Strength Evaluation of Clay Soil Using Fly Ash and Lime

Mirhamza Noorzai, Amanpreet Tangri

Abstract: ***one of the possible problems that could appear in execution projects like highway construction, mass construction, industrial and residential building construction is low strength of underneath soil. Many methods have been used to stabilize such soil but are in high demand. In this research paper lime used as modifier and binder, and fly ash, which is a by-product producing in millions of tons every year and responsible for environmental contamination is used as clay soil stabilizers. initially, several laboratory experimental tests were conducted on clay soil with various percentages of lime (0%, 2%, 4%, 6%, 8%, and 10%) by weight. the results indicate that the addition of 7% of lime gives optimum results and increase the strength of soil up to twice. in the second round of investigation, many specimens were prepared with addition of 7% lime and various percentages of fly ash (4%, 8%, 12%, 16%, and 20%) by weight on the wet side (+2% of OMC), dry side (-2% OF OMC) and optimum water content. soil specimen were tested after (7, 14, and 28) days of curing. the results indicate that, as fly ash content increasing, the unconfined compressive strength (UCS) of soil increases till an optimum point (180 Kpa) which shows around (4) times increment. time of curing has considerable impacts on soil strength. the 28 days curing brought 44.5% improvement in the UCS of clay soil. addition of fly ash and lime make the soil more durable, after 12 wetting-drying cycles, the soil still indicates 98kpa compression strength which is 48% more than untreated soil strength.***

Key words: Clay soil, Lime, Fly ash, Unconfined Compressive Strength

I. INTRODUCTION

Soil which swells with receiving moisture and shrink with releasing moisture is recognized as expansive clay soil. Expansive soil absorbs water and gets soft inflate and the potential to release water get reduced in rainy seasons. In drier seasons soil release water due to evaporation and cracks become exist. It is known in the geotechnical engineering field that swelling of expansive soil originated by moisture alteration result big troubles leading to severe damage to buildings and foundations. Nalbantog˘ lu, Z. (2004) [1]. Expansive clay soil is also named as black cotton soil due to its dominant black color and abundantly growing of cotton plant in such soil. Usually, this soil finds in dry and semi-dry regions in the world such as India, Australia, China, Canada, South Africa, Israel, and the United States. About 0.8*106 km^2 area of India has covered by this soil and expanded over the states of Gujarat, Maharashtra, Rajasthan, Madhya Pradesh, Southern part of Utter Pradesh, and some parts of Andhra Pradesh and Chennai Kumar A et al.,(2007)[2].Various innovative soil stabilization techniques have been used for a specific foundations but are in high demand all over the world such as drilled piers, moisture barriers, belled pierss, and friction piers have been used to reduce the problems caused by expansive soils. Apart from these techniques, the addition of various additives including cement, lime, fly ash, and calcium chloride have a substantial result to stabilize the soil Kumar B.R.P. & Sharma R.S., (2004)[3]To grow up the economic level of a country industrial development is a must and it increases the demand for energy. Construction of thermal power plants fulfill the energy demands for industries. Raw material uses for heating in the thermal power plants are usually coal, natural fuel, and natural gas. These power plants produce wastes in large amount every year around the world which are responsible for pollution. To manage the contamination arising out of these wastes efforts should be taken to use these waste as raw materials in various profitable purposes.Millions of tons of various industrial wastes are being produced in the manufacturing industries & thermal power plants every year in India as well as all over the world. Most of these wastes left unutilized and causing environment hazardous by contaminating the soil, water, and air Zha F et al(2008)[4]. Some of these wastes utilized in soil stabilization, road construction, and in other construction fields. Some of these wastes like fly ash & blast furnace slag have pozzolanic properties and have utilized in the construction industry along with cement or lime as activators. Fly ash is non-plastic fine silt material, extracting from flue gases of a furnace fired with coal. It has constituted from various compositions according to the coal type burned in power plant. It has been predicted to overstep 100 million tons of fly ash generation worldwide every year by the year 2000 Kumar B.R.P. & Sharma R.S., 2004[3]. Usually, fly ash has smaller Specific Gravity than conventional soil. It is a non-plastic silt-size material which consists of aluminum oxide, iron oxide, unoxidized carbon, and often hollow spheres of silicon Athanasopoulou A (2014), [5].

The combination of fly ash extensively depends on the coal type and nature burned and the power plant operational characteristics. Fly ash is a pozzolanic material which its engineering properties can improve with the addition of cement and lime Kumar A et al 2007[3].

Revised Manuscript Received on MAY 07, 2019.

Mirhamza Noorzai, Civil Engineering Department, Chandigarh University, Punjab, India
Amanpreet Tangri, Civil Engineering Department, Chandigarh University, Punjab, India,

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

During last few decades' usage of lime as clay soil stabilizer has been increasing. As it reduces volume alteration of clay soil caused by seasonal moisture changes. Comprehensive research studies have been accomplished on clay soil stabilization using lime (Kassim and Chern 2004; Mohamed et al.2009; Tangri A and Jha J 2016) [6, 7, and 8]. With addition lime to soil several reactions can provoke, which include: a) reduction of moisture content of soil, b) intracrystalline swelling reduction, c) osmotic swelling reduction, d) rainfall of calcium carbonate and/or soil particles binding upon carbonation of portlandite, e) solution of clay minerals and other mineral phases Elert K et al., (2018)[9].

As Sabry (1977) [10] found that addition of lime could beneficially modify various significant engineering characteristics of soft soils. As addition of lime considerably reduce plasticity of soil, reduces shrinkage cracking and cause to reduce shrinkage limits of soil. All these modification ends with increments in the unconfined compressive strength and California Bearing Ratio (CBR) of soil.

II. MATERIALS

The clay soil used for the study, was collected from Mohali, Punjab, India (fig. 1). The soil excavated from 0.5 to 1 m depth from a sedimentary area. The collected soil placed in plastic bags and then carried to the laboratory for testing. Several laboratory tests were performed to determine the fundamental properties of untreated soil such as index properties of soil (liquid limit, plastic limit, and plasticity index), compaction properties of soil (MDD and OMC), and Specific Gravity of soil. Table (1)

Table 1. Physical and engineering properties of untreated clay soil and flash and

property	Fly ash	soil
Liquid Limit (%)	32	32
Plastic Limit (%)	15	15
Plasticity Index (%)	17	17
Specific Gravity	2.11	2.65
MDD (g/cm3)	1.193	1.87
OMC (%)	28.69	12
Unified soil classification system	Class F	CL
gravel	0	0
sand	65.24	8.571
silt	31.6	76.029
clay	3.16	15.4

The grain size analysis of the soil shows that soil composes of (8.571%) sand, (76.029%) silt, and (15.4%) clay. The soil classified as (CL) based on the Unified Soil Classification system fig (2).

Fly ash used for experimental work is class F type which is collected from (Ropar Thermal Power Plant), the basic properties of fly ash tabulated in table (1) and lime used in the experimental program is collected from (Kharar, Punjab).

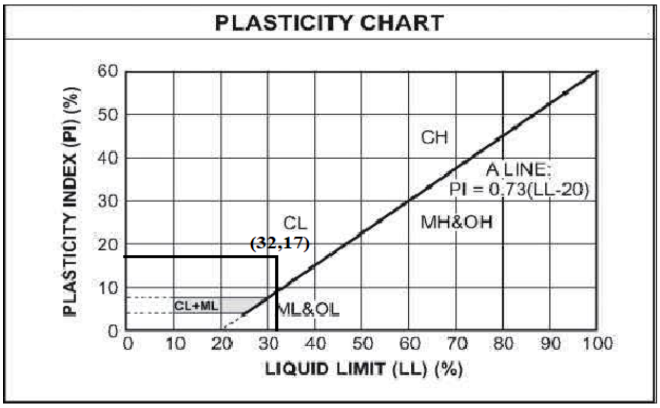


Figure 2. Liquid limit vs plasticity index

III. EXPERIMENTAL PROGRAM

The overall experimental program is carried out in two stages. In the first stage, lime added clay soil in various percentages (0%, 2%, 4%, 6%, 8%, and 10%) by weight. The compaction properties of soil (maximum dry density and optimum moisture content) determined using the Standard Proctor Test as per code (IS 2720-PART VII-1980.Numerous specimens (at least three specimens for each mixture) were

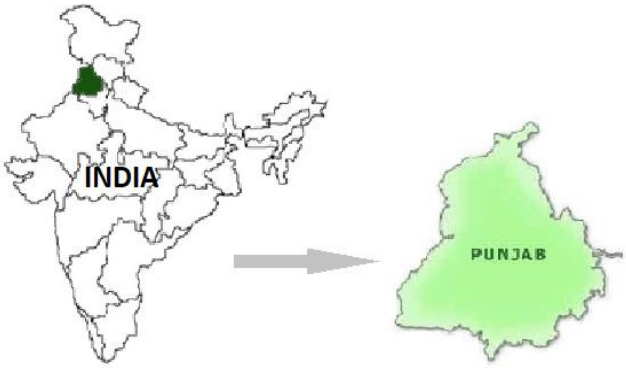


Figure 1. Location map of the study area.

prepared using a split mold (7.6 m long, 3.8 m diameter) as per code (IS-2720-PART-10-1991). Samples were tested through the UCS testing machine. In the second stage, various percentages of fly ash (4%, 8%, 12%, 16%, and 20%) and the optimum amount of lime obtained already from first stage investigation added to clay soil.

Specimens were prepared as per code (IS-2720-PART-10-1991) using a split mold (7.6 m long, 3.8 m diameter) and compacted at wet side (+2% of OMC), dry side (-2% of OMC) and optimum water content already calculated for each soil-additive admixture separately according to (IS-2720-PART 7-1980) code. Specimens were stored at 25oC temperature and cured for (7, 14, and 28) days. Samples have tested through the unconfined compressive testing machine.

To investigate the durability of lime-fly ash treated soil, based on IS: 4332 (part IV) – 1968, at least three specimens were prepared and cured for 28 days and tested after 12 wetting-drying cycles.

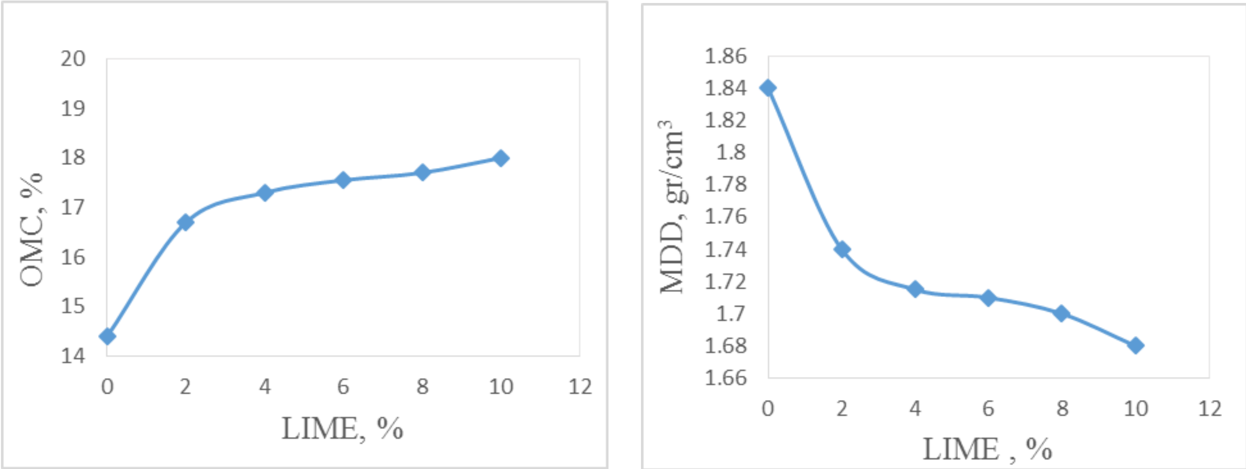


Figure 3. Figure 3. Effects of lime on OMC and MDD of clay soil.

IV. Results and Discussion

The compaction characteristics of the soil have been studied using standard Proctor test based on (IS 2720-PART VII-1980). To determine the effects of lime and lime-fly ash on OMC and MDD of clay soil Standard Proctor test have been carried out on virgin soil and lime and lime-fly ash treated soil. In first stage lime mixed with virgin soil (0%, 2%, 4%, 6%, 8%, and 10%) by weight. The addition of lime to clay soil provides a plenty of calcium ions (Ca+) and magnesium ions (Mg+). These ions displace potassium ions (K+) and sodium ions (Na+) trough cation exchange process with replacement of (Ca+) and (Mg+) ions with (k+) and (Na+) ions.

As per the above chemical reactions and cation exchanging process plasticity index of clay soil reduces significantly.

Reduction in plasticity is always accompanied with swelling reduction Sharma N K (2012) [11]. The results, attained from the standard proctor test are plotted in fig (3). Results show that with increasing lime content (0% - 4%) interval the optimum moisture content increase rapidly and from (4% - 10%) lime content the optimum moisture content graph took increasing trend smoothly and with increasing lime content (0-10%) by weight maximum dry density of lime treated soil indicates reduction. similar result obtained by researches (Asgari M. R. et al 2013, Noorzad R & Motevalian S 2018) [12, 13].

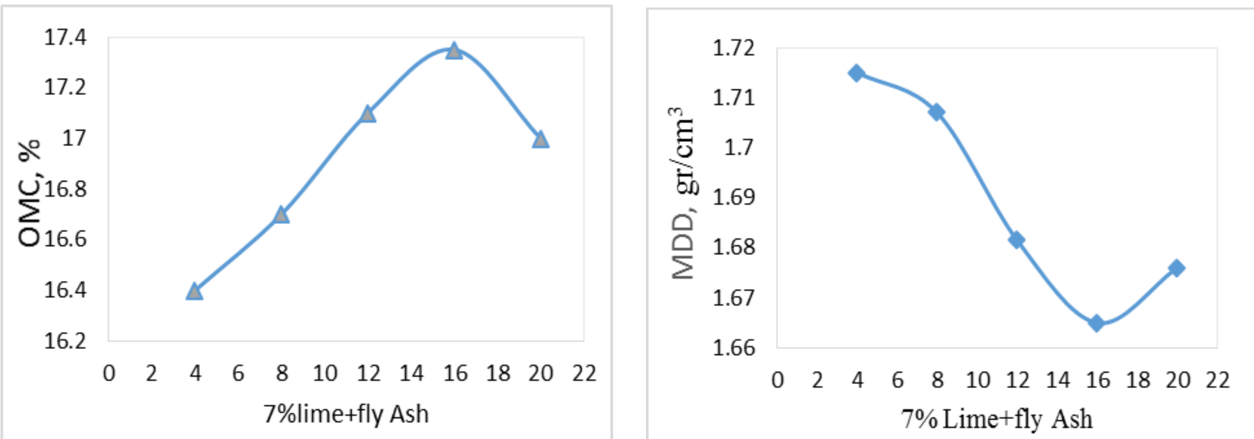


Figure 5. Effects of lime on OMC and MDD of clay soil.

The Unconfined Compressive Strength of untreated clay soil is calculated to be around 45 kpa fig (4) which indicates a soft soil. To investigate the effects of lime on UCS of clay soil tests were carried out on clay soil samples with various percentages of lime (0%, 2%, 4%, 6%, 8%, and 10%) by weight.

With referring to fig (4), addition of 7% of lime to the clay soil gives optimum results which increase the bearing capacity of clay soil up to 75 kpa.

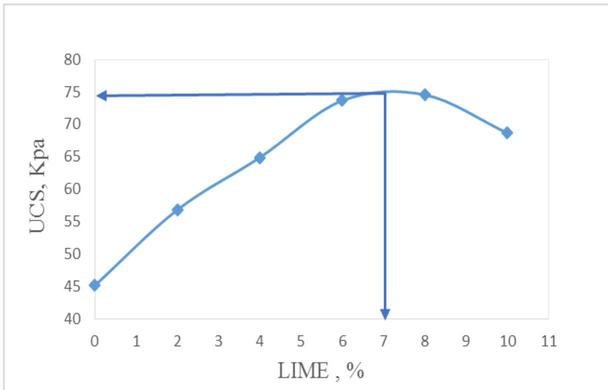


Figure 4. . Effects of lime on OMC and MDD of clay soil

As per second stage of investigations lime-fly ash admixture added to the soil in(7%L-4%FA, 7%L-8%FA, 7%L-12%, 7%L-16%FA,

7%L-20%FA) by weight. The addition of fly ash to clay soil provide a plenty of (Ca+2, Al3+, Fe2+, etc.) under ionize conditions which can provide flocculation of dispersed clay partials.
The results attained from standard proctor test, plotted in fig

specimens were prepared at wet side (+2% of OMC), dry side (-2% of OMC) and optimum water content and were tested after (7, 14, 28) days curing. Results plotted in fig (6, 7). Table (2) shows overall UCS test results. Similar result obtained by (Mishra N.K 2012) [14].

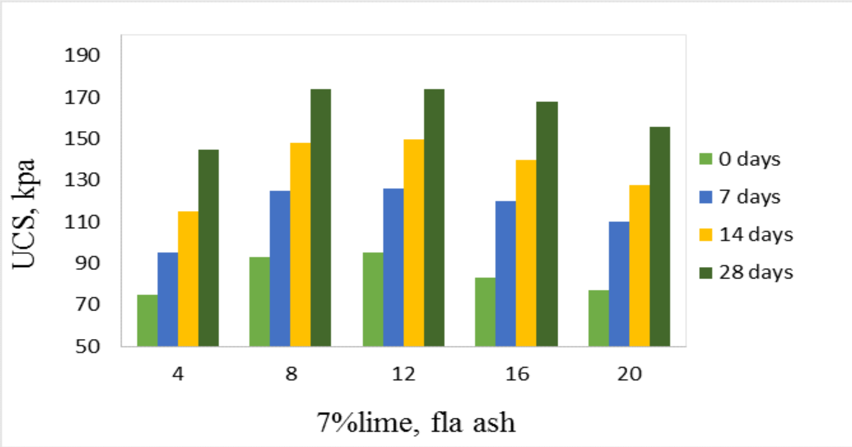


Figure 6. . Effects of 7%lime + fly ash on Unconfined Compressive Strength of the soil.

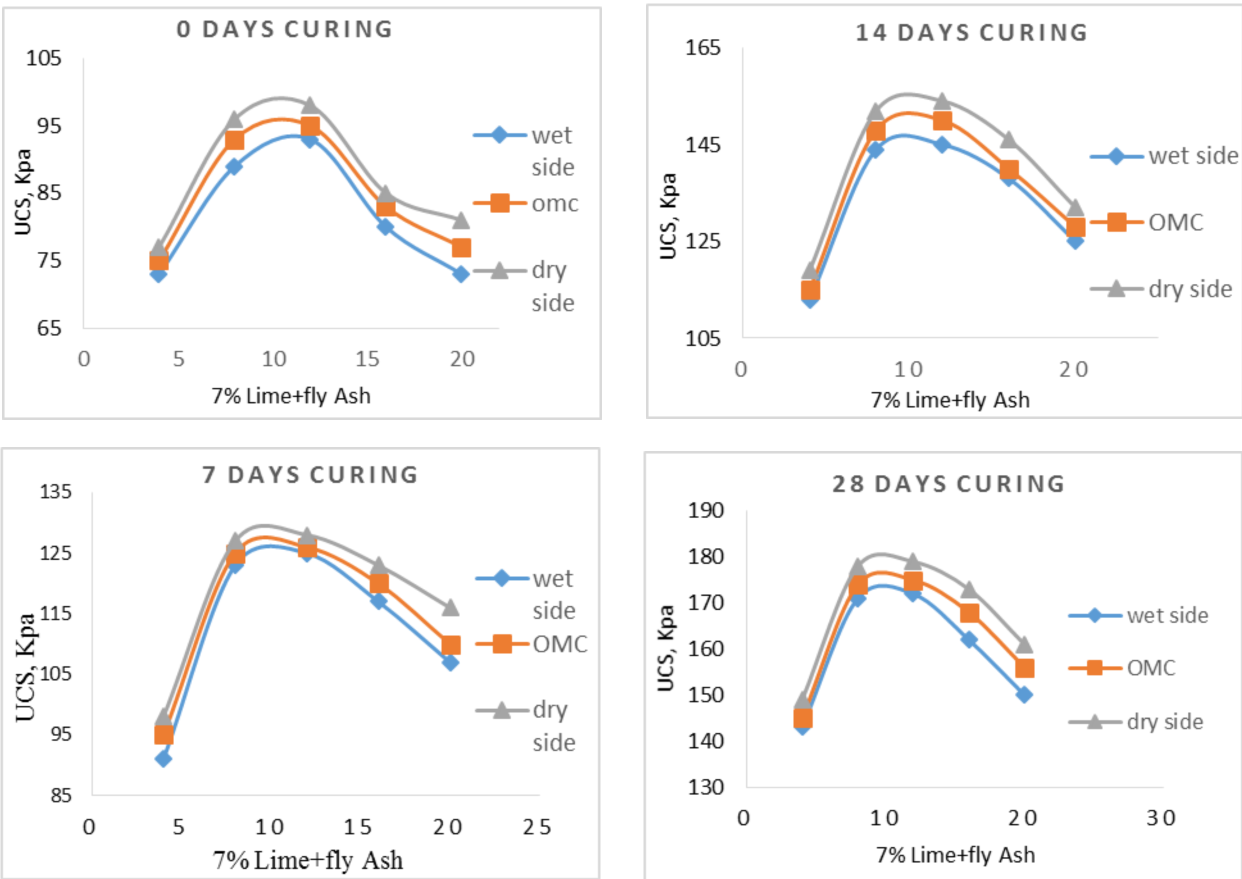
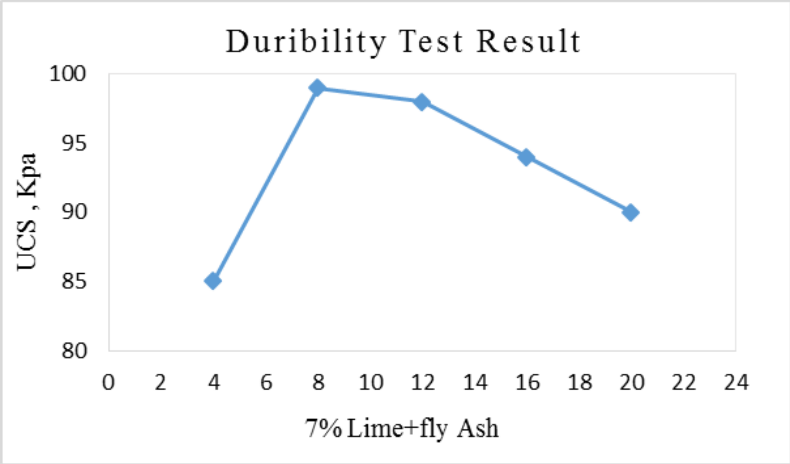


Figure 7. Effects of fly ash plus 7% of lime on UCS with variation in time of curing.

(5), show that with increasing fly ash (4 - 20%) by weight plus 7% lime content in the clay soil, the optimum moisture content graph getting increase till a maximum point then drop down and the maximum dry density graph getting decrease till the lowest point then getting up, fig(5). To study the effects of lime and fly ash on UCS, 7% of lime and various percentages of fly ash (4%, 8%, 12%, 16%, 20%) added to clay soil,

With increasing fly ash content, the unconfined compressive strength of soil increases till an optimum point and then decreases slightly and with increasing curing time unconfined compressive of soil increases.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



Addition of fly ash and lime make the soil more durable. Referring to the UCS test results, table (2), after 12 wetting-drying cycles soil has 98kpa strength which is 48% more than untreated soil strength.

Figure 8. Effects of fly ash plus 7% of lime on UCS after 12 wetting- drying cycles

Table (2) Over all UCS test results.

Lime-Fly Ash		0 Days Kpa	7 Days Kpa	14 Days Kpa	28 Days Kpa	After 12 Wetting-Drying Cycles Kpa
7%L+%4FA	Wet side	73	91	113	143	82
	OMC	75	95	115	145	85
	Dry side	77	98	119	149	88
7%L+%8FA	Wet side	89	123	144	171	91
	OMC	93	125	148	174	99
	Dry side	96	127	152	178	102
7%L+%12FA	Wet side	93	129	145	171	92
	OMC	95	126	150	174	98
	Dry side	98	121	154	178	103
7%L+%16FA	Wet side	80	117	138	162	91
	OMC	83	120	140	168	94
	Dry side	85	124	146	173	99
7%L+%20FA	Wet side	73	107	125	150	87
	OMC	77	110	128	156	90
	Dry side	81	116	132	161	94

V. CONCLUSION

Based on the experimental study carried out on lime and lime-fly ash treated clay soil, the following outcomes can be drawn:

1. As lime content increases (0% - 4%), the optimum water content of soil increase rapidly and then from (4% - 10%) lime content the optimum moisture content graph took increasing trend smoothly. With increasing lime content (0-10%) by weight, maximum dry density of lime treated soil indicates reduce.
2. According to the results of UCS test, 7% of lime is the optimum amount to add clay soil which increases the strength of clay soil up to twice compare to untreated soil.
3. As fly ash increases (4 - 20%) by weight plus 7% lime content in the clay soil, the optimum moisture content graph getting increase till a maximum point then drop down and the maximum dry density graph getting decrease till the lowest point then getting up.
4. As fly ash content is increasing, the UCS of soil increases till an optimum point (180 Kpa) which shows around (4) times increment.
5. Time of curing has considerable impacts on soil strength 28 days curing brought 44.5% improvement in clay soil strength.
6. Addition of fly ash and lime make the soil more durable. Referring to the unconfined compressive strength test results, table (1), after 12 wetting-drying cycles soil has 98kpa strength which is 48% more than untreated soil strength.

REFERENCES

1. Nalbantogˇ lu, Z. (2004)," Effectiveness of Class C fly ash as an expansive soil stabilizer", Construction and Building Materials, Volume 18, Issue 6, July 2004, Pages 377-381
2. Kumar A et al (2007)," Influence of Fly Ash, Lime, and Polyester Fibers on Compaction and Strength Properties of Expansive Soil", Journal of Materials in Civil Engineering ©ASCE, Vol. 19, No. 3.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

3. Kumar B.R.P. & Sharma R.S. (2004)," Effect of Fly Ash on Engineering Properties of Expansive Soils", Journal of Geotechnical and Geoenvironmental Engineering©ASCE, Vol. 130, No. 7
4. Zha F et al (2008), "Behavior of expansive soils stabilized with fly ash", Springer Science+Business Media B.V., Vol. 47, No.509.
5. Athanasopoulou A (2014), "Addition of Lime and Fly Ash to Improve Highway Subgrade Soils", Journal of Materials in Civil Engineering, Vol. 26, No. 4.
6. Kassim KA, Chern KK (2004)," Lime stabilized malaysian cohesive soils. J Kejuruteraan Awam 16:13–23
7. Mohamed AS, Mohamed AS, Yaser MM (2009) Utilization of lime for stabilizing soft clay soil of high organic content. Geotech Geolo Eng 27:105–113
8. Tangri A and Jha J (2016)," Improvement in Strength and Durability of Soil using Blast Furnace Slag and Lime", Engineering Conference on Sustainability in Geotechnical Engineering Practices and Related Urban Issues, 23-24, 2016, Mumbai, India.
9. Elert K et al (2018)," Smectite formation upon lime stabilization of expansive marls", Applied Clay Science, Vol 158, PP 29-36.
10. Sabry MA (1977)," Mineralogical and engineering properties of compacted soil lime mixture. PhD thesis, Oklahama State University, Oklahama
11. Sharma N K (2012)," Stabilization of a Clayey Soil with Fly Ash and Lime: A Micro Level Investigation", © Springer Science Business Media B.V., Geotech Geol Eng., 30:1197–1205 DOI 10.1007/s10706-012-9532-3.
12. Asgari M. R. et al (2013), "Experimental study on stabilization of a low plasticity clayey soil with cement/lime", Arab J Geosci © Saudi Society for Geosciences, 8:1439–1452.
13. Noorzad R & Motevalian S (2018)," Improvement of Clayey Soil with Lime and Industrial Sludge", Geotechnical and Geological Engineering© Springer International Publishing AG, Volume 36, issue 5, pp 2957–2966
14. Mishra N.K (2012) "Strength characteristics of clayey sub-grade soil stabilized with fly ash and lime for road works" Indian geotech (july-september 2012) 42 (3):206-211