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CORRELATION BETWEEN STABILIZED PLASTIC SOIL PROPERTIES AND STABILIZER CONTENT

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ABSTRACT

This study deals with a development of correlations between the stabilized cohesive soil properties and stabilizer content using lime, fly ash, and lime with fly ash. Results of cohesive soil properties are selected from different published studies before and after stabilization. Index properties and strength properties are considered for developing correlations with the stabilizer content. The developed correlations provide a simplified and instant selection of stabilizer type and content for a particular engineering purpose.

KEYWORDS: Cohesive soil. Lime, Fly ash, Compressive strength, Maximum dry density, Optimum moisture content.

INTRODUCTION

Soil is naturally formed materials used as a natural foundation for all structures. The soil properties can be improved using stabilization by additives like cement, lime fly ash, bitumen, etc. One of the main factors for selection stabilizer is the soil properties. Stabilization using lime, fly ash and lime with fly ash is an effective process for improving both workability and strength of cohesive soils [1].

A short term reaction including cation exchange and flocculation taken place to reduce the soil plasticity with lime treatment. In this case, the lime is the strong alkaline base, which is case of Base Exchange. Calcium ions remove sodium, potassium and hydrogen cations and also change electrical charge density around the clay particles. This reaction causes increase in binding particles together and is the reason behind the process of flocculation and aggregation with subsequent drop of soil plasticity. A long term pozzolonic reaction is taken place to increase the strength and maintain a stable lime stabilized soil state [2].

Many studies indicated a drop of soil plasticity by lime treatment. The degree of reactivity and reduction in plasticity depends on the mineralogical properties of soil and the lime percent treated with [3, 4, 5].

Studies have been also conducted to determine the effect of lime on the unconfined compressive strength of stabilized cohesive soil. An increase of the strength was determined with lime treatment, providing that as the lime content increasing the strength will increase up to a maximum value corresponding to optimum lime content, above which the strength will be reduced [3,4].

Treatment of cohesive soil by fly ash has been studied by many investigators. The soil plasticity was found to decrease with increasing the fly ash content. On the other hand, the strength of stabilized soil as an unconfined compressive strength or California Bearing Ratio (CBR) found to improve remarkably with the addition of fly ash [4, 5, 6].

METHODOLGY

In order to develop a correlation between the stabilized soil properties and the stabilizer content, thirteen soils of cohesive nature were selected from the literature and considering a total of thirteen different cases of stabilized soils. A process of statistical analysis, regression and fittings are used for the objectives of this study.

Lime and fly ash as a single stabilizer are considered with different percentages. Lime with fly ash is also considered for stabilized soils of 3% and 5% lime having different percentages of fly ash.

The added percentages of lime used in correlation ranged as (0 – 12%), while the fly ash ranged as (0 – 30%). The properties of soils before and after treatment are shown in Table (1), Table (2), and Table (3). In general the range of natural soil properties are as follow:

- Plasticity Index (P.I): 29% - 50%
- Optimum Moisture Content (OMC): 20% - 29%
- Maximum Dry Density (MDD): 12.9 – 15.8 kN/m^3

Table 1.Results of effect of lime on soil properties

Soil No.	Ref. No. from which soil is taken	Lime %	P.I %	OMC %	MDD kN/m^3	UCS kN/m^2
1	3	0	37	24.3	14.3	283
		3	24	22	15.0	406
		6.5	10	19.2	15.6	1560
2	3	0	41	25.7	15.3	237
		3.5	27	22.2	15.9	546
		7	11	18.9	16.2	1920
3	3	0	31	29	12.9	357
		3	22	26.6	13.4	641
		6	10	23.1	14.3	2015
4	3	0	50	28.8	13.8	154
		3.5	27	25.3	14.9	411
		7	9	22.4	16.9	1130
5	3	0	32	20	15.8	267
		2.5	25	18.1	16.1	386
		5.5	9	16.4	16.7	1814
6	4	0	48.4	24.3	14.94	31.3
		2	26.3	23.6	15.54	108.1
		2.5	22.4	25.4	14.78	117.8
		3	19.3	26.2	14.56	87.0
		4	17.7	26.6	14.47	79.3
7	5	0	29.32	25	15.1	101.50
		2	20.34	25.1	15.1	113.12
		4	19.98	26	14.9	134.56
		6	18.73	27.3	14.8	138.83
		8	15.54	28.2	14.8	167.33
		10	15.07	28.5	14.7	216.93
		12	15	29.3	14.6	254.03

Table 2. Results of effect of fly ash on soil properties

Soil No.	Ref. No. from which soil is taken	Fly ash %	P.I %	OMC %	MDD kN/m^3	UCS kN/m^2
1	6	0	37.6	14.24	16.8	114
		15	41.31	14	16.7	122
		20	41.65	14	16.9	123
		30	39.57	14	17.1	120
2	7	0	8.63	8.9	21.1	388
		3	5	9	20.7	410
		5	11.3	8.2	23.1	444
		6	9	10.2	23.5	888
		9	9	9.3	22.1	488
3	8	0	38	16	16.6	38.87
		5	35.10	21.4	15.7	161.5
		10	25.21	16	16.4	478.0
		15	17.64	20	15.7	192.0
		20	31.00	20	15.4	182.0
		25	30.50	-	-	-
4	9	0	23.3	16.66	19.3	1299
		5	18	17.44	19.4	987
		10	12.64	19.13	18.6	1415
		15	14.33	16.88	17.9	593
5	10	0	43.9	12.4	17.8	152
		5	34.4	13.1	17.1	167
		10	31.6	14	16.9	225
		15	31.5	14.7	16.8	254
		20	29.2	15	16.7	278
		25	25.3	14.5	16.7	290

Table 3. Results of effect of lime with fly ash on soil properties

Soil No.	Ref. from which soil is taken	Lime %	Fly ash %	OMC %	MDD kN/m^3
1	11	3%	5%	14.3	19.44
		3%	10%	21.54	16.16
		3%	15%	26.5	14.90
		3%	20%	28.0	14.80
2	12	5%	5%	16.2	17.1
		5%	10%	16.3	17.0
		5%	15%	16.4	16.85
		5%	20%	17	16.95
3	13	5%	5%	16.8	17.3
		5%	10%	17	17.4
		5%	15%	16	17.2
		5%	20%	17.2	17.5
		5%	25%	16.5	17.0
4	14	5%	5%	15.6	16.8
		5%	10%	16.7	16.6
		5%	15%	16.8	16.5
		5%	20%	16.8	16.4
		5%	25%	16.6	16.2
5	15	7%	15%	24.3	14.89
		7%	20%	28.5	14.15

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RESULTS AND DISCUSSION OF RESULTS

Effect of lime

Effect of lime on soil plasticity behaviors

The results of effect of lime on the soil plasticity are shown in Table (1) and Figure (1). It can be seen that as the lime content increase the soil plasticity index decreases. In general the range of reduction for the used lime contents is (49% - 82%). The relation between lime content and plasticity index is determined as:

$$P.I = 36.902\, e^{-0.177\, L} \quad (1)$$

Where:
P.I - Plasticity index in percent
L - Lime content in percent

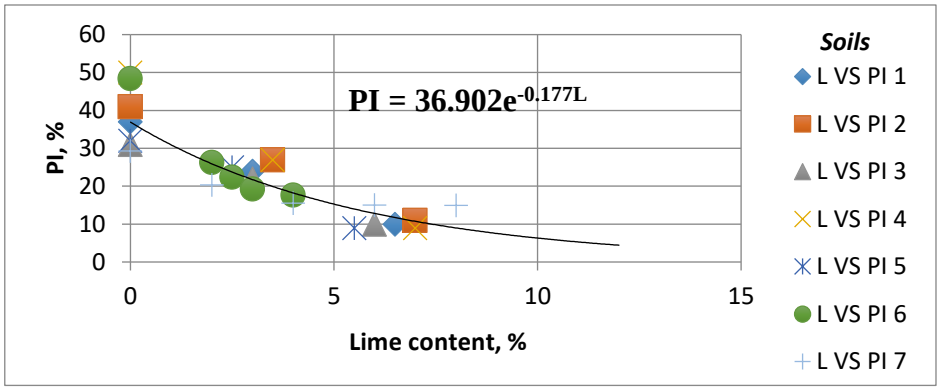

Figure 1. Effect of lime on Plasticity index (PI) of different soils

Effect of lime on optimum moisture content:

Table (10) and Figure (2) are showing the results of effect of lime on optimum moisture content of stabilized soils for the give lime contents and soils. In general, the lime decreasing the optimum moisture content of soil within the range of a reduction of (13% - 28%). The statistical analysis showed the relation as follows:

$$OMC = 24.852 - 0.8128\, L \quad (2)$$

Where:
OMC - Optimum moisture content in percent
L - Lime content in percent

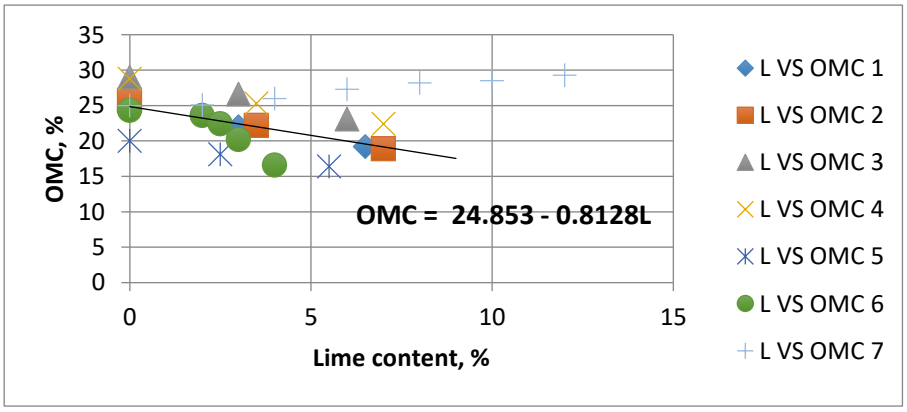

Figure 2. Effect of lime on Optimum moisture content (OMC) of different soils

Effect of lime on maximum dry density

The results of this effect is shown in Table (1) and Figure (3) indicated that as the lime content increasing the maximum dry density increases. In general the increase is shown to be ranged as (4% - 22%) for the give lime contents and soils. The relation between the lime content and maximum dry density determined to be as follows:

MDD = 14.794 + 0.059 L (3)

Where:

MDD - Maximum dry density in kN/m^3

L - Lime content in percent.

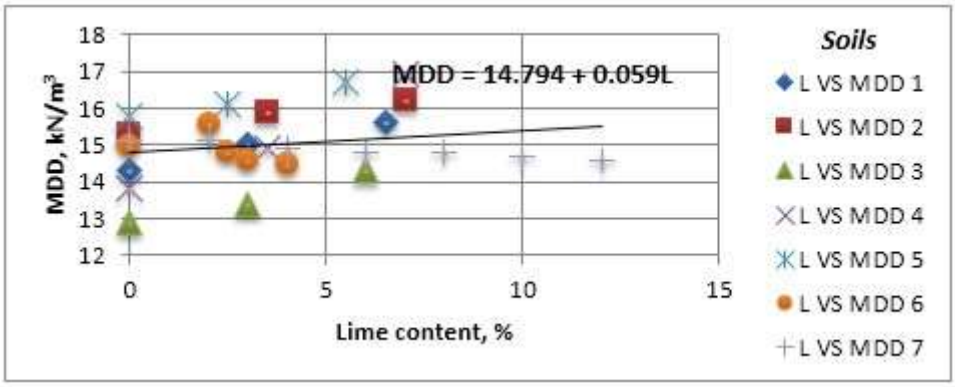

Figure 3. Effect of lime on maximum dry density (MDD) of different soils

Effect of lime on Unconfined compressive strength

The unconfined compressive strength of the given stabilized soils shown to be increasing as the lime content increases for the mentioned used lime percentages. The results of the effect of lime on compressive strength are given in Table (1) and Figure (4). The relationship between the compressive strength and lime content is found to be;

UCS = 177.56 e $^{0.1241\ L}$ (4)

Where:

UCS - Unconfined compressive strength in kN/m^2

L - Lime content in percent

The increase in strength is happened due to pozzolonic reaction of lime with the soil constituents. The increase in strength in general determined to be ranged as (151% - 710%) or 1.51 -7.1 folds.

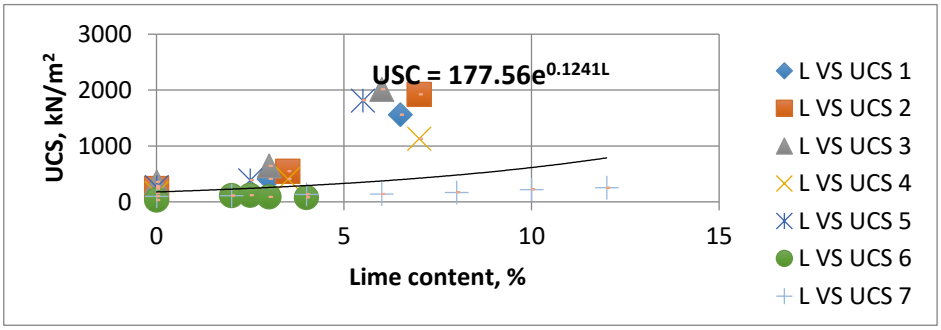

Figure 4. Effect of lime on unconfined compressive strength (UCS) of different soils

Effect of fly ash

Effect of fly ash on soil plasticity

Table (2) and Figure (5) show the results of the soils before and after treatment with fly ash. The effect is shown to be a decrease in plasticity index as the fly ash percent increasing. Range of the decrease is estimated to be (0-43%). The general relation calculated using a statistical analysis is shown as follows:

P.I = 40.414 – 0.6211 FA (5)
Where:
P.I - Plasticity index in percent
FA - Fly ash content in percent

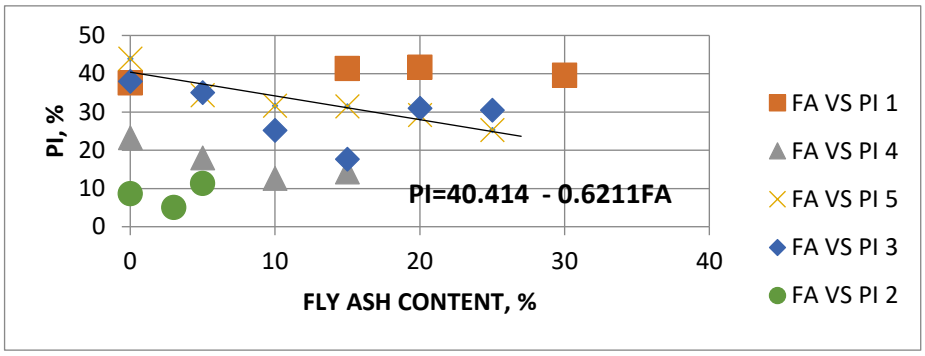

Figure 5. Effect of fly ash on plasticity index (PI) of different soils

Effect of fly ash on optimum moisture content
The results of the effect of fly ash on optimum moisture content are shown in Table (2) and Figure (6) for the given soils and fly ash percentages. It can be seen that as the fly ash content will be higher the optimum moisture content be lower. Range of reduction is shown to be as (0 -7%). Accordingly the statistical analysis gave a general relationship between the fly ash and optimum moisture content as:

OMC = 14.195 – 0.0083 FA (6)
Where:
OMC - Optimum moisture content in percent.
FA – Fly ash content in percent.

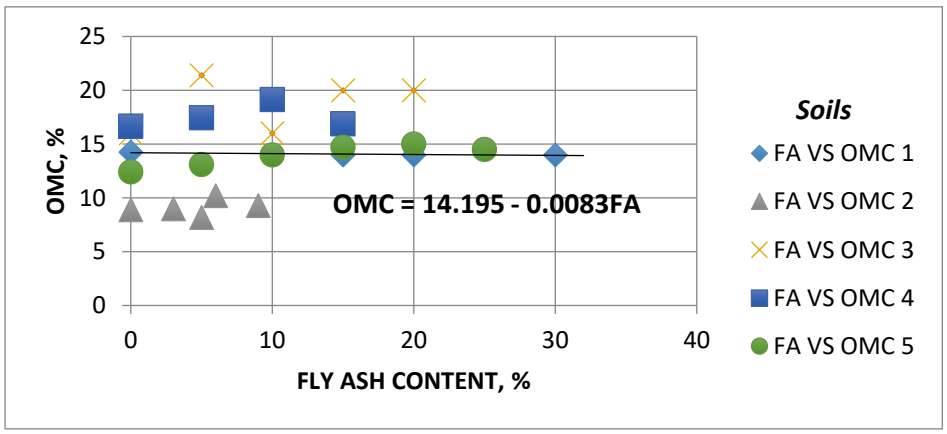

Figure 6. Effect of fly ash on optimum moisture content (OMC) of different soils

Effect of fly ash on maximum dry density
Figure (7) and Table (2) show the results of this effect. The increase in fly ash content causes a decrease in maximum dry density of stabilized soil. The range of reduction is calculated to be (1.7 – 5%) for the give soils and fly ash contents. A relation between the maximum dry density and fly ash content is determined to be as;
MDD = 19.928 – 0.2358 FA (7)
Where:
MDD - Maximum dry density in kN/m^3

FA - Fly ash content in percent

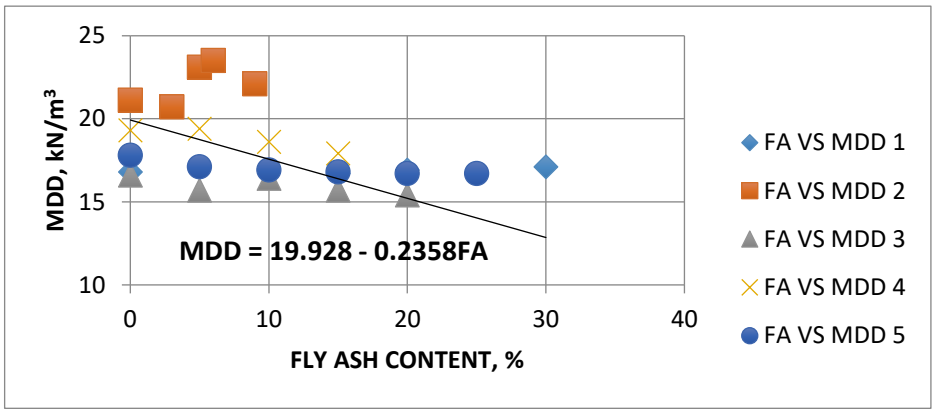

Figure 7. Effect of fly ash on Maximum dry density (MDD) of different soils

Effect of fly ash on unconfined compressive strength

The results of the effect of fly ash on unconfined compressive strength of stabilized soils for the give percentages of fly ash are shown in Table (2) and Figure (8). It can be seen that the fly ash increasing the unconfined compressive strength of soils individually, while decreasing it for all soils statistically. The increase in strength found to be of a range of (5% - 369%). Statistical analysis produced the following relation for this effect:

UCS = 529.28 – 12.771 FA (8)

Where:

UCS - Unconfined compressive strength in kN/m^2

FA - Fly ash content in percent.

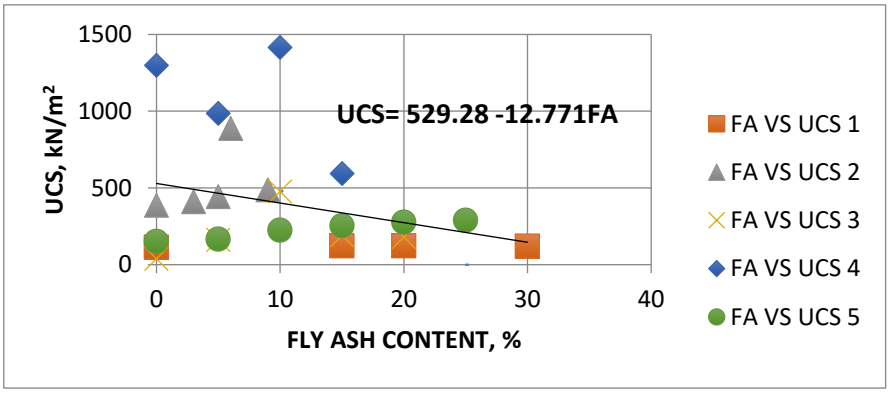

Figure 8. Effect of fly ash on unconfined compression strength (UCS) of different soils

Effect of fly ash with the lime

The effects of fly ash on stabilized soil properties treated with 3% lime and on soil treated with 5% lime are shown in Table (3). It can be noted that for both stabilized soils taken from different studies and from different soil origins, the fly ash increasing the optimum moisture content and decreasing the maximum dry density. This is given for fly ash percentages of 5%, 10%, 15%, 20% and 25%.

CONCLUSIONS

The following conclusions can be drawn from this study;

- Increasing the lime content causes a decrease in plasticity index and optimum moisture content of stabilized soil.
- The maximum dry density and unconfined compressive strength are increasing as the lime content increases.

- The plasticity, optimum moisture content, and maximum dry density decrease as the fly ash content increases.
- Increasing fly ash causes an increase in unconfined compressive strength of stabilized soils individually, and a reverse effect obtained statistically for all soils.
- Relationships between lime content and plasticity index, optimum moisture content, maximum dry density and unconfined compressive strength of stabilized soils are developed and given.
- Relationships between fly ash content and plasticity index, optimum moisture content, maximum dry density and unconfined compressive strength of stabilized soils are developed and given.

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