© January 2016 | IJIRT | Volume 2 Issue 8 | ISSN: 2349-6002

STRENGTH AND DEFORMATION CHARACTERISTICS OF MECHANICALLY STABILIZED EXPANSIVE SOILS USING FLY ASH AND LIME

Ch.Vaishnavi Devi, Dr. D. S. V. Prasad
Civil Engineering Department, B.V.C. Engineering College, Amalapuram, A.P,India.

***Abstract*- This paper presents investigation encompasses studying the strength and deformation characterstics of mechanically stabilized expansive soils using lime and flyash. The Coarse fraction decreases OMC, increases MDD and CBR, but effect is insignificant for coarse fraction less than 30% to 40% by weight of soil. Swelling pressure and unconfined compressive strength decreases with coarse fraction. OMC in general decreases with % fly ash. MDD increases up to certain % of fly ash. Optimum fly ash at which MDD is highest, is lesser for low liquid limit soils. Liquid limit and Plasticity index decrease with the % fly ash, but Plastic limit decreases for high liquid limit soils and increases for low liquid limit soils. Fly ash stabilization increases the strength by 40% to 110%. Soaked CBR is not sensitive to fly ash initially up to certain % of fly ash . The deformation modulus in general is found to increase with fly ash except in the initial regions. The effect of coarse fraction is dominant on deformation modulus than liquid limit in fly ash treated expansive soils.**

***Index Terms*—Expansive soil, coarse fraction, fly ash, lime and mechanical stabilization.**

I. INTRODUCTION

Expansive soils, popularly known as black cotton soils in India, are one of the major regional deposits of India. Expansive soils swell and shrink in a marketed way due to gain or loss in moisture content. Therefore, during summer when evaporation from the ground and transpiration due to vegetation exceeds the rainfall, the expansive soil dries up and moisture deficiency develops in the soil, giving rise to soil shrinkage. During the rains, the soil absorbs moisture and swells. Soils containing the clay mineral Montimorillonite generally exhibit these properties. Because of their susceptibility to high seasonal volumetric changes, extensive damages have been caused to residential buildings, highways, rail beds and other structures founded on them. . Some of the damages were usually observed in the buildings which are

constructed on expansive soils are diagonal and vertical cracks in the interior and exterior, Horizontal cracks in the exterior and interior walls ,Longitudinal cracks in the roof slab due to cantilever action, Separation of roof slab from the exterior walls, Separation of flooring from the exterior walls, Leaning out of exterior walls.

Now the present investigation is to study the feasibility of using expansive soil as a construction material in projects like airfield and highway pavements, tank bunds, and earthen embankments with and without addition of admixtures namely fly ash and /or lime.

In nature, expansive soils may present with varying liquid limits and varying coarse fraction. Both liquid limit and coarse fraction can affect the properties of expansive soils.

First objectives of the present investigation is to study the effect of coarse fraction as well as liquid limit on

1. Compaction characteristics of expansive soil.
2. Strength and Deformation characteristics of an expansive soil.
3. Swelling characteristics of an expansive soil.

The second objective of the present investigation is to study the possibility of using Fly ash for mechanical stabilization of expansive soil. It is intended to obtain Optimum fly ash from view point of compaction characteristics, strength and deformation characteristics.

The third objective is to determine optimum lime content for fly ash treated expansive soils and to study the effect of lime & curing period on compaction, strength and deformation characteristics of fly ash treated expansive soils.

In order to meet the objectives of present investigation two different expansive soils having liquid limits of 54% and 106% were obtained from two different locations. A series of tests were conducted on these soils by mixing them with varying proportions of coarse fraction, Fly ash and Lime.

II. MATERIALS AND METHODOLOGY

A. Materials

Locally available expansive soils from two different places was used in this study. The physical and engineering properties of the expansive soils are given in Table 1. Fly ash used in this investigation has been obtained from the Electro-Static Precipitator (ESP) hoppers of Vijayawada Thermal Power Station (VTPS) located at Ibrahimpatnam and Lime stone is available aplenty in Kadapa District and number of cement industries and lime butties are located in and around Kadapa and Proddutur The specific gravity of the fly ash was 2.1max dry density 13.63 kN/m^3 · Optimum moisture content 22%,C.B.R soaked and unsoaked values are 10.73%,0.95%.lime chemical composition was Cao 92%,Mgo 8%

Property	**Soil 1**	**Soil 2**
Specific gravity	2.6	2.6
Liquid limit, %	54	106
Plastic limit, %	34.38	67
Shrinkage limit%	3.57	5.69
Optimum moisture content, %	18.8	28.92
Maximum dry density, kN/m^3	17.37	14.44
Type	CH	CH
Free swell index %	70	130
Unconfined compressive strength(Kpa)	140.16	83.89
Cohesion,c in kpa	110	64.59
Angle of internal friction,ϕ in degrres	1.12	1.11
C.B.R(SOAKED)%	2.09	1.36
PH	8.0	8.5

B. Methodology

In order to meet the objectives of the present investigation a total of three series of tests are conducted on two different soils.

The first series of tests are aimed at studying the influence of coarse fraction on compaction, strength and swelling characteristics of two different expansive soils.

The second series of tests are aimed at determining 'Optimum Fly Ash' from the view point of plasticity characteristics, compaction characteristics, strength and deformation characteristics. This series of tests are conducted on four soil samples, of which two were derived from soil 1 by adding 25% and 70% coarse fraction and two more were derived from soil 2 on similar lines. Fly ash is mixed with these soils in different proportions and tests are conducted.

The third series of tests are aimed at studying the influence of optimum lime on plasticity, compaction and strength characteristics of expansive clays treated with optimum fly ash. The optimum fly ash obtained from second series of tests is used in this series of tests and the tests are conducted on all the four soils on which second series of tests were conducted. Expansive soils treated with Optimum Fly Ash are mixed with lime in different proportions. pH of all these mixers is determined and optimum lime content is taken as the one at which pH becomes asymptotic to lime content. All the tests were conducted immediately after addition of lime and also after two different curing periods namely 7 days and 28 days.

III.RESULTS AND DISCUSSION

1. The Coarse fraction decreases OMC, increases MDD and CBR, but effect is insignificant for coarse fraction less than

30% to 40% by weight of soil. Swelling pressure and unconfined compressive strength decreases with coarse fraction but effect being insignificant for coarse fraction more than 30%to 40% by weight of soil.

Table 2: Properties of soil mixtures

S. No.	PROPERTY	Soil 1 + 25% CF (M1)	Soil 1 + 70% CF (M2)	Soil 2 + 25% CF (M3)	Soil 2 + 70% CF (M4)
1	Gravel (%)	0	0	0	0
2	Sand (%)	25	70	25	70
3	(Silt + Clay) (%)	75	30	75	30
4	+425μ (%)	25	70	25	70
5	Liquid Limit (%)	54	54	106	106
6	Plastic Limit (%)	19.62	19.62	39	39
7	Plasticity Index (%)	34.38	34.38	67	67
8	IS Classification	CH	SC	CH	SC
09	Free swell index (%)	70	70	130	130
10	Maximum dry density (KN/m3)	17.47	19.07	14.97	14.24
11	Optimum moisture content (%)	18.6	12.8	27.6	14.24
12	Swelling pressure (Kg/cm^2)	1.5	0.4	1.7	0.85
13	Swelling potential (%)	11.45	2.35	14.32	0.85
14	Unconfinedcompressive strength(Kpa)	54.4	30.92	52.63	58.55
15	C.B.R (Soaked) (%)	1.88	2.32	1.52	2.32
16	Cohesion (Kpa)	48.32	45.25	41.29	72.73
17	Angle of internal friction(degrees)	0.84	5.29	8.4	2.32
18	pH	8	8	8.5	8.5

2. Optimum fly ash at which MDD is highest, is lesser for low liquid limit soils i.e., 05% and higher for high liquid limit soils i.e., 25%

Table 3: Optimum fly ashes of all the four mixtures

S.NO	PROPERTIES	OPTIMUM FLY ASH			
		M1	M2	M3	M4
1	Unconfined compressive strength	≥15	≥10	≥25	≥30
2	Cohesion	≥25	≥25	≥25	≥25
3	Angle of internal friction	=10	=15	=0	=15
4	C.B.R	≥25	≥50	≥05	≥50
5	Peak stress (UCC Test)	≥15	≥15	≥25	≥25
6	Deformation modulus(peak stress)	≥50	≥50	≥25	≥50
7	Deformation modulus(1/2peak stress)	≥05	≥50	≥25	≥50
8	Deformation modulus(1/3peak stress)	≥05	≥50	≥25	≥50
9	Peak stress (Tri - axial shear Test)	≥10	≥25	≥15	≥25
10	Deformation modulus(peak stress)	≥10	≥50	≥25	≥25
11	Deformation modulus(1/2peak stress)	≥10	≥25	≥50	≥50

12	Deformation modulus(1/3peak stress)	≥10	≥05	≥50	≥50

3. Fly ash stabilization increases the strength by 40% to 110%, the strength gain being higher for low liquid limit soils and lesser for high liquid limit soils.

Table 4: Swelling Characteristics of untreated and fly ash treated mixtures

S.NO	MIXTURES	Swelling Characteristics	
		Swelling Pressure (P_s) (Kg/cm^2)	Swelling Potential (S_p) (%)
1	M1	1.5	11.45
2	M1+35%FA	1.6	7.4
3	M2	0.4	2.35
4	M2+40%FA	0.92	3.2
5	M3	1.7	14.32
6	M3+25%FA	0.6	3.8
7	M4	0.85	0.85
8	M4+40%FA	0.66	3.2

4. Soaked CBR is not sensitive to fly ash initially up to certain % of fly ash, but increases sharply beyond that fly ash content (≥ 25%).
5. The deformation modulus in general is found to increase with fly ash except in the initial regions. The effect of coarse fraction is dominant on deformation modulus than liquid limit in fly ash treated expansive soils.

6. Optimum lime content is directly proportional to Coarse fraction and inversely proportional to Liquid limit. Optimum lime is more sensitive to coarse fraction and less sensitive to liquid limit.
7. From the view point of swell potential, mixtures with low coarse fraction respond better to the lime stabilization. At optimum lime content, swell potential reduced to non critical levels after 28 days of curing. Swell pressure also reduced significantly for almost all the mixtures.

8. From view point of deformation modulus, lime stabilization is very encouraging. The increase in deformation modulus is higher for high liquid limit soils being 12 to 15 times than for low liquid limit soils being 6 to 9 times.
9. Lime stabilization resulted in significant increase in strength (UCC and CBR). In this case, mixtures with high coarse fraction are more reactive than mixtures with low coarse fraction.

.

TABLE 5: PROPERTIES OF SOIL - FLY ASH - LIME MIXTURES

Table 6 : Soil properties of untreated and lime treated mixtures with curing periods

S.No	Property	Soil-Fly ash mixtures											
		M1			M2			M3			M4		
		Without FA	35%FA	35%FA+9%L	Without FA	40% FA	40%FA+ 11.5%L	Without FA	25% FA	25% FA+ 8%L	Without FA	40% FA	40%FA +11% L
Plasticity characteristics													
1	LL	54	45	41	54	41.6	21	106	72	59	106	48.2	43
2.	PL	19.62	29	27.2	19.62	27.1	16.8	39	33.7	35.9	39	23.34	32.32
3	PI	34.38	16	13.8	34.38	14.5	4.2	67	38.3	23.1	67	24.86	10.68
4	S.L	3.57	11	25.52	3.57	18	22.35	5.69	6.43	21.55	5.69	10.63	29.05
5	FSI	70	40	15	70	25	10	130	50	28	130	34	22

Table 7: Deformation characteristics of sample at OMC & MDD

Table 8: Deformation characteristics of sample at SMC & MDD

S.NO	SOIL TYPE	CURING PERIOD(DAYS)	PROPERTIES					
			UCC(Kpa) Sample @ SMC & MDD)	Sample at OMC & MDD		Soaked CBR(%)	Swelling characteristics	
				C(kpa)	Φ		Ps(Kg/cm2)	Sp
1	M1+35%FA	-	104	70	4.0	4.3	1.6	7.4
2	LF1	0	127.41	67.11	18.134	32.02	4.4	3.1
		7	134.47	124.03	26.44	63.13	1.5	1.6
		28	-	149.4	28.33	169.8	0.5	0.56
3	M2+40%FA	-	59	43.8	8.6	9.2	0.92	3.2
4	LF2	0	112.25	44.26	2.25	16.47	1.0	1.65
		7	135	52.17	16.65	43.07	0.6	0.55
		28	-	156.19	40.07	158.53	0.4	0.35
5	M3+25%FA	-	70.63	58	0.045	2.56	0.6	3.8
6	LF3	0	140.5	120.48	3.292	25.21	5	2.965
		7	150	137.63	13.04	37.65	2.7	1.415
		28	-	238.75	26.04	142.22	1.6	0.35
7	M4+40%FA	-	85	54.2	3.7	6.6	0.66	3.2
8	LF4	0	120.25	56.37	11.96	35.48	1.5	1.32
		7	166.11	142.64	26.44	59.8	0.5	0.85
		28		160.64	46.3	228.1	0.35	0.08

S.NO	SOIL TYPE	Curing periods (days)	Peak stress (Kg/cm2)	Strain (peak stress)	Deformation modulus(Kg/cm2)		
					Peak stress	½ peak stress	1/3 peak stress
1	M1+35% FA	-	1.72	0.88	19.4	27.8	24.5
2	LF1	0	2.525	0.038	67.44	109.8	105.2
		7	5.2	0.058	89.65	72.22	54.17
		28	6.35	0.055	115.45	94.77	72.98
3	M2+40% FA	-	1.28	0.7	21	24.5	19.8
4	LF2	0	0.98	0.036	27.22	65.33	65.33
		7	2	0.062	32.25	26.31	21.5
		28	9.4	0.051	184.31	149	113.93
5	M3+25% FA	-	1.16	0.062	18.86	18.12	17.59
6	LF3	0	2.625	0.068	38.6	36.45	29.17
		7	3.895	0.043	90.58	79.48	63.33
		28	8.81	0.038	231.84	183.54	143.25
7	M4+40% FA	-	1.28	0.061	20.8	21.2	17.20
8	LF4	0	1.78	0.056	31.78	25.42	20.11
		7	5.8	0.056	103.57	79.45	62.36
		28	11.9	0.039	305.12	330.55	226.66

REFERENCES

1. Abduljauwad, S.N.(1995).”Improvement of plasticity and swelling potential of calcareous expansive soils, ”Journal of Geotechnical Engineering, 1995, vol.26(1), pp.3-16.
2. Acosta, H.A., Edil, T.B., Benson, C.H. (2003). “Soil stabilization and drying using fly ash”.Geo Engineering Report No. 03-03 Department of Civil and Environmental Engineering,University of Wisconsin-Madison.
3. Altmeyer, W.T., “Discussion of Engineering properties of Expansive clays,” proceedings, ASCE, Vol. 81, Separate No. 658, Mar 1955, pp 17-19.
4. Anon,(1985).”Lime stabilization construction manuals,” English edition. National lime association, Arlington, VA.
5. Arnold,G.(1984).”The Genesis mineralogy and Identification of expansive soils,” Proc. Of the 5th International Conf. on expansive soils. Adeloide, pp.32-36.
6. ASTM (1993).”Standard specification for fly ash and Raw or Calcined natural pozzolan for use as a mineral Admixture in Portland cement concrete,” Annual books of ASTM standards,618-93, vol.02,Philadelphia,PA,USA,PP.310-312.
7. Bell, F.G (1993). “Engineering treatment of soils”, E & FN Spon. London.
8. Bell,F.G(1996).”Lime stabilization of clay minerals and soils,” Engineering Geology42, pp.223-237.
9. Bhuvanesvari, S.,Robinson, R.G., Gandhi, S.R. (2005) “Stabilization of expansive soils using fly ash”, Fly ash Utilization programme (FAUP),TIFAC,DST,New Delhi-110016.
10. Brhyn,O.R., Laken,T., and Aas,G.(1983),”Stabilization of sensitive clays with hydroxyl-aluminium compared with unslaked lime,” Proc. Of the 8th European Conf. on SM & FE, Helsinki,vol.2,pp.885-896.
11. Broms,B., and Boman,p. (1975) “Lime stabilized columns” 5th Asian regional conference on SM and FE. Bangalore, India 227-234.
12. Broms,B., and Boman,p. (1993) ,“Lime columns-a new foundation method”. Journal

S.NO	SOIL TYPE	Curing periods (days)	Peak stress (Kg/cm2)	Strain (peak stress)	Ultimate stress (Kg/cm2)	Strain (ult.stress)	Deformation modulus(Kg/cm2)		
							Peak stress	½ peak stress	1/3 peak stress
1	M1+35%FA	-	2.18	0.14	-	-	16.00	34.2	35.6
2	LF1	0	2.55	0.04	2.05	0.053	63.75	106.25	121.42
		7	2.69	0.056	2.15	0.074	48.04	57.1	52.64
		28	-	-	-	-	-	-	-
3	M2+40%FA	-	1.89	0.060	-	-	21.00	30.00	27.00
4	LF2	0	2.245	0.078	1.34	0.093	28.78	24.95	22.68
		7	2.7	0.06	2.03	0.071	45	48.2	42.85
		28	-	-	-	-	-	-	--
5	M3+25%FA	-	1.41	0.125	-	-	11.28	27.115	26.11
6	LF3	0	2.81	0.058	1.4	0.04	48.45	55.43	121.42
		7	3.0	0.06	2.4	0.073	50	55.55	55.55
		28	-	-	-	-	-	-	-
7	M4+40%FA	-	1.70	0.084	-	-	20.00	34.10	37.50
8	LF4	0	2.85	0.061	1.3	0.16	38.52	35.06	32.52
		7	3.3	0.055	2.6	0.146	60	78.57	73.3
		28	-	-	-	-	-	-	-

of Geotechnical Engineering division, ASCE 105,PP.539-556.

13. BS1377-1975.Test 2(A), Determination of liquid limit, preferred method using the cone penetrometer. British Standard Institution.

14. Chen, F. H.,(1965), "The Use of Piers to Prevent the Uplifting of Lightly Loaded Structures Founded on Expansive Soils," Proceedings, First International Research and Engineering Conference on

S.NO	SOIL TYPE	Curing periods (days)	Peak stress (Kg/cm2)	Strain (peak stress)	Ultimate stress (Kg/cm2)	Strain (ult.stress)	Deformation modulus(Kg/cm2)		
							Peak stress	½ peak stress	1/3 peak stress
1	M1+35%FA	-	2.18	0.14	-	-	16.00	34.2	35.6
2	LF1	0	2.55	0.04	2.05	0.053	63.75	106.25	121.42
		7	2.69	0.056	2.15	0.074	48.04	57.1	52.64
		28	-	-	-	-	-	-	-
3	M2+40%FA	-	1.89	0.060	-	-	21.00	30.00	27.00
4	LF2	0	2.245	0.078	1.34	0.093	28.78	24.95	22.68
		7	2.7	0.06	2.03	0.071	45	48.2	42.85
		28	-	-	-	-	-	-	--
5	M3+25%FA	-	1.41	0.125	-	-	11.28	27.115	26.11
6	LF3	0	2.81	0.058	1.4	0.04	48.45	55.43	121.42
		7	3.0	0.06	2.4	0.073	50	55.55	55.55
		28	-	-	-	-	-	-	-
7	M4+40%FA	-	1.70	0.084	-	-	20.00	34.10	37.50
8	LF4	0	2.85	0.061	1.3	0.16	38.52	35.06	32.52
		7	3.3	0.055	2.6	0.146	60	78.57	73.3
		28	-	-	-	-	-	-	-

Expansive Clay Soils, Texas A&M University, College Station, 1965, pp 152-171.

15. Chen, F. H. (1975). “Foundations on expansive soils”. Elsevier Scientific pub co., Amsterdam.
16. Chen, F. H. (1988). “Foundations on expansive soils”, 2nd Ed., Elsevier Science, New York.
17. Cokca, E. (2001). “Use of Class C fly ashes for the stabilization of an expansive soil.” Journal of Geotechnical and Geoenvironmental Engineering, 127(7), 568-573.
18. Dakshinamurthy, V. and Raman, V., “A Simple Method of Identifying an Expansive Soil,” Soils and Foundations, Japanese Society of Soil Mechanics and Foundation Engineering, Vol. 13, No. 1, Mar 1973, pp 91-104.
19. Duncan,J.(1992), “Soil strengths from back analysis of slope failures,”stability and performance of slopes and Embankments-II, Geotechnical special publication No.31, VolI,pp890-904, R.B seed and R.W.Boulanger,Eds., ASCE.
20. Dunlop,R.J (1973).”Lime stabilization for Newzeland Roads,” NRB Road Research units.Tech. record 2, 87p.