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PERFORMANCE ANALYSIS OF EXPANSIVE SOIL TREATED WITH STONE DUST AND FLY ASH

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CHAPTER-1

INTRODUCTION

1.1 Basics:-

The Highways generally consists of subgrade, subbase, base and wearing course. The subgrade is an important part of highway Development. But in some areas of expansive soil or black cotton soil it is very much difficult to get selected soil. The selected soil is not available in a nearby reach so it has to be transported from long distance which increases the period and cost of the construction work. Hence need for soil improvement by using stone dust and fly ash.

Limestone is made up of varying proportions of chemicals such as (i) calcium carbonate ($CaCO_3$), (ii) Magnesium carbonate ($MgCO_3$), (iii) Silica (SiO_2), (iv)Alumina (Al_2O_3), (v) Iron oxide (Fe_2O_3), (vi) Sulphate (SO_3) and (vii) Phosphors (P_2O_5) with calcium and magnesium carbonate being the two major components **(Harris, P. M., 1982).** Limestone dust is the most regular form of calcium carbonate which is used widely for the stabilization of soil.

Fly ash is one of the residues generated in combustion and comprises the fine particles that rise with the gases. In an industrial circumstance, fly ash usually refers to ash produced during the combustion of coal. It is having a fineness of about in the range between 4000 cm^2/g – 8000 cm^2/g. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reaches the chimneys of coal-fired power plants depending upon the source and constitute of the coal being burned, the components of fly ash vary considerably. It may comprise one or more of the subsequent elements or the substances in quantities from trace amounts to several beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins.

1.2 Expansive soils:-

In Area of India Such as (A.P.) Andhra Pradesh, (M.P.) Madhya Pradesh, Maharastra of Deccan Trap are Rich in Black Cotton Soil (Expansion Soil). Black cotton soils are also found in river valley of Tapi, Godavari, Krishna and Narmada. In the north western part of Deccan Plateau and in the upper parts of Krishna and Godavari, the depth of black soil is very large. chemical decomposition of the rocks such as basalt and trap are the Reason for the arrangement of Such Residual Soil. Also these type of soils are formed due to the weathering of igneous rocks and the cooling of lava after a volcanic eruption. These soils are rich in (i) Magnesia, (ii) Iron, (iii) Lime and (iv) Alumina but lack in the contents like (i) Phosphorus, (ii) Nitrogen and (iii) Organic matter.

Their color differs from black color to chestnut brown color, and principally consists of high percentage of clay sized particles. On an average about 20% of the total land area of our country is covered with the expansive soils. Because of their moisture retentiveness, these soils are suitable for dry farming and are suitable for growing cottons, cereals, rice, wheat, jowar, oilseeds, citrus fruits and vegetables, tobacco and sugarcane.

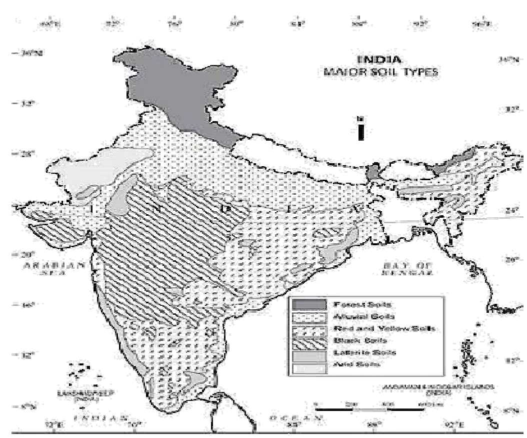


Figure 1.1 Major Soil Types in India

1.3 Fly Ash

The fly ash is a waste by product of coal, which is extracted from the flue gases of a coal fired furnace situated in the industry. These have close similarity with the volcanic ashes, which were used as hydraulic cements in early ages. These volcanic ashes were considered as one of the best pozzolanas used till now in the whole world.

Now a day due to rapid urbanization and industrialization the demand of power supply has been grown up, these results in setting up of a numerous number of thermal power plants. These thermal power plants utilize the coal to produce the electricity and thereafter the coal is burnt, whatever the mineral residue is remained is called as Fly Ashes (FA). These fly ashes are collected from the Electro static precipitator (ESPs) of the plants.

1.4 Stone Dust

River sand is expensive due to extreme cost of conveyance from natural sources. Additionally substantial consumption of these sources makes natural issues.

1.5 Objectives of the Study

The prime aim of the present investigation is to assess the usefulness of the stone dust and fly ash as soil reinforcement. The present investigation has been limited to the following studies,

1. To study the strengthening of soil of low bearing capacity.
2. To study the effect of stone dust in soil preventing intermixing of the soft subgrade and the harder sub- base.
3. To study the effect of fly ash as a additive material in the soil mix.
4. To study the influence of stone dust and fly ash on California Bearing Ratio.

CHAPTER-2

LITERATURE REIEW

2.1 Standard Technique for Improving Properties of Soil

There are many situations where the strength and other properties of the soil have to be improved by ground improvement techniques.

Soil stabilization is a technique aimed at increasing or maintaining the stability of a soil mass or otherwise improving its engineering properties.

Many techniques of soil improvement are discussed in literature. In earlier period, The Research Were Made By Ozer M Ulusay R and Isik N.S. "Evaluation of damage to light structures erected on as fill material rich in expansion soil(2001), Tiwari K Khandelwal S and Jatale on Performane , Problems and Remedial Measured for the Structures Constructed on Expansion Soil (2002), Ji-ru, Z. and Xing, C., Stabilization of Expansive Soil by Lime and Fly Ash(2002), Wild, S., Kinuthia et al, D.D., "Suppression of swelling associated with formation in the lime stabilized sulphate bearing clay soils by the fractional replacement of lime with ground granulated blast furnace slag (1999).

Soil improvement methods are classified as follows:

1. Mechanical Stabilization
2. Chemical Stabilization
3. Bitumen Stabilization
4. Cement Stabilization
5. Thermal Stabilization
6. Lime Stabilization
7. Electrical Stabilization
8. Stabilization by grouting
9. Sand Stabilization

2.2.1 Economics Construction of Rural Road

Rakesh Kumar, P.K. Jain et al. (2013) had done the work for economic construction of rural roads for this he did comparative study of cost of road construction on sub-grades having different CBR values. Three type of typical sub-grade soils namely black cotton soil (CBR value 2%), yellow soil (CBR value 7%) and the soft moorum (CBR value 10%) were selected.

Yellow soil and moorum are good for road construction as these have high value of CBR and low value D.F.S. 23 and 13 respectively.

2.2.2 Behavior of Expansive Soil Mixed With Lime and Fly Ash

D. S. Tolia et. al (2003) has been studied the properties of the expansive soil mixed with the lime and varying percentage of fly ash. **D. S. Tolia et. al** has been conducted lots of laboratory tests.

From the result in the following conclusions have been made:

When lime is added to the expansive soil, it reduces liquid limit, increases plastic limit and decreases plasticity index of the soil. Addition of fly ash with fixed percentage of lime (i.e. 4% in this case) further decreases liquid limit. Determination of plastic limit becomes difficult as fly ash content increases. From the study, it is also noted that liquid limit of the soils obtained with 4% lime and 40% fly ash.

The optimum moisture contained (OMC) of stabilize size increases at maximum dry density (MDD) decreases in fly ash contained for a fixed percentage of lime.

2.2.3 Engineering Behavior of Saw Dust Mixed Cotton Soil

Soni (2006) had done the work for improving the properties of black cotton soil mixed with saw dust. The saw dust mixed black cotton soil has minimum increase in liquid limit at 15% of saw dust mix, and has minimum value of plasticity index due to increase in plastic limit. This makes the blended mix less plastic in nature.

Decrease in plasticity index and increase in shrinkage limits clearly indicates that after addition of saw dust to expansive soil, the expansive soil tends to become non-expansive and volumetrically stable in nature.
Differential free swell also reduce considerably. The index of differential free swell has come down from the range of high to a range of moderate hence the ill effects due to the volume change of the expansive soil will be less.
Soaked CBR value for 15% addition of saw dust increases by 135% of raw soil.
Bricks made by mixing saw dust with black cotton soil in certain proportion have shown satisfactory result.
From his study it is very clearly that the addition of light weight waste materials like saw dust can improve the behaviour of Expansive soil.

2.2.4 Behavior of Sand and Nylon Fiber Mixed Black Cotton Soil

Saxena A. K. (2005) had done work for black cotton soil for minimize the problem of swelling and improving the CBR value by mixing locally available sand and artificial fiber (Nylon Fiber) and also did the comparative study on cost of construction of road and CBR value of soil sub grade and sand-Nylon fiber mixed with black cotton soil. The sand and fiber were mixed randomly in varying percentage from 10% to 20% and 1% to 2% respectively. After mixing sand and Nylon fiber with black cotton soil in various percentages by weight of the soil. It is noted that there was a reduction in swelling pressure up to 51% and increase in CBR value from 3.49 to 6.98%.
Saxena A. K. (2005) found some conclusions from his work as follows:
Percentage of sand and fiber were directly proportional to maximum dry density, the value of MDD increases with the increased percentages of sand and fiber in the black cotton soil.
Percentage of sand and fiber were inversely proportional to OMC as the value of OMC becomes lower with the higher percentage of sand and fiber in the black cotton soil.
CBR was found to be doubled with the 20% sand and 2% fiber black cotton soil.
Swelling pressure was considerably reduced by 51% for 20% sand and 2% fiber.
Inclusion of sand – Nylon fiber increases strength as well as other engineering properties of black cotton soil and Nylon fiber is not Bio-degradable, therefore the change in the behavior of reinforced soil will not vanish.

2.2.5 Soil Improvement by locally available materials: A Comparison

V. K. Tantway (2007) Concluded that the strength behaviour of the stone dust mixed with any type of soil has improved substantially. The mixed soil is better compactable and lesser compressible in comparison to Non-plastic clay and grading of the soil also improved by addition of 25% stone dust which is presented. For coarse graded granular sub-base material. So the soil mixed with 25% of stone dust can be used for granular sub-base material in road construction work.
So the locally available material can improve the soil properties by addition it, in the plastic soil. Addition of lime required more water than the sand, so the sand is useful in that area where water is not available in large quantities. For improvement of the plastic soil percentage of sand required more as compared to lime. Addition of lime-fly ash in the soil needs more quantity than the lime.

2.6 Treatment of expansive soil by Fly Ash Based on the self-cementitious properties, fly ashes are divided in to two categories – Class C and Class F (ASTM C618-08a). Both types are pozzolanic. Class C fly ash has generally higher calcium content, measured as CaO, (more than 10%) and is self cementitious. Although many investigators thought that the self-cementitious properties were the results of the presence of free CaO in fly ash, **Joshi (2000)** reported that it is the calcium in the glassy phase i.e. fly ash particles which produces cementitious compounds on hydration even without the presence of free lime.

Cocka (2001) has examined the effect of high-calcium and low-calcium, class C fly ashes, for stabilization of an expansive soil in Turkey. The study compared the behavior of the soil-lime, soil-cement, and soil-fly ash mixes. The test soil had liquid limit and plastic limit of 74% and 22%, respectively. Lime and cement were added to the expansive soil in the range of 0–8%. It was found that class C fly ash can be effectively used for improvement of expansive soils. Addition of 20% fly ash, substantially decreased the swelling potential of the expansive soil. Further increase in fly ash content was not beneficial. It has also been observed that the beneficial effect of 20% fly ash, in reducing the swell potential, is similar with that of 8% lime.

CHAPTER 3
MATERIALS AND METHODOLOGY USED

3.1 Materials Used

This chapter describes the soil under investigation and the properties of the other materials those are expansive soil, stone dust and fly ash used to improve the properties of soil. Moreover, the details of the investigations conducted are also presented in this chapter.

1- Expansive Soil (ES)

The expansive soil used in this research study is a bentonite, available nearby area. The soil is light brown in color and of smooth in texture. This is characteristically a highly expansive soil, the swelling ingredient of which is montmorillonite. The soils were mixed uniformly, oven dried, lumps broken and sieved through a 425 micron sieve and stored in polythene bags for testing. The soil sample for the present work was collected from opposite BHMRC, Bhopal Madhya Pradesh. Characterization of the test expansive soil is presented in the next section of this chapter.

2- Fly Ash (FA)

The fly ash used in the experiments is a waste product. This is a non-self cementing fly ash. The fraction passing 425 micron was used for various tests in this experimental study. The sample for the present work is collected from Dirk India Ltd., Bhopal Madhya Pradesh. Characterization of the test fly ash is presented in the next section of this chapter.

3- Stone Dust (SD)

The stone dust used in our work is a quarry waste material. Quarry dusts are considered as one of the well acknowledged and in addition practical ground improvement technique for weak soil deposits. They provide the primary function of strengthening and thus improve the deformation and strength characteristics of weak soil regions. The sample for the present work is collected from stone crusher located Berasia Rd. Ratua village, Bhopal Madhya Pradesh.

Table-3.1: Index and Engineering Properties of Stone Dust

Properties of Stone Dust	Value
Index Properties	
Liquid Limit (%)	NIL
Plastic Limit(%)	NP (Non-Plastic)
Plasticity Index	NP (Non-Plastic)
Specific Gravity	2.58
Engineering Properties	
Optimum Moisture Content (%)	11.5%
Maximum Dry Density (kN/m^3)	15.4
California Bearing Ratio (CBR)	7.8%

3.2 Index Properties of Expansive Soil

Only dry sieving was done in the case of expansive soil because wet sieving was not done as the expansive soil particles absorb water, swell and become sticky. Sedimentation analysis was not done on the 75µ size fraction as the swelling of expansive soil particles can yield particle size distribution. Furthermore, the expansive soil suspension appears like gel and remains stable for a long period. The fractions of soil passing from 425 micron and 75 micron sieves are presented in Table-3.1

Table-3.2 Grain size distribution of Expansive Soil

S. No.	Sieve Size (micron)	% Passing by weight
1	425	100
2	75	74.2

The Liquid limit (LL) tests were done on fly ash-clay mixtures using both Cassagrande's apparatus. Plastic limit (PL) tests are done by thread rolling method. The Atterberg limits and Engineering properties of the expansive soil are presented in Table-3.2.

Table-3.3 Index and Engineering Properties of Expansive Soil

Properties of Expansive Soil	Value
Index Properties	
Liquid Limit (%)	51%
Plastic Limit(%)	27.4%
Plasticity Index	23.6
Specific Gravity	2.24
Differential free swell (%)	86%
Engineering Properties	
Optimum Moisture Content (%)	20.3%
Maximum Dry Density (kN/m^3)	1.54%
California Bearing Ratio (CBR)	1.79%

Based on the liquid limit (LL) and plasticity index (PI), the expansive soil is classified as clay of high compressibility (CH) as per the Plasticity Chart.

3.3 Fly Ash Configuration.

Ash produced in small dark flecks by the burning of powdered coal or other materials and carried into the air, is called fly ash. The mineral residue that is left behind after the burning of coal is the fly ash. The Electro Static Precipitator (ESP) of the power plants collect these fly ashes. For the purpose of investigations in this study, fly ash was obtained from Dirk India Ltd., Bhopal. To separate out the vegetation and foreign material, this fly ash was screen through a 2 mm sieve. The samples were dried in the oven for about 24 hours before further usage.

Fly Ash is a combustion product, it can be assumed that all the above elements are present in the oxide form. Considering this, the molecular percentages of the compounds (oxides) by of the above elements are estimated as:

Table-3.4 Composition of Fly Ash (FA)

S. No.	Content	% Quantity
1	SiO2	49.5 - 54.5%
2	Al2O3	25.3 - 33.8%
3	Fe2O3	6.8 - 8.0%
4	CuO	3.6 - 7.6%
5	TiO2	2.4 - 3.2%
6	K2O	0.8 - 1.7%
7	CaO	0 - 1.3%

3.3.1 Index and Engineering properties of Fly Ash (FA)

The grain size distribution curve of fly ash achieved by combining data from wet sieving and sedimentation analysis is as presented in the Figure 3.1below. It is observed that the fly ash is silt sized, and the gradation curve is well graded.

The **D90, D50** and **D10** of the test fly ash are 120μ, 51μ and 12μ respectively.

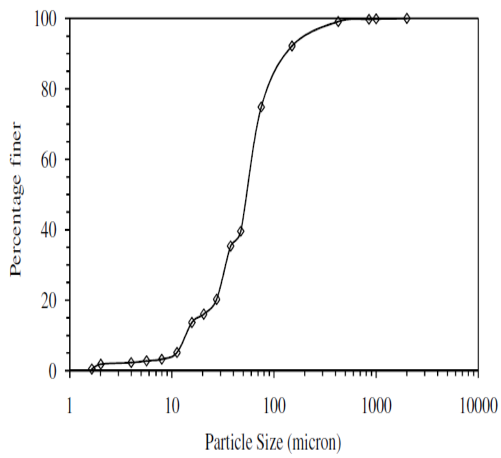


Fig.3.1 Grain size distribution of fly ash

Table-3.5 Index and Engineering Properties of Fly ash

Properties of Fly Ash	**Value**
Index Properties	
Liquid Limit (%)	31%
Plastic Limit(%)	Non-Plastic
Plasticity Index	Non-Plastic
Specific Gravity	1.9%
Engineering Properties	
Optimum Moisture Content (%)	21%
Maximum Dry Density (kN/m^3)	12.50

3.4 Methodology Adopted

To evaluate the effect of fly ash and stone dust as a stabilizing additive in expansive soils, series of tests, where the content of fly ash and stone dust in the expansive soil was varied in values of 10% to 40% (multiples of 10) by weight of the total quantity taken. The Indian Standard codes were followed during the conduction of the following experiments:

- Liquid & Plastic limit test – IS 2720 (Part 5) - 1985
- Specific gravity test – IS 2720 (Part 3) - 1980
- Free swell index test – IS 2720 (Part 40) - 1977
- Standard proctor test – IS : 2720 (Part 7) - 1980
- California bearing ratio (CBR) test – IS : 2720 (Part 16) - 1987

Index Properties Liquid Limit, Plastic Limit and Plasticity Index of the untreated expansive soil and the expansive soil treated with fly ash & stone dust determined by following Standard procedures as per IS: 2720 (Part-5)-1985; IS: 2720 (Part-6)-1972. Specific Gravity test were determined by using Pycnometer bottle method as per IS 2720 Part III.

Free Swelling Index Test In present investigation Swelling index test was carried out on untreated expansive soil and the expansive soil treated with fly ash & stone dust determined by following standard procedures as per IS:2720 (Part-40)-1977.

Compaction Characteristics **T**he Compaction Characteristics of untreated expansive soil and treated Expansive soil with various percentages of fly ash & quarry dust such as Optimum Moisture Content and Maximum Dry Density were determined in the laboratory by following standard test procedure of IS heavy compaction test as per IS 2720 part VIII.

California Bearing Ratio (CBR) Test In present investigation CBR test was carried out on prepared soil samples of Untreated Expansive soil and treated Expansive soil with various percentages of Quarry dust under un soaked condition as per recommendations in IS 2720 part XVI-1987 as shown in the **fig.3.2.**

Fig. 3.2 California Bearing Ratio Test Apparatus

Chapter – 4

Test Results

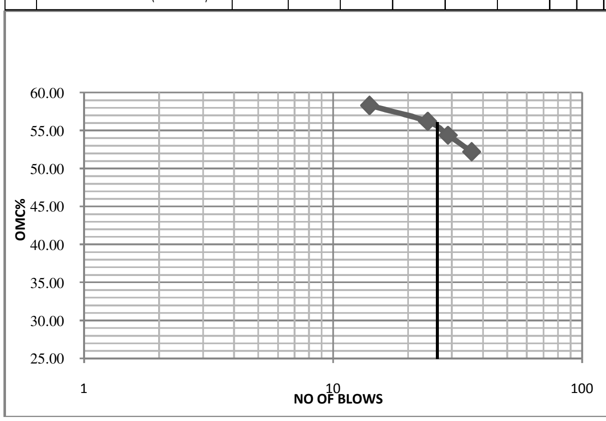
4.1 Test Results with different percentages of Stone Dust as admixture in expansive soil

ATTERBERG LIMITS

(AS PER IS 2720 PART - V)

Test Result of Expansive Soil

SR. NO.	DETERMINATION NO.	UNIT	LIQUID LIMIT (LL) 1	2	3	4	PLASTIC LIMIT (PL) 1	2	3	4
1	No. of Blows	Nos.	14	24	29	36				
3	Container No.	Nos.	11	18	19	20	10			
7	Wt. Container	Gms.	14.5	13.2	14.1	13.5	14.2			
4	Wt. Container + Wet. Soil	Gms	75.5	72.4	98.2	83.8	27.0			
5	Wt. Container + Dry Soil	Gms.	53.0	51.1	68.6	59.7	24.7			
6	Wt. Water (4) – (5)	Gms.	22.4	21.3	29.6	24.1	2.3			
8	Wt. Dry Soil (5-7)	Gms.	38.5	37.9	54.5	46.2	10.5			
9	Moisture Content (6/8x100)	%	58.3	56.2	54.4	52.2	22			



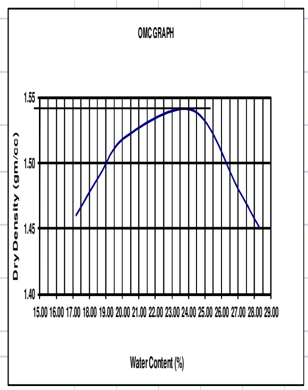
Liquid Limit : 55.30 %
Plastic Limit : 22.00 %
Plastic Index:(LL) –(PL) : 33.30 %

Proctor Density Test of Soil [(IS:2720 Part-7)-1983]

Test Result of Expansive Soil

All Wts. are in gram

Water Content (%)	17.20	18.60	20.20	24.30	27.00	28.30
Wt. of Mould (E)	4505	4505	4505	4505	4505	4505
Wt. of Mould + Sample (F)	6216	6272	6332	6419	6385	6365
Wt. Of Sample (F-E) = (G)	1711	1767	1827	1914	1880	1860
Volume of Mould	1000	1000	1000	1000	1000	1000
Bulk Density (H) = (G)/(E)	1.711	1.767	1.827	1.914	1.880	1.860
Dry Density = H/[(1)+(D/100)]	1.46	1.49	1.52	1.54	1.48	1.45
container no.	11	8	21	23	24	26
wt. of container	14.53	14.32	13.80	13.35	12.86	12.79
wt. of container + wet soil	75.70	68.52	58.15	68.17	64.55	58.34
wt. of container + dry soil	66.73	60.02	50.70	57.45	53.56	48.29
wt. of water	8.98	8.50	7.45	10.72	10.99	10.05
wt. of dry soil	52.20	45.70	36.90	44.10	40.70	35.50



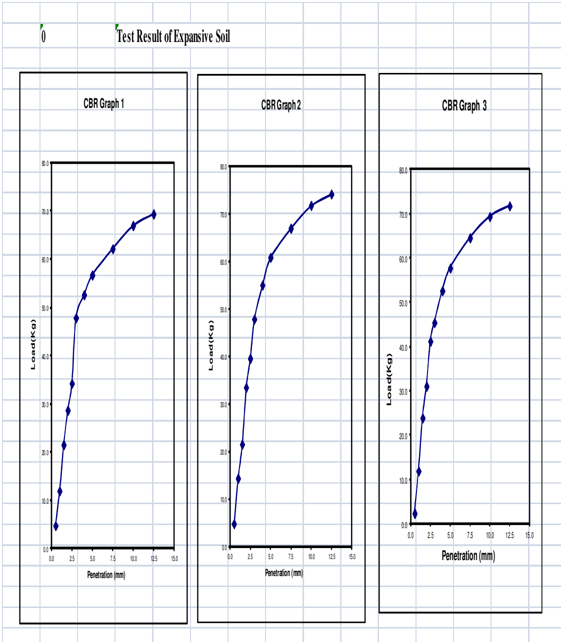
O.M.C. (%)	=	23.20
M.D.D. (gm/cc)	=	1.540

C.B.R. Test of Soil [IS:2720(Part-16)]

CBR Test Results.

Penetration	I Test		II Test		III Test		
mm	Reading	Load Intensity	Reading	Load Intensity	Reading	Load Intensity	
0	0	0	0	0	0	0	
0.5	2	4.78	2	4.78	1	2.39	
1	5	11.96	6	14.35	5	11.96	
1.5	9	21.53	9	21.53	10	23.92	
2	12	28.71	14	33.49	13	31.10	
2.5	14	34.25	17	39.59	17	41.24	
3	20	47.84	20	47.84	19	45.45	
4	22	52.63	23	55.02	22	52.63	
5	24	56.72	25	60.83	24	57.75	
7.5	26	62.19	28	66.98	27	64.59	
10	28	66.98	30	71.76	29	69.37	
12.5	29	69.37	31	74.16	30	71.76	
CBR AT 2.5 MM		2.50		2.89		3.01	**2.80**
CBR AT 5.0 MM		2.76		2.96		2.81	**2.84**

Therefore CBR of Soil 2.84



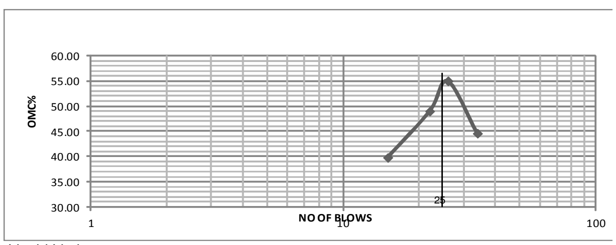
4.1.1 Atterberg's Limit:

ATTERBERG LIMITS

(AS PER IS 2720 PART - V)

Test Results of Expansive soil with 10% Fly Ash

SR. NO.	DETERMINATION NO.	UNIT	LIQUID LIMIT (LL)				PLASTIC LIMIT (PL			
			1	2	3	4	1	2	3	4
1	No. of Blows	Nos.	15	22	26	34				
3	Container No.	Nos.	12	13	14	15	16			
7	Wt. Container	Gms.	14.2	13.7	14.1	13.5	14.3			
4	Wt. Container + Wet. Soil	Gms	62.4	70.3	80.0	71.4	31.4			
5	Wt. Container + Dry Soil	Gms.	48.7	51.7	56.6	53.5	27.3			
6	Wt. Water (4) – (5)	Gms.	13.7	18.6	23.4	17.8	4.1			
8	Wt. Dry Soil (5-7)	Gms.	34.5	38	42.5	40	13			
9	Moisture Content (6/8x100)	%	39.8	49	55	44.6	31.4			



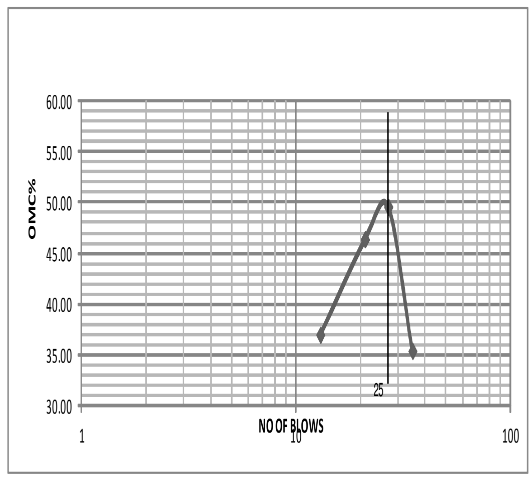
Liquid Limit : 52.00 %
Plastic Limit : 20.60 %
Plastic Index:(LL) –(PL) : 31.40 %

ATTERBERG LIMITS

(AS PER IS 2720 PART - V)

Test Results of Expansive Soil with 20% Fly Ash

SR. NO.	DETERMINATION NO.	UNIT	LIQUID LIMIT (LL)				PLASTIC LIMIT (PL)			
			1	2	3	4	1	2	3	4
1	No. of Blows	Nos.	13	21	27	35				
3	Container No.	Nos.	1	2	3	4	5			
7	Wt. Container	Gms.	13.7	13.5	14.0	13.4	13.7			
4	Wt. Container + Wet. Soil	Gms	56.2	61.1	64.8	63.5	28.1			
5	Wt. Container + Dry Soil	Gms.	44.7	46.0	48.0	50.4	24.9			
6	Wt. Water (4) – (5)	Gms.	11.5	15.1	16.9	13.1	3.2			
8	Wt. Dry Soil (5-7)	Gms.	31	32.5	34	37	11.2			
9	Moisture Content (6/8x100)	%	37	46.4	49.6	35.4	28.2			



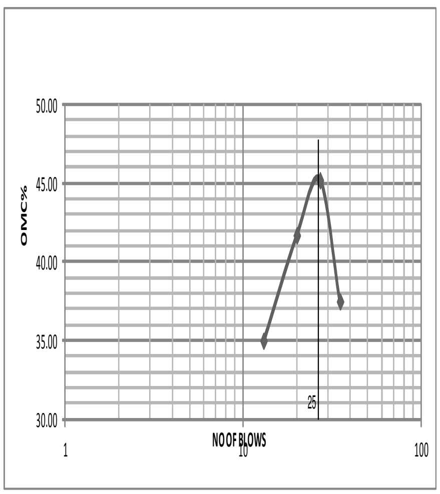
Liquid Limit : 48.00 %
Plastic Limit : 19.80 %
Plastic Index:(LL) –(PL) : 28.20 %

ATTERBERG LIMITS

(AS PER IS 2720 PART - V)

Test Results of Expansive Soil with 30% Fly Ash

SR. NO.	DETERMINATION NO.	UNIT	LIQUID LIMIT (LL)				PLASTIC LIMIT (PL)			
			1	2	3	4	1	2	3	4
1	No. of Blows	Nos.	13	20	27	35				
3	Container No.	Nos.	11	12	13	14	15			
7	Wt. Container	Gms.	14.5	14.2	13.7	14.1	13.5			
4	Wt. Container + Wet. Soil	Gms	57.7	64.0	71.3	73.5	30.5			
5	Wt. Container + Dry Soil	Gms.	46.5	49.4	53.4	57.3	27.1			
6	Wt. Water (4) – (5)	Gms.	11.2	14.7	17.9	16.2	3.4			
8	Wt. Dry Soil (5-7)	Gms.	32	35.2	39.7	43.2	13.6			
9	Moisture Content (6/8x100)	%	35	41.7	45.2	37.5	24.85			



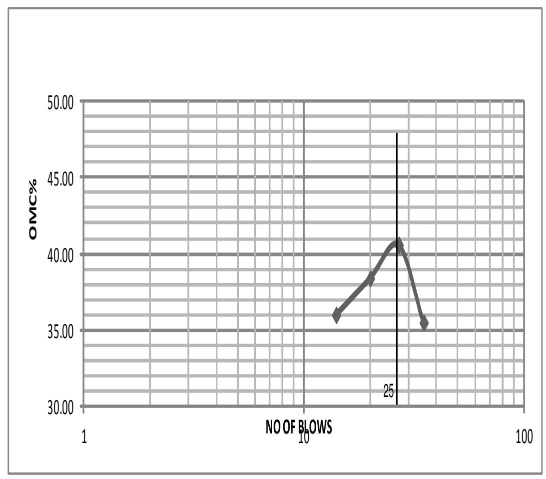
Liquid Limit : 43.45 %
Plastic Limit : 18.60 %
Plastic Index:(LL) –(PL) : 24.85 %

ATTERBERG LIMITS

(AS PER IS 2720 PART - V)

Test Results of Expansive Soil with 40% Fly Ash

SR. NO.	DETERMINATION NO.	UNIT	LIQUID LIMIT (LL)				PLASTIC LIMIT (PL)			
			1	2	3	4	1	2	3	4
1	No. of Blows	Nos.	14	20	27	35				
3	Container No.	Nos.	17	18	19	20	21			
7	Wt. Container	Gms.	13.1	13.2	14.1	13.5	13.8			
4	Wt. Container + Wet. Soil	Gms	60.4	64.4	68.9	69.0	32.1			
5	Wt. Container + Dry Soil	Gms.	47.9	50.2	53.1	54.5	28.8			
6	Wt. Water (4) – (5)	Gms.	12.5	14.2	15.8	14.6	3.3			
8	Wt. Dry Soil (5-7)	Gms.	34.8	37	39	41	15			
9	Moisture Content (6/8x100)	%	36	38.4	40.6	35.5	21.7			



Liquid Limit : 39.50 %
Plastic Limit : 17.80 %
Plastic Index:(LL) –(PL) : 21.70 %

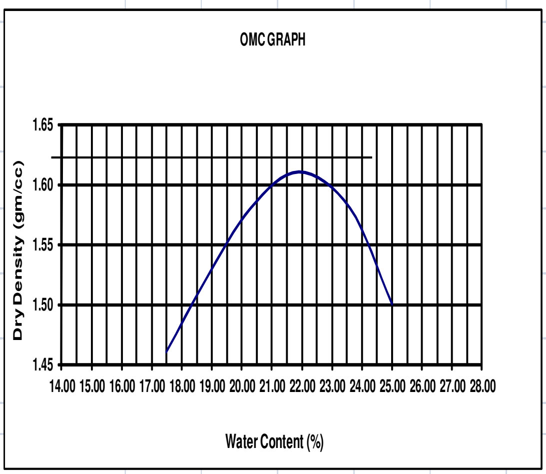
4.1.2 IS Heavy Compaction:

Proctor Density Test of Soil [(IS:2720 Part-7)-1983]

Test Results of Expansive soil with 10% Fly Ash

All Wts. are in gram

Water Content (%)	17.50	18.80	20.30	21.90	23.60	25.00
Wt. of Mould (E)	4505	4505	4505	4505	4505	4505
Wt. of Mould + Sample (F)	6221	6311	6406	6468	6458	6380
Wt. Of Sample (F-E) = (G)	1716	1806	1901	1963	1953	1875
Volume of Mould	1000	1000	1000	1000	1000	1000
Bulk Density (H) = (G)/(E)	1.716	1.806	1.901	1.963	1.953	1.875
Dry Density = H/[(1)+(D/100)]	1.46	1.52	1.58	1.61	1.58	1.50
container no.	13	14	16	17	18	19
wt. of container	13.68	14.14	14.29	13.08	13.24	14.09
wt. of container + wet soil	75.01	68.43	58.68	66.84	63.55	58.46
wt. of container + dry soil	65.88	59.84	51.19	57.18	53.94	49.59
wt. of water	9.14	8.59	7.49	9.66	9.61	8.88
wt. of dry soil	52.20	45.70	36.90	44.10	40.70	35.50



O.M.C. (%)	=	21.95
M.D.D. (gm/cc)	=	1.610

C.B.R. Test of Soil [IS:2720(Part-16)]

CBR Test Results.

Penetration	I Test		II Test		III Test		
mm	Reading	Load Intensity	Reading	Load Intensity	Reading	Load Intensity	
0	0	0	0	0	0	0	
0.5	3	7.18	3	7.18	2	4.78	
1	6	14.35	7	16.74	6	14.35	
1.5	11	26.31	11	26.31	12	28.71	
2	14	33.49	16	38.27	16	38.27	
2.5	18	43.84	19	45.21	19	46.58	
3	22	52.63	23	55.02	22	52.63	
4	25	59.80	25	59.80	25	59.80	
5	27	64.73	27	65.76	29	68.84	
7.5	31	74.16	32	76.55	31	74.16	
10	32	76.55	35	83.72	34	81.33	
12.5	34	81.33	37	88.51	36	86.12	
CBR AT 2.5 MM		3.20		3.30		3.40	**3.30**
CBR AT 5.0 MM		3.15		3.20		3.35	**3.23**

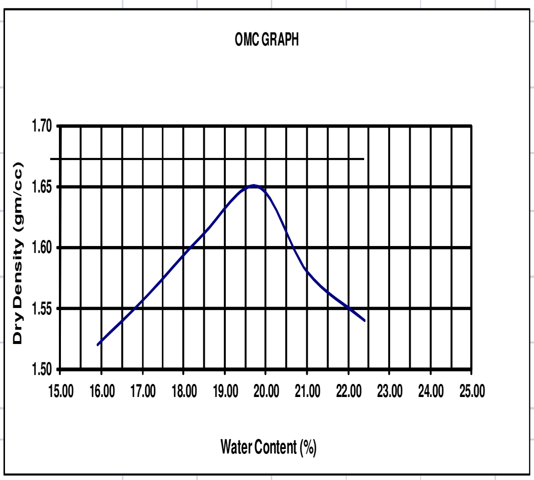
Therefore CBR of Soil **3.30**

Proctor Density Test of Soil [(IS:2720 Part-7)-1983]

Test Results of Expansive Soil with 20% Fly Ash

All Wts. are in gram

Water Content (%)	15.90	17.10	18.45	19.80	21.00	22.40
Wt. of Mould (E)	4505	4505	4505	4505	4505	4505
Wt. of Mould + Sample (F)	6267	6332	6412	6482	6417	6390
Wt. Of Sample (F-E) = (G)	1762	1827	1907	1977	1912	1885
Volume of Mould	1000	1000	1000	1000	1000	1000
Bulk Density (H) = (G)/(E)	1.762	1.827	1.907	1.977	1.912	1.885
Dry Density = H/((1)+(D/100))	1.52	1.56	1.61	1.65	1.58	1.54
container no.	1	2	3	4	5	6
wt. of container	13.75	13.51	13.96	13.38	13.71	14.08
wt. of container + wet soil	69.84	72.17	68.80	66.21	59.08	63.04
wt. of container + dry soil	62.15	63.61	60.26	57.48	51.21	54.08
wt. of water	7.70	8.57	8.54	8.73	7.88	8.96
wt. of dry soil	48.40	50.10	46.30	44.10	37.50	40.00



O.M.C. (%)	=	19.73
M.D.D. (gm/cc)	=	1.650

C.B.R. Test of Soil [IS:2720(Part-16)]

CBR Test Results.

Penetration	I Test		II Test		III Test		
mm	Reading	Load Intensity	Reading	Load Intensity	Reading	Load Intensity	
0	0	0	0	0	0	0	
0.5	4	9.57	4	9.57	3	7.18	
1	7	16.74	9	21.53	11	26.31	
1.5	18	43.06	15	35.88	16	38.27	
2	21	50.23	19	45.45	19	45.45	
2.5	23	56.17	24	58.23	24	57.54	
3	28	66.98	29	69.37	28	66.98	
4	32	76.55	33	78.94	31	74.16	
5	36	85.28	36	85.28	35	84.26	
7.5	38	90.90	38	90.90	37	88.51	
10	39	93.29	40	95.68	39	93.29	
12.5	41	98.08	42	100.47	41	98.08	
CBR AT 2.5 MM		4.10		4.25		4.20	**4.18**
CBR AT 5.0 MM		4.15		4.15		4.10	**4.13**

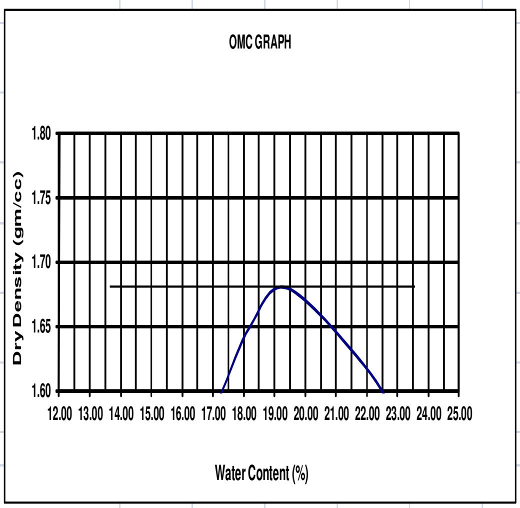
Therefore CBR of Soil **4.18**

Proctor Density Test of Soil [(IS:2720 Part-7)-1983]

Test Results of Expansive Soil with 30% Fly Ash

All Wts. are in gram

Water Content (%)	16.60	17.30	18.20	19.40	21.90	23.20
Wt. of Mould (E)	4505	4505	4505	4505	4505	4505
Wt. of Mould + Sample (F)	6324	6382	6455	6511	6480	6439
Wt. Of Sample (F-E) = (G)	1819	1877	1950	2006	1975	1934
Volume of Mould	1000	1000	1000	1000	1000	1000
Bulk Density (H) = (G)/(E)	1.819	1.877	1.950	2.006	1.975	1.934
Dry Density = H/[(1)+(D/100)]	1.56	1.60	1.65	1.68	1.62	1.57
container no.	12	13	14	15	16	17
wt. of container	14.17	13.68	14.14	13.52	14.29	13.08
wt. of container + wet soil	68.50	70.92	74.66	69.64	69.51	64.82
wt. of container + dry soil	60.77	62.48	65.34	60.52	59.59	55.08
wt. of water	7.74	8.44	9.32	9.12	9.92	9.74
wt. of dry soil	46.60	48.80	51.20	47.00	45.30	42.00



O.M.C. (%)	=	20.05
M.D.D. (gm/cc)	=	1.680

C.B.R. Test of Soil [IS:2720(Part-16)]

CBR Test Results.

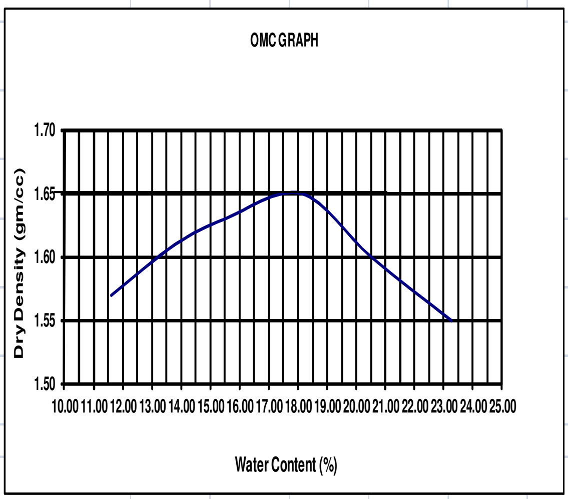
Penetration	I Test		II Test		III Test		
mm	Reading	Load Intensity	Reading	Load Intensity	Reading	Load Intensity	
0	0	0	0	0	0	0	
0.5	4	9.57	3	7.18	4	9.57	
1	8	19.14	8	19.14	9	21.53	
1.5	16	38.27	15	35.88	14	33.49	
2	22	52.63	18	43.06	18	43.06	
2.5	26	61.65	25	60.28	25	60.97	
3	28	66.98	28	66.98	29	69.37	
4	33	78.94	32	76.55	34	81.33	
5	38	91.45	37	89.39	38	90.42	
7.5	40	95.68	39	93.29	39	93.29	
10	41	98.08	41	98.08	41	98.08	
12.5	43	102.86	42	100.47	42	100.47	
CBR AT 2.5 MM		4.50		4.40		4.45	**4.45**
CBR AT 5.0 MM		4.45		4.35		4.40	**4.40**
Therefore CBR of Soil			**4.50**				

Proctor Density Test of Soil [(IS:2720 Part-7)-1983]

Test Results of Expansive Soil with 40% Fly Ash

All Wts. are in gram

Water Content (%)	11.60	13.80	15.50	18.10	20.50	23.25
Wt. of Mould (E)	4505	4505	4505	4505	4505	4505
Wt. of Mould + Sample (F)	6257	6337	6388	6454	6433	6415
Wt. Of Sample (F-E) = (G)	1752	1832	1883	1949	1928	1910
Volume of Mould	1000	1000	1000	1000	1000	1000
Bulk Density (H) = (G)/(E)	1.752	1.832	1.883	1.949	1.928	1.910
Dry Density = H/[(1)+(D/100)]	1.57	1.61	1.63	1.65	1.60	1.55
container no.	24	25	26	21	22	23
wt. of container	12.86	15.57	12.79	13.80	14.06	13.35
wt. of container + wet soil	65.31	70.30	65.23	65.76	65.51	66.35
wt. of container + dry soil	59.86	63.67	58.19	57.80	56.76	56.35
wt. of water	5.45	6.64	7.04	7.96	8.75	10.00
wt. of dry soil	47.00	48.10	45.40	44.00	42.70	43.00



O.M.C. (%)	=	**18.00**
M.D.D. (gm/cc)	=	**1.650**

C.B.R. Test of Soil [IS:2720(Part-16)]

CBR Test Results.

Penetration	I Test		II Test		III Test		
mm	Reading	Load Intensity	Reading	Load Intensity	Reading	Load Intensity	
0	0	0	0	0	0	0	
0.5	5	11.96	6	14.35	4	9.57	
1	10	23.92	11	26.31	9	21.53	
1.5	17	40.67	16	38.27	15	35.88	
2	22	52.63	21	50.23	20	47.84	
2.5	25	58.91	25	59.60	24	58.23	
3	28	66.98	27	64.59	28	66.98	
4	31	74.16	32	76.55	34	81.33	
5	34	81.33	36	85.28	37	87.34	
7.5	42	100.47	38	90.90	42	100.47	
10	44	105.25	42	100.47	44	105.25	
12.5	45	107.64	44	105.25	45	107.64	
CBR AT 2.5 MM		4.30		4.35		4.25	**4.30**
CBR AT 5.0 MM		4.10		4.15		4.25	**4.17**

Therefore CBR of Soil **4.30**

CHAPTER - 5

5.1 Comparison on Stabilization of Expansive soils with Stone Dust and Fly Ash

Atterberg's limits, IS heavy compaction, Free swelling index and soaked CBR tests were conducted with different percentages of fly ash and stone dust as a admixture in expansive soil for finding the optimum percentage of additives.

5.1.1 Liquid Limit and Plastic Limit

From the figures 4.1 & 4.2, it is observed that as the percentage of fly ash and dust increases, there is marked reduction in liquid limit and plastic limit of clay tested. This decreased plasticity or plasticity index of the soil is very much required in road construction to avoid the failure patterns in the construction over the expansive subgrade soils. The liquid limit at 40% addition of fly ash and stone dust show the liquid limit values 39.50% and 31.10% respectively. For the same soil tested with fly ash and stone dust, it is observed that the plasticity characteristics of soil are low in case of soil treated with the stone dust compared to fly ash.

5.1.2 Modified Proctor Test (OMC & MDD Test)

The variations of compaction characteristics such as Optimum Moisture Content and Maximum Dry Density for the expansive clay treated with fly ash and stone dust are presented in figure 3.3 & 4.4. From the figures, It is also observed that the clay sample of fly ash and stone. It is also observed that the clay sample when replaced with 30% of stone dust yielded maximum dry density of 1.85 kg/m^3 at optimum moisture content of 15.75% and 30% of fly ash yield maximum dry density of 1.75kg/m^3 at OMC of 20.05%. The percentage increase in the MDD at optimum levels of fly ash and stone dust additions to the clay are 12% and 22% respectively.

5.1.3 Free Swell Index (FSI)

Figures present the variation in of FSI with the addition of admixture. From Figure 4.5, it is observed that the FSI values of the expansive soil have decreased with the increase in percentage of stone dust/flyash content. As the admixture content increases, the clay place is replaced and hence reduced swelling and shrinkage of the admixture treated clay. From the test results, it is observed that at 40% addition of stone dust to the clay has resulted 69% decrease in FSI, and similarly at 50% addition of flyash, there is a 29% reduction in FSI. Figure 4.6, presents the variation in FSI corresponding to combination of equal proportion of stone dust and flyash.

Combination on FSI From this plot, it is noticed that at 50% addition of admixture (i.e., 25% stone dust + 25% flyash) to the clay, the reduction in FSI is 35%. Hence, it is notable to adopt the combination of flyash and stone dust in addition to the insitu clay for construction purpose.

5.1.4 California Bearing Ratio (CBR)

Soaked CBR test results of flyash/stone dust treated soil are presented in Graph. No 08. From this Graph, it is observed that as the percentage of Blend such as flyash /stone dust elevated, the CBR also Boost in a Rational Quantity. The optimum values of CBR is found at 23% of flyash and 30% of stone dust. The percentage increase in CBR corresponding to 23% flyash and 30% stone dust addition to the soil are 100% and 235% respectively.

CHAPTER - 6

6.1 Implication

The Below listed implications can be made from the experimental work borne out and comparison outcome in this study.

- The Soil Properties such as Free Swell Index, Optimum Moisture Content , Atterberg's limits are Declined and Maximum Dry Density, California Bearing Ratio values are Elevated.
- When flyash and stone dust is added to the expansive soils the Atterberg's limits, Optimum, Free Swell Index are decreased and Maximum Dry Density, California Bearing Ratio values are increased.
- The optimum percentages of flyash and stone dust observed are 25% and 30% respectively for improving the properties of expansive soils.
- It is observed from the study that the performance of stone dust is much more effective when compared to flyash.
- There is a maximum improvement in strength properties for the combination of flyash and stone dust when compared to flyash/stone dust individually.

Based on the results obtained and comparisons made in the present study, the following conclusions can be drawn:

- The Maximum Dry Density (MDD) value of the black cotton soil initially decreased with the addition of fly ash.
- The Unconfined Compressive Strength (UCS) of the soil with variation of fly ash content showed similar trend as that of the MDD values, except the fact that the peak value was observed for a fly ash content of 20% by weight.
- In un-soaked California Bearing Ratio (CBR) tests of soil conducted with varying fly ash content, the CBR increased gradually with the increase in fly ash content till its valuation was 20% by weight of the total mixture; it decreased thereafter.
- The change in case of soaked California Bearing Ratio (CBR) tests of soil with varying fly ash content was, however, uneven. It decreased with the initial addition of fly ash (10% by weight of total mixture), and then increased till fly ash content reached 30% by weight of total mixture. The values declined thereafter.
- When in the Fly Ash and Black Cotton Soil Blend we elevated the content of Fly Ash ,the fall in the Value of Free swell Ratio found. This decrease was also reciprocated by the plasticity index (Denominations). Plasticity index denominations values are directly proportional to percent

swell in an expansive soil, thus affecting the Expanison behavior of the soil-fly ash Blend.

- Thus, fly ash as an additive decreases the swelling, and increases the strength of the black cotton soil.

6.2 Scope for future study

 Fly ash along with another additive like lime, murrum, cement, and other such materials can be used together, and may be varied in quantity to obtain the best possible stabilizing mixture.

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