ANALYSING ENGINEERING PROPERTIES OF HIGHWAY SUBGRADE SOIL BY ADDING MIXTURE OF LIME AND FLYASH

Mystica Lizzy, S and A. Priya

Department of civil Engineering ,Madha Engineering College, Chennai-69

INTRODUCTION

Pavement engineers have long term benefits of increasing the bearing capacity and durability of pavement sub grade of soil by mixing in a cementitious binder during reconstruction or new construction. Foderal and state highway engineers have a renewed interest in "perpetual pavement" which will benefit from "perpetual foundations". Millions of dollars can be saved by soil sub grade stablilization in comparison to cutting out and replacing the unstable sub grade soil. When included in pavement design, stabilizing the sub grade can result in reducing the thickness of other pavement layers (Rounds and Chi, 1985).

Lime alone has traditionally been used in clay-bearing, highly cohesive soils whereas Portland cement has been used to bind non-cohesive, granular or poorly cohesive soils. Likewise Portland cement is mainly used to stabilize an aggregate sub base or base course (Tran and Sherif, 1995). For a low cohesive, silty soil or for reclaiming full depth asphalt pavement recent investigations and some recent practice has shown that lime and Class F fly ash stabilization can be economically engineered for long-term performance. For appropriable soils, LFA can offer cost savings by reducing material cost by up to 50% as compared to Portland cement stablilization (Mandal, 1994).

Flyash and lime: Fine – grained soils with high clay (<0.005mm) and silt (<0.074) content are generally less desirable as pavement subgrade than natural soil containing higher amounts of granular material such as gravel and sand. Soils with more than 25% passing the 74 micron (0.074mm or 200mesh) sieve and a plasticity index (I_p) of at least 10 are amenable to lime stabilization. High silt, low clay sub grades with 25-75% passing the 74 micron and a I_p of 10-20 will greatly benefit in terms of bearing capacity and strength from a combination of lime and fly ash more than lime alone due to the pozzolanic reaction of the lime-fly ash (LFA) combination. The lack of reactive silica and alumina due to the lower clay content is made up by the silica and alumina added from the fly ash. The lime increases the soil's pH, solubilizing alumina and silica for the pozzolanic formation of calcium silica and calcium aluminates (Schriener *et al.,* 1995 and Serpell and Wagner, 1997).

Lime fly ash or Portland cement can be used to stabilize soils with I_p less than 20. However, the lime is better to react with and breakdown the clay fraction than Portland cement. Portland cement is through to be more applicable to lower I_p of soils, i.e., less than 12, because the strengths desired are attained faster and the clay content for lime modification is low. Publications by the U.S. Army Corps of Engineers and Transportation Research Board recognize the utility of lime-fly ash for coarser-grained soils that have little clay or plastic fines, including silt (Zucchelli, 1992 and Arora, 2005).

Lime and soil modification: Lime is an excellent choice for short-time modification of soil properties. Lime can modify almost all fine-grained soils, but the most dramatic improvement occurs in clay soils of moderate to high plasticity. Modification occurs because calcium cations supplied by the hydrated lime replace the cations normally present on the surface of the clay mineral, promoted by the high pH environment of the lime-water system (Gur charan singh, 1996 and Punmia, 2005).

METHODOLOGY

PROCEDURE FOR MIXING OF ADMIXTURE

The mixing of lime and flyash in ratio 1:2.

The percentage of admixture mixed by weight.

Admixture percentage	Lime percentage	Fly ash percentage	RATIO
0	0	0	----------
6	2	4	2:4
9	3	6	3:6
12	4	8	4:8

1.Particle size Distribution

The test carried out as per IS-2720-1975(Part-IV)

2.Proctor compaction test

The test carried out as per IS-2720-1975(Part-VII)

3.specific gravity

The test carried out as per IS-2720-1975(Part-IX)

4.Unconfined compressive strength

The test carried out as per IS-2720-1975(Part-X)

5.California bearing ratio

The test carried out as per IS-2720-1975(Part-XVI)

6.Permeability of soil

The test carried out as per IS-2720-1975(Part- XVII)

7.Direct shear test

The test carried out as per IS-2720-1975(Part-XIII)

RESULTS

Particle size distribution observed and recorded in Table 1-4.

Table 1. Sieve analysis test results for 0% admixture

Sl. No.	IS sieve number	Aperture Size in mm	Empty weight of sieve (gm)	Weight of sieve+ Soil (gm)	Weight of soil retained (gm)	% of soil retained	Cumulatie % retained	% finer
1	480	4.75	422	483	61	12.2	12.2	87.8
2	240	2.36	398	469	71	14.2	26.4	73.6
3	120	1.18	393	484	95	19	45.4	54.5
4	60	0.6	374	455	81	16.2	61.6	38.4
5	30	0.3	349	413	64	12.8	74.4	25.6
6	15	0.15	351	441	90	18	92.4	7.6
7	Pan	-	390	428	38	7.6	100	0

Table.2. Sieve analysis test results for 6% admixture

Sl. No.	IS sieve number	Aperture Size in mm	Empty weight of sieve (gm)	Weight of sieve+ Soil (gm)	Weight of soil retained (gm)	% of soil retained	Cumulatie % retained	% finer
1	480	4.75	422	495	73	13.7	13.7	86.3
2	240	2.36	398	479	81	15.2	28.9	71.1
3	120	1.18	393	484	91	17.2	46.1	53.9
4	60	0.6	374	433	59	11.2	57.3	42.7
5	30	0.3	349	437	88	16.6	73.9	26.1
6	15	0.15	351	423	72	13.6	87.5	12.5
7	Pan	-	390	456	66	12.5	100	0

Table 3. Sieve analysis test results for 9% admixture

Sl. No.	IS sieve number	Aperture Size in mm	Empty weight of sieve (gm)	Weight of sieve+ Soil (gm)	Weight of soil retained (gm)	% of soil retained	Cumulatie % retained	% finer
1	480	4.75	422	485	63	11.5	11.5	88.5
2	240	2.36	398	469	71	13.1	24.6	75.4
3	120	1.18	393	476	83	15.2	39.8	60.2
4	60	0.6	374	431	57	10.5	50.3	49.7
5	30	0.3	349	443	94	17.2	67.5	32.5
6	15	0.15	351	450	99	18.2	85.7	14.3
7	Pan	-	390	468	78	14.3	100	0

Table4. Sieve analysis test results for 12% admixture

Sl. No.	IS sieve number	Aperture Size in mm	Empty weight of sieve (gm)	Weight of sieve+ Soil (gm)	Weight of soil retained (gm)	% of soil retained	Cumulatie % retained	% finer
1	480	4.75	422	520	98	17.5	17.5	82.5
2	240	2.36	398	475	77	13.8	31.3	68.7
3	120	1.18	393	482	89	15.9	47.2	52.8
4	60	0.6	374	429	55	9.8	57	43
5	30	0.3	349	429	80	14.3	71.3	28.7
6	15	0.15	351	425	74	13.2	84.5	15.5
7	Pan	-	390	479	87	15.5	100	0

Test results for specific gravity given in table 5.

Table 5. Specific gravity test results

Percentage of admixture	Empty weight of pycnometer (gms)	Weight of pycnometer+soil (gms)	Weight of pycnometer+ soil+water (gms)	Weight of Pycnometer+ bottle (gms)	Specific Gravity (G)
0%	645	920	1716	1546	2.61
6%	645	945	1735	1546	2.70
9%	645	970	1752	1546	2.73
12%	645	994	1770	1546	2.79

Proctor compaction test results are given below (Table 6-9)

Weight of empty mould=4620gms
Diameter of mould=10cm
Height of the mould=12.5cm
Volume of the mould(V)=981.75cm^3

Table 6. Proctor compaction test results for 0% admixture

water content (%)	Weight of soil+mould(gms)	Weight of soil W (gms)	Bulk density Y_s=w/v (gm/cm^3)	Dry density = Y_s /1+w (gm/cm^3)
6	6649	2029	2.066	1.949
8	6694	2074	2.112	1.955
10	9754	2134	2.173	1.975
12	6804	2184	2.224	1.985
14	6794	2174	2.214	1.942

Table 7.Proctor compaction test results for 6% admixture

water content (%)	Weight of soil+mould(gms)	Weight of soil W (gms)	Bulk density Y_s=w/v (gm/cm^3)	Dry density = Y_s /1+w (gm/cm^3)
8	6714	2094	2.133	1.975
10	6764	2144	2.184	1.985
12	6850	2230	2.271	2.025
14	6694	2074	2.113	1.855
16	6714	2094	2.133	1.975

Table 8. Proctor compaction test results for 9% admixture

water content (%)	Weight of soil+mould(gms)	Weight of soil W (gms)	Bulk density Y_s=w/v (gm/cm^3)	Dry density = Y_s /1+w (gm/cm^3)
8	6610	1990	2.027	1.876
10	6710	2080	2.119	1.926
12	6790	2170	2.211	1.974
14	6910	2290	2.231	2.047
16	6760	2140	2.18	1.88

Table 9. Proctor compaction test results for 12% admixture

water content (%)	Weight of soil+mould(gms)	Weight of soil W (gms)	Bulk density Y_s=w/v (gm/cm^3)	Dry density = Y_s /1+w (gm/cm^3)
8	6650	2030	2.068	1.915
10	6740	2120	2.16	1.963
12	6780	2160	2.2	1.964
14	6830	2210	2.252	1.975
16	6800	2180	2.22	1.914

Test results for unconfined compressive strength is given in tables 10-18

Table 10. UCC test results for 0% admixture with 3days curing

Dial gauge reading	Proving rin Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	Strain $e=\Delta L/L$	Stress =P/A Kg/cm^2
50	5	0.5	0.929	1.450	12.207	0.071	0.119
100	5	1	0.857	1.450	13.225	0.143	0.110
150	11	1.5	0.786	3.190	14.427	0.214	0.221
200	16	2	0.714	4.640	15.870	0.286	0.292
250	21	2.5	0.643	6.090	17.633	0.357	0.345
300	27	3	0.571	7.830	19.837	0.429	0.395
350	32	3.5	0.500	9.280	22.671	0.500	0.409
400	38	4	0.429	11.020	26.449	0.571	0.417
450	43	4.5	0.357	12.470	31.739	0.643	0.393
500	47	5	0.286	13.630	39.674	0.714	0.344
550	52	5.5	0.214	15.080	52.899	0.786	0.285
600	56	6	0.143	16.240	79.348	0.857	0.205
650	59	6.5	0.071	17.110	158.696	0.929	0.108

Table 11 UCC test results for 6% admixture with 3days curing

Dial gauge Reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain $e=\Delta L/L$	ress =P/A Kg/cm^2
50	1	0.5	0.929	0.290	12.207	0.071	0.024
100	5	1	0.857	1.450	13.225	0.143	0.110
150	5	1.5	0.786	1.450	14.427	0.214	0.101
200	5	2	0.714	1.450	15.870	0.286	0.091
250	10	2.5	0.643	2.900	17.633	0.357	0.164
300	16	3	0.571	4.640	19.837	0.429	0.234
350	22	3.5	0.500	6.380	22.671	0.500	0.281
400	32	4	0.429	9.280	26.449	0.571	0.351
450	44	4.5	0.357	12.760	31.739	0.643	0.402
500	57	5	0.286	16.530	39.674	0.714	0.417
550	70	5.5	0.214	20.300	52.899	0.786	0.384
600	80	6	0.143	23.200	79.348	0.857	0.292
650	90	6.5	0.071	26.100	158.696	0.929	0.164
650	155	6.5	0.071	44.950	158.696	0.929	0.283

Table 12.UCC test results for 9% admixture with 3days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain $e=\Delta L/L$	ress =P/A Kg/cm^2
50	5	0.5	0.929	1.450	12.207	0.071	0.119
100	7	1	0.857	2.030	13.225	0.143	0.154
150	15	1.5	0.786	4.350	14.427	0.214	0.302

200	35	2	0.714	10.150	15.870	0.286	0.640
250	50	2.5	0.643	14.500	17.633	0.357	0.822
300	62	3	0.571	17.980	19.837	0.429	0.906
350	75	3.5	0.500	21.750	22.671	0.500	0.959
400	82	4	0.429	23.780	26.449	0.571	0.899
450	100	4.5	0.357	29.000	31.739	0.643	0.914
500	110	5	0.286	31.900	39.674	0.714	0.804
550	125	5.5	0.214	36.250	52.899	0.786	0.685
600	145	6	0.143	42.050	79.348	0.857	0.530

Table 13. UCC test results for 0% admixture with 14days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	ress =P/A Kg/cm^2
50	0	0.5	0.929	0.000	12.207	0.071	0.000
100	0	1	0.857	0.000	13.225	0.143	0.000
150	25	1.5	0.786	7.250	14.427	0.214	0.503
200	60	2	0.714	17.400	15.870	0.286	1.096
250	80	2.5	0.643	23.200	17.633	0.357	1.316
300	110	3	0.571	31.900	19.837	0.429	1.608
350	130	3.5	0.500	37.700	22.671	0.500	1.663
400	150	4	0.429	43.500	26.449	0.571	1.645

Table 14. UCC test results for 6% admixture with 14days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	tress =P/A Kg/cm^2
50	5	0.5	0.929	1.450	12.207	0.071	0.119
100	8	1	0.857	2.320	13.225	0.143	0.175
150	60	1.5	0.786	17.400	14.427	0.214	1.206
200	110	2	0.714	31.900	15.870	0.286	2.010
250	130	2.5	0.643	37.700	17.633	0.357	2.138
300	140	3	0.571	40.600	19.837	0.429	2.047

Table 15. UCC test results for 9% admixture with 14days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	tress =P/A Kg/cm^2
50	5	0.5	0.929	1.450	12.207	0.071	0.119
100	5	1	0.857	1.450	13.225	0.143	0.110
150	45	1.5	0.786	13.050	14.427	0.214	0.905
200	90	2	0.714	26.100	15.870	0.286	1.645

250	117	2.5	0.643	33.930	17.633	0.357	1.924
300	148	3	0.571	42.920	19.837	0.429	2.164
350	153	3.5	0.500	44.370	22.671	0.500	1.957
400	165	4	0.429	47.850	26.449	0.571	1.809
450	170	4.5	0.357	49.300	31.739	0.643	1.553
500	172	5	0.286	49.880	39.674	0.714	1.257
550	180	5.5	0.214	52.200	52.899	0.786	0.987

Table 16. UCC test results for 0% admixture with 28days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	tress =P/A Kg/cm^2
50	0	0.5	0.929	0.000	12.207	0.071	0.000
100	5	1	0.857	1.450	13.225	0.143	0.110
150	51	1.5	0.786	14.790	14.427	0.214	1.025
200	115	2	0.714	33.350	15.870	0.286	2.102
250	160	2.5	0.643	46.400	17.633	0.357	2.631
300	170	3	0.571	49.300	19.837	0.429	2.485

Table 17. UCC test results for 6% admixture with 28days curing

Dial gauge reading	roving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	tress =P/A Kg/cm^2
50	0	0.5	0.929	0.000	12.207	0.071	0.000
100	33	1	0.857	9.570	13.225	0.143	0.724
150	105	1.5	0.786	30.450	14.427	0.214	2.111
200	165	2	0.714	47.850	15.870	0.286	3.015
250	180	2.5	0.643	52.200	17.633	0.357	2.960

Table 18. UCC test results for 9% admixture with 28days curing

ial gauge reading	Proving ring Reading	ΔL cm	1-e	Load (P) Kg (1div=.29kg)	A= $A_0/(1-e)$ cm^2	rain e=ΔL/L	tress =P/A Kg/cm^2
50	0	0.5	0.929	0.000	12.207	0.071	0.000
100	15	1	0.857	4.350	13.225	0.143	0.329
150	102	1.5	0.786	29.580	14.427	0.214	2.050
200	160	2	0.714	46.400	15.870	0.286	2.924
250	205	2.5	0.643	59.450	17.633	0.357	3.372
300	227	3	0.571	65.830	19.837	0.429	3.319

Test results for permeability of soil given in tables 19-21

Length of specimen (L)=13cm
Diameter of the specimen=7.5cm

Diameter of stand pipe=0.5cm
Area of stand pipe(a)=0.2cm^2
Area of specimen(A)=132.8 cm^2

Table 19 Permeability test results for 0% admixture

Sl.No	Head in cm		Time (S)	Permeability $K=a/A[L/T]\ln[H_1/H_2]$ (cm/s)
	H_1	H_2		
1	95	85	10	$2.177X10^{-4}$
2	85	75	12	$2.042X10^{-4}$
3	75	65	13	$2.155X10^{-4}$
4	65	55	14	$2.330X10^{-4}$
5	55	45	15	$2.619X10^{-4}$

Table 20. Permeability test results for6% admixture

Sl.No	Head in cm		Time (S)	Permeability $K=a/A[L/T]\ln[H_1/H_2]$ (cm/s)
	H_1	H_2		
1	95	85	16	$1.360X10^{-4}$
2	85	75	17	$1.440X10^{-4}$
3	75	65	19	$1.474X10^{-4}$
4	65	55	20	$1.635X10^{-4}$
5	55	45	22	$1.785X10^{-4}$

Table 21. Permeability test results for 9% admixture

Sl.No	Head in cm		Time (S)	Permeability $K=a/A[L/T]\ln[H_1/H_2]$ (cm/s)
	H_1	H_2		
1	95	85	27	$0.806X10^{-4}$
2	85	75	35	$0.700X10^{-4}$
3	75	65	38	$0.737X10^{-4}$
4	65	55	42	$0.788X10^{-4}$
5	55	45	48	$0.718X10^{-4}$

RESULTS

Average permeability coefficient for 0% admixture =$2.264X10^{-4}$cm/s
Average permeability coefficient for 6% admixture =$1.568X10^{-4}$cm/s
Average permeability coefficient for 0% admixture =$0.768X10^{-4}$cm/s

Test results for california bearing ratio given in table 22-24.

Diameter of plunger=5cm
Area of plunger=19.6cm^2

Table 22. CBR test results for 0%admixture

Sl.no	**Dial gauge netration (mm)**	**Proving ring Reading** (1div=2kg)	**Load (kg)**	**Load Kg/cm^2**
1	1	2	4	0.204
2	2	20	40	2.040
3	3	35	70	3.571
4	4	75	150	7.653
5	5	120	240	12.244

The CBR value for 2.5mm penetration=(2.5/70)x100=3.57%
The CBR value for 5mm penetration=(12.1/105)x100=11.5%

The CBR value=11.5%

Table 23. CBR test results for 6%admixture

Sl.no	**Dial gauge netration (mm)**	**Proving ring Reading** (1div=2kg)	**Load (kg)**	**Load Kg/cm^2**
1	1	6	12	0.631
2	2	24	48	2.526
3	3	54	108	5.684
4	4	118	236	12.421
5	5	160	320	16.842

The CBR value for 2.5mm penetration=(4.5/70)x100=6.3%
The CBR value for 5mm penetration=(16.5/105)x100=15.5%

The CBR value=15.5%

Table 24. CBR test results for 9%admixture

Sl.no	**Dial gauge netration (mm)**	**Proving ring Reading** (1div=2kg)	**Load (kg)**	**Load Kg/cm^2**
1	1	7	14	0.736
2	2	33	66	3.473
3	3	72	144	7.578
4	4	119	238	12.526
5	5	162	324	17.052

The CBR value for 2.5mm penetration=(5.5/70)x100=7.3%
The CBR value for 5mm penetration=(17.3/105)x100=16.4%

The CBR value=16.4%

Test results for direct shear test given in tables 25.

Area of shear box=36cm^2

Table 25. Direct shear test results for 0% admixture

Sl.no	rmal Load(kg)	Proving ring reading	Shear load (1div=0.2kg)	Normal stress Kg/cm^2	Shear Stress Kg/cm^2
1	1.4	10	2	0.039	0.055
2	2.1	14	2.8	0.058	0.077
3	2.8	16	3.2	0.078	0.088
4	3.5	20	4	0.097	0.111

Test results are given in tables 27- 31.

Table 26.PARTICLE SIZE DISTRIBUTION

	0%	6%	9%	12%
Effective size	0.18mm	0.12mm	0.1mm	0.12mm
Uniformity coefficient(C_u)	10.56	12.5	10	8.33
Coefficient of curvature(C_c)	0.476	0.680	0.784	0.44
Coefficient of Permeability	0.0324cm/s	0.014cm/s	0.01cm/s	00144cm/s

The coefficient curvature values are greater than 4 so the soil is to be well graded soil.

Table 27.PROCTOR COMPACTION TEST

Admixture	0%	6%	9%	12%
isture content(%)	12	12	14	14
Dry density (gm/cm^3)	1.985	2.025	2.047	1.914

The maximum dry density at 9% admixture and optimum moisture content is 14%

Table 28. SPECIFIC GRAVITY

Admixture	0%	6%	9%	12%
ecific gravity(G)	2.61	2.7	2.73	2.79

The specific gravity increases gradually with increase of admixture.

Table 29. UNCONFINED COMPRESSIVE STRENGTH

Admixture	0%	6%	9%
3days curing	0.417kg/cm^2	0.417kg/cm^2	0.959kg/cm^2
14days curing	1.663kg/cm^2	2.138kg/cm^2	2.164kg/cm^2
28days curing	2.637kg/cm^2	3.015kg/cm^2	3.372kg/cm^2

The UCC strength increases with increasing the percentage of admixture

Table 30. PERMEABILITY

Admixture	0%	6%	9%
Coefficient of permeability(K)	2.264x10^{-4}cm/s	1.568x10^{-4}cm/s	0.768x10^{-4}cm/s

The permeability decreases with increasing the percentage of admixture.

Table 31. CALIFORNIA BEARING RATIO

Admixture	0%	6%	9%
CBR (%)	2.3	15.5	16.4

The CBR value increases with adding of admixture

The angle of shearing resistance is34^0 evenafter adding the admixtute

CONCLUSION

- The optimum percentage of admixture mixed to the soil is 9%.
- We get maximum dry density is 2.047gm/cm^3 and optimum moisture content is 14%.
- The UCC and CBR values are increased when adding of 9% admixture.

We conclude that permeability decreases and CBR value increases with adding of admixture.

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