process [4]. Cement characteristics tends to caused shrinkage and cracking problem, hence adding fly ash to the admixture improves the soil-cement properties. Fly ash has many benefits when it comes to fresh concrete since fly ash reduces the water demand, improves the workability, and reduces the heat of hydration [5].



This research is proposed to assess the impact of using fly ash as main agent in increasing the soft soil bearing capacity and to identify the optimum composition of fly ash, cement, and soil regarding to the swelling value. By utilizing the fly ash as main stabilizing agent of soft soil, it can be a solution to reduce environmental problem.

## 2. Materials and methods

Soft soil sample in Figure 1a were obtained from Lambung Mangkurat University Banjarmasin Campus area. Based on Unified Soil Classification System (USCS), the soft soil sample is categorized as high plasticity silts. The complete engineering properties are summarized in Table I.

**Table 1.** Engineering properties of the soft soil sample

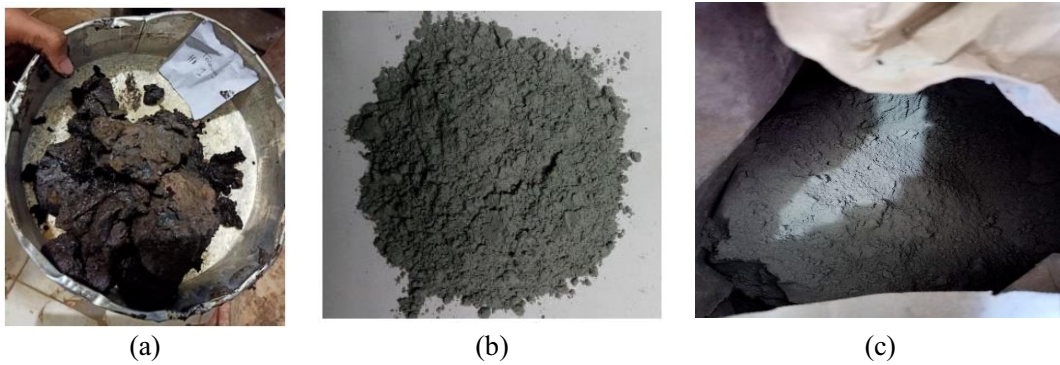
Soil parameter	Value
Water content	269.64%
Specific gravity ( $G_s$ )	2.636
Unconfined compression test ( $q_u$ )	0.101 kg/cm <sup>2</sup>
Liquid limit (LL)	68%
Plastic limit (PL)	42%
Plasticity Index (PI)	26%
Shrinkage limit (SL)	72.49%
Sand	14.30%
Silt and Clay	85.70%

It is also interesting to know the swelling value of soft soil sample mixed with cement and fly ash. The swelling value indicates expansive behavior of soft soil. From Table 1, plasticity index of 26% corresponding to degree of expansion is at medium degree, moreover, the degree of expansion may increase further to very high degree since the shrinkage limit value is 72.49%. The swelling potential may range from 1.5% to more than 25%. The relationship of degree of soil expansion with shrinkage limit and plasticity index is presented in Table 2.

**Table 2.** Degree of soil expansion corresponding to PI and SL [6]

Degree of expansion	Swelling potential (%)	Plasticity Index (%)	Shrinkage Limit (%)
Very High	> 25	> 41	>30
High	5 - 25	28 - 41	20 -30
Medium	1.5 - 5	18 - 28	10-20
Low	0 - 1.5	< 18	< 10

The cement used in this study is the Ordinary Portland Cement Type I which commonly contains of CaO, SiO<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, dan Fe<sub>2</sub>O<sub>3</sub>. The cement is shown in Figure 1c. The fly ash as shown in Figure 1b as the main stabilizing agent is from burning coal produces coal combustion residuals (CCR), or byproducts, of Asam-asam Power Plant in Tanah Laut District of South Kalimantan Province. The fly ash chemical properties are shown in Table 3.



**Figure 1.** Material (a) soft soil sample and (b) fly ash (c) cement

**Table 3.** Major chemical components of fly-ash from Asam-asam Power Plant [7]

Component	%
SiO <sub>2</sub>	49.65
Fe <sub>2</sub> O <sub>3</sub>	19.63
Al <sub>2</sub> O <sub>3</sub>	12.91
CaO	8.07
MgO	5.9
K <sub>2</sub> O	0.77
SO <sub>3</sub>	0.15
LOI	1.35

From Table 3, the fly ash is categorized as Fly Ash Type C based on ASTM C 618 and Canadian Standard CSA A-23.5 because it has SiO<sub>2</sub> from 30% to 50% dan CaO higher than 8%.

**Table 4.** Samples in this study

Sample	<i>Stabilizing agent</i>		Curing time (day)
	Fly Ash (%)	Cement (%)	
CFA10%	10	10	7
CFA15%	15	10	7
CFA20%	20	10	7

There are three samples with combination of fly ash and cement as stabilizing agent of the soft soil. Fly ash content varies from 10%, 15%, and 20% while cement content keep constant at 10%. The three samples are presented in Table 3.

The method to obtain the bearing capacity of samples were California Bearing Ratio (CBR) test based on SNI 1744:2012 [8]. The samples were soaked until 7 days to consider the cement and fly ash slow setting time. Proctor compaction method was applied to all samples with 56 blows per layer of 5 layers in total assumed that the samples reached their maximum dry

density and optimum moisture content. Swelling test was also performed to observe the expansion behavior of soil-admixture.

### 3. Results and discussions

Compaction test for sample combination of cement 10% and fly ash 15% was performed to observe the corresponding optimum moisture content (OMC) to the maximum dry density (MDD). The compaction test result shown OMC of 27.73%, corresponding to maximum dry density of 1.28 gr/cm<sup>3</sup>. Figure 2 shows the relationship of CBR test result to the combination of fly ash in the sample for 7 days curing time. It indicates the increase of CBR value with the increase of fly ash content. This behavior was also found in the experimental study by Binal [9] where the soil is categorized as very high swelling potential (>50% swelling index) combined with high alkaline fly ash (without cement). It was observed that the combination of 25% fly ash and soil could increase the CBR value to 68.7 times [9]. In this study the increase of CBR value reaches almost 50% for 20% fly ash composition which is reasonable because it is added with cement of 10%.

In Figure 2, fly ash of 10% and cement of 10% results in CBR of 15.06% while fly ash of 15% gives slightly increase to 19.21%. Contrast to the CFA10% and CFA15%, CFA20% with fly ash 20% shows much higher CBR of 49.36%. This condition may relate to the optimum fly ash content to the soil-cement mixture. Study by KW et al also indicates that the optimum fly ash content is also at 20% where CBR value reduced at 25% fly ash content [10].

Based on Pavement Design Manual 2017 [11], the pavement layer thickness can be reduced by increasing the CBR value in soil subgrade. It also mentions that soil subgrade with CBR value larger than 10% can be categorized as high CBR while soil subgrade with CBR value between 3% and 10% categorized as medium CBR. Hence, the mixture of soil subgrade to fly ash of 10% and cement of 10% is sufficient to increase CBR value of base courses of pavement system and it can further reduce the pavement layer thickness by increasing the fly ash to 20%.

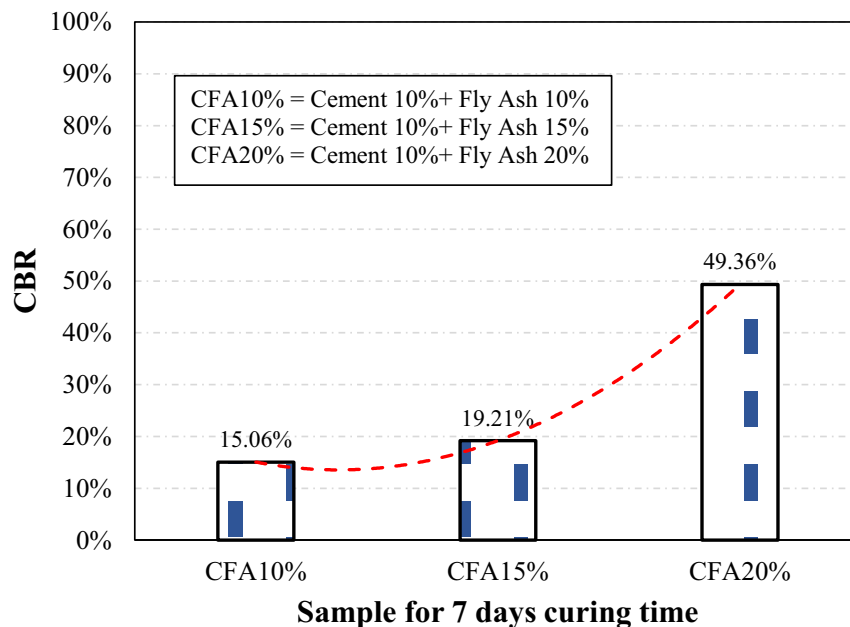


Figure 2. CBR test result

From Figure 3, the effect of mixing fly ash and cement to soft soil sample reduce the swelling value from maximum of larger than 25% based on Table 2 to maximum swelling value of 3.6%. By increasing the fly ash content while keeping the cement content constant, the swelling value reduces further to 2.3%. This behavior indicates the water content in soil porous decrease when mixing soil with fly ash and cement. Fly ash content of 15% and of 20% in general is not differ significantly. It is also concluded that the swelling value after 20 hours increases relatively slower.

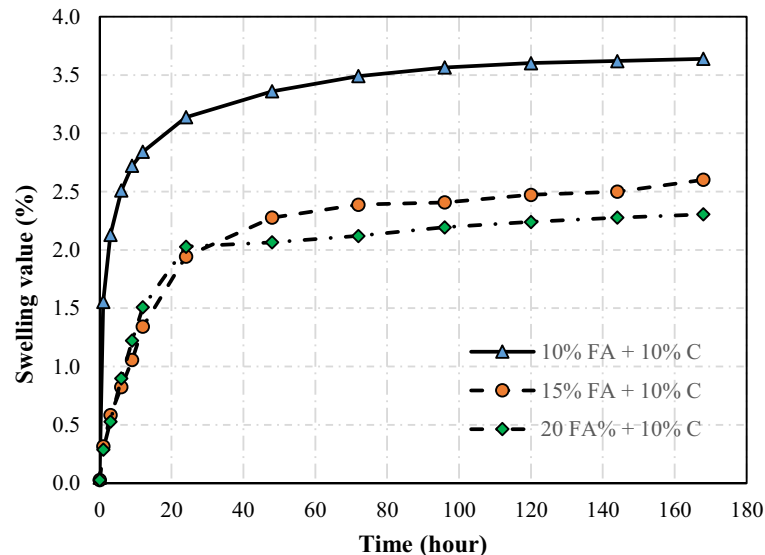


Figure 3. Swelling value versus time

#### 4. Conclusions

The results of stabilization of soft soil using fly ash as main stabilizing agent and cement as complement has been discussed. Increasing the fly ash content will increase CBR value which means the bearing capacity of soft soil also improve. Bearing capacity improvement caused by mixing fly ash and cement proves the increase in soil stability. CBR value of Fly ash of 20% is significantly higher compared to of 10% and 15%. Mixing fly ash and cement to soft soil is also capable to reduce the swelling value which relates to the expansion of soil. The swelling potential can be reduced to be less than 5% or the degree of expansion will be on low or medium degree.

#### 5. Acknowledgement

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