Proceedings of Indian Geotechnical Conference IGC-2014
December 18-20, 2014, Kakinada, India

EFFECT OF CURING ON THE STRENGTH BEHAVIOUR OF LIME-FLY ASH-EXPANSIVE SOIL MIXES

KVNS Raviteja, Research Scholar, Indian Institute of Technology Hyderabad, kvnsravi.teja@gmail.com
K Ramu, Professor, UCEK-JNTU Kakinada, kramujntu@gmail.com
R Dayakar Babu, Professor, KITS-Divili, baburd1108@hotmail.com

ABSTRACT: Expansive soils occupying almost 3 lakh km^2 in the Indian subcontinent found to be highly problematic due to their extensive swelling and shrinkage nature. This rapid volume change leads to upliftment of foundations, differential settlements, heaving, rutting, etc. on the overlying structures. Concerning with the above problems an effective, economical and long-term method lime stabilisation was selected. In this work it is attempted to study the effect of curing period on the strength behaviour expansive soil treated with lime and fly ash by conducting triaxial shear (UU) test for 0, 3, 7, 14, 28 days with some twenty different proportions.

INTRODUCTION

In India, about 20% of the total land area was covered by expansive soils, popularly known as black cotton soils (because of their colour and their yield to the cotton crop). These soils are highly problematic because of their alternate swelling and shrinking nature, when subjected to seasonal moisture fluctuations. This rapid volume change can produce large amount of stresses some times as high as 720 kPa on the structures constructed in them. Most of these problems are due the presence of the clay mineral named as montmorillonite. Because its high specific surface area ranges from 800 - 1000m^2/g, it adsorbs more amount water molecules on to its surface causing intense swelling. This swelling behaviour of soils has been influenced by many other factors such as amount of clay minerals, physicochemical properties of pore fluid, soil density, water content, plasticity indices, surcharge pressure, temperature and time. Another major disadvantage by these expansive soils is that it takes some years to cause an extensive damage to a structure mean while the problem will tend to ignorance. Creeping in expansive soils will also tends to large lateral pressures and finally makes them vulnerable to slide over.

Fly ash is a versatile industrial waste that was collected from the Electro Static Precipitators (ESP) of coal based thermal power plants. India was producing more than 160 million tons of fly ash per year which makes it as the largest industrial-waste of our country. Among the total waste that has been generated every year only 40% has been gainfully utilizing in different fields of engineering and the remaining 60% was dumping in the ash dykes which requires approximately 4.84 crore m^3 of landfill space. If we can make use of that remaining percentage also then we can effectively conserve vast amount of land area and utilize the waste as an admixture for stabilizing weak soils.

Lime has been proved as an effective stabilizing agent even from the period of Romans, in the soils with more percentage of fines. Lime stabilisation is highly suggestible for expansive soils as it develops from base exchange and cementation processes between clay particles and lime. The stabilisation process is a long-term process. In the short-term, lime modifies and immediately improves workability and compactability of soils. The initial reaction occurs as a result of cation exchange of calcium ions (Ca^{2+}). The result of cation exchange is increasing flocculation of clay particles and changes in the plasticity properties of clay. Though the instant effect of lime in improving the strength properties was ineffective, it will have greater effectiveness in improving the strength properties with time.

In this work, an attempt has been made to study the long lasting effect of lime and fly ash by analyzing the improvement in the strength properties of lime-fly ash-soil matrix for different periods of curing.

REVIEW OF LITERATURE

Cocka (2001) studied the effect of fly ash on expansive soil and confirmed that the plasticity index, activity and swelling potential of the samples decreased with increasing percent stabilizer and curing time. The optimum content of flaysh in decreasing the swell potential was found to be 20% [1].

Fusheng Zha et al. (2008) observed that the shear strength of the expansive soil has been increased significantly when treated using lime and fly ash with curing time of 7 days [2].

Lasledj and Muzahim (2008) concluded that hydrated lime treatments are very effective in reducing the swelling pressure and consequently the swelling potential of the treated expansive clay soils. With the addition of 8% lime, both swelling potential and pressure were reduced to zero after three days of curing time [3].

Hakari and Udayshankar (2010) stated that the strength of soil is observed to improve considerably with curing which is due to the pozzolanic reactivity of the free lime content of the fly ash. A mix of fly ash of class-C with increased curing periods may be more effective in further improving the strength of the black cotton soil. For a curing period of 7 days, the trend of increase in the strength is found more pronounced and the unconfined compressive strength increases from 238.52 kN/m^2 for M10 mix to 395.7 kN/m^2 for M50 mix [4].

According to Emilliani et al. (2010), the shear strength observed of sample mixtures cure for 7 days were decreasing when amount of fly ash governed by 80% of the total weight of the mixture. Besides that, 60% of fly ash by weight and clay mixture gave the highest value of axial stress exerted [5].

Khelifa et al. (2011) found that a significant increase in cohesion was observed at later ages in samples stabilized with 8% lime content. The addition of natural pozzolana resulted in a marginal effect on cohesion and internal friction angle with increasing curing period. The combination 20% Natural Pozzolana + 8% Lime exhibited a high increase in cohesion beyond 28 days curing period [6].

Ethan (2011) observed that the addition of fly ash to the expansive soil rubber mix (ESR) improved the critical state strength of the ESR mixtures. For specimens stabilized with fly ash, the critical state friction angle was improved from 31 degrees (for the ESR) to between 31.6 to 32.4 degrees for the ESR-fly ash cured for 7 and 14 days [7].

Hayder (2012) observed that the value of cohesion increased with increasing the amount of fly ash in soil mixtures to 15% of fly ash then decreased. The value of cohesion increased with curing time to 14 days. The increase in Ø with added fly ash in all samples is independent of curing time of the mixture. The increase in Ø of all the mixtures for 7, 14 and 21 days curing time is more than that of no cure time [8].

Verma and Maru (2013) observed that with the increase in curing time for the treated soil, the swell potential and swelling pressure decreased. Soils immediately treated with fly ash show no significant change in the unconfined compressive strength. However, after 7 days curing of the fly ash treated soils, the unconfined compressive strength increased significantly [9].

Ghobhadi et al. (2013) reported that with the addition of 7 % lime, a considerable improvement in UCS was achieved after a curing time of 30 days [10].

Darshan et al. (2014) observed that the lime treated soil mixtures have shown the strength reaching upto 700 kpa for 30% ash and 6% lime cured for 60 days [11].

Sivapullaiah and Arvind (2014) concluded that with addition of 6 % lime, the strength of soil-fly ash mixtures increases with curing period [12].

From the above literature it is clear that curing time influences the strength parameters when added with the optimum percentages of lime and fly ash.

OBJECTIVE

To determine the long lasting effect of lime and fly ash on the expansive soil cured for 3, 7, 14, 28 days by analysing the improvement in the strength properties.

METHODOLOGY

Materials Used

The soil used in this study is a typical expansive soil with high swelling nature. The expansive soil was collected at a depth of 0.5m to 1m on the river banks of komaragiripatnam village, East Godavari Dist., Andhra Pradesh State, India. The properties of untreated soil are presented in the Table 1.

Fly ash of Class-F has been adopted in this work as an admixture in the proportions varying from 0% to 40% with an increment of 10% to the weight of the soil. The required quantity of fly ash was collected from the second basin of Dr. Narla Tatarao Thermal Power Station (NTPS) formerly known as VTPS of Vijayawada, Andhra Pradesh.

Commercial grade hydrated Birla lime [$Ca(OH)_2$] bought from market has been adopted in this work as an additive to impart binding property to the soil mix in the proportions varying from 0% to 9% with an increment of 3% to the weight of the soil.

Table-1 Virgin Expansive Soil Properties

S.No	Property	Value
1.	Specific Gravity	2.66
2.	Liquid Limit	85.4 %
3.	Plastic Limit	33.1 %
4.	Plasticity Index	52.3 %
5.	Shrinkage Limit	11.2 %
6.	Sand	5 %
7.	Silt& Clay	95 %
8.	DFS	140 %
9.	IS Classification	CH
10.	OMC	31 %
11.	MDD	1.48 g/cc
12.	Unsoaked CBR	2.01 %
13.	Soaked CBR	0.74 %
14.	Cohesion	54 kPa
15.	Angle of Friction	0 degrees

Experimental Program

The air dried soil was pulverized and then sieved through 4.75mm sieve. Lime and fly ash are added and replaced respectively in 19 different proportions (given in Table 2) to the soil by weight and compacted at the optimum moisture content. Triaxial samples of 38mm diameter, 76mm height are then prepared tested immediately and 3, 7, 14, 28 days curing respectively. The samples are set for curing in the desiccator inorder to retain 100% moisture content. Unconsolidated Undrained (UU) test was performed on all the samples inorder to determine their strength parameters.

RESULTS AND DISCUSSIONS

Lime adopted in this work for the purpose of stabilizing the soil to impart cementing property to the soil mix. This cementation process developed from the reaction between calcium that present in lime and silica and alumina in the soil, forming calcium-silicate hydrate (CSH) and calcium-Aluminate (CAH) or calcium-aluminate-silicate. These reactions contribute to flocculation by bonding adjacent soil particles together and strengthen the soil with curing period. This reaction is called pozzolanic reaction and it depends on curing period and temperature. The cementitious compounds produced are possesses high strength and low-volume change. It was observed that at all percentages of lime (0, 3, 6 and 9%) with addition of fly ash the cohesion value was found to be increased continuously upto 20% of fly ash for all curing periods (0, 3, 7, 14, 28 days) and then decreased with further addition of fly ash content as shown in Figs 1-4.

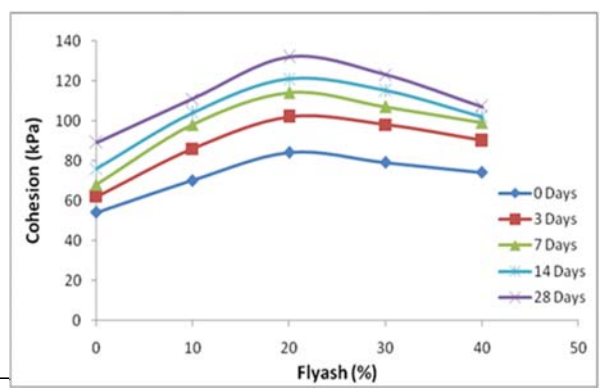

Fig 1 Variation of cohesion with fly ash for different curing periods at 0% lime

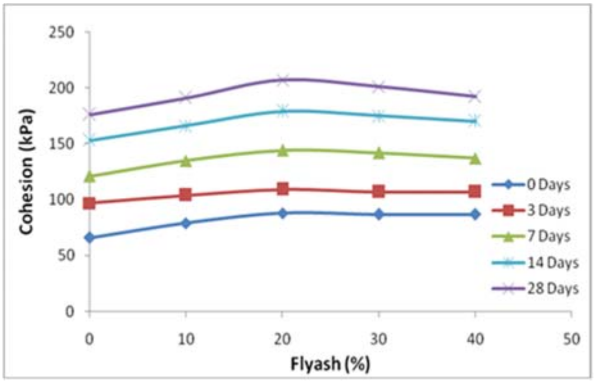

Fig 2 Variation of cohesion with fly ash for different curing periods at 3% lime

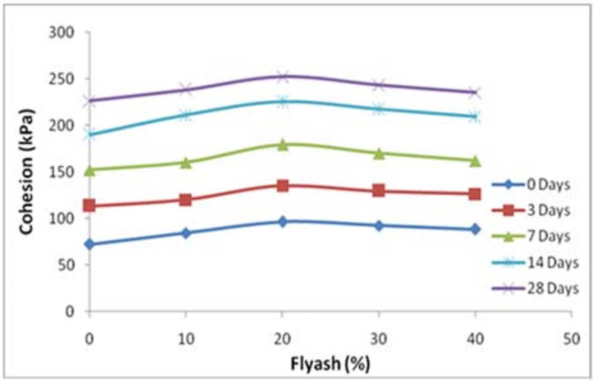

Fig 3 Variation of cohesion with fly ash for different curing periods at 6% lime

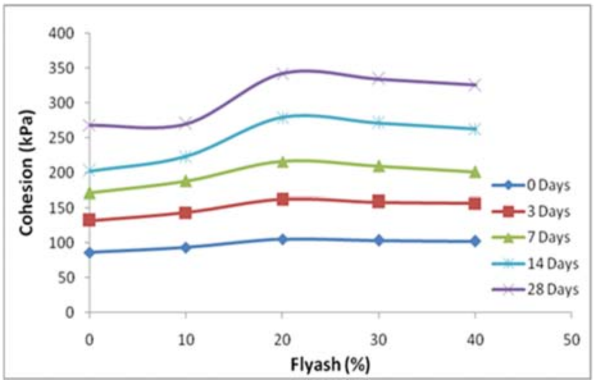

Fig 4 Variation of cohesion with fly ash for different curing periods at 9% lime

The value of frictional angle has been increased continuously for 0, 3, 7, 14, 28 days of curing when added with 0% of lime as shown in Fig 5.

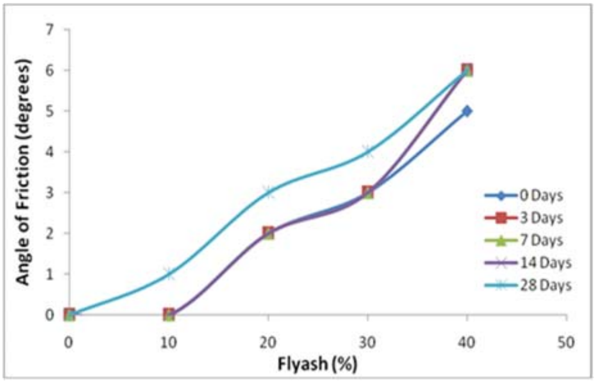

Fig 5 Variation of Frictional Angle with fly ash for different curing periods at 0% lime

The value of frictional angle has been increased continuously and remained constant for 0, 3, 7, 14, 28 days of curing when added with 3% of lime as shown in Fig 6.

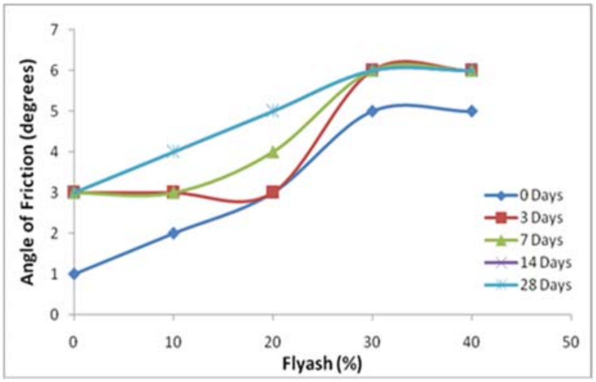

Fig 6 Variation of Frictional Angle with fly ash for different curing periods at 3% lime

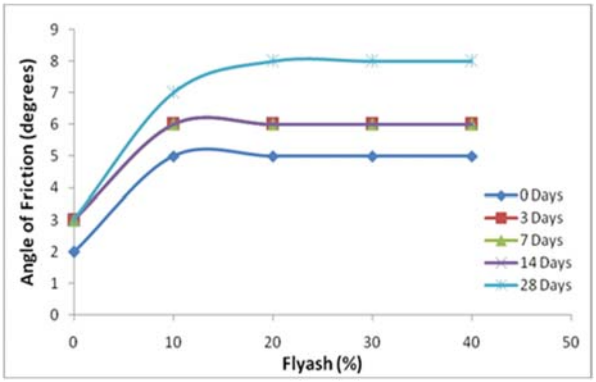

Fig 7 Variation of Frictional Angle with fly ash for different curing periods at 6% lime

The value of frictional angle has been increased initially and then remained constant for 0, 3, 7, 14, 28 days of curing when added with 6% of lime as shown in Fig 7.

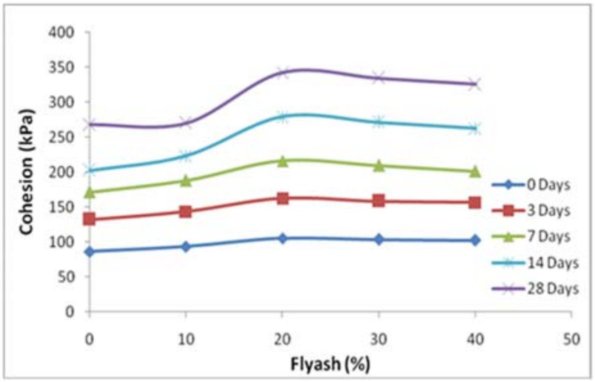

Fig 8 Variation of Frictional Angle with fly ash for different curing periods at 9% lime

The Unconfined Compressive Strength (UCS) value was found to be increased with increase in the fly ash content upto 20% and then decreased slightly with further addition of fly ash at all lime percentages (0%, 3%, 6%, and 9%) for all the curing periods as shown in Figures 9-12.

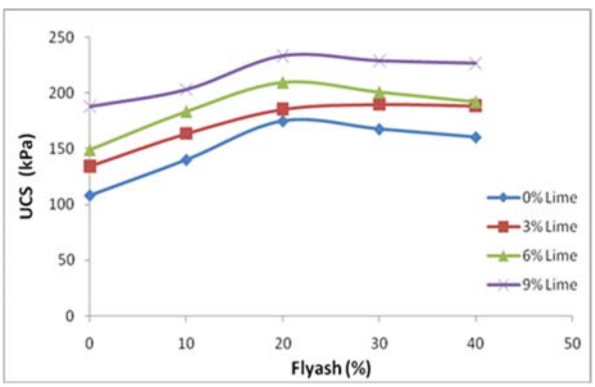

Fig 9 Variation of UCS with fly ash & lime for 0-day curing

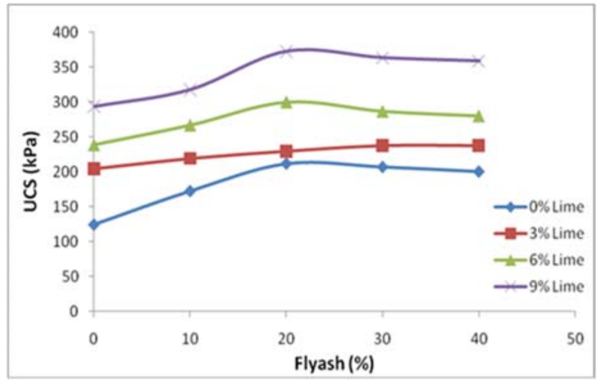

Fig 10 Variation of UCS with fly ash & lime for 3-days curing

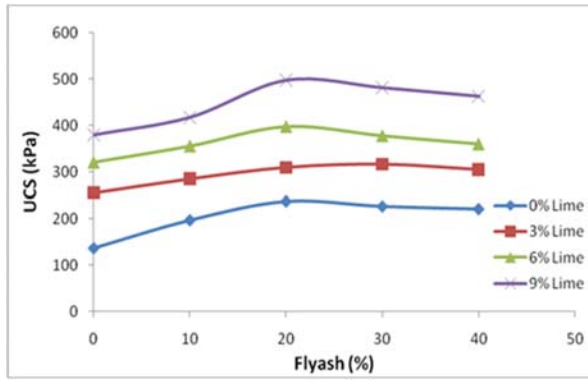

Fig 11 Variation of UCS with fly ash & lime for 7-days curing

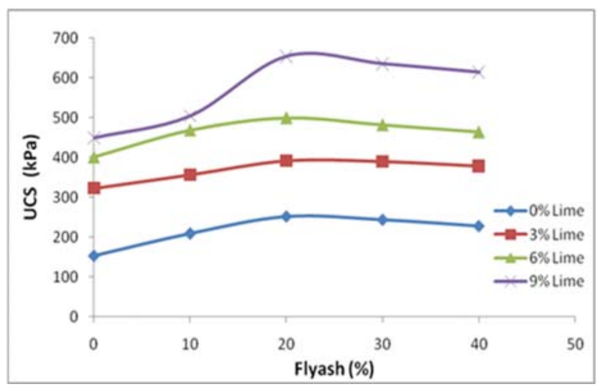

Fig 12 Variation of UCS with fly ash & lime for 14-days curing

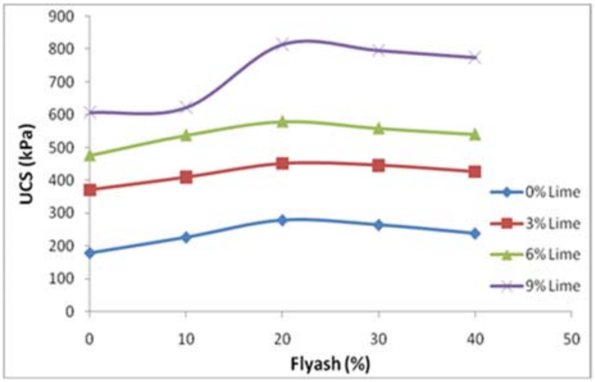

Fig 13 Variation of UCS with fly ash & lime for 28-days curing

CONCLUSIONS

- From the laboratory studies, it was observed that the expansive soil chosen was a problematic soil having high swelling, with high plasticity and low strength characteristics.
- There is a gradual increase in cohesion with an increment in the % replacement of fly ash up to 20% and curing it for 28 days, the improvement was about 1.5 times and upon further increment there is a marginal decrease in cohesion value.
- The cohesion value was found to be improved by five times when the virgin soil was replaced with 20% fly ash and further blended with 9% lime on curing for 28 days.
- The corresponding unconfined compressive strength was improved by about 6.5 times when replaced with 20% fly ash, blended with 9% lime on curing for 28 days.
- The efficacy of treated expansive soil was assessed thereby giving a two-fold advantage in improving a problematic soil and also solving the problem of waste disposal.

REFERENCES

[1] Erdal Cokca (2001) "Use Of Class C Fly ashes for the Stabilization – of an Expansive Soil" *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, July, pp. 568-573.

[2] Fusheng Zha, Songyu Liu, Yanjun Du and Kerui Cui (2008), Behavior of expansive soils stabilized with fly ash, *Natural Hazards*, Vol. 47, Issue 3, pp. 509-523.

[3] Lasledj Abdelmadjid, Al-Mukhtar Muzahim, (2008) Effect of Hydrated Lime on the Engineering Behaviour and the Microstructure of Highly Expansive Clay, The 12th International Conference of *International Association for Computer Methods and Advances in Geomechanics (IACMAG)*, pp 3590-3598.

[4] Hakari & Udayshankar (2010), Geotechnical Characteristics of Hubli Dharwad Black Cotton Soils Mixed with Fly ash: An Experimental Evaluation, *Indian Geotechnical Conference – 2010, GEOtrendz*. pp.441- 444.

[5] Emilliani Anak Geliga and Dygku Salma Awg Ismail (2010), Geotechnical Properties of Fly ash and its Application on Soft Soil Stabilization, *UNIMAS E-Journal of Civil Engineering*, Vol. 1: issue 2 /April 2010, pp.1-6.

[6] Khelifa Harichane, Mohamed Ghrici and Said Kenai (2010), Effect of curing time on shear strength of cohesive soils stabilized with combination of lime and natural pozzolana, *International Journal of Civil Engineering*, Vol. 9, No. 2, June 2011, pp. 90-96.

[7] Ethan Patrick Wiechert (2011), Report on "Beneficial use of off-specification fly ashes to increase the shear strength and stiffness of expansive soil-rubber (ESR) mixtures." *Colorado State University*.

[8] Hayder A. Hasan (2012), Effect of Fly ash on Geotechnical Properties of Expansive soil, *Journal of Engineering and Development*, Vol. 16, No.2, pp. 306-316.

[9] Verma S K and Maru S (2013), Behaviourial Study of Expansive Soils and its Effect on Structures–A Review, *International Journal of Innovations in Engineering and*

Technology (IJIET), Vol.2 Issue 2, pp:228-238.

[10] M. H. Ghobadi, Y. Abdilor, R. Babazadeh (2013), Stabilization of clay soils using lime and effect of pH variations on shear strength parameters, *Bulletin of Engineering Geology and the Environment*.

[11] Sai Darshan T R, Shankar and Maya Naik (2014), Influence of Fly ash on the Strength Behaviour of Lime and Cement Treated Red Soil, *International Journal of Environmental Research and Development*. ISSN 2249-3131 Volume 4, Number 2 (2014), pp. 135-140

[12] P. V. Sivapullaiah, Arvind Kumar Jha (2014), Gypsum Induced Strength Behaviour of Fly ash-Lime Stabilized Expansive Soil, *Geotechnical and Geological Engineering*, June 2014.