

## PAPER DETAILS

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## Effect Of Fly Ash And Its Curing Time On Specification Of Fly Ash – Silty Soil Mixture

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### Abstract

In this study, the specification of silty soils with fly ash and effect of curing time in mixture of silty soil with fly ash type C of has been researched. In this paper tests such as determination of water content, Atterberg limits, Standard proctor and Undrained Unconsolidated Triaxial (UU) tests has been done. By adding different amount of fly ash (3%, 5%, 7% and 10% ) and curing time of (1, 7, 14) days, the internal angle of friction ( $\phi$ ) and shear strength ( $\tau$ ) has been increased. The maximum increase occurred by adding 3% fly ash in 7 days. Atterberg limits on different combination of soil- fly ash show almost same results and do not have noticeable changes.

**Keywords:** fly ash, curing time, internal angle friction, shear strength.

### 1. INTRODUCTION

Soils are significantly effective in the stability of structures and roads built on them. Environmental and climatic conditions can cause soil properties to change. Different soils have different features. The engineering properties of the soil can also vary depending on the type of soil, topography conditions, degree of stiffness, water content, consolidation pressure, loading and drainage conditions [1]. Therefore, the soil used at the construction site may not always have the desired properties. Today, due to the rapidly increasing construction and decreasing construction soils, it is compulsory to build structures on almost any type of soil. Especially in transportation and road structures, many weak and problematical soils must be crossed. Due to technological and economic reasons, it is not an appropriate solution for the construction site to be replaced or to use more appropriate soils instead of the soil that does not have the desired features. On the other hand, increasing industrial wastes cause environmental pollution and the problem of disposal of these wastes is a common problem in all countries. These materials can be construction materials such as lime, cement and artificial polymers, or fly ash, metal slag, used car tires that emerge as industrial waste [2]. It is possible to use waste materials in building and road construction. The use of wastes as a filling material in the construction industry helps to preserve nature due to the reduced use of clay and other natural materials. In recent years, wastes have been used as alternative additives in the stabilization of soils and also a more economical solution to the improvement of the properties of problematical soils. Soils that create serious problems in the appearance of the variable

presence of water, although they do not create a problem under ordinary conditions, are called problematical soils [3].

The main objectives of soil stabilization methods are to increase the bearing strength and strength of the soil, to reduce settlements, to reduce deformations due to stress, to reduce swelling potential, to reduce permeability, to reduce liquefaction potential in earthquakes, to evaluate waste materials, to store waste and to protect groundwater. In this study, various soil stabilization methods were investigated and an experimental study on stabilization with fly ash was carried out. Fly ash is a material appropriate for use in road infrastructure construction. Description of fly ash According to TS 639, it is a combustion residue in the form of powder or ground coal or lignite coal as a result of burning at high temperatures and drifted with flue gases, in the form of silica and alumino-siliceous powder [4]. Fly ashes are materials that can be used as pozzolan because of their pozzolanic properties [5]. The presence of binder materials such as ground blast furnace slag, silica fume, metacaolin and rice husk ash compared to the amount of fly ash is limited [6]. Therefore, the most commonly used pozzolan type is fly ash [7]. Fly ash is darker gray than cement, very fine grain, soft material to be touched by hand [8]. The lightness of the color depends on the coal it is obtained and its burning feature. Fly ash obtained from lignite coal is more brown. It is the unburned carbon inside which gives the fly ash black color when the combustion is not complete. Fly ash implementation on weak and problematical soil is a widely used method and has been used for many years to successfully increase the strength and hardness properties of the soil [9]. Fly ash is an appropriate alternative in soil stabilization because it decreases economic and environmental effects. In recent years several investigations have been performed to show the effect of flyash on clayey soil. Nazaroghlu and Dehghanian showed that addition of fly ash decreases the swelling of clayey soils. It was also concluded that by addition of 15% of the additive, the consolidation rate and the permeability (k) reduces significantly. It can be concluded that the best and optimum percentage of additive is 15% and higher amounts does not affect the behavior of mixture [10].

In this research paper, type C fly ash which is taken from Çatalağzı thermal power plant is used in combination with silty soil samples. C type fly ashes are high-limestone ashes, and they have pozzolanic properties. Soil samples used for this study are taken from Şile, Istanbul and has been identified as high plastic silt (MH) according to the Unified Soil Classification System (USCS). The main purpose of this research is to investigate the effect of adding different amount of fly ash to the silty soil and as well as effect of curing time, in what percentage and for how many days the internal friction angle ( $\Phi$ ) and shear strength ( $\tau$ ) would find its highest increase. Based on the laboratory test results, effect of curing time on specification of fly ash – silty soil mixture is discussed in this research.

## 2. MATERIAL AND METHOD

Silty soil and fly ash type C are the materials that have been used for this study. Type C fly ash contains 15% to 35% CaO and fly ash is obtained by combustion of non-bituminous coal and other lignite. The type of fly ash is generally determined by ASTM C618 [11]. By adding different percentage of fly ash 3%, 5%, 7% and 10% and curing time of ( 1, 7, 14 ) days, we have tried to increase the shear strength ( $\tau$ ) of the mixture which maximum increasement happened by adding 3% fly ash in 7 days. In this research experiment such as determination of water content, Atterberg limits, proctor and Triaxial test are done. All tests were done in according to TS 1500, TS1900-1 and TS1900-2 standards [12,13,14]. Notations related to the test samples are given in Table 1.

Table 1. Notations related to the test samples

Mixing ratios of tests samples	Notations
Silt	S
Silt with 3% fly ash	SFA/3
Silt with 5% fly ash	SFA/5
Silt with 7% fly ash	SFA/7
Silt with 10% fly ash	SFA/10

## 2.1 Determination of specific weight

It is defined as the ratio of grain volume weight to unit volume weight of water. The specific weight, also known as the unit weight, is the weight per unit volume of a material. For defining the specific weight, in coarse-grained soils, glass bottles which have jar-shaped having volume of 1 liter is used but for fine-grained soils, glass bottles which have smaller volumes (50-100 cm<sup>3</sup>) is used which is called pycnometer. A commonly used value is the specific weight of water on Earth at 4°C, which is 9.807 kN/m<sup>3</sup> or 62.43 lbf/ft<sup>3</sup>. This experiment is done twice and the average of experiments is our specific weight.

Table 2. Specific weight of the samples

Soil Type	Silt
Average (Mg/m <sup>3</sup> )	2.6

## 2.2 Proctor compaction test and specification of water content

The aim of this test is to specify the optimum water content ( $\omega$ ) and maximum dry unit volume weight of the sample ( $\gamma_d$ ). The test was prepared in accordance with TS 1900-1 standard. The results obtained from the experiment are given in figure 1.

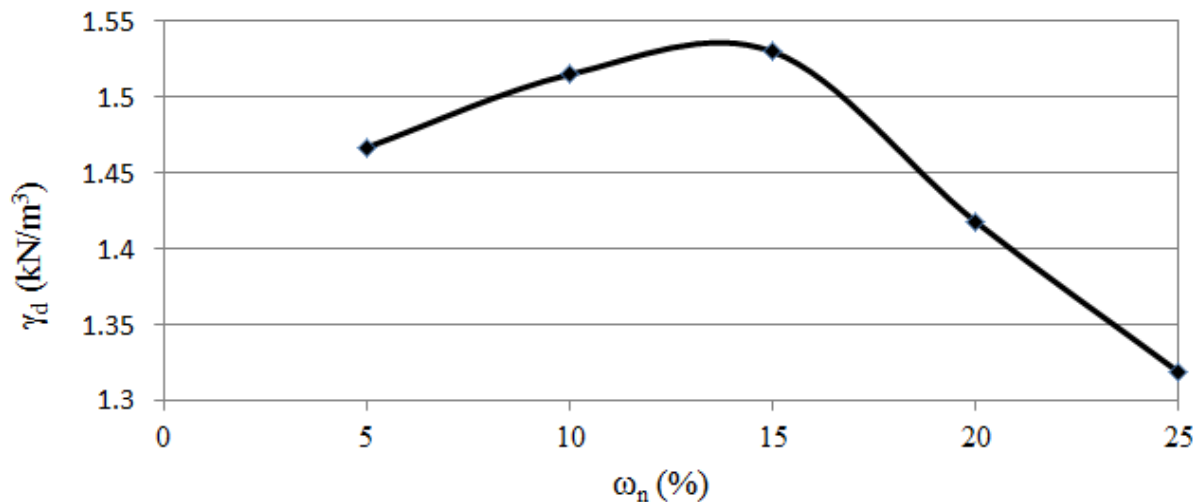


Figure 1. grain size distribution curve of silty soil material

Table 3. Maximum dry unit volume weight

Water percentage	5%	10%	15%	20%	25%
Weight of Mold+sample (g)	3300	3407	3497	3460	3397
weight of compacted soil (g)	1461	1568	1658	1621	1558
Wet unit weight (gr/cm <sup>3</sup> )	1.548	1.661	1.756	1.717	1.650
Dry unit weight (gr/cm <sup>3</sup> )	1.467	1.515	1.530	1.418	1.319

Table 4. Determination of water content

Water percentage	5%	10%	15%	20%	25%
Cap No	1	2	3	4	5
Wet sample+cap (g)	148	143	144	147	166
Dry sample+Cap (g)	143.10	135.70	131.87	131.45	143.58
Weight of Water (g)	4.90	7.30	12.13	15.55	22.42
Weight of Cap (g)	53.94	60	53.31	57.64	54.20
Water content (g)	5.50	9.64	15.60	21.07	25.08

At the end of the experiment, the maximum dry unit volume weight was found 1.53 gr/cm<sup>3</sup> and the optimum water content was 15.6%.

### 2.3 Atterberg Limits

The different behavior of soils depending on the water content has been described experimentally by Atterberg. The boundary water contents defined by Atterberg are called Atterberg boundaries or consistency boundaries. At the liquid limit, the floor may slowly flow under its own weight. In the case of plastic, the desired shape can be easily given to the floor. In the semi-solid state, the desired shape is hardly given to the ground, cracking occurs on the ground. In the solid state, the ground cannot be shaped. According to ASTM D 2487 the classification of soil has been identified MH which is high plastic silt. The specification of high plastic silt which is used in the study are shown in table 5.

Table 5. Specification of high plastic silt

USCS Classification	MH
Liquid limit , LL (%)	58
Plastic limit, PL (%)	38
Plastic index , PI (%)	20
Optimum water content, w <sub>opt</sub> (%)	15.6
Specific weight, G <sub>s</sub>	2.6
Maximum dry density, $\gamma_{kmax}$ (gr/cm <sup>3</sup> )	1.53

In this study, liquid limit and plastic limit test results on sample mixtures are given in Table 6. At the end of the experiments, the Plasticity Index (PI) does not change too much with increasing fly ash ratio.

Moreover, it can be seen that 3% fly ash can reduce the PI and consequently the swelling of the soil approximately 40%.

Table 6. Atterberg limits of the samples

Test Samples	Liquid Limit (%)	Plastic Limit (%)	Plasticity
S	58	38	20
SFA/3	46.83	32.75	14.08
SFA/5	47.06	31.29	15.77
SFA/7	47.33	31.10	16.23
SFA/10	46.82	30.47	16.35

## 2.4 Triaxial( UU) Test

After the samples were mixed and compacted at optimum water contents, 3 sets of three-axis experiments were performed. In each set of experiments, hydrostatic pressure ( $\sigma_3$ ) was determined as 50,100 and 150 kPa. Since the ground is under the effect of three-axis stress, the closest shear strength parameter is obtained from field tests. Therefore, the most common test method to determine the shear strength is the triaxial test [15-16]. Generally, the triaxial pressure test is carried out in three ways: Consolidated - drainage test (CD), consolidated - undrained test (CU test) and unconsolidated - undrained test (UU test). In soil mechanics, critical stress caused by very fast loading is important. The best representation of this situation in the laboratory environment is the UU test. The cohesion (C) and the internal friction angle ( $\phi$ ) calculated at the end of the experiments are shown in Table 7.

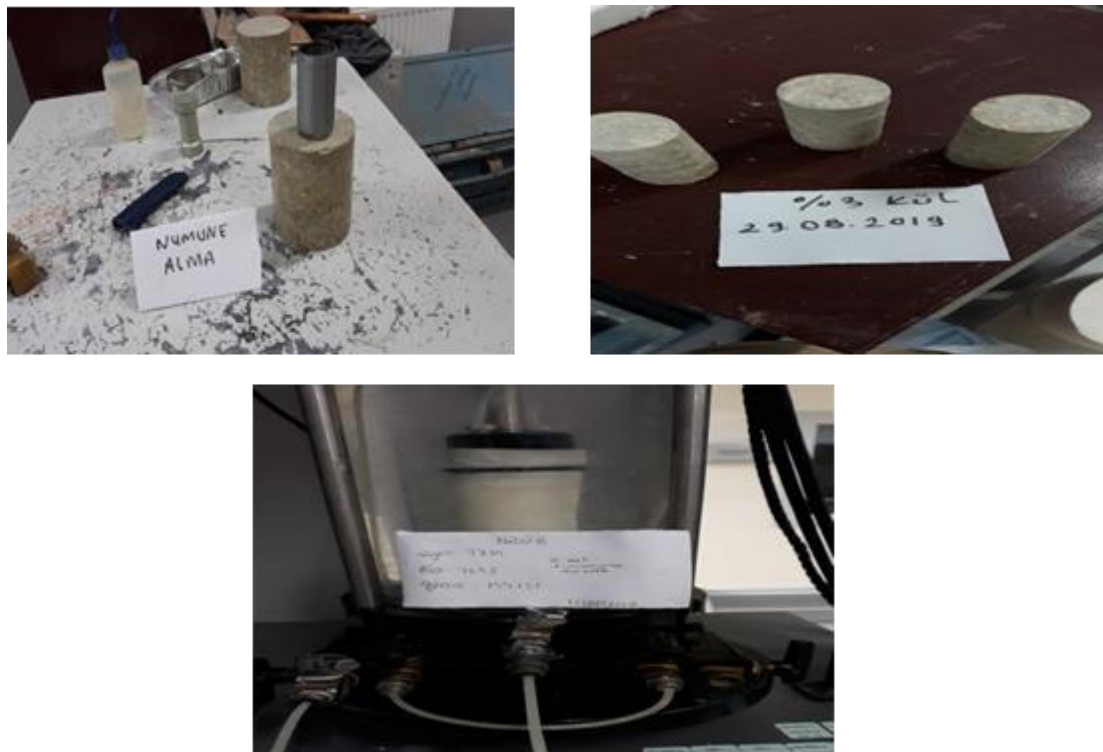


Figure 2 : Sample preparation of Undrained Unconsolidated Triaxial (UU) test

Table 7. Triaxial compressive strength test with different ratios of fly ash and silt

Fly ash-silt ratio	1 day	7 days	14 days
100% silt	$\phi=26.17^0$ C=22.83 kPa	Same as 1 <sup>st</sup> day	Same as 1 <sup>st</sup> day
3% fly ash	$\phi=24.33^0$	$\phi=30.85^0$	$\phi=15.36^0$
%97 silt	C=67.9 kPa	C=49.2 kPa	C=87.93 kPa
5% fly ash	$\phi=17.1^0$	$\phi=19.9^0$	$\phi=12.9^0$
%95 silt	C=10.12 kPa	C=20.46 kPa	C=48.2 kPa
7% fly ash	$\phi=14.3^0$	$\phi=15.63^0$	-
%93 silt	C=29.45 kPa	C=49 kPa	-
10% fly ash	$\phi=11.5^0$	$\phi=15.13^0$	-
%90 silt	C=28.75 kPa	C=31.8 kPa	-

In the table 7, the internal angle of friction ( $\phi$ ) has reached its maximum by adding 3% fly ash in 7 days but the cohesion(c) is unstable. For more clarification and more assurance we also calculated the shear strength ( $\tau$ ) to find the exact increase by using Mohr coulomb formula  $\tau = \sigma \tan(\phi) + c$ . The results are shown in table 8.

Table 8. Shear strength of the tests with different ratios of fly ash and silt

Fly ash-silt ratio	1 day	7 days	14 days
3% fly ash	$\tau=264.93$ kPa	$\tau=337.415$ kPa	$\tau=196.82$ kPa
%97 silt			
5% fly ash	$\tau=75.485$ kPa	$\tau=158.24$ kPa	$\tau=120.11$ kPa
%95 silt			
7% fly ash	$\tau=75.24$ kPa	$\tau=143.66$ kPa	-
%93 silt			
10% fly ash	$\tau=73.77$ kPa	$\tau=101.21$ kPa	-
%90 silt			

In the table 8 , maximum shear strength( $\tau$ ) is found by adding 3% fly ash in 7 days and there was no need to calculate the shear strength for 7% and 10% for 14 days.

#### 4. RESULTS

In this study, Determination of water content, Atterberg limits, Proctor test and Triaxial (UU) tests were performed. By increasing amount of fly ash in silt, the Plasticity Index (PI) does not have remarkable change. Hence it can be seen that adding 3% fly-ash decreases PI to nearly 40%. Moreover, It can be concluded that adding higher ratios of fly-ash does not reduce PI. In Triaxial (UU) test the internal friction angle ( $\phi$ ) and shear strength ( $\tau$ ) has been increased which maximum increase happened by adding 3% fly ash to silty soil. At higher ratios, the shear strength decreased considerably. It means that adding higher values of flyash (higher than 3%) has a negative effect on soil strength. On the other hand, it was

observed that fly ash reduces friction angle. Comparison of 7-day curing time reveals that time effect has a positive effect on shear strength of soil- fly ash mixtures in all proposed ratios. Furthermore, the highest shear strength is achieved in 3% fly ash- silt mixture. It can be observed that 14-day curing time has a negative effect regarding 7-day curing time.

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