International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Effect of Lime and Fly ash on Load Bearing Capacity of Expansive Clay soil

Asres Getnet Workie , Shamshad Alam

Abstract: ***Expansive soil is a problematic soil which found in wide part of the world that has a high degree of sensitivity, nature of expansion and shrink behavior during water adding and removing this caused insufficient bearing capacity, excessive differential settlement and instability on excavation and embankment forming those conditions accelerate damage of building structure, road highway and dam. Attempt to undertake construction in such type of soil result will be bearing capacity failure, settlement problem. One of the well-known application of Lime and fly ash were improve Atterberg limits, compaction characteristics, bearing capacity and prevention of swelling problem of expansive clay that is why the main reason to select lime and fly ash in this project, both are good binding material to increase the cohesion force and shear strength of soil and assured to established rigid pavements and foundations. The mixing proportion of lime, fly ash and combination of lime and fly ash are (0%, 2 %, 4 %), (10%, 15% ,20%), (2 %+10 %, 2 % +15 %, 2 % +20 %) and (4 %+10 %, 4 % + 15 % , 4 %+ 20 %) with expansive soil respectively and then explored how much it modify the characteristics of soil like maximum dry density moisture content, consistency limits, FSI, UCS and CBR value which compare to untreated soil. Lime and fly ash treated soil carried out various tests Such as Moisture content test, consistency limit, compaction test, Unconfined Compression swelling index test and California bearing ratio test then after justify weather the bearing capacity of soil is good or not . Classification of soil was determined by conducting plasticity index and swelling index tests. Effect of lime and fly ash on soil index properties were assessed by conducting Atterberg limits test, strength of soil were assessed by conducting compaction test, UCS tests and CBR test and swelling properties were checked by conducting swelling index test. Expansive clay soil were mixed with lime, fly ash and combination of lime - fly ash by replacement process of soil and then cured for 7, 14 and 28 days.***

Key words: Atterberg limits, bearing capacity, unconfined compressive strength (UCS), CBR

I. INTRODUCTION

The objective of determination of ultimate bearing capacity of the soil in foundation should carry the load with no shear failure. The settlement caused by the structural load should not exceed the allowed deformation for stability of construction. The load bearing capacity of expansive soil can be carried out using experimental analysis and theoretical results fit with those obtained from experimental result. A literature analysis expression that the majority of the bearing capacity theories such Terzaghi's bearing capacity theory, coordinated with the experimental results include homogeneous soils in the foundations. Soil behaviors were assumed to remain constant for the load bearing capacity exploration and Expansive soils is not permit for road construction, foundation of buildings, alignment of lined canal gravity dam because of the high volume fluctuations happen as a result of saturating and drying with seasonal variation of climate especially in Ethiopia has failed entirely. These main engineering structures subsequently suffer from serious distresses and damages due to problem of expansive soil. Expansive soil has poor load carrying capacity which required to modified and create rigid foundation.

The load carrying capacity of a clay estimated by the strength test. In a conception of shear stress and strength, load carrying capacity of clay soil equivalent to magnitude of major principal stress at failure point in shear. This estimated stress at failure point of specimen is known as unconfined compression strength (*qu*). According to his determination, ultimate bearing capacity $qu = 2c \tan(45° + \emptyset/2)$, $\emptyset = 0°$, for a purely cohesive soil, $qu = 2c$ *where* $\emptyset$ is angel of internal friction and c cohesion [15].

Chen and IS describe relationship between swelling potential, degree of expansion, free swelling index and atterberg limits. According to this clarification the soil classify low, medium, high and very high expansive based on plasticity index value. [14], [16].

Table 1: the relationship of degree of expansion, free swell index with atterberg limits

Degree of expansion	Free swell index (%)	Plasticity index (%)	Shrinkage limit
Low	<50	<12	<15
Medium	50 -100	12 – 23	15 -30
High	100 – 200	23 -32	30 -60
Very high	> 200	>32	>60

Estimated of bearing capacity depends on CBR value. Justification it based on CBR value described the table below [7].

Table 2: relation of bearing capacity with CBR of subgrade of soil

CBR (%)	Bearing capacity
2 – 5	Poor
6 -9	Medium
9 – 15	Good
>15	Very good

In soil mechanics and foundation engineering book described unconfined compressive strength (q_u) of a soil. It is equivalent to failure load per unit area when standard cylindrical specimen is tested in unconfined compression testing machine. [13]

Manuscript published on 30 September 2019.
*Correspondence Author(s)
Asres Getnet, Geotechnical Engineering, Sharda University, Greater Noida, India.
Dr. Shamshad Alam (assistance professor), Geotechnical Engineering, Sharda University, Greater Noida, India.

II. LITERATURE REVIEW

The effect of lime on engineering properties of expansive Soil was investigated by adding varying percentages of lime i.e. 2%, 5%, 9% and 12% and alters different parameters such as strength of the soil, bearing capacity and consistency limit of the soil. The peak dry density, UCS and The CBR (Unsoaked) is increased at 9% lime treated soil while specific gravity, plasticity index and swelling index decreased compared to untreated soil [1].

Lime provides cost-effective technique of soil stabilization. The amount of lime used for stabilization of soil is recommended from 5% to 10% and Lime amendment of soil results in an increased in strength by cat ion exchange capacity [2].

The effect of diesel contamination on UCS of expansive clay, as increase in diesel contamination, the UCS value decreased from 86 kPa to 36 kPa with increase of diesel from 0 to 9%, a decrease of 58.14 % with addition 9% diesel. 9 % dolime fine stabilized diesel contaminated expansive soil provides better UCS result compared to diesel contaminated expansive soil with different curing period. [3].

Experimental Investigation on Clay Soil Stabilization using Lime and Rice Husk Ash. Swelling soil has low carrying capacity due to high plasticity behavior, this problem exposes foundation for Excessive settlement therefore usage of lime and rice husk ash improves the shear strength of clay soil From 106 kPa to 439.47 kPa at 6% lime while shrinkage limit, plasticity index and swelling index decreased from 5.4% to 0%, 37.47% to 8.18% and 47.87% to 7% respectively at 10% RHA+8% lime [4].

Improvement in Bearing Capacity of a Soft Soil by Addition of Fly Ash. The authors described improvement of CBR and UCS was found adding 7% to soft soil and decreased swelling properties of soil and also improved of Bearing Capacity of Soil using Cement, Lime and Chemical. They were deals with stabilizing the soil using different stabilizers (lime, chemical, and cement) in by taken varying percentage of about 2%,4%,6%,8% and 10% of every stabilizer(lime, cement and calcium chloride). In this project paper indicated that Lime is used as best clay treated binding powders for extremely dynamic swelling clays improve by lime. The bearing capacity and strength of the soil was increased by 1.5% using lime stabilizer [5, 6].

Effect of Addition of Lime on the Properties of RBI-81 Treated Expansive Soil Subgrade. As the dosage of RBI increased from 2% to 6%, for specimens cured for 7days, CBR increased from 2.19% to 3.35%.

The investigation indicated that the adding of RBI-81 is not appropriate for extremely flexible soils regardless of the curing period. Lime can be mixed with RBI-81 to achieve wanted strength [10].

The Effect of Lime Content on the Bearing Capacity and Swelling Potential of Expansive Soil. This report indicated increasing addition of lime (4%, 6%, 8% and 10%), plastic limit value is increasing and liquid limit, shrinkage limit, plastic index decreases. Addition of 4% lime, value of the IP is below 17%, i.e. 16.64%, but the addition of 10% of lime, value of IP is 10.67% [7].

Improvement of plasticity index value of swelling clay soil by lime stabilization" in this paper addition of lime from 0% to 4%, liquid limit decreased from 49.8% to 10.86% but it shows increasing tendency for higher percentage of lime. L.L decreased 78.2% and P.L decreased 70.4% due to addition of 4% lime. For plastic limit it varies 18.7% to 5.54% for 0% to 4% lime addition. Now in case of plasticity index value, it shows 31.1% for 0% lime but it reduced to 5.32% for 4% lime content. Further increase of lime it shows increasing tendency. So for finding minimum plasticity index value 4% lime addition is best [9].

Improving the Characteristics of Expansive Subgrade Soils Using Lime and Fly Ash. Applying combination of lime with fly ash on high expansive soil play important role to reduce Plasticity index [8].

Behavior of Expansive Soils with lime and its effect on Structures. Tests on expansive soils conducted at different curing and soaking periods. The laboratory results shown the increment of in strength was recorded after 14 days of cured period with 8% of lime used. He reported that lime is the basic binding material to increase the strength of expansive soil [11].

Fly ash used to reduce the plasticity characteristics of expansive soil. At higher percentage of fly ash The liquid limit, plastic index , optimum moisture content (OMC),free swell and swelling pressure decreased while plastic limit ,shrinkage limit, maximum dry density (MDD) ,soaked and un soaked CBR increases with an increase in fly ash content. Plasticity index reduces by 30-40% with the addition of 10-15% fly ash [12].

III. MATERIALS AND METHODS

A .Methods

Reviewed secondary sources form the literature, research seminar papers, previous studies and internet. Kerosene, lime and fly ash were purchased from market while soil samples was taken in favorite area fit with the project research topic. All data used in this project work obtained by conducting series of laboratory work. Sample preparation of the experimental work involved sieving of soil to the required particle size and Classification of soil was determined by conducting index property and plasticity index chart. Effect of lime and fly ash on soil index properties were assessed by conducting Atterberg limit tests on treated and untreated soils and strength properties were assessed by conducting compaction test and UCS test.The load carrying capacity of specimen conducted by CBR test as well as unconfined strength test. Swelling properties of expansive clay soil checked by performed swelling index test by using kerosene and also it will be checked by swelling potential test and Expansive soil were mixed with different proportion of lime , fly ash and lime with fly ash then cured for 7, 14 and 28 days

.B .Material used

Fly Ash: it is a fine material which has pozzolanic properties, when it added to soil to improve soil parameters. The size ranges from 1µm-150µm, Surface area 300-700 m^2/kg, and Specific gravity 2.1-3, Silica (SiO2) content up to 60% .There are two types of fly ash, those are C type and F type fly ash.

Retrieval Number: K15730981119/19©BEIESP
DOI: 10.35940/ijitee.K1573.0981119
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Type C fly ash known as High Calcium content fly ash which occupied 300 – 400 m /kg. The average particle size is less than 20 µm.
Type F fly ash known as Low Calcium content fly ash and its surface area occupied 200 – 300 m /kg.
Lime: it made from lime stone which is excellent stabilizer for expansive soil which apply in the area of concrete foundations, embankment slopes and canal alignments. Lime mixing, with clay soil, the calcium ions (Ca) from hydrated lime move to the surface of the clay particles and displace water and other ions.
Application of lime on clay soil is reduce plasticity index, swelling pressure and increase CBR UCS and durability.

Kerosene

It is fluid chemicals used to determine specific gravity of clay soil and free swelling index of soil

Soil samples was air-dried in large pans and was then broken up to pass the 4.75 mm sieve. Samples of the soil were screened in 4.75 mm sieve to remove the larger particles. For atterberg limits require material passing the 425 micron sieve. The material that passed 4.75 mm sieve was air dried and pulverized with a human labor crush. After the material was broken up, it was then used for hydrometer analysis, Atterberg Limits, standard proctor test, UCS and CBR test. The soil was broken up with a hand crush and then mixed with water. The proportion of lime, fly ash and soil indicated in the following table.

Table 3: proportion of soil, lime and fly ash

soil	Lime	Fly ash
100 %	0	0
98 %	2 %	
96%	4%	
90	0	10
85		15
80		20
88 %	2 %	10 %
83 %		15 %
78 %		20 %
86 %	4 %	10 %
81 %		15 %
76 %		20 %

V. RESULT AND DISCUSSION.

A.Atterberg limits

Atterberg limits include LL, PL and PI which play an important role in soil identification and classification system. One of the important and principle aims of this study was to evaluate the changes of liquid limits, plastic limits, and plasticity index with addition of lime and fly ash to target soils. To achieve the required result, Atterberg limits test should be conducted on both natural soils and different content of lime and fly ash added to soil.

Figure 1: Liquid limit device Casagrande type

Figure 2: Plastic limit device

Atterberg limits device was used to determine the liquid limit of each soil using the material passing through a 425 µm sieve. The plastic limit of each soil was determined by using soil passing through a 425 µm sieve and rolling 3-mm diameter threads of soil until they began to crack. The plasticity index was then computed for each sample based on the liquid and plastic limit obtained.
The liquid limit and plasticity index were then used to classify weather the soil is low clay (CL), medium clay (CI), highly clay (CH).The soil was classified based on clay content using soil index chart. All categorizations provided in this research was based on the laboratory testing result. Depend on the result in this project work the soil is medium clay (CI) type.

Table 4: Effect of lime and fly ash on atterberg limits

admixture	Liquid limit (%)	Plastic limit (%)	Plastic index (%)
0 % lime	42.25	19.3	22.95
2 % lime	37.11	20.6	16.51
4 % lime	31.78	21	10.78
10 % fly ash	31.5	20.5	11
15 % fly ash	29	22	7
20 % fly ash	31	21	10
2 % lime +10 % fly ash	30.77	23	7.77

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2 % lime + 15 % fly ash	28.8	24.6	4.2
2 % lime + 20 % fly ash	25.32	23	2.32
4 % lime + 10 % fly ash	26.56	22.6	3.96
4 % lime + 15 % fly ash	24.37	23	1.37
4 % lime + 20 % fly ash	23.16	23	0.16

Addition of 2 % to 4 % lime on expansive clay insignificant reduction of liquid limit of soils. 10 % to 20 % fly ash added in to soil, level of liquid limit gradually dropped specially 15 % fly ash mixed soil appropriately reduced liquid limit and decline plasticity index of soil.

Plastic limit of clay was also another Atterberg limit greatly affected by lime and fly ash. Adding lime and fly ash into expansive clay increased the plastic limit at any percentage of treated sample. The chart shown the above the plasticity index and liquid limit value for untreated sample indicated that the soil grouped in medium compressible clay but after addition of lime from 2% to 4%, the LL decrease to 31.78 % and PI decline to 10 .78 % the soil found in low compressible clay however usage of 10 % to 20 % fly ash LL decreased and the soil changes from medium expansion clay (CI) (untreated) to low expansion clay (CL). Combination of lime with various percentage of fly ash, L.L decreases much greater than lime mixed and fly ash mixed soil i.e. 82.1 % at 4 % lime + 15 % fly ash, P.L increased by 19.2 % due to addition of 4% lime+20 % fly ash. Now in case of plasticity index value, it shows 22.25 % for normal clay but it reduced to almost zero % for 4% lime + 15 % fly ash content. Generally combination of lime and fly ash mix soil is the more effective than individual stabilizers and changes the soil from medium expansive to non-expansive.

B .Free swelling index

It is determined by using kerosene instead of water, as lime and fly ash content increase the free swell index is rapidly decrease ,it solved by the following empirical formula.

$$FRI = \frac{\text{volume of soil} - \text{volume of kerosene}}{\text{volume of kerosene}} \times 100.$$

Table 5: Effect of lime and fly ash on free swelling index of soil

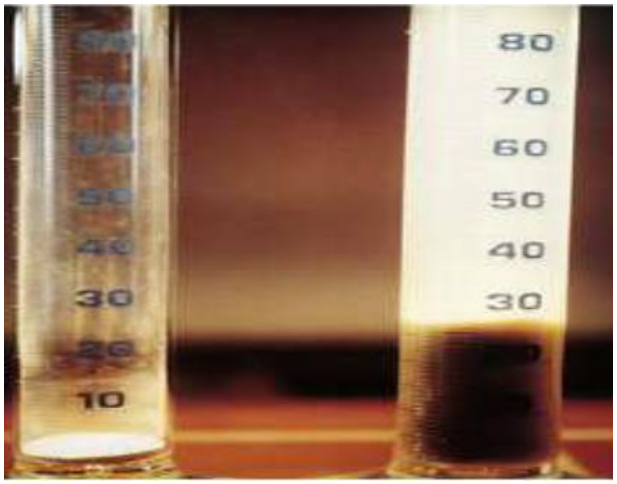

Figure 3: a device used to measure free swelling index

Admixture		FSI (%)
Lime (%)	Fly ash (%)	
0	0	90.9
2		59.1
4		33.6
0	10	36.6
	15	27.3
	20	22.7
2	10	31.8
	15	18.2
	20	13.6
4	10	9.0
	15	0.0
	20	0.0

From the above table shows free swelling index is decrease due to adding lime and fly ash especially combination of lime –fly ash mixed soil. In untreated soil the FSI value determine in laboratory indicated soil classified as medium expansive but after addition of lime and fly ash to soil, FSI dropped to low expansive, specifically the soil come to no expansion at 4 % lime + 15 % fly ash. Generally combination of lime and fly ash is more effective than fly ash treated and lime treated soil to reduced free swelling index

C .Standard compaction test of soil

Compaction one of the important method of densification of soil by minimize air voids. The peak dry density and the corresponding OMC are read from the curve. Specimens showing a high compaction unit weight are best in supporting civil engineering structure due to minimum voids. Compaction of soil increase the density, shear strength, bearing capacity, those reducing the voids, settlement and permeability.

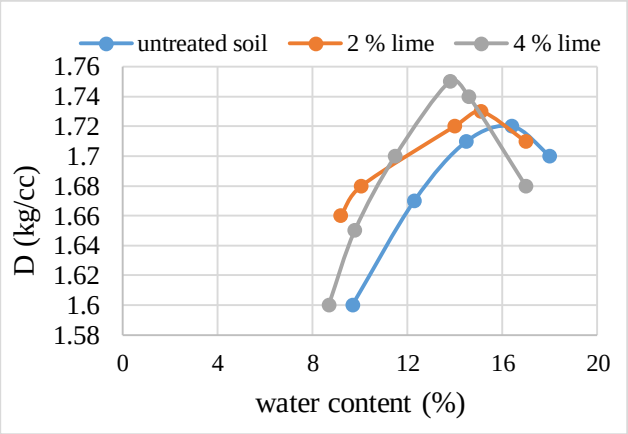

Figure 4: Effect of lime on compaction test of soil

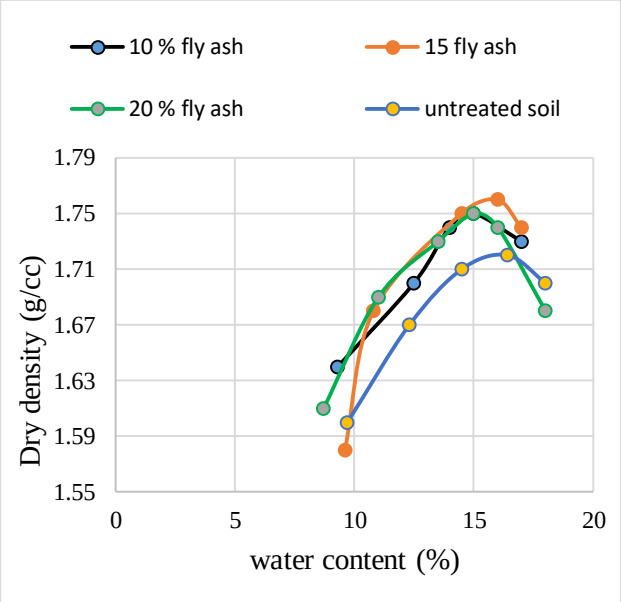

Figure 5: Effect of fly ash on compaction test of soil

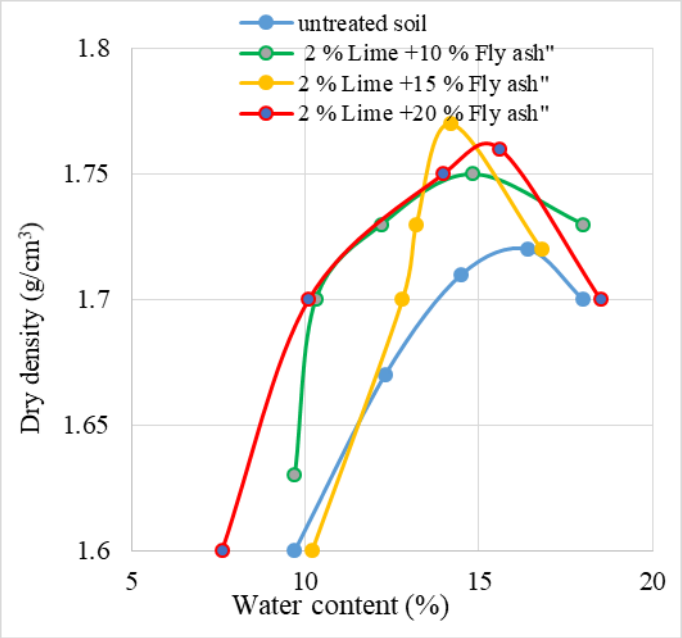

Figure 6: Effect of 2 % lime with various fly ash on compaction test

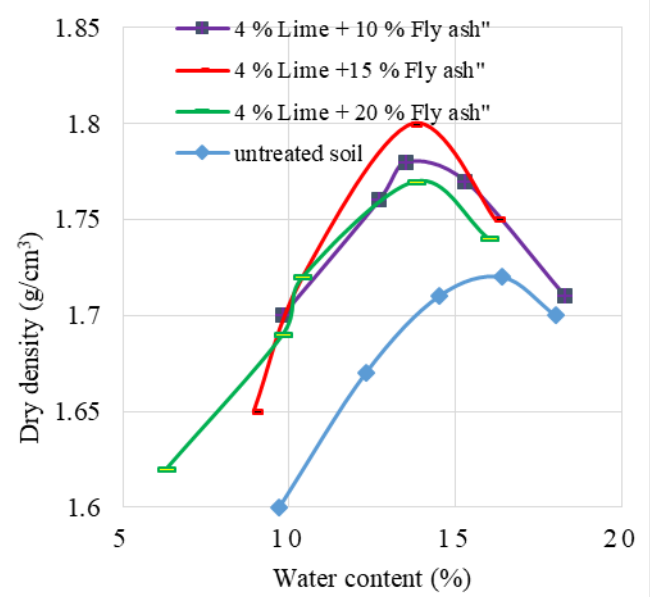

Figure 7: Effect of 4 % lime with various percentage of fly ash on compaction test.

.Table 6: effect of lime and fly ash on OMC and MDD of soil

Admixture		OMC (%)	MDD (g/cc)
Lime (%)	Fly ash (%)		
0	0	14.5	1.72
2		15.1	1.73
4		13.8	1.75
0	10	15	1.75
	15	16	1.76
	20	15	1.75
2	10	14.8	1.75
	15	14.2	1.77
	20	15.6	1.76
4	10	13.5	1.78
	15	13.7	1.8
	20	13.9	1.77

The above graphs show the peak dry density increases with adding lime from 2 to 4%, while a reduction in the peak dry density occurred when fly ash increases from 15% to 20%. Perceptive that compaction of clay in laboratory comprises the filler of the soil particles such that its voids are reduced to the minimum. The increment of MDD obtain at lime-fly ash mixed soil compare to only lime and fly ash with soil while a reduction of MDD observed at 2% lime + 20% and 4 % lime + 20 % fly ash mixed soil. The increment of OMC obtained at 2% lime + 20 % fly ash and 15% fly ash mixed soil.

The MDD value obtained in 4 % lime, 15 % fly ash, and 4 % lime – 15 % fly ash are 1.75 g/cc,1.76 g/cc and 1.8 g/cc respectively In this thesis work combination of lime- fly ash is successes fully increase peak dry density better than only lime and fly ash treated soil.

D. Unconfined compression test

Unconfined compressive strength (qu) is explain as peak load reached per unit area.

Strength test was done on all prepared samples in each percent of lime and fly ash using a strain speed of 0.01 per minute and data gathering was takes place in recording the applied load on specimen until fail. The soil samples compacted in Shelby tube and take samples from mould tube, then after cured for 7, 14 and 28 days and tested to UCS for each number of days.

The undrained shear strength (Su) is essential for the determination of the bearing capacity of foundations, dams, etc. In clay soil it is normally estimated by unconfined compression test, $S_u = \frac{q_u}{2}$ when the soil is under the $\emptyset = 0$, ($\emptyset$= the angle of internal friction), $S_u = cu + \sigma tan\emptyset = cu$.

Table 7: Effect of lime and fly ash on UCS of soil

Lime (%)	UCS (kPa)	Fly ash (%)	UCS (kPa)
0	140	0	140
2	200	10	275
4	285	15	295
		20	280

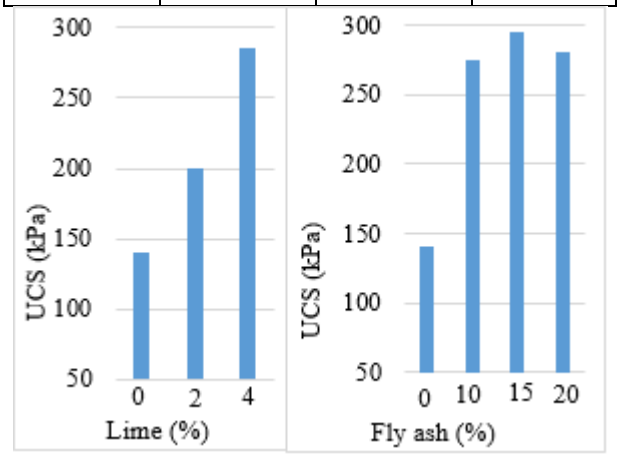

Figure 8: Effect of lime and fly ash on UCS of soil

Table 8: Effect of combination of lime with fly ash on UCS

Lime (%) +fly ash (%)	UCS (kPa)	CU (kPa)
0 + 0	140	70
2+ 10	262.4	131.12
2 +15	310	155
2+ 20	292.24	146.12
4 + 10	289.5	144.75
4 + 15	345	172.5
4 +20	297.5	148.75

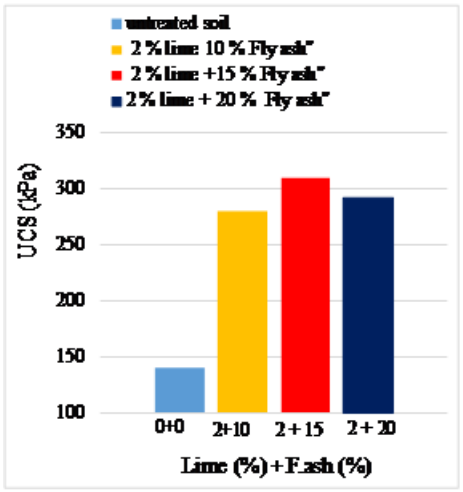

Figure 9: Effect of various percentage of fly ash with 2% lime on UCS of soil

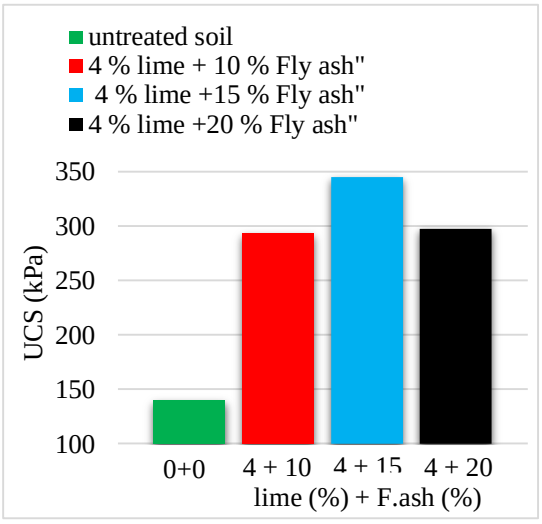

Figure 11: Effect of various percentage of fly ash with 4 % lime on UCS of soil.

When a soil was treated with lime, fly ash and combination of lime –fly ash, increased curing period produces a stronger mixture. The analysis was made to determine how lime and fly ash affect soil strength with in different curing period, as the curing period increase, the strength of soil must be increase. The unconfined strength test evaluated based the following schedules, i.e. 7, 14 and 28 days to analysis the effect of long-term curing carrying capacity of soil. Fly ash which produced strong samples with quite good strength value. From the above table and graph shows Small quantity of lime mix with soil, insufficient increase the unconfined compression strength of soil i.e2 % lime and .4 % lime added to soil, 4 % lime implies better result relative to 2 % lime and untreated soil, UCS value increase from 140 KPa to 285 KPa at 4 %. In fly ash treated soil, among different percentage of fly ash content applying to the sample, 15 % of fly ash mixed to soil relatively provides better result , 295 KPa obtained compare to 140 KPa normal soil and combination of Lime- fly ash treated samples successfully increase the shear stress and unconfined strength of soil.

This indicated that both lime – fly ash added together ,the bearing capacity of soil increase effectively and create rigid substructures, 2% lime + 15 % fly ash achieves 310 KPa, this is maximum value of 2 % lime combine with various percentage of fly ash content added to the soil, it does not show any effective improvement of strength and deformation properties however, 4% lime with various percentage of fly ash content mixed soil can be increasing strength of soils sufficiently, especially at 4 % lime + 15% fly ash content is believed to increase strength up to 345 KPa. Further increase the fly ash content to the soil, the strength of soil decrease because the high soil quantity replaced by fly ash powder, then the fly ash dominated soil properties besides this void space come to is increase.

Effect of curing time: When a soil was treated with lime, fly ash and combination of lime –fly ash, increased curing period produces a stronger mixture. The analysis was made to determine how lime and fly ash affect soil strength with in different curing period, as the curing period increase, the strength of soil must be increase. The unconfined strength test evaluated based the following schedules, i.e. 7, 14 and 28 days to analysis the effect of long-term curing carrying capacity of soil.

Figure 10: Typical photo of sample preparation for UCS test in different curing time

Table 9: Effect of curing time on UCS of lime treated soil

Lime (%)	UCS (kPa) of different Curing time			
	0 day	7 day	14 day	28 day
0	140	650	772	1025
2	200	713	830	1120
4	261	810	1071	1154

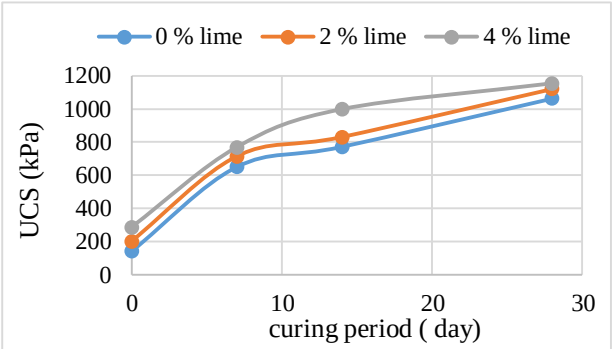

Figure 11: Effect of curing period on UCS of lime treated soil

Table 10: Effect of curing time on UCS of fly ash treated soil

Fly ash (%)	UCS value of soil for different curing period			
	0	7 day	14 day	28 day
Untreated soil	140	650	772	1025
10	275	768	926	1127
15	295	814	991	1220
20	280	696	830	1095

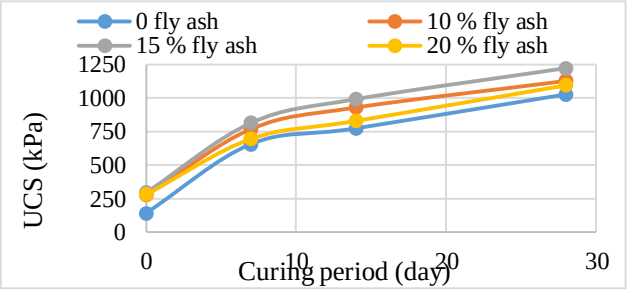

Figure 12: Effect of curing period on UCS of fly ash treated soil

Table 11: Effect of curing time on UCS of combination of lime fly ash treated soil

Lime (%) + fly ash (%)	UCS of soil for different curing period			
	0 day	7 day	14 day	28 day
2 + 10	262	784	942	1145
2 + 15	290	814	986	1166
2 + 20	292	685	844	1033
4 + 10	290	830	956	1038
4 + 15	315	891	1023	1320
4 + 20	298	713	866	1041

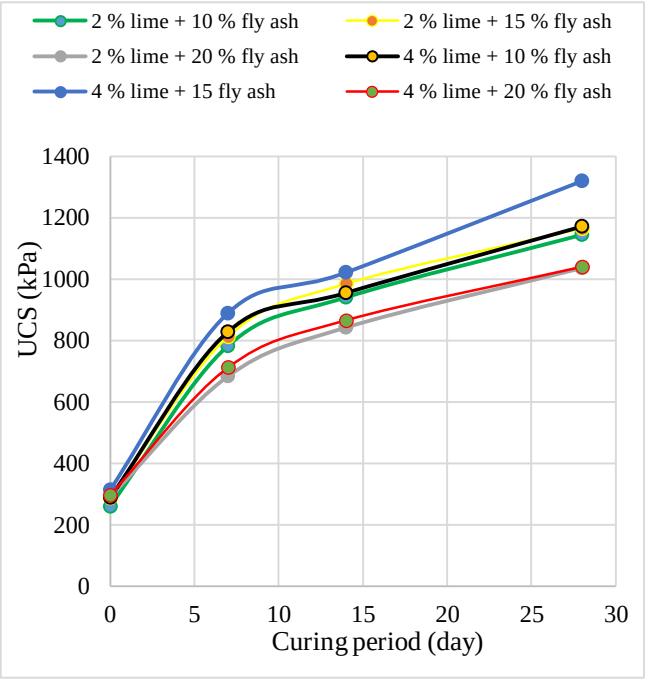

Figure 13: Effect of curing period on UCS of lime – fly ash treated soil

The variation of Unconfined Compression Strength occurred within the same quantity of fly ash content due to different curing days, take as an example of untreated soil of 0 day curing period, implies the result 140 KPa, after 7, 14 and 28 days have got to the following result ,650 kPa, 772 kPa and 1025 kPa respectively.

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This indicated that curing time affect strength of samples. using 15 % fly ash to soil obtained 814 kPa in 7 day to 1220 kPa in 28 day and soil strength comparatively better for 28 days curing period; as shown the graph and table above further increase in the quantity with increase curing period no considerable increase in the strength because the method is replacement of by mass due to this lime and fly ash quantity dominate soil properties and caused to reduction cohesion force.

When 2% lime + 15 % fly ash added to the expansive soil, the unconfined compression strength increases from 292 KPa (untreated) to 1033 kPa at 28 days of curing while 4 % lime+ 15 % fly ash mixed soil with specific curing period is the most efficient to increase the Unconfined Compressive Strength i.e. 345 kPa to 1320 kPa but 4 % lime + 20 % fly ash reduced unconfined compression strength..

E .California Bearing Ratio (C.B.R.) test

It established by California Division of Highway as a criteria of categorizing and assessing soil subgrade for flexible pavements. The sample during testing time was kept just below the tip of collar. Soil sample passing sieve size 4.75mm, the wet sample compacted in five layers with 56 blows of a 4.5kg hammer.

This test is used to forecast penetration resistance of soil in which the source of load come from standard plunger with appropriate density and optimum moisture. Conducting this test is easy and has been broadly explored for field application of flexible pavement

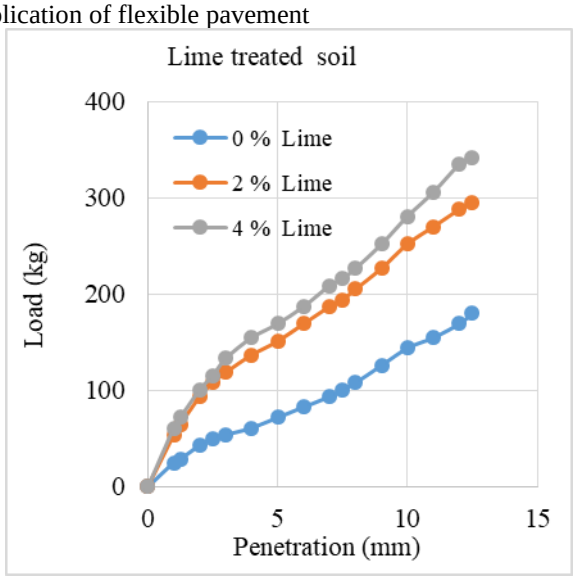

Figure 14: Effect of lime on load carrying capacity of soil

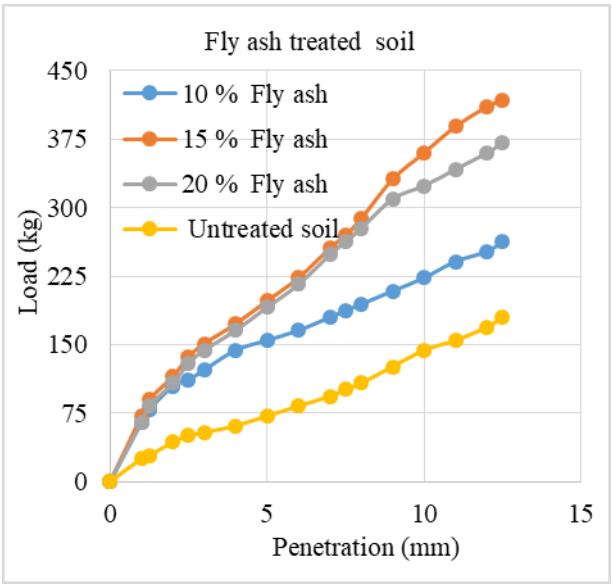

Figure 15: Effect of fly ash on load carrying capacity of soil

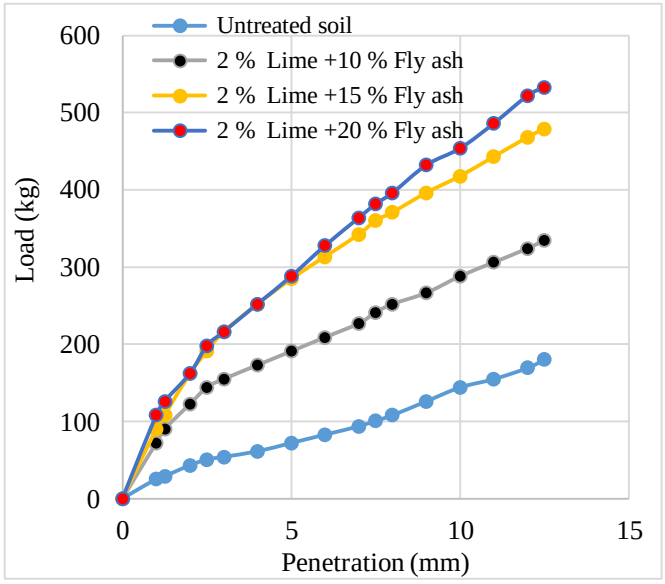

Figure 16: Effect of 2 % lime with various fly ash on load carrying capacity of soil.

Retrieval Number: K15730981119/19©BEIESP
DOI: 10.35940/ijitee.K1573.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

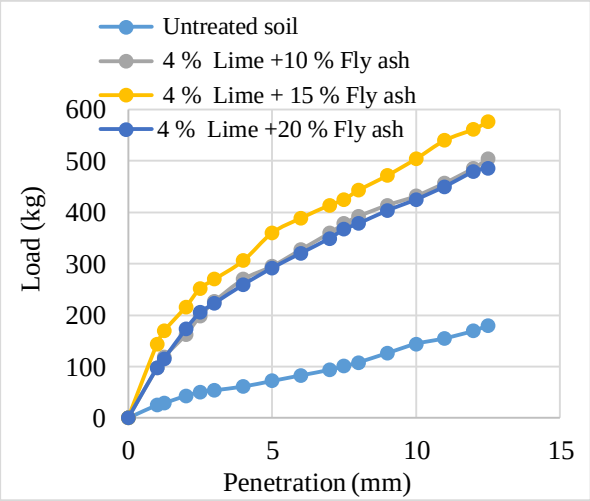

Figure 17: Effect various percentage of fly ash on load carrying capacity of soil.

Table 12: Effect of lime and fly ash on CBR (unsoaked) of soil

Stabilizers		CBR (%)	Bearing capacity justification
Lime (%)	Fly ash (%)		
0	0	3.68	Poor
2		7.88	Medium
4		8.4	Medium
0	10	8.15	Medium
	15	9.98	Good
	20	9.47	Good
2	10	10.5	Good
	15	13.93	Good
	20	14.5	Good
4	10	14.45	Good
	15	18.4	Excellent
	20	14.98	Good

Table 13: Effect of soaking time on CBR of lime -fly ash treated soil.

Stabilizers		CBR (%)	Bearing capacity justification
Lime (%)	Fly ash (%)		
0	0	2.63	Poor
2		4.73	Poor
4		5.3	Medium
0	10	4.73	Medium
	15	6.3	Medium
	20	4.99	Medium
2	10	4.99	Medium
	15	6.57	Medium
	20	4.99	Medium
4	10	6.3	Medium
	15	7.62	Medium
	20	6.3	Medium

Increasing the value of CBR with the addition of lime content of 2 % - 4 %, the CBR value qualified good soil bearing capacity. The CBR value associated with the bearing capacity between 6 - 9%, classified as good bearing capacity but in this research the CBR value obtained more than 9 % in combination of lime – fly ash treated specimen. It shows combination of lime- fly ash is recommended stabilizers for increased penetration resistance of poor soil. This indicated that small quantity of lime combine with fly ash mixed with soil is more effective than lime and fly ash treated soil .The highest value of CBR recorded in combination in 4 % lime + 15 % fly ash. The plot in Figure clearly demonstrated that load resistance increases in Unsoaked CBR from 3.6% (untreated) to 18.4 % While reduction in the CBR was observed at 4% lime + 20 % fly ash and 20% fly ash.

Increases CBR (soaked) from 2.63% (untreated) to 5.3 % with 4 % lime treated soil, 6.3 % CBR obtained at 15 % fly ash treated sample but still the improvement found in range of low bearing capacity however 4 % lime + 15 % fly ash treated soil after 4 day soaking implies 7.62 % which qualified good bearing capacity because the result lies between 6 – 9, this dosage of combination is the best one to increase load penetration resistance of soil. This is considered to be really successful and essential process to provide good subgrade. Further increase fly ash, soaked CBR decrease.

CONCLUSION

The investigation conducted on lime treated clay, fly ash treated clay and combination of lime -fly ash treated clay, from this analysis lime- fly ash treated clay is effective to improve bearing capacity of soil and successfully changes the soil from medium expansion to non-expansion soil. Lime reduce plasticity index i.e. using 4 % lime, PI would be reduced by 53 % while usage of 15 % fly ash reduced by 69.5 % however combination of 4 % lime + 15 % fly ash reduced plasticity index 94 %, it shows already change to non-plastic soil.. Free swelling index of soil reduced by lime and fly, using 4 % lime ,the FSI reduced by 63 %, using 15 % fly ash ,the FSI reduced by 70 % while combination of 4 % lime +15 % fly ash mixed soil , the FSI completely reduced 100% or change to non-expansive soil Standard proctor compaction test affected by quantity of lime and fly ash added to the soil, the peak MDD is 1.8 g/cc which record in combination of 4 % lime + 15 % fly ash mixed soil , it is the big number compare to single stabilizers.

Strength of untreated soil was lower than lime and fly ash treated soil. the UCS value increased 50 % in 4 % lime mixed soil , 53% in 15 % fly ash treated soil and increased by 60 % at 4 % lime + 15 % fly ash . Further increase the fly ash content, the strength of soil decrease. The effect of curing time on treated and untreated soil caused to increase ultimate bearing capacity of soil, as the curing period increase, the strength of soil efficiently increase. Long curing period provides better strength that is UCS value increase more than 100% at 28 days for each percent of sample.

The CBR value of untreated soil is 3.68 % which is classified under poor bearing capacity. In 4 % lime treated soil ,it increase to 8.4 %, while15 % fly ash stabilized soil, provides better results which is 9.98 %, both results indicated the soil qualified good bearing capacity however 4 % lime and 15 % fly ash combine together ,provides 18.4 % , it is grouped under excellent bearing capacity of soil. CBR value of soil affected by soaking time, the soaking time increase, its value decrease, this leads to soil got poor load penetration resistance.

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AUTHORS PROFILE

Asres Getnet is M.Tech from Sharda University and studying Geotechnical engineering. Asres obtained his B. Tech degree form Arba Minch University in the year 2016 and M. Tech from Sharda University in the year 2019. Asres has also served the water resources and irrigation engineering as a teaching in 2 year in AMU.

Dr. Shamshad Alam is Ph. D from NIT Rurkela and working as an Assistant Professor at Sharda University. Dr. Alam obtained his B. Tech degree form Jamia Millia Islamia in the year 2010 and M. Tech from NIT Rourkela in the year 2014. Dr. Alam has also served the industry as a structure design engineer and designed sever RCC and Steel structure involves in the thermal power plant.