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Influence of Fly Ash Addition on Behavior of Soft Clayey Soil

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K E Y W O R D S

Soft soil, Fly ash, soil treatment, Stabilization

A B S T R A C T

This paper investigates the impact of the fly Ash addition on the Geotechnical properties of soft soil as well as chooses the optimum percentage added of fly ash. To understand the behavior of fly ash mixed with soil, a number of laboratory experiments testing conducted on clayey soil-fly ash mixture in several percentages (5,10,15,20,25, and 30%) as Atterberg test, Specific gravity test, compaction test, California Bearing Ratio (C.B.R) Test, Unconfined Compressive Strength (UCS) Test, Consolidation Test. Test results indicate rising in plastic limit and liquid limit as fly ash adding. Specific gravity decreased essentially by adding fly ash. Whereas there was falling on the Dry unit weight value with the contract to the decreasing in the water content. The CBR and UCS values were increased with increasing fly ash content. 20% was the optimum fly Ash content. This study also benefits the effective use of fly ash and thus a cost-effective method for improving the soil properties.

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1. Introduction

Construction of buildings or any structures on problematic ground exhibits some risk due to the fact these soils have undesirable shear strength and excessive compressibility [1]. Soft soils are recognized with a low value of undrained shear strength which about (cu < 40 kPa) and excessive compressibility values. Those soils are covering almost the southern Iraqis area. From many area data was collected which demonstrated that The Cu below 30 kPa in Basrah Governorate. It recorded about below 40 kPa in Missan and Nasirya Governorates, however, Excessive compression indices about 0.3 were also pointed [2].

Prabakar et al. [1]. Investigates fly ash impact on soil's strength behavior. Results confirmed that the fly ash addition led to make the soil dry density low. Decreases in dry density trending as 15–20%. The

void ratios and porosity vary by the fly ash percentages increasing in soils. More fly ash till 46%, leads the void ratios in clayey soils to increase by 25%. The shear strength of the fly ash-soil mixture is enhanced because of the addition of fly ash. As fly ash content increases, the shear strength is increased in soil. The shear stress is increased non-linearly with an increase in fly ash content.
Reyes and Pando [3] investigate the use of CFBC fly ash for soil improvement. Results show that when CFBC fly ash adding to soft soils provides good ground properties like strength and stiffness.
Yaseen et al. [4] conducted the bearing capacity of shallow foundation build on weak soil stabilized using adding fly ash the results indicate a good enhancement in the trending of foundation with added fly ash. Studied showed the improvement of clayey soil when mixed with lime and fly Ash [5]. The test results clarified when flying Ash mixed with soil led to improved Geotechnical properties.
Ozdemir [6] investigate the improvement of soft soil in terms of increase bearing capacity by mixing with fly ash. Results indicated by using Class C fly ash there was a better performance in bearing capacity of Elmadağ soil and swelling decreased. The (CBR) test of treated and untreated soil samples were investigated by [7]. Results showed an increase in the CBR value of marine clay and realized A better results when using such improved soil in pavement construction as subgrade and also for several types of foundations with 25% fly ash and 9% lime mixing proportion. Researchers [8] showed the impact of fly ash on the strength behavior of fine soil. Several tests were performed on soil-fly ash mixture with (2, 4, 6, 8, and 10%) content which Clarify that the Maximum dry density value (MDD) increased as increasing fly Ash content up to 5.81% by 6%. Whereas the UCS at 6% fly Ash content was increased about 10.9%. In addition, the use of fly ash as the additive to soil represent a more effective way to become the soil much stable.

2. Soil and Used Material

I. The Soil Properties

A brown clayey soil was gathered from Al-Nahrawan city east of Baghdad. Standard tests were carried out to obtain the properties of the soil used. Results are summarized in Table 1, the grain size distribution of the soil used which represents the following percentages: Rounding the values as (7 % sand, 44% silt, and 49% clay) as illustrated in Figure 1. The soil is classified as CL according to the USCS.

Table 1: Physical properties of the soil used

Property index	Value index	Standard index
Liquid Limit %	32	ASTMD4318
Plastic Limit %	17	ASTMD4318
Plasticity index %	15	ASTMD4318
Specific gravity	2.69	ASTMD854
Gravel larger than 2mm)	0	ASTM D422
Sand (0.06 to 2mm)	7.02	ASTM D422
Silt (0.005-0.06mm)	43.98	ASTM D422
Clay (less than 0.005 mm)	49	ASTM D1557
Ma ximum moisture content	16.7	ASTM D1557
USCS	21	

II. The Fly ash used

The fly ash used is obtained from the south of Baghdad thermal power plant. The chemical composition is given in Table 2. According to [9]. The fly ash could be classified as Class C fly ash. Figure 2 illustrates the fly ash used in the study.

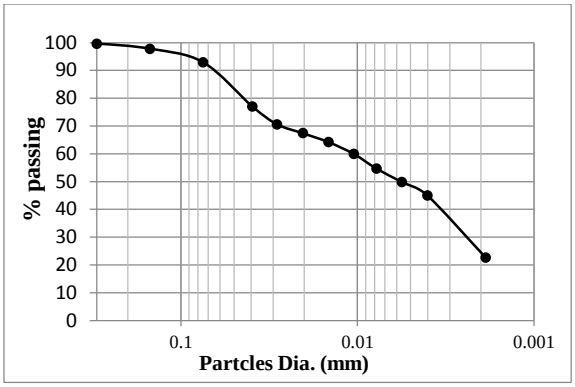

Figure 1: Grain size distribution of the soil used

Table 2: Chemical composition of fly ash used

Compositions	Value (%)
SiO_2	32.16 %
Fe_2O_3	6.13 %
Al_2O_3	18.37 %
TiO_2	<0.01 %
CaO	28.23 %
MgO	8.16 %
CO_3	0.34 %
Na_2O	2.83 %
K_2O	3.19 %

Figure 2: Fly ash used

3. Sample Preparation

In this work, soil samples dried out and being through a 425-micron sieve before getting used during this study. The prepared samples are then mixed with the predefined amount of ash and water. A manually mixing was used in this work and the tests were performed with respect to standard procedures. Several Geotechnical tests include (Consistency limit Test, specific gravity Test, compaction Test, CBR Test, USC Test, Consolidation Test). were performed on seven specimens, as untreated and treated in varying fly Ash content as (5, 10, 15, 20, 25, and 30)%. The mixing process recognized as a weight proportion of weight of the untreated soil (soft Soil). CBR, UCS and Consolidation tests conducted at maximum dry density and OMC of every test specimens.

4. Test Results and Discussion

I. Consistency Limits Results

The Atterberg limits of seven specimens include unmixed and mixed soil in various fly Ash content was resolved and the results were given in Table 3. While Figure 3 & 4 illustrate the liquid and plastic limit of soil influenced by mixing with fly ash. It can be observed from these figures that an increase in liquid limit and the plastic limit values The fly ash added led to rising in the (L.L) value from 32% to 54.61%,

(P.L) increased from 17.31% to 21.97% at fly ash content 20%. That was because of the imparted lime content from fly ash to the soft soil that makes the plastic limit value increased as fly ash content increased, that the total water content soil reduced which further led to reduce the thickness in the diffuse layer and alteration of particles of the clay, and finer soil particles replaced by the coarser particles of fly Ash. Clearly, to notice that didn't any plasticity value at fly ash percent (25% and 30%) that's because the soil becomes like granular soil and mixture soil becomes more dispersed structure. Finally, this result agrees with the result obtained by [6, 10].

Table 3: Atterberg test result values for samples with the various fly-ash percentage

% Fly ash	Liquid limit%	Plastic limit%	Plasticity Index%
0	32	17.13	14.87
5	42.3	20.05	22.25
10	43.9	20.8	23.1
15	43.9	21.7	22.2
20	46.4	21.97	24.43
25	52.1	----	52.1
30	54.6	----	54.6

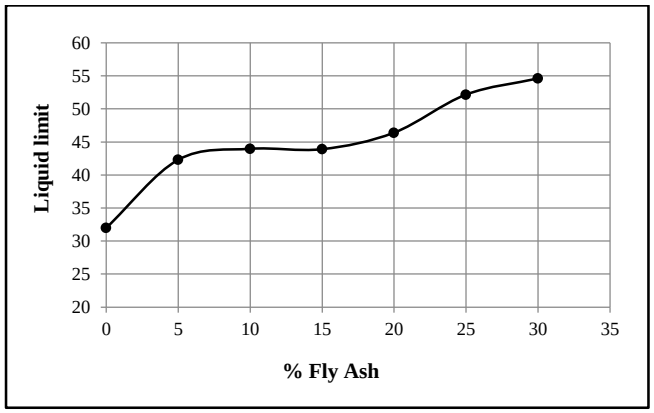

Figure 3: Liquid limit variation with fly-Ash %

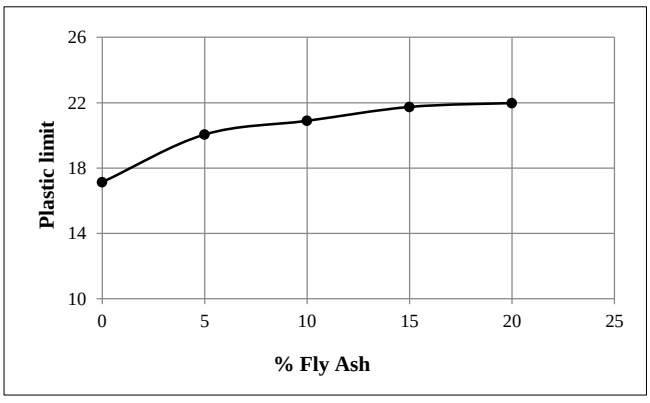

Figure 4: Plastic limit variation with fly-ash%

II. Specific Gravity Results

Seven samples in different mix proportions of fly ash were conducted to examine the Specific Gravity. The results were plotted in Figures 5. It can be observed from the figure the more fly ash adding lead to the decrease in the specific gravity value and that agree with the findings of [1, 11, 12]. The reason associated with the rearrangement of soil particles with the addition of fly ash clayey content is diminishing while silt content is expanding. [13] observed close results.

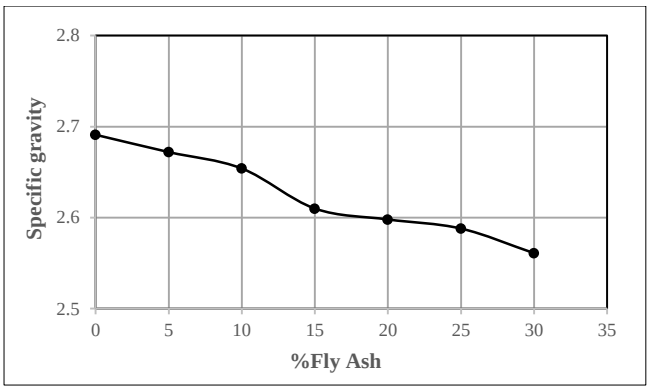

Figure 5: variation of specific gravity with fly-ash%

III. Compaction Test

Seven specimens as unmixed and mixed soils with many contents of fly Ash which prepared in order to trace the impact of fly Ash on the compaction. As shown in Figure 6, As high as the content of fly Ash dry density value become less. That imputed to the weight of fly ash, which is considered as light material. Furthermore, it has a large number of gaps which semi-spheres in shape and can be used like replacement fill materials in soft soil mixtures led to less density or the closing up of clay particles which occurred with the appearance of adequate moisture prompting increment in voids and as result falling in dry density value. Whereas it was built up in the OMC of the soil with rising in fly Ash contents. That's associated with fly ash react with the mineral of soil, which formed a cruel gel silicate that bonds the particles of Mixture, or because of the closed up of voids that presence in the sample mixture for more water after perfect the cation exchange response then during applied compaction the voids are occupied with the aid of more water. The same results were conducted by [11, 14, 15].

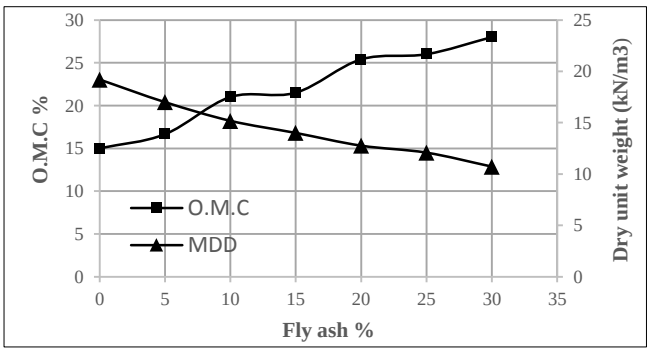

Figure 6: O.M.C and Dry unit weight with Different fly Ash content.

IV. C.B.R Test (Unsoaked Samples)

Samples were prepared as unmixed and mixed with multi percentages of fly ash to recognize fly Ash impact. Test carried out at optimum moisture content and maximum dry density for remolded compacted soils. With many contents of fly ash, the relationship between the load and penetration shown in Figure 7 CBR value is raised as increasing the content of fly Ash. At 20% fly Ash content, there was noticed increased after which its start decreasing as showed in Figure (8). The results of CBR tests are listed in Table (4). Which are in a well close with those recommended by [14]. An increment in the CBR value was anticipated due to the sedative forming of adhesion gel between minerals present in soil and the fly ash. Calm reduces the CBR is appropriate to more fly ash content which not led in the reaction, that hence intestinal areas in the pattern yet, therefore, reduces compound within treated samples.

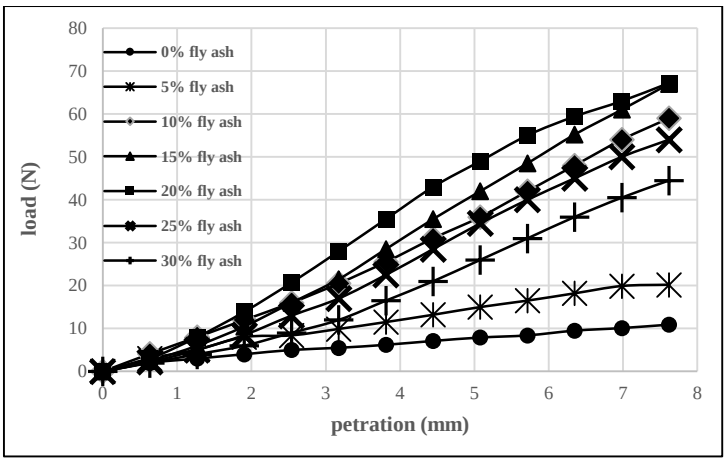

Figure 7: load versus penetration with different fly Ash percentages

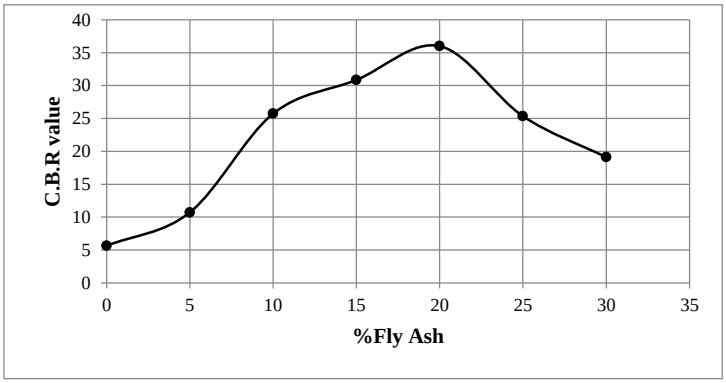

Figure 8: CBR Variation with fly Ash %

Table 4: CBR values with different fly Ash %

% Fly ash	CBR value	%increases
0	5.64	----
5	10.72	90
10	25.73	356.2
15	30.86	447.1
20	36	538.3
25	25.35	349.6
30	19.1	238.85

V. Unconfined Compressive Strength (UCS) Test

Untreated and treated samples with variable mix proportion of fly Ash. Figure 9 represents the impact of the fly ash addition on the value of unconfined compressive strength. That result agrees with the result obtained by [16, 17]. It can be noticed that the unconfined compressive value increases with increase the fly ash content. Beyond 20% fly, the UCS values were decreased. The pozzolanic reactivity occurred between minerals of soil and calcium aluminates of fly ash that lead to produce cementations properties. That reason for rising the UCS values. Whereas the UCS value becomes less that's because of the pozzolanic reaction that occurred in soil. The reaction between calcium presence in fly Ash and clay mineral that led to reduce the size of the diffused water layer surrounding the clay particles. This reduction in this layer makes soft soil become more close to another that led to the closing up of soil particles, that made soil behavior as sand or silt like. Table 5 listed the UCS test results.

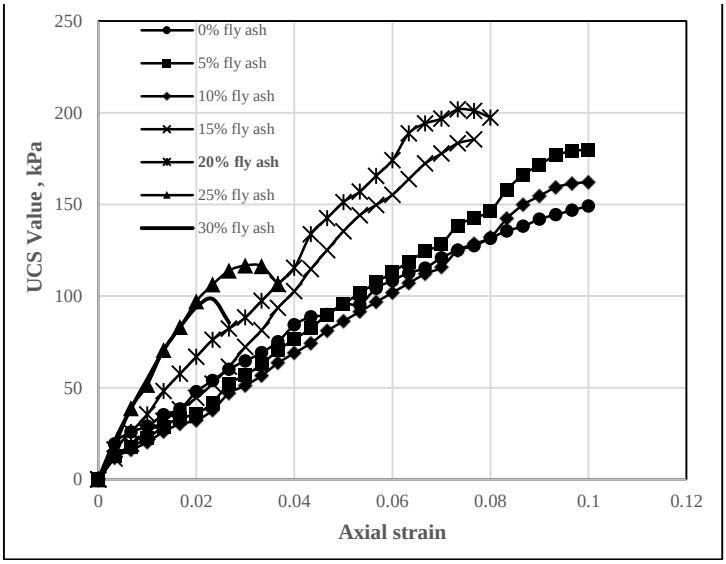

Figure 9: Axial strain versus unconfined value with different fly Ash %.

Table 5: the results of UCS Test

% fly ash	UCS value (KPa)
0	149.1
5	179.86
10	154.7
15	185.35
20	201.03
25	116.22
30	98.38

VI. Consolidation Settlement Test

Consolidation test carried out for samples; as unmixed and mixed with many contents of fly Ash. Result of the tested samples represented as effective stress versus void ratio as shown in Figure 10. Table 6 listed results. It can be seen from it that the compression index Cc reduced as fly ash content build-up also the value of (S_{cf}) final consolidation settlement of soil and the optimum content is at 20% Fly Ash which results in compression index =0.0842 and final consolidation settlement =0.638 mm there is a slight raising beyond this percent. Fly ash affect significantly in reduction Cc and f Scf of each sample, that because of the pozzolanic reaction between fly ash and minerals present in the soil. The results are similar that obtained by [18, 19].

Table 6: Consolidation Test Results

%Fly Ash	C_c	C_r	a_v	mv	Scf (mm)
0	0.2476	0.0764	0.277	0.194	1.7416
5	0.147	0.0654	0.3388	0.221	1.572
10	0.1612	0.0093	0.294	0.185	1.3369
15	0.1249	0.0541	0.2642	0.165	0.639
20	0.0842	0.0481	0.3333	0.197	0.638
25	0.1662	0.0468	0.3888	0.236	0.8349
30	0.1486	0.0757	0.35	0.212	1.2259

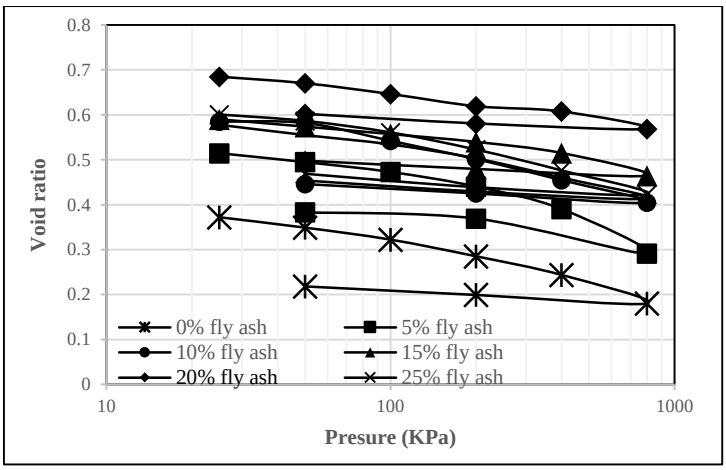

Figure 10: Effective stress versus void ratio with different Fly Ash %.

5. Conclusions

Based on different experimental tests conducted on soft soil specimens treated by various Fly Ash contents from results the main conclusions drawn through the experimental work are summarized:

1- There is a decrease in the specific gravity of soil with increasing fly ash content due to its low specific gravity.

2- For soft soil-fly ash mix. there is an increase in the plastic and liquid limit value by about (32 - 54.6)% and (17.3 to 21.97)% respectively.

3- The value of the maximum dry density (MDD) was downward whereas optimum water content (OPC) reaches the peak value for soil as fly ash percentage increased .

4- It is noticed that UCS increases by about (149.1 to 201.03) kPa with fly ash percentage increased to 20%. which decreased the (UCS) value as increasing the Fly Ash content.

5- CBR value increased about (90.1-538.3%) as fly ash percentage increased up to 20%, after that as Fly Ash content increased the CBR decreased.

6- Soil mixing with Fly Ash lead to improved compressibility index CC.

7- 20% is the Optimum content which noticed from CBR and UCS tests. which added to problematic soft soil in order to improve the Geotechnical properties.

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