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"STUDY ON STABILIZATION OF CLAYEY SOIL USING FLY ASH AND LIME"

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Abstract - *Clayey soils are one of the most predominantly available soil in India. This soil exhibit undesirable engineering properties like compressibility, high shrink-swell potential and low bearing capacity on wetting which make them unsuitable for construction. This study was intended to observe the alteration in the behavior of the clayey soil on addition of Fly Ash and lime in different percentages. In this study the clayey soil was obtained from the bank of Ajay river in Birbhum district of West Bengal state. The physical and index properties like Liquid Limit(LL), Plastic Limit(Pl) and Plasticity Index(PI) of the soil was determined by performing various tests like Atterberg Limit Test and Pycnometer Test. The compaction characteristics were evaluated by conducting SPT(Standard Proctor Test).The UCS(Unconfined Compressive Strength) and CBR(California Bearing Ratio)test were also conducted as indicative strength parameters. After evaluation of different properties of the clayey soil Fly Ash(FA) was added in increasing percentages of 5% in each succession(e.g. 5%,10%,15%,20%,25%,30%) and same set of tests were performed as on clayey soil. The test results indicated positive change in the engineering properties of the clayey soil. The optimum value of Fly Ash additive was fixed then to a value of 25% and then percentage of lime is varied in increasing succession of 2% at each stage(e.g. 2%,4%,6%,8%).The combination of Fly Ash and lime showed further improved results in SPT,CBR and UCS tests.*

Key Words: SPT (Standard Proctor Test), CBR (California Bearing Ratio), UCS (Unconfined Compression Test), FA (Fly Ash), LL (Liquid Limit), PL (Plastic Limit),PI (Plasticity Index)

1. INTRODUCTION

The growth and development of any region can be attributed to the infrastructural facilities of the region and the soil stratum of that place provides the base for the construction of different utilities. Sometimes the locally available soil is inconsistent with the adequate range of geotechnical engineering properties required for the desired construction. The constructors are compelled to work on the locally by improving their strength properties by using some additives as removal and hauling of the soil mass is neither an economical nor a feasible task. Clayey soil are one of such kind of soil which exhibit certain properties like high swell-shrink potential and large compressibility making them unsuitable for construction. Therefore these soil are needed to be treated before any type of construction for safety and durability. The improvement in engineering properties of soil using different soil improvement techniques is termed as soil improvement or soil stabilization .Different soil stabilization methods are:

1. **Mechanical Stabilization**- It is the process of improving the properties of soil using gradation.

2. **Chemical stabilization**-It is the process of blending and mixing chemical additives to improve engineering behaviour of soil.

3. **Thermal stabilization**-Sometimes heating and cooling operations are performed on some soils to improve their strength characteristic, which is called thermal stabilization.

4. **Complex Stabilization**-In order to make the stabilization process more efficient sometimes two or more methods are applied simultaneously on soil sample this is called complex stabilization.

In this study the method adopted for stabilizing clayey soil is chemical stabilization using additives. The materials used as additives are grouped as pozzolanic (rice husk ash, Fly Ash etc.), binder (cement, lime, cement kiln dust, lime sludge etc.) and inert (sand, quarry dust, ceramic dust etc.) are added to soil individually or in combination. The additives used in this study are Fly Ash (as a pozzolanic material) and lime (as a binder). The characteristics of the treated soil depend upon the type of the additive and its reaction with the soil. The utilization of Fly Ash which is a by product in coal fuelled power plants in stabilization of soil will help in reducing the threat of its proper and safer disposition.

2. MATERIALS USED IN THE STUDY

2.1 SOIL

The soil for this study was obtained from the bank of Ajay River in Birbhum district of West Bengal. A series of experiments were conducted on the virgin clayey soil to determine its different properties. The geotechnical properties of the virgin clayey soil have been shown in the table as follows:

Table 1: Properties of Soil

Serial No.	Properties	Value
1	Specific Gravity	2.47 g/cm^3

2	Liquid Limit(LL)	38.22 %
3	Plastic Limit(PL)	14.46 %
4	Plasticity Index(PI)	23.76%
5	Optimum Moisture Content (OMC)	17.39 %
6	Maximum Dry Density (MDD)	1.55 g/cc
7	Unconfined Compressive Strength (UCS)	0.18 kg/cm^2
8	California Bearing Ratio (CBR)	1.45%

2.2 FLY ASH

The Fly Ash for the purpose of this work was obtained from the Fly Ash brick manufacturer located in Industrial Area, Sindri. The Fly Ash obtained was a Class C Fly Ash.

Table 2 General Properties/composition of Fly Ash

Serial No.	Property/constituent	Values
1	Specific Gravity	2.2 g/cm^3
2	SiO_2	40%
3	CaO	24%
4	Al_2O_3	17%
5	Fe_2O_3	6%
6	MgO	5%
7	SO_3	3%

2.3 LIME

The Lime for this investigation was obtained from the local market.

Table 3: General Specifications of Lime

Serial No.	Property/Constituent	Values
1	Specific Gravity	2.2 g/cm^3
2	Bulk Density	0.6 g/cm^3
3	$CaO+Ca(OH)_2$	85%
4	CO_2	7%
5	MgO	5%
6	SO_3	2%

3. EXPERIMENTAL METHODOLOGY

A set of tests were conducted on virgin soil to determine its proper and specific classification. This was done through wet sieving for (Particle Size Distribution) then it's liquid and plastic limits were determined using Cassagrande's Apparatus. After that standard proctor test was done to determine its MDD and OMC. UCS and CBR tests were performed on the clayey soil to determine the respective values.

After that the soil was mixed with Fly Ash in increasing percentages of 5% by mass of the clayey soil and same set of tests were performed on soil specimens carrying varying contents of Fly Ash. The SPT test was carried out to determine the optimum percentage of Fly Ash. UCS and CBR tests were also conducted at each Fly Ash content. After determination of optimum content of Fly Ash, lime is added to the constant optimum Fly Ash content in increasing 2% percent by mass at each stage (i.e. 2%, 4%, 6%, 8%). Same set of tests are conducted for every combination of Fly Ash and lime.

4. RESULTS AND DISCUSSIONS

The results of tests conducted on the soil specimens with varying percentages of additives are expressed through tables and also presented in the form of graphs.

4.1 Variation in soil properties on addition of Fly Ash

Initially only Fly Ash was used in the soil as an additive in following order;

Table 4: Description of soil and Fly Ash proportions in different samples

Serial No.	Soil (%)	Fly Ash (%)
1	100	0
2	95	5
3	90	10
4	85	15
5	80	20
6	75	25
7	72.5	27.5

4.1.1 Variation of MDD and OMC with addition of Fly Ash

The results of the Standard Proctor Test (SPT) conducted on the clayey soil samples mixed with varying proportions of Fly Ash are tabulated as follows:

Table 5: Effect of Fly Ash on MDD and OMC

Serial No.	Fly Ash content (%)	MDD (g/cm^3)	OMC (%)
1	0	1.55	17.39
2	5	1.65	17.64
3	10	1.77	16.00
4	15	1.84	14.70
5	20	1.87	14.28
6	25	1.89	13.88
7	27.5	1.86	14.28

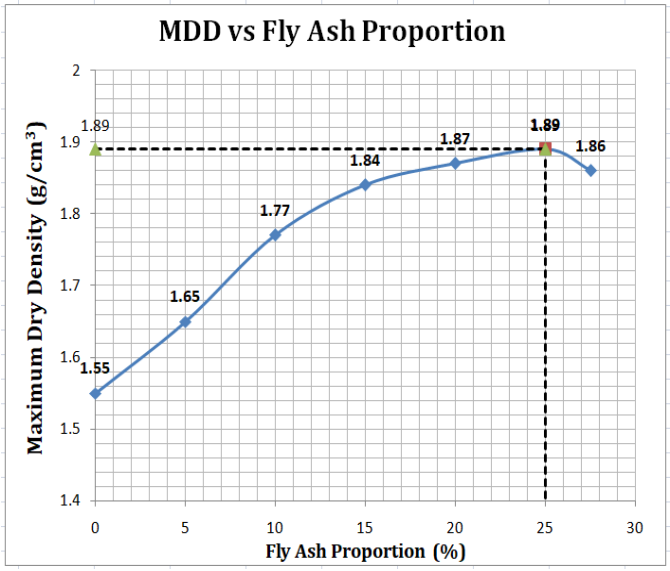

Fig 1: Variation of MDD on increase in Fly Ash Proportion

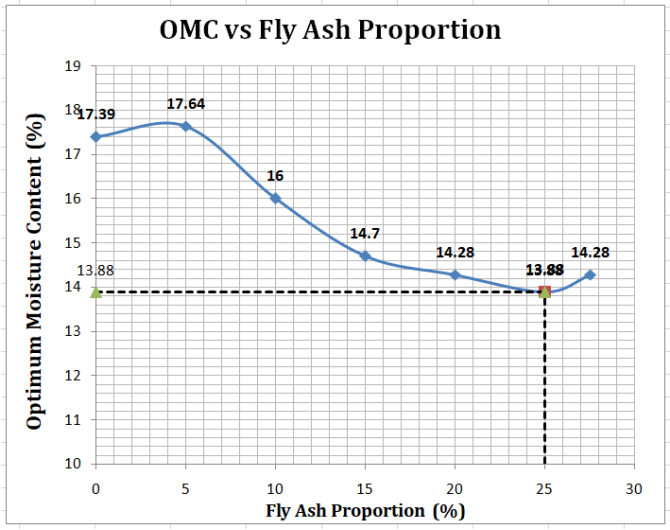

Fig 2: Variation of OMC on increase in Fly Ash Proportion

- It can be observed from the curve in fig 1 that on increasing the Fly Ash content to 25% the MDD increased from 1.55 g/cm^3 to a value of 1.89 g/cm^3. Further addition of fly ash to 27.5% in the soil resulted in reduction of MDD to a value of 1.86 g/cm^3.

- From the fig 2 it can be observed that the OMC values show decrement with increase in fly ash content till 25% attaining a value of 13.88% from 17.89%. Further addition of fly ash in the soil resulted in increment of OMC value of 14.28% at Fly Ash content of 27.5%.

4.1.2 Variation of Unsoaked CBR values and UCS values with addition of Fly Ash

The Fly Ash mixed clayey soil is used to carry out California Bearing Ratio (CBR) test and Unconfined Compressive Strength (UCS) test. The results of CBR and UCS tests are listed below;

Table 6: Effect of Fly Ash on Unsoaked CBR and UCS values

Serial No.	Fly Ash Content (%)	CBR (%)	UCS(kg/cm²)
1	0	1.45	0.18
2	5	2.81	0.22
3	10	4.69	0.25
4	15	6.82	0.26
5	20	9.2	0.29
6	25	10.64	0.31
7	27.5	9.65	0.27

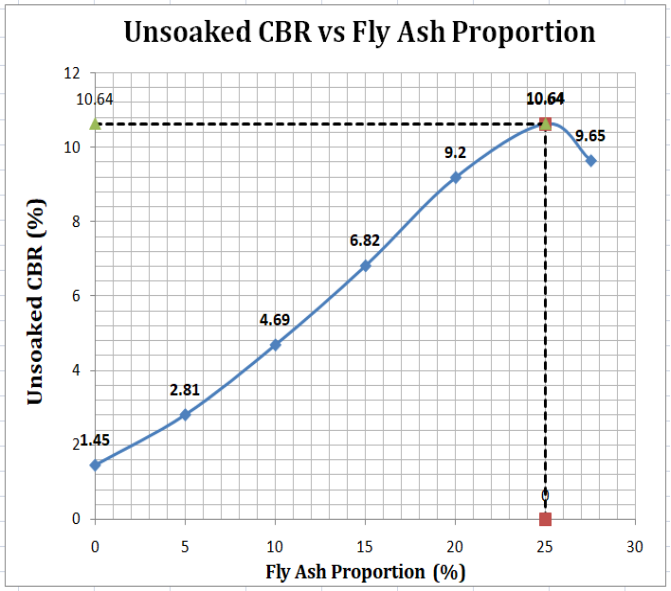

Fig 3: Variation of CBR on increase in Fly Ash Proportion

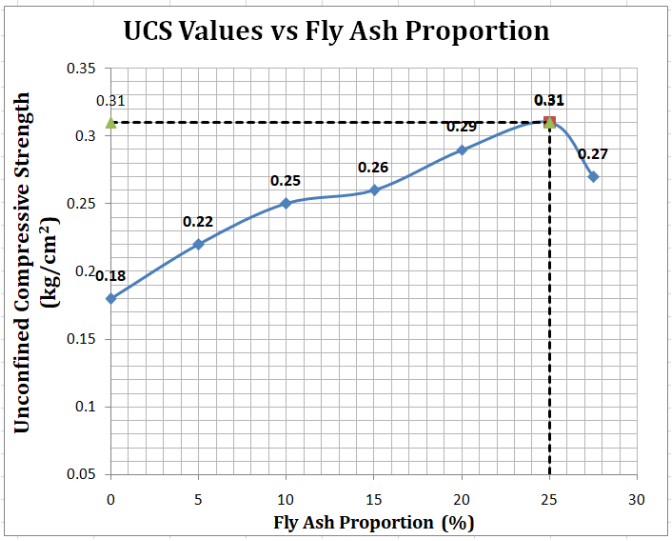

Fig 3: Variation of UCS on increase in Fly Ash Proportion

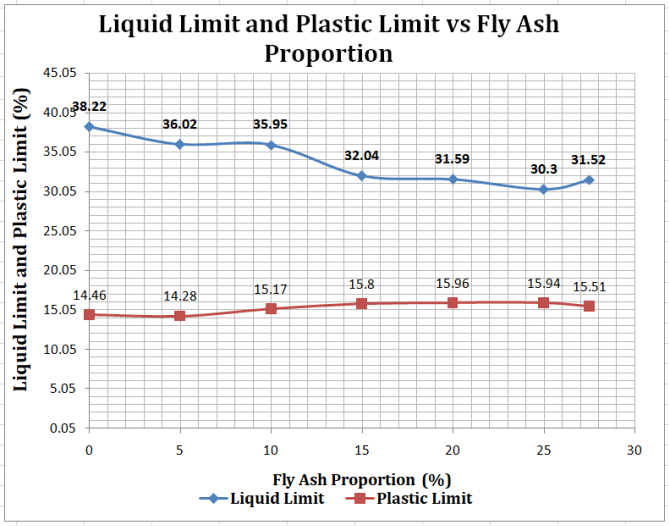

Fig 4: Variation of Liquid Limit and Plastic Limit with increase in Fly Ash Proportion

- It can be observed from the curve in fig 3 that on increasing the Fly Ash content to 25% the unsoaked CBR increased from 1.45% to a value of 10.64%. Further addition of fly ash to 27.5% in the soil resulted in reduction of unsoaked CBR to a value of 9.65%.

- From the fig 4 it can be observed that the UCS values showed increment with increase in fly ash content till 25% attaining a value of 0.31 kg/cm^2. Further addition of fly ash in the soil resulted in decrement of UCS value of 0.27 kg/cm^2 at Fly Ash content of 27.5%.

4.1.3 Variation of Liquid Limit and Plastic Limit with addition of Fly Ash

The results of the liquid limit tests and plastic limit tests with increasing percentages of fly ash are tabulated below;

Table 7: Effect of Fly Ash on Liquid Limit and Plastic Limit values

Serial No.	Fly Ash Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	0	38.22	14.46	23.76
2	5	36.02	14.28	21.74
3	10	35.95	15.17	20.78
4	15	32.04	15.80	16.24
5	20	31.59	15.96	15.63
6	25	30.30	15.94	14.36
7	27.5	31.52	15.51	16.01

- It can be observed from the curves in fig 4 that on increasing the Fly Ash content to 25% the Liquid Limit reduced from 38.22% to a value of 30.30% and the Plastic Limit increased from 14.46% to 15.94%. Further addition of fly ash to 27.5% in the soil resulted in increment of Liquid Limit to a value of 31.52% and reduction in Plastic Limit to a value of 15.51%.

- The table7 depicted that the Plasticity Index reduced from 23.76% to a value of 14.36% at 25% Fly Ash content.

4.2 Variation in soil properties with addition of Lime

From the tests conducted on soil mixed with Fly Ash, the optimum content of Fly Ash was determined to be 25%. Hence further tests were performed by adding Lime in varying percentages to the clayey soil mixed with a constant Fly Ash content of 25%.

Table 8: Description of soil, Fly Ash and Lime proportions in different samples

Serial No.	Soil (%)	Fly Ash (%)	Lime (%)
1	75	25	0
2	73	25	2
3	71	25	4
4	69	25	6
5	67	25	8

4.2.1 Variation of MDD and OMC with addition of Fly Ash

The results of the SPT test conducted on the soil samples mixed with varying proportions of Fly Ash are tabulated below:

Table 9: Effect of Lime on MDD and OMC

Serial No.	Lime (%)	MDD (g/cm³)	OMC (%)
1	0	1.89	13.88
2	2	1.91	13.33
3	4	1.97	12.90
4	6	1.99	12.50
5	8	1.98	12.90

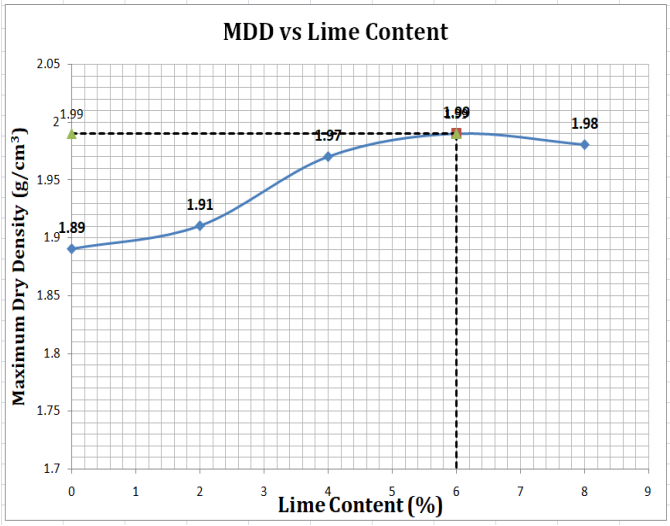

Fig 5: Variation of MDD on increase in Lime Proportion

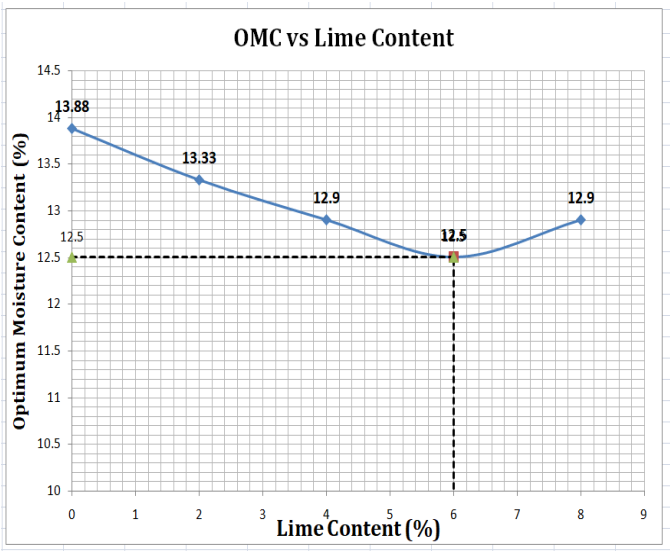

Fig 6: Variation of OMC on increase in Lime Proportion

- From the table 9 above it can be observed that the MDD increased from 1.89 g/cm³ to 1.99 g/cm³ when Lime content increased from 0 to 6%.The OMC followed a reduction trend and attained a value of 12.50% at a Lime content of 6%.The Figures fig 5 and fig 6 show that the MDD value decreased to 1.98 g/cm³ and OMC value increased to 12.90% with increase in Lime content to 8%.

4.2.2 Variation of Unsoaked CBR values and UCS values with addition of Lime

The results of CBR and UCS tests are listed below;

Table 10: Effect of Lime on Unsoaked CBR and UCS values

Serial No.	Lime (%)	CBR (%)	UCS (kg/cm²)
1	0	10.64	0.31
2	2	11.58	0.32
3	4	12.35	0.31
4	6	11.16	0.29

- The above table 10 shows that the CBR value increased from 10.64% to 12.35% with increase in Lime content to 4% and the UCS value increased to 0.32 kg/cm² at 2% Fly Ash content.

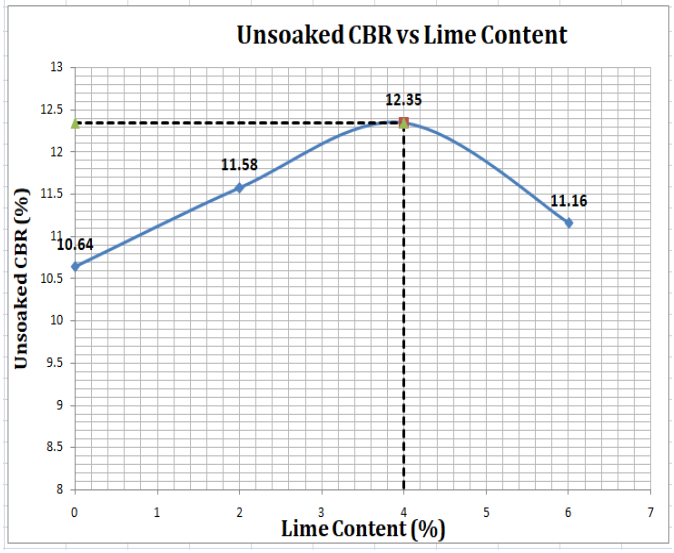

Fig 7: Variation of CBR on increase in Lime Proportion

- The fig 7 shows that the CBR value decreased from 12.35% at 4% Lime content to a value of 11.16% for a lime content of 6%. This may be due to additional cementing property introduced by addition of lime in the fly ash mixed clayey soil.

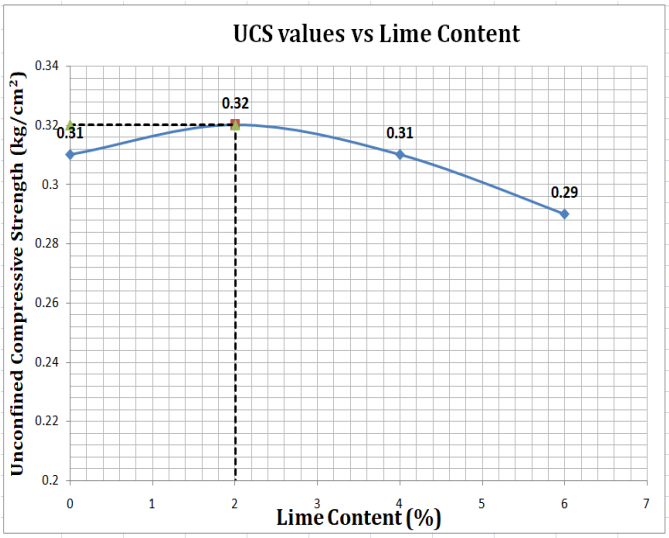

Fig 8: Variation of UCS on increase in Lime Proportion

- The above fig 8 shows that the UCS value decreased from a value of 0.32 kg/cm² at 2% Lime content to a value of 0.29 kg/cm² for the lime content value of 6%.

5. CONCLUSIONS

The following conclusions can be derived from the results of various experiments performed on different samples of the clayey soil treated with Fly Ash and Lime:

1. The soil used for the study had Liquid Limit 38.22%(>35%) and Plasticity Index value greater than 17% which confirmed that it was clay of intermediate plasticity (C I soil).

2. Initially when only Fly Ash was added to the soil, the MDD improved from 1.55 g/cm3 to 1.89 g/cm3 and this maximum value of 1.89 g/cm3 was obtained with 25% Fly Ash.

3. Only Fly Ash mixed soil the exhibited increase in unsoaked CBR value from 1.45% to 10.64% and UCS increased from 0.18kg/cm² to 0.31 kg/cm².Both results of unsoaked CBR value and UCS value were observed at 25% Fly Ash content.

4. These results confirmed the optimum percentage of Fly Ash to be 25% for mixing of Lime.

5. Lime was added in varying percentages keeping the Fly Ash content constant at 25%.The results of Standard Proctor Test (SPT) showed that highest value of MDD was obtained at a Lime content of 6% and the highest value of MDD was 1.99 g/cm³.

6. With fixed percentage of Fly Ash at 25% and varying percentages of Lime, the values of unsoaked CBR test increased from 10.64% to 12.35% and this maximum value of unsoaked CBR was obtained at 4% Lime.

7. The UCS values also increased from 0.31 kg/cm² to 0.32 kg/cm² and this maximum UCS value was obtained at 2% Lime content.

8. The Liquid Limit showed a consistent decrease from 38.33% to 30.30% till the Fly Ash content reached 25%.

9. The Plastic Limit showed increment of a small magnitude while increasing from 14.46% to 15.94% at 25% Lime. The Plasticity Index reduced from 23.76% to 14.36% at 25% Fly Ash.

10. From above results, the optimum percentage of Fly Ash and Lime were found to be 25% and 6% for soil under foundation. The combination of 25% Fly Ash and 4% Lime will be suitable for pavement sub-grade.

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