ISSN Print: 2394-7500
ISSN Online: 2394-5869
IJAR 2015; 1(6): 34-39
www.allresearchjournal.com
Received: 13-03-2015
Accepted: 29-04-2015

M.N.V. Surya Narayana Raju
M. Tech Student, B.V. C. Engineering College, Odalarevu, East Godavari District.

D.S.V. Prasad
Professor& Principal B.V. C. Engineering College, Odalarevu, East Godavari District.

M. Anjan Kumar
Professor& Principal B.V. C. Engineering College, Rajahmundry, East Godavari District.

G.V.R. Prasada Raju
Professor& Registrar, JNT University, Kakinada, East Godavari District.

Correspondence:
M.N.V. Surya Narayana Raju
M. Tech Student, B.V. C. Engineering College, Odalarevu, East Godavari District.

Evaluation of the Properties of Fly Ash on Strength and Swelling Aspect of an Expansive Soil

M.N.V. Surya Narayana Raju, D.S.V. Prasad, M. Anjan Kumar, G.V.R. Prasada Raju

Abstract
Swelling soil always create problems more for lightly loaded structures than moderately loaded structures. By consolidating under load and changing volumetrically along with seasonal moisture variation, these problems are manifested through swelling, shrinkage and unequal settlement. As a result damage to foundation systems, structural elements and architectural features defeat the purpose for which the structures are erected. An attempt to study such unpredictable behaviour and through research on how to bring these problems under control form the backdrop for this project work. Pre-stabilization is very effective method in tackling expansive soil. Therefore a number of laboratory experiments are conducted to ascertain host of soil engineering properties of a naturally available expansive soil before and after stabilization. Pre and post stabilized results are compared to arrive at conclusion that can thwart expansive soil problems.

Index properties of expansive soil like liquid limit, plastic limit and shrinkage limit with and without fly-ash have been compared. Along with these Atterberg limits, grain size distribution has also determined. The swelling potential of expansive soil is determined with different percentage of fly-ash. For different percentages of fly-ash 1) maximum dry density and 2) optimum moisture contents are found by the proctor compaction test and the comparison graphs are drawn. The strength aspects of expansive soil are determined for soil specimens with different fly-ash concentrations through Unconfined Compression Test and California Bearing Ratio Test and the results are compared through the graphs.

The above experimental results are compared among them to obtain a percentage concentration of fly-ash with swelling soil which gives best results for lower value of swelling potential and higher strength.

Keywords: Evaluation; Fly Ash; Swelling; Expansive Soil;

1. Introduction

For centuries mankind was wondering at the instability of earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Swelling soil always create problem for lightly loaded structure, by consolidating under load and by changing volumetrically along with seasonal moisture variation. As a result the superstructures usually counter excessive settlement and differential movements, resulting in damage to foundation systems, structural elements and architectural features. In a significant number of cases the structure becomes unstable or uninhabitable. Even when efforts are made to improve swelling soil, the lack of appropriate technology sometimes results volumetric change that are responsible for billion dollars damage each year. It is due to this that the present work is taken up. The purpose was to check the scope of improving bearing capacity value and reduce expansiveness by adding additives. There are number of additives for soil modification like ordinary Portland cement, fly ash, lime fly ash etc.

In many centuries, coal is the primary fuel in thermal power plant and other industry. The fine residue from these plants which is collected in a field is known as fly ash and considered as a waste material. The fly ash is disposed of either in the dry form or mixed with water and discharged in slurry into locations called ash ponds. The quantity of fly ash produced world wide is huge and keeps increasing every day. Four countries, namely, China, India, United State and Poland alone produce more than 270 million tons of fly ash every year.

India has a totally installed capacity of 100,000 MW of electricity generation. Seventy three percentage of this is based on thermal power generation. The coal reserves of India is estimated around 200 billion metric tons. Because of this, 90% of Indian thermal power stations are coal

based. There are 85 coal based thermal power station and other power station in the country.
Expansive soils are popularly called as Black cotton soils in India subjected to lot of swelling and shrinkage characteristics. These soils are available in huge quantities of North coastal Districts of AP. Structures constructed on these soils have been facing differential settlements Resulting severe damages. Some of them are cracks in buildings, heaving of canals, failure of retaining structures and roads in many parts of North Coastal Districts of AP. Many attempts have been made after the properties of expansive soils of these areas to meet the different tasks, the popular technique is removing partly/fully these expansive soils and foundation medium with a desirable one. Therefore stabilization is one of such attractive methods. Addition of Flyash to Expansive soil is one such attempt to understand the possible mechanism governing the behaviour of expansive soils-Flyash mixes. Flyash is an industrial waste obtained from thermal power plants by burning of coal. In India these plants produce 130 MT Flyash as a waste product. Therefore bulk stabilization of Flyash become very essential in view of huge producing and to reduce the impact on disposal areas under Environmental concerns.
Utilization in Geotechnical applications are Subgrades, Embankment Materials, Backfill and Structural Materials.
Srivatasava. R. K *et al.*, (2001) studied the effect of Flyash on Expansive soil and reported that UCS values increases with Flyash. Boominathan, A. *et al.*, (1996) [2], B.R. Phanikumar *et al.*, (2009) [14], J.M. Kate, (2009) [8] studied expansive soil stabilized with Flyash and lime used as Geotechnical material. Sridharan. A *et al.*, (1997) [17] Pandian. N. S *et al.*, (2001, 2002) reported that addition of Flyash increases CBR friction angles, can be used in construction of embankments.
Ramakrishna *et al.*, (2001) [15] identified that addition of Flyash increases the UCS and CBR values.
In this an attempt is made to study the interaction between Flyash and Expansive soils by conducting swell, Compaction and Strength tests at various moulding water contents to verify their interaction and can be used as Geotechnical material in constructional activities.
Presently, India produced nearly 100 million metric tons of coal ash that is expected to double in next 10 years. The most common method adopted in India for disposal of coal ashes is the wet method. This method requires, apart from a large capital investment about 1 acre of land for every 1 MW of installed capacity. Thus ash ponds occupy nearly 26,300ha of land in India. The utilization of fly ash was just 3% in 1994, but there is a growing realization about the need for conservation of the environment in India.
With the above in view, experiment on swelling soil has been done with fly-ash as additive.

2. Present Experimental Procedures

2.1 Grain size Analysis

Grain size analysis is done for
- Mechanical sieve and
- Hydrometer analysis

Expansive soil and for fly ash by using following procedures as per IS: 3104-1964

2.2 Specific Gravity

The specific gravity of soil was determined by using Pycnometer (volumetric flask) as per IS: 2720(part-III/sec-I) 1980.

2.3 Liquid limit

The liquid limit was determined in the laboratory by the help of standard liquid limit apparatus. About 120g of the specimen passes through 425µ sieve was taken. A groove was made by groove tool an IS: 9259-1979 designates. A brass cup was raised and allowed to fall on a rubber base. The water content correspond to 25 blows was taken as liquid limit. The value of liquid limit was found out for swelling soil and swelling soil with 20% fly-ash.

2.4 Plastic limit

The value of plastic limit was found out for swelling soil and swelling soil with 20% fly-ash as per IS: 2720(part-V)-1986.

2.5 Optimum moisture content and maximum dry density

The Optimum moisture content and dry density of swelling soil with various percentage of fly-ash (0%,10%,20%,30%,40%,50%) was determined by performing the "standard proctor test" as per IS: 2720(part VII)1965. The test consist in compacting soil at various water contents in the mould, in three equal layers, each being given 25 blows of 2.6kg rammer dropped from a height of 31cm. The collar removed and the excess soil is trimmed of to make it level. The dry density is determined and plotted against water content to find OMC and corresponding maximum dry density

2.6 Free swell Index

The free swell index for swelling soil as well as soil+fly-ash mix (0%,10%,20%,30%,40%,50%) was determined as per IS:2720 (part-II). The procedure involved in taking two oven dried soil samples (passing through 425µ IS sieve), 20g each were placed separately in two 100ml graduated soil sample. Distilled water was filled in one cylinder and kerosene (non-polar liquid) in the other cylinder up to 100ml mark. The final volume of soil was read after 24hours to calculate free swell index.

2.7 Unconfined compression test

This test was conducted on various sample with fly-ash concentration (0%,10%,20%,30%,40%,50%) prepared at OMC, subjected to unconfined compression test. The test so conducted with reference to IS: 2720 part-10(1991) & 4330-5(1970).

2.8 C.B.R test

C.B.R test were determined soil + fly-ash (0%,10%,20%,30%,40%,50%) as per IS:2720-16(1961). The sample so prepared at OMC. Two samples were made for each concentration of fly-ash, one sample tested at OMC (unsoaked) and other was tested at saturation after four days soaking.

3. Grain Size Distribution of Swelling Soil

Table 1: Hydrometer readings of Swelling Soil

SL No	Elapsed time (min)	Hydrometer reading	Meniscus reading	Corrected hydrometer reading	H	Effct. Height He	Fact. M*10-5	Particle size	% of finer corrs to N1	% of Finer corrs to N
1	0.5	23.00	0.5	23.50	11.8	20.15	1277	0.0810	79.81	19.79
2	1	22.50	0.5	23.00	11.9	20.25	1277	0.0570	78.07	19.36
3	2	20.50	0.5	21.00	12.3	20.65	1277	0.0410	71.13	17.64
4	4	20.00	0.5	20.50	12.4	20.75	1277	0.0290	69.40	17.21
5	8	20.00	0.5	20.50	12.4	20.75	1277	0.0200	69.40	17.21
6	16	18.00	0.5	18.50	12.8	21.15	1277	0.0150	62.46	15.49
7	30	18.00	0.5	18.50	12.8	21.15	1277	0.0110	62.46	15.49
8	45	17.50	0.5	18.00	12.9	21.25	1277	0.0087	60.72	15.05
9	60	17.00	0.5	17.50	13.0	21.35	1277	0.0076	58.99	14.62
10	240	15.50	0.5	16.00	13.3	21.65	1277	0.0040	53.78	13.33
11	300	15.00	0.5	15.50	13.4	21.75	1277	0.0030	52.05	12.90
12	1440	13.00	0.5	13.50	13.8	22.15	1277	0.0016	45.11	11.18

3.1 Grain Size Distribution of Fly Ash

Table 2: Hydrometer readings of FLY ASH

SL No	Elapsed time (min)	Hydrometer reading	Meniscus reading	Corrected hydrometer reading	H	Effct. Height He	Fact. M*10-5	Particle size	% of finer corrs to N1	% of finer corrs to N
1	1	19.50	0.5	20.00	12.5	20.07	1321	0.059	72	24.25
2	2	17.00	0.5	17.50	13.0	20.57	1321	0.042	63	21.22
3	4	13.50	0.5	14.00	13.7	21.27	1321	0.030	50.4	16.97
4	8	10.50	0.5	11.00	14.3	21.87	1321	0.021	39.6	13.34
5	15	7.50	0.5	8.00	14.9	22.47	1321	0.016	28.8	9.70
6	30	4.50	0.5	5.00	15.5	23.07	1321	0.011	18.0	6.00
7	60	3.80	0.5	4.30	15.4	23.01	1321	0.008	15.48	5.21
8	120	2.50	0.5	3.00	15.9	23.47	1321	0.005	10.80	3.64
9	240	1.50	0.5	2.00	16.1	23.67	1321	0.004	7.2	2.43

3.2 Liquid Limit Test

Table 3: Liquid Limit of swelling soil

SL No	Empty wt (g).	Wet soil+ Can wt (g).	Wet wt (g).	Dry wt (g).	Wt. of water (g)	Water content (%age)	No of blows
1	2.36	10.0	7.64	4.64	3.00	62.65	42
2	2.54	13.6	11.06	6.76	4.30	63.60	39
3	2.40	12.6	10.10	6.10	4.00	65.57	28
4	2.51	11.2	8.69	5.19	3.50	67.43	26
5	2.46	14.0	11.54	6.74	4.80	71.21	18

3.3 Plastic Limit Test

Table 4: Plastic limit of swelling soil

SL No	Can no	Empty wt (g).	Wet soil+ empty wt (g).	Wet wt (g)	Dry wt (g)	Water wt (g)	Plastic limit (%age)
1	52	2.40	5.8	3.40	2.5	0.9	36
2	53	2.48	7.3	4.82	3.52	1.3	36.9
3	30	2.49	6.7	4.21	3.01	12	39.8
Average plastic limit	37.5						

3.4 Shrinkage Limit Test

Table 5: Shrinkage limit of swelling soil

SL No	Description	Sample(g)
1	Mass of empty mercury dish	39.38
2	Mass of mercury dish with mercury equal to volume of the shrinkage dish	278.9
3	Mass of mercury	239.52
4	Volume of shrinkage dish(V1)	17.61
5	Mass of empty shrinkage dish	5.74
6	Mass of shrinkage dish+ wet soil	33.70
7	Mass of wet soil(M1)	27.96
8	Mass of shrinkage dish+ dry soil	21.80
9	Mass of dry soil(Ms)	16.06
10	Mass of mercury dish + mercury equal in volume of dry pat	161.6
11	Mass of mercury displaced by dry pat	112.1
12	Volume of dry pat(V2)	8.24
13	Volumetric shrinkage(Vs)	113.0
14	Shrinkage ratio(SR)	1.94
15	Shrinkage limit	15.75

3.5 Unconfined Compressive Strength Test

Table 6: Unconfined compressive strength test for swelling soil only

SL No	OBSERVATION				CALCULATION		
	Dial Gauge		Proving ring		Strain(ε)	Corrected	Compressive
	Reading	Deformation (mm)	Reading	Load (KN)		Area (mm^2)	strength(σ1) (N/mm^2)
1	0	0	0	0	0	1963.49	0
2	50	0.5	10	0.034	0.0049	1973.26	0.017
3	100	1.0	14	0.048	0.0099	1982.92	0.024
4	150	1.5	30	0.102	0.0148	1992.78	0.051
5	200	2.0	47	0.160	0.0198	2002.74	0.080
6	250	2.5	58	0.197	0.0247	2012.80	0.098
7	300	3.0	69	0.235	0.0297	2022.96	0.116
8	350	3.5	75	0.255	0.0346	2033.22	0.125
9	400	4.0	82	0.279	0.0396	2043.59	0.137
10	450	4.5	84	0.286	0.0445	2047.64	0.140
11	500	5.0	86	0.292	0.0495	2064.65	0.141
12	550	5.5	89	0.303	0.0545	2073.37	0.146
13	600	6.0	87	0.296	0.0580	2084.38	0.142
14	650	6.5	86	0.292	0.0630	2095.50	0.139
15	700	7.0	85	0.289	0.0680	2106.74	0.137
16	750	7.5	85	0.289	0.0730	2118.11	0.136
17	800	8.0	82	0.279	0.0780	2129.59	0.131
18	850	8.5	82	0.279	0.0830	2141.20	0.130
19	900	9.0	81	0.275	0.0880	2152.90	0.128
20	950	9.5	80	0.272	0.0930	2164.80	0.126

4. Results

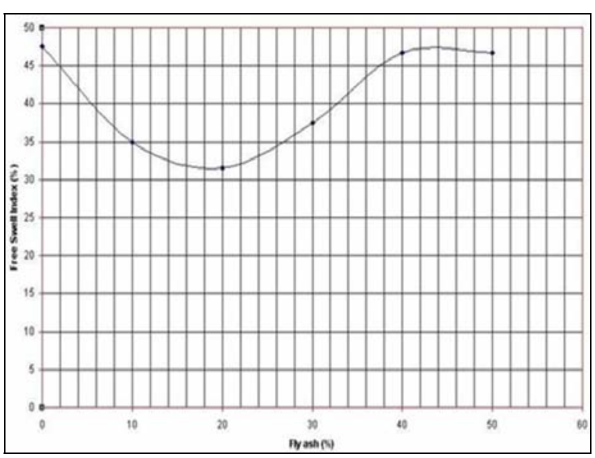

Fig 1: Free swell index at various percentage of fly-ash

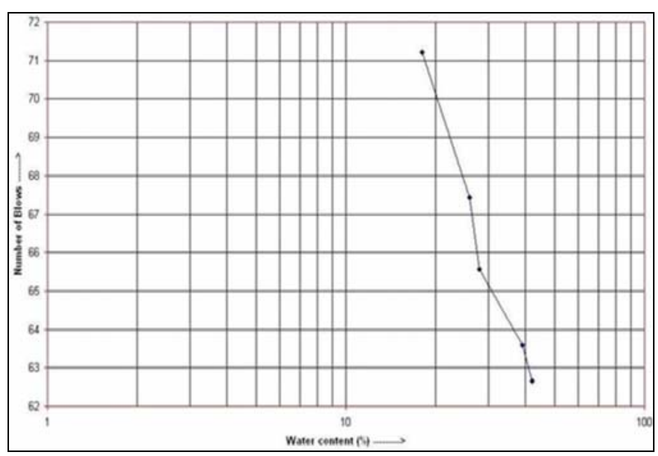

Fig 2: Liquid limit of swelling soil

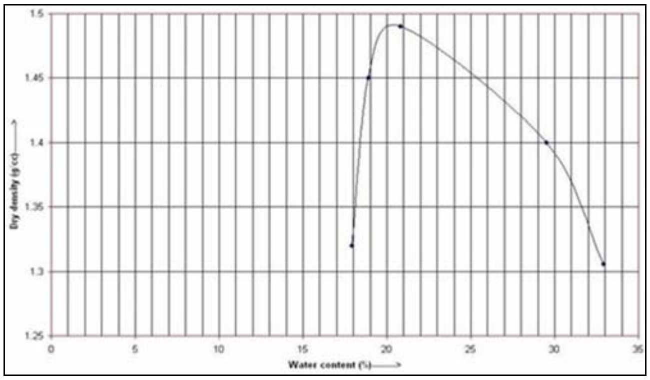

Fig 3: Proctor compaction Test for swelling soil

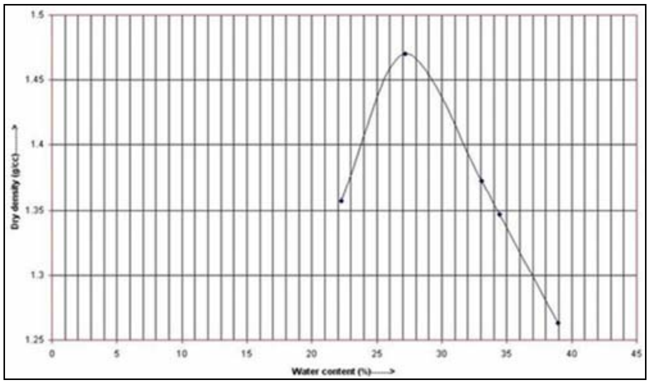

Fig 4: Proctor compaction Test with swelling soil+10% fly-ash

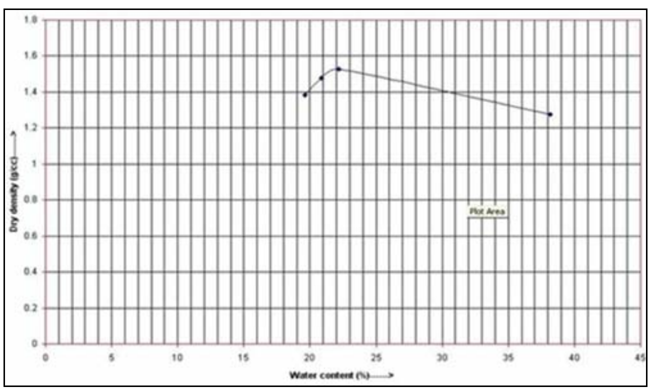

Fig 5: Proctor compaction Test with swelling soil+20% fly-ash

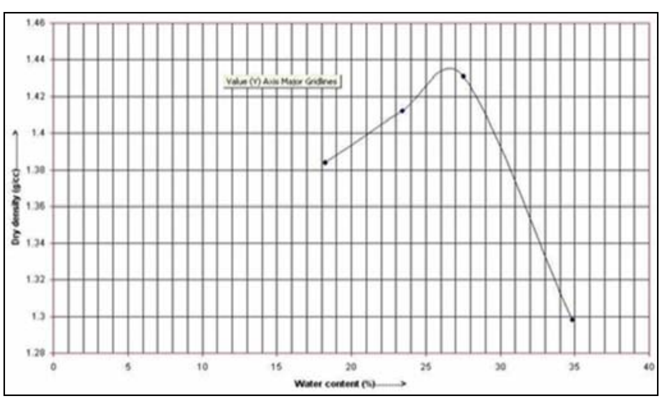

Fig 6: Proctor compaction Test with swelling soil+30% fly-ash

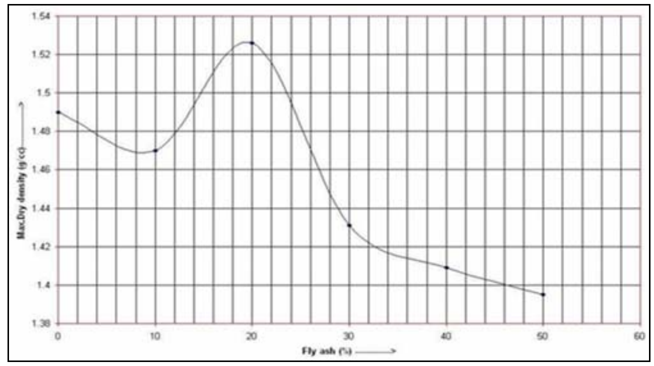

Fig 7: Comparison of maximum dry density against fly-ash percentage

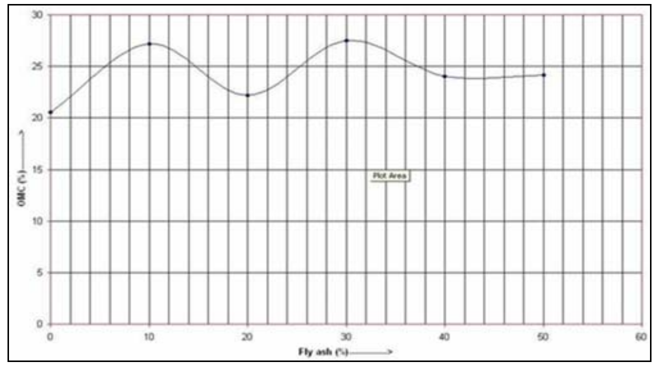

Fig 8: Comparison of Optimum Moisture Content against fly-ash percentage

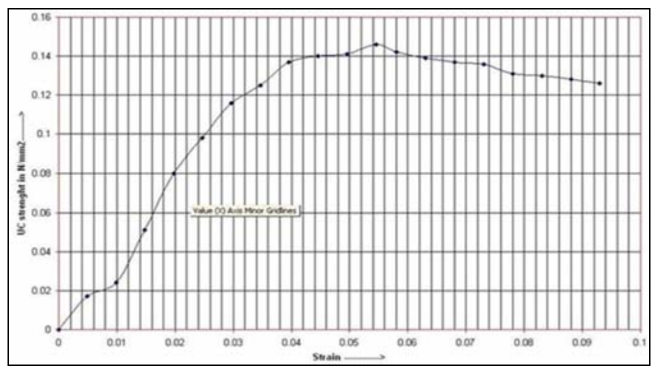

Fig 9: Unconfined comp. strength of swelling soil only

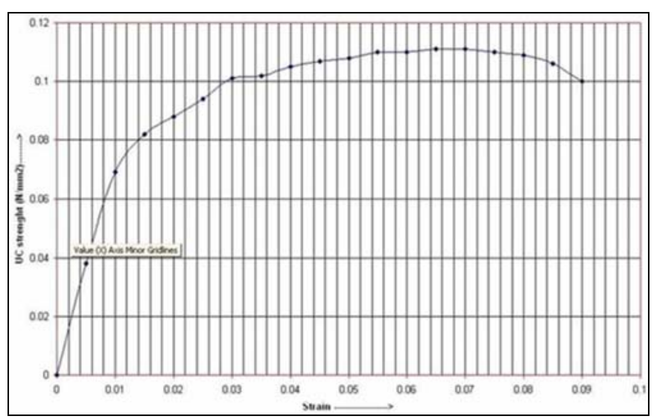

Fig 10: Unconfined comp. strength of swelling soil+10% fly-ash

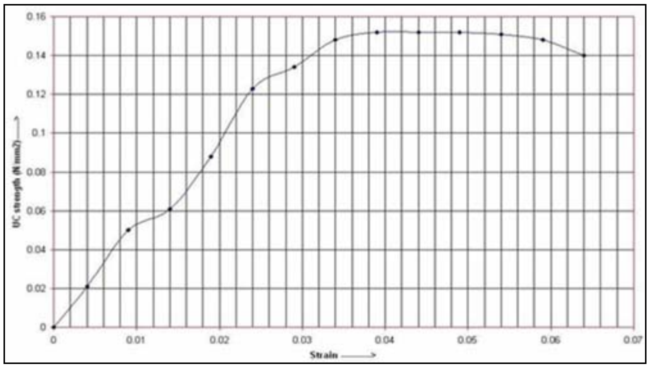

Fig 11: Unconfined comp. 9olkstrength of swelling soil+20% fly-ash

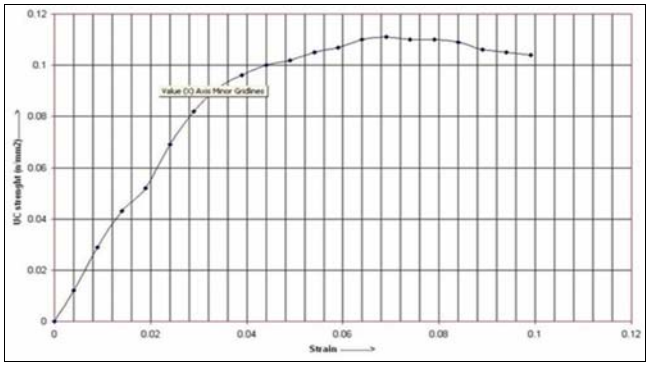

Fig 12: Unconfined strength of swelling soil+30% fly-ash

5. Conclusion

- On increasing fly-ash content free swell index decreases steadily to a lowest value at 20% fly-ash and then it increases slightly to have a peak at 40% fly-ash content. Beyond 40% Fly-ash. it again declines.
- Unconfined compressive strength decreases on adding of fly-ash up to 10% and then increases up to 20% fly-ash content to have the greatest value of q_u max =0. 152N/mm^2. Then it declines to have another lower value at 30% fly-ash and takes another peak (at 0.116 N/mm$^{2)}$ at 40% fly-ash. Beyond this, it again declines.
- C.B.R value of unsoaked sample tested at OMC with 20% fly-ash content is found to be maximum (23.27 percent).Hence for the maximum C.B.R value the optimum value of fly-ash mix is 20 percent.
- The maximum dry density is highest (1.54g/cc) and optimum moisture content is least (22.29 percent) found by proctor compaction test, are obtained at 20 percent content of fly-ash.
- Atterberg limits are obtained are also optimum when the fly-ash content is 20 percent.

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