ECONOMIC EVALUATION OF FLEXIBLE PAVEMENT WITH RESPECT TO FLY ASH AND LIME STABILIZATION OF EXPANSIVE SUB-GRADE SOIL IN VIJAYAWADA

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ABSTRACT

Black cotton soils cover about 25 % of the total land area in India. They are problematic to civil engineering structures because they undergo large volume changes due to variations in water content. In order to improve their properties, different admixtures are used. Among them, fly ash, which is the byproduct of combustion of pulverized coal in thermal power plants is being increasingly used. In our report, the study carried out on the engineering properties of black cotton soil as affected by different percentages of a fly ash and combination of lime and fly ash. Lime and the natural soil both are easily available materials at the most of places. Fly ash is a waste product resulting from the combustion of powdered coal in the steel and the thermal power plants. It acts as a pozzolan with lime, yielding slow setting cement which has been found suitable for stabilizing most types of soils. Locally available soil stabilized with lime-fly ash (LF A) as admixtures results in economical construction of good roads especially in the area in the vicinity of steel and thermal power plants. Its use in the construction would indirectly help in solving the problem of disposal of huge quantities of generated fly ash, which is an industrial waste. The results show that adding fly ash and lime to black cotton soil not only helps to improve the engineering properties of black cotton soil but also helps in the utilization of fly ash which can reduce the disposal and pollution problems associated with fly ash.

Keywords: Economic Evaluation Of Flexible Pavement, Stabilization With Lime,-Fly Ash.

Introduction

Many parts of the world suffer from constructing problems that associated with expansive clay soils. These problems include cracking, break-up of pavements, heaving, and damaging building foundations.

Much attention has been focused in recent years on conserving natural resources and energy. Numerous waste products and/or byproducts from various industrial and commercial processes, normally deposited in landfills, have been proposed for use as alternate construction materials. The use of alternate materials needs to be encouraged for both the economy of construction and conservation of materials. One byproduct that has shown considerable promise as an alternate construction material is fly ash. The use of this waste product in lime-fly ash (LFA) stabilized granular materials as an alternative to cement treated materials for base construction.

There are more than 60 Thermal power stations in our country producing 80-90 million tones of fly ash per year. Disposal of this huge waste material is assuming proportions of a national problem. This waste material has potential to be converted into a meaningful wealth as a new construction material i.e. lime-fly ash mixture to be used in stabilization of locally available soil in embankment, road construction etc. Due to pozzolanic properties of LFA mixture, its use in highway construction will eliminate the need for expensive borrow materials, improve the quality of wet and unstable sub grade, results into decrease in pavement thickness as a consequence of improvement in sub grade conditions and permits substitution of certain low cost or inferior type of materials in the pavement construction.

The use of lime-fly ash (LFA) is gaining momentum in India where shortage of cement is quite acute due to its increasing demands in view of all-round development activities. With these factors in view the use of lime-fly ash stabilized soil for road construction is likely to become a common practice in India with its vast expanse of village roads.

Objectives of the study

- to alter the chemical properties of soil
- to avoid changes in soil characteristics due to increase or decrease of moisture content
- to increase shear strength of soil
- to increase resistance softening action of water
- to reduce the chances of swelling due to wetting and shrinkage due to withdrawal of moisture
- to improve the strength of sub bases, bases and in case of low cost roads
- to increase the compressive strength of soil irrespective of moisture content
- to improve permeability
- to reduce compressibility and their by settlements

- to reduce frost susceptibility

Experimental programme:

Introduction

In this chapter experiments conducted using flyash and lime to improve the physical properties like liquid limit, plastic limit, plasticity index and to improve the strength characteristics. Brief reviews of various testing procedures are given in this chapter.

Plasticity limits and indices

Liquid limit

The liquid limit is the water content expressed as a percentage of oven dried soil at which the soil has a small shear strength. The liquid limit tests for all the samples were carried out using4. cone penetration method. Due to the low plasticity characteristics it is difficult to cut the groove in certain cases.

Plastic limit

The plastic limit is the water content at which soil begins to crumble when rolled in to 3 mm diameter threads. For this approximately take 50 grams of air dry soil passing 425 micron IS sieve. Mixing water is adjusted so as to bring the consistency to near plastic or remouldable with fingers. Keep the soil in 24 hrs in humid conditions if it is clay. Form a ball of soil with hands and roll it with fingers on glass plate with an approximate rate of 80-90 strokes per minute and this process is continued till threads are of 3 mm diameter. When the thread crumbles, collect the crumbled soil pieces and determined its moisture content.

Tests for engineering properties

Compaction test

Compaction test is the densification of soil by reduction of air voids. The purpose of a laboratory compaction test is to be determine, the quantity of water to e added for field compaction test is to determine, the quantity of water to be added for compaction of soil and the resulting density expected. To accomplish this, a laboratory test that will give a degree of compaction comparable to that obtained in the field method is necessary. This method is proposed by proctor in 1933 is currently used the world over. In the early days of compaction, because the construction equipment was small and relatively low densities, the proctor method, widely known as standard proctor test (as per IS code, light compaction test) that used a small amount of compactivity energy was popular.

A representative sample weighing approximately 16 kg of thoroughly mixed air dried material is mixed with water. Place the processed soil in an air tight tin for about 18 to 20 hours to ensure through mixing of water with the soil. Weight the empty mould after greasing the inside. Assemble the mould on the base plate. Fix the collar. Compact the soil in three layers using 25 blows per layer. The blows should be distributed uniformly over the surface of each layer. Score the each layer compacted soils with a spatula before putting the soil for the next layer. All layers should be equal in height, and the final height obtained after removal of the collar should be just enough for trimming purposes. Weight the mould with the compacted soil and obtain the moisture content preferably from the middle of the sample, like this again using a fresh part of soil specimen every time and adding a higher water content than the preceding one. For the water content determination from the top, middle and the bottom portions were taken. Water content versus dry density graphs were plotted, from these graphs max dry density and optimum moisture content were observed.

Fall cone test

This method was introduced in 1915y Mr. John Olsson for the geotechnical commission of the Swedish state railways. The equipment is originally designed for classifying the soils. In this test it is assumed that the shear strength of the soil at constant penetration of a cone is directly proportionally to the weight of the cone and Hansbo(1957) as referred in manual has shown that the relation between shear strength and penetration 'h' of a cone weight Q is given by
$S=k\ (Q/h^2)$

Where k is a constant. which depends mainly on the angle of the cone, but is also influenced by the sensitivity of the clay. Relation between the depth of the penetration and undrained shear strength is given in Table 4.1. As referred in manual, for Norwaian clays, Skaen-Haug(1931) by compression with the shear tests determined the correlation between the cone penetration and the undrained shear strength.. the royal Swedish Geotechnical institute presented in 1957 a proceeding with a new approach to the interpretation of the cone holder. Select the appropriate cone and arrange it in contact with the magnet by pressing the knob fully-in. Make sure that the reading through the sharp edge of cone suspension head coincides with zero., if not adjust th zero of the scale by setting with the two screws holding the scale. Adjust the height by operating the hand wheel so that the tip of the cone just touches the top surface of the soil. Now release the cone by pressing the trigger. In order to avoid disturbance to the head, hold the head firmly with the hand and then only release the cone. Note down the reading to the nearest tenth of mm by the help of magnifying glass.

Unconfined compressive strength

To measure the shear strength of the soil this test will be conducted in which the confining pressure is zero .in this type of unconfined compression testing machine a proving ing is to measure the compressive force. There two plates having cone settings for the specimen. The specimen is placed on the bottom plate and then raised gradually to make contact with the upper plate. The dial guage and proving ring is set to zero.

The compressive load is applied to the specimen by turning the handle. As the handle turned the upper plate moves down ward and in some machines the upper plate is fixed and compressive load is applied by raising the lower plate. The handle is turned gradually so as to produce an axial strain occurs whichever is earlier.

The UCS tests were performed in accordance with ASTM D 2166.the sample sizes were of 40 mm diameter and 80 mm length. At the optimum moisture content (OMC) and maximum unit weight values of the natural soil, the tests were performed.

The compressive force is determined from the proving ring reading and the axial strain from the dial gauge reading. In an unconfined compression test, the minor principal stress is zero. The major principal stress is equal t the deviator stress.

The axial stress at which the specimen fails is known as the unconfined compressive strength. The stress strain curve can be obtained from the axial stress and axial strain at different stages before failure.

It is ideally suited for measuring the unconsolidated undrained shear strength of intact, saturated clays. The sensitivity of the soil may be easily determined by conducting the test on an undisturbed sample and then on the remoulded sample.

Methodology

Two soils (soil A, soil B) are collected from different locations. With these soils conducted the tests without stabilizing the other materials or additives. And then the addition of the flyash with varying percentagewise 10%,20%,30%,40% tests were conducted. Lime is added to flyash alone and conducted free swell index to determine the optimum lime content. With the addition of 5%(optimum lime obtained)to the soil to varying percentages of fly ash (10%,20%,30%,40%) the tests were conducted. And also by increasing the lime content to 8% of lime repeated all the tests to find the variation of the strength behaviour of the soils in contact with different curing periods.

Results and Discussion

Grain size distribution curves

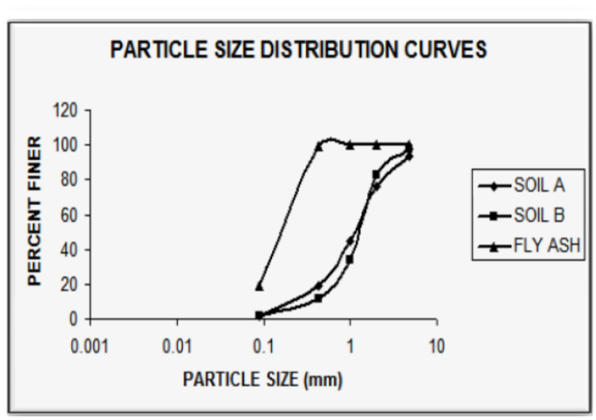

FIG.1: GRAIN SIZE ANALYSIS OF SOIL A, SOIL B, &FLYASH.

Grain size distribution curves of the samples were grouped according to the type of soil-A, soil-B and fly ash and plotted on the same graph. The following table 1.1 shows the particle distribution.

TABLE .1.1: the grain size analysis of soil A, soil B & Fly ash

Grain size/ type of soil	*Gravel %*	*Sand %*	*Silt & Clay %*
Soil-A	*6*	*45*	*49*
Soil-B	*4*	*48*	*48*
Fly ash	*0*	*81*	*19*

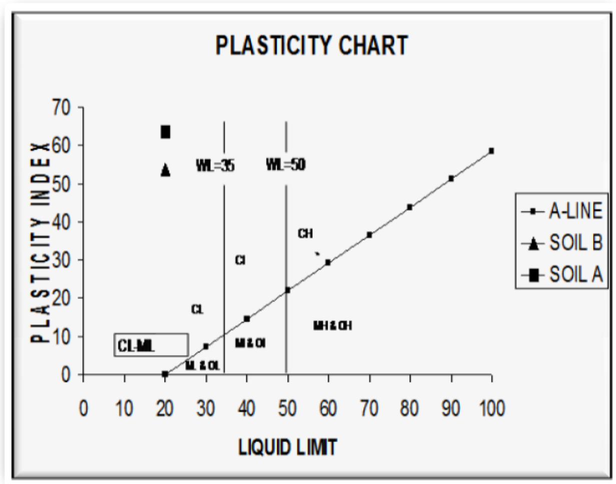

FIG.2: VARIATION OF PLASTICITY INDEX WITH THE LIQUID LIMIT OF SOIL A, SOIL B.

Plasticity chart shows both soils are clay soils with low compressibility

Specific Gravity

The average specific gravity of soils and fly ash fraction passing I.S Sieve 425 microns was observed to be as shown in table.2.2

TABLE.2.2: Specific gravity of soil A, soil B & Fly ash

Type of soil	*Specific Gravity*
Soil-A	*2.51*
Soil-B	*2.64*
Fly ash	*2.01*

Optimum Lime Content

The Optimum Lime Content for soils determined by the unconfined compressive test with curing. From the charts the results obtained shown in table 1.3

TABLE.1.3: Optimum lime content of soil A, soil B

Soil type	*Optimum Lime Content %*
Soil-A	*8*

Soil-B	*8*

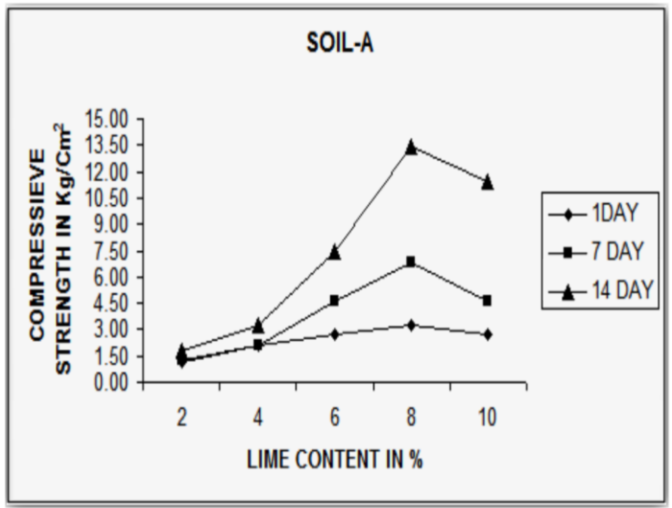

Fig 3: optimum lime content of soil 'A' after leaving for 1day, 7days, and 14 days contact period.

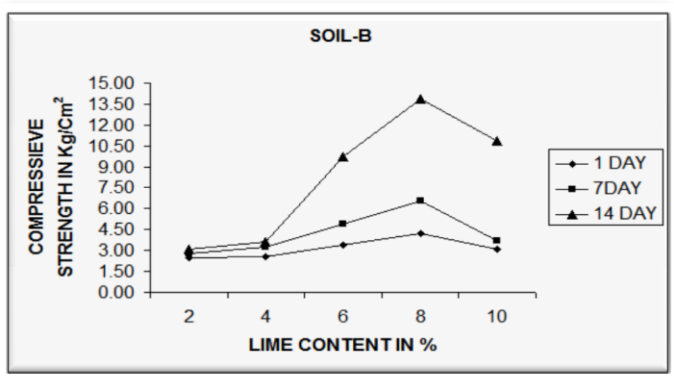

Fig4: optimum lime content of soil 'A' after leaving for 1day, 7days, and 14 days contact period

The Optimum Lime Content for fly ash determined by the Modified Free Swell Index and by pH values.

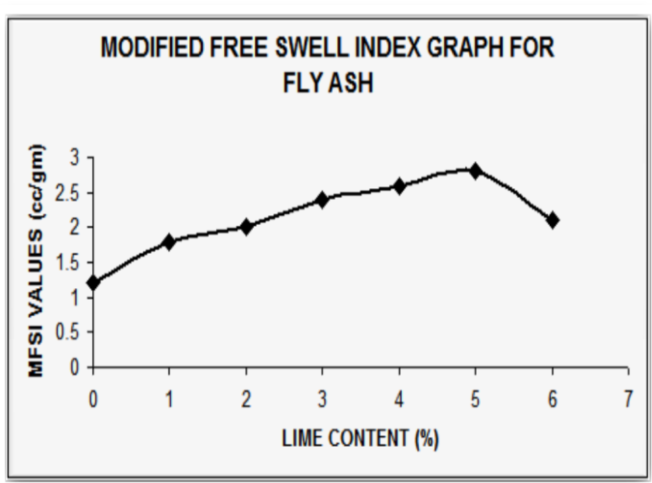

Fig 5: Variation of modified free swell index values with different lime content for flyash

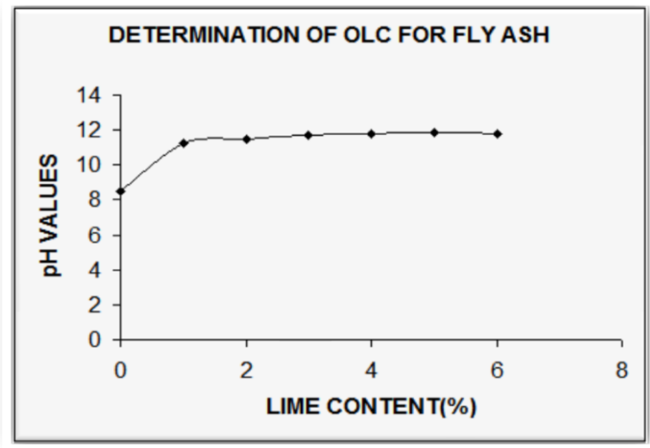

Fig 6: optimum lime content for fly ash by ph values

The Optimum Lime Content of fly ash obtained from the chart as **5%**

Consistency Limits

Consistency Limits of soils and fly ash as shown in table-1.4

Shrinkage limits of soils for OLC of fly ash and soils with variation of fly ash as shown in table-1.4. Shrinkage limit increases as the increase in fly ash content and lime.

TABLE 1.4 Shrinkage Limits of soil A, soil B and after addition of flyash in different percentages and with addition of 5%&8% lime

Shrinkage Limit Test	*SOIL A*	*SOIL B*
Natural Soil	*12.35*	*8.95*
Soil+10%FA	*14.72*	*9.42*
Soil+20%FA	*18.80*	*11.17*
Soil+30%FA	*22.90*	*13.96*
Soil+40%FA	*27.28*	*32.67*
Soil+5%L+10%FA	*36.78*	*39.94*
Soil+5%L+20%FA	*45.05*	*46.03*
Soil+5%L+30%FA	*40.65*	*51.17*
Soil+5%L+40%FA	*43.32*	*38.63*
Soil+8%L+10%FA	*24.07*	*48.32*
Soil+8%L+20%FA	*28.54*	*47.73*
Soil+8%L+30%FA	*26.73*	*46.42*

Soil+8%L+40%FA	29.15	44.84

Liquid limit and plastic limit

The range of the observed values of liquid limit and plastic limit are as shown in tables with respective curing periods and for the Optimum Lime Content for fly ash &for soils with variation of fly ash

TABLE 5.5 SOIL SAMPLE-A LIQUID LIMIT

Percent	Curing Period				
	0 Days	1 Days	7 Days	14 Days	28 Days
10%F	63.36	67.17	70.92	75.01	76.54
20%F	62.15	65.26	69.03	73.45	75.97
30%F	61.99	63.31	68.36	69.28	71.13
40%F	59.03	61.96	64.48	67.17	68.65
5L%+10%F	65.65	67.86	73.37	76.71	78.72
5%L+20%F	63.16	65.94	70.35	74.08	76.56
5%L+30%F	62.17	63.28	68.98	70.36	72.92
5%L+40%F	60.58	61.82	66.72	68.56	71.92
8%L+10%F	69.70	74.42	78.31	80.57	81.90
8%L+20%F	65.92	69.90	74.43	78.92	79.09
8%L+30%F	63.62	67.03	69.23	74.54	77.99
8%L+40%F	62.40	65.28	67.03	71.56	75.13

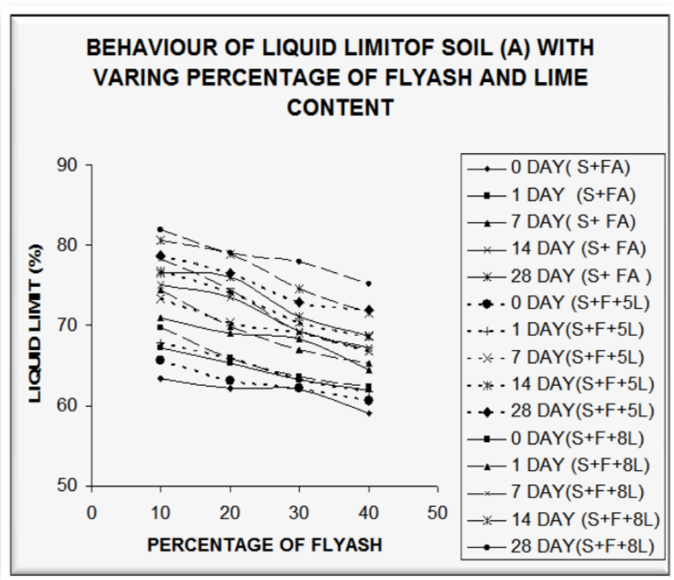

Fig7: Behaviour of liquid limit of soil (A) with varying percentages of flyash and lime content

TABLE 1.6 SOIL SAMPLE-A PLASTIC LIMIT

Percent	Curing Period				
	0 Days	1 Days	7 Days	14 Days	28 Days
10%F	32.81	27.27	24.62	34.44	45.07
20%F	28.92	34.59	26.80	41.27	33.92
30%F	26.67	19.82	27.20	38.68	47.17
40%F	41.25	20.99	25.00	46.67	29.31
5L%+10 %F	47.83	30.24	41.05	45.25	44.44
5%L+20 %F	36.64	28.65	41.24	43.80	40.44
5%L+30 %F	34.34	26.24	39.12	42.00	41.58
5%L+40 %F	36.54	25.25	35.83	38.08	39.52
8%L+10 %F	40.00	32.25	51.32	42.40	46.34
8%L+20 %F	38.38	31.25	31.25	42.72	41.23
8%L+30 %F	36.29	20.73	20.73	33.17	46.94
8%L+40 %F	32.94	33.13	33.13	38.00	39.77

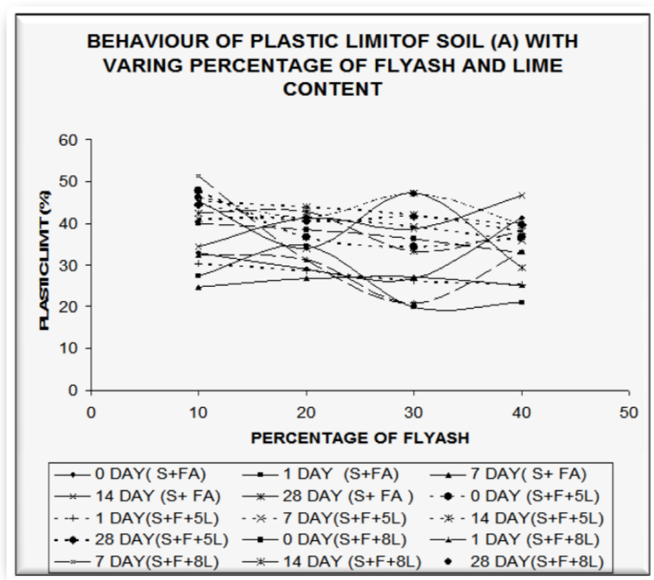

Fig 8: Behavior of plastic limit (%) of soil (A) with varying percentages of flyash and lime content

TABLE 1.7 SOIL SAMPLE –B LIQUID LIMIT

Percent	Curing Period				
	0 Days	1 Days	7 Days	14 Days	28 Days
10%F	65.60	66.82	67.17	68.50	68.85
20%F	63.74	65.28	66.65	67.58	67.90
30%F	62.02	63.81	64.88	65.35	66.79
40%F	60.85	61.90	62.95	64.02	64.98
5L%+10%F	79.86	84.48	85.68	85.85	86.88

5%L+20%F	*75.33*	*78.92*	*79.68*	*81.57*	*82.95*
5%L+30%F	*73.00*	*76.53*	*77.54*	*78.84*	*79.19*
5%L+40%F	*70.60*	*74.65*	*75.90*	*77.89*	*78.39*
8%L+10%F	*80.32*	*86.67*	*88.95*	*89.37*	*90.37*
8%L+20%F	*78.35*	*80.97*	*83.97*	*85.98*	*86.23*
8%L+30%F	*75.93*	*77.36*	*79.25*	*81.38*	*80.44*
8%L+40%F	*73.32*	*76.17*	*77.97*	*79.13*	*82.23*

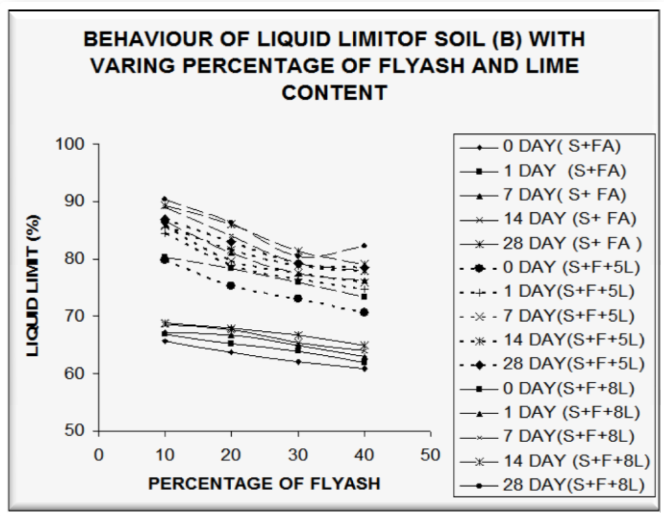

Fig 9: Behaviour of liquid limit of soil (B) with varying percentages of flyash and lime content

TABLE 1.8 SOIL SAMPLE –B PLASTIC LIMIT

Percent	*Curing Period*				
	0 Days	*1 Days*	*7 Days*	*14 Days*	*28 Days*
10%F	*30.00*	*28.70*	*30.91*	*26.56*	*39.71*
20%F	*29.66*	*30.00*	*25.64*	*27.63*	*28.39*
30%F	*23.19*	*26.5*	*29.03*	*29.79*	*31.00*
40%F	*21.05*	*25.46*	*30.67*	*27.54*	*28.45*
5L%+10%F	*24.28*	*52.22*	*42.86*	*41.03*	*46.51*
5%L+20%F	*37.65*	*36.58*	*37.30*	*38.54*	*41.60*
5%L+30%F	*79.78*	*45.00*	*49.39*	*39.66*	*50.00*
5%L+40%F	*31.43*	*35.24*	*34.34*	*48.68*	*40.69*
8%L+10%F	*40.69*	*52.03*	*43.34*	*52.17*	*58.43*
8%L+20%F	*38.29*	*50.00*	*46.88*	*52.17*	*50.51*
8%L+30%F	*36.42*	*45.36*	*46.59*	*45.83*	*46.99*
8%L+40%F	*34.51*	*41.46*	*44.44*	*62.86*	*52.38*

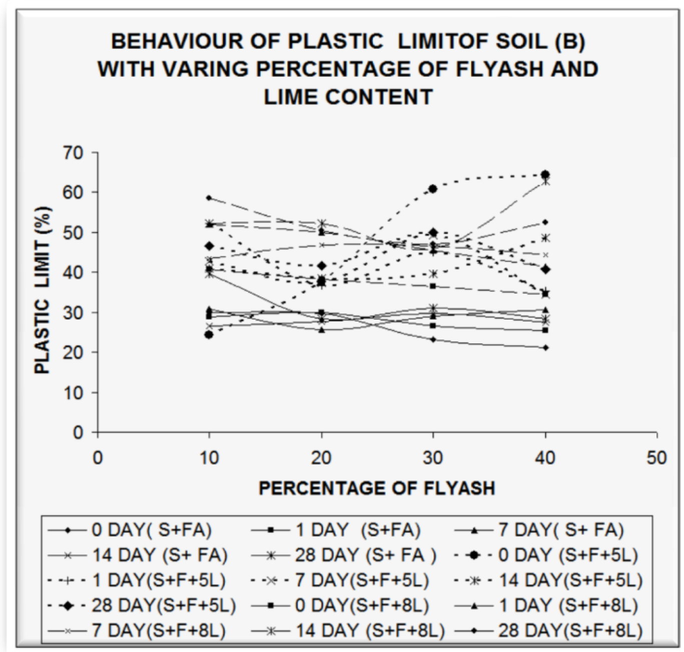

Fig 10: Behaviour of plastic limit (%) of soil (B) with varying percentages of flyash and lime content

Compaction test

Compaction test was conducted for the soil samples A, B and for flyash independently with different water contents. With the obtained results graphs were plotted maximum dry density versus water content.

Optimum moisture content and maximum dry density for soils and fly ash as shown in charts

The maximum dry density is($\gamma_{d)} =$ 1.18 g/cm^3 and optimum moisture content is found 35.5% from the graph for the soil sample (A)

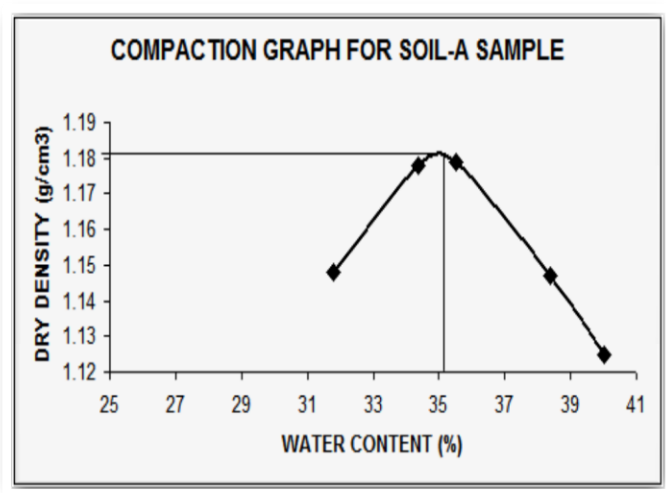

Fig 11: Variation of Dry density with different

water contents for soil sample (A)

The maximum dry density is($\gamma_{d)} =$ 1.33 g/cm^3 and optimum moisture content is found 29.70% from the graph for the soil sample (B)

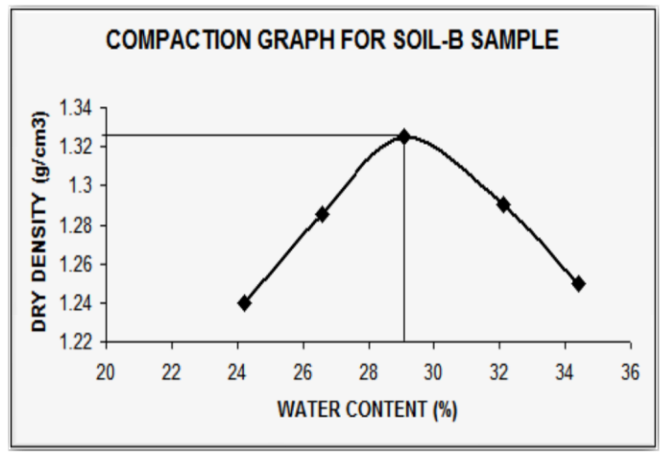

Fig 12: Variation of Dry density with different water contents for soil sample (B)

The maximum dry density is($\gamma_{d)} =$ 1.13 g/cm^3 and optimum moisture content is found 24.65% from the graph for Flyash

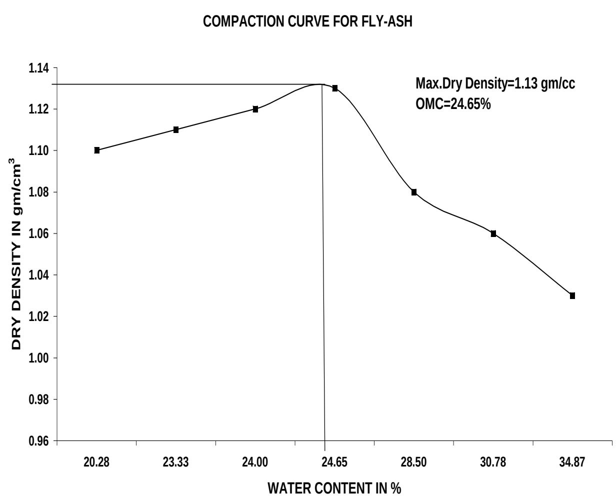

Fig 13: Variation of Dry density with different water contents of Flyash

UNCONFINED COMPRESSION TEST:

UCS test is conducted for the soil samples A, B and for flyash independently. With the obtained results graphs were plotted between axial stress versus axial strain

The UCS for the soils and fly ash are as shown in tables and charts

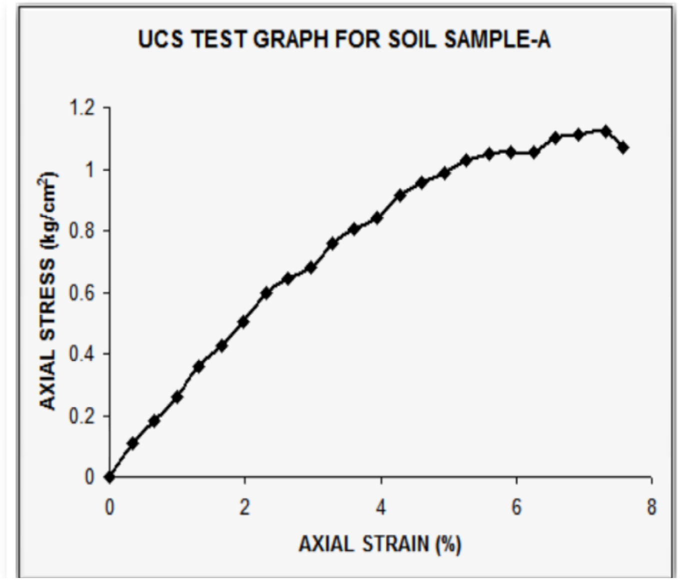

Fig 14: Variation of Axial stress with axial strain for the soil sample (A)

The compressive strength of soil sample–A is 1.12 kg/cm^2

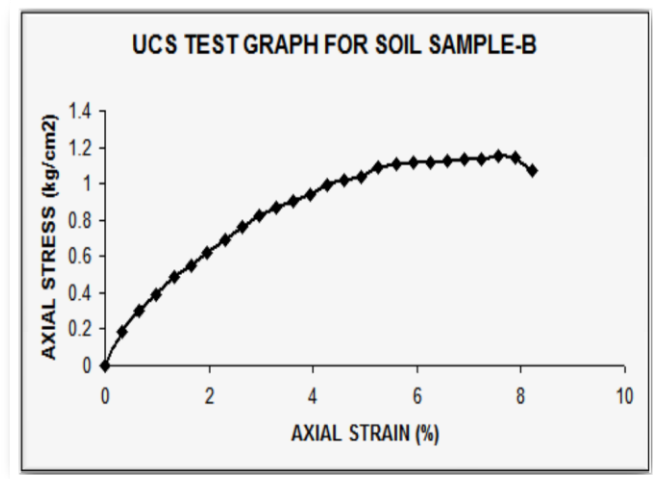

Fig 15: Variation of Axial stress with axial strain for the soil sample (B)

The compressive strength of soil sample–B is 1.15 kg/cm^2

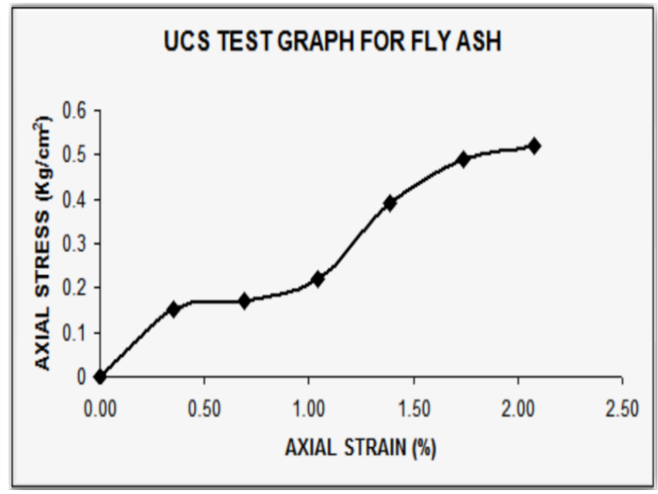

Fig 16: Variation of Axial stress with axial strain for the soil sample (A)

The compressive strength of fly ash is 0.53 kg/cm²

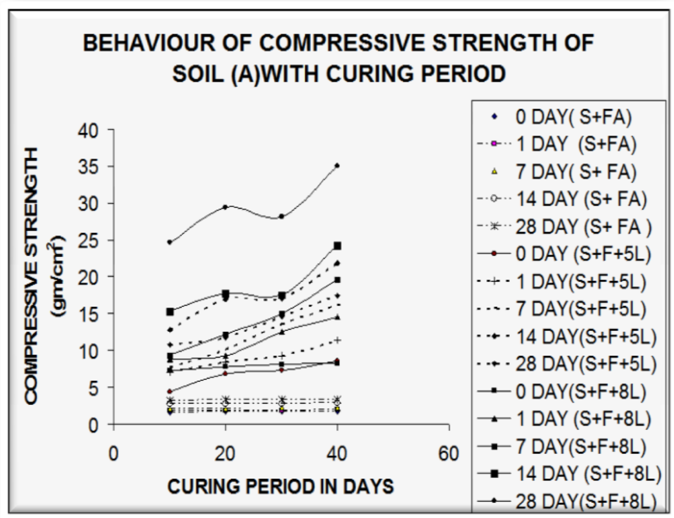

Fig 17: Behaviour of Compressive strength of soil (A) with varying percentages of flyash and lime content

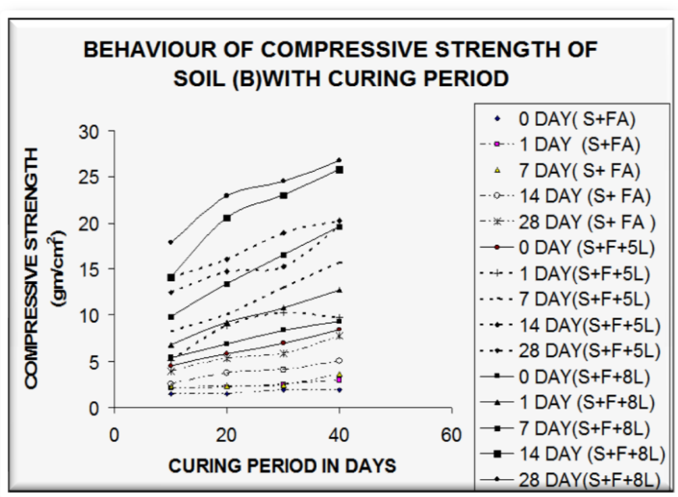

Fig 18: Behaviour of Compressive strength of soil (B) with varying percentages of flyash and lime content

The unconfined compressive strength of soil-A, variation of fly ash and with curing period as shown in above chart. There is no much effect on the strength of soil-A & soil-B, with variation of fly ash because of lesser lime content in the fly ash, so there is negligible amount of pozzolanic reaction takes place between soil and fly ash

The unconfined compressive strength of soil-A, variation of lime and fly ash with curing period as shown in above chart. There is slightly increase in the strength of soil-A & soil-B, with curing period.

Conclusions

1. Liquid limit of the soil decreases, plastic limit increases and plasticity index decreases. This behaviour indicates that the soil makes a attempt to convert in to a non-swelling type of a soil, which is good for sub base material.
2. As the fly ash & lime percentages increases the liquid limit and the plastic index decrease.
3. As the curing period increases the strength behaviour of stabilized soil increases.
4. The strength behaviour of lime treated soil+flyash is increases than soil+fllyash mix.
5. Not much change in the properties was seen after subjecting the soil to cycles of alternate wetting and drying. This suggests that bonding obtained for soil after adding fly ash and lime contents.

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