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# Analysis of thermal power plant fly ash and lime in increasing shear strength of soft clay

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**Abstract.** Soil is the basic foundation for any civil engineering structures. It is required to bear the loads without failure. In some places, soils are weak which cannot resist the oncoming loads. Soft clay is known to have low strength and high compressibility. Utilization of additive is a method that can be applied to increase shear strength of soft clay. This study was conducted to determine the effectiveness of mixing fly ash, lime and soft clay with different percentage in order to increase the strength. A series of laboratory test were conducted in determining the physical properties, compaction and shear strength on soft clay soil. The soil samples; both disturbed and undisturbed were obtained from the vicinity of Politeknik Sultan Idris Shah (PSIS). Two tests carried out are compaction and direct shear strength. From the results, the highest strength of soft clay was at 69 kPa by mixing soil with 12% fly ash + 4% lime.

## 1. Introduction

Soft clays are known to have low shear strength, low permeability and weak confining pressure. According to [1], the soft clays also are highly compressible, and it exhibits moderate swelling when comes in contact with moisture. This behavior is due to the presence of clay minerals with expanding lattice structure. The soft clay is very hard when it is dry but loses its strength on wetting. These characteristics will give the problems to the structure or foundation because of the shear failure of different settlement and it is become more serious in the future because of damage that will happen either in slow or fast condition [2]. In area of Sabak Bernam, Selangor which is consists 13.6% of paddy fields area which is known to have abundance of soft clay. The strength of soft clay changes according to the presence of water. Thus, the structures constructed on soft clay produce problem mainly in settlement, sedimentation and stabilization.

The aim of this study is to increase the shear strength of soft clay by using fly ash as an additive material. Utilization of additive is one method that can be applied to increase strength and stabilize the soil. Based on previous research, it was found that fly ash having higher free lime content shows higher shear strength. In Malaysia, the amount of fly ash generated by thermal power plant keeps increasing year by year [3]. According to previous work [4], the volume of fly ash would increase as the demand for power increases. Millions of tons of fly ash are produced each year due to the massive consumption of coal. The industry is facing problem to develop efficient and economical technique recycle of fly ash.

Fly ash can be utilized with some additives, and converted into a non-hazardous material and applied in eco-friendly way. Fly ash possesses a wide range of chemical composition and pH values depending on the nature of coal and process of coal burnt. Moreover the fly ash contains maximum hollow particles of lower apparent specific gravity than most of the solid particles. The affinity of non-



plastic fly ash to react with soil and reduces the plasticity of soil-fly ash mixtures was previously observed [5]. According to [6], the shear strength behavior of soil mixed with fly ash forms an important potential alternative additive to soft clay.

This paper presents physical properties of the soft clays from Sabak Bernam, the analysis of shear strength and the varying percentage of potential thermal power plant fly ash and lime additives in producing the optimum mixture that produce the highest shear strength. Fly ash is expected to improve the soft clay properties. Lime is another additive applied, which is locally available to improve soft clay characteristic.

## 2. Methodology

The soil sample tested for this study was soft clay taken from Sabak Bernam at soil depth situated 1.0 m below the surface layer. Soil sample were taken in the form of disturbed and undisturbed by using box sampler method. The additive material used in this study consist of thermal power plant fly ash and lime. Thermal power plant fly ash is a waste material of coal combustion at high temperatures and pressures in the thermal power plant. This fly ash is suitable for utilization as pozzolanic material. It reacts chemically with calcium hydroxide at room temperature to form compounds that have cementation properties in the presence of moisture. Fly ash is composed of high amount of reactive silica and alumina. These reactive elements complete the hydration chemistry of cement. On the other hand, fly ash is characterized as one of the residues created in burning chamber from the coal in electrical power plant and contains the fine particles that carried upwards with the flue gases [7].

In this study, the fly ash was collected from a power station at TNB Janamanjung Sultan Azlan Shah, Manjung in the State of Perak, and was sieved through a 425  $\mu\text{m}$  sieve in order to remove any foreign materials. Lime used in this study is hydrated lime because it is fine powder and less caustic [7]. The mixture percentage used in this research is shown in Table 1. According to [8], lime mixed with fly ash generally ranges from 12 to 30%, with fine-grained soils requiring higher percentages. Lime with fly ash ratios normally range from 1:10-1:2, with ratios of 1:3-1:4 being most common.

**Table 1.** Percentage admixture used in this study.

Sample (Soil + Fly Ash + Lime)	
Fly Ash	Lime
12%	
16%	4%
20%	
12%	
16%	8%
20%	

The physical test such as Atterberg limit, moisture content and specific gravity of the soil were performed according to British Standard (BS5930:1999). The data of these index properties were used to classify the soil in the Unified Soil Classification System (USCS). In order to prepare sample for direct shear test, standard proctor compaction were conducted to get optimum moisture content for every mixing sample with their percentage and 95% from their maximum dry density. The compaction test obtained from this study is to determine the optimum moisture content because the pozzolanic characteristics of fly ash will only react in the presence of water.

### 3. Results and discussion

#### 3.1. Index properties of soil

The physical tests were performed according to British Standard (BS1377 :1990). The data in Table 2 were used to classify the soil. On the basis of this data, the soil can be classified as CV (clay of very high plasticity) [9]. Moreover, the moisture content of soil is 104.40%. According to Barnes [2], extremely high plasticity clay is in the range of 100-200%.

**Table 2.** Summary of index properties in this study.

Parameters		Values
Moisture Content, $\omega$ (%)		104.40
Specific Gravity, $G_s$		2.45
Atterberg Limit:	Plastic limit, PL (%)	33.49
	Liquid limit, LL (%)	109.45
Plasticity Index, $PI = (LL - PL)$ %		75.96

#### 3.2. Specific of gravity fly ash

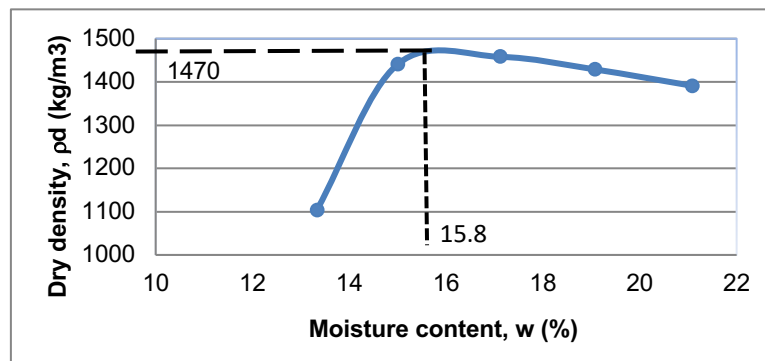
Specific gravity is the ratio of the mass of a given volume of a material to the mass of the same volume of water. The specific gravity of fly ash is 2.60 (sieve passing 425  $\mu\text{m}$ ), obtained by small pycnometer test. Meanwhile Table 3 shows comparison of specific gravity of fly ash according to previous studies. From the previous researchers and the studies, the specific gravity in Malaysia is shown to be within 1.90– 2.55. The value of specific gravity of fly ash is different due to the different nature of coal formation [10].

**Table 3.** Comparison of specific gravity of fly ash according to previous studies.

Specific Gravity, $G_s$	Reference
2.6	This work
2.51	[12]
1.90-2.55	[13]
2.06	[14]
2.3	[15]

#### 3.3. Compaction test

Compaction tests were conducted using 2.5 kg hammer 25 blows per layer with three layers (BS1377:Part 4:1990:3.5). The purpose of doing this test is to get optimum moisture content and maximum dry density for the soil and optimum moisture content for every mixture sample (soil+fly ash+lime). Figure 1 shows the compaction of soil curve. From the graph, maximum dry density,  $\rho_{dmax}$  is 1470  $\text{kg/m}^3$  and the optimum moisture content is found to be 15.8%. The maximum dry density and the optimum moisture content of admixture samples obtained from this test are shown in Table 4. The value of the result is used to make samples for direct shear test.



**Figure 1.** Compaction curve for soft clay.

**Table 4.** The maximum dry density and the optimum moisture content of admixture samples.

Admixture samples	Maximum dry density, $\rho_d \text{ max (kg/m}^3\text{)}$	Optimum Moisture Content, $\omega_{\text{opt}} \text{ (}\% \text{)}$
L4%+FA12%	1457	16
L4%+FA16%	1300	22
L4%+FA20%	1349	17.5
L8%+FA12%	1340	18
L8%+FA16%	1385	17
L8%+FA20%	1459	24.5

### 3.4. Direct shear test

Direct shear test were conducted to observe the shear strength of a soft clay when it fails due to water infiltration under a relatively high shear stress condition. Based on previous researchers [15], the strength of soft clay are within the range of 20-50 kPa. Table 5 shows a comparison of maximum shear strength between admixtures of different percentage. From the analyzed data, the optimum admixture found to increase the shear strength of soft clay to 69 kPa is soil + 4% lime + 12% fly ash. Pozzolanic characteristics in fly ash has been proven to increase of soil shear strength, thus confirms the potential of fly ash being the stabilization agent for soil.

**Table 5.** Comparison of maximum shear strength between admixtures.

Sample (Soil+Fly Ash+Lime)		Maximum shear strength (kPa)
Fly Ash	Lime	
12%		69
16%	4%	69
20%		69
12%		60
16%	8%	60
20%		60

Adding a small amount of lime (4%) in addition to the fly ash increases shear strength of soft clay. This may be attributed to the presence of hydrated lime, which ensures a quick pozzolanic reaction leading to the formation of a cemented matrix, which provides extra strength to the soil mixture. This

indicates that the quantity of fly ash up to optimum content can induce pozzolanic reaction and cemented materials effectively contributing to shear strength increase, while the additional quantity of fly ash acts as unbounded silt particles, which has neither appreciable friction nor cohesion, causing a decrease in shear strength [16]. However, increasing the percentage of fly ash did not show any significant increment in the shear strength.

#### 4. Conclusion

All the tests conducted in this study were to determine the effectiveness of fly ash in increasing shear strength of soft clay. Based on the findings discussed, fly ash, the available local material shows the ability of being an additive material in soil strength. Within the range of 20 kPa-50 kPa, an increment in shear strength can be seen in every sample tested compared with the shear strength of original soft clay from previous study [15].

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